GROUNDWATER MONITORING AND MANAGEMENT PLAN

DRAKE COAL PTY LTD –
DRAKE COAL PROJECT

24 October 2014

QCOAL GROUP

TABLE OF CONTENTS

Tables

Figures

1. INTRODUCTION

1.1 Background

This Groundwater Monitoring and Management Plan (GMMP) has been prepared by Drake Coal Pty Ltd (Drake Coal) to address groundwater related regulatory conditions for the Drake Coal Project (the Project).

This GMMP is subject to the requirements of the following documents:

- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) Referral 2010/5457 Approval Conditions (EPBC Conditions) for Drake Coal, issued by the Australian Department of Environment (DoE).
- Environmental Authority (EA) – EPML00393013 (Schedule E: Groundwater) issued and administered by the Queensland Department of Environmental and Heritage Protection (DEHP).
    - The EA is the key environmental permit and details the environmental conditions (EA Conditions) imposed by the state of Queensland to undertake the Project, for each Environmental Value relevant to the EA. The conditions have been derived to address anticipated impacts of the Project and are developed to be measurable and auditable.

Background data along with detailed impact assessments and proposed mitigations is presented in the following documentation, which has previously been provided to both DEHP and DoE:

- The Drake Coal Project Environmental Management Plan (the EMP).
    - The EMP provides an overview of the baseline environment, the potential impacts and mitigations to achieve the environmental objectives stated in the EA.
- The Drake Coal Project Water Management Plan
    - The Water Management Plan details the overall surface water management for the Project for surface water.
- The Drake Coal Project Environmental Impact Statement (the EIS).
- The Drake Coal Project Supplementary Environmental Impact Statement (the SEIS).

Additionally the DEHP Model Mining Conditions Guideline - 130626 EM944 Version 4 (Model Mining Conditions Guideline) provides specific advice on how to comply with EA Conditions and as such has been referred to in preparation of this GMMP.

1.2 Purpose of GMMP

This GMMP has been prepared as a single document to satisfy the requirements for groundwater management and monitoring in the EPBC Conditions and the EA Conditions; in particular the EPBC Conditions which relate to a GMMP and the EA Conditions which relate to a groundwater monitoring program.

A complete list of EPBC Conditions and EA Conditions for groundwater is included in **Section 3**.

Additional information has been included in this GMMP to inform areas of monitoring or management which are considered necessary to satisfy the EPBC conditions and the EA Conditions, but which may not have been explicitly stated in those documents.

The intent of the GMMP is to provide a “live” document which can be readily used and referred to during operations, which covers both the EPBC Conditions and EA Conditions, without unnecessary content or repetition.

1.3 Drake Coal Corporate Details

Drake Coal is a subsidiary of QCoal Pty Ltd (QCoal). QCoal is a privately owned Queensland company based in Brisbane and has been active in Queensland coal exploration and mining over the last 25 years.

- Street address:
  - Drake Coal Pty Ltd
    Level 15/40 Creek St
    Brisbane QLD 4000
- Postal address:
  - Drake Coal Pty Ltd
    PO Box 10630 Adelaide St
    Brisbane QLD 4000
- Contact numbers
  - Phone 07 3002 2900

1.4 GMMP Preparation

This GMMP has been prepared by Julian Dobos[1] – Senior Environmental Officer at QCoal.

1.5 Review of GMMP

The GMMP will be subject to internal reviews by an appropriately qualified person[1], with the objective of the review being to determine ongoing suitability of GMMP, or, make recommendations where the GMMP requires revision, as follows:

- Every alternate year (regular review)
- Upon any amendment of the EA relating to groundwater
- Upon significant change in the mine plan (pit layout)
- As a recommendation or outcome of a groundwater investigation (e.g. exceedance investigation)
- As part of any internal or external EA audit recommendation
- As a result of the findings from a review of the numerical model
- As a result of the findings from review/s undertaken by a suitably qualified expert[2] at the request of the Minister[3].

As the GMMP is a live document intended for operational use, GMMP reviews may also be on an as required basis, if opportunities for refinement of the GMMP are identified during operation. The specific objective and therefore the method/aspects of the review will depend on the reason for the review. However, where a regular review is being undertaken all aspects of the GMMP will be appraised to determine its suitability, adequacy and effectiveness. Results of any review will be implemented into an updated GMMP where required, consistent with the commitment to continual improvement.

Details regarding reviews of the numerical groundwater model are discussed in **Sections 7.7** and **7.8**.

1 Appropriately qualified as per the EA definitions: Appropriately qualified person means a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relating to the subject matter using the relevant protocols, standards, methods or literature.

2 Suitably qualified expert as per the EPBC conditions definitions: a person who has professional qualifications, training, skills or experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relating to the subject matter using the relevant protocols, standards, methods or literature.

3 Minister as per EPBC conditions definitions: the Minister administering the EPBC Act and includes a delegate of the Minister.

2. PROJECT DESCRIPTION

2.1 Project Location, Tenures and Underlying Landowner

The Project site is located in the northern Bowen Basin, approximately 17 kilometres (km) south of Collinsville (**Figure 2-1**).The road access point to the Project will be from the existing Bowen Developmental Road, located in the east of the Project site. Drake Coal has been granted three mining leases (ML): ML 10349, ML 10350 and ML 10351 (**Figure 2-2**), which comprise the Project area.

As shown on **Figure 2-2**, the entire Project area is located on the "Birralee" property, which is owned by Mr Christopher Wallin – QCoal Managing Director:

- To the west the "Birralee" property extends between 4.4 km and 14.9 km beyond the Project boundary, to the Bowen River.
- Immediately to the east is the Bowen Developmental Road and on the other side the Jax Coal Mine, which is an established coal mine also entirely located on "Birralee", which extends between 1.4 km and 4.3 km beyond the Project boundary to the "Birralee" property boundary.
    - Abutting the Jax Coal Mine area are the Sarum and Sarum Extension mining lease applications that cover the majority of land on the eastern side of the Project extending north and south.
- Immediately to the north is the Cows Coal Mine, which is an established multi pit coal mine operation, located on land which is no longer utilised or declared as a stock route and which has a permit to occupy granted to Mr Christopher Wallin – QCoal Managing Director.
    - To the north of the Cows Coal Mine is the Sonoma Coal Mine, which is an established multi pit coal mine operation, located partially on land owned by Mr Christopher Wallin – QCoal Managing Director.
- Immediately to the south of the Project is the Bowen River, across which is the "Havilah" property owned by Colinta Holdings Pty Ltd, which is a subsidiary of Glencore (a mining company).

There are no significant commercial coal seam gas resources identified within the Project area. The Project will not impact on other coal, gas and mineral resources in the region.

2.2 Project Overview

A full description of the Project is provided in Volume 1, Chapter 3 of the EIS. It is anticipated that construction (e.g. roads and dams) will commence in late-2014, with extractive mining commencing thereafter.

The Project will be developed as an, open-cut coal mine. Exploration activities undertaken by Drake Coal have defined a recoverable coal resource in excess of approximately 200 Mt. As such the Project will involve the mining of up to 10 Mtpa of ROM coal to produce approximately 6 Mtpa of combined coking and thermal coal products for the export market.

ROM coal will initially be hauled to the Sonoma Coal Mine for washing and rail transport to Abbot Point after load out, via the coal handling and preparation plant (CHPP) and balloon loop located on the Sonoma Coal Mine. Subsequently a CHPP and rail loop may be constructed on the Project area (as has already been approved).

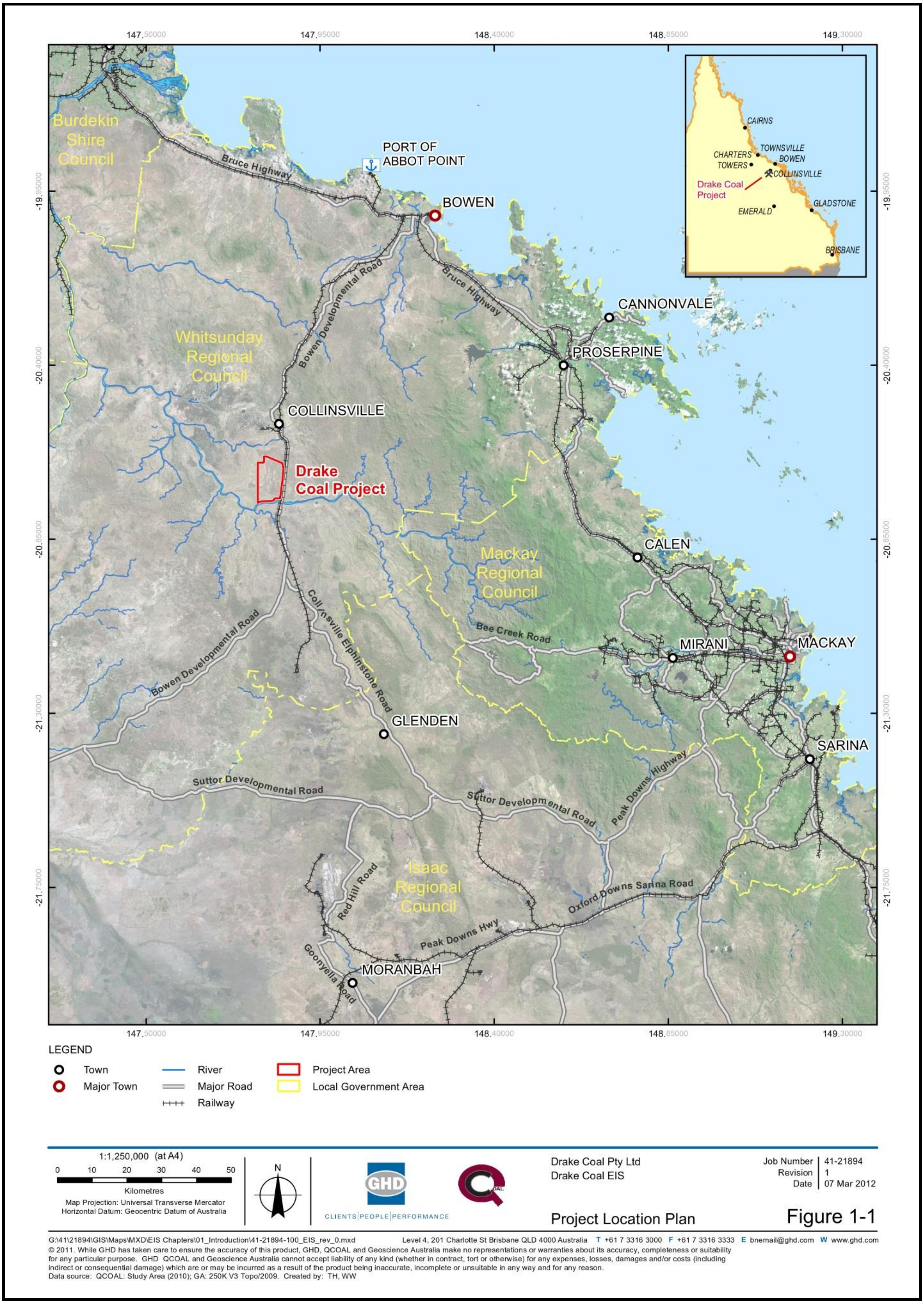

Figure 2-1 Project Location

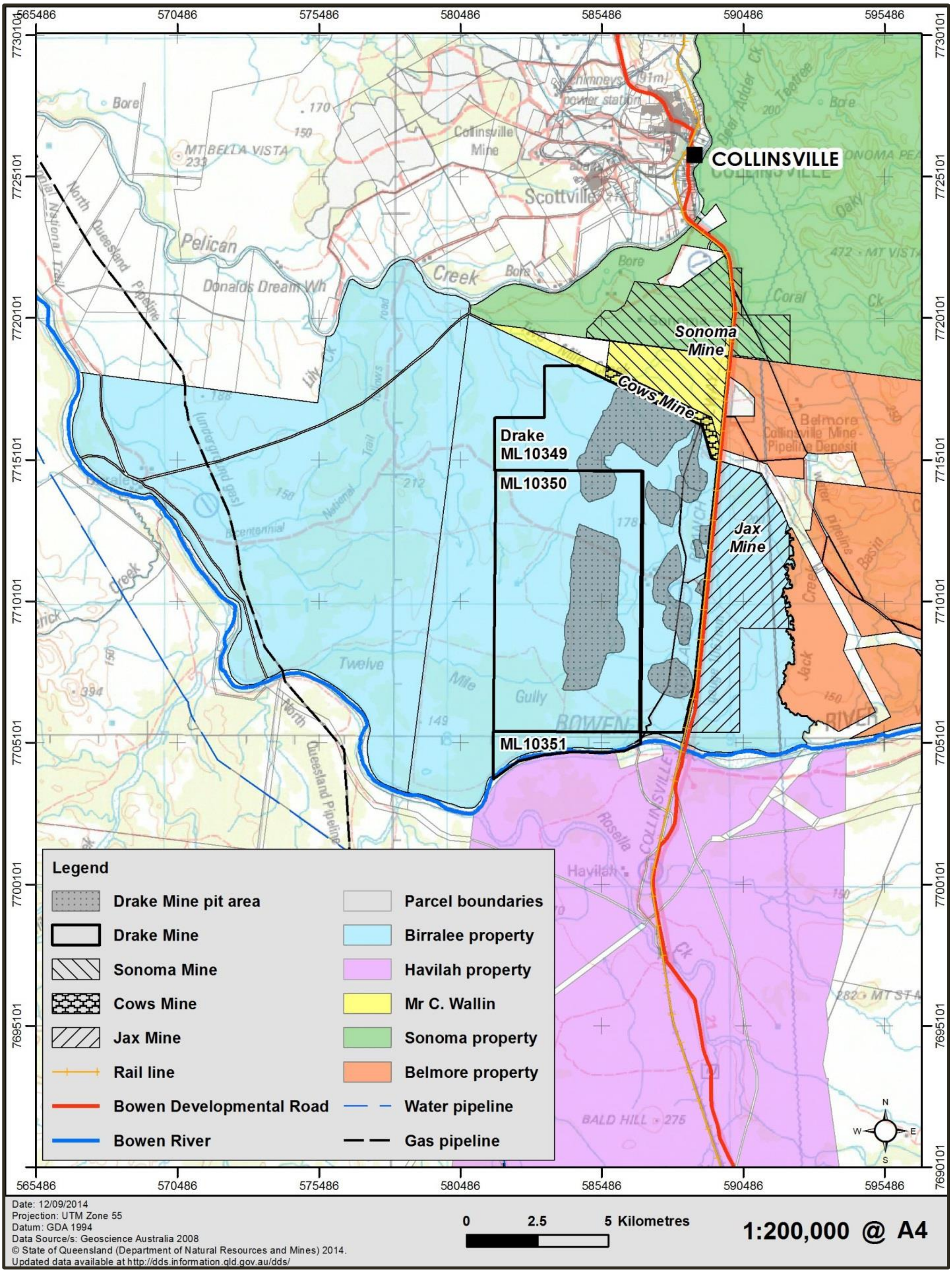

Figure 2-2 Project Tenures and Underlying Properties

2.3 Resource Base and Mining Method

The Project area covers a complete sequence of the Moranbah Coal Measures which is part of the Blackwater Group. The Moranbah Coal Measures contain seven persistent coal seams. In the Project area the Moranbah Coal Measures sub-crop in a north to northeast direction and dip at low angles to the east and southeast. All coal seams have economic potential.

At the start of a new open-cut area, a box-cut is developed, with the overburden being dumped in an out of pit spoil dump or used to backfill an existing void. Coal mining commences once sufficient overburden is removed to expose the coal seams and involves working a number of blocks in conjunction with one another to develop a staggered pattern in relation to the vertical coal seam horizons. The number of blocks required for coal production depends on the productivity requirement of the pit. Once sufficient floor area is available in the mine pit, dumping then commences in-pit allowing progressive backfilling of the void as mining progresses in defined strips across the resource area.

2.4 Project Components

The key elements of the Project are:

- Open-cut pits. In the initial years mining activities will focus on West Pit 2, North Pit, South Pit and N10 Pit. Mining will occur 7 days per week and excavate to depths up to 140 m bgl. Over the mine life several satellite pits will also be established;
- Out of pit spoil dumps will be established during initial years of mining. In-pit dumping will commence once void space is available;
- Coal handling civil works, including a run of mine (ROM) pad;
- Mine haul roads to connect the open-cut pits to the coal processing area;
- A Coal Handling and Preparation Plant (CHPP) capable of processing 1,400 tonnes per hour (t/hr). The CHPP will be constructed adjacent to the proposed rail loop;
- Process water will be recovered from coal rejects and dewatered fines from the CHPP. Reject material will be pumped to a co-disposal facility for placement and further water recovery;
- A train load-out facility;
- A rail balloon loop and connection of the loop to the existing Newlands-Abbot Point rail line;
- A water management system to manage site stormwater flows, control run-off, prevent erosion, divert clean water and capture and manage mine area runoff and pit water for reuse;
- A Mine Infrastructure Area (MIA) including administration buildings, ablution buildings, vehicle maintenance workshops and a concrete batching plant;
- Process water storage and distribution system;
- A 33 kilovolt (kV) power line constructed in conjunction with Ergon Energy;
- Water supplied by SunWater and stored on-site in the main water storage area; and
- Site access via the existing Bowen Developmental Road.

2.5 Mine Layout

The proposed mine development sequence targets low strip ratio high quality coal first. Generally this coal is found in the western portions of the Project area. An overview of the mining layout is shown in **Figure 2-3**.

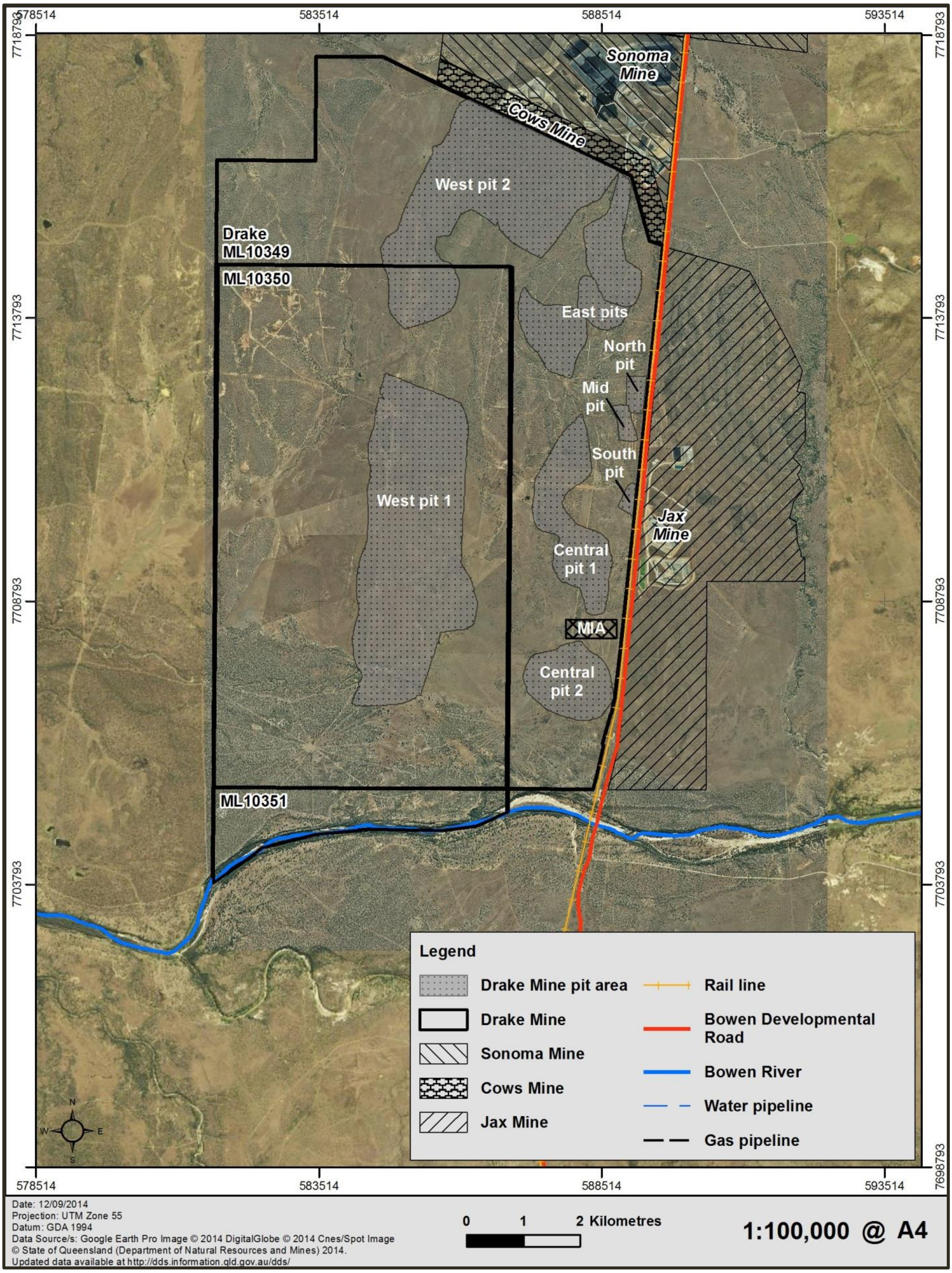

Figure 2-3 Project Layout

2.6 Surface Water Management

During mining operations, the Water Management Plan will consider key aspects of surface water across the site, including but not limited to:

- Separate mine affected and non-mine affected water circuits;
- Sediment facilities;
- Co-disposal facility and holding facilities;
- Pit water storage;
- Runoff from undisturbed areas being diverted away from disturbed areas;
- Runoff from disturbed areas being captured in sedimentation ponds, with retention times sufficient to settle coarse suspended sediment;
- Rainfall runoff being managed through drainage systems, diversions (where required), levee banks and sedimentation ponds;
- Scour protection will be provided at discharge points if required;
- Water pumped from active pits will also be directed to sediment ponds. Where possible, water collected in sediment ponds will be reused for dust suppression or process water; and
- Water quality criteria will be developed for releases from sediment ponds to existing surface drainage systems.

2.7 Rehabilitation and Decommissioning

At completion of mining and rehabilitation works the site will be returned to a low-intensity cattle grazing use. The final rehabilitated landform will consist of a regraded final pit void, backfilled only to cover and seal off the coal seam faces, together with a topsoiled, revegetated and contour terraced plateau. Contour batters/drains will collect rainfall and this will be fed to sediment control ponds

The main components of the progressive rehabilitation will include:

- Topsoil horizons across the Project area are typically 0.3 m thick. Topsoil from the mining area will be removed by a scraper and either placed in stockpiles or directly placed on rehabilitation areas. Topsoil stockpiles will be seeded to eliminate erosion. The period of storage will be minimised in order to reduce the detrimental effects of storage on any native seed in the soil;
- Constructing a final stable landform consisting of out of pit overburden dumps, in pit overburden dumps and rehabilitated final voids;
- Progressive construction of dumps to final landform design, minimising reshaping at the end of mining.
- Contour ripping will occur immediately after topsoil placement to control erosion;
- Seeding with appropriate seed mix prior to wet seasons to maximise the benefits of rainfall;
- Applying appropriate fertilisers for plant establishment (if required);
- Respreading cleared vegetation on rehabilitated land; and
- Managing direct rainfall and runoff from the rehabilitated landform in sediment storage facilities and rehabilitated final voids.

All infrastructure constructed by the Drake Coal and its contractors during the mining activities, including water storage structures, will be removed from the site at cessation of mining activities, except where agreed in writing by the post mining land owner / holder.

The rail-spur and balloon loops owned by Drake Coal, along with any overhead electricity facilities, signalling equipment and concrete sleepers will be salvaged post closure of the mine.

3. Approval Conditions for Groundwater

3.1 EPBC Conditions

EPBC Conditions 10, 11, 12, 13 and 14, stipulate groundwater conditions and the preparation, submission and content of a GMMP. Presented in **Table 3-1** are the EPBC Conditions and the relevant section of the GMMP where conditions are addressed.

Table 3-1 EPBC Conditions for Groundwater

EPBC Conditions	GMMP Section
EPBC Condition 10: The approval holder must submit a Groundwater Monitoring and Management Plan (GMMP) to the Department for the Minister's approval. The approved GMMP must be implemented.	**General condition**
EPBC Condition 11: The GMMP must be approved by the Minister in writing prior to the commencement of dewatering activities in the mining pits depicted in Figure 3 of the Environmental Management Plan.	**General condition**
EPBC Condition 12: The GMMP must include but is not limited to:	
12-a: the groundwater quality and trigger levels as described in Schedule E of the Queensland Environmental Authority	**Section 5.6.1, Section 5.6.2,**
12-b: a detailed description of the actions, including timeframes, the approval holder will take if groundwater quality and or level triggers (referred to in Condition 12a of this approval) are exceeded or predicted to be exceeded	**Section 6 (and all subsections)**
12-c: a strategy to conduct and landholder bore survey to determine water supply bores and water users in the vicinity of the project that may be impacted by mining activities and the potential to incorporate those bores into the groundwater monitoring program.	**Section 4.5, Section 4.5.1**
12-d: Details of how the existing groundwater monitoring program will be expanded to better determine surface-groundwater interaction, including monitoring locations, parameters to be measured, monitoring frequency and reporting requirements.	**Section 5.8**
12-e: a numerical groundwater model to simulate and quantify groundwater drawdown extent and flow impacts on the Bowen River, and validate the assumptions and potential risks and impacts of the project on groundwater resources identified in the EIS documents. The model must be developed with reference to the National Water Commission Groundwater Modelling Guidelines and must include a monitoring strategy to validate the model.	**Section 7 (and all subsections)**
12-f: the methods, frequency and timeframes in which the GMMP and numerical groundwater model will be reviewed.	**Section 1.5, Section 7.7 and Section 7.8**
EPBC Condition 13: The minister may be written request, require the GMMP be reviewed by a suitable qualified expert. Following any review, the GMMP must be revised and updated accordingly and submitted to the Minister for approval. **Note 2**: To ensure efficiency the approval holder may prepare and align the GMMP required under the conditions of approval with the requirements of the groundwater monitoring program required under the Queensland Environmental Authority, EA, as long as the relevant matters under the EPBC conditions are clearly and adequately addressed.	**General condition**
EPBC Condition 14:	
14-a: If the groundwater quality and or level triggers referred to in Condition 12a of this approval are exceeded and an investigation is completed in accordance with Schedule E of the Environmental Authority, the approval holder must notify the Department within 3 months on becoming aware of the exceedance.	**Section 6 (and all subsections)**
14-b: If requested, the approval holder must provide copies of any exceedance investigation documents to the Department, in a timeframe agreed in writing by the Department, which state the cause, response, and actions undertaken to prevent further occurrences.	

3.2 EA Conditions

EA Conditions – Schedule E, stipulate groundwater conditions and the preparation, submission and content of a groundwater monitoring plan. Presented in **Table 3-2** are the groundwater EA Conditions (Schedule E) and the relevant section of the GMMP where conditions are addressed.

Table 3-2 EA Conditions for Groundwater

EA Conditions	GMMP Section
EA Condition E1: The holder of this environmental authority must not release contaminants to groundwater.	**General condition**
EA Condition E2 – Monitoring and Reporting: All determinations of groundwater quality and biological monitoring must be performed by an appropriately qualified person.	**Section 5, Section 5.3.2.3, Section 5.7, Section 5.9**
EA Condition E3: Groundwater quality and levels must be monitored at the locations and frequencies defined in Table – E1 Groundwater monitoring locations and frequency and Attachment – Project Groundwater Bores for quality characteristics identified in Table E2 - Groundwater quality triggers and limits.	**Section 5.1, Section 5.2.1, Section 5.2.2**
EA Condition E4: Groundwater levels when measured at the monitoring locations specified in Table E1 -Groundwater monitoring locations and frequency must not exceed the groundwater level trigger change thresholds specified in Table E3 - Groundwater level monitoring below.	**Section 5.6.1**
EA Condition E5 – Exceedance Investigation: If quality characteristics of groundwater from compliance bores identified in Table E1 - Groundwater monitoring locations and frequency exceed any of the trigger levels stated in Table E2 - Groundwater quality triggers and limits or exceed any of the groundwater level trigger threshold stated in Table E3 - Groundwater level monitoring, the holder of this environmental authority must compare the compliance monitoring bore results to the reference bore results and complete an investigation in accordance with the ANZECC and ARMCANZ 2000.	**Section 5.6.1, Section 5.6.2, Section 6 (and all subsections)**
EA Condition E6: Results of monitoring of groundwater from compliance bores identified in Table E1 - Groundwater monitoring locations and frequency must not exceed any of the limits defined in Table E2 - Groundwater quality triggers and limits.	**Section 5.6.2**
EA Condition E7 – Bore construction and maintenance and decommissioning: The construction, maintenance and management of groundwater bores (including groundwater monitoring bores) must be undertaken in a manner that prevents or minimises impacts to the environment and ensures the integrity of the bores to obtain accurate monitoring.	**Section 5.9**
EA Condition E8 – Groundwater monitoring program: A Groundwater monitoring program must be developed by an appropriately qualified person that will determine compliance with the environmental authority conditions, prior to the commencement of dewatering activities. The groundwater monitoring program must include at a minimum: a) Location of monitoring bores and groundwater aquifers to be monitored b) Proposed frequency of monitoring of groundwater levels and water quality; and c) Groundwater monitoring within the following formations: i Bowen River alluvium ii Moranbah coal measures iii Exmoor formation; and iv Blenheim subgroup Monitoring results must be provided to the administering authority upon request.	**Section 1.4, Section 5 (and all subsections)**
EA Condition E9 – Stygofauna monitoring: The holder of this environmental authority must undertake an Stygofauna pilot sampling study in accordance with Guideline No. 54a: Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia in the following bores to be constructed in the alluvium associated with the Bowen River: • Bore DK1301 • Bore DK1302 • Bore DK1303 If stygofauna are identified during the pilot sampling study that are determined to be endemic to the area and are also determined to be at risk of mining related impacts, further sampling should be undertaken and the results should be given to the administering authority.	**Section 4.4, Section 5.7**

4. Groundwater Values

A key objective of monitoring groundwater across the Project area is to track and quantify any change in groundwater conditions, to then quantify any potential unauthorised environmental harm[4] and associated environmental impacts which may occur to the Project area groundwater values. This information in turn is required for the management of any impacts (prevention, mitigation and responses).

Therefore an understanding of the actual groundwater values across the Project area is required and is discussed in the following subsections.

4.1 Geology of the Project Area

The Project is located in the northern Bowen Basin, where active subsidence and deposition during the Permo-Triassic was centred within an extensional terrain known as the Taroom Trough. This deposition centre was situated marginal to the Collinsville Shelf in the west, which typically behaved as a stable platform throughout. The deformed Taroom Trough of the north Bowen Basin is defined by the Nebo Synclinorium, where contained sediments and volcanics of the western two-thirds dip gently toward the major synclinal axis in the east. Post-depositional compression has resulted in a fold-and-thrust style of deformation, particularly on the eastern side of the basin, and sediments along this margin generally dip steeply toward the west.

The Project site is underlain by the late Permian Blackwater Group consisting of lithic sandstone, siltstone, shale, conglomerate, dolomite and tuff and minor coal. This is surrounded and underlain by the low to upper Permian Blenheim Subgroup described as a succession of siltstone, sandstone, conquite and limestone i.e. the Blackwater Group is an outlier surrounded by the Blenheim Subgroups. Collinsville Coal Measures with easterly regional deep underlie the Blenheim Group.

Regionally, the stratigraphic sequence is summarised as follows: the Permo-Triassic sediments of the Bowen Basin are overlain by a veneer of unconsolidated Quaternary alluvium and colluvium, poorly consolidated Tertiary sediments and, in places, remnants of Tertiary basalt flows. The gross stratigraphy of the Project area comprises the basal Lizzie Creek Volcanics and overlying marine Back Creek Group, non-marine Blackwater Group, and Tertiary sediments of the Suttor Formation.

A conceptualisation of the Project stratigraphy is presented in **Figure 4-1**.

[4] EA Condition A2 states that authorised harm is permitted in accordance with the conditions of the EA.

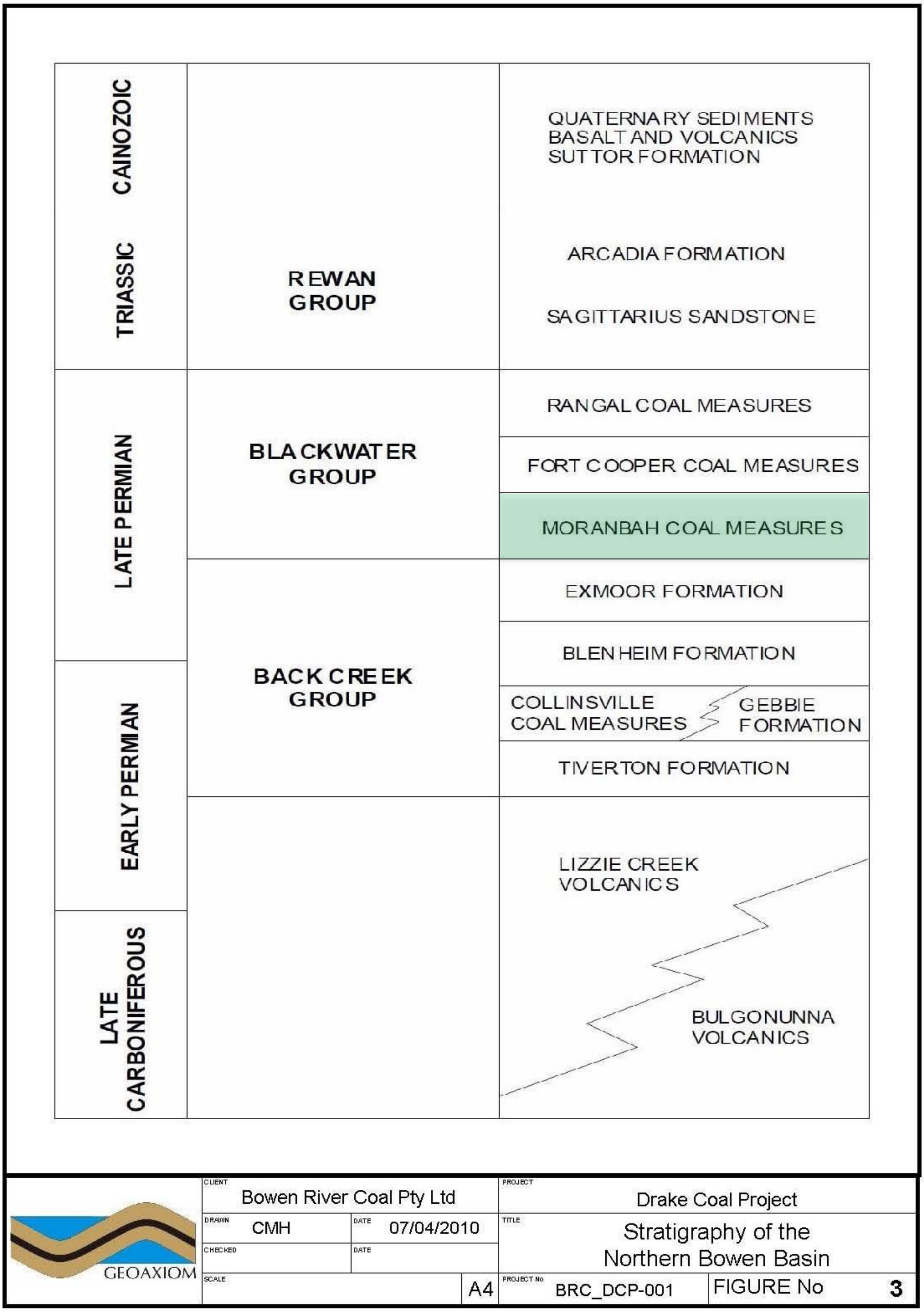

Figure 4-1 Project Stratigraphy

4.2 Groundwater to Surface Water Interactions and Aquifer Connectivity

As part of the EIS baseline groundwater studies, interaction between groundwater and surface water was considered, as well as interaction between various identified groundwater bearing units. Of particular note was the assessment of any potential connection between the groundwater and the Bowen River (which is the main surface water body in the vicinity of the Project).

The findings of the studies indicated that there is limited connectivity between the alluvium and the underlying Permian coal measures. This observation is considered to be consistent with the low expected permeability of the majority of the coal measures strata. In addition the major ion chemistry results indicate a clear difference between groundwater sampled from the coal measures and surface water samples, further suggesting limited groundwater – surface water interaction.

The groundwater level hydrographs, the groundwater quality data and the expected low permeability of the coal measures aquitards suggests limited interaction between the alluvium and the underlying coal measures. Given that the Bowen River flows through strata of alluvial material the EIS concludes that there is limited connection between the coal measures and the Bowen River.

Due to the highly ephemeral nature of Twelve Mile Gully and Two Mile Creek the alluvial deposits associated with these water courses are expected to be dry for the majority of the time. No significant groundwater – surface water interaction is therefore anticipated along these minor creeks.

As such the studies conclude that surface water in the vicinity of the Project is generally not reliant on groundwater for flow and as such is not considered a groundwater value (with the Bowen River subject to specific consideration and modelling).

However it is noted that three of the bores which are required to be monitored (**Section 5.1**) are specifically located adjacent the Bowen River in the alluvial material, to provide some confirmatory monitoring data during operations and to intercept any potential impacts.

In addition, as part of the GMMP, numerical groundwater modelling was undertaken with a focus on the potential for the Project to impact the Bowen River (**Section 7.6.3**).

4.3 Springs and Groundwater Dependent Ecosystems

As part of the EIS baseline groundwater investigations, springs, swamps, wetlands and Groundwater Dependent Ecosystems (GDEs) were considered. The findings of the EIS indicate that:

- there are no known groundwater springs or seeps in the Project area
- GDEs are unlikely to exist in the vicinity of the Project
  - stygofauna is discussed separately in **Section 4.4**.

Springs, swamps, wetlands and GDEs are therefore not considered a groundwater value across the Project site.

4.4 Stygofauna

As part of the EIS baseline survey assessments, a stygofauna pilot survey was undertaken in May 2011 in accordance with *Guideline No. 54a: Sampling Methods and Survey Considerations for Subterranean Fauna in Western Australia* (the stygofauna guideline). Stygofauna sampling was undertaken in ten (10) bores across the study area; samples were obtained from six (6) bores, while the remaining four (4) bores were dry. No stygofauna was recorded from any of the samples obtained during the pilot survey; however it is noted that low abundances of terrestrial invertebrates including Diptera adults and Coleoptera larvae were recovered from some samples (these are typical of ingress from surface environments and are not obligate subterranean forms, i.e. are not styogofauna).

As such the EIS determined that the absence of stygofauna from the sampled bores indicates there is a low likelihood of stygofauna occurring in the groundwater across the site. Stygofauna is therefore not considered a groundwater value across the Project site. An additional confirmatory stygofauna pilot study (see **Section 5.7**) will be undertaken in groundwater bores which were not installed at the time of the EIS pilot study.

4.5 Groundwater Users (Private Groundwater Facilities and Registered Bores)

Groundwater resource management in Queensland involves the identification of Groundwater Management Units (GMU) within areas that are heavily utilised and Unincorporated Areas (UA) where use and/or monitoring data is limited. GMUs are defined by the extent of aquifer systems while UAs are established by dividing the remaining area in Queensland based on geological region boundaries (ANRA, 2007). The Project is located within the Bowen UA, which covers an area of 153,800 km^2. Average groundwater resource usage in the Bowen UA is estimated to be 14,900 ML/yr compared to an estimated sustainable yield of 260,000 ML/yr (National Land and Water Resources Audit, 2001).

It should be noted that groundwater licences are not required for sub-artesian abstraction within UAs.

The current low levels of groundwater use within the Bowen UA, may conservatively be considered to include pastoral, irrigation, mining, stock and domestic and town water. The quality of the groundwater is generally described as marginal, with typically poorer quality groundwater encountered within coal bearing strata. Given the current, relatively low level of groundwater utilisation with the Bowen UA, there are no priority issues for groundwater management and the current level of extraction is considered to be sustainable (National Land and Water Resources Audit, 2001).

As part of the EIS groundwater assessment, a search of the Queensland Government Groundwater Database (GWDB) administered by the former Department of Environment and Resource Management (DERM), now Department of Natural Resource Management (DNRM), was undertaken. As per the GWDB there were 53 registered bores within 10 km of the Project area; no bores were listed within the Water Entitlement and Resource Database (WERD). This finding is consistent with the Project area forming part of the Bowen UA.

Of the 53 registered bores within 10 km of the Project:

- Four (4) are identified as bores intended for potential water use (e.g. supply) (RN25008, RN125696, RN125698 and RN140020), the closest of which is RN140020 located around 5.4 km east of the Project area boundary (Figure 4-2).
- 21 bores are stated as monitoring or investigation boreholes and are therefore not for groundwater use.
- 20 have no recorded use and as such could conservatively be assumed as being water supply bores, the closest of which is RN33167 which is approximately 3 km north from the closet Project mining pit; however RN33167 is located within the Sonoma Coal Mine area and is therefore known by Drake Coal to not be used for water supply (Figure 4-2).
- 8 have been abandoned or destroyed.

It should be noted that:

- The Cows/Sonoma Coal Mines to the north of the Project site has already been developed;
- The Jax Coal Mine to the east is currently being developed for coal;
    - To the east of the Jax Coal Mine is the Sarum and Sarum Extension mining lease applications, covering the majority of land on the eastern side of the Project.

The results of the groundwater database registered bore search indicate there are no registered bores used or potentially used as water supply closer than 5.4 km to the Project (5.4 km to the east).

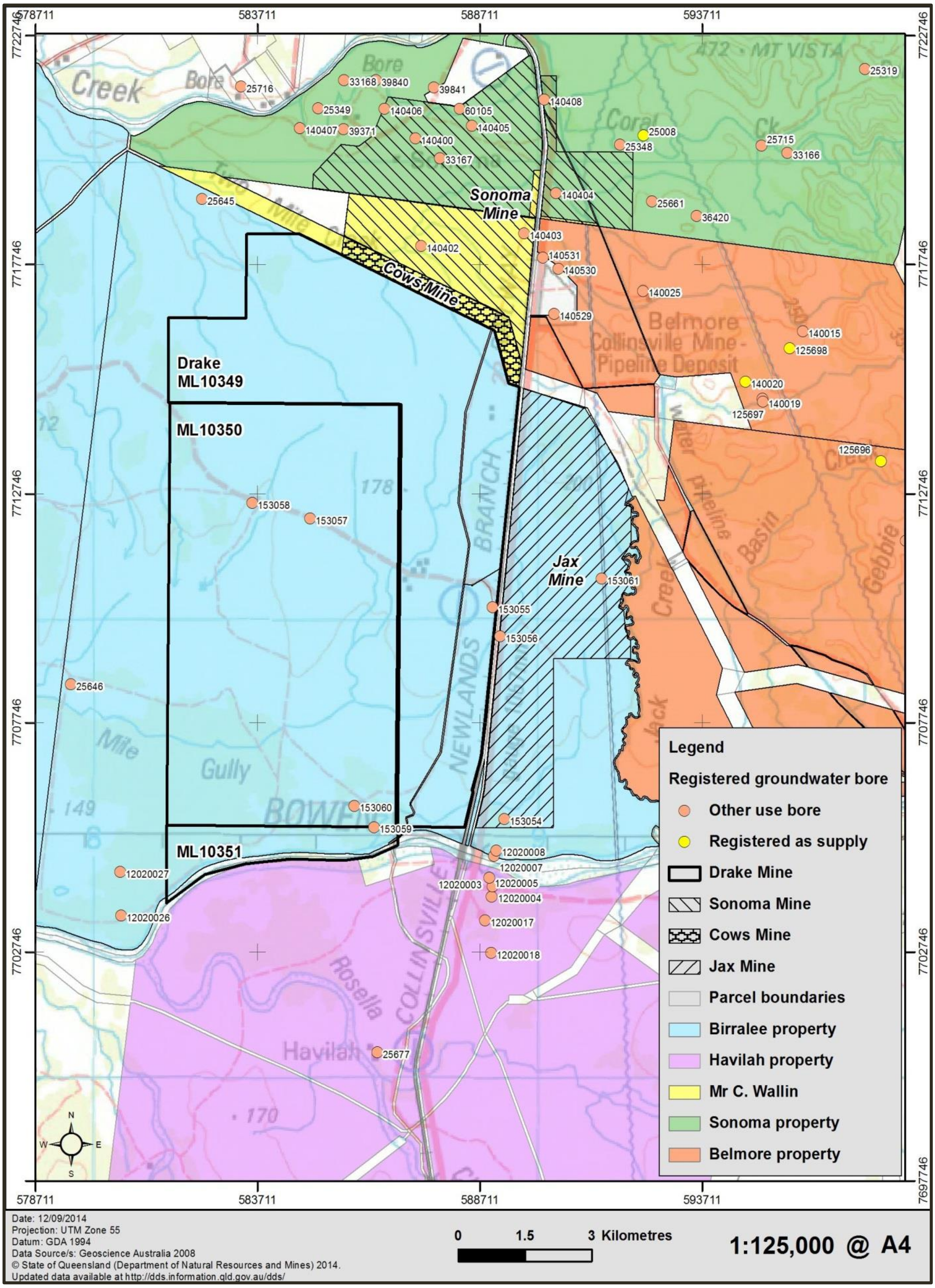

Figure 4-2 Registered Bores

This further indicates that groundwater use (conservatively including pastoral, irrigation, mining, stock and domestic and town water) is not considered a groundwater value across or in the immediate vicinity of the Project site. However as an additional measure of confirmation, the EPBC Conditions (**Section 3.1**) require that a strategy to conduct a landholder bore survey is included as part of the GMMP.

4.5.1 Landholder Bore Survey

In satisfaction of EPBC Condition 12-c, Drake Coal has formally completed the landholder bore survey for the properties north of the Bowen River (in order to present the results in this GMMP) and provides a strategy to complete a survey for the property south of the river.

The results of the GWDB search (**Section 4.5**) capture data relating to registered bores north and south of the Bowen River. As per **Section 4.5**, there are no registered bores north or south of the Bowen River in the vicinity of the Project which are used as a water supply (the closest registered bore potentially used for water supply is 5.4 km to the east RN140020). As such the intent of the landholder bore survey is to capture data relating to any unregistered bores on or adjacent the Project site.

The landholder bore survey was undertaken by Drake Coal involving the following:

1. Identify the relevant properties and areas for the survey.
2. Undertake surveys of landholders or landholder representatives for the identified properties, to ascertain the presence of any bores not registered with the Groundwater Database.
3. If any unregistered bores are ascertained as present, undertake a discussion to collect data on locations, depths, geology, yields, pumping details, usage and water quality.

As per the location and surrounding property description presented in **Section 2.1** and **Figure 2-2**, the properties identified as being relevant for the landholder bore survey are:

- “Birralee” on which the Project is located and which extends to the west and east;
- The privately held land to the north; and
- “Havilah” to the south.

The results of the surveys are as follows:

- “Birralee” (the Project area as well as to the west and east of the Project area)
  - This property is owned by Mr Christopher Wallin – QCoal Managing Director
  - Survey results indicate no unregistered bores within the “Birralee” property
- The privately held land to the north (two separate parcels of land):
  - One parcel is subject to a permit to occupy held by Mr Christopher Wallin – QCoal Managing Director
  - One parcel is owned by Mr Christopher Wallin – QCoal Managing Director
  - Survey results indicate no unregistered bores within the privately held land to the north
- “Havilah” to the south
  - This Property is owned by Colinta Holdings Pty Ltd, which is a subsidiary of Glencore (a mining company).
  - As this property is located south of the Bowen River, a strategy to undertake an unregistered bore survey is proposed as per EPBC Condition 12-C, as follows:
    - Review the results of the numerical model to determine the presence and extent of any potential drawdown south of the Bowen River;
    - Contact the representative for the Havilah property and undertake a survey for unregistered bores within the area of any potential drawdown; and
    - If unregistered bores are identified review their suitability for inclusion in the monitoring program.

The results of the landholder bore survey indicate that there are no unregistered bores on or adjacent the Project area; as such there is no opportunity to include landholder bores in the GMP for the Project.

5. Groundwater Monitoring Program

Groundwater monitoring should include manual measurement of water levels, collection of field water quality parameters and collection of samples for subsequent laboratory analysis; in addition monitoring may include downloading of level loggers (where installed).

All groundwater monitoring must be undertaken by an appropriately qualified person as defined by the EA, as per the requirements of the below (and any updates thereof):

- Department of Environment and Heritage Protection (2009) Monitoring and Sampling Manual 2009, Version 2, July 2013.
- AS/NZ 5667 11 1998 (Water Sampling Guidelines – Part 11 Guidance of sampling of groundwater).
- Australian Governments Groundwater Sampling and Analysis – A Field Guide (2009:27 GeoCat#6890.1)

5.1 EA Bores (Locations, Monitoring Frequency and Targeted Formations)

The bores which are required to be monitored, the location and elevation of each bore, as well as the required monitoring frequency, are stipulated in the EA Conditions (EA Table E1). The below table (**Table 5-1**) presents the information from EA Table E1, with the addition of the geological formations targeted by each bore. The bore locations are presented in **Figure 5-1**.

Table 5-1 EA – Table E1 Bore Locations including Targeted Formations

Bore number*	Longitude (decimal degree, GDA94)	Latitude (decimal degree, GDA94)	Surface RL (mAHD)	Monitoring Frequency	Formation
Reference Bores					
BR752	147.8546	-20.7050	164.3	Quarterly	Upper coal seam (Blackwater Group – Rangal, Fort Cooper and Moranbah)
DK1301	147.8204	-20.7505	tba	Quarterly	Alluvium (Bowen River)
DK014	147.8250	-20.7444	138.0	Quarterly	Composite coal measures to Exmoor (Upper coal seam into and through Exmoor)
Compliance Bore					
BR993	147.8159	-20.6885	159.2	Quarterly	Upper coal seam (Blackwater Group – Rangal, Fort Cooper and Moranbah)
DKWB02A	147.8292	-20.7484	136.9	Quarterly	Shallow quaternary sands and gravels (Quaternary alluvium)
DKWB02B	147.8249	-20.7443	141.4	Quarterly	Shallow quaternary sands and gravels (Quaternary alluvium)
DK1302	147.8127	-20.7503	tba	Quarterly	Alluvium (Bowen River)
DK1303	147.8001	-20.7515	tba	Quarterly	Alluvium (Bowen River)

Notes:
* Where a bore has been removed as a direct result of mining, monitoring of that bore is not required (as per EA Table E1).

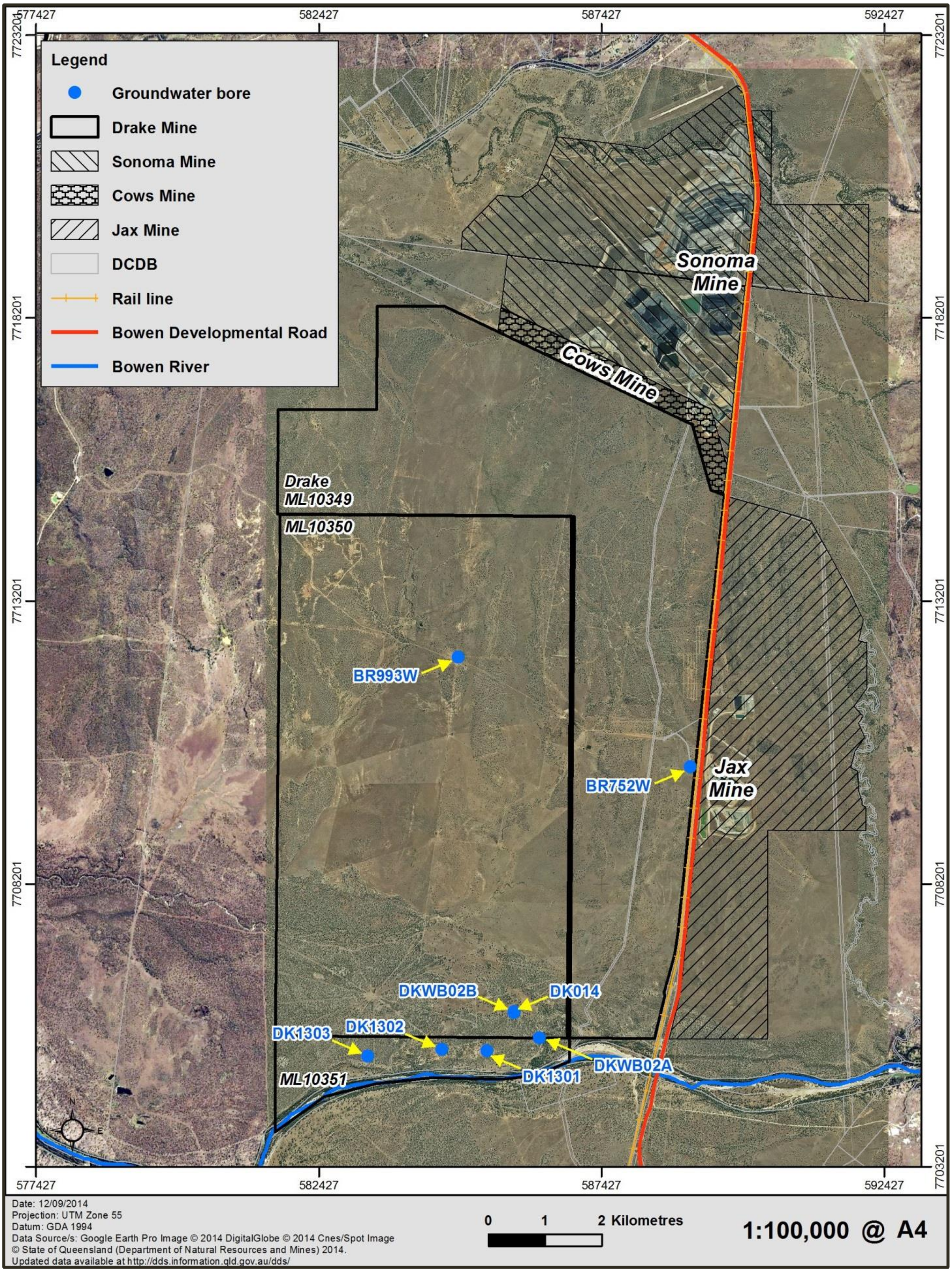

Figure 5-1 Drake EA Monitoring Bore Locations

5.2 Required Monitoring Parameters

Groundwater monitoring is required to track changes in groundwater level and quality.

5.2.1 Level monitoring

The objective is to track change in groundwater levels by monitoring the water level within all bores (listed in **Section 5.1**) either manually and/or by automated level logging. Requirements for monitoring of water level are stipulated in EA Condition E3, EA Condition E4 and EA Table E3.

5.2.2 Water quality monitoring

The objective is to track change in groundwater quality by monitoring the water quality within all bores (listed in **Section 5.1**). Requirements for monitoring of water quality are stipulated in EA Condition E3 and EA Table E2, which lists prescribed parameters, as presented below in **Table 5-2**.

Table 5-2 EA Required Groundwater Quality Parameter List

Water Quality Parameters		
pH	Hardness	Ammonia-N
Nitrate-N	Nitrite-N	Sulfate
Total Dissolved Solids	Aluminium	Arsenic
Boron	Cadmium	Chromium
Copper	Fluoride	Lead
Mercury	Molybdenum	Nickel
Selenium	Zinc	Benzene
Carbon tetrachloride	-	-

All quality parameters stipulated in EA Table E2 require samples to be collected and delivered to a laboratory for analysis, with the exception of pH; pH may be determined either by laboratory analysis or by using a field pH water quality meter. With respect to metals, analysis should be undertaken for total and dissolved metals, with the EA trigger and limits being applied to dissolved concentrations only.

5.3 Monitoring Methodology

5.3.1 Water level measurements

Water level measurements can be undertaken either manually or by automated loggers or both. Data from loggers should be used in conjunction with manual measurements as a confirmatory measure.

5.3.1.1 Manual Level Measurements

Manual measurement of water level within a bore should be undertaken at each monitoring event (regardless of the presence of automated level loggers). Two measurements are required in order to determine groundwater depth below ground level (bgl), as per the below:

1. Measure and record the bore top of casing (ToC) height to ground level
2. Measure and record and the depth to water within the bore from the ToC
    - Where non-aqueous phase liquid (NAPL) is present an interface probe is required and measurements should be taken from ToC to NAPL level in addition to water level
3. Calculation: *Groundwater depth bgl = Water level from ToC – Height of ToC to ground level*

Additional physical monitoring should be undertaken to ensure continued functionality of the bore:

4. Total depth of the bore measured from the top of casing (to track any silting up of the bore)
5. Condition of the bore (evidence of interference, damage etc)

Water level measurements are generally undertaken using water level sensors (dippers). Use/servicing/maintenance/calibration of dippers or interface probes should always be in accordance with manufacturer's instructions.

5.3.1.2 Level loggers

Some wells may have groundwater level loggers installed, which are pressure transducers that log (record) pressure at given time intervals (e.g. every 6 hours). Loggers are installed below the prevailing water level within the bore at a known depth from the ToC. The pressure data is used to calculate the water level and provides a log of any changes in level. Where a level logger is installed the battery should be checked, the logged data downloaded and the memory cleared, on a regular basis as per manufacturer's instructions.

Data from loggers is downloaded into software (specific to the logger manufacturer). Data compensation is required to adjust the raw logged data for barometric pressure (i.e. air pressure) and the installation depth of the sensor. As such one additional logger must be installed above the water level in a bore, to specifically record barometric pressure and be downloaded in the same manner as the water level loggers.

Once compensated correctly, level data should be representative of groundwater level (bgl) and be available for interpretation. The method of barometric and installation depth compensation, level calculations, will be as per the specific manufacturer's software.

Installation/downloading of data/servicing/maintenance/calibration of the loggers should always be in accordance with manufacturer's instructions and software requirements.

As at August 2014, the bores which have automated loggers installed are as follows:

- BR752
- DK1301
- DK014
- BR993
- DKWB02A
- DKWB02B
- DK1302
- DK1303

5.3.2 Water quality sampling

5.3.2.1 Purging

Water samples collected from monitoring bores for the purposes of groundwater quality monitoring, are intended to represent the groundwater within the surrounding formation i.e. therefore sampling for water quality from bores should be of fresh formation water and disturbed standing bore water.

Selection of purging methodology will depend on the particulars of each bore and the conditions at the time of monitoring. Methods, or exceptions to the adopted methods due to field circumstances (such as inclement weather, equipment failure, blockages etc.), should be recorded on the field sheets.

For this reason there are a number of methods of purging/sample collection which can be employed including air purging, pumping, hand bailing, hydroseleeves and low flow/micro purge. Once representative water is recovered, water quality sampling should be undertaken.

5.3.2.2 Field water quality parameters and analytical sample collection

Methods for water collection for sampling will depend on the method of purging; as such the selection of methodology will depend on the particulars of each bore and the conditions at the time of monitoring.

Based on the required water quality parameters (see **Section 5.2.2**), field water quality parameters are not required for EA compliance purposes. However, the collection of field parameters can assist in the bore purging process depending on the method (i.e. can demonstrate when fresh formation water is being recovered) and also as a comparative data point in the interpretation of laboratory data (i.e. compare field pH and laboratory pH). As such where a calibrated water quality meter is available, field parameters should be recorded on the field sheet – temperature, pH and electrical conductivity (EC) as a minimum; dissolved oxygen, ORP and turbidity should also be recorded where possible.

Once field parameters are recorded (if applicable), laboratory analytical samples should be collected in the appropriate sample containers (**Section 5.4.3**) for the analytical parameters stated in EA Table E2 (**Section 5.2.2**).

A Chain of Custody (CoC) form should then be completed (**Section 5.5.2.1**) and samples transported to the selected analytical laboratory (**Section 5.3.2.5**).

5.3.2.3 Field QA/QC

During monitoring of groundwater, field quality control and quality assurance (QA/QC) procedures and methods should be observed at the direction of the appropriately qualified person who is undertaking the monitoring, in consideration of the below:

- Department of Environment and Heritage Protection (2009) Monitoring and Sampling Manual 2009, Version 2, July 2013.
- AS/NZ 5667 11 1998 (Water Sampling Guidelines – Part 11 Guidance of sampling of groundwater).
- Australian Governments Groundwater Sampling and Analysis – A Field Guide (2009:27 GeoCat#6890.1)

5.3.2.4 Storage/Transport of samples

In general samples should remain chilled after collection during storage and transportation; however correct storage of samples after collection should be as per the recommendations stated by the selected laboratory and as per the relevant sample container. Samples once collected in the appropriate container have recommended holding times (i.e. maximum times that a sample can be stored prior to analysis) which vary depending on the desired laboratory analyses and the sample container. Storage and transport of samples should consider the recommended holding times for the various water quality parameters as stated by the selected laboratory for the required analysis and the relevant sample container

Sample containers which have the potential to break during transportation, such as glass bottles, should be protected (e.g. bubble wrap sleeves are usually provided with the container).

5.3.2.5 Laboratory analyses

Any analytical laboratories engaged to undertake analyses as part of EA compliance monitoring must be accredited by the National Association of Testing Authorities (NATA) for the requested analyses. Submission of samples to analytical laboratories will be accompanied by the appropriate CoC form, filled out to include the required analyses and reporting information.

Laboratories to which samples are sent for analyses will be considered the primary laboratory. Where a triplicate sample (inter-laboratory sample) is taken and is required to be forwarded to a secondary laboratory for inter-laboratory quality control purposes, that laboratory will be considered the triplicate laboratory. Accordingly, the CoC must state be that the triplicate sample is to be forwarded by the primary laboratory to the triplicate laboratory.

It is noted that NATA accredited laboratories will generally undertake laboratory quality control procedures including surrogates, blanks, method blanks etc. The quality control results should be reviewed by the recipient prior to acceptance of the groundwater laboratory results from any laboratory.

5.4 Monitoring Equipment

5.4.1 Equipment

For groundwater sampling, the adopted methodology (and accordingly the equipment) should meet all requirements under the EA Conditions, EPBC Conditions and the prescribed water sampling guidelines. Consultants/contractors undertaking groundwater sampling must demonstrate the methodology is compliant with the above. All equipment must be in serviceable condition and be operated as per the manufacturer's instructions, including decontamination procedures between sampling locations, where required for multi-use equipment (such as pumps).

5.4.2 Calibration

Monitoring equipment requiring calibration should be calibrated and maintained according to the manufacturer's instructions. Calibration records should be kept by the person/s undertaken the monitoring for a minimum period of five (5) years and provided to Drake Coal upon request.

5.4.3 Sample Containers

The correct sample containers required for collection/transport of samples (bottles, vials and jars) should be available for sample collection at the time of monitoring. Different sample containers are required for different analytes (quality parameters). For example, the container required for samples to be analysed for metals is different to the container required for samples to be analysed for nutrients. The appropriate sample containers required for the proposed laboratory analyses should be established by the person/s undertaken the groundwater monitoring; in general the laboratory selected for analyses will provide the appropriate containers upon request.

5.5 Documentation and Data Management

5.5.1 Field sheets

Drake Coal will provide a specific field sheet template to be completed by consultants/contractors when undertaking groundwater monitoring. The field sheet has spaces for each of the required field measurements to be recorded. Field sheets should be completed for every sampling point, including for sample points which are dry upon inspection and should be filled out in their entirety. Field sheets will be scanned and provided to Drake Coal.

As a minimum the field sheets will require the following data to be recorded:

- Name of sampler, data/time of monitoring and weather conditions
- Bore identification number and overall condition of bore (evidence of interference)
- Water level measurements (**Section 5.3.1.1**)
- Actions taken to download any automated level logger (**Section 5.3.1.2**)
- Water quality sampling – methods, volumes, purge data, field quality parameters and analytical sample collection (**Section 5.3.2**)

5.5.2 Laboratory Documentation

5.5.2.1 Chain of Custody

Drake Coal will provide a specific CoC form template, to be completed by consultants/contractors when submitting samples to an analytical laboratory. CoCs should be completed in full and be submitted with the samples. Drake Coal groundwater samples should not be on CoCs with samples from other sites or samples of other types (such as surface water). Drake Coal's representative must be marked on the CoC as the recipient of laboratory documentation.

5.5.2.2 Analytical Reports

Laboratory analytical reports should be sent to Drake Coal's representative as per the CoC form.

5.5.3 Data Management

Monitoring records, reports and data associated with monitoring groundwater as per the EA Conditions must be kept for a minimum of five years. Drake Coal will maintain two groundwater databases:

- a level database comprising manual and automated level logger results
- a quality database comprising field and laboratory quality results

5.6 Monitoring Results Interpretation - EA Trigger Level and Compliance

Once accepted, processed and input into the relevant groundwater database (**Section 5.5.3**), groundwater level and quality monitoring data will require comparison against the trigger limits for the various parameters, as prescribed in the EA.

5.6.1 Groundwater Level Compliance (Level Trigger Thresholds)

All bores stated in **Section 5.1**should be monitored for level as per EA Condition E3.

Groundwater level monitoring data should be compared against the prescribed groundwater level trigger thresholds relevant to the specific bores stated in EA Table E3, as per EA Condition E4. The below table (**Table 5-3**) presents those bores required by the EA to be subject to level trigger thresholds and the applied level trigger thresholds for each stated bore.

Table 5-3 EA – Table E3 Groundwater level monitoring

Bore number	Level trigger threshold
BR993	2m reduction (bores target coal measures)
BR752	
DK014	
DKWB02A	5m reduction (bores target alluvium in proximity to Bowen River)
DKWB02B	
DK1302	
DK1303	

Bore DK1301 is not included in EA Table E3 (and therefore is not included in **Table 5-3**); DK1301 would therefore not require comparison against level trigger thresholds. This exclusion is because of its proximity to bores DK1302, DK1303 and DKWB02A, which target the same Bowen River alluvium (**Section 5.1**) and which are all compared against the level trigger threshold. Level monitoring data from DK1301 is still required (**Section 5.1**) and will be used in interpreting any groundwater fluctuations noted in the Bowen River alluvium, as well as be available for use in any required investigation.

When groundwater level monitoring results are compared to the level trigger thresholds (as per EA Condition E4):

- If results do not exceed the level trigger thresholds for the relevant bore, then no actions are triggered.
- If results exceed the level thresholds for the relevant bore (EA Condition E5), the actions presented in **Section 6** are triggered.

5.6.2 Groundwater Quality Compliance (Quality Triggers and Limits)

All bores stated in **Section 5.1** should be monitored for quality as per EA Condition E3.

Groundwater quality data should be compared against the prescribed triggers and limits stated in EA Table E2, as per EA Condition E3. The below table (**Table 5-4**) presents the groundwater quality triggers and limits from EA Table E2, for the prescribed quality parameters (**Section 5.2.2**) and is therefore subject to change as per the EA.

Table 5-4 EA – Table E2 Groundwater quality monitoring

Parameter	Units	Contaminant Triggers
pH	pH units	6-9
Hardness	(mg/L)	2,592
Ammonia-N	(mg/L)	7.263
Nitrate-N	(mg/L)	0.196
Nitrite-N	(mg/L)	0.820
Sulfate	(mg/L)	86.25
Total Dissolved Solids	(mg/L)	9,550
Aluminium	(mg/L)	0.289
Arsenic	(mg/L)	0.004
Boron	(mg/L)	0.29
Cadmium	(mg/L)	0.0048
Chromium	(mg/L)	0.009
Copper	(mg/L)	0.026
Fluoride	(mg/L)	0.4
Lead	(mg/L)	0.020
Mercury	(mg/L)	0.0001
Molybdenum	(mg/L)	0.002
Nickel	(mg/L)	0.014
Selenium	(mg/L)	0.01
Zinc	(mg/L)	0.479
Benzene	(µg/L)	1
Carbon tetrachloride	(µg/L)	5

With respect to metals, analysis should be undertaken for total and dissolved metals, with the EA trigger and limits being applied to dissolved concentrations only.

When groundwater quality monitoring results are compared to the triggers and limits (as per EA Condition E3):

- If results do not exceed the quality triggers or limits, then no actions are triggered.
- If results exceed the quality triggers or limits (EA Condition E5), the actions presented in **Section 6** are triggered.

5.7 Additional Stygofauna Monitoring

As per EA Condition E9 (**Section 3.2**), a stygofauna pilot sampling study is required for the following bores which target the Bowen River alluvium (as these bores were not in place at the time of the stygofauna survey undertaken for the EIS, see **Section 4.4**):

- Bore DK1301
- Bore DK1302
- Bore DK1303

The pilot study should be undertaken in accordance with the stygofauna guideline.

If the results of the pilot study identify stygofauna that are determined to be both endemic to the area and at risk from mining related impacts, further sampling should be undertaken and the results should be issued to the administering authority.

As per the stygofauna guideline, bores should be in place a minimum of six (6) months prior to sampling for stygofauna, to allow for equilibrium and colonisation to occur. Accordingly the stygofauna pilot study will be planned and undertaken by an appropriately qualified person (as defined by the EA), a minimum of six (6) months after installation.

5.8 Expansion of Groundwater Monitoring Program

One of the key considerations of the groundwater assessments undertaken during the EIS was the determination of surface water – groundwater interaction, in particular due to the proximity of the Bowen River (see **Section 4.2**).

For this reason three of the bores which are required to be monitored (**Section 5.1**) are specifically located adjacent the Bowen River in the alluvial material, to provide some confirmatory monitoring data during operations and to intercept any potential impacts.

However to facilitate continued improvement of the groundwater monitoring program and to ensure that key data is being captured, the groundwater monitoring program will be subject to evaluation against monitoring and modelling data, to identify data gaps and opportunities for expansion to undertake additional monitoring.

The results of operational groundwater monitoring and the results of the verification of the numerical groundwater model against the monitoring data, should be used to identify opportunities to fill potential data gaps. More specifically, once operational groundwater monitoring data over several seasons is available and verification of the numerical model has been attempted/completed, potential data gaps can be identified where additional monitoring may be required, including:

- Locations
- Targeted depths
- Quality parameters
- Frequency of monitoring to improve temporal resolution of data
- Frequency of reporting

Once the numerical groundwater model has been reliably verified against operational monitoring data, the model can be used to identify areas where potential groundwater impact in relation to surface water might occur; those identified areas may then be considered for additional bore installation and monitoring (if none already exist in the area).

5.9 Bore Construction, Maintenance and Decommissioning

The drilling and installation of water bores will be undertaken by licenced drilling contractors, in accordance with the conditions of the EA pertaining to waste management, spill prevention and response, emergency/incident reporting and general environmental duty of care. Bores will be cased and constructed to prevent any hydraulic connection between various strata through the bore annulus.

As part of the monitoring methodology (**Section 5.3**), monitoring includes a physical inspection of the condition of the bore for evidence of interference or damage. Monitoring will be undertaken by appropriately qualified persons, who will be required to record any issues with bore operation. Level monitoring (**Section 5.3.1.1**) includes the physical measurement of total bore depth. If this measurement differs from previous records or from the bore construction report, it may be an indication of silting up or cracked/damaged casing or screen. If the monitoring results include anomalous results or comments, the condition of the bore will be confirmed as part of any investigation, which may require the use of a "down hole" camera to further identify the issue.

In the event that condition of the bore is confirmed as requiring maintenance, the corrective actions will depend on the identified issue and cause, but may include flushing out with clean water or re-development (continuous pumping). If the issue cannot be corrected *in-situ*, the bore may be re-drilled and re-installed in the same location (over drill the existing bore and install a new bore) or a new bore may be installed adjacent the faulty bore as a replacement.

At the cessation of groundwater monitoring (i.e. post rehabilitation) the bores may either be handed over to the landholder (upon specific agreement) or decommissioned. In general decommissioning involves grout being poured into the bore to completely fill the casing to ground level (or just below) and the cutting off of surface standpipe. In this way no cavity remains and there can be no bore related connection between various strata.

6. Trigger and Limit Exceedances

6.1 Exceedance Procedure

Where a groundwater monitoring result exceeds the triggers and/or limits for either level or quality (**Section 5.6**), the EPBC Conditions and EA Conditions (**Section 3**) stipulate a sequence of comparison, investigation, notification and reporting actions as presented in **Figure 6-1**. Discussion on investigations, corrective actions and notification/reporting requirement is provided in the following sub-sections.

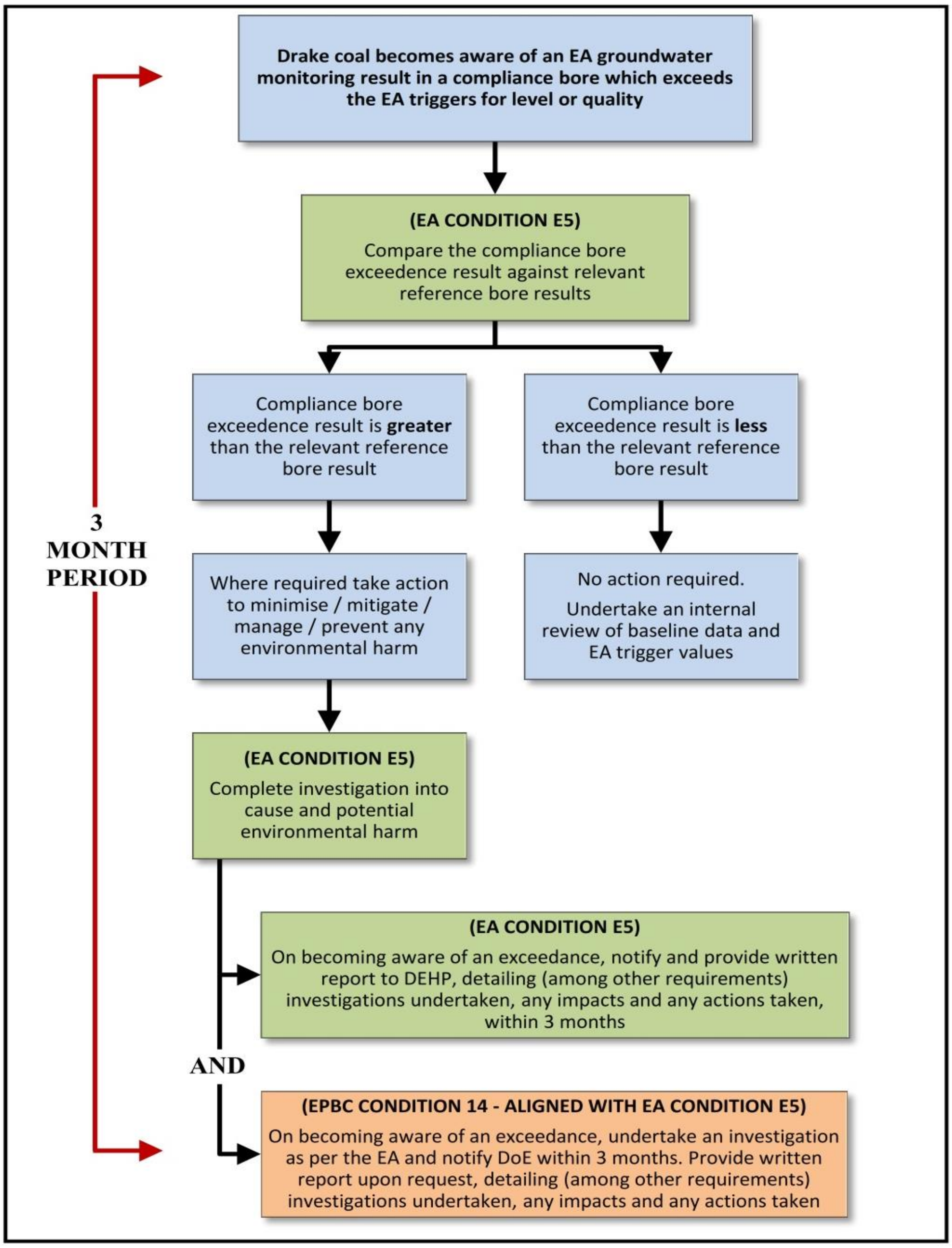

Figure 6-1 Exceedance Investigation, Notification and Reporting Requirements

The Model Mining Conditions Guideline provides instruction on how to comply with EA Condition E5, in particular the exceedance/investigation requirements, as shown in **Figure 6-2** below.

Guideline
Model mining conditions

Exceedance Investigation

E5 If quality characteristics of groundwater from compliance bores identified in **Table E3 - Groundwater monitoring locations and frequency** exceed any of the trigger levels stated in **Table E4 - Groundwater quality triggers and limits** or exceed any of the groundwater level trigger threshold stated in **Table E5 - Groundwater level monitoring**, the holder of this environmental authority must compare the compliance monitoring bore results to the reference bore results and complete an investigation in accordance with the ANZECC and ARMCANZ 2000

How do I comply:

If the level of contaminants at the compliance monitoring bore does not exceed the reference bore results, then no action is to be taken. If however the level of contaminants at the compliance monitoring bore is greater than the reference bore results, an investigation is to be completed in accordance with the ANZECC and ARMCANZ 2000 into the potential for environmental harm and a written report is to be provided to the administering authority within 3 months, outlining:

a) details of the investigations carried out
b) details of environmental impacts observed
c) actions taken to prevent environmental harm.

Where an exceedence of a trigger level has occurred and is being investigated, then no further reporting is required for subsequent trigger events for that quality characteristic within the 3 month investigation period.

Figure 6-2 Model Mining Conditions Guideline – How to Comply with EA Condition E5

As per the actions summarised in **Figure 6-1** and the prescribed method of compliance with EA Condition E5 (**Figure 6-2**), if a level or exceedance result exceeds an EA trigger or limit, a comparison between reference and compliance bores in undertaken to determine the requirement for an investigation:

1. If the result is from a reference bore then no investigation is required
    a. A review of the groundwater data and EA trigger or limit values may be undertaken
2. If the result is from a compliance bore, then compare the compliance bore result against the result from the relevant reference bore/s
    a. If the compliance bore result is less than the reference bore result, then no investigation is required and a review of the groundwater data and EA trigger or limit values may be undertaken
    b. If the compliance bore result is greater than the reference bore result, an investigation is required along with requirements for regulatory notification. If the findings of the investigation recommend actions to prevent any environmental harm, those actions should be carried out.

6.2 Investigations into Exceedance of Trigger or Limits

Where a compliance bore monitoring result has exceeded a trigger or limit for level or quality, and the subsequent comparison indicates the result is greater than the relevant reference bore, an investigation is required.

Investigations will be entirely dependent on the particulars of the exceedance but should include:

- Details of the exceedance
    - Location (bore) and date of the sample/measurement/logged data point
    - The exceedance result itself, comparison against triggers/limits, comparison against reference bore
- Examination into cause
    - non mining causes: e.g. sampling/measurement error, climactic influences, natural variation (comparison against historical datasets)
    - mining related causes: e.g. dewatering, spills, seepage
- Examination of consequence
    - Has the exceedance resulted in any unauthorised environmental harm and evaluation of any associated environmental impacts?

If the investigation into the cause concludes it is not mining related then no further actions are required, however, a review of EA trigger and limit values may be undertaken.

If the investigation concludes that the exceedance is the result of mining activities and that the exceedance caused unauthorised environmental harm which has resulted in identified environmental impacts, then actions to minimise/mitigate/manage the impacts associated with the unauthorised environmental harm should be implemented. In addition measures should be implemented to aid in the prevention of further occurrences of the unauthorised harm and associated environmental impacts.

6.3 Actions to Minimise Impacts and/or Prevent Further Occurrences

Where mining activities have been shown to cause unauthorised environmental harm with associated environmental impacts on groundwater values, minimisation and preventative actions may be required. Examples of potential groundwater impacts include:

- Potential to drawdown regional groundwater levels by pit dewatering.
- Potential contamination of groundwater through seepage of waste rock dumps and in-pit rejects.
- Pollution of groundwater from surface activities may occur from seepage of co-disposal facilities and accidental release of hydrocarbons (e.g. fuels and oils) or other contaminants.

The specific actions required will be dependent on the particulars of the groundwater value, the specific impacts which have occurred, and the mechanisms and activities identified in the investigation as the cause/s.

Actions may include:

- Detailed hydrogeological/groundwater review and assessment
- Review of mining procedures
- Redrilling of bores
- Review of mine closure plans
- Review of GMMP and/or numerical model
- Compensation
- Contaminated land assessments and remediation planning

Additional actions may also include the preparation of detailed response plans where more comprehensive investigations/actions have been identified as being required; these may include:

- conducting a full risk assessment
- developing a conceptual model where sources, pathways and receptors are identified and assessed
- assessment of how and the rate at which inter aquifer leakage may be occurring
- assessment of the potential effects on the receiving environment and the need for further investigation/ assessment

It is noted that emergencies and incidents relating to spills and seepage occurrences are addressed specifically and separately in the EA Conditions, with separate and specific conditions for reporting, management, investigations, remediation and prevention.

6.4 Notification and Reporting

The Project has notification and reporting requirements to DEHP (under the EA Conditions) and to DoE (under the EPBC Conditions) as presented in **Section 3**.

6.4.1 EA Conditions – Notification and Reporting

EA Condition E5: *Exceedance Investigation: "If quality characteristics of groundwater from compliance bores identified in Table E1 - Groundwater monitoring locations and frequency exceed any of the trigger levels stated in Table E2 - Groundwater quality triggers and limits or exceed any of the groundwater level trigger threshold stated in Table E3 - Groundwater level monitoring, the holder of this environmental authority must compare the compliance monitoring bore results to the reference bore results and complete an investigation in accordance with the ANZECC and ARMCANZ 2000."*

EA Condition E5 does not specify requirements for reporting of exceedances to DEHP; however, the Model Mining Conditions Guideline provides instruction on how to comply with EA Condition E5, including notification and reporting requirements, as shown in **Figure 6-2**.

As per the Model Mining Conditions Guideline for EA Condition E5, if exceedance of a trigger or limit occurs in a compliance bore and the exceedance value is greater than the relevant reference bore value, an investigation is required. The EA Conditions require notification to DEHP via submission of a written report within 3 months of becoming aware of the exceedance. The written report should outline the exceedance, the investigation details, any environmental impacts and any actions taken to prevent reoccurrence or to mitigate those impacts.

6.4.2 EPBC Conditions – Notification and Reporting

EPBC Condition 14:

- *14-a: "If the groundwater quality and or level triggers referred to in Condition 12a of this approval are exceeded and an investigation is completed in accordance with Schedule E of the Environmental Authority, the approval holder must notify the Department within 3 months on becoming aware of the exceedance."*
- *14-b: "If requested, the approval holder must provide copies of any exceedance investigation documents to the Department, in a timeframe agreed in writing by the Department, which state the cause, response, and actions undertaken to prevent further occurrences."*

As such the notification and reporting requirements of the EPBC Conditions to the DoE align with the notification and reporting requirements of the EA to DEHP; specifically, DoE would be notified of an exceedance and provided with investigation results (if requested) in line with DEHP.

This approach prevents unnecessary notifications being received by DoE and ensures consistent notification and reporting timeframes between DoE and DEHP.

7. Numerical Groundwater Model

7.1 Background

The EPBC Conditions include two conditions which relate to the requirement for a numerical groundwater model as per the below:

- EPBC Condition 12-e: "*a numerical groundwater model to simulate and quantify groundwater drawdown extent and flow impacts on the Bowen River, and validate the assumptions and potential risks and impacts of the project on groundwater resources identified in the EIS documents. The model must be developed with reference to the National Water Commission Groundwater Modelling Guidelines and must include a monitoring strategy to validate the model.*"
- EPBC Condition 12-f: "*the methods, frequency and timeframes in which the GMMP and numerical groundwater model will be reviewed.*"

Accordingly Drake Coal engaged Australian Groundwater and Environmental Consultants Pty Ltd[5] (AGE) to develop the groundwater numerical model, for inclusion in this GMMP, as per the EPBC Conditions. A summary of the numerical model methods, key assumptions and results is provided in the following subsections, along with an overview of previous EIS groundwater modelling and a comparison of the numerical model against the EIS findings.

7.1.1 Objectives of the Numerical Model

The requirements of the EPBC Conditions were used to identify the following key objectives for the numerical model:

- Simulate and quantify the extent of any groundwater drawdown associated with the Project;
- Establish if this has any impact on the flow in the Bowen River and if so quantify any loss of flow;
- Use the model to validate (confirm) the findings of the EIS in relation to potential risks and impacts on any groundwater resources (values) identified across the Project area.

The identified objectives are a key consideration in determining the actual required functionality of the model (i.e. what does the numerical model have to be able to do to achieve the key objectives); this in turn informs the modelling approach and methods which is considered most suitable.

As such in order to achieve the stated objectives of the EPBC Conditions, the numerical model is required to include (but not limited to) the following broad functionality:

- simulate and quantify interactions between various groundwater bearing units (interconnectivity) across the Project area;
- simulation and quantification of groundwater inflows into mining pits;
- simulation and quantification of drawdown (cones of depression) extents associated with groundwater inflows into pits;
    - consideration of individual Project pits (pit drawdown)
    - consideration of the Project pits collectively (cumulative Project drawdown)
    - consideration of any relevant external potential sources of drawdown, such as adjacent mining operations (cumulative local area drawdown)

[5] AGE are recognised as industry experts in groundwater with extensive experience in numerical modelling, coal mining operations, impact assessment and the hydrogeology of the north Bowen Basin.

- simulate and quantify the relationship between groundwater and the Bowen River (surface to groundwater connectivity);
- where any drawdown extents have been shown to encroach on the Bowen River, simulate and quantify any potential impacts (loss of flow) on the Bowen River; and
- where any drawdown extents have been shown to encroach on any identified groundwater resources/values (such as water supply bores), simulate and quantify any potential impacts.

7.1.2 Guidelines

The numerical model was developed in line with the *National Water Commission Groundwater Modelling Guidelines*[6] (the modelling guidelines).

The modelling guidelines classify models according to the level of confidence in the model predictions, with the adopted classification reflecting a number of considerations including:

- the level of data available to support model development;
- the calibration process; and
- the manner in which the predictions are formulated.

As this numerical model is required under the EPBC Conditions and due to the proximity of the Bowen River which is a key modelling focus, a Class 2 model was recommended (see also **Section 7.5.2**).

7.2 Overview of Results from EIS Groundwater Model

As part of the EIS groundwater study, groundwater modelling was undertaken using the Marinelli and Niccoli (2000) analytical modelling approach (analytical model). The following subsections summarise the outcomes of the analytical model to allow for confirmation and comparison against the results from the numerical model.

7.2.1 Analytical Modelling Method

The analytical model was used to simulate pit inflows and associated potential drawdown extents for various development progression scenarios (as the pits increase in size as the Project expands). In addition the analytical model was also used to estimate the potential impacts on potential loss of flow in the Bowen River associated with the modelled drawdown.

Given that the findings of the EIS concluded that the groundwater had low value across the project area for key potential resources such as springs and GDEs (**Section 4.3**), stygofauna (**Section 4.4**), groundwater users (**Section 4.5**), and notably that the groundwater to surface water interactions (connection to the Bowen River) were found to be limited (**Section 4.2**), this approach was considered highly suitable for the EIS. This is particularly so given the conservative assumptions inherent in the analytical model method, but also the conservative values adopted for the various model inputs.

The analytical model uses a series of hydrogeological equations to calculate steady state or long term average inflows into a mine pit. In practice, due to the nature of the proposed mining operations, steady-state conditions are unlikely to develop. For example, development of small pits (such as Central 1) pit is expected to be completed in less than two years. The conceptual drawdown cone associated with dewatering operations in this pit will gradually expand as water is pumped from storage within the Permian Coal Measures; however, given the relatively short period of mining in this pit it, is likely that the drawdown cone associated with this pumping will not have reached steady-state by the end of year

[6] Barnett B., Townley L.R., Post V., Evans R.E., Hunt R.J., Peeters L., Richardson S., Werner A.D., Knapton A. and Boronkay A., (2012), *"Australian groundwater modelling guidelines"*, Waterlines report, National Water Commission, Canberra, June 2012.

two. At this point, dewatering operations will cease and hence the drawdown cone will begin to gradually contract.

In terms of the cone of influence of dewatering operations, the assumption of steady-state conditions in the analytical model therefore represents a specific measure of conservatism, or 'worst' case scenario assessment.

The results of the analytical model considered:

- hydraulic conductivities;
- standing pit water;
- pit dimensions and schedules;
- the effect of decreased saturated thickness near the pit walls (Zone 1);
- the distributed nature of recharge to the water table; and
- upward flow through the pit floor (Zone 2).

The analytical model was completed for a range of assumed input values for key parameters. The full details of the EIS modelling method is presented in the EIS and SEIS documents, which include information on:

- actual analytical model equations
- conceptual hydrogeological assumptions
- specific hydrogeological parameter values which were assumed as inputs to the equations
- the iterative method of calibration for various modelled outputs; and
- comparison against measured groundwater bore and pit inflows in the existing adjacent Sonoma Coal Mine.

7.2.2 Analytical Modelling Results

7.2.2.1 Pit Inflows and Drawdown Extent

The results of the analytical model are presented in **Figure 7-1** , extracted from the EIS, for maximum and minimum pit inflows and drawdowns.

Pit	Min Predicted Inflow (ML/d)	Max Predicted Inflow (ML/d)	Min Predicted Cone of Influence (km)	Max Predicted Cone of Influence (km)
West 1	1.361	2.753	1.130	5.470
West 2	1.452	2.956	1.195	5.708
East 1	0.085	0.152	0.238	1.180
East 2	0.075	0.112	0.176	0.878
East 3	0.623	1.514	0.961	4.434
East 4	0.063	0.107	0.192	0.956
Central 1	0.095	0.174	0.257	1.278
Central 2	0.422	0.892	0.700	3.240
Central 3	0.174	0.274	0.288	1.440
Central 4	0.060	0.111	0.213	1.042

Figure 7-1 EIS Analytical Model Results – Pit Inflows and Drawdown Extents

The maximum drawdown extents were then considered cumulatively across the project area, with results presented in **Figure 7-2**, extracted from the SEIS (note that when considering registered bores please refer to **Section 4.5**).

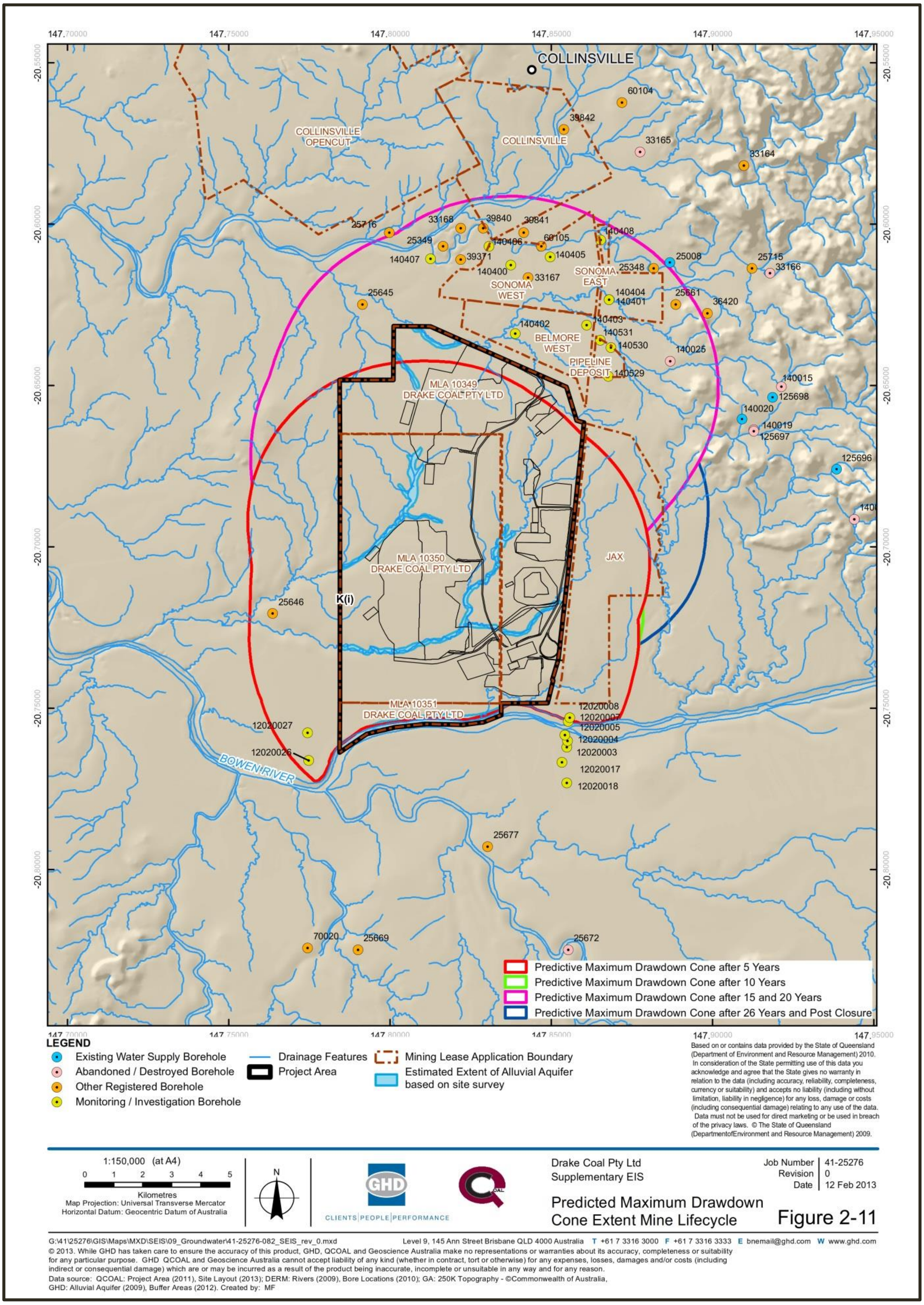

Figure 7-2 EIS Analytical Model Results – Drawdown Extent Map

The analytical model concluded that none of the registered bores registered for potential use as water supply, are within the estimated cone of influence of any of the proposed open pits. No impacts on groundwater level in any known water supply well are therefore anticipated.

In addition no known springs or GDEs exist in the estimated cone of depression.

7.2.2.2 Potential Bowen River Impacts

In the event that maximum potential drawdown estimated by the analytical model occurs (as presented in **Figure 7-2**) and if there is a connection between the underlying Permian coal measures and the Bowen River alluvial material (which is considered unlikely as per **Section 4.2**), the EIS used the analytical model to estimate potential impacts to the flow of the Bowen River.

In the above scenario where the Bowen River surface water and underlying Permian groundwater are connected, then the actual cone of influence in the coal measures would be unlikely to extend south beyond the Bowen River. That is because the leakage induced through the connection from the overlying river into the Permian cone of depression, effectively halts the extent of drawdown at the river. Hence, the maximum impact on the river can be estimated by calculating the proportion of the cone of influence which would hypothetically extend south of the river.

Maximum flow loss in the Bowen River was calculated as 0.47ML/day between years 11 to 15 of mining. This calculation was accepted by DNRM as an appropriate drawdown calculation during the EIS submission process.

The EIS and SEIS concluded that a 0.47ML/day flow loss, represents an insignificant impact to the Bowen River (i.e. even if there was a hydraulic connection, there would be insignificant impacts to the Bowen River, even at periods of seasonal low flow).

Using the Bowen River flow data at Jacks Creek gauge (immediately upstream of the site), long term average flow in the river is around 1,797 ML/day and hence the predicted flow impacts of 0.47ML/day represent less than 0.03% of average flow in the river and are therefore considered to be minor and would have no impact to the regional water balance.

7.2.2.3 Summary

Based on the groundwater assessments, investigations into groundwater values and resources and the analytical modelling assessment undertaken, the EIS concluded that:

- The maximum potential drawdown for the project is 5.47km (which is not considered likely but is the maximum based on the upper range of hydraulic parameters)
- There are no groundwater users within that distance that can be impacted
- There are no springs or GDEs in the distance which can be impacted
- The maximum potential impact to flow in the Bowen River is <0.03% of the average flow in the river and that an impact of that scale is considered insignificant.

As such the overall finding of the EIS was that the potential risk to groundwater resources and the Bowen River was low.

7.3 Conceptual Hydrogeological Model

Detailed discussion of the hydrogeology across the site and the region is provided as part of the EIS.

7.3.1 Geological Model for Groundwater Numerical Model

The regional geology is described in **Section 4.1**.

Drake Coal created a detailed geological model for the Project area and immediate surrounds based on data from:

- exploration drilling undertaken across the Project area;
- exploration drilling as well as operational pit geology data from the adjacent Sonoma, Cows and Jax Coal Mines; and
- broad scale exploration drilling data from the Havilah property south of the Bowen River.

This model was configured at AGE's request to identify the key basal seams and accumulated coal seam thicknesses for the requested groupings. The geological model captured the faulting and displacement of seams.

The base of weathering elevation was used to define the floor of the cover material. The surface geology model for the area is less detailed with exploration data focussed on coal seam geology, as such the distribution of surficial cover material of interest (i.e. alluvium) across the Project site has been projected based on the location and dimensions of the surface drainages and the topography of the areas adjacent those drainages.

The weathered cover material is understood to be mostly comprised of fines (silts and clays), although there would be isolated sand and gravel pockets where historical river channels have existed.

As such the geological model refined for use in the numerical groundwater model, has been interpreted around the target coal seams in the Moranbah Coal Measures separated by interburden. Underlying these layers is the Exmoor formation, which is also incorporated into the model as a single discrete unit, as the modelled mining activities do not penetrate that formation.

On the eastern margin of the Project area, aligned to the deeper central part of the basin, the Fort Copper Coal Measures overly the Moranbah Coal measures, and these are also represented in the numerical model as a single discrete unit. Further to the east, the Moranbah Coal Measures and Exmoor Formation subcrop again (forming the other side of the basin) whilst the underlying Lizzie Creek Volcanics outcrop.

A review of the available data indicates that the hydrogeological regime across the area, can in general be considered as having two main potential hydrostratigraphic components (although site specific evidence indicates that actual alluvial aquifers are limited in areas removed from the notable surface watercourses):

- Shallow unconfined, heterogeneous, isolated aquifers in the Cainozoic alluvial sediments; and
- Deeper confined aquifers within the Permian coal seams.

It is generally accepted that in the Bowen Basin, coal strata have a higher permeability than the inter-burden and therefore comprise the main water bearing beds. The review of the resource exploration data for the Project indicates that the inter-burden is typically comprised of fine-grained sandstone, siltstone and mudstone that are of low primary porosity, and are therefore expected to yield only very limited quantities of poor quality groundwater.

It is a key feature and important to note that identified thrust fault displacements are in the order of 20-40 m greater than the typical thickness of the coal seams, which are only several metres thick; these faults interrupt the lateral extent and continuity of the coal seam aquifers. It is understood there is only limited broken ground associated with the faults and therefore the faults would only be expected to transmit low volumes of groundwater.

Presented in **Figure 7-3** is a schematised geological cross section of the entire Project area from north to south. It should be noted that as the cross section is 14,000 m long while the depth is only 400 m, the vertical exaggeration is 1:15 and hence care should be taken when interpreting this cross section.

A critical aspect of the numerical modelling is the interaction of the mine with the Bowen River. Presented in **Figure 7-4** is a more detailed schematic of the geology in proximity to the Bowen River, extracted from the cross section presented in **Figure 7-3**. This demonstrates how the coal seams at this location dip below the river and continue getting deeper within the Bowen Basin to the south of the Project area. Again care should be taken in interpreting this figure as there is a vertical exaggeration of 1:2, to cater for a 2,750 m distance for a 300 m depth

7.3.2 Recharge Processes

Across the region, recharge to the aquifers occurs through rainfall infiltration and infiltration occurring with intermittent flooding of the Bowen River, particularly in the material along the Bowen River alignment. Based on transient model calibrations, the water balance indicates that volumetrically the intermittent flooding of the Bowen River is the predominant mechanism; however the bulk of that flooding related inflow is released immediately (or relatively quickly) back into the Bowen River when the flooding subsides.

As such the overall rate of recharge is estimated to be very low for the Project area and the region. This low rate is due to the clayey nature of the cover material reducing infiltration from rainfall, with most rainfall becoming surface runoff. For the infiltration of rainfall which does occur, the majority would either be lost through vegetation uptake (evapotranspiration) or potentially become interflow and express at surface drainages (however no observed base-flow existed in any waterway across the Project, with the exception off the Bowen River) leaving a small proportion of infiltration reaching and being retained in aquifers in the Project area.

7.3.3 Discharge Processes

Based on the groundwater values discussed in **Section 4.5**, there are no registered bores used or potentially used as water supply closer than 5.4 km to the Project (5.4 km to the east), and no unregistered bores at all in the relevant properties. As such groundwater extraction for either domestic or agricultural use is not considered a mechanism of groundwater discharge.

As such the potential discharge mechanisms for groundwater which have been considered are:

- Groundwater to surface drainages as base flow; however it is noted that no observed base-flow existed in any waterway across the Project with the exception of the Bowen River
    - Surface expression of groundwater is not noted anywhere on or adjacent the site, with the only exception associated with an intermittent flood water related "surge and return" of Bowen River flood waters propagating into the immediate surrounding material, and then a flow back into the river out of the material when flood waters recede.
    - Accordingly and as discussed in **Section 4.2**, surface water in the vicinity of the Project is generally not reliant on groundwater for flow and as such is not considered a groundwater value (with the Bowen River subject to specific consideration and modelling).
- Evapotranspiration; and
- Adjacent mining operation pit inflows.

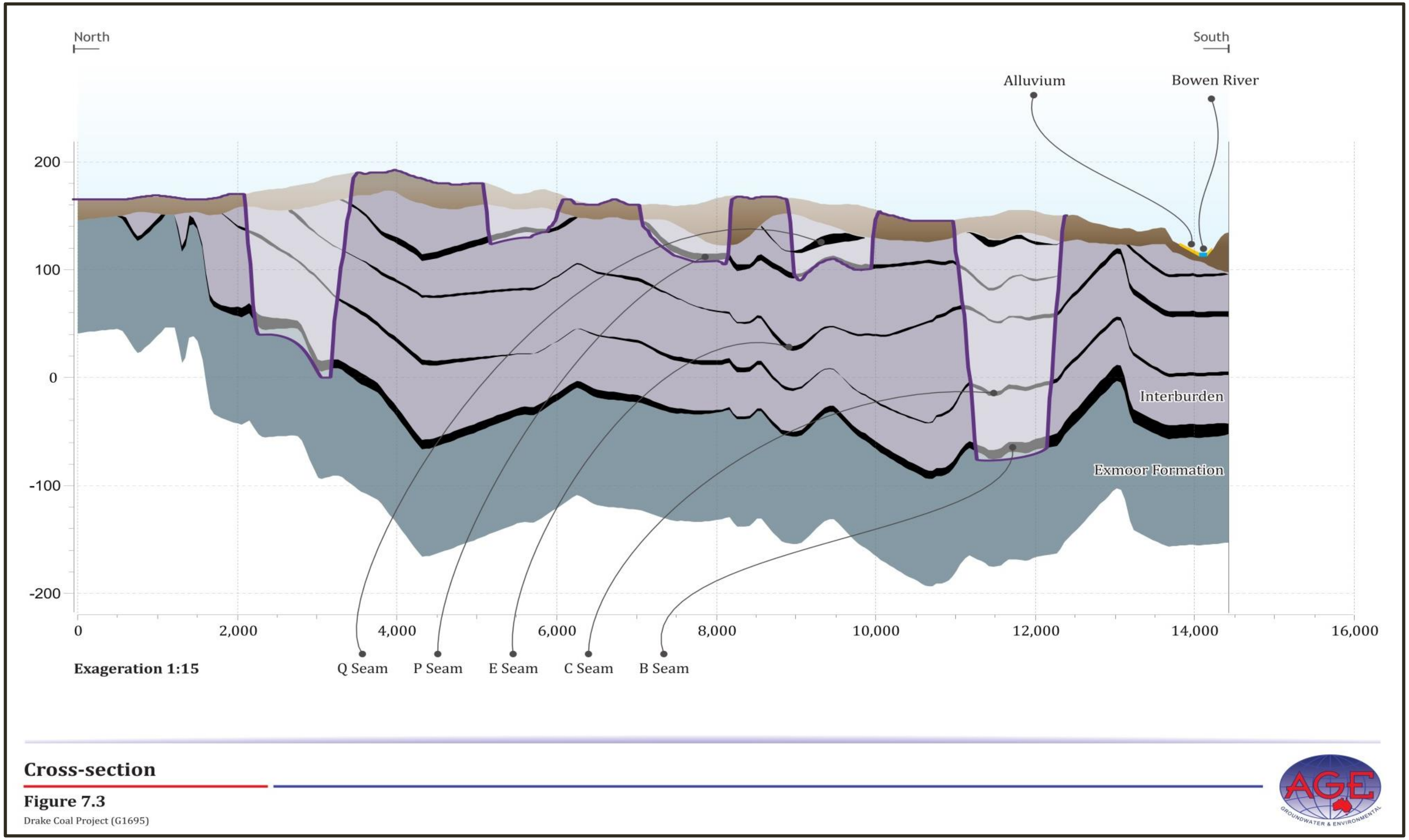

Figure 7-3 North-South Geological Cross Section Entire Project Area 1:15 Exaggeration

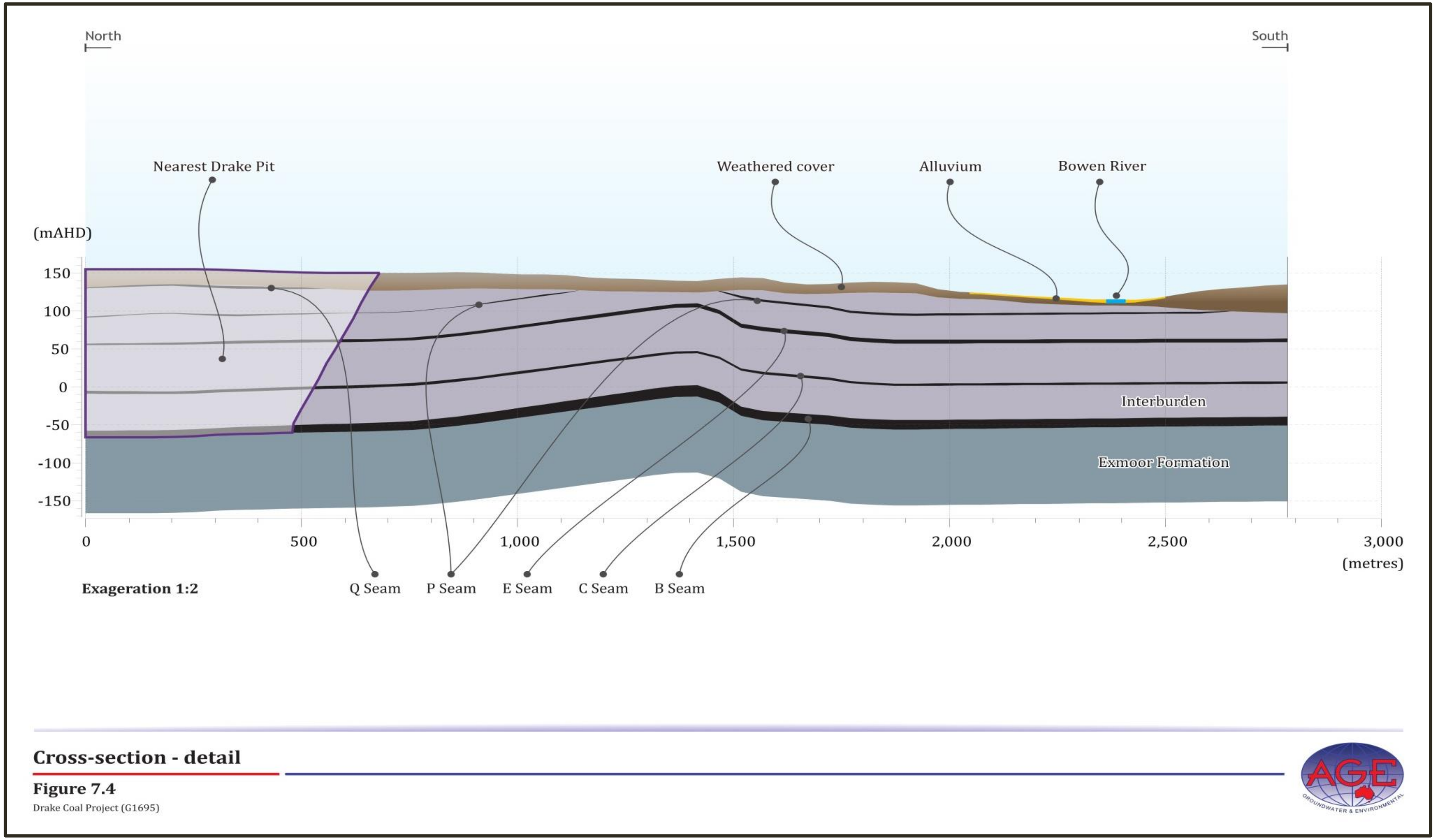

Figure 7-4 North-South Geological Cross Section Bowen River 1:2 Exaggeration

7.3.4 Groundwater Movement

The Sonoma Coal Mine to the north of the Project area, mines from the same targeted coal measures as for the Project and has recorded pit inflows during its operation. As such any inflow data is considered directly representative of the relevant hydrostratigraphic units for the Project.

Pit inflow was observed at the Sonoma Coal Mine main pit wall in August 2014 at a rate of approximately 1ML/day, which is considered within the expected range for the region and geology. Within the Sonoma Coal Mine main pit the coal seams are noted as being wet, while the interburden is noted as being dry and dusty during mining. Evaporation off the working face would account for some of this interburden dryness, although the observation more likely indicates that the interburden is tight with low storage and low hydraulic conductivity, as would be expected.

Observed groundwater levels from existing monitoring bores across the area indicate groundwater flow directions that follow the topography, with water generally moving towards the south west. The dominant surface drainage feature in the area is the Bowen River to the south of the Project site.

As previously stated the Bowen River is subject to some limited interaction with the surrounding shallow groundwater system, such as flooding related inflows into the surrounding material and subsequent drainage back into the river upon receding flood waters. However it is noted that flow in the Bowen River is regulated in non-rainfall periods by the Bowen River Weir (9.3 km upstream of the Project in the Bowen River) and importantly releases from the Eungella Dam (105 km upstream of the Project in the headwaters of the Bowen River), which dominates the non-rainfall flow regime of the Bowen River.

7.4 Numerical Model Development

7.4.1 Software and Code Selection

The MODFLOW-SURFACT code package was used to simulate groundwater flows within the Project boundary, which uses computational modules based on mass-conserving algorithms.

SURFACT is a commercial derivative of the standard MODFLOW code, which is a recognised industry standard for numerical groundwater modelling. It has some distinct advantages over the standard MODFLOW that are beneficial for the simulation of mining activity. SURFACT simulates variably saturated conditions, which is critical where mining progressively de-saturates model cells within the mining footprint. The MODFLOW pre and post processor PMWIN (Chaing and Kinzelbach, 1996) generated some of the input files along with Project specific (AGE developed) FORTRAN code.

7.4.2 Model Structure

The conceptualised geology and hydrogeological model (**Section 7.3**), developed based on extensive exploration drilling data and associated geological models across the Project area, was input into the numerical modelling software as layers. Each layer was divided into model cells of a certain X and Y dimension, depending on the level of resolution required at that point (e.g. mining areas may require greater resolution than non-mining areas).

The aim of the layer discretisation (transferring the continuous geological model into discrete components) was to accurately represent the detail of the geology across the Project area, while allowing for a manageable number cells based on model run time limits (i.e. the more cells in the model the longer the computational run-time of each scenario).

To achieve this, the model grouped contiguous geological units with similar hydraulic properties, into single hydrostratigraphic layers, while capturing the discrete seams and interburden within the targeted Permian sequence.

As such, the model represented and modelled the main hydrostratigraphic units as fourteen layers:

1. Alluvium and weathered cover material
2. Weathered cover material (down to base of weathering)
3. Fort Cooper Coal Measures
4. Interburden
5. Coal seam (Q seam)
6. Interburden
7. Coal seam (P seam)
8. Interburden
9. Coal seam (E seam)
10. Interburden
11. Coal seam (C seam
12. Interburden
13. Coal seam (B seam)
14. Exmoor Formation

The model grid was 18 km wide (east-west) and 25 km long (north-south), and was aligned north-south in consideration of the east west flow of the Bowen River in the Project area. Model boundaries (extent) were set between 5 km and 10 km from proposed mining areas, depending on the direction and features requiring consideration in those directions. This was to avoid computational boundary effects along the model boundary (i.e. the model extent was set outside anticipated drawdown, ensuring the model did not cut off or incur computational boundary errors prior to the full extent of any drawdown).

The model cell sizing was set generally at 500 m x 500 m, which was refined to 50 m x 50 m within the key areas such a proposed mining areas and the Bowen River, comprising a total of 841,960 cells. Presented in **Figure 7-5** is the grid for the full extent of the numerical model, including surrounding mine operations and to the south of the Bowen River.

7.4.3 Hydrogeological Assumptions

Broad hydrogeological assumptions made in the development of the numerical model include:

- adopted recharge rate is a deep drainage value and as such it is has encapsulated the reduction of water that infiltrates due to evapotranspiration;
- stresses on the system vary on a monthly basis during the transient calibration, and are set to annual average rates for the future mine predictions;
- variation in Bowen River height is applied uniformly along the cells representing the river;
- the Bowen River height for the transient simulation is varied on a monthly basis and has been sourced from an average daily water level for the corresponding recorded month; and
- faulting in the Project area is represented by the Horizontal Flow Barrier (HFB) model package, which assigns a low enough conductance to provide disconnection within the coal seams; however, the applied conductance is comparable to the interburden hydraulic conductivity resulting in reduced effect on these already tight units. The location of the HFB cells is based on the structure mapping from the Bowen Basin geological model.

Hydraulic parameters (e.g. conductivity), vary from model layer to layer, which vary over time for some sections (e.g. pit expansion and backfill). As such the model considers numerous values for a range of hydrogeological parameters across a range of hydrostratigraphic units (see **Section 7.5.2**), based on:

- field tests (such as bore pump tests) undertaken during the EIS;
- geological observations made during the exploration program;
- calibration of model parameters to observed groundwater bore hydrographs; and/or
- published values applicable for the north Bowen Basin and the targeted coal measures.

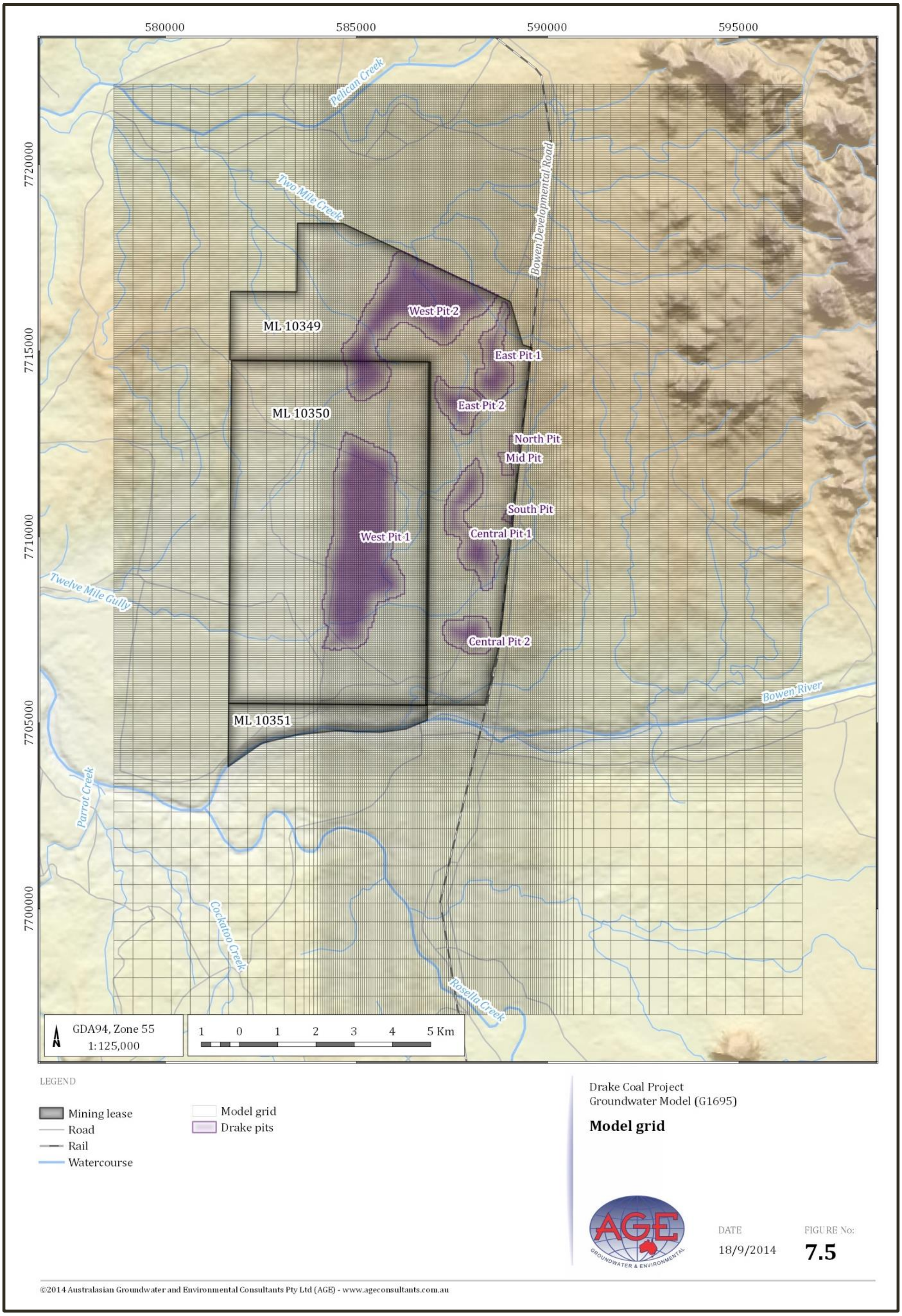

Figure 7-5 Model Extent and Grid

7.4.4 Representing the Mining Operation/s

The mining process, specifically the dewatering due to mining, is simulated using the SURFACT Drain (DRN) package. Drains are assigned to dewater model cells that are within the extent of mining pit shell. As such, as a particular pit expands more cells fall within the extent of the pit shell and get assigned Drains, as pits are backfilled the Drain assignation is removed (turned off) from those cells.

A nominally high conductance term is applied to model cells within the pit shells, to ensure that the model cell becomes completely de-saturated within the pit shell.

In-pit spoil storage is also simulated by assuming a 3 year operation window for the mining. That is, if an area of the pit had been dewatered for three years, on the fourth year the Drain boundary condition would be turned off and the model cell's aquifer parameters would be converted to spoil properties, for the relevant cells. The opportunity for recharge to occur is expected to increase across the spoil; therefore the recharge value is also modified in the model at these locations.

At the completion of mining some pits are planned to have a final void, as such for each pit the area identified as remaining void is also modified. To create a final void space in the model, an approach referred to as a 'high-k lake' is used. This involves setting the hydraulic conductivity nominally high to allow free movement of water (horizontally and vertically) within the void, and the storage properties are changed to effectively remove the porous matrix, providing the void. Additional recharge is applied across the void surface as well to account for its capture of direct rainfall and runoff directed into the pit as closure management strategies.

Some pits are located with mapped faults passing through them. When one of these structures is mined through, the conductance term applied to these specific HFB cells is given the same value as the coal seam hydraulic conductivity.

7.4.5 Representing Surface Drainage

The SURFACT river model package was used to simulate the river and creek drainages in the region. The bed of the major river and creek cells were set at 1.0 m below the most recent LIDAR digital elevation data along the Bowen River alignment. The model represented all other creeks and drainage lines as drains, where only flow of water from the aquifer to the stream could occur (i.e. the model assumes that ephemeral drainage channels and streams are not a notable source of recharge).

There is a minor sub-catchment divide that occurs through the centre of the Project area that splits the drainage catchments to either the north or the south. Surface drainage to the north reports to Pelican Creek, while surface drainage occurring in the south will eventually arrive in the Bowen River.

7.5 Numerical Model Calibration

Calibration of the numerical model aims to adjust the modelling parameters to achieve a comparable simulation of groundwater levels to actual measured groundwater levels at the individual monitoring bores across the Project, and to replicate the general pattern of the groundwater potentiometric surface and direction of flow. The steady state groundwater scenario of the model was calibrated using both automated and manual techniques, by adjusting parameters across the entire model domain. The model parameters were uniform for each geological unit represented in the model.

7.5.1 Observation Data

Observation data used for the calibration comprises bore water levels collected from numerous monitoring and exploration bores.

For the pre-mining conditions (considered as the baseline water levels for the area, representing September 2007 when the Sonoma Coal Mine commenced), groundwater level data was sourced from available monitoring bore data across the Sonoma Coal Mine and also from the GWDB. The available GWDB data was generally a standing water level at the time of drilling the bore, which generally predated the initial Sonoma Coal Mine data of 2007.

Bore data measured across the Project area was also used for the pre-mining conditions, as the selected bores are considered unaffected by the existing adjacent mines due to their distance from neighbouring pits. It is noted that some of the Project bores have historically been dry and have not therefore provided a useable water level measure. In this instance, those bores were flagged and the model output was checked to confirm a simulated prediction of water levels below the base of those bores.

7.5.2 Calibration Results

The hydraulic parameters (see also **Section 7.4.3**) adopted from the calibration for the key geologies (discussed in **Section 7.4.2**) is presented below in **Table 7-1**.

Table 7-1 Hydraulic Parameters

Layer	Parameter	Value
Layer 1 and 2 Alluvium Weathered Material (Regolith)	Horizontal Hydraulic Conductivity [kh]	Alluvium 1 m/day Regolith 0.001 m/day
	Vertical Hydraulic Conductivity [kv]	Alluvium 0.1 m/day Regolith 6×10^{-4}
	Specific Yield [S_y]	Alluvium 0.05 Regolith 0.01
	Specific Storage [S_s]	Alluvium 5×10^{-4} Regolith 1×10^{-4}
Layers 3, 4, 6, 8, 10, 12 and 14 Interburden	Horizontal Hydraulic Conductivity [kh]	1×10^{-4} m/day
	Vertical Hydraulic Conductivity [kv]	1 x 10-5 m/day
	Specific Yield [S_y]	5×10^{-4}
	Specific Storage [S_s]	1×10^{-6}
Layer 5, 7, 9, 11, and 13 Coal Seams	Horizontal Hydraulic Conductivity [kh]	1×10^{-2} m/day
	Vertical Hydraulic Conductivity [kv]	1×10^{-3} m/day
	Specific Yield [S_y]	5×10^{-3}
	Specific Storage [S_s]	5×10^{-5}
All Layers Lizzie Creek Volcanics	Horizontal Hydraulic Conductivity [kh]	9×10^{-7} m/day
	Vertical Hydraulic Conductivity [kv]	1×10^{-6} m/day
	Specific Yield [S_y]	1×10^{-4}
	Specific Storage [S_s]	1×10^{-6}

Along with the hydraulic properties of the assumed alluvium and weathered cover, the recharge rate to for these layers was also calibrated. These two values calibrated to very low percentages of annual average rainfall as shown below in **Table 7-2**.

Table 7-2 Calibrated Recharge

Geology	Recharge: Percentage of Rainfall (%)	Recharge (mm/year)
Alluvium	0.057	0.39
Weathered material (Regolith)	0.0002	0.001

The calibration of the steady state model conditions was undertaken and the results plotted on a scatter diagram showing the model simulated predictions against the observed data, as presented in **Figure 7-6**.

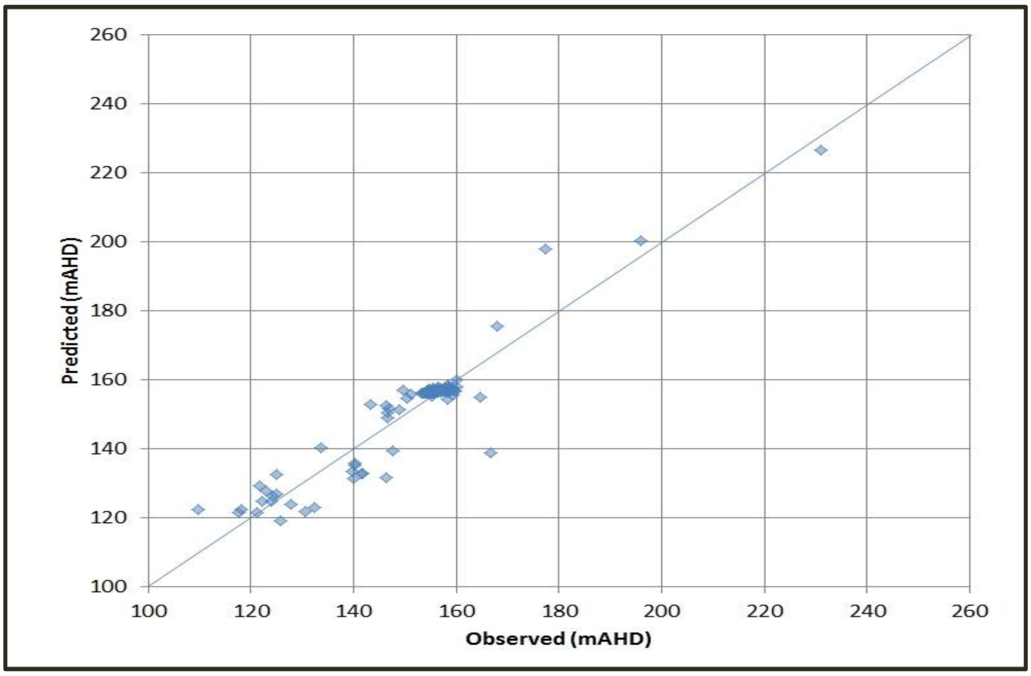

Figure 7-6 Steady State Calibration Plot

The root-mean square deviation (RMSD), which is a statistic similar to standard deviation, was used to measure the variability between values predicted by a model and the values actually observed. The model reported a calculated RMSD for the calibrated steady state model of 5.3 m. The RMSD was then scaled against the observed total groundwater level changes (as per **Figure 7-6**, there is a 121.6 m difference in total head water level between the maximum and minimum observed values); this provides a steady state model Scaled RMSD ratio of 4.3%, which indicates a close and satisfactory match between observed and predicted water levels.

The modelled steady state groundwater budget (where water entering the groundwater system equals water exiting the groundwater system) is presented for the entire model grid in **Table 7-3**.

Table 7-3 Steady State Model Water Budget for Entire Model Domain

Parameter	Groundwater Input (ML/Day)	Groundwater Output (ML/Day)
Rainfall recharge: direct rainfall infiltration into groundwater	0.036	--
River leakage: flow of river/creek water into groundwater	Bowen River: 0.276*	--
River baseflow: flow of groundwater into river/creek	--	Bowen River: 0.298 Other: 0.014
TOTALS	**0.312**	**0.312**

* As per **Section 7.4.5**, all surface water features except the Bowen River are represented as drains where only flow of water from the aquifer to the stream could occur (i.e. the model assumes that ephemeral drainage channels and streams are not a notable source of recharge); as such the Bowen River Represents the only source of river leakage across the model.

Under steady state conditions, Bowen River baseflow is 0.298 ML/day with a leakage of 0.276 ML/day; as such the Bowen River has a net baseflow of 0.0217 ML/day. The average daily flow in the Bowen River (as measured at the Jacks Creek Weir) is 1,797 ML/day; therefore the model estimates that under steady state conditions baseflow represents ~0.001% for the average daily flow, in the Bowen River.

Calibration of the transient model was undertaken on a primarily manual basis, with results plotted on a scatter diagram showing the simulated model predictions against observed data, as per **Figure 7-7**.

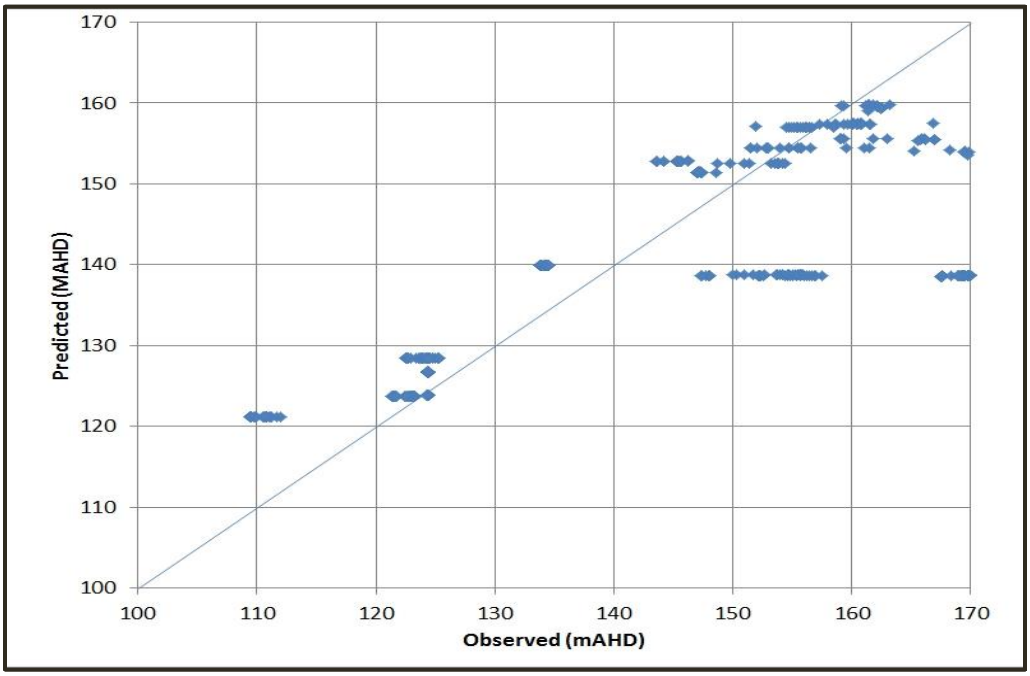

Figure 7-7 Transient Calibration Plot

Statistically the transient model calibration does not have as close of a fit, as for the steady state condition. The model reported a calculated RMSD for the calibrated transient model of 12.4 m. The RMSD was then scaled against the observed total groundwater level changes (as per **Figure 7-7**, there is a 62.3 m difference in total head water level between the maximum and minimum observed values); this provides a transient model Scaled RMSD ratio of 19.8%. This result is not unexpected because the very low recharge rates determined in the steady state calibration, lead to predicted water levels which are generally unresponsive to recharge events. The transient calibration process has seen the storage values as a mechanism for providing a response in the hydrographs, by generally going towards the lower bounds assigned.

Conceptually the recharge observed in hydrographs in some bores which has affected the transient calibration, could be in response to:

- Flooding in the Bowen River associated with rainfall upstream of the Project area, causing flood waters to propagate outwards into the surrounding alluvial material in the vicinity of monitoring bores in that area, after which the alluvial material seeps water back into the river when the river level drops (previously referred to as a “surge and return” scenario).
- During high rainfall events there is localised flooding in areas across the Project area in proximity to monitoring bores, which would provide both a wetted up soil profile and sufficient residence time to allow for some anomalous deep drainage to occur in the immediate vicinity of the monitoring bore.

Based on the low levels of rainfall derived recharge determined in the steady state calibration, the primary mechanism of recharge simulated in the model is associated with water levels in the Bowen River (with levels based on observed stream gauge data). In the transient predicted water balance on the Bowen River (presented in **Figure 7-8**), this mechanism is demonstrated with large volumes of water entering the alluvial material surrounding the river during high flow events, followed by a lag and then declining rate of seepage back out of the alluvium, back to the river boundary condition.

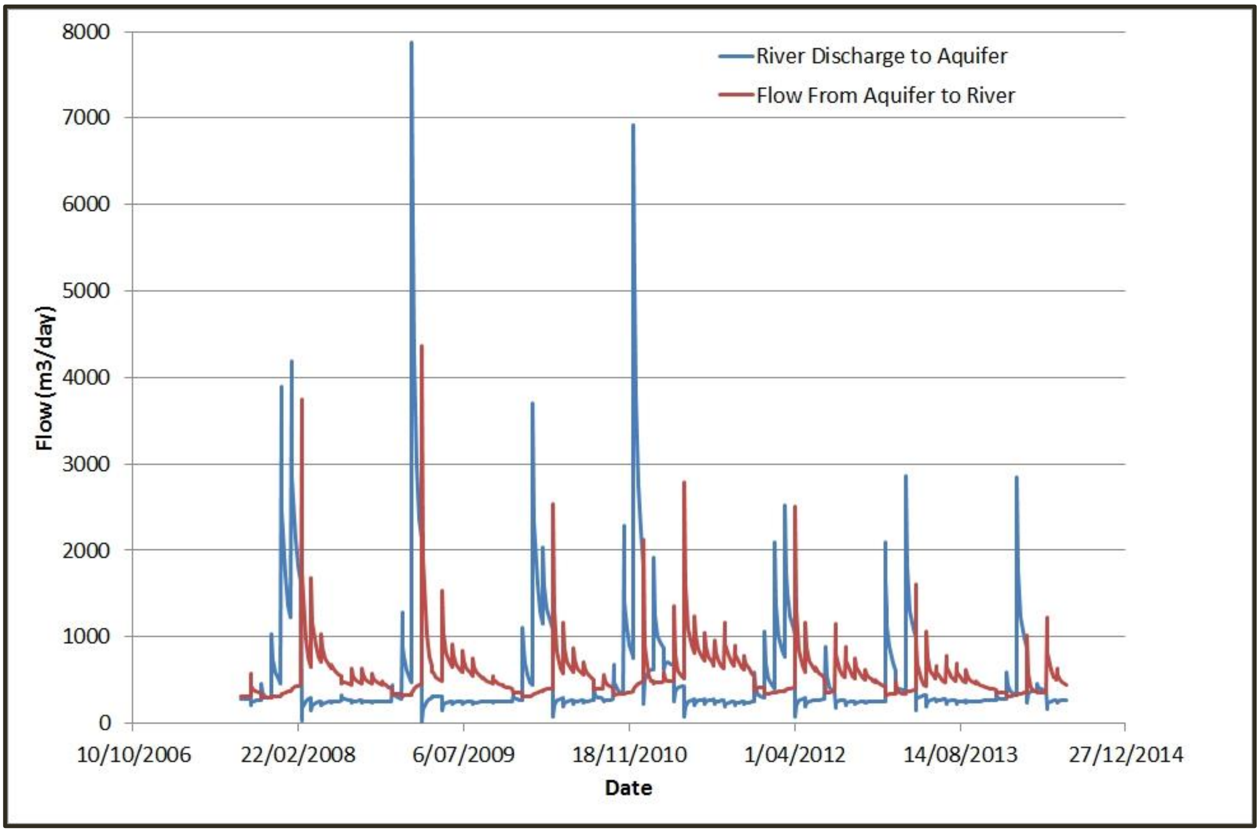

Figure 7-8 River Budget Transient Calibration Plot

Another limitation impacting on the calibration of the transient scenarios, was that monitoring bores in and around the Sonoma Coal Mine, which were used as a data source, did not show any declining water levels despite being adjacent dewatering activities for the Sonoma mine pit (i.e. any drawdown related to Sonoma Coal Mine has not extended beyond the immediate vicinity of the pit to any of the bores where drawdown data could be collected). While this does limit the available calibration data it does provide direct evidence that actual mining operations to the north of the Project have had no historical drawdown effects measured, which indicates that that historical drawdown related groundwater impacts have not occurred for Sonoma Coal Mine.

The modelling guidelines (**Section 7.1.2**) provide a method to classify the confidence level for groundwater models, as Class 1, Class 2 or Class 3 in order of increasing confidence (i.e. Class 3 has the highest level of confidence). Several factors are considered in determining the model confidence level:

- available data;
- calibration procedures;
- consistency between calibration and predictive analysis; and
- level of stresses.

The model is currently considered a Class 2 due to the following criteria:

- Data
  - the majority (excluding erroneous results) of all groundwater monitoring data over the calibration period has been used in the calibration process; and
  - high resolution digital elevation data used across the entire model domain.
- Calibration
  - Scaled RMSD is considered acceptable in the context of available data and developing a fit for purpose model; and
  - recent available steady state and transient calibration data was used.
- Prediction
  - temporal discretisation and stresses are within the range of those used in the calibration model.
- Key indicators
  - calibration statistics meet agreed targets;
  - mass balance error is close to zero;
  - model parameters are consistent with conceptualisation; and
  - appropriate computational methods and spatial discretisation used.

The Class 2 confidence level is suitable for predicting groundwater responses to arbitrary changes in applied stress or hydrological conditions, and is considered suitable for the evaluation and management of potentially high-risk impacts.

7.6 Numerical Model Predictive Results

7.6.1 Drawdown Extent

The drawdown modelling predictions are calculated by running two paired simulations: one assuming no mining development, and one assuming all mining dewatering activities are undertaken. In this way the numerical model can eliminate any naturally occurring changes in groundwater level and establish the changes in groundwater associated with dewatering activities (i.e. drawdown is then the difference at any particular time-step between these two simulations).

Importantly it is noted that the drawdown has been modelled in a cumulative manner across the broader area, looking at the predicted drawdown from the proposed Project pits, as well as including any drawdown from the adjacent mining operations (Sonoma, Cow and Jax). In this way a more representative scenario of groundwater in the broader area is modelled. This scenario is a key consideration in looking at potential impacts to features of interest such as the Bowen River.

Predicted drawdown was modelled from the year 2015 (commencement of dewatering) through to 2057 (cessation of mining), and is presented for a selection of years to demonstrate the predicted progression of groundwater movement for the duration of the mine, as follows:

- 1 year (end of 2015);
- 3 years (end of 2017);
- 5 years (end of 2019);
- 10 years (end of 2024);
- 15 years (end of 2029);
- 20 years (end of 2034);
- 30 years (end of 2044); and
- End of mining (2057).

For each year, the drawdown modelling results are presented for two key hydrostratigraphic layers, Layer 1 and Layer 13 (although all layers discussed in **Section 7.4.2** were modelled and considered in the findings):

- Layer 1 representing the weathered cover material and shallow alluvium; and
- Layer 13 predominantly representing the B seam which is the lowest of the target mining seams.

The results of the drawdown modelling are presented as contours in **Figure 7-9** to **Figure 7-24** with the outer contour representing a 1 m drawdown.

After the first year of Project operation, the drawdown within the Project lease is limited, with overall drawdown for the area primarily associated with neighbouring mine sites. As time progresses the extent of mining and the size of the Project pits increases and as would inherently be expected the associated drawdown increases.

The drawdown in the weathered cover material is eventually predicted to migrate towards the south of the Project area, directly associated with the commencement of mining in the southernmost pit (Central Pit 2) between years 5 and 10. Ultimately drawdown associated with Central Pit 2 encroaches on the alluvial sediments of the Bowen River from approximately year 30 onwards. More specifically, drawdown in the cover material/alluvial across the Project area is predicted to encroach on the Bowen River until approximately year 20 to 25. From that period onwards the drawdown progression in the upper layer is buffered somewhat.

The predicted drawdown in the B seam can be seen propagating below the Bowen River in the later mining years.

The maximum extent of predicted drawdown from the numerical model does not exceed that maximum predicted drawdown extent from the analytical model undertaken in the EIS (**Figure 7-2**) for either the cover material and alluvium, or the represented coal seam, with the exception of the coal seam drawdown noted as extending to the south of the Bowen River.

It is important to note that this deeper coal seam related drawdown does not show any interaction with the Bowen River.

The Central 2 pit is the closest pit to the Bowen River and can be seen in the earlier detailed cross section (**Figure 7-4**). This pit targets the deepest coal seam (B Seam) and is in a location where the geological model indicates the B Seam floor is at -80 mAHD. Dewatering this deep pit is predicted to result in a steep cone of depression that will propagate outwards away from the pit. Mining at the pit is expected to be complete in 2035 after which the in pit spoil (backfill) and implementation of a residual void (which was included in the numerical model), will permit the commencement of additional recharge to occur. However, the time taken for recovery of groundwater levels within the spoil (upwards of 230m thick) and void, means the drawdown extents are shown to continue through to the end of the mining operations. Central Pit 2 is shown to be the main contributor to any potential impacts which may occur at the Bowen River.

Complete recovery of predicted drawdown can be seen in some of the earlier pits, well before the completion of mining activities, which is again a result of in pit spoil (backfill) and associated additional recharge.

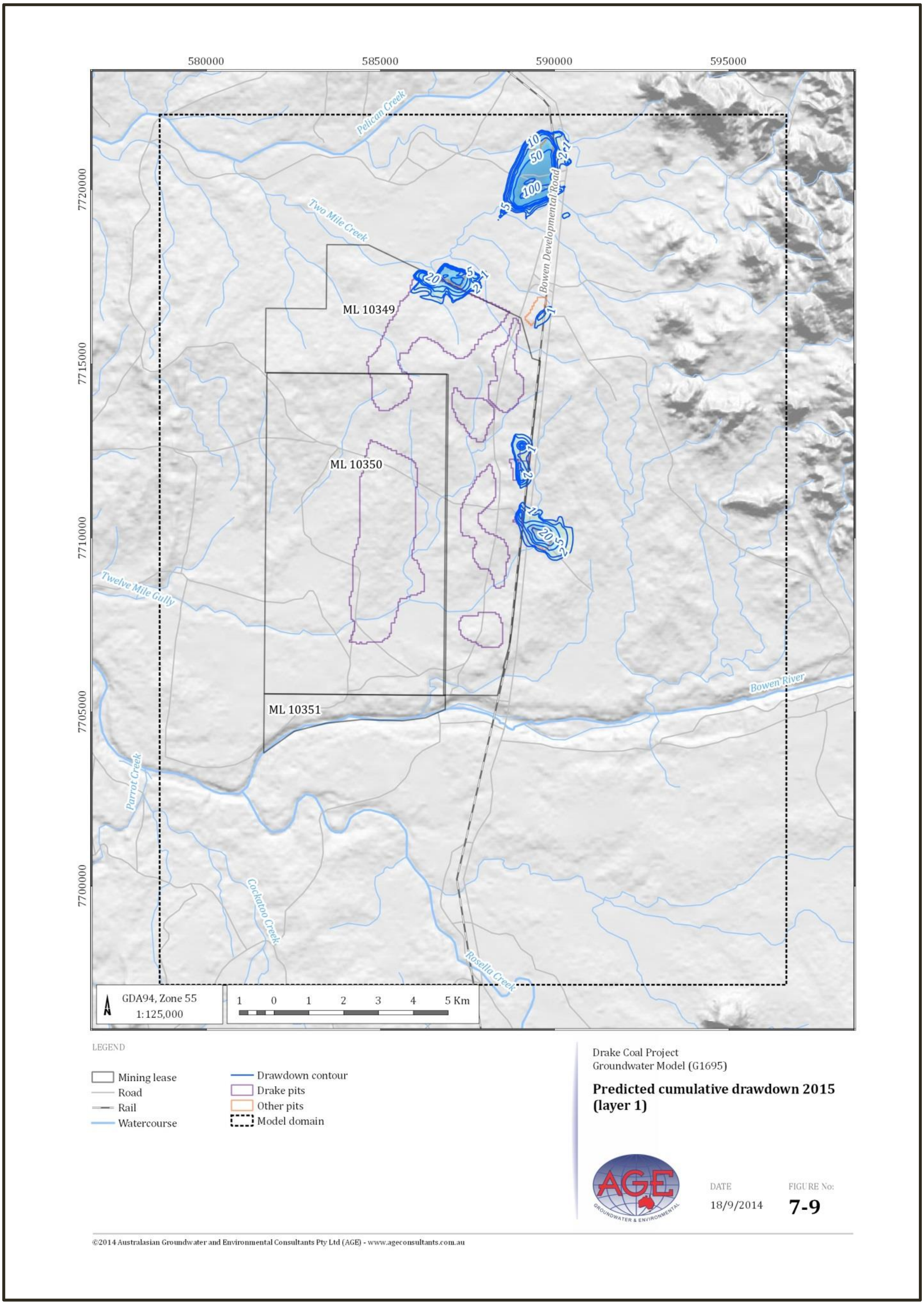

Figure 7-9 Predicted Drawdown Year 1 Layer 1 (cover material and shallow alluvium)

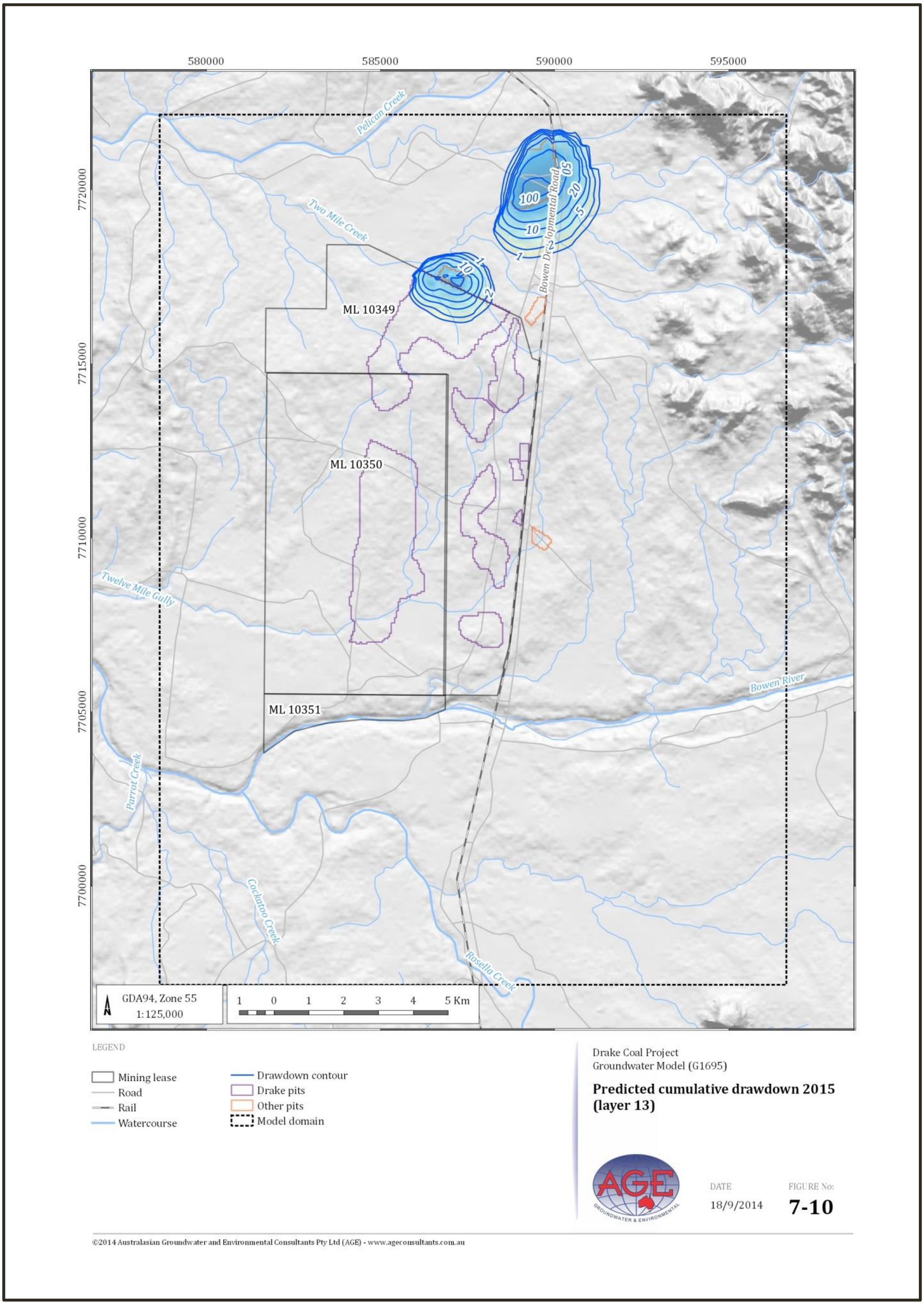

Figure 7-10 Predicted Drawdown Year 1 Layer 13 (representing target coal seams)

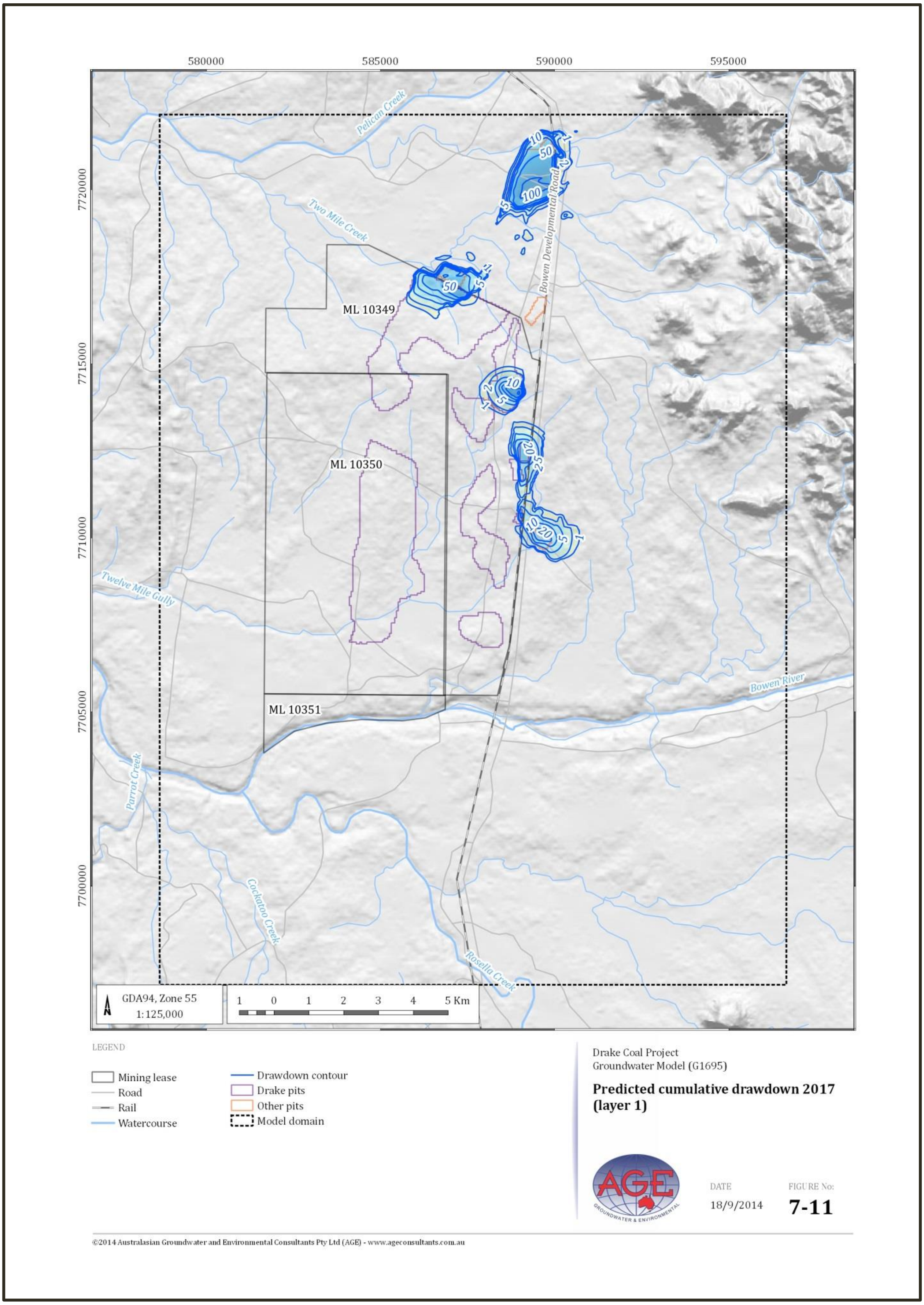

Figure 7-11 Predicted Drawdown Year 3 Layer 1 (cover material and shallow alluvium)

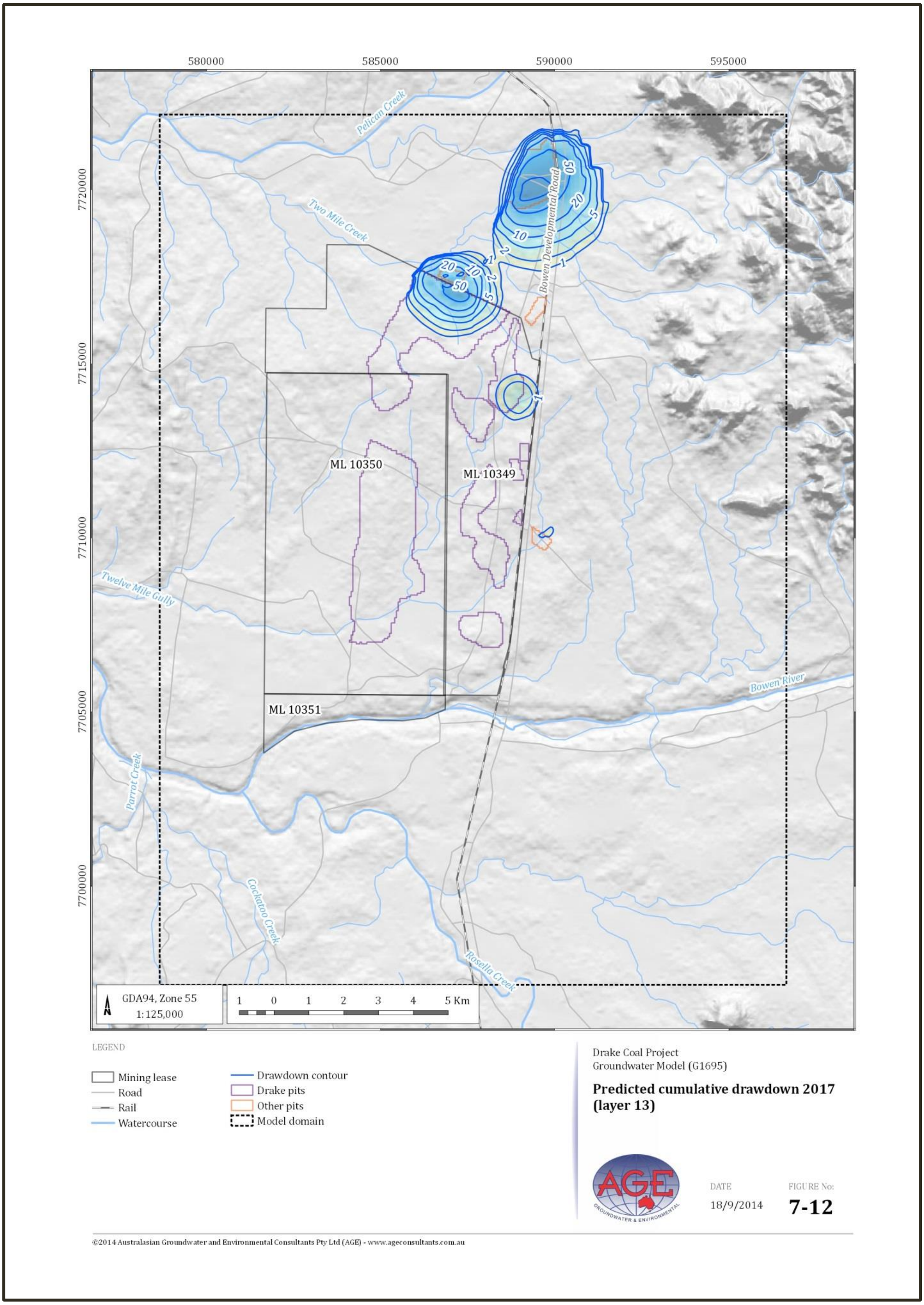

Figure 7-12 Predicted Drawdown Year 3 Layer 13 (representing target coal seams)

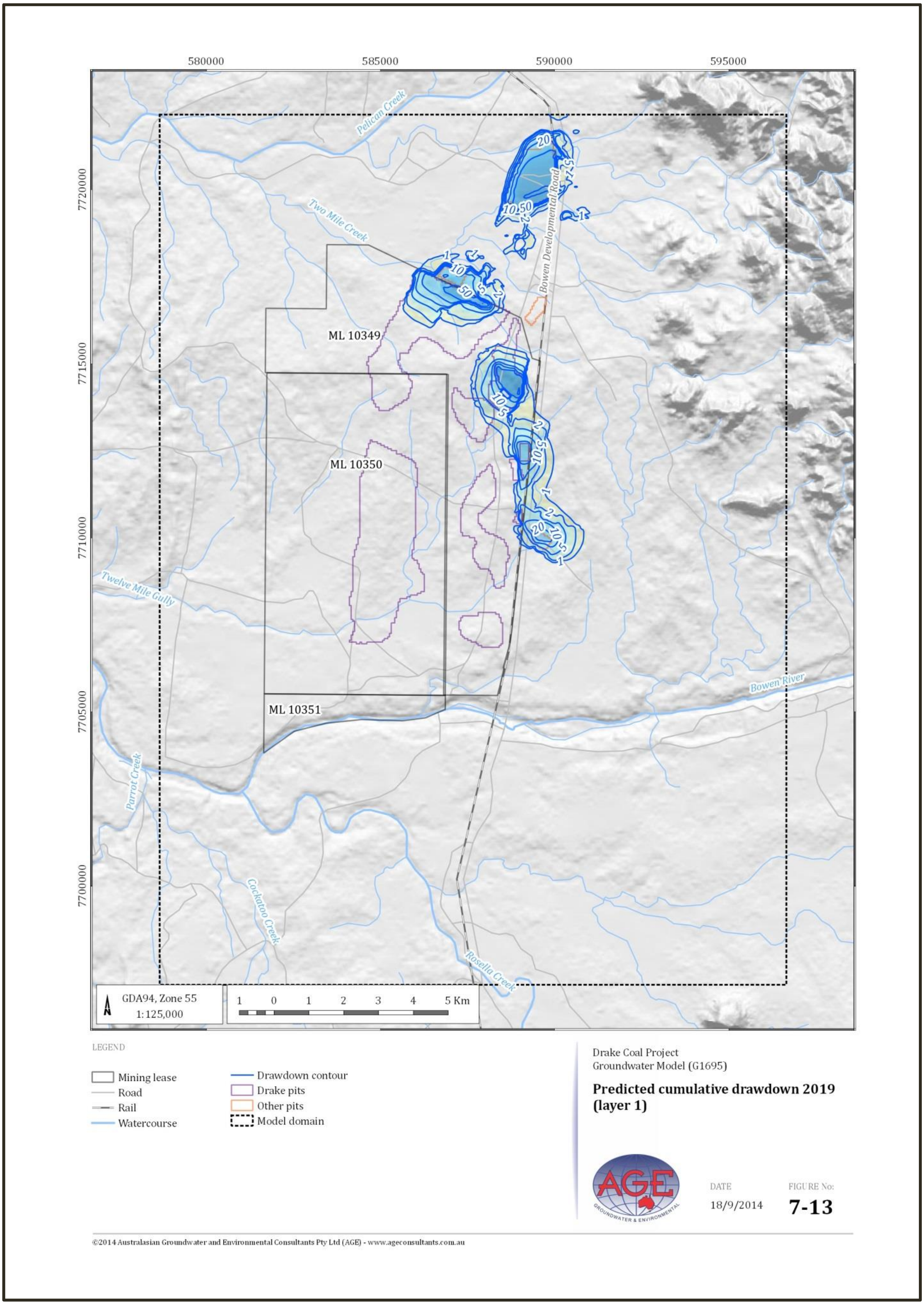

Figure 7-13 Predicted Drawdown Year 5 Layer 1 (cover material and shallow alluvium)

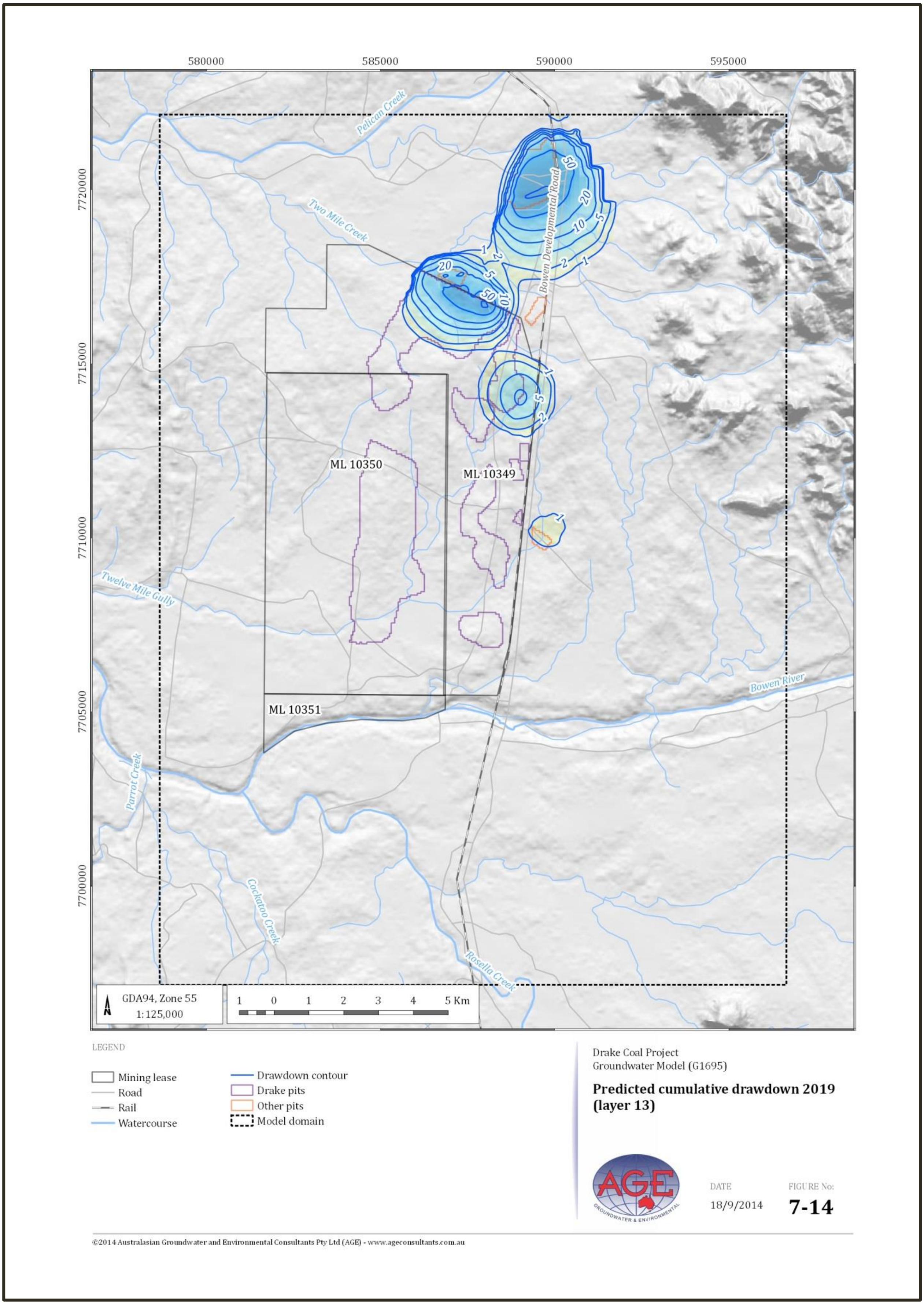

Figure 7-14 Predicted Drawdown Year 5 Layer 13 (representing target coal seams)

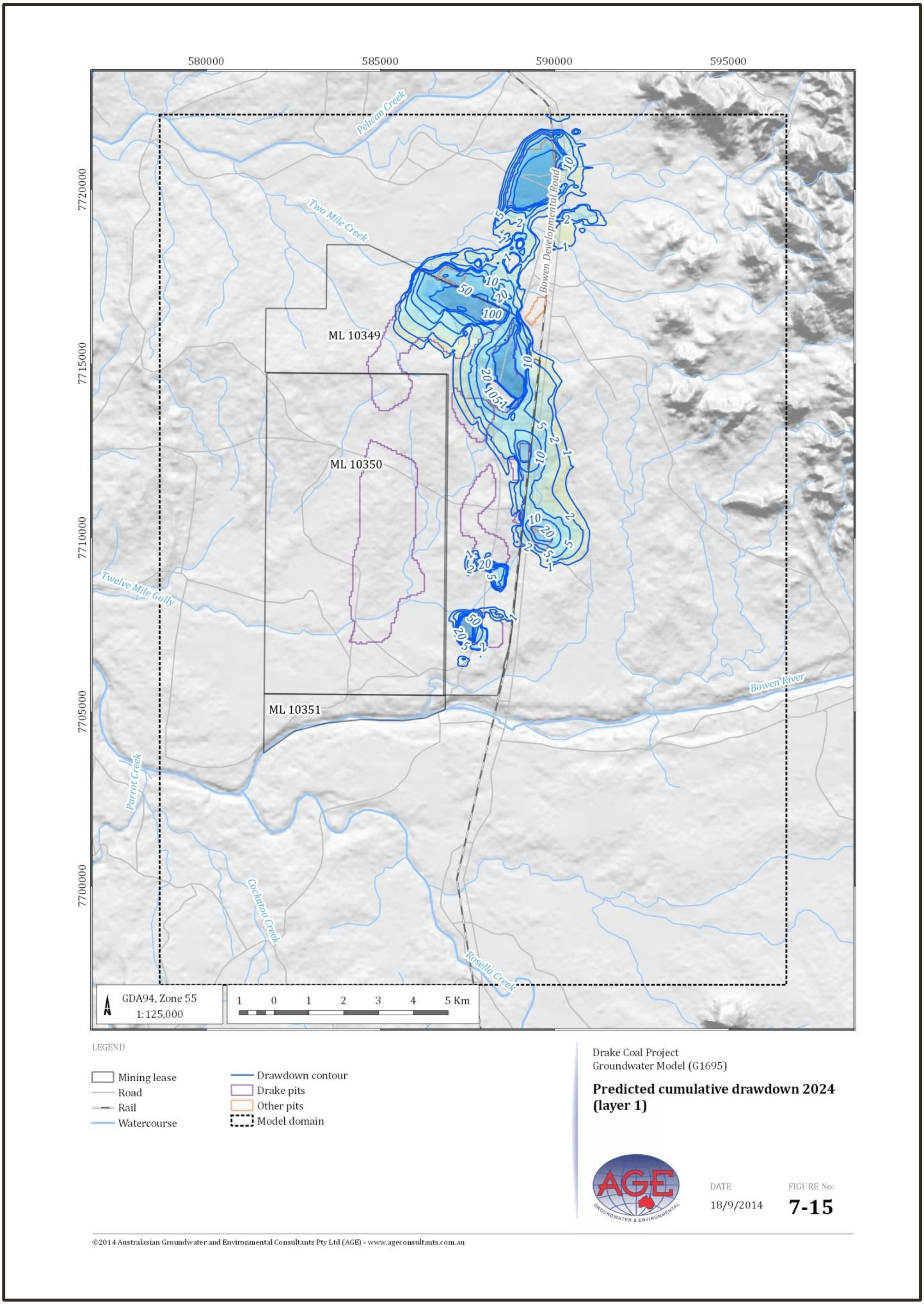

Figure 7-15 Predicted Drawdown Year 10 Layer 1 (cover material and shallow alluvium)

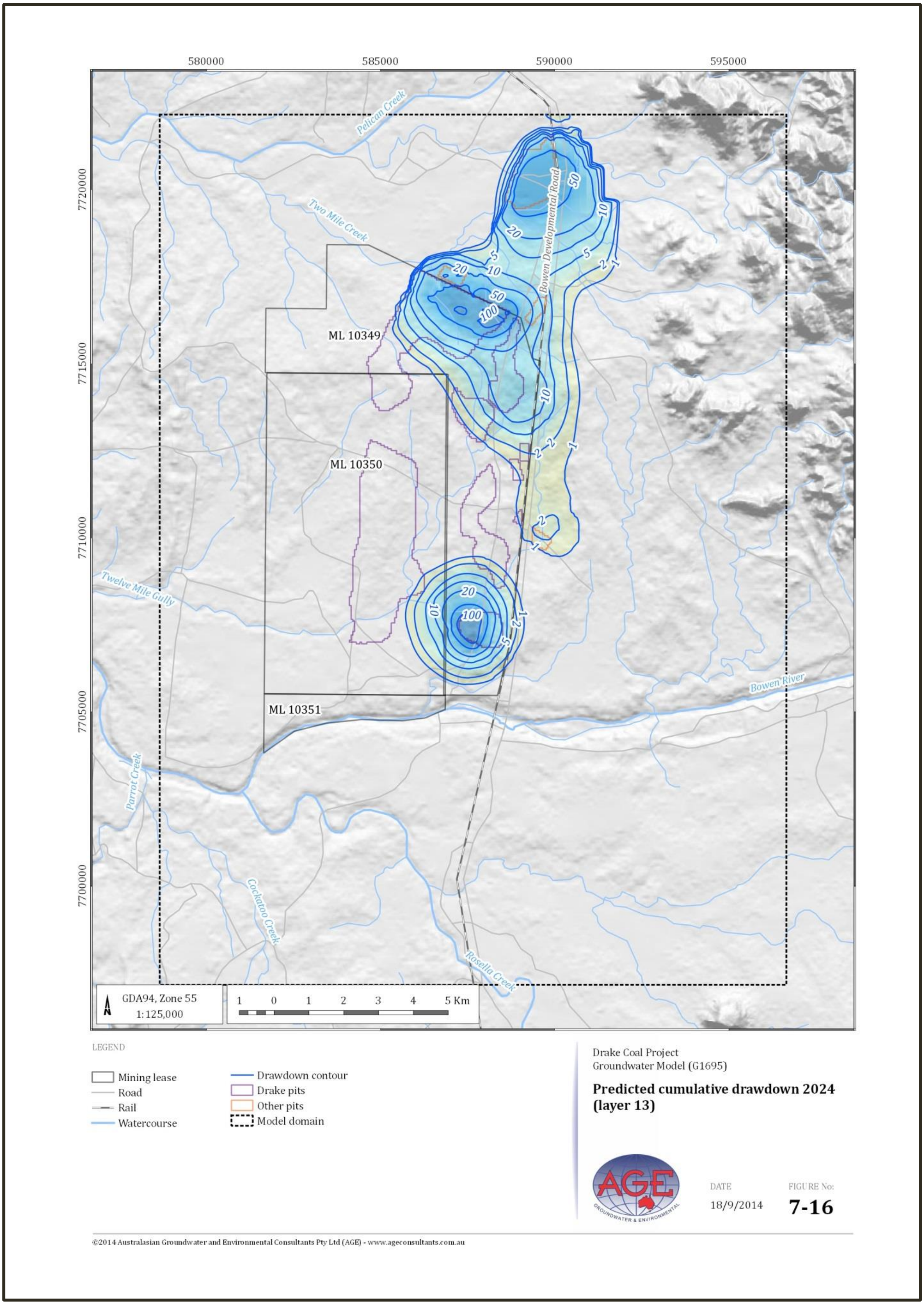

Figure 7-16 Predicted Drawdown Year 10 Layer 13 (representing target coal seams)

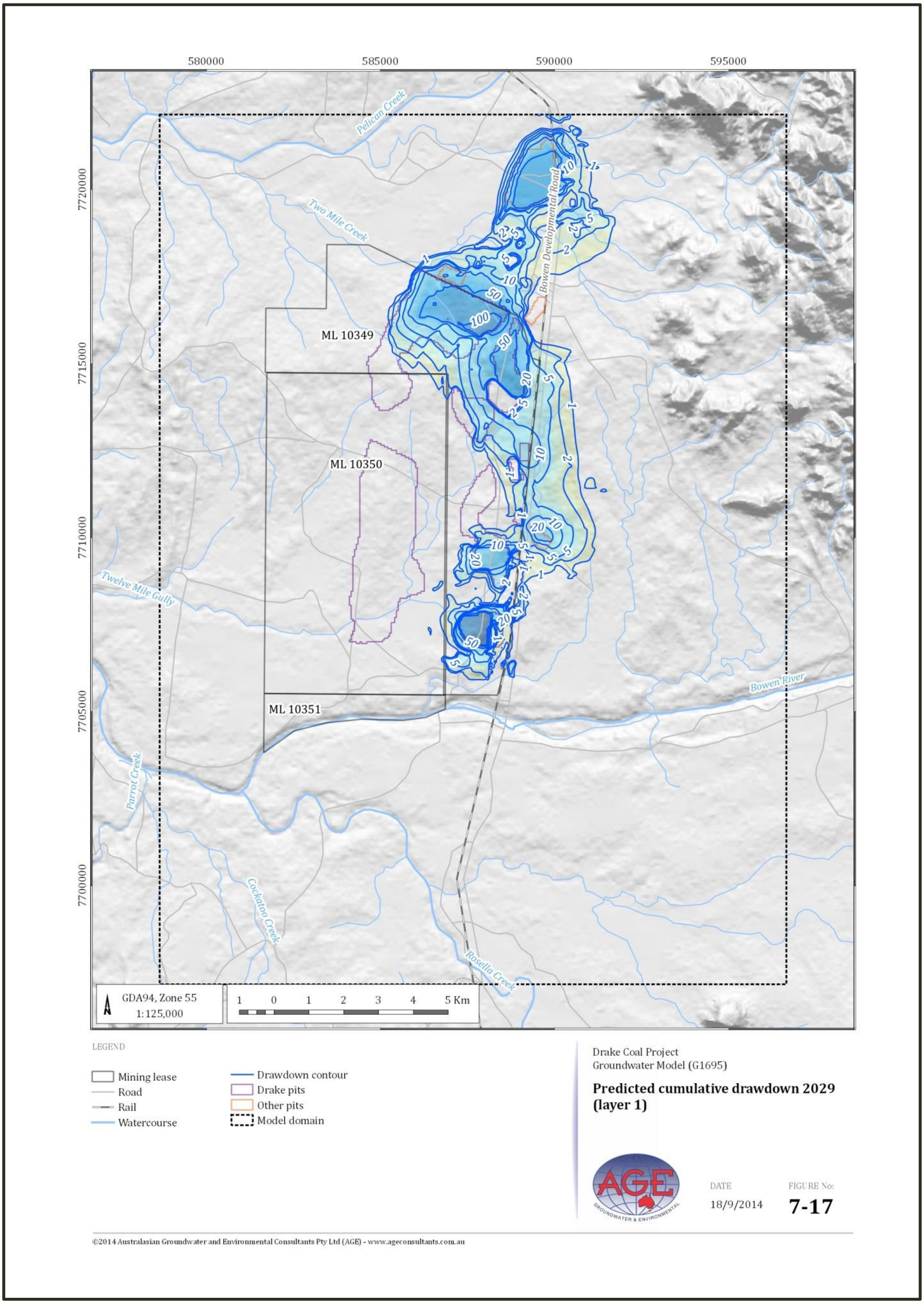

Figure 7-17 Predicted Drawdown Year 15 Layer 1 (cover material and shallow alluvium)

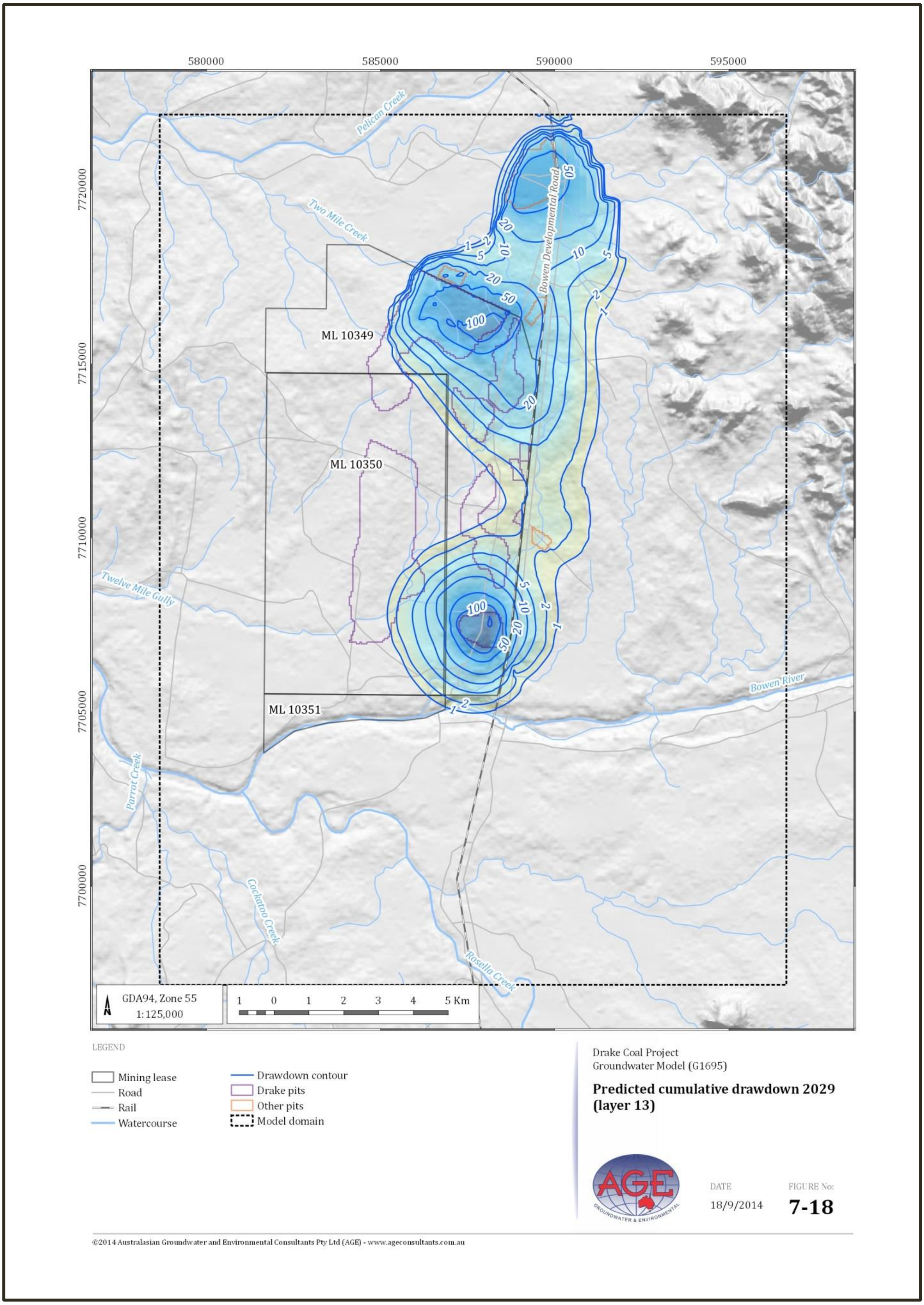

Figure 7-18 Predicted Drawdown Year 15 Layer 13 (representing target coal seams)

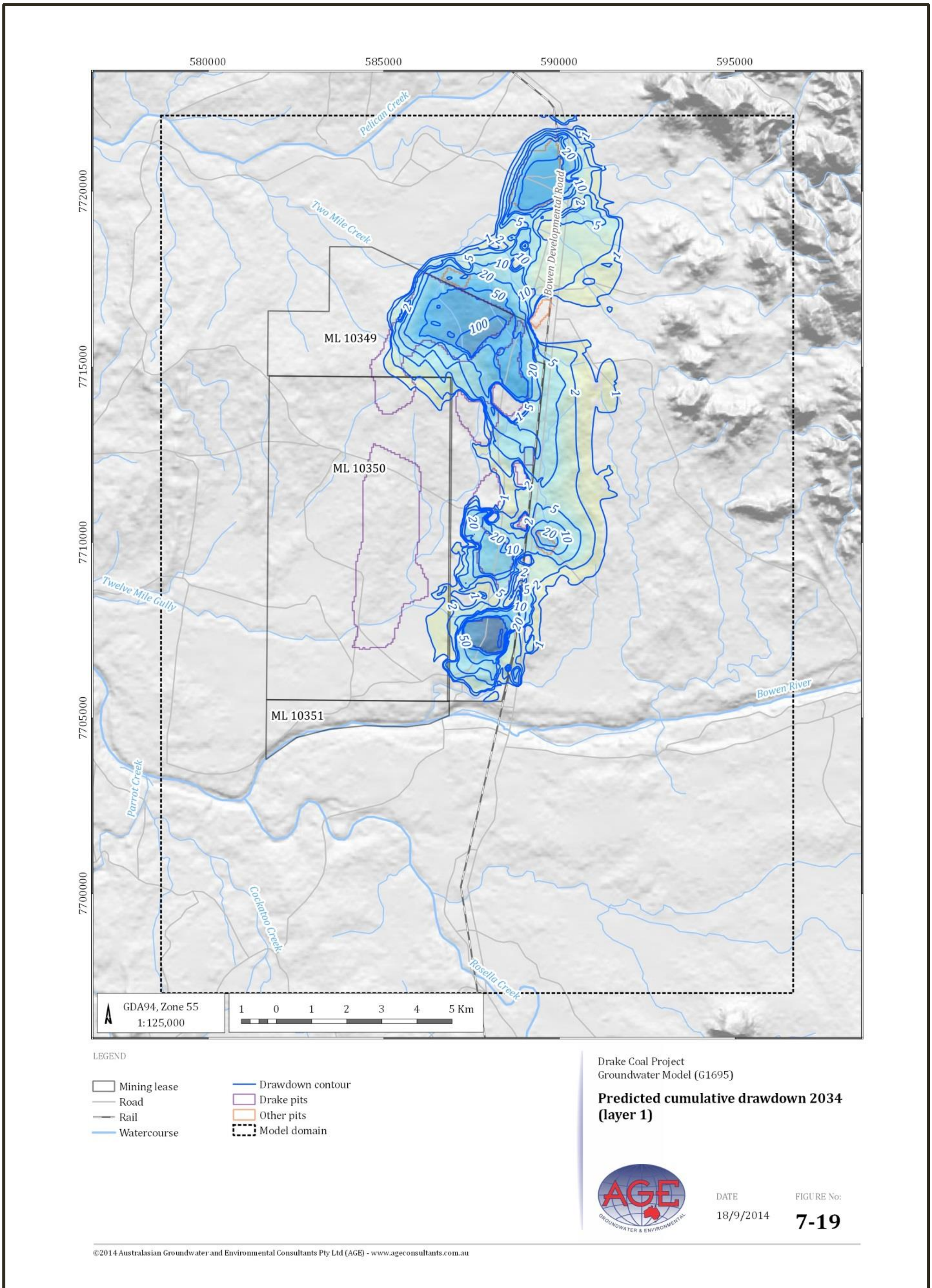

Figure 7-19 Predicted Drawdown Year 20 Layer 1 (cover material and shallow alluvium)

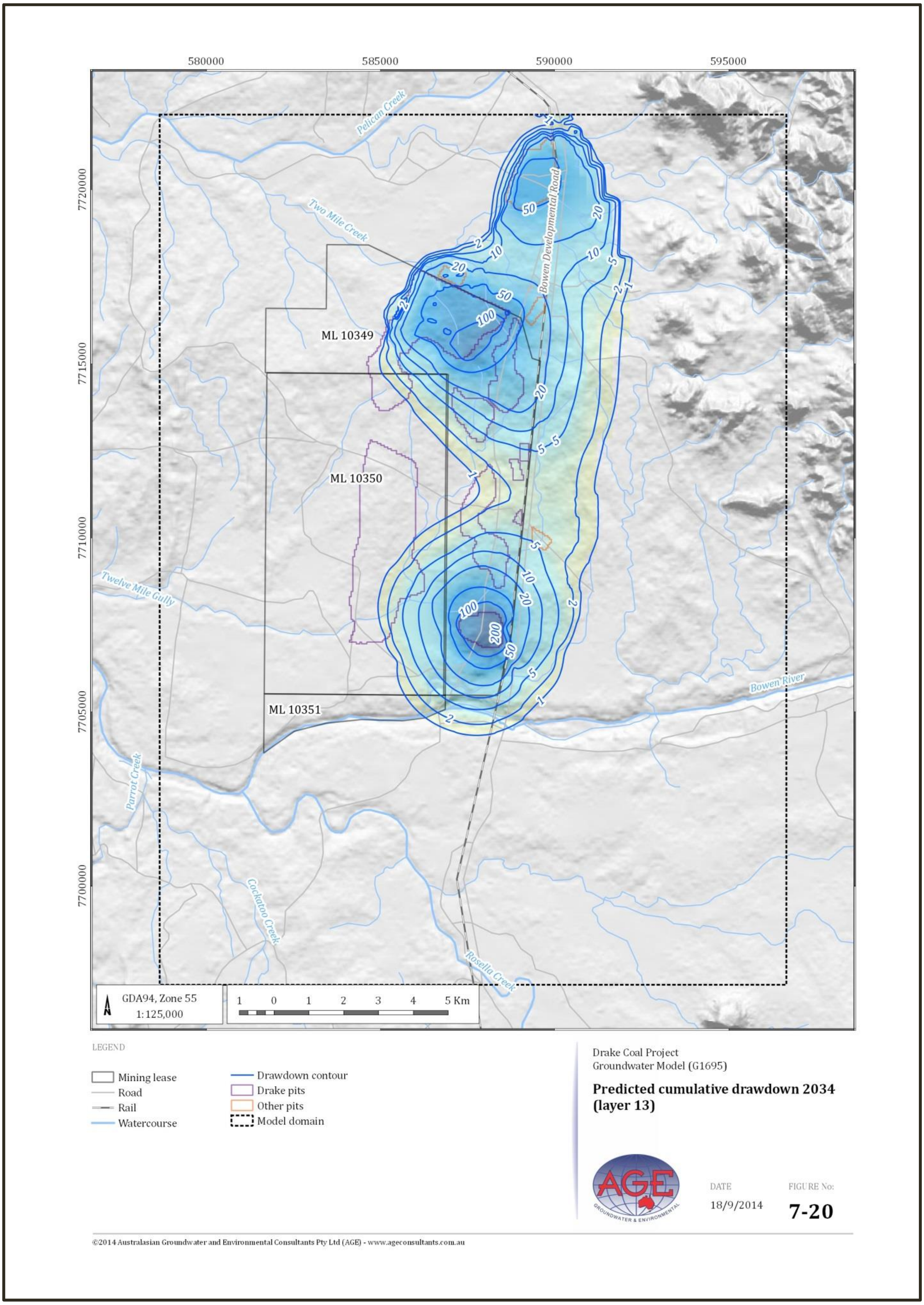

Figure 7-20 Predicted Drawdown Year 20 Layer 13 (representing target coal seams)

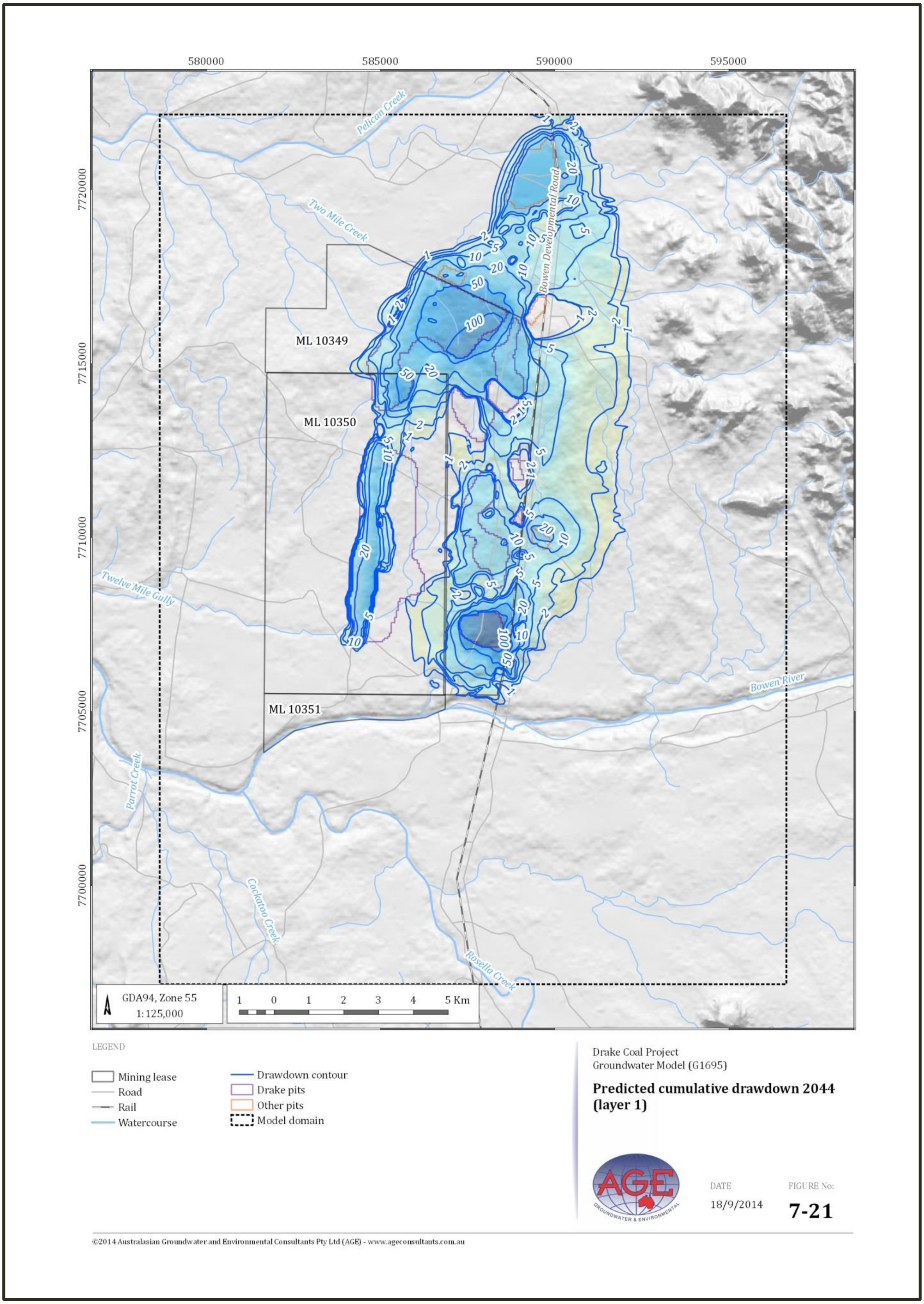

Figure 7-21 Predicted Drawdown Year 30 Layer 1 (cover material and shallow alluvium)

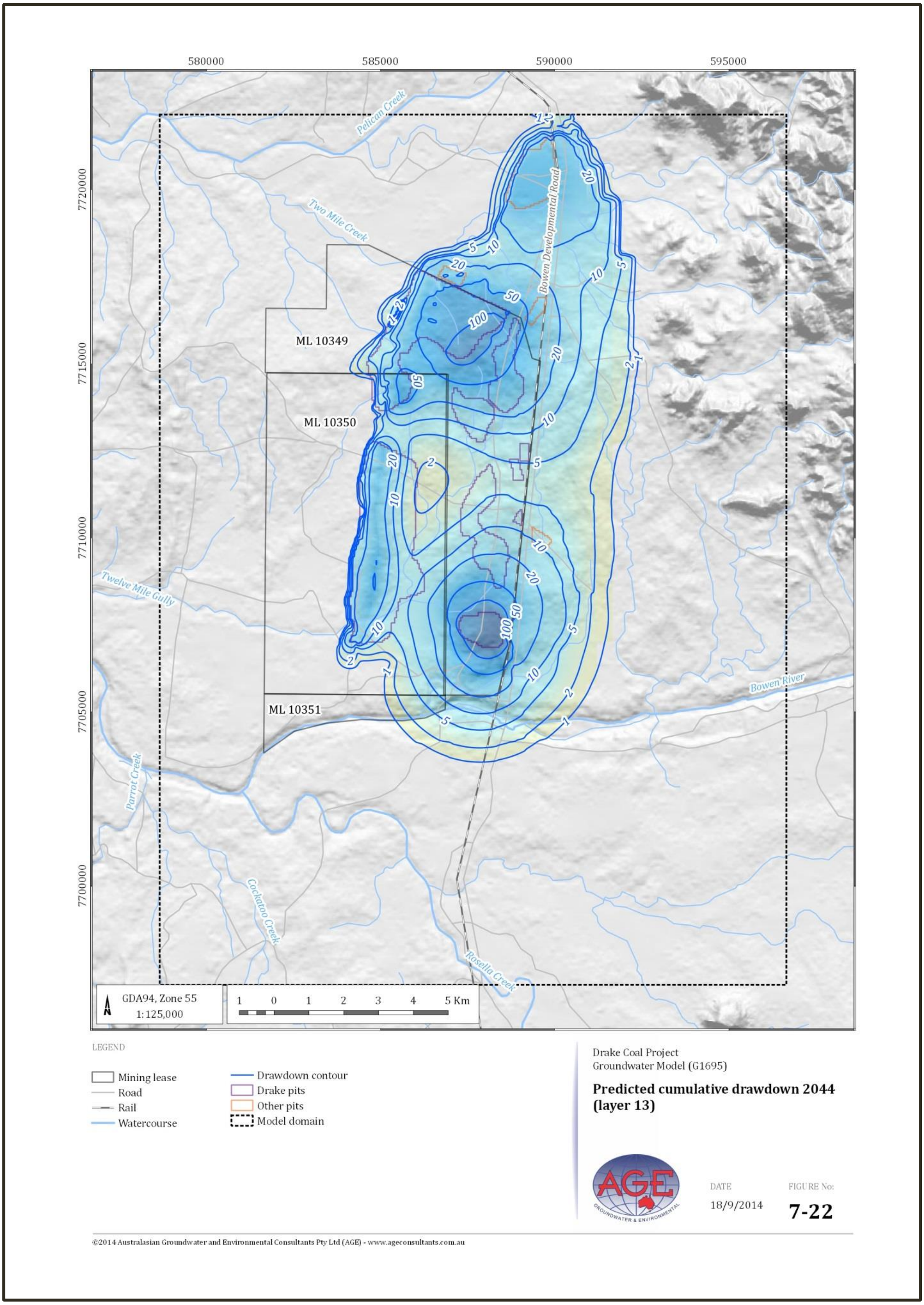

Figure 7-22 Predicted Drawdown Year 30 Layer 13 (representing target coal seams)

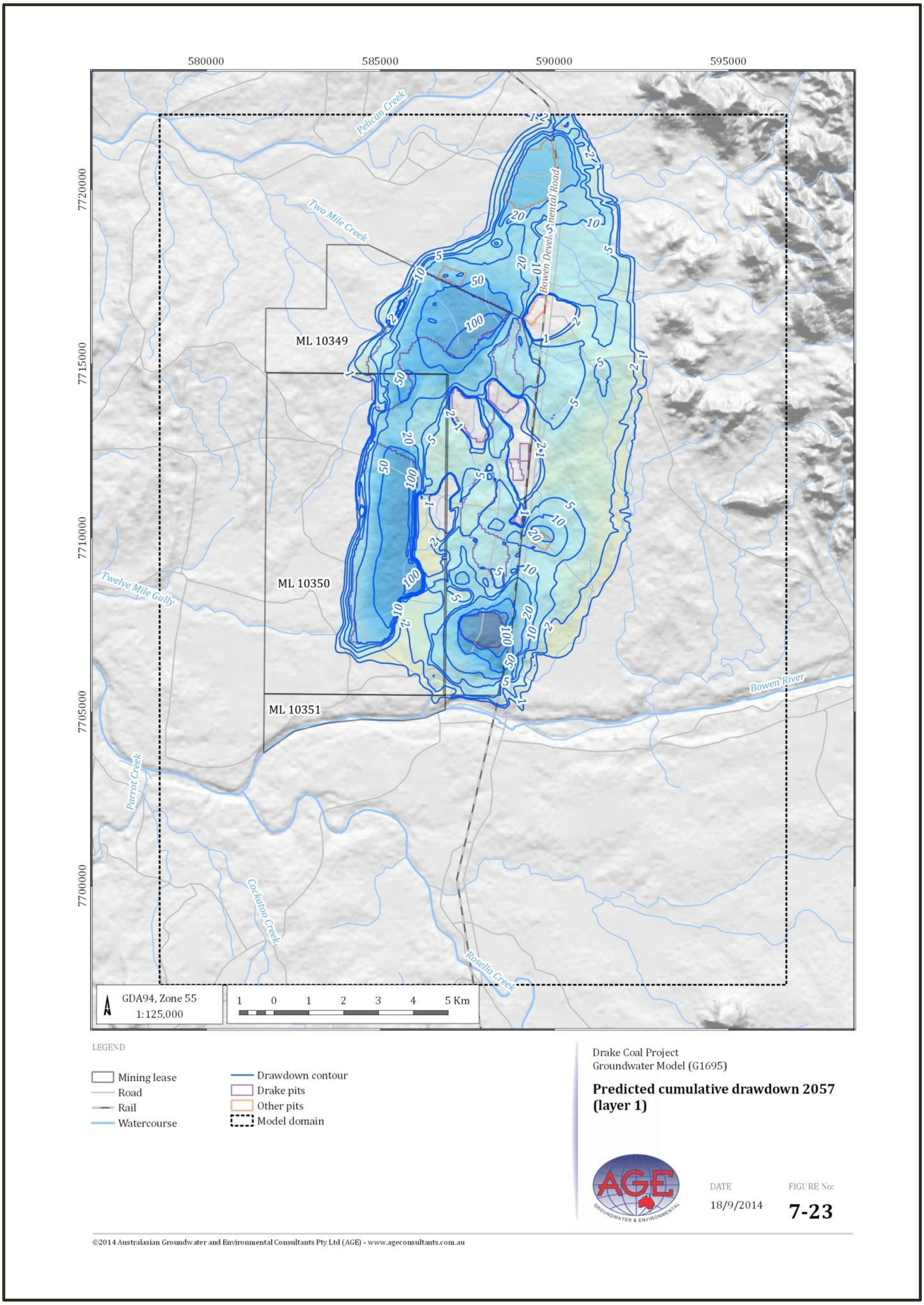

Figure 7-23 Predicted Drawdown End of Mine Layer 1 (cover material and shallow alluvium)

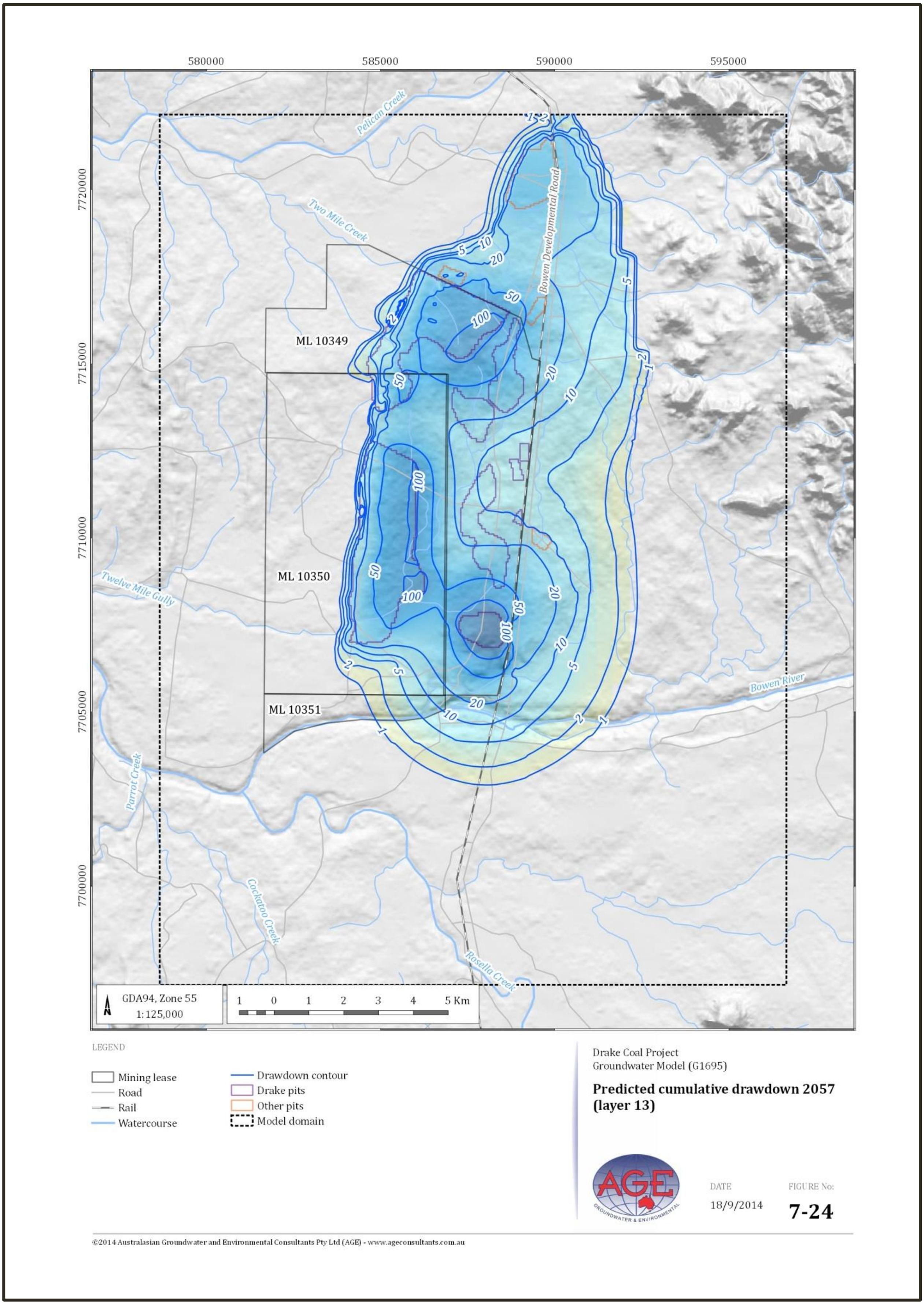

Figure 7-24 Predicted Drawdown End of Mine Layer 13 (representing target coal seams)

7.6.2 Pit Inflows

The pit inflow predictions for the Project are presented in **Figure 7-25**.

These values are noted as being generally lower than those estimated by the analytical methods in the EIS (**Figure 7-1**); however this result is expected given the drawdown extent from the numerical model is smaller than analytical model.

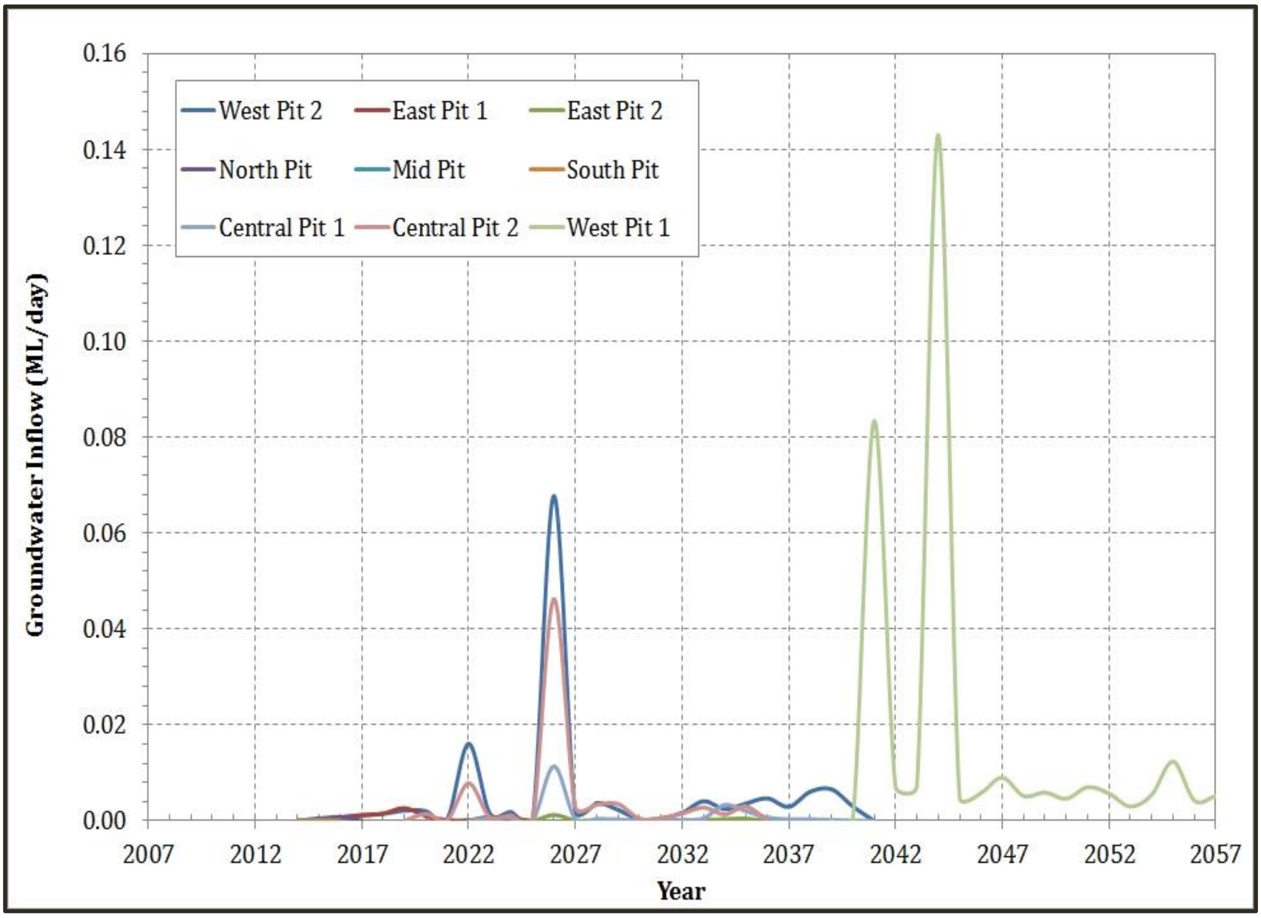

Figure 7-25 River Budget Transient Calibration Plot

West Pit 1 provides the largest predicted daily inflow, peaking at 0.14ML/day. This inflow is the largest as it is the only pit continually operating through towards the end of the mine life, as well as having the largest operating footprint.

Operational detail as to the precise mine progression will inherently not become available until the commencement of operations, as such, the mine progression is based on the initial plans presented in the EIS and subsequent mine planning information to encompass the proposed start and finish dates within the pit. The progression of West Pit 2 assumes a working face the full length of the north-south extent of the pit, slowly progressing down dip towards the east. This large working face may have contributed to this higher inflow in comparison to other pits.

7.6.3 Impacts on the Bowen River

As per the results of the drawdown modelling, the drawdown associated with Central Pit 2 extends to the south and eventually encroaches on the alluvial sediments of the Bowen River. Consequently the model predicts a reduction in the water flowing out of the surrounding alluvium into the Bowen River; as discussed in **Section 7.3.3** and **Section 7.5.2** water flowing into the river from the surrounding alluvium is associated with the lagged seepage of flood water out of the alluvium.

As stated in **Section 7.5.2** the model estimates that 0.0217 ML/day is the net baseflow under steady state conditions; when the model is run under transient conditions the net baseflow for the Bowen River with no mining activities is estimated at 0.0206 ML/day (20.6 m^3/day), as shown in **Figure 7-26** which shows the Bowen River transient net baseflow for non-mining and for mining.

The predicted impact on the base flow of the Bowen River is a reduction of from 0.0206 ML/day to 0.0176 ML/day (a reduction of ~0.003 ML/day or 3 m^3). The Bowen River average daily flow is 1,797 ML/day and as such a ~0.003ML/day reduction represents a potential impact of a 0.0002% reduction in flow (additionally it is noted that during non-rainfall periods, flow in the Bowen River is regulated through releases from Eungella Dam). As a comparison the EIS analytical model estimated a conservative impact of 0.03% of flow, compared with 0.0002% from the numerical model.

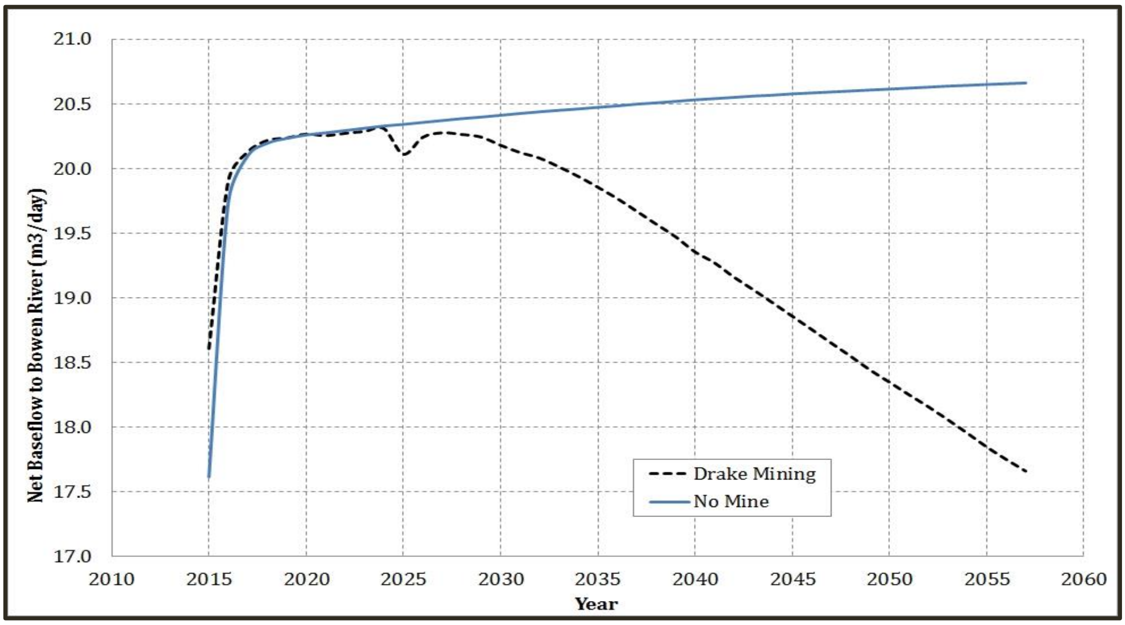

Figure 7-26 River Budget Transient Calibration Plot

The initial rise shown in **Figure 7-26** is due to the completion of the transient simulation where river heights were dynamically varied. The river height then remains static for the predictions of mining at the Project and as such this net baseflow migrates to a new equilibrium.

7.6.4 Summary of Numerical Model and Comparison with EIS Findings

One of the key objectives of the numerical model (**Section 7.1.1**) was to enable validation (confirmation) of the findings of the EIS in relation to potential risks and impacts on any groundwater resources (values) identified across the Project area; the below table (**Table 7-4**)presents a comparison of the findings in the EIS against the outcomes of the numerical model, for key groundwater values and impact assessment considerations. The overall findings of the numerical model indicate that the impact assessment for groundwater in the EIS remains valid, is still applicable and is considered conservative.

Table 7-4 Validation of EIS Findings with the Numerical Model

Key Groundwater Values and Aspects	EIS Findings	Numerical Model Results	Comparison
Drawdown extents	**North of the Bowen River** Maximum potential drawdown is 5.47km.	**North of the Bowen River** Drawdown extents are less than were estimated in the EIS, for both the weathered cover material and shallow alluvium, and for the representative coal seams.	The numerical model predicted drawdown is less than the EIS estimated drawdown. Note: the EIS and the numerical model presented drawdown south of the Bowen River differently, but the findings of the EIS with regard to drawdown are still applicable and conservative, as the Bowen River is modelled separately by the numerical model.
	South of the Bowen River Drawdown extending south of the Bowen River presented as a numerical assessment of potential impacts on the flow of the Bowen River, if drawdown extended under the river.	**South of the Bowen River** Cover material and shallow alluvium: drawdown did not extend south of the Bowen River in the cover material and shallow alluvium (as would be expected). Representative coal seams: the numerical model presented predicted drawdown south of the Bowen River in the representative coal seams, but no connection to the overlying Bowen River alluvium was identified. Numerical model identified that any impacts on the Bowen River are associated with the cover material and shallow alluvium.	
Potential impacts on the Bowen River	0.47 ML/day potential loss of flow (0.03% of average daily flow) This impact on flow was assessed as being insignificant to the Bowen River, even at periods of low flow, with no impact to the regional water balance.	0.003 ML/day potential loss of flow (0.0002% of average daily flow) Numerical modelling indicates that potential impacts to the Bowen River are two orders of magnitude less than was stated in the EIS and are considered insignificant.	The findings of the EIS for the Bowen River are still considered applicable and are confirmed as being conservative.
Pit Inflows	Maximum predicted pit inflow of 2.956 ML/day for West Pit 2	Maximum predicted pit inflow of 0.14 ML/day for West Pit 2	The findings of the EIS for pit inflows are generally higher than predicted by the numerical model; however this is expected given the extent of predicted drawdown from the numerical model is smaller than those from the analytical model. As such the findings of the EIS are still considered applicable and are confirmed as being conservative.

Landholder bores	No registered bores used for water supply were within the drawdown extent. As such no impact identified for landholder bores.	Drawdown extents are less than were estimated in the EIS, for both the weathered cover material and shallow alluvium, and for the representative coal seams. No registered bores used for water supply (or screened in the coal measures) were within the numerical drawdown extent presented in the representative coal seam south of the Bowen River. A landholder bore survey was completed and no unregistered bores were identified within the drawdown extent.	As the numerical model predicts a smaller drawdown extent than the EIS, the EIS findings of no registered bores within the extent of the predicted drawdown are still applicable. No unregistered bores were identified within the drawdown extent.
Springs and GDEs	No springs or GDEs identified within the drawdown extent.	The numerical model predicted a smaller drawdown extent than the EIS analytical model estimates.	As the numerical model predicts a smaller drawdown extent than the EIS, the EIS findings of no springs or GDEs within the extent of the predicted drawdown is still applicable.
Stygofauna	The EIS determined that the absence of stygofauna from the sampled bores indicates there is a low likelihood of stygofauna occurring in the groundwater across the site. Stygofauna is therefore not considered a groundwater value across the Project site.	Drawdown extents are less than were estimated in the EIS, for both the weathered cover material and shallow alluvium, and for the representative coal seams.	The EIS findings of no impact to stygofauna are still considered applicable.

7.7 Numerical Model Validation

Validation of the model can be done by comparing the model predictions to observation data that has not been used for the calibration of the model. All available observational data was used in the calibration of the groundwater model and as such, the strategy for validation would be to continue the monitoring regime and revisit the model at a specified time in the future to examine the predictions against the field observations. This would be in the form of a review of the model.

In addition to the data collected after a period of time from the existing monitoring bore network, any additional bores which are installed in that period and/or any sources of data which were previously unavailable should also be used in the validation comparison.

A period of data collection would be required prior to undertaking the validation to ensure it was meaningful. It is suggested that at least two years of data collection be undertaken prior to any model recalibration. During this time it is suggested that monitoring include particular consideration on aspects of the model which were observed to have the most relative uncertainty with regard to model inputs, to allow for a potential reducing in that area of uncertainty, potentially including:

- Measurement of groundwater inflows into the Project open cut pits;
- Monitoring of groundwater levels in proximity to the Bowen River to capture flood related changes in water levels in the surrounding alluvium and subsequent drainage back into the river;
- Observation of areas of alluvium and cover material when pre-stripping to refine the surficial geology layers in the model;
- Refined on-ground topographical survey data collected during operations; and
- In general the continued monitoring in existing bore network to increase the temporal data set.

7.8 Review of Numerical Model

This GMMP will be subject to reviews as per **Section 1.5**; however reviews of the actual numerical model will be undertaken separately, as such reviews will require consideration of specific model components, factors, inputs, methods and results.

The numerical model will be subject to reviews by an appropriately qualified person on a regular and an as required basis, as follows:

- Regular reviews
    - Every alternate year (regular review) using the monitoring data for the last two years
- As required reviews
    - Upon any amendment of the EA relating to groundwater which may affect the findings of the numerical model
    - Upon significant change in the mine plan (pit layout)
    - As a recommendation or outcome of an groundwater investigation (e.g. exceedance investigation)
    - As part of any internal or external EA or EPBC audit recommendations
    - New data sources become available data:
        - New groundwater bores installed and reliable monitoring data becomes available
        - Mining pit inflow data becomes available
    - As a result of the findings from a review of other aspects of the GMMP.

Where a regular review is being undertaken the objective should be to determine ongoing suitability of the model and to make recommendations where the model requires revision. The methods of regular reviews will generally include (but will not be limited to) the following:

- Comparison of the available water groundwater level data with the predicted water levels for the respective year of operation;
- Comparison of the actual measured pit inflows with the predicted water levels for the respective year of operation; and
- Comparison of any available water level response data in relation to rainfall events and the associated height of the Bowen River, with the predicted responses for those events.

Based on these comparisons the model's ability to simulate surface-groundwater interactions, pit inflows and drawdown extents, is assessed against measured data.

Where an as required review is being undertaken the specific method/aspects of the review will depend on the reason for the review; however as with regular reviews, the findings should determine the ongoing suitability of the numerical model, or, make recommendations where the model requires revision.

It is considered that the first review of the numerical model should be undertaken after two years from the commencement of dewatering activities, in order to allow for the collection of operational data (such as any pit inflow data with any seasonal variation in inflow rates) and additional collection data in the alluvium, against which the numerical model predictions can be reviewed.