# Appendix I
# Groundwater Impact Assessment

Australasian Groundwater & Environmental Consultants

Report on

# Groundwater Impact Assessment Boggabri Coal Mine Modification 10

Prepared for
Xenith Consulting Pty Ltd

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Australasian Groundwater and Environmental Consultants Pty Ltd

Brisbane Head Office
Level 2, 15 Mallon Street
Bowen Hills QLD 4006
t: (07) 3257 2055

Newcastle
4 Hudson Street
Hamilton NSW 2303
t: (02) 4962 2091

Perth
46B Angove Street
North Perth WA 6006
t: (08) 6383 9970

Townsville
Unit 1, 60 Ingham Road
West End QLD 4810
t: (07) 4413 2020

ageconsultants.com.au | linkedin.com/company/ageconsultants

# Executive Summary

The Boggabri Coal Mine (BCM) is located approximately 15 kilometres (km) northeast of the township of Boggabri in northwestern New South Wales (NSW). Boggabri Coal Operations Pty Ltd (BCOPL) is seeking approval on behalf its joint venture participants to modify its approved mining operations under State Significant Development approval (SSD) 09_0182 for the BCM, hereafter referred to as MOD 10. MOD 10 seeks approval to facilitate the orderly progression of mining operations at BCM into the Modification Mining Area, located northwest of the approved Mine Disturbance Boundary but entirely within the existing Project Boundary. MOD 10 will facilitate the recovery of an additional 30 Million tonnes (Mt) of run-of-mine (ROM) coal resources and extend the mine life by four years until the end of 2040.

This groundwater impact assessment consists of two parts: first, a description of the existing hydrogeological environment, and second, an assessment of MOD 10 on that environment. The report's scope aims to meet the state and federal assessment requirements under the NSW Aquifer Interference Policy (AIP) and the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). The groundwater impact assessment for MOD 10 concentrated on specific and relevant 'quantities of interest' (QoIs), as suggested by the guidelines developed by the Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development (IESC). These QoIs include drawdown and reductions in yield for water supply bores, and drawdown reducing groundwater availability to the poplar box woodland ecological communities within the Nagero Creek alluvium.

The most productive groundwater system in the area is the Gunnedah Formation, located within the lower sections of the Quaternary alluvium. Less productive groundwater systems are found in the shallow alluvium (Narrabri Formation) and parts of the Permian coal measures. Basement volcanics create a relatively impermeable unit and are situated beneath both the alluvium and the coal measures. The productivity of these groundwater systems is reflected in the local Water Sharing Plans (WSPs), which specify that the 'highly productive' Upper Namoi Alluvium and the 'less productive' Gunnedah-Oxley Basin Porous Rock are present in the region.

The impact of MOD 10 on the groundwater regime was assessed using a numerical groundwater flow model designed to represent the cumulative impacts of the Boggabri, Tarrawonga, and Maules Creek Complex (BTM Complex). This model has been incrementally refined and updated over the past decade, with the most recent significant update completed in 2024. The current model version provides a sophisticated and robust assessment tool based on the latest understanding of the groundwater regime in the region. The currently approved mining at BCM and the proposed mining for MOD 10 were represented in the numerical model. The potential impacts after mining ceases were assessed over a period of 200 years by continuing the simulations under long-term average climatic conditions.

Modelling results indicate that the cumulative impacts of MOD 10 would largely meet the AIP's Level 1 minimal impact considerations, while incremental impacts relative to approved mining would meet all the AIP's Level 1 minimal impact considerations. In particular:

- water table declines of more than 2 m (Level 1 minimal impact consideration) are not predicted at any water supply work within alluvial water sources;
- exceedances of the Level 1 minimal impact considerations threshold are predicted within the Gunnedah-Oxley Basin Porous Rock Water Source for the cumulative mining scenario. The predicted decline in the water table within the Gunnedah-Oxley Basin Porous Rock Water Source is predominantly due to approved mining, with the incremental impact of MOD 10 considered minimal;
- the nature of the impacts associated with MOD 10 indicates that the beneficial use (in terms of quality and quantity) of surrounding groundwater systems will not be affected;
- the maximum cumulative water table drawdown during mining could impact several high-priority Groundwater Dependent Ecosystems (GDEs), as listed under the relevant WSPs, and exceed the Level 1 minimal impact consideration provided in the AIP around Goonbri, Bollol and Back Creeks. Cumulative drawdowns are maximum in GDEs adjacent to TCM (Goonbri Creek) and MCCM (Back Creek), and in the order of 1.5 m in GDEs along the Bollol Creek;
- cumulative drawdown within Nagero Creek as a result of MOD 10 and other mining operations is consistent with the currently approved mining scenario; and
- additional groundwater take is generally accommodated by existing licences, excluding the final year of mining when it is predicted to exceed licences by 2 ML.

Incremental impacts associated with MOD 10 are not significant and demonstrate minimal incremental change from currently approved mining. There is no measurable change in drawdown in the alluvium as a result of MOD 10; further changes in the Permian drawdown are consistent with the progression of mining operations. The GWMP and associated monitoring program, including newly installed bores in the Nagero Creek alluvium, are considered sufficient to monitor any potential changes to groundwater levels or quality associated with the progression of mining.

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# Groundwater Impact Assessment
# Boggabri Coal Mine Modification 10

## 1 Introduction

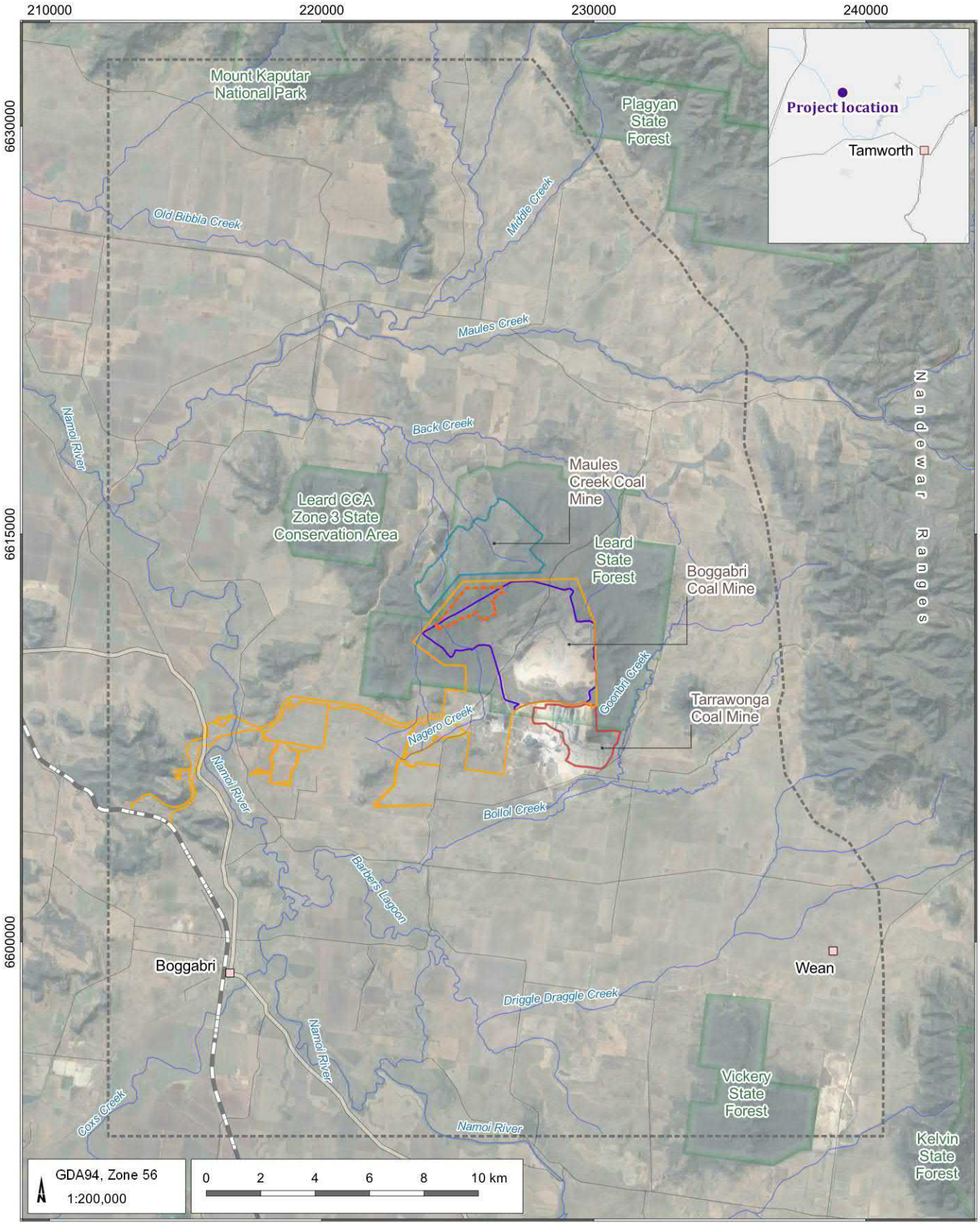
Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) has been commissioned by Xenith Consulting Pty Ltd (Xenith) on behalf of Boggabri Coal Operations Pty Ltd (BCOPL) to undertake a Groundwater Impact Assessment (GIA) of a proposed extension to operations at the Boggabri Coal Mine (BCM) (MOD 10). The GIA will be appended to a Modification Report being prepared by Xenith in support of an application to modify the BCM approval (SSD 09_0182) under Section 4.55(2) of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

BCM is located approximately 15 km northeast of the township of Boggabri in northwestern NSW and forms part of the Boggabri, Tarrawonga and Maules Creek (BTM) Mining Complex (BTM Complex) (Figure 1.1). The BTM Complex includes the BCM, and the Whitehaven-owned Maules Creek Coal Mine (MCCM) and Tarrawonga Coal Mine (TCM). Figure 1.1 shows the project location. For the groundwater impacts assessment purposes, the study area is defined in this figure as the polygon delimiting the extent of the BTM Complex model used for impact assessment.

BCOPL operates the BCM on behalf of the joint venture participants. SSD 09_0182 allows the continuation of open cut mining operations at BCM, including mining down to the Templemore coal seam, at a rate of up to 8.6 Million tonnes per annum (Mtpa) of ROM coal until the end of 2036 (MOD 8).

BCOPL is seeking approval to modify its approved mining operations under SSD 09_0182 (MOD 10). MOD 10 seeks approval to facilitate the orderly progression of mining operations at BCM into the Modification Mining Area, towards the northwest beyond the approved Mine Disturbance Boundary, but entirely within the existing Project Boundary to recover additional coal resources. Key parameters for MOD 10 include the following changes beyond those approved by MOD 8 to SSD 09_0182:

- An additional 85 hectares (ha) of disturbance within the existing Project Boundary and beyond the disturbance footprint currently approved for BCM (Figure 1.2). The existing Vegetation Corridor will be maintained as conditioned in SSD 09_0182.
- Recovery of coal down to the Templemore coal seam within the existing Mine Disturbance Boundary, resulting in the recovery of approximately 15.4 Mt of additional ROM coal resources.
- Mining and recovery of coal resources down to the Templemore coal seam within the Modification Disturbance Footprint. This represents an additional 14.5 Mt of ROM coal.
- An additional four years of mining activities (beyond the additional three years approved for MOD 8) out to the end of 2040.
- Changes to the conceptual final landform design to reflect the additional overburden materials to be mined and the increase in mining area.




LEGEND

- Populated Place
- Principal Road
- Minor Road
- Railway
- Drainage
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent
- BTM Complex Model Extent
- State Forest

Groundwater Impact Assessment Boggabri Coal Mine Modification 10 (BCO5002.001)

**Project location**

AGE

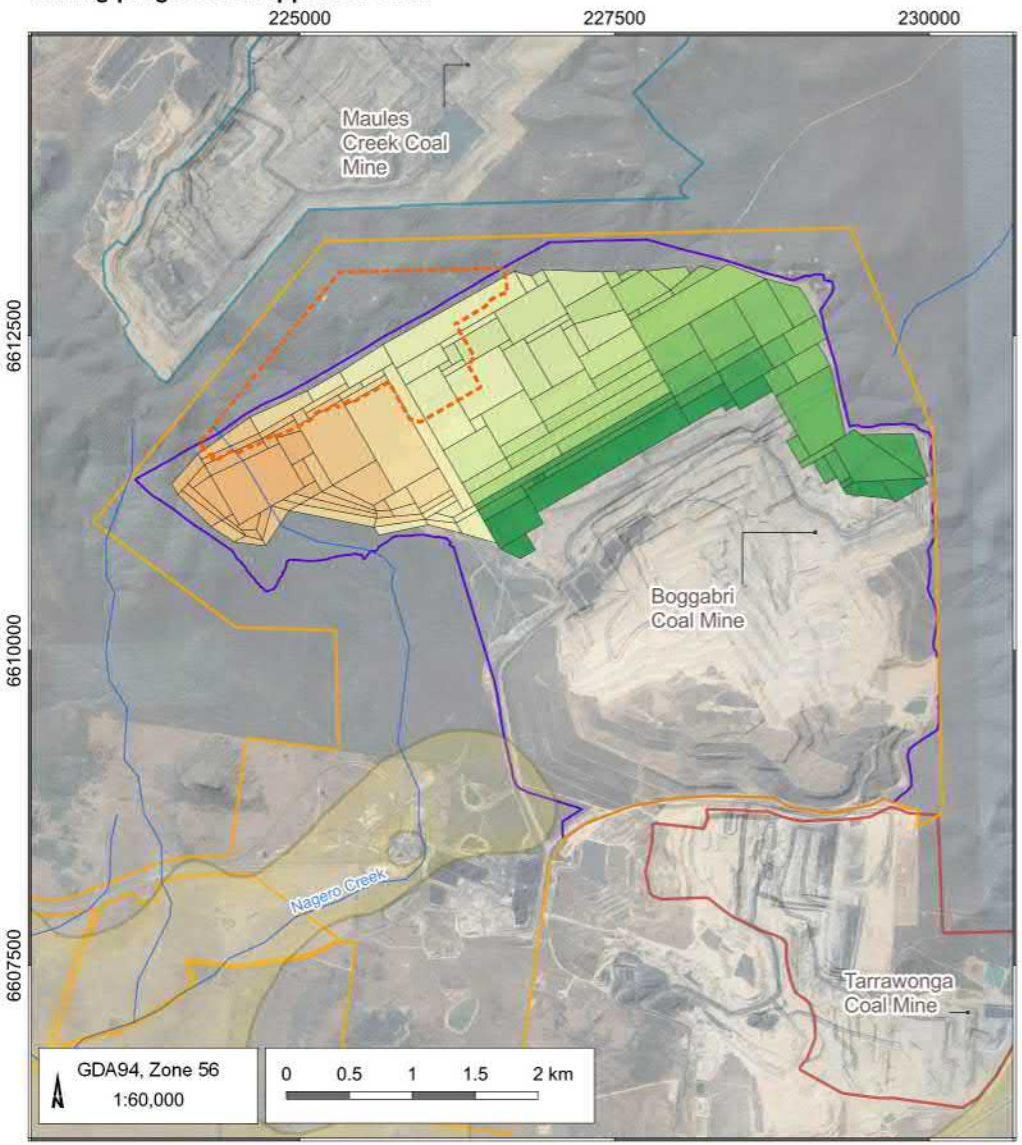
DATE 10/03/2025

FIGURE No: **1.1**

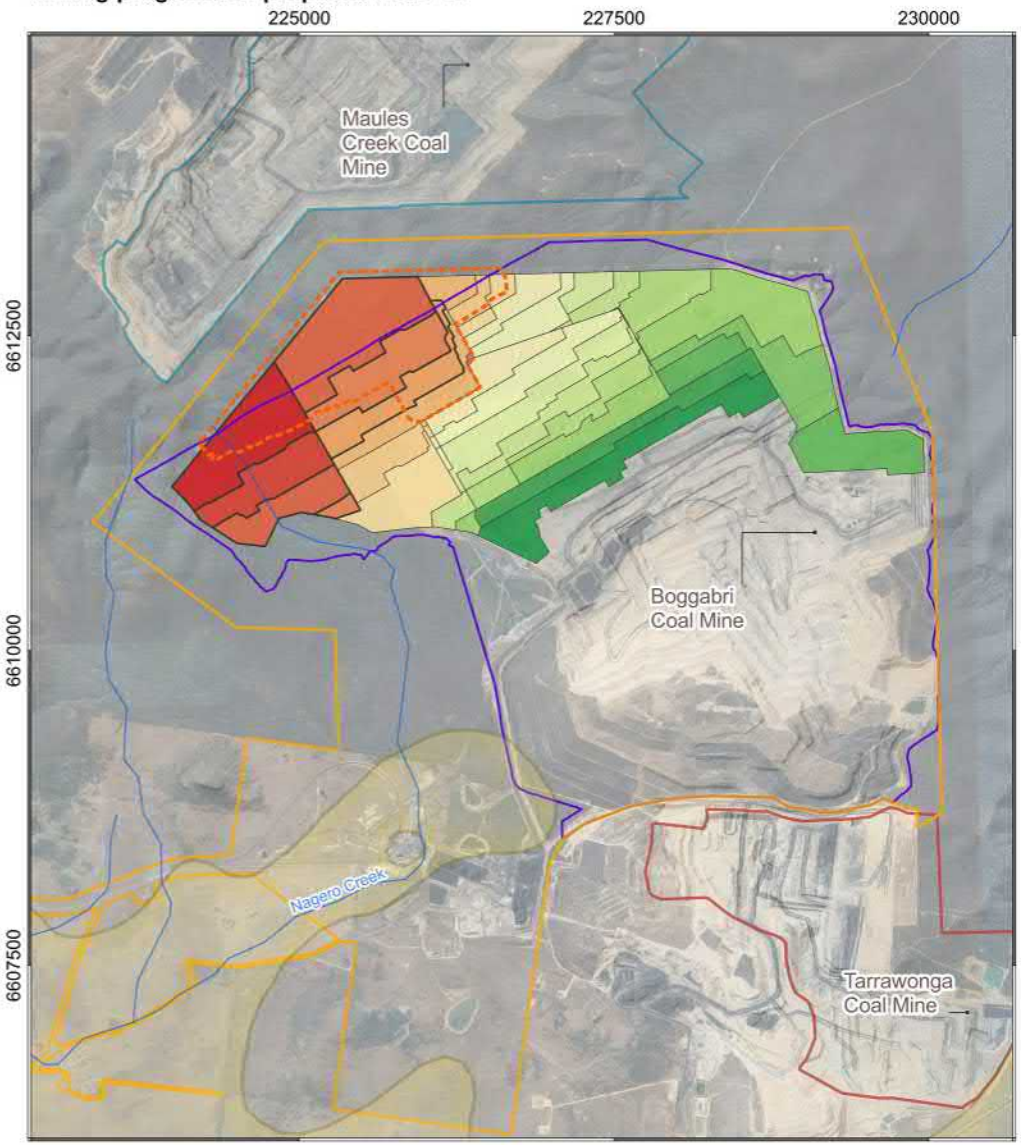
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## Mining progression approved BCM




## Mining progression proposed MOD 10




LEGEND

- Drainage
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent
- Alluvium Extent

**Mining Progression**

| | | |
|---|---|---|
| 2023 | 2029 | 2035 |
| 2024 | 2030 | 2036 |
| 2025 | 2031 | 2037 |
| 2026 | 2032 | 2038 |
| 2027 | 2033 | 2039 |
| 2028 | 2034 | 2040 |

AGE

Groundwater Impact Assessment
Boggabri Coal Mine Modification 10 (BCO5002.001)

**Comparison of approved BCM and proposed MOD 10 mining progression**

DATE
31/03/2025

FIGURE No.
**1.2**

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Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\01.02_BCO5002.001_Comparison of approved BCM and proposed MOD 10 mining progression.qgz

# 2 Objective and scope of work

The objective of the GIA is to assess the types and likelihood of impacts and the magnitude of environmental risk to the groundwater regime posed by MOD 10 to support the regulatory decision-making process. In particular, the GIA for MOD 10 addresses the standard mining industry Secretary's Environmental Assessment Requirements (SEARs) developed by the NSW Department of Planning, Housing and Infrastructure (DPHI) and the requirements of the NSW regulatory framework relating to groundwater impact studies. Consideration was also given to the additional assessment requirements provided in correspondence dated 30 August 2024 by the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) following the referral decision that the Boggabri Coal Mine Modification 10 (EPBC 2024/09887) is a Controlled Action under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (20 August 2024). A scope of work was comprised of the following main tasks to achieve this objective:

- Stage 1 – Data review and gap analysis;
- Stage 2 – Data collection;
- Stage 3 – Conceptual model;
- Stage 4 – Numerical model;
- Stage 5 – Impact and risk assessment; and
- Stage 6 – Mitigation, management, and monitoring.

During Stage 1, a review of the available datasets was conducted, revealing gaps in the understanding and monitoring of the groundwater regime. A data collection program was initiated to address these identified gaps. Stage 2 involved planning additional groundwater monitoring bores to fulfil prior commitments from MOD 8 and to provide supplementary data for model updates. Drilling and installation of monitoring bores were carried out concurrently with the model updates. The existing and new data collected during Stage 2, available at the time, were used to update the conceptual model of the groundwater regime in Stage 3. In Stage 4, the numerical model (BTM Complex numerical model) was updated according to the scheduled update, which occurs every three years under the consent conditions for the BCM. Predictions from the BTM Complex numerical model were used to evaluate the nature and magnitude of risks in Stage 5, with risk management addressed in Stage 6.

This report describes the outcomes of the work program developed to address the project objectives and is divided into the following main sections:

- **Section 3** summarises the regulatory framework at both the NSW and Commonwealth levels and outlines where regulatory requirements have been addressed within the groundwater assessment report.
- **Section 4** provides a summary of the site's environmental setting and surroundings.
- **Section 5** describes the regional and local geology.
- **Section 6** summarises the existing groundwater monitoring network and the planned network expansion, which is progressively completed to verify modelling predictions. Appendix C includes additional information describing the installation of the additional groundwater monitoring sites.
- **Section 7** presents the conceptual hydrogeological model developed for the site.
- **Section 8** provides a high-level summary of the BTM Complex numerical model; details are provided in Appendix F.
- **Section 9** describes the predicted cumulative and MOD 10 specific impacts and outlines risks to the groundwater regime and receptors.
- **Section 10** summarises the uncertainty analysis of model predictions, with a complete uncertainty analysis provided in Appendix F.
- **Section 11** compares the predicted impacts associated with MOD 10 with the NSW and Commonwealth regulatory framework requirements for groundwater assessments.
- **Section 12** outlines ongoing groundwater monitoring, mitigation and management measures.

# 3 Regulatory framework

The sections below summarise the NSW State and Commonwealth regulatory frameworks for groundwater management and groundwater impact assessment for major projects.

## 3.1 NSW state regulatory framework

Figure 3.1 shows the NSW legislation, policy, regulations and guidelines that must be considered when preparing groundwater assessments in the project area. The main elements of the NSW regulatory framework are:

- *Water Management Act 2000*;
- Water Sharing Plans (WSP);
- Aquifer Interference Policy (AIP) (2012); and
- Groundwater Assessment Toolbox.

The sections below summarise each element of the regulatory framework and how it applies to the groundwater assessment.

### 3.1.1 Water Management Act 2000

The NSW *Water Management Act 2000* provides for the 'protection, conservation and ecologically sustainable development of the water sources of the State'. The *Water Management Act 2000* provides arrangements for controlling land-based activities that affect the quality and quantity of the state's water resources.

The *Water Management Act 2000* includes the concept of 'no more than minimal harm' for both the granting of water access licences (WALs) and approvals. Aquifer interference approvals are not to be granted unless the Minister is satisfied that adequate arrangements are in place, ensuring that no more than minimal harm will be caused to the aquifer (s 97(6)) or its dependent ecosystems as a consequence of its being interfered with in the course of the activities to which the approval relates. Section 3.1.2 outlines the "minimal impact considerations" provided within the AIP, and the project impacts are compared to the minimal impact considerations in Section 11.

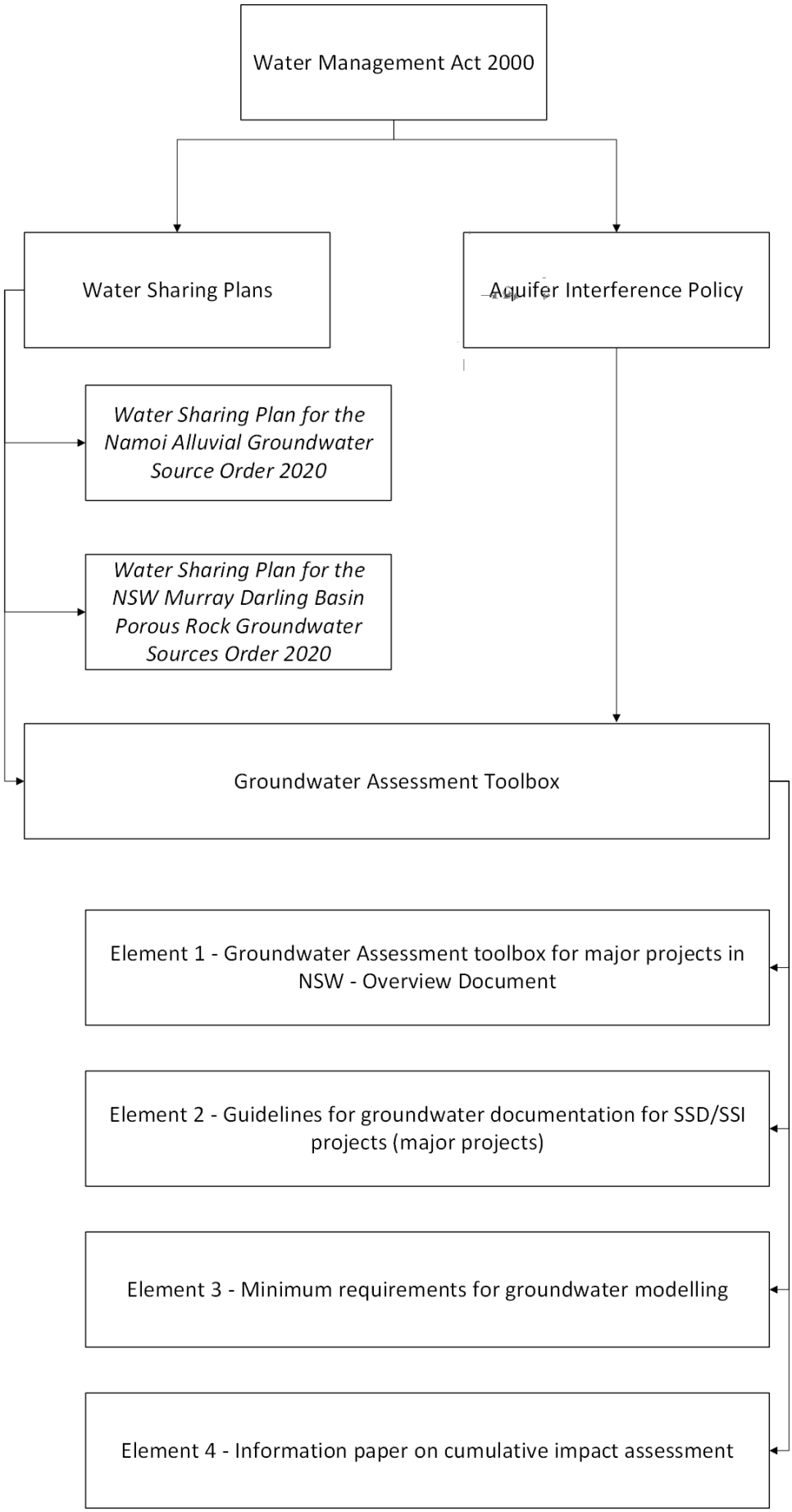



Figure 3.1 Summary of NSW regulatory framework for groundwater assessments

### 3.1.2 Aquifer Interference Policy

The NSW *Water Management Act 2000* defines an aquifer interference activity as involving any of the following:

- penetration of an aquifer;
- interference with water in an aquifer;
- obstruction of the flow of water in an aquifer;
- taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and
- disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

Examples of aquifer interference activities include mining, coal seam gas extraction, the injection of water, and commercial, industrial, agricultural and residential activities that intercept the water table or interfere with aquifers.

The AIP establishes and objectively defines 'minimal impact considerations' related to water-dependent assets under the NSW *Water Management Act 2000*. The minimal impact considerations comprise a series of threshold levels that define the minimal impact on groundwater sources, connected surface water sources, groundwater-dependent ecosystems (GDEs), culturally significant sites, and water users. The thresholds specify water table, groundwater pressure drawdown ranges, and groundwater and surface water quality changes. Two levels of minimal impact considerations are specified: Level 1 and Level 2. If the predicted impacts are less than the Level 1 minimal impact considerations, then the impacts are considered acceptable. If the predicted impacts exceed level 1 thresholds but are within the accuracy of an otherwise robust model, the impacts will be considered within the range of acceptability with additional monitoring, mitigation, or remediation. Where predicted impacts exceed Level 1 minimal impact considerations by more than the accuracy of an otherwise robust model, the assessment will involve additional studies to fully assess these predicted impacts. If this assessment shows that the predicted impacts do not prevent the long-term viability of the relevant water-dependent asset, then the impacts will be considered acceptable.

The minimal impact considerations for aquifer interference activities are based on whether the water source is classified as 'highly productive' or 'less productive' and whether the water source is alluvial or porous/fractured rock. More information on the WSP that describes the management of the alluvial and porous/fractured rock groundwater sources in the region surrounding the Project is provided in Section 3.1.3.

The AIP defines a 'highly productive' groundwater source as one that has been declared in the *Water Management (General) Regulation 2018*, made under the *Water Management Act 2000* (NSW), and datasets based on the following criteria:

- has a total dissolved solids (TDS) concentration of less than 1,500 milligrams per litre (mg/L); and
- contains water supply works that can yield water at a rate greater than 5 litres per second (L/s).

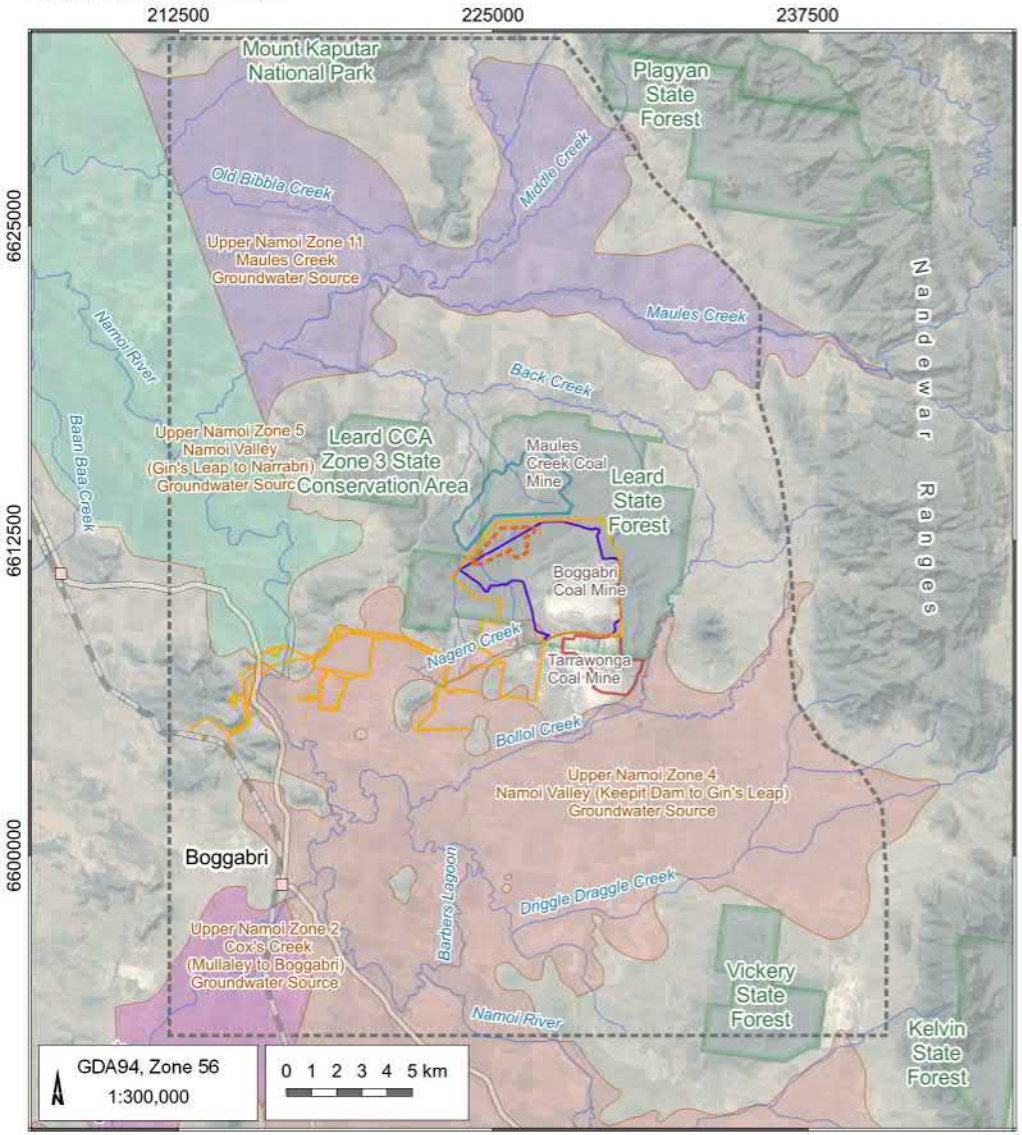
'Less productive' groundwater sources refer to all aquifers that do not meet the 'highly productive' criteria for yield and water quality. The alluvial groundwater systems in the Project region are classified as 'highly productive', whilst the ridge regions where mining occurs and in the bedrock under the alluvial aquifer are classified as 'less productive' aquifers (Figure 3.2).

For water supply bores (water users) installed within highly productive alluvial water sources such as the Namoi River alluvium, the Level 1 minimal impact consideration threshold is *"a maximum of a 2 m decline cumulatively at any water supply work."* For both groundwater sources Level 2 applies "*if more than a 2 m decline cumulatively at any water supply work then make good provisions should apply*".

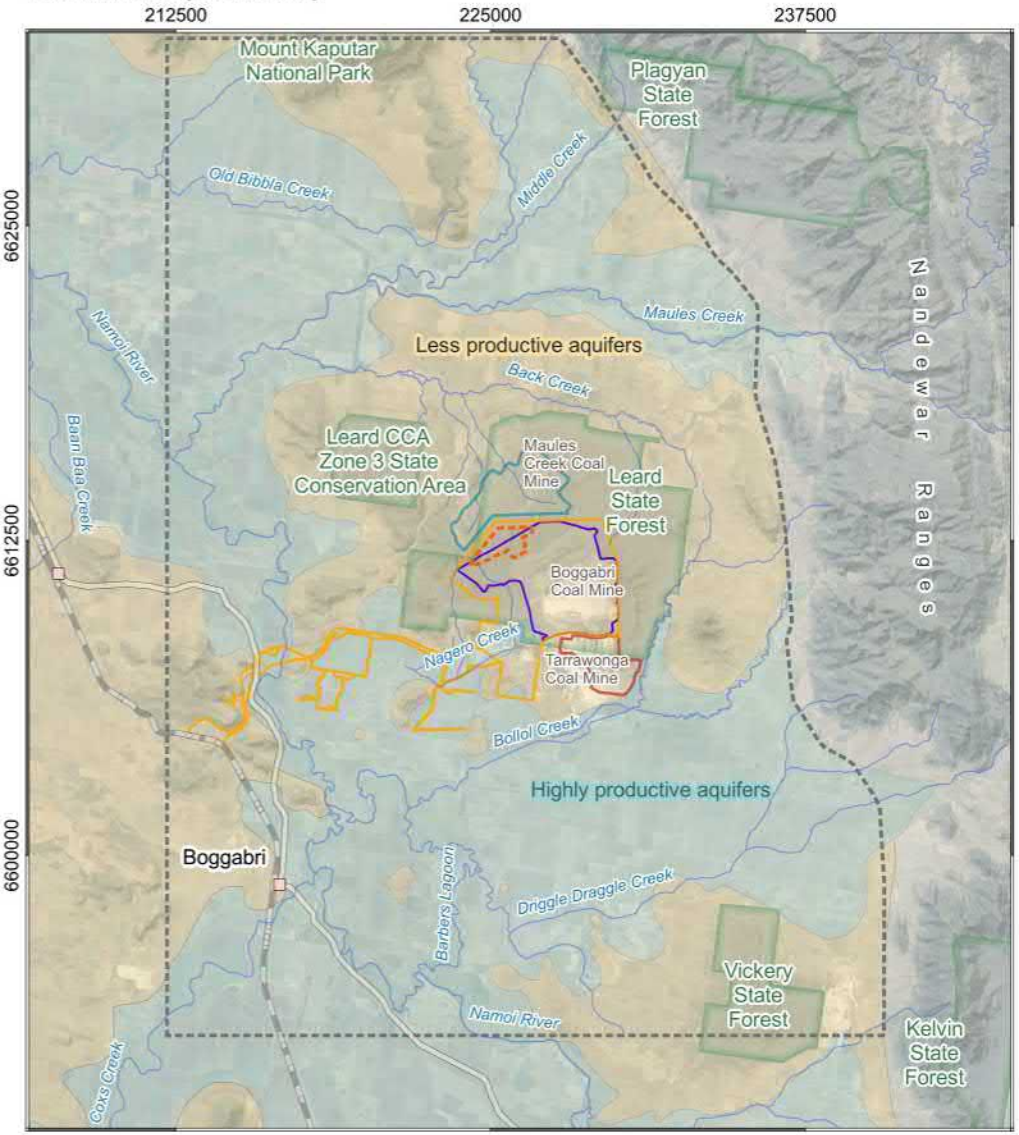
For groundwater-dependent ecosystems (GDEs) within highly productive alluvial water sources, such as those identified along the Namoi River and tributaries, the Level 1 minimal impact consideration threshold is *"less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan…".* As discussed in Section 7, high-priority groundwater-dependent vegetation is mapped on the WSP along the riparian zones of Nagero Creek, within the vicinity of BCM.

The WSPs covering the study area (see Section 3.1.3) do not identify any high-priority culturally significant sites.

## Groundwater sources




## Groundwater productivity




LEGEND

- Populated Place
- Principal Road
- Railway
- Drainage
- State Forest
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent
- BTM Complex Model Extent

**Groundwater Productivity**

- Higly Productive Alluvial
- Less Productive Porous Rock

AGE

Groundwater Impact Assessment Boggabri Coal Mine Modification 10 (BCO5002.001)

**Groundwater sources and aquifer productivity**

DATE
10/03/2025

FIGURE No.
**3.2**

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Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\03.02_BCO5002.001_Groundwater Sources and aquifer productivity.qgz

The AIP also provides a process for aquifer interference activities to account for water take impacts through water licencing. The AIP states that:

> *"All water taken by aquifer interference activities, regardless of its quality, needs to be accounted for within these extraction limits...*
>
> *A water licence is required under the Water Management Act 2000 (unless an exemption applies, or water is being taken under a basic landholder right) where any act by a person carrying out an aquifer interference activity causes:*
>
> - *the removal of water from a water source; or*
> - *the movement of water from one part of an aquifer to another part of an aquifer; or*
> - *the movement of water from one water source to another water source, such as:*
>   - *from an aquifer to an adjacent aquifer; or*
>   - *from an aquifer to a river/lake; or*
>   - *from a river/lake to an aquifer."*

Water take can be categorised into consumptive, passive and incidental water take. The AIP states that a WAL is required for the aquifer interference activity regardless of whether water is taken directly for consumptive use or incidentally. 'Consumptive water take' is defined as water directly taken from an aquifer by pumping and consumed by the activity, whilst 'passive water take' is defined as water losses from a groundwater system that occur indirectly due to an adjacent activity. 'Incidental water take' is defined in the AIP as:

> *"Water that is taken by an aquifer interference activity that is incidental to the activity; including water that is encountered within and extracted from mine workings… This water is not actually required to be used as part of the process of carrying out that activity*."

Further information on water licensing is provided in Section 3.1.3.

Proponents of aquifer interference activities are required to provide predictions of the volume of water to be taken from a water source as a result of the proposed activity. Estimates of water take are required so that water licences can be acquired to account for water taken by the activity. The water take estimates are typically identified as part of the project's assessment through the government assessment process. During operations, water take from various water sources is to be measured and reported in an annual review. When the take occurs, the WAL must hold a sufficient share component and water allocation to account for the peak water take from the relevant water source. Section 3.1.3 provides more information on the WALs held by BCOPL to account for water take that occurs due to aquifer interference activities. Estimates of water take due to the approved and proposed mining are provided in Section 9.4.

### 3.1.3 Water Sharing Plans

Within the study area, groundwater is managed under two WSPs:

- Water Sharing Plan for the Namoi Alluvial Groundwater Sources Order 2020 (WSP for the Namoi Alluvial Groundwater Sources); and
- Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources Order 2020 (WSP for the NSW Murray Darling Basin Porous Rock Groundwater Sources).

The WSP for the Namoi Alluvial Groundwater Sources encompasses all water contained in unconsolidated alluvial sediment aquifers associated with the Namoi River and its tributaries. Alluvial aquifers present in the investigation area are divided into local management zones:

- Upper Namoi Zone 11 (Maules Creek);
- Upper Namoi Zone 5 (Namoi Valley Gin's Leap to Narrabri);
- Upper Namoi Zone 4 (Namoi Valley Keepit Dam to Gin's Leap); and
- Upper Namoi Zone 2 (Cox's Creek Mullaley to Boggabri).

Outside the alluvial areas, groundwater is managed under the Gunnedah-Oxley Basin sub-division of the WSP for the NSW Murray Darling Basin Porous Rock Groundwater Sources. This sub-division includes all Permian, Triassic, Jurassic, Cretaceous and Tertiary rocks, as well as any alluvial sediments within outcropped areas.

Under the 2020 updates to the WSPs, high-potential (connectivity) terrestrial GDEs, as defined in the GDE Atlas of Australia (Bureau of Meteorology, 2019) are now considered high-priority GDEs under the NSW *Water Management Act 2000*. As such, the minimal impact consideration of the AIP related to high-priority GDEs should be considered.

Each groundwater management zone has a specific number of WALs, which pertain to the total annual entitlement (excluding basic access rights). Table 3.1 presents the total entitlements for each water source and the entitlements held by BCM to account for the mine's consumptive, passive, and incidental water take.

Table 3.1 Water access licence entitlements 2024/25

| Groundwater Source | Total number of WALs | Total entitlement (units shares) [a/b] | BCM entitlement (unit shares) [a/b] |
|---|---|---|---|
| Upper Namoi Zone 11 | 30 | 2,223 | 20 |
| Upper Namoi Zone 5 | 78 | 15,992 | 0 |
| Upper Namoi Zone 4 | 171 | 21,032 | 1,028 |
| Upper Namoi Zone 2 | 30 | 7,141 | 0 |
| Gunnedah-Oxley Basin | 156 | 27,293 | 842 |

**Notes:** Data taken from the WaterNSW Water Register for the 2024/25 financial year accessed: https://waterregister.waternsw.com.au/water-register-frame; (accessed on 06/02/2025).

(a) ML – megalitres; and

(b) Unless the Minister otherwise determines, at the commencement of each water year an available water determinations of 1 ML per unit share for all listed Groundwater Sources. Maximum carryover of remaining water allocation account is equal to 1 ML per unit share for the Gunnedah-Oxley Basin Groundwater Source, and 2 ML per unit share for all listed alluvial Groundwater Sources.

Releases from Keepit Dam regulate the flow of the Namoi River. The Namoi River is classified as the Upper Namoi Regulated Water Source. It is managed under the WSP for the Upper Namoi and Lower Namoi Regulated River Water Sources 2016 (NSW). All other surface water in the investigation area is managed under the WSP for the Namoi and Peel Unregulated Rivers Water Sources 2012 (NSW), an updated version (2025) is currently on public exhibition, and the finalised plan is proposed to commence on or before 1 July 2025.

### 3.1.4 Groundwater assessment toolbox

The Groundwater Assessment Toolbox (GAT) (NSW Department of Planning and Environment, 2022a) is a collection of technical guidelines that aim to create a collaborative, transparent, and enabling environment for preparing and reviewing groundwater assessments in NSW, particularly for SSD and state-significant infrastructure (SSI) projects. The specific objectives of the GAT are to:

Objective 1: Provide a framework to investigate, assess the impacts on, manage and monitor groundwater resources and their interaction with surface water resources within the footprint of a major project

Objective 2: Clarify the department's expectations (minimum requirements) from groundwater documentation, including groundwater modelling that is prepared for major projects and used to support and inform the impact assessment

Objective 3: Identify practical approaches for the assessment of cumulative groundwater impacts.

The GAT has five main elements as follows:

- Element 1 – GAT overview document (NSW Department of Planning and Environment, 2022a)
- Element 2 – Guidelines for groundwater documentation (NSW Department of Planning and Environment, 2022b)
- Element 3 – Minimum requirements for groundwater modelling (NSW Department of Planning and Environment, 2022c)
- Element 4 – Information paper on cumulative groundwater impact assessment (NSW Department of Planning and Envionment, 2022d)

The fifth element of the GAT is the AIP, summarised in Section 3.1.2. The groundwater assessment has been structured to provide the information requested within the GAT and refers to GAT requirements where appropriate within the main document and appendices.

### 3.1.5 Existing approval conditions

As discussed in Section 1, BCOPL currently holds SSD 09_0182 (as modified), which details groundwater-specific approval requirements that include the implementation of a Groundwater Management Plan (condition 38(c)) and a Leard Forest Mining Precinct Water Management Strategy (condition 38(d)). These conditions state that BCOPL is required to:

> *'co-ordinate modelling programs [with surrounding mines] for validation, re-calibration and re-running of the groundwater and surface water models using approved mine operation plans (condition 38(d))*; and
>
> *[implement] a program to validate the groundwater model for the project, including an independent review of the model every 3 years, and comparison of monitoring results with modelled predictions (condition 38(c)).'*

The groundwater modelling technical report contained within Appendix F describes the coordinated validation, recalibration, and rerunning of the BTM Complex numerical model and represents an update to the model after the previous update described by AGE (2022). This model has been reviewed by an independent peer reviewer (Dr Noel Merrick), with the assessment letter provided in Appendix G.

## 3.2 Commonwealth regulatory framework

Figure 3.3 shows the Commonwealth legislation and guidelines to consider when preparing groundwater assessments in the project area. The main elements of the Commonwealth regulatory framework are:

- *Environment Protection and Biodiversity Conservation Act* (EPBC Act);
- Significant Impact Guidelines; and
- Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development (IESC) – information guidelines and explanatory notes (IESC, 2024).

Existing operations at BCM are also approved under the EPBC Act as per the Boggabri Coal Mine Extension approval (EPBC 2009/5256) and Boggabri Coal Mine Modification 8 approval (EPBC 2021/8875).

MOD 10 has also been referred (EPBC 2024/09887) to the Commonwealth government, which has determined that these changes are a Controlled Action and will require approval under the EPBC Act.

The sections below summarise each element of the regulatory framework and how it applies to the groundwater assessment.

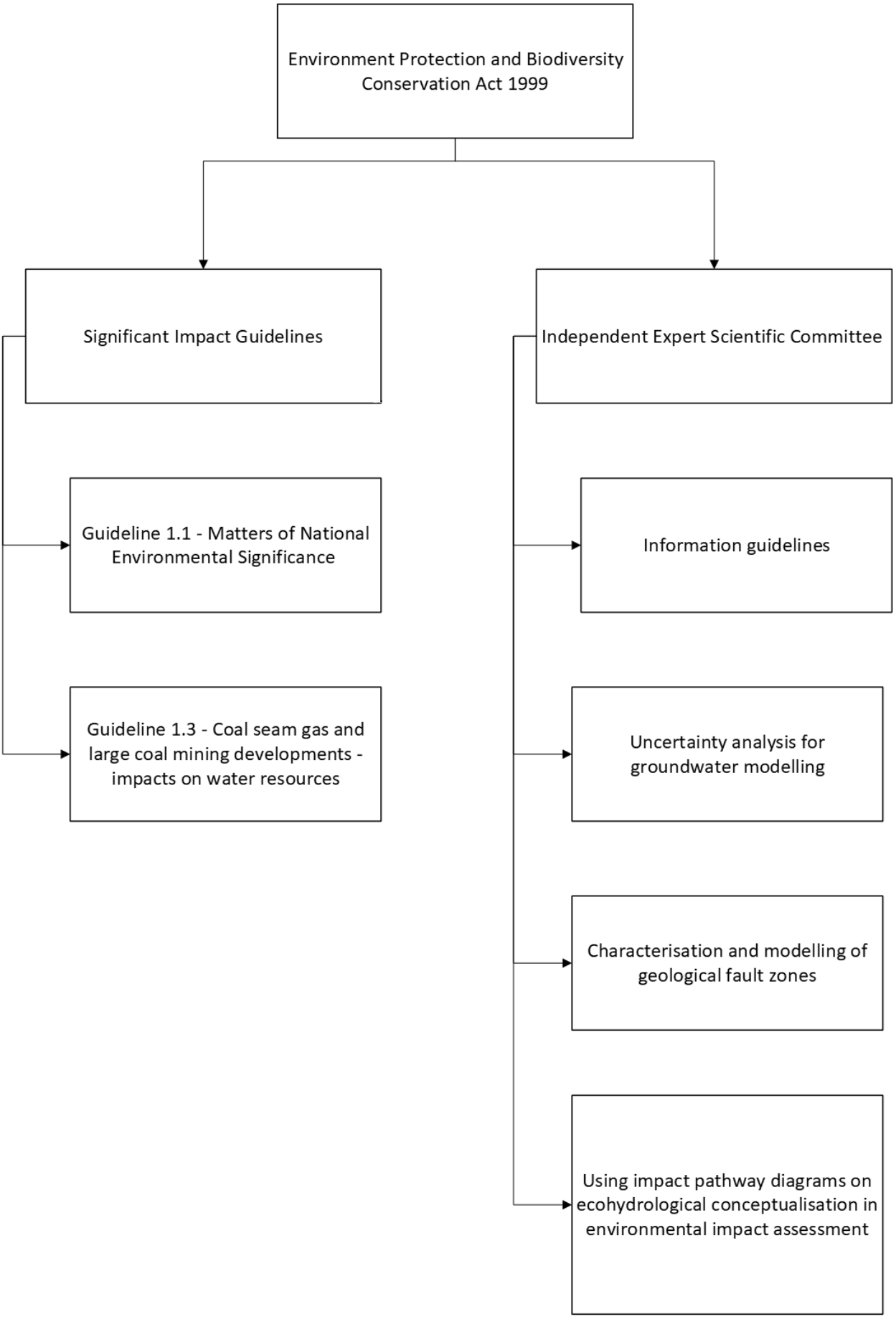



Figure 3.3 Summary of Commonwealth regulatory framework for groundwater assessments

The DCCEEW administers the EPBC Act. It is designed to protect national environmental assets, known as matters of national environmental significance (MNES). Under the 2013 amendment to the EPBC Act (the water trigger), significant impacts on water resources associated with coal mining and/or coal seam gas (CSG) developments were included as an MNES.

The DCCEEW has developed several guidelines to guide the assessments of the significance of impacts to MNES that are protected under the EPBC Act. Those Significant Impact Guidelines related to the groundwater assessment are:

- Significant impact guidelines 1.1: Matter of National Environmental Significance; and
- Significant impact guidelines 1.3: Coal seam gas and large coal mining developments - impacts on water resources.

The bilateral agreement with the NSW Government under the EPBC Act notes that NSW should seek and consider expert advice from the IESC regarding coal seam gas or large coal mining developments likely to significantly impact water resources. Correspondence from DCCEEW dated 30 August 2024 indicates that the assessment of the impacts of MOD 10 on water resources is to be jointly referred to the IESC for review as part of the NSW Government's assessment.

The IESC has developed a series of guidelines and explanatory notes that outline how groundwater assessments should be approached and the information required to be presented within the assessment documentation to enable IESC review and consideration in preparation for its advice to government regulators.

The Information Guidelines developed by the IESC outline the necessary information to enable the IESC to provide robust scientific advice to government regulators on the water-related impacts of CSG and large coal mining development proposals. The Information Guidelines have been considered during the preparation of this GIA, as well as relevant explanatory notes, which include:

- explanatory note on uncertainty analysis for groundwater modelling (Peeters & Middlemis, 2023);
- characterisation and modelling of geological fault zones (Murray & Power, 2021); and
- using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessment (Commonwealth of Australia, 2024).

## 3.3 Non-regulatory guidance

Other non-regulatory guidance that was considered when preparing this GIA include:

- Australian Groundwater Modelling Guidelines (Barnett, et al., 2012); and
- Groundwater Modelling Decision Support Initiative (GMDSI, 2020).

The GMDSI is a joint initiative of the mining industry and academia that guides groundwater modelling intended to support decision-making processes (GMDSI, 2020). It includes a wide range of resources and methodologies that were considered during the numerical modelling process.

## 3.4 Project flow chart

Figure 3.4 shows the main elements of the groundwater assessment designed to address the regulatory framework review. It highlights the multifaceted nature of the groundwater assessment process and its interactions with the NSW and Commonwealth regulatory departments and the peer reviewer.

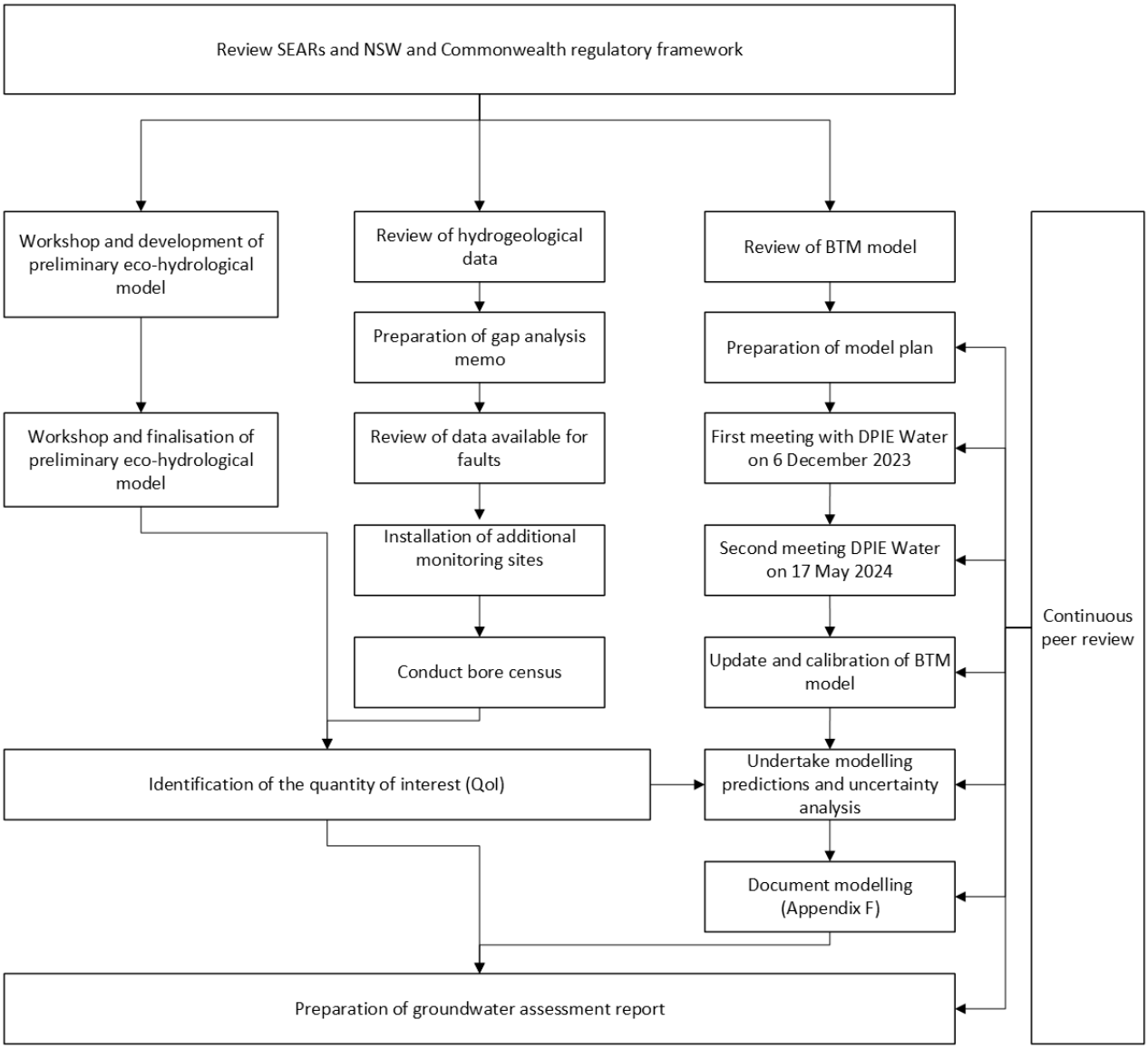



Figure 3.4 Flow chart of groundwater assessment development process

## 3.5 GAT check list

The GAT includes a check list that outlines the content of groundwater assessment reports required for SSD/SSI. This table is reproduced in Table 3.2 and cross-references to the sections within this report where the requested content is provided.

Table 3.2 Groundwater Assessment Toolbox requirements and location addressed within report

| GAT Requirement | Provided in Report Section |
|---|---|
| **Project setting** | |
| Scope of the project described (including construction, operation and closure). | Section 1 |
| Location of project clearly identified (address and real property description, and/or lot and plan information). | Section 1 |
| Environmental setting described (including topography, climate, the location of surface water features, biodiversity values and land use). | Section 4 |
| Appreciation of regional and local geological setting clearly stated. | Section 5 |
| Geological structural features potentially affecting groundwater behaviour identified. | Section 5.3 |
| Will any project related excavation remain above the water table? | Yes |
| Have baseline groundwater field investigations been conducted and report provided? | Appendix C and Appendix D |
| Have the relevant Water Sharing Plans and relevant water sources been identified? | Section 3.1 |
| Has the proponent consulted with the local community, local Aboriginal, community, council, NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW) – Water Group[1], EPA, and WaterNSW (where relevant) to establish cultural and environmental values of the water sources? | Yes |
| **Receptors** | |
| Have mapped high priority groundwater dependent ecosystems, listed in the relevant Water Sharing Plans, been identified. | Section 7.12.3 |
| Has the proponent reviewed the GDE Atlas to identify any other mapped potential groundwater-dependent ecosystems in the project area? | Section 7.12.3 |
| Has the proponent identified other potential groundwater dependent ecosystems out of other technical specialist analysis? Have the technical specialists used outputs from the GIA for their ecological assessment? | Section 7.12.3 |
| Have considered and identified potential culturally significant sites listed in the relevant Water Sharing Plans been identified? | Section 7.12.1 |
| Has the proponent identified third-party users in the vicinity that might be impacted identified (registered/unregistered)? | Section 7.12.2 |
| **Groundwater elevation and flow** | |
| Are monitoring bore locations and depths provided and appropriate based on depth and scale of proposed development? | Section 6 |
| Are measurements recorded at a frequency suitable to detect potential changes (EIS or post-approval)? | Section 6 |
| Has a bore census of existing third-party bores in the project area been completed? | Section 7.12.2 |
| Is the groundwater baseline provided sufficient (AIP requires 2 years)? | Section 7.5 |

| GAT Requirement | Provided in Report Section |
|---|---|
| Has the proponent assessed vertical gradients between overlying water sources? | Section 7.6 |
| Has the proponent provided water table elevation and potentiometric surface contour plans for water sources pre-development (including consideration of wet/winter and summer/dry seasonal variations), supported by points labelled with measured groundwater elevation? | Section 9.1 |
| Has the proponent provided evidence of spatial and temporal assessment of groundwater elevation and flow (that is, vertical and lateral with time and seasons)? | Section 7.5 |
| **Hydraulic properties** | |
| Has the proponent conducted hydraulic tests at various locations across the project area? For example, slug tests, pumping tests, packer tests, core tests. | Section 7.3 |
| Has the proponent conducted a literature review of potential hydraulic properties for the water sources in the project area? For example, other projects in the area or textbook values. | Section 7.3 |
| **Groundwater quality** | |
| Has the proponent included sufficient spatial & temporal variation in groundwater quality data? | Section 7.11 |
| Was the potential for cross-contamination of aquifers assessed sufficiently? | Section 7.6 |
| Is the baseline groundwater quality defined and described sufficiently with respect to the cultural and environmental values and the development? | Section 7.11 |
| Is quality assurance data provided? | - |
| **Conceptual hydrogeological model** | |
| Has the proponent described the hydrostratigraphic units in the project area? | Section 7.2 |
| Has the proponent assessed and described potential surface water-groundwater interaction? | Section 7.7 |
| Has the proponent considered existing water use in the area? | Section 7.12.2 |
| Has the proponent provided a graphical representation of the conceptual hydrogeological model (cross-section or three-dimensional block model) to show hydrostratigraphy and other groundwater processes described above? | Appendix A |
| Has the proponent provided a graphical representation of potential groundwater dependence of GDEs within the project area? | Section 7.12.3 |
| **Impact Assessment** | |
| Is the assessment methodology commensurate with the risk and as agreed with the department's Water division? For example, analytical model versus simple numerical model vs complex numerical model? | Appendix F |
| Has the proponent completed the Aquifer Interference Assessment Framework form? | Appendix E |
| Has the proponent assessed the predicted impacts against the Aquifer Interference Policy "minimal impact considerations"? | Appendix E |

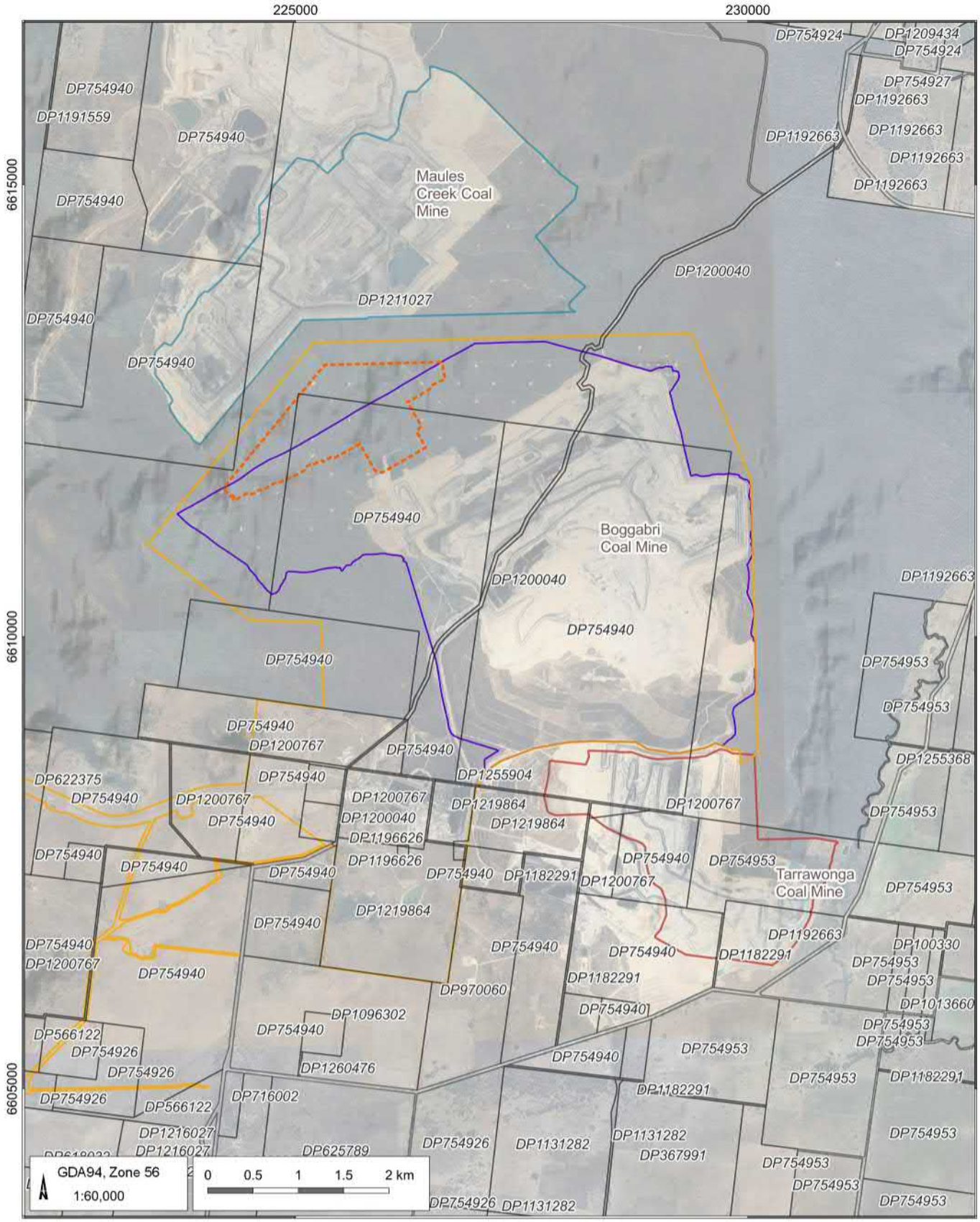
| GAT Requirement | Provided in Report Section |
|---|---|
| Has the proponent assessed the predicted impacts during construction, operations and post-development? | Section 9 |
| Have the potential impacts from changes in water quality, water quantity, aquifer integrity and biological integrity of groundwater dependent ecosystems been identified and quantified? | Section 9.6 |
| Has the proponent assessed the potential presence of acid sulfate soils? | Section 9.7 |
| Has the proponent assessed the potential for generation of acid metalliferous drainage? | Section 9.7 |
| Has the proponent documented the predicted annual water take (per water source) on an annual basis? | Appendix F |
| Has the proponent documented the licensing pathway proposed to secure the required water entitlement for water access licence(s) for the predicted take? | Section 9.4 |
| Has the proponent assessed impacts on the groundwater dependent ecosystems and culturally significant sists in accordance with the Aquifer Interference Policy considerations? | Section 9.6 |
| **Management and mitigation measures** | |
| Are the documented management and mitigation measures practical and measurable? | Section 12 |
| Has the proponent documented the approach to the proposed monitoring program during construction and operations? | Section 6 |

**Note:** 1 Previously NSW Department of Planning, Industry & Environment (DPIE).

# 4 Project setting

## 4.1 Project location

The BCM is located approximately 12 km northeast of the township of Boggabri. Figure 4.1 shows the BCM boundary, proposed Modification and lot boundaries.




LEGEND

- Lot Boundaries
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

Groundwater Impact Assessment
Boggabri Coal Mine Modification 10 (BCO5002.001)

**BCM and lot boundaries**

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DATE 10/03/2025

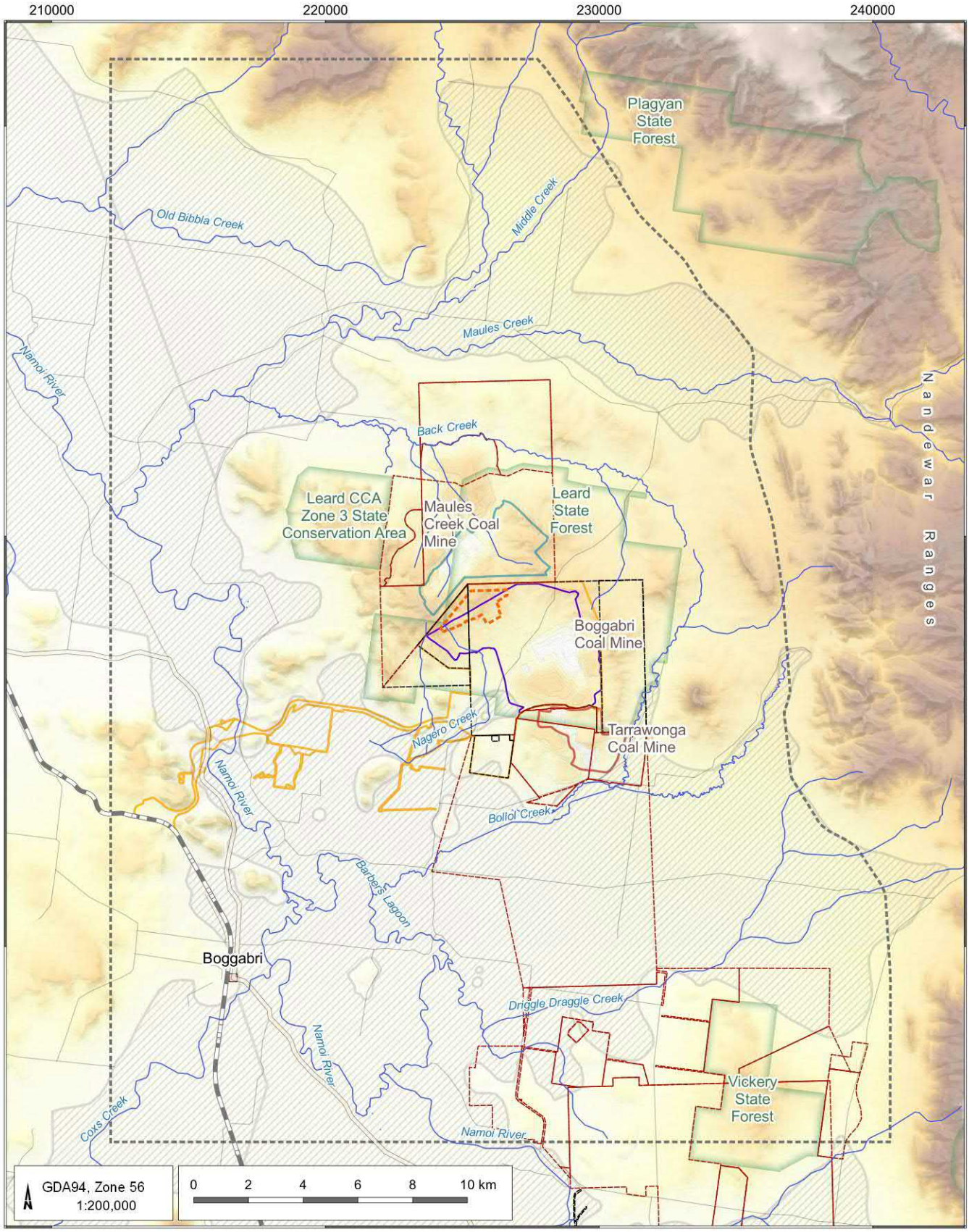
FIGURE No. **4.1**

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Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\04.01_BCO5002.001_BCM and lot boundaries.qgz

## 4.2 Terrain and drainage

The investigation and surrounding area's terrain is characterised by wide, flat alluvial plains bounded by wooded hills and ridgelines. The geomorphology is influenced by the underlying geology, with volcanic and sedimentary bedrock outcropping along ridgelines and overlain by alluvial sediments along the significant floodplains in the area. The BCM is the middle of three mines that form the BTM Complex and is bound by ridgelines to the north and east that rise to more than 400 metres Australian Height Datum (m AHD) (Figure 4.2). Approximately 8 km east of BCM, the terrain changes to the notably more mountainous Nandewar Ranges, which form part of the Great Dividing Range and rise to over 1,000 m AHD in certain areas.

The hills and slopes surrounding the BCM are drained by a series of generally westward-flowing ephemeral creeks that meander across the adjacent floodplains and discharge into the Namoi River. The Namoi River is approximately 8 km to 10 km west of BCM and is the most significant surface water drainage feature in the area. Tributaries of the Namoi River include Maules Creek to the north of the BTM Complex, Bollol Creek to the south and Nagero Creek to the west of BCM. These tributaries flow westward and have extensive, broad, gently sloping floodplains that connect to the Namoi River floodplain. The headwaters for Maules Creek and Bollol Creek are located within the Nandewar Ranges, and the upper catchments can provide large volumes of runoff to the creeks that persist for short durations. Surface water drainage from the catchment area that BCM occupies flows into Nagero Creek, a minor tributary of the Namoi River, located at the southwest corner of BCM. The Namoi River surface flows are regulated through the storage and release of water from upstream dams, which include Keepit Dam, located upstream of Gunnedah, and Split Rock Dam, situated on the Manilla River, a tributary of the Namoi River.




LEGEND

- Populated place
- Drainage
- Principal Road
- Minor Road
- Railway
- state forest
- Alluvium
- BTM Model Extent
- BCM tenements
- MCCM and TCM tenements
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

**Elevation (mAHD)**

- 200
- 300
- 400
- 500
- 600
- 800
- 900

Groundwater Impact Assessment Boggabri Coal Mine Modification 10 (BCO5002.001)

**Topography**

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DATE 26/03/2025

FIGURE No: **4.2**

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## 4.3 Climate

The climate of the investigation area is characterised by hot summers, with thunderstorms and comparatively mild dry winters. Climate data for the area was sourced from the Scientific Dataset for Landowners (SILO) (2024), for the coordinates 30.60°S, 150.15°E. The SILO dataset is used to obtain location-specific climate data interpolated from surrounding weather stations. Climate data from 2006 to 2024 was analysed as mining commenced at BCM in 2006. Table 4.1 and Figure 4.3 presents the SILO data.

The mean annual rainfall between 2006 and 2024 was 608 millimetres per year (mm/year). Over half of the rainfall occurs in the warmer months (November to March). Evaporation rates (pan evaporation) exceed rainfall throughout the year, with the highest deficit between rainfall and evaporation occurring during the summer months.

Table 4.1 Summary of climate averages (January 2006 to December 2024)

| Month | Mean monthly rainfall (mm) | Mean monthly pan evaporation (mm) |
|---|---|---|
| January | 63 | 245 |
| February | 68 | 202 |
| March | 63 | 175 |
| April | 31 | 124 |
| May | 34 | 82 |
| June | 49 | 56 |
| July | 33 | 63 |
| August | 39 | 93 |
| September | 40 | 134 |
| October | 45 | 185 |
| November | 77 | 212 |
| December | 66 | 237 |
| **Annual** | **608** | **1,808** |

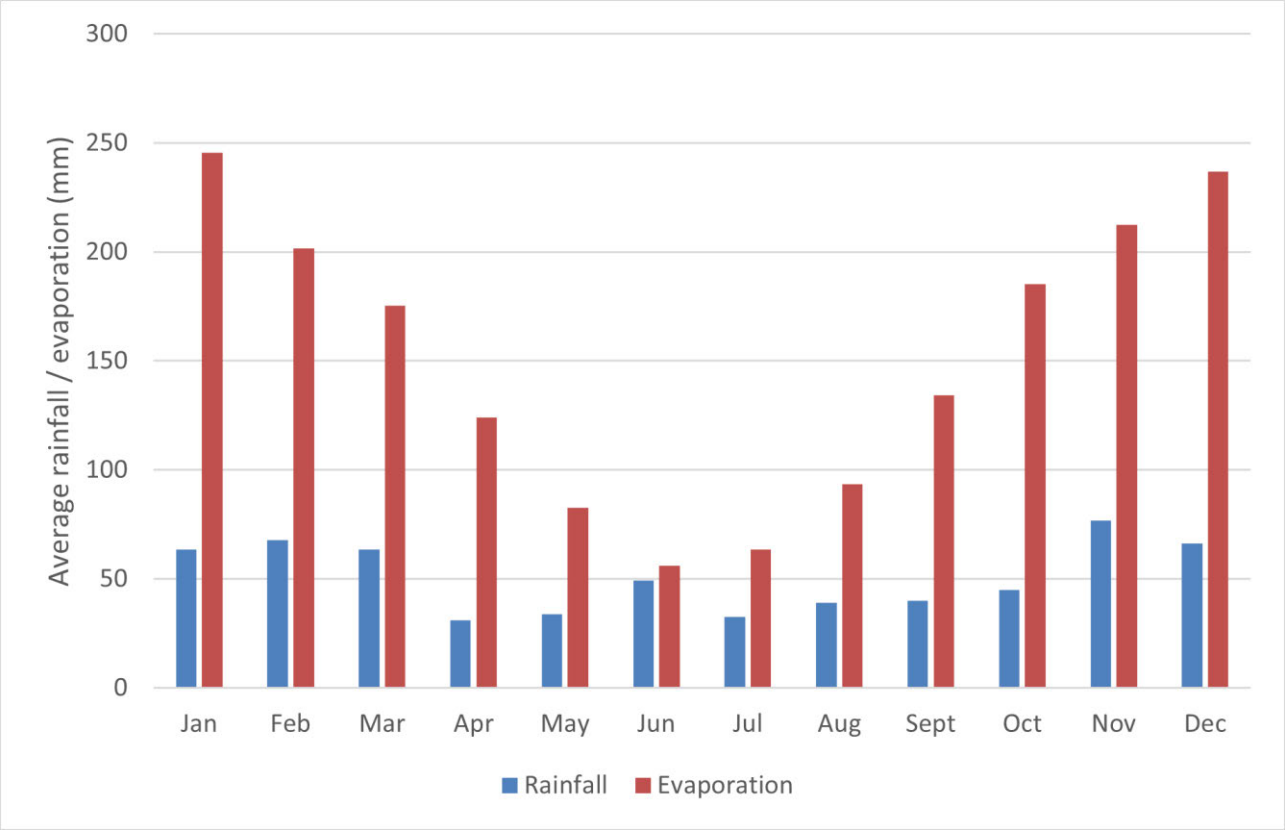
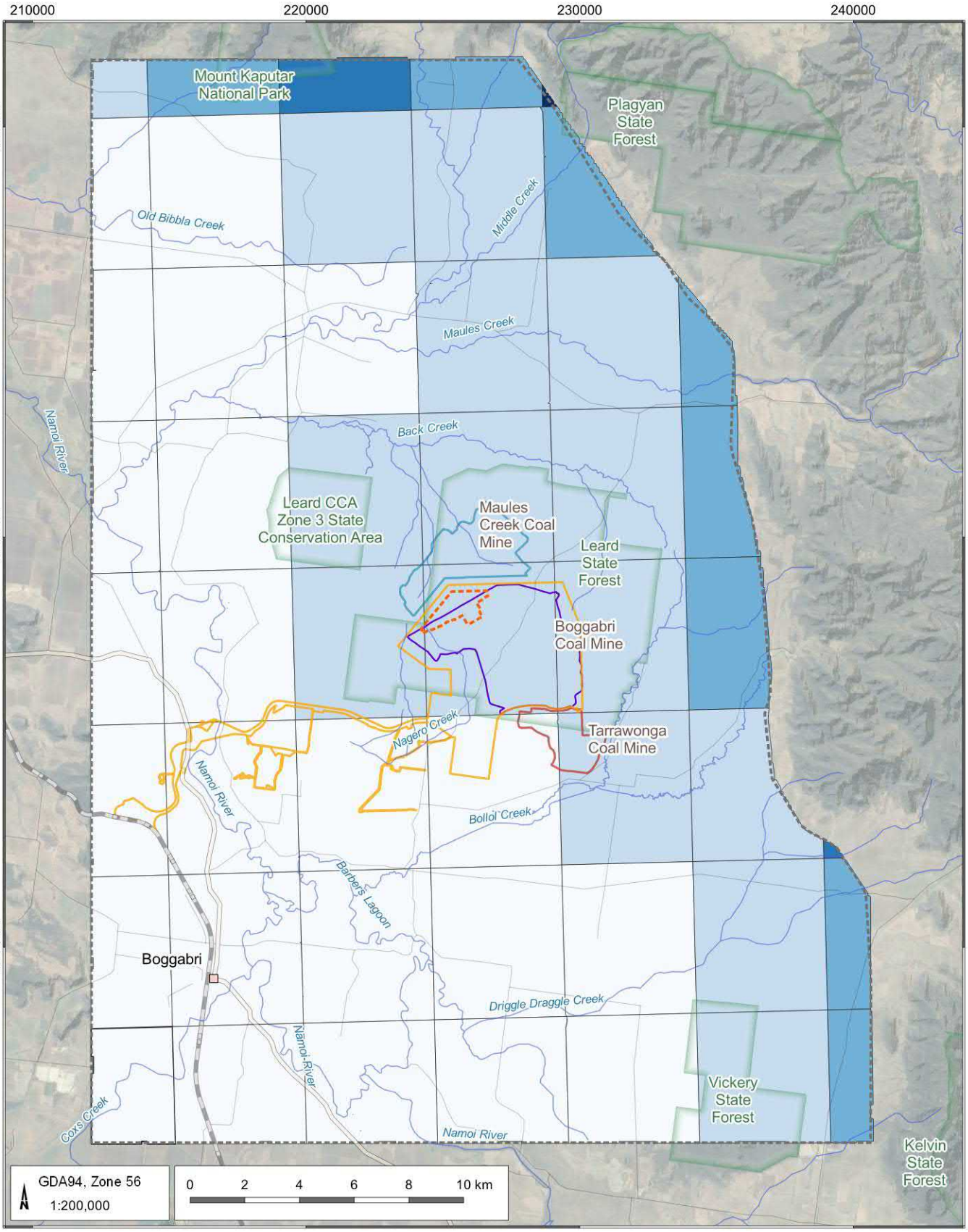



Figure 4.3 Average monthly rainfall and pan evaporation (January 2006 to December 2024)

The topography of the region influences the pattern and magnitude of rainfall and evaporation. Figure 4.4 and Figure 4.5 show the SILO (2024) gridded rainfall and potential evaporation data for the region available for the period 2005-2023. Average rainfall and potential evaporation vary spatially. Higher average rainfall and lower evaporation rates are observed east of the study area, close to the Nandewar Range. In contrast, lower average rainfall and the highest potential evaporation rates are observed in the Namoi floodplain and its tributaries in the west.




LEGEND

- Populated Place
- Principal Road
- Minor Road
- Railway
- Drainage
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent
- BTM Complex Model Extent

**Rain (mm/year)**

- 566-599
- 599-632
- 632-664
- 664-697
- 697-730

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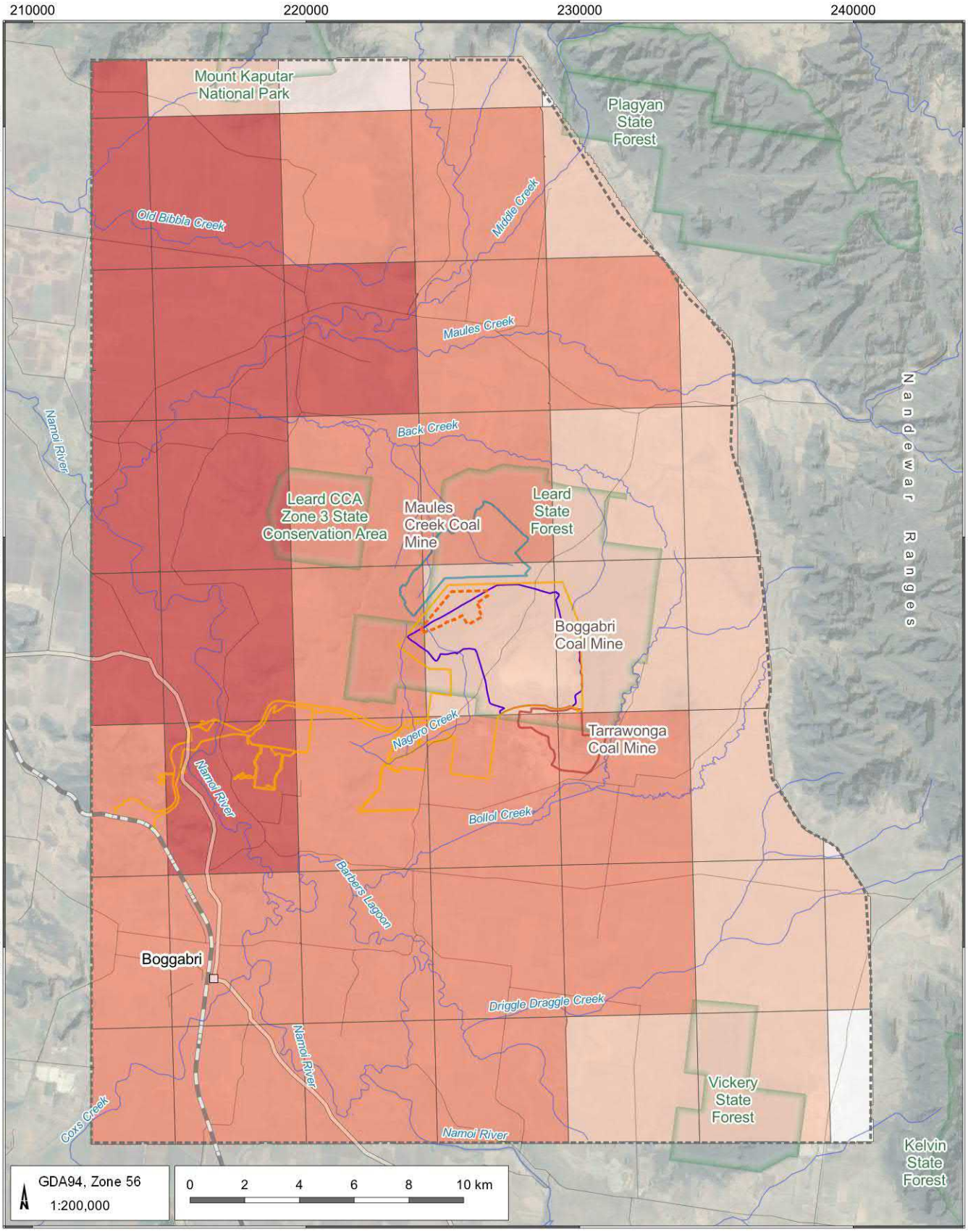
**Average rainfall (source: SILO)**

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FIGURE No: **4.4**

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LEGEND

- Populated Place
- Principal Road
- Minor Road
- Railway

**Drainage**

- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent
- BTM Complex Model Extent
- State Forest

**PET (mm/year)**

- 1700-1741
- 1741-1781
- 1781-1822
- 1822-1862
- 1862-1902

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**Potential evaporation (Source: SILO)**

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FIGURE No: **4.5**

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The cumulative rainfall departure (CRD), also referred to as the residual rainfall mass, was calculated to place recent rainfall years into a historical context. The CRD is calculated by subtracting the long-term average monthly rainfall from the actual monthly rainfall, providing a monthly departure from average conditions that accumulate over time. A rising slope in the CRD plot indicates periods of above-average rainfall, while a falling slope indicates below-average rainfall. A standard technique for assessing groundwater level trends is visually comparing the water level hydrographs with the CRD. The CRD can be used to assess if changes in groundwater levels are correlated with rainfall.

Variations in CRD for the period 2006 to 2024 for latitude and longitude -30.6, 150.15, are shown in Figure 4.6, with historical data to 1950 for long-term reference. Notable trends that occurred after the onset of mining include an eight-year period of below-average rainfall from 2012 to 2020. From 2017 to 2020, NSW experienced a significant drought characterised by above-average temperatures, below-average rainfall, and a rainfall deficit of nearly 800 mm, as indicated by the sharp slope in the CRD curve. From 2020 to 2023, the region experienced higher-than-average rainfall, peaking in late 2023 before declining in 2024.

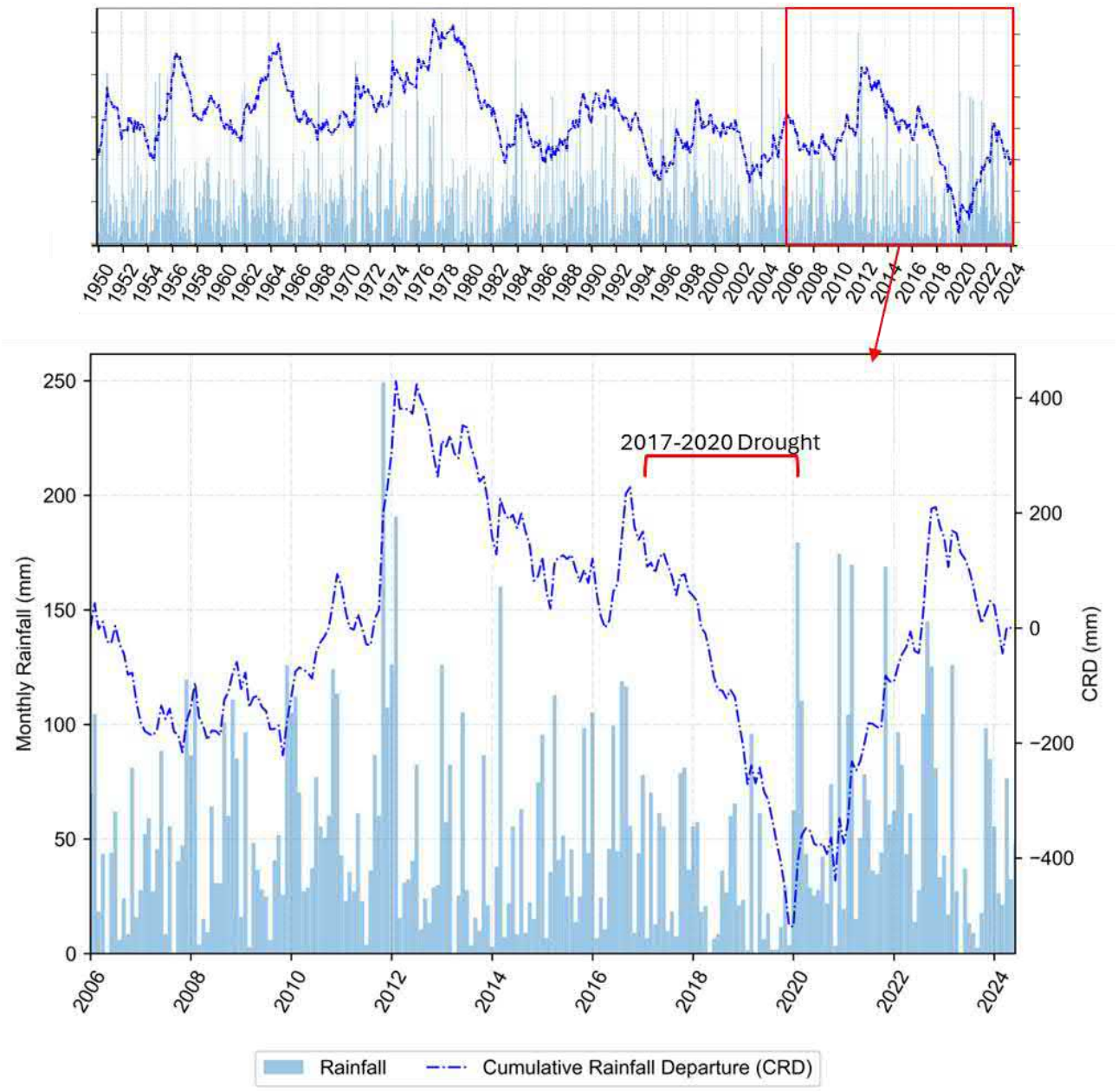



Figure 4.6 Cumulative rainfall departure for location -30.6, 150.15

## 4.4 Land use

### 4.4.1 Approved mining at BTM Complex

BCM is one of three mines that form the BTM Complex, with mining taking place to the north at the adjacent MCCM and to the southeast at TCM (Figure 4.2).

Construction of BCM commenced in 2005, with the first coal being delivered to the ROM coal pad in October 2006. The current method of open cut mining allows coal extraction to occur in the uppermost seams of the Maules Creek Formation, including the Herndale, Onavale, Teston, Thornfield, Braymont, Bollol Creek, Jeralong and Merriown seams. In January 2024, MOD 8 to MP 09_0182 was granted, facilitating coal extraction down to the Templemore coal seam within the approved Mine Disturbance Boundary. Mining is approved to a maximum rate of 8.6 Mtpa of ROM coal until the end of 2036. The mined areas of BCM are being progressively backfilled with waste rock as the working face advances. Rehabilitation has started in waste rock areas that have reached their final post-mining landform.

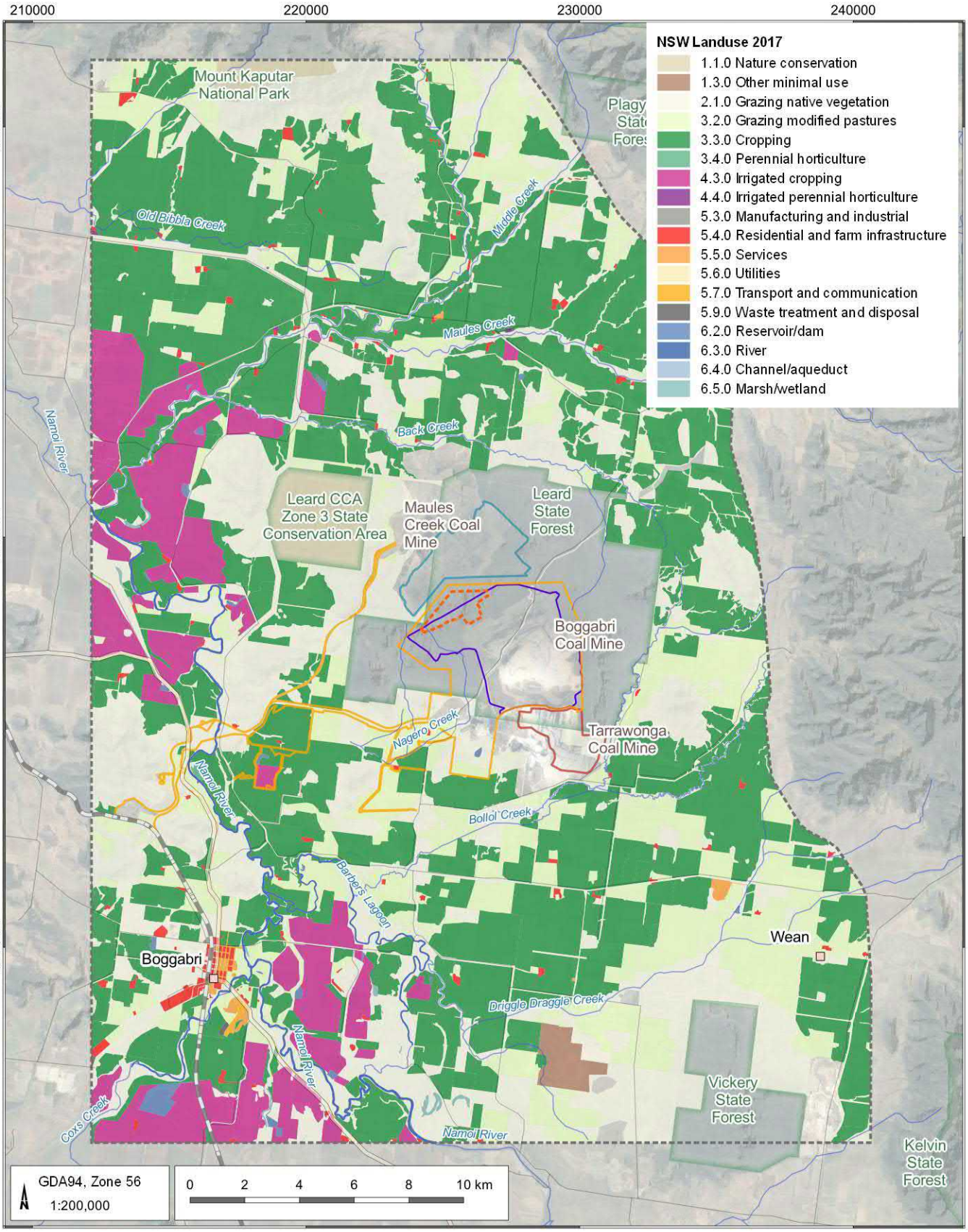
MCCM commenced in 2015 and is approved to extract up to 13 Mtpa until the end of 2034 (MP10_0138). A landform Modification (MOD 7) was approved for MCCM in 2021 without a change to extraction limits or completion dates.

Tarrawonga commenced in 2006 and is approved to extract up to 3.5 Mtpa run-of-mine coal until the end of 2030 (MP11_0047).

Other mining activities within the region include the Goonbri exploration licence (EL 7435) to the east of the Tarrawonga Mine, the Vickery Mine (located approximately 18 km south of BCM), and the Narrabri Mine (located approximately 27 km west-northwest of BCM).

### 4.4.2 Agriculture and forestry

Within the investigation area, forestry occurs in relatively high-elevation areas, with agricultural activities taking place in the alluvial plains and lower ridge areas (Figure 4.7). The Namoi River alluvial floodplain supports an array of agricultural enterprises. Parts of the investigation area are irrigated, using water sourced from the regulated Namoi River or alluvial groundwater.




LEGEND

- Populated Place
- Principal Road
- Minor Road
- Railway
- Drainage
- State Forest
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent
- BTM Complex Model Extent

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## Land use

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FIGURE No: **4.7**

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# 5 Geology

The following sections describe the geology at a regional and local scale, as well as the occurrence of geological structures.

## 5.1 Regional setting and stratigraphy

The BCM is located within the Maules Creek Sub-basin, part of the larger Gunnedah Basin. The Maules Creek Sub-basin is bounded to the west by the north-south trending volcanic Boggabri Ridge and to the east by the Mooki Thrust Fault System (Gunn, 2002). BCM is situated east of the Boggabri Ridge at the western edge of the Maules Creek Sub-basin, where coal seams are close to the surface and are, therefore, suitable for open cut mining. Figure 5.1 shows the stratigraphic sequence within the Gunnedah Basin (left) and the Maules Creek Sub-basin (right) with a summary of the dominant lithologies.

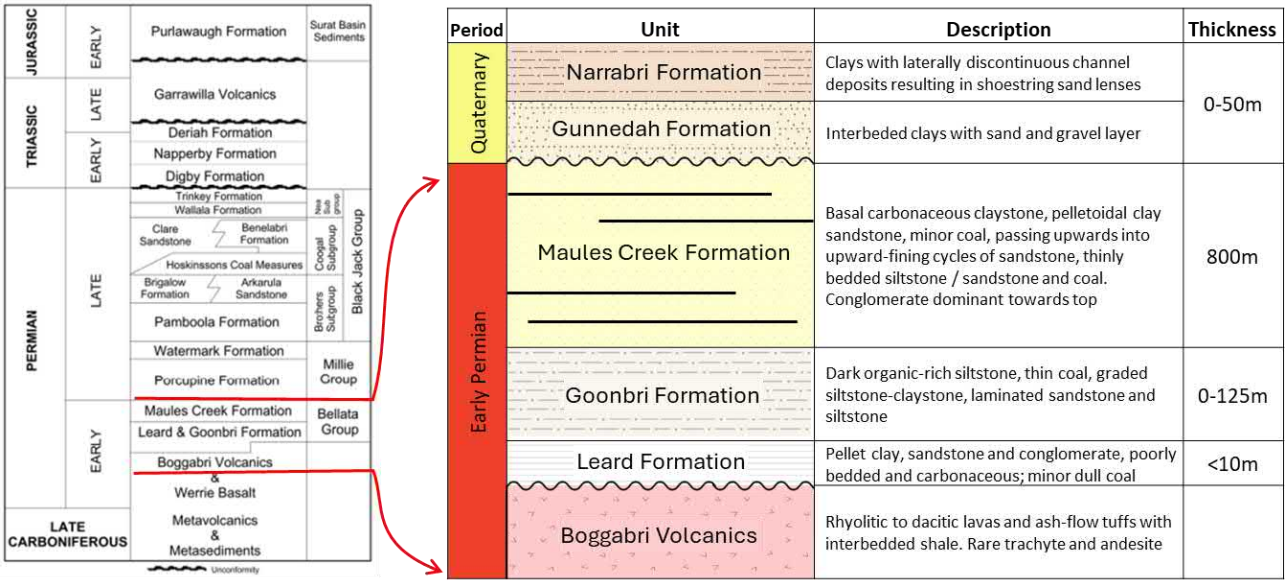
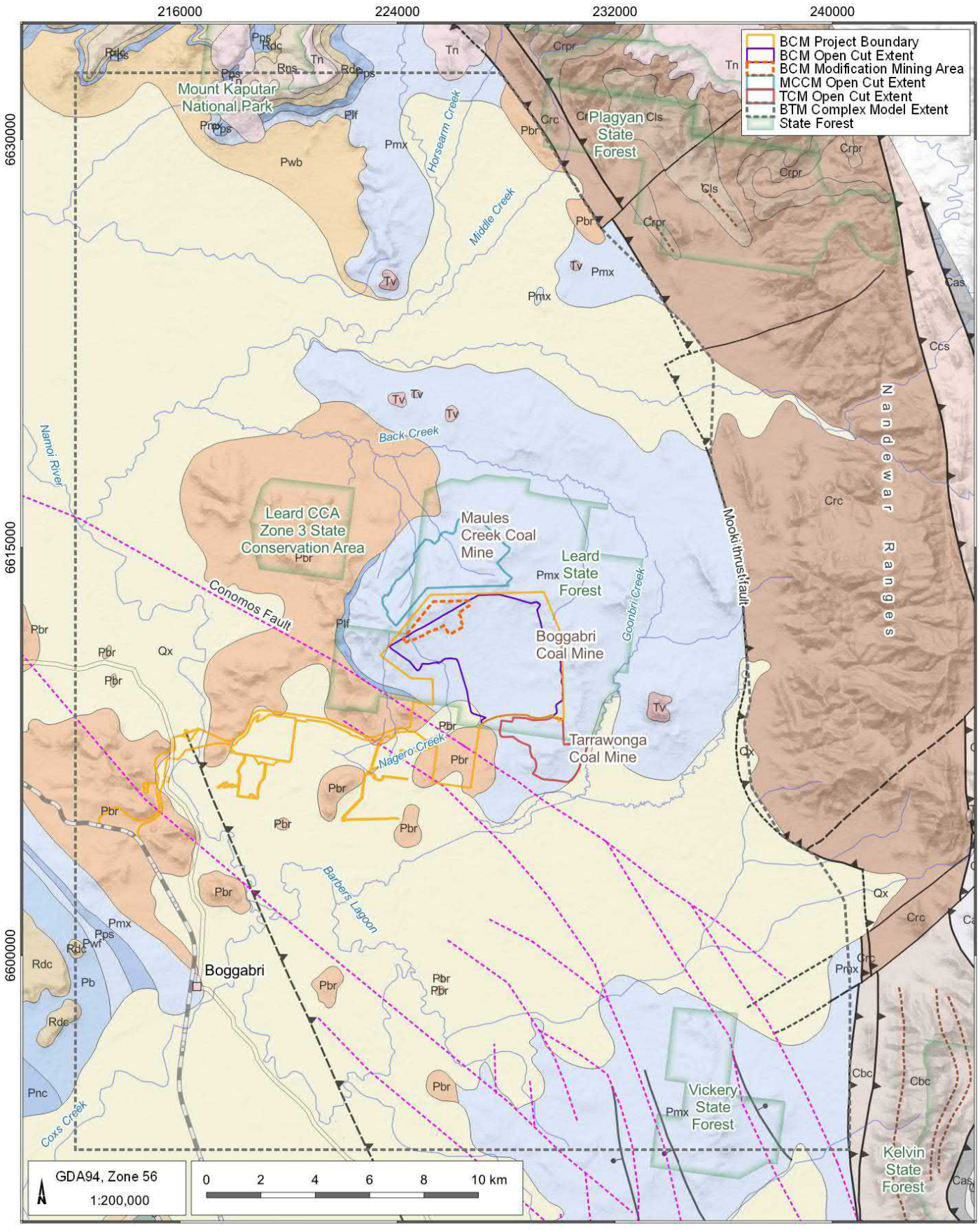



Figure 5.1 Stratigraphic sequence Gunnedah Basin (left) and Maules Creek Sub-basin (right) adapted from Tadros (1993) and Danis and O'Neil (2013)

Figure 5.2 illustrates the surface geology of the area after Pratt (1998) and shows the mining activities west of the Maules Creek sub-basin, where the coal measures onlap against the basal Boggabri volcanics. Alluvial plains are present around Maules Creek, Bollol/Driggle Draggle Creeks, Goonbri Creek, Nagero Creek and the Namoi River and are located north, south, and west of BCM, respectively. Tertiary volcanic and the Leard Formation are not widespread at outcrop within the region.




LEGEND

- Populated Place
- Principal Road
- Railway
- Drainage
- Locally Mapped Faults
- Fault, Accurate
- Fault, Concealed
- Thrust Fault, Accurate
- Thrust Fault, Concealed
- Fold, Accurate

**Gunnedah Coalfield Rock Unit (100K)**

- Qx - Quaternary Sediments
- Tn - Tertiary Nandewar Volcanics
- Tv - Tertiary Volcanics
- Jgi - Glenrowan Intrusives
- Rns - Napperby Formation
- Rdc - Digby Formation
- Pnc - Black Jack Group
- Pb - Pamboola Formation
- Pwf - Watermark Formation
- Pps - Porcupine Formation
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pwb - Werrie Basalt
- Pbr - Boggabri Volcanics
- Cbc - Currabubula Formation
- Cls - Lark Hill Formation
- Crc - Rocky Creek Conglomerate
- Crpr - Plagyan Rhyodacite Tuff Member
- Ccs - Clifden Formation
- Cas - Caroda Formation
- Cabb - Barney Spring Andesite Member

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## Regional geology

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FIGURE No: **5.2**

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## 5.2 Local Geology

### 5.2.1 Quaternary alluvium

Alluvial plains surround the mined Permian outcrop (Figure 5.2) and include the following:

- Maules Creek alluvium to the north of BCM;
- Bollol, Driggle Draggle and Barneys Spring Creek alluvium to the south of BCM;
- Nagero Creek alluvium, which is a relatively minor flood plain with a tongue-like shape situated immediately southwest of BCM; and
- Namoi River alluvium to the west of BCM.

The alluvium is typically divided vertically into two geological units: the Narrabri Formation at the surface and the underlying Gunnedah Formation. This distinction is adopted to characterise differences in alluvial sediments, which are generally upward-fining (Herr, et al., 2018). Gates & Ross (1980) were the first to differentiate between the two alluvial units, noting that:

- the Narrabri Formation forms the surficial cover and comprises extensive overbank clays, with lesser channel sands/gravels deposited by leveed meandering streams; and
- the underlying Gunnedah Formation fills the main paleochannel floors and consists of moderately well-sorted sands/gravel with interbedded clays deposited by braided streams.

Other studies of the Namoi alluvium suggest that this differentiation may be an oversimplification. Acworth et al. (2015) state that: *'detailed examination has failed to detect any evidence of a boundary between Narrabri and Gunnedah formations revealing rather a gradual change in dominance of clays and silts over sands and gravels embedded in a clay-rich matrix.'*

At a regional scale, the alluvium is generally thickest within the main Namoi River alluvial plain (often more than 100 m), thinning towards the edges of the plain and along the tributaries (McNeilage, 2006). A review of the thicknesses of the Narrabri and Gunnedah formations indicates that alluvium is thickest where the Gunnedah Formation is present, suggesting the presence of paleochannels. The Nagero Creek alluvium near the BCM ranges in thickness from less than 20 m to 40 m.

### 5.2.2 Weathering

The total thickness of surficial soils and weathered bedrock varies and depends on factors such as the extent and frequency of fracturing. In the immediate vicinity of BCM, mine geological models show that weathering within the Maules Creek Formation and the Boggabri volcanics extends from 1 m to 30 m below the surface. Sandstones and conglomerates appear most affected by the weathering process, while finer-grained sediments form an effective barrier to weathering. Deeper weathering profiles may develop along fractures and other structural features. Figure 5.3 shows the Permian Maules Creek Formation within the BCM in 2019 and the upper weathering profile.




Figure 5.3 Permian Maules Creek Formation within Boggabri Mine showing upper weathering profile

### 5.2.3 Tertiary volcanics

Tertiary volcanic intrusions are not extensive in the area; however, local outcrops have been mapped, such as Goonbri Mountain to the east of the TCM. Pratt (1998) noted that these undifferentiated volcanics may be outliers of the Nandewar Volcanic Complex, which is approximately 20 km north of the BTM Complex. Dykes are known to be present within all three mines within the BTM Complex and were observed during the May 2019 AGE site inspection. However, despite their presence, dykes within the BTM Complex are a relatively minor component of overall geology. Figure 5.4 shows the TCM in 2019 and a small vertical dyke encountered in the active face, these are also encountered within the pit at BCM.




Figure 5.4 Mine face at TCM in 2019 showing coal seam and white vertical clay dykes

### 5.2.4 Permian Maules Creek Formation

Figure 5.5 shows a stratigraphic column representative of the BTM Complex, including the coal seams within the Maules Creek sub-basin and the coal seams targeted for mining at BCM.

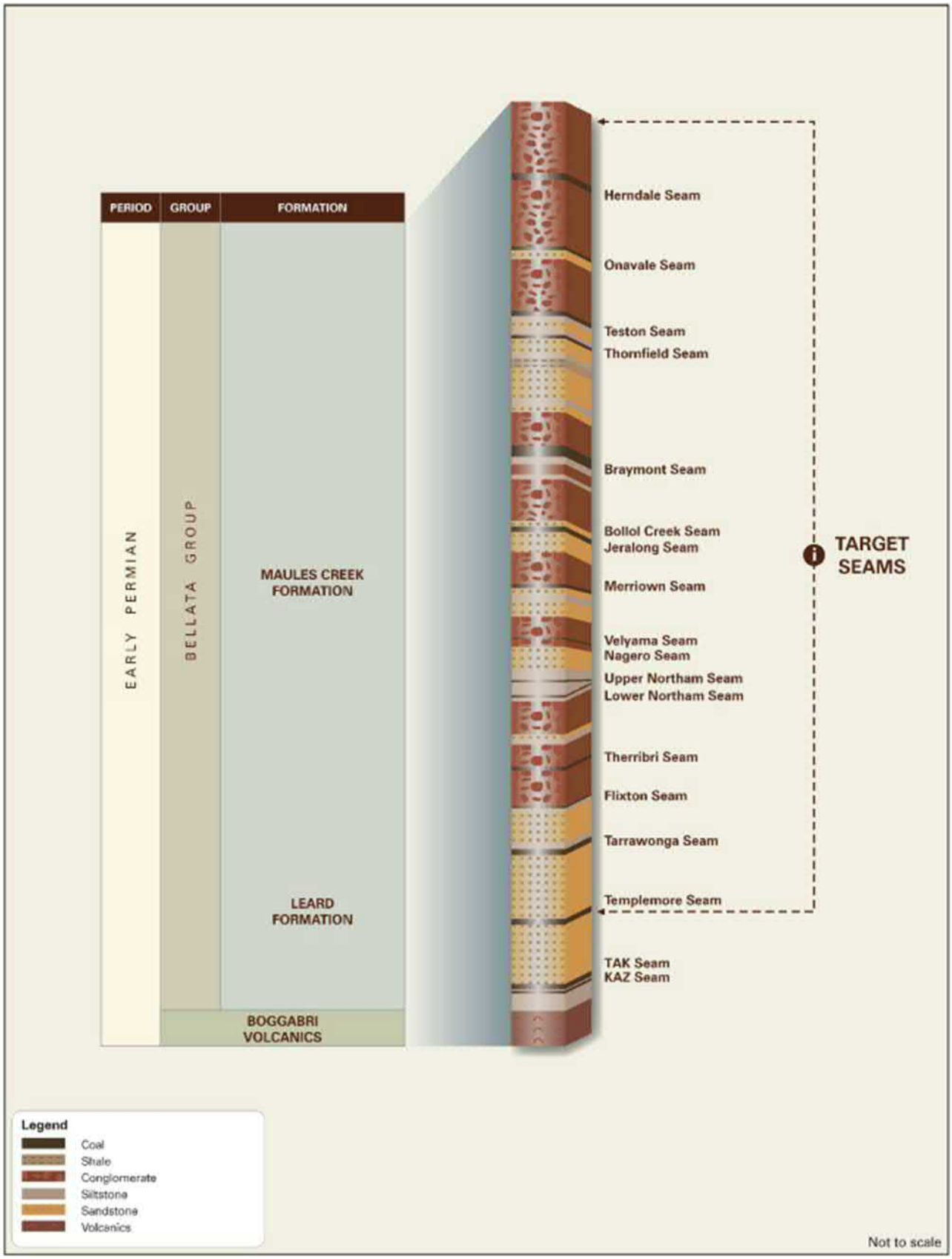



Figure 5.5 Local stratigraphic column (from AGE (2020) and Hansen Bailey (2010))

The Permian Maules Creek Formation is a thick sequence of interbedded coarse-grained conglomerate, sandstone, mudstone and coal. Mining activities are limited to the extraction of high-quality coal seams (Figure 5.5) within the Maules Creek Formation, with the underlying Leard Formation only containing a few minor coal seams of poor quality (Whitehouse, 1993). Relatively thick sequences of interburden separate coal seams and are predominantly comprised of cemented conglomerate (Figure 5.6), with less frequent layers of sandstone and siltstone.

The Maules Creek Formation sediments typically dip between 2° and 5° to the east. The dip is steepest in the west, near the Boggabri volcanics, and becomes gentler toward the east. As the sequence levels out, it also thickens, reaching a maximum thickness of between 745 m and 1,135 m close to the Mooki Thrust Fault System (Cowen Geodata Services, 1995). Coal seams are interpreted to have developed on a weathered paleo-surface of varying topography, with seams in the eastern half of the basin highly split relative to mining areas at the western edge of the Maules Creek Sub-basin.

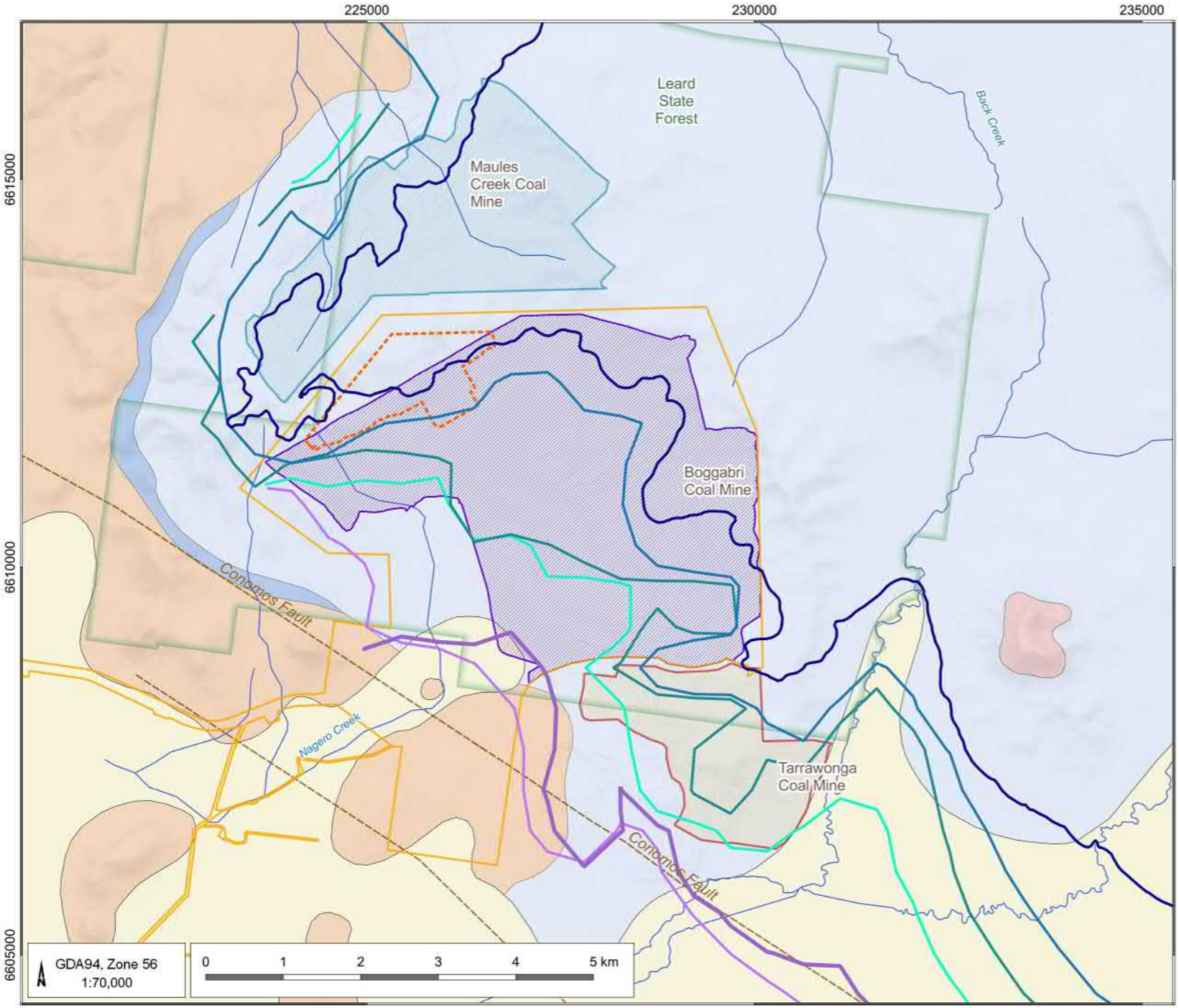
The coal measures at the western edge of the Maules Creek Sub-basin either onlap onto the Boggabri Volcanics or subcrop beneath regolith or alluvium. Figure 5.7 shows the location of modelled coal seam subcrops (JB Mining, 2010). This information is particularly relevant, as coal seams form the primary pathways for groundwater transmission within the Permian sequence. The subcropping areas, therefore, have the potential to create a level of connectivity with the alluvial aquifers where they subcrop under a blanket of alluvial sediments. Figure 5.7 shows that in proximity to BCM, only the Merriown, Velyama and Nagero seams are modelled to subcrop under the tongue of alluvium associated with the Nagero Creek.



Figure 5.6 Photograph of Permian Maules Creek Formation conglomerates - 2019

### 5.2.5 Leard Formation

The Lower Permian Leard Formation is the basal unit in the Gunnedah Basin sequence, resting unconformably on the weathered volcanic basement (Hamilton, Beckett, & Weber, 1989). The formation is typically 12 m to 18 m thick, with a maximum thickness of 32 m, and consists of buff-coloured kaolinised pelletoidal claystone, conglomerate, sandstone, and siltstone, often interbedded with coal (Tadros, The Gunnedah Basin, New South Wales, 1993). Clasts within the strata are generally kaolinite clay pellets less than 25 mm in diameter. Many of the colluvial deposits in the Leard Formation are derived from the weathering of the basal volcanic rocks (Tadros, 1995).




LEGEND

- Drainage
- Locally mapped faults
- State forest
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- TCM Open Cut Extent
- MCCM Open Cut Extent

**Gunnedah Coalfield rock unit (1:100k)**

- Qx - Quaternary Sediments
- Tv - Tertiary Volcanics
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pbr - Boggabri Volcanics

**Subcropping seams**

- Herndale, Onavale, Teston and Thornfield
- Braymont
- Bollol Creek
- Jeralong
- Merriown
- Velyama and Nagero

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## Sub-cropping coal seams

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FIGURE No.
**5.7**

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### 5.2.6 Boggabri volcanics

The silicic Boggabri volcanics form the western boundary of the Maules Creek Sub-basin. They were formed in a small-scale rifting environment during the late Carboniferous/early Permian (Tadros, 1995). The volcanics were then subject to extensive erosion and weathering during the very early Permian, resulting in an irregular paleo-topography onto which the sediments of the Maules Creek Formation were deposited.

The Boggabri volcanics outcrop to the west of the BCM. The eastern flank of the volcanics dips steeply to the east with coal seams stratigraphically lower than the Jeralong seam onlapping onto the volcanics in the vicinity of the BCM. Coal seams lower than Nagero intercalate with the Pelletoidal claystones of the Leard formation, which unconformably overlies the Boggabri volcanics at depth.

## 5.3 Structural Geology

### 5.3.1 Hunter-Mooki thrust fault system

The Gunnedah Basin is bounded to the east by the Hunter-Mooki Thrust Fault, which separates it from the New England Fold Belt. This fault exhibits both compressional and left-lateral strike-slip movement (Glen, 2005) and extends along the eastern boundary of both the Sydney and Gunnedah basins.

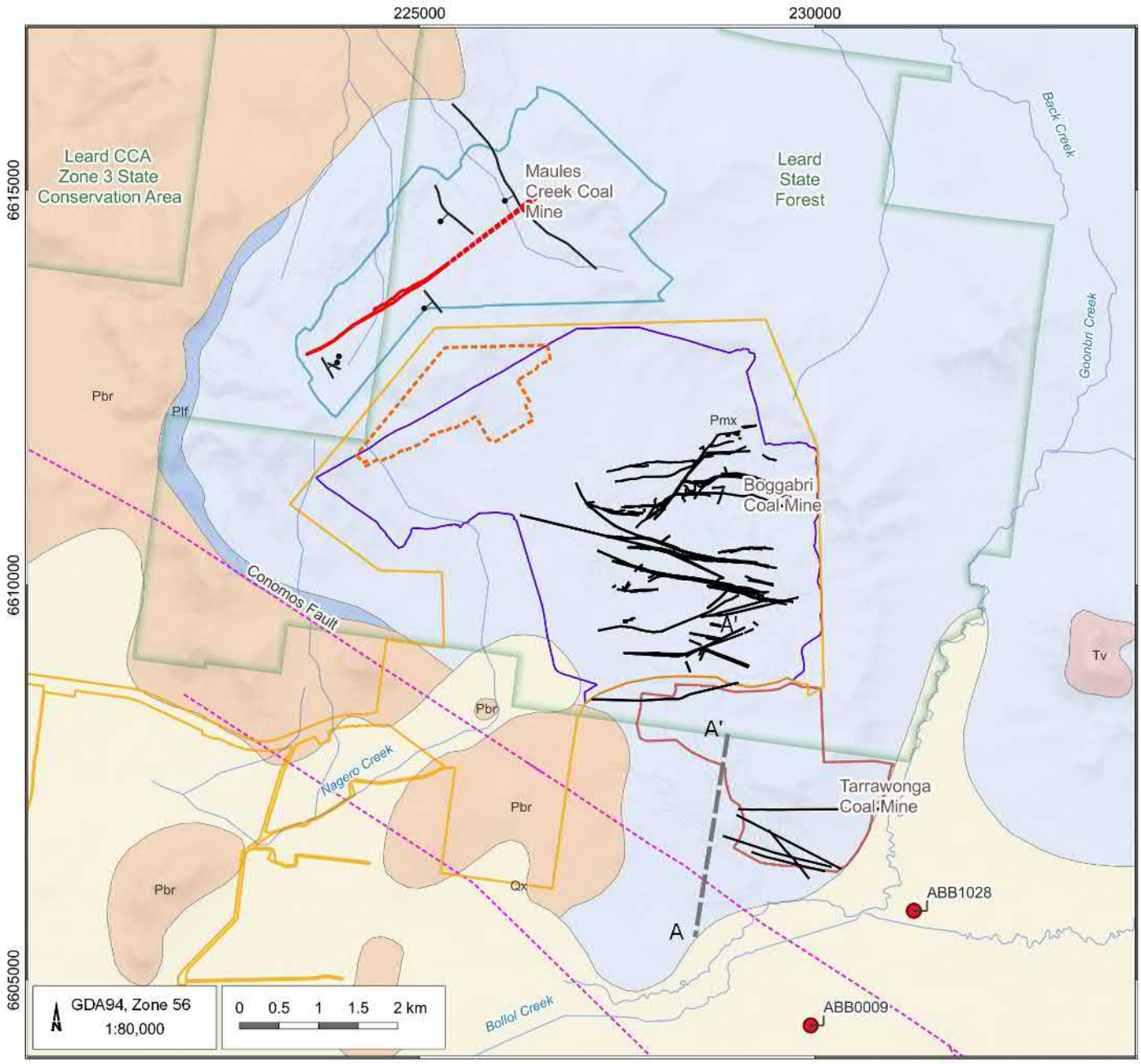
Several additional sub-parallel and perpendicular faults likely related to the Hunter-Mooki Fault System have been mapped south of the TCM between the BTM Complex and VCM. These faults have been tentatively identified with vertical throws ranging from 20 m to 50 m (AGE, 2014). This observation is supported by Whitehouse (1993), who noted that *'… faulting, both subparallel and perpendicular to the Hunter-Mooki Fault system, has displaced a block in the southeast, with respect to the remainder of the area. Several of the other blocks have been displaced some 40 m to 50 m, by prominent faults.'*

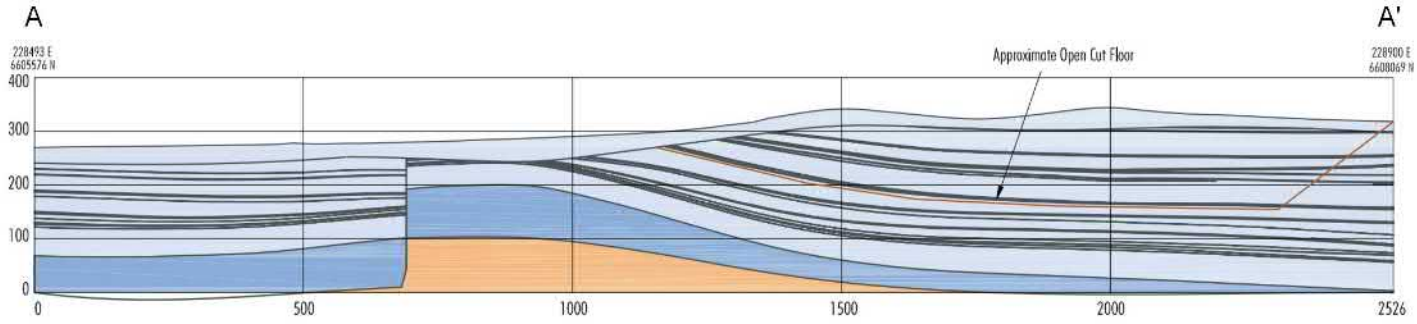
### 5.3.2 Conomos Fault

The Conomos Fault strikes NW-SE (~300 degrees) with a reported displacement ranging from 60 m to 100 m (Figure 5.8), with the north block up (JB Mining, 2019). A previous version of the TCM geological model, which extends beyond the inferred location of the Conomos Fault, confirms its presence. However, the Conomos Fault was not included in the regional JB Mining (2010) geological model, which served as the basis for previous groundwater models (AGE, 2014; AGE, 2018). The Conomos fault was included in the most recent modelling (AGE 2022) as a combined conduit barrier and in the impact assessment for MOD 10.

### 5.3.3 Locally mapped faults

Several faults have been mapped within the BCM open cut extent (Figure 5.8) faults range in strike from 067 to 078 degrees, with estimated vertical throws generally ranging from 0.1 m to 1.5 m and up to 2 m. Highly altered dykes cross cutting coal seams have also been observed within the open cut pits at TCM and BCM (Figure 5.4).




Source: Tarrawonga Coal Pty Ltd (2011)

LEGEND

- ABB Series Bores
- Drainage
- Locally Mapped Regional Faults
- MCCM Local Faults
- TCM and BCM Locally Mapped Faults
- Dike
- Dike Inferred
- Conomos Fault Cross Section
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

**Gunnedah Coalfield Rock Unit (100k)**

- Qx - Quaternary Sediments
- Tv - Tertiary Volcanics
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pbr - Boggabri Volcanics

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## Geological structures

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FIGURE No: **5.8**

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# 6 Groundwater monitoring network

Groundwater levels and quality are monitored at BCM via a network of standpipe monitoring bores and vibrating wire piezometers (VWP). A regional network (the 'REG' series bores) is also installed further from the mining areas and is designed to detect any cumulative impacts from the BTM Complex. The sections below summarise the various campaigns previously undertaken to install the monitoring bores. Further details on the discussed monitoring bore network can be found in the BCM groundwater management plan (Idemitsu, 2024) lodged on 28 February 2025, and the BTM Complex water management strategy (Resource Strategies, 2019). Active and planned groundwater monitoring locations specific to BCM are listed in Table 6.1, planned network expansion is illustrated in Figure 6.1 and the complete BTM monitoring network is illustrated in Figure 6.2 and Figure 6.3.

The BTM Complex monitoring network comprises bores installed in alluvium, the Maules Creek Formation (including coal seams and interburden), and the Boggabri volcanics Figure 6.3. Monitoring in the region commenced in the 1970s with the installation of the 'GW' bores in the Namoi alluvium by WaterNSW. Coal and interburden monitoring commenced in 2006 with the start of the BCM and TCM. Monitoring at BCM focuses on the primary quantities of interest (QoIs), including monitoring drawdown and water quality in the Nagero Creek, Bollol Creek, and Goonbri Creek alluvial systems, as well as the propagation of drawdown to the east towards the Namoi alluvium.

Table 6.1 BCM monitoring network

| Bore ID | Type | Easting MGA94 (m) | Northing MGA94 (m) | Install depth (m bgl) | Formation | Incl. in GWMP 2024 | Sampling frequency |
|---|---|---|---|---|---|---|---|
| **Bore field bores** | | | | | | | |
| Belleview 3 MB | Standpipe | 218887 | 6607064 | 23-30 | Alluvium | Yes | Water levels – daily<br>Field parameters - Quarterly<br>Water quality - Biannually |
| Cooboobindi PB | Production Bore | 217917 | 6606240 | 18-31<br>34-45<br>48-64<br>66-76<br>78-89 | Alluvium | Yes | Water volumes – Daily during abstraction<br>Field parameters - Quarterly<br>Water quality - Biannually |
| Cooboobindi MB | Standpipe | 217939 | 6606232 | 23-89 | Alluvium | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| Victoria Park PB | Production Bore | 221961 | 6605011 | 34-37<br>50-57 | Alluvium | Yes | Water volumes – Daily during abstraction<br>Field parameters - Quarterly<br>Water quality - Biannually |
| Victoria Park MB | Standpipe | 221966 | 6604988 | 34-37<br>50-57 | Alluvium | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| **Mining area bores** | | | | | | | |
| GW3115 | Standpipe | 225174 | 6608903 | 42 | Boggabri volcanics | - | Field parameters - Quarterly<br>Water quality - Biannually |
| IBC2110 | Standpipe | 225939 | 6607684 | 91-97 | Boggabri volcanics | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| IBC2111 | Standpipe | 225949 | 6607683 | 36-42 | Boggabri volcanics | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| IBC2181 | Standpipe | 226848 | 6612477 | 108 | Merriown coal seam | - | Water levels - Daily |
| MB5_V1 | VWP | 233060 | 6613116 | 202 | Merriown coal seam | - | Water levels - Daily |

| Bore ID | Type | Easting MGA94 (m) | Northing MGA94 (m) | Install depth (m bgl) | Formation | Incl. in GWMP 2024 | Sampling frequency |
|---|---|---|---|---|---|---|---|
| MB5_V2 | VWP | 233060 | 6613116 | 192 | Permian Sediments | - | Water levels - Daily |
| MB5_V3 | VWP | 233060 | 6613116 | 188 | Merriown coal seam | - | Water levels - Daily |
| MB5_V4 | VWP | 233060 | 6613116 | 166 | Permian Sediments | - | Water levels - Daily |
| MB9_V1 | VWP | 231468 | 6608167 | 82 | Merriown coal seam | - | Water levels - Daily |
| MB9_V2 | VWP | 231468 | 6608167 | 74 | Permian Sediments | - | Water levels - Daily |
| MB9_V3 | VWP | 231468 | 6608167 | 65 | Merriown coal seam | - | Water levels - Daily |
| MB9_V4 | VWP | 231468 | 6608167 | 53 | Permian Sediments | - | Water levels - Daily |
| MW6 | Standpipe | 225466 | 6608059 | 18-22 | Alluvium | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| MWP01 | Seepage Monitoring | 226237 | 6606226 | - | Shallow subsurface | No | Field parameters - Quarterly<br>Water quality - Biannually |
| MWP02 | Seepage Monitoring | 226602 | 6606615 | - | Shallow subsurface | No | Field parameters - Quarterly<br>Water quality - Biannually |
| MWP03 | Seepage Monitoring | 226187 | 6606954 | - | Shallow subsurface | No | Field parameters - Quarterly<br>Water quality - Biannually |
| MWP04 | Seepage Monitoring | 226287 | 6606893 | - | Shallow subsurface | No | Field parameters - Quarterly<br>Water quality - Biannually |
| MWP05 | Seepage Monitoring | 226467 | 6607187 | - | Shallow subsurface | No | Field parameters - Quarterly<br>Water quality - Biannually |
| MWP06 | Seepage Monitoring | 225986 | 6607202 | - | Shallow subsurface | No | Field parameters - Quarterly<br>Water quality - Biannually |
| MWP07 | Seepage Monitoring | 226348 | 6607382 | - | Shallow subsurface | No | Field parameters - Quarterly<br>Water quality - Biannually |

| Bore ID | Type | Easting MGA94 (m) | Northing MGA94 (m) | Install depth (m bgl) | Formation | Incl. in GWMP 2024 | Sampling frequency |
|---|---|---|---|---|---|---|---|
| **Planned or recently installed bores (BEP series)** | | | | | | | |
| BEP_01a | Standpipe | 225422 | 6608111 | 27 | Lower Nagero Creek alluvium | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| BEP_01b | Standpipe | 225422 | 6608111 | 14 | Upper Nagero Creek alluvium | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| BEP_02 | Standpipe | 225951 | 6608659 | 17 | Upper Nagero Creek alluvium | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| BEP_03 | Standpipe | 224742 | 6607720 | 15 | Nagero Creek alluvium | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| BEP_04a | Standpipe | 226994 | 6613000 | 311 | Templemore | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| BEP_04b | Standpipe | 226994 | 6613000 | 222 | Nagero coal seam | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| BEP_04c | Standpipe | 226994 | 6613000 | 169 | Merriown coal seam | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| BEP_05-V1 | VWP | 229203 | 6613002 | 233 | Merriown coal seam | Yes | Water levels - Daily |
| BEP_05-V2 | VWP | 229203 | 6613002 | 291 | Nagero coal seam | Yes | Water levels - Daily |
| BEP_05-V3 | VWP | 229203 | 6613002 | 404 | Tarrawonga coal seam | Yes | Water levels - Daily |
| BEP_05-V4 | VWP | 229203 | 6613002 | 434 | Templemore coal seam | Yes | Water levels - Daily |
| BEP_06-V1 | VWP | 225422 | 6608111 | 30 | Boggabri volcanics Upper | Yes | Water levels - Daily |
| BEP_06-V2 | VWP | 225422 | 6608111 | 60 | Boggabri volcanics Mid | Yes | Water levels - Daily |
| BEP_06-V3 | VWP | 225422 | 6608111 | 88 | Boggabri volcanics Lower | Yes | Water levels - Daily |
| BEP_07-V1*[1] | VWP | 233538 | 6611833 | 116 | Braymont coal seam | Yes | Water levels - Daily |

| Bore ID | Type | Easting MGA94 (m) | Northing MGA94 (m) | Install depth (m bgl) | Formation | Incl. in GWMP 2024 | Sampling frequency |
|---|---|---|---|---|---|---|---|
| BEP_07-V2*[1] | VWP | 233538 | 6611833 | 220 | Nagero coal seam | Yes | Water levels - Daily |
| BEP_07-V3*[1] | VWP | 233538 | 6611833 | 326 | Tarrawonga coal seam | Yes | Water levels - Daily |
| BEP_07-V4*[1] | VWP | 233538 | 6611833 | 407 | Templemore coal seam | Yes | Water levels - Daily |
| BEP_08*[1] | Standpipe | 236973 | 6611809 | 100 | Eastern side of Hunter-Mooki Fault | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| BEP_09-V1*[1] | VWP | 225951 | 6608658 | 100 | Boggabri volcanics Upper | Yes | Water levels - Daily |
| BEP_09-V1*[1] | VWP | 225951 | 6608658 | 120 | Boggabri volcanics Mid | Yes | Water levels - Daily |
| BEP_09-V1*[1] | VWP | 225951 | 6608658 | 140 | Boggabri volcanics Lower | Yes | Water levels - Daily |
| BEP_10-V1*[1] | VWP | 227344 | 6608717 | 110 | Therribri coal seam | Yes | Water levels - Daily |
| BEP_10-V2*[1] | VWP | 227344 | 6608717 | 140 | Templemore coal seam | Yes | Water levels - Daily |
| BEP_10-V3*[1] | VWP | 227344 | 6608717 | 160 | Boggabri volcanics | Yes | Water levels - Daily |
| BEP_11 | Standpipe | 224551 | 6603416 | 11 | Upper Bollol Creek alluvium | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| BEP_12*[1] | Standpipe | 234275 | 6610614 | 116 | Braymont coal seam | Yes | Field parameters - Quarterly<br>Water quality - Biannually |
| **Cumulative (Regional) monitoring bores** | | | | | | | |
| REG01_V1 | VWP | 226945 | 6622396 | 119 | Jeralong coal seam | Yes | Continuous |
| REG01_V2 | VWP | 226945 | 6622396 | 135 | Merriown coal seam | Yes | Continuous |
| REG01_V3 | VWP | 226945 | 6622396 | 194 | Nagero coal seam | Yes | Continuous |
| REG01_V4 | VWP | 226945 | 6622396 | 282 | Therribri coal seam | Yes | Continuous |
| REG02_V1 | VWP | 232722 | 6620459 | 60 | Coal seam | Yes | Continuous |

| Bore ID | Type | Easting MGA94 (m) | Northing MGA94 (m) | Install depth (m bgl) | Formation | Incl. in GWMP 2024 | Sampling frequency |
|---|---|---|---|---|---|---|---|
| REG02_V2 | VWP | 232722 | 6620459 | 120 | Coal seam | Yes | Continuous |
| REG02_V3 | VWP | 232722 | 6620459 | 200 | Coal seam | Yes | Continuous |
| REG02_V4 | VWP | 232722 | 6620459 | 260 | Coal seam | Yes | Continuous |
| REG03 | Standpipe | 217164 | 6619558 | 54 | Boggabri volcanics | - | Quarterly for baseline, then biannually |
| REG04 | Standpipe | 219322 | 6612763 | 69 | Boggabri volcanics | - | Quarterly for baseline, then biannually |
| REG05A | Standpipe | 220646 | 6609514 | 20 | Alluvium | - | Quarterly for baseline, then biannually |
| REG06 | Standpipe | 223100 | 6606534 | 91 | Boggabri volcanics | - | Quarterly for baseline, then biannually |
| REG07_V1 | VWP | 233543 | 6605348 | 68 | Braymont coal seam | Yes | Continuous |
| REG07_V2 | VWP | 233543 | 6605348 | 148 | Merriown coal seam | Yes | Continuous |
| REG07_V3 | VWP | 233543 | 6605348 | 243 | Nagero coal seam | Yes | Continuous |
| REG07A | Standpipe | 23354 | 6605359 | 27 | Alluvium | Yes | Quarterly for baseline, then biannually |
| REG08_V1 | VWP | 230030 | 6615113 | 92 | Braymont coal seam | - | Continuous |
| REG08_V2 | VWP | 230030 | 6615113 | 221 | Merriown coal seam | - | Continuous |
| REG08_V3 | VWP | 230030 | 6615113 | 274 | Nagero coal seam | - | Continuous |
| REG09_V1 | VWP | 234232 | 6610591 | 116 | Braymont coal seam | - | Continuous |
| REG09_V2 | VWP | 234232 | 6610591 | 175 | Merriown coal seam | - | Continuous |
| REG09_V3 | VWP | 234232 | 6610591 | 268 | Nagero coal seam | - | Continuous |
| REG10_V1 | VWP | 226722 | 6618261 | 55 | Braymont coal seam | - | Continuous |
| REG10_V2 | VWP | 226722 | 6618261 | 144 | Merriown coal seam | - | Continuous |

| Bore ID | Type | Easting MGA94 (m) | Northing MGA94 (m) | Install depth (m bgl) | Formation | Incl. in GWMP 2024 | Sampling frequency |
|---|---|---|---|---|---|---|---|
| REG10_V3 | VWP | 226722 | 6618261 | 178 | Nagero coal seam | - | Continuous |
| REG10_V4 | VWP | 226722 | 6618261 | 186 | Upper Northam coal seam | - | Continuous |
| REG10A | Standpipe | 226717 | 6618260 | 8 | Alluvium | - | Quarterly for baseline, then biannually |
| REG12 | Standpipe | 222632 | 6617358 | 41 | Boggabri volcanics | - | Quarterly for baseline, then biannually |
| REG13 | Standpipe | 219713 | 6611129 | 130 | Boggabri volcanics | - | Quarterly for baseline, then biannually |
| REG14 | Standpipe | 225547 | 6602649 | 93 | Boggabri volcanics | - | Quarterly for baseline, then biannually |
| **Private or government bores** | | | | | | | |
| GW002523 | Standpipe | 233735 | 6606529 | 38 | Unknown | Yes | Field parameters - Biannually |

**Notes:** Field parameters: Water level, pH, electrical conductivity (EC), temperature.
Water quality: major ions, dissolved metals, nutrients and alkalinity.

* Planned, not installed at time of writing.

* [1] Bores proposed not yet approved.

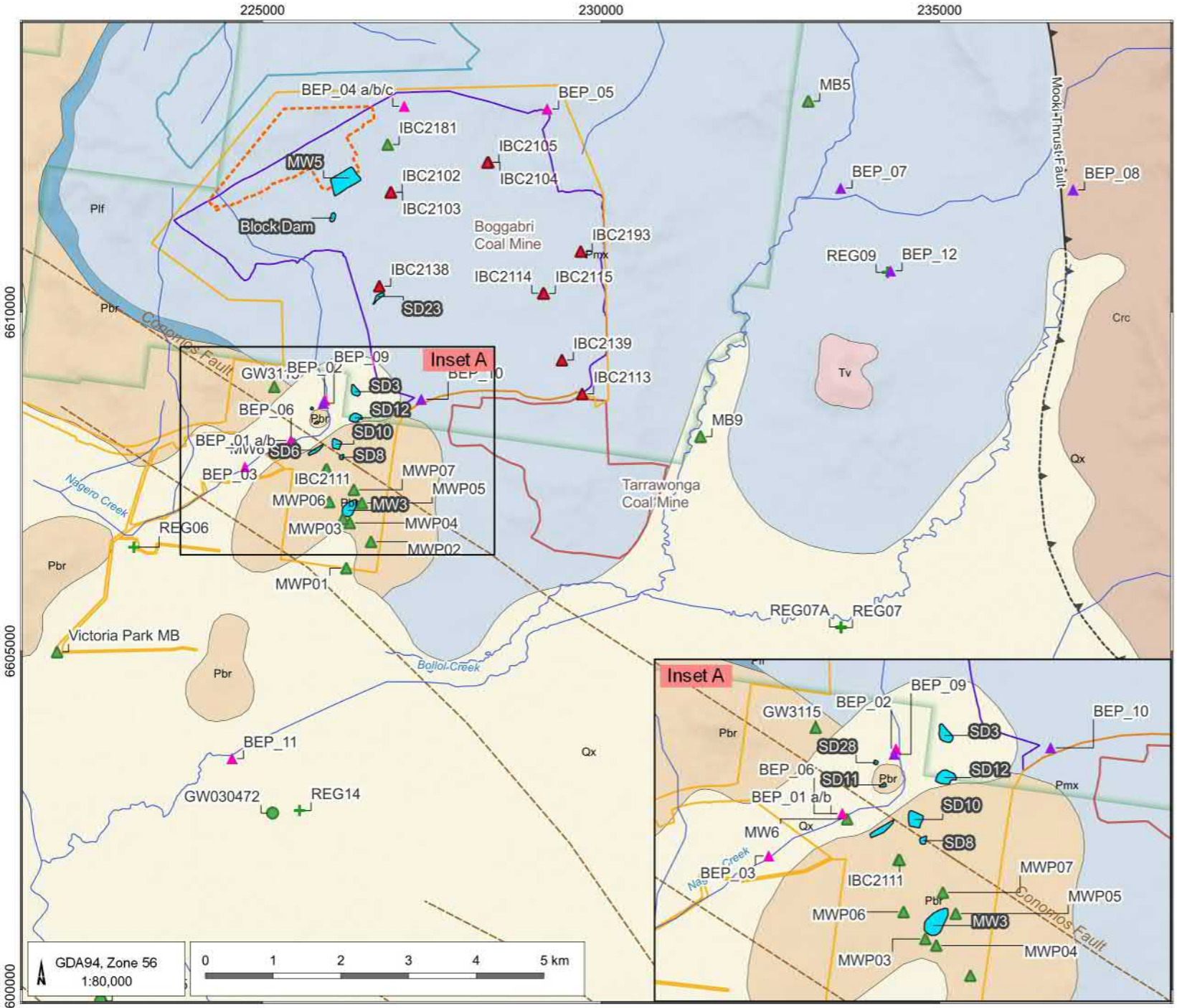
## 6.1 'BEP' series

A program for installing additional groundwater monitoring bores commenced in 2024 and is expected to continue into 2025. The purpose of these bores is to meet MOD 8 commitments and to expand the existing groundwater monitoring network. Bores committed to be drilled as part of the MOD 8 commitments have been drilled and installed. Additional bores to expand the existing monitoring network, including those recommended by AGE (2019), are proposed and are awaiting final review. Bores installed in 2024 and early 2025 include BEP_01a, BEP_01b, BEP_02, BEP_03, BEP_04a, b and c, BEP_05, BEP_06 and BEP_11. Construction details for installed bores are included in Appendix C. Planned locations, depths and formations are listed in Table 6.1 and illustrated in Figure 6.1. The rationale for each planned installation is included in Table 6.2.

Table 6.2 Rational for planned BEP series monitoring bores

| Bore IDs | Status* | Commitment / recommendation | Rationale/comment | Type of monitoring and geology |
|---|---|---|---|---|
| BEP_01a<br>BEP_01b | Installed | MOD8 EPBC 2021/8875 | Monitoring in the Nagero Creek alluvium, which is consistent with MOD 8 commitments. Bores adjacent to mapped Poplar Box Woodland. | 2 x SPs in alluvium |
| BEP_02 | Installed | MOD8 EPBC 2021/8875 | Monitoring in the Nagero Creek alluvium, which is consistent with MOD 8 commitments. | 1 x SP in alluvium |
| BEP_03 | Installed | MOD8 EPBC 2021/8875 | Monitoring in the downstream Nagero Creek alluvium, which is consistent with MOD 8 commitments. | 1 x SP in alluvium |
| BEP_04a<br>BEP_04b<br>BEP_04c | Installed | MOD8 EPBC 2021/8875 | Partially replaces mined-out 'IBC' series of bores. Allows for the collection of groundwater level and quality data in the deeper seams targeted by MOD 8 and the Extension Project. | 3 x SPs in Templemore, Nagero, and Merriown seams |
| BEP_05 | Installed | MOD8 EPBC 2021/8875 | BCM-specific monitoring of groundwater levels in the deeper seams targeted by the MOD 8 Amendment. Records of the expected coal seam depressurisation as mining progresses will improve the calibration of future updates to the numerical groundwater model. | VWP – 4 x sensors in Templemore, Tarrawonga, Nagero, and Merriown seams |
| BEP_06 | Installed | AGE recommendations | Assessment of potential impacts propagating to the west through the volcanics. Consistent with AGE (2019) recommendations. | VWP – 3 x sensors in Boggabri volcanics |
| BEP_07 | Proposed | AGE recommendations | Long-term monitoring in deep to shallow Permian coal seams. Assessment of impact propagation towards Goonbri Creek and Bollol Creek. Consistent with AGE (2019) recommendations. | VWP – 4 x sensors in Templemore, Nagero, and Merriown, and Braymont seams |
| BEP_08 | Proposed | In line with IESC guidance | Assessment of lithology and water pressures east of the mapped Mooki thrust fault. Appreciation of fault behaviour in line with IESC guidance. Consistent with AGE (2019) recommendations. | 1 x SP on the eastern side of Mooki Thrust Fault |
| BEP_09 | Proposed | In line with IESC guidance | In line with IESC guidance, this assesses the Conomos Fault role in the hydrogeological regime. Relative to AGE (2019), the position has been adjusted so that the monitoring point is now located on the road corridor and closer to the Conomos fault (500 m). | VWP – 3 x sensors in Boggabri volcanics |
| BEP_10 | Proposed | AGE recommendations | Monitoring connectivity between the coal seams and the volcanics. | VWP – 3 x sensors in Therribri, Templemore, and Boggabri volcanics |
| BEP_11 | Installed | AGE recommendations | Monitoring groundwater levels and quality in the downstream portion of Bollol Creek, where cumulative impacts are predicted and where there is evidence that the water table may be close to the surface. | 1 x SP in alluvium |
| BEP_12 | Proposed | NRAR request | Coal seam monitoring bore to verify existing VWP data as per NRAR requests. | 1 x SP in Braymont seam |

**Note:** * Status as of 01/05/2025.




LEGEND

- Drainage
- Local Mapped Faults
- Thrust Fault, Accurate
- Thrust Fault, Concealed
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent
- State Forest
- Surface water storage

**Monitoring Bores**

- BCM - Active
- BCM - Destroyed
- Cumulative - Active
- Planned
- Installed 2024/2025

**Gummedah Coalfiel rock unit (1:100K)**

- Qx - Quaternary Sediments
- Tv - Tertiary Volcanics
- Crc - Rocky Creek Conglomerate
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pbr - Boggabri Volcanics

Groundwater Impact Assessment
Boggabri Coal Mine Modification 10
(BCO5002.001)

**BCM monitroing network and planned expansion**

DATE
22/05/2025

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FIGURE No.
**6.1**

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## 6.2 'IBC' and ‘MB’ series

Prior to the commencement of BCM, Parsons Brinkerhoff (2008) conducted a baseline groundwater assessment that included the installation of monitoring bores, permeability testing, and groundwater modelling for the first six years of the mine's life. This project included installing the ‘IBC’ series of bores around the BCM mining area, which comprised thirteen bores targeting coal seams between the Braymont and Merriown seams and the volcanic basement. Many of these bores were located within the approved footprint and have been destroyed as mining operations have progressed. Three active bores remain, including IBC2110, IBC2111, and IBC2181.

BCOPL installed three additional ‘MB’ monitoring sites in late 2018 as part of the groundwater management plan commitments. These sites comprised two VWPs (MB5 and MB9) installed into the interburden/Merriown seam, and a single adjacent monitoring bore (MB9A) installed into the alluvium (Figure 6.1).

## 6.3 'REG' series

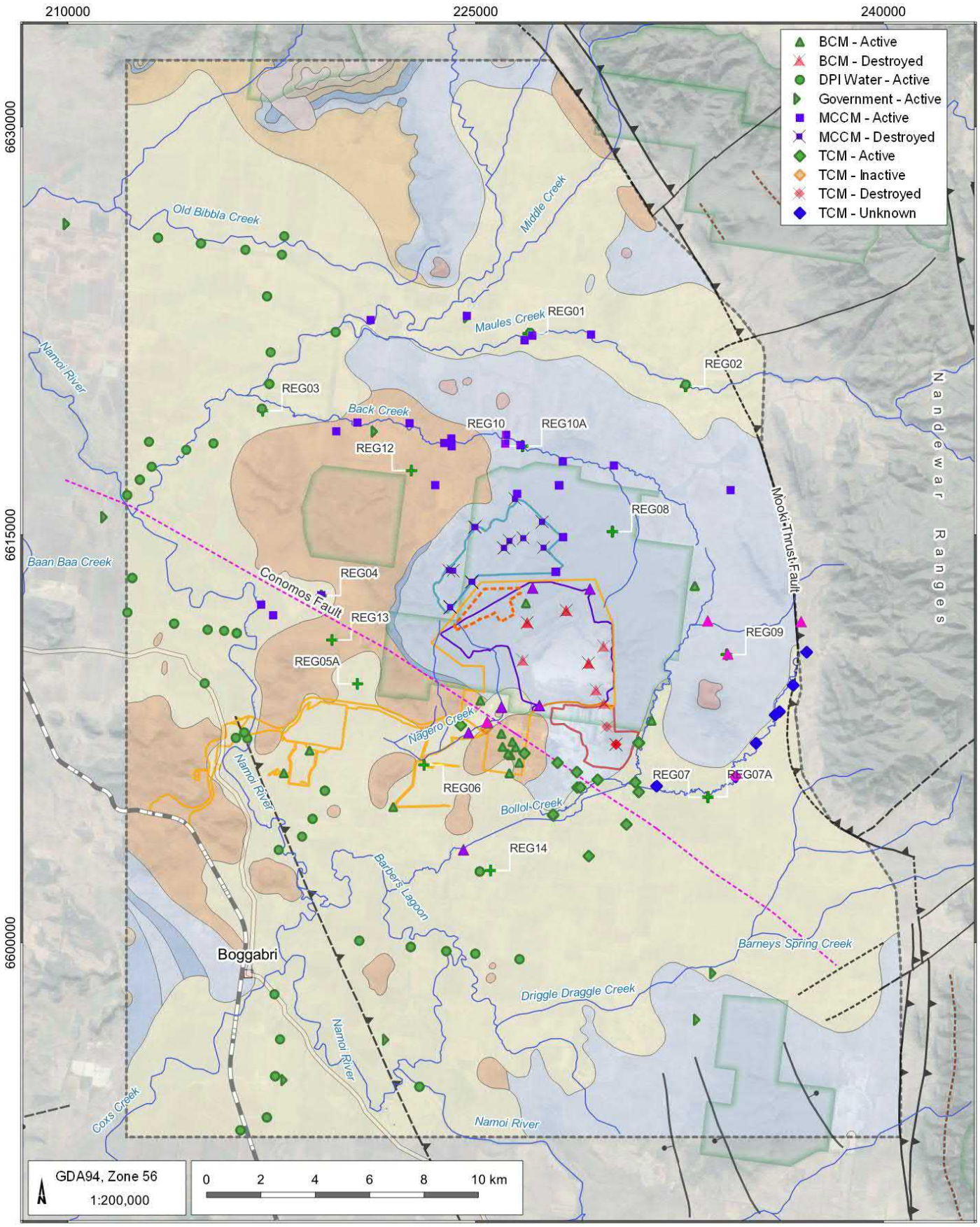
The ‘REG’ series bores were installed to measure the cumulative effects of all BTM Complex mining (Figure 6.2). The cumulative monitoring 'REG’ series consists of nine standpipe bores: three installed in the alluvium and six in the Boggabri volcanics. Additionally, six multi-level VWPs with sensors are installed in Jeralong, Merriown, Nagero, Therribri, Braymount, Upper Northam, and the fault zone. Details of the REG bores are outlined in Table 6.1 and plotted in Figure 6.2.

## 6.4 'GW' series

WaterNSW maintains a network of monitoring bores within the Namoi Valley alluvium surrounding the BCM. These bores monitor groundwater levels and quality within the Narrabri and Gunnedah Formations. Some of these bores have been monitored routinely since the mid-1970s, providing a long record of groundwater level trends. Several bores have telemetered electronic water level loggers, with real-time datasets available online.

## 6.5 Tarrawonga/Maules Creek mine monitoring

Each mine manages a network of monitoring bores at TCM and MCCM. Data from these bores is included in the BTM Complex numerical model, summarised in Appendix F.




LEGEND

- Populated Place
- Principal Road
- Railway
- Drainage
- Locally Mapped Faults
- Fault, Accurate
- Fault, Concealed
- Thrust Fault, Accurate
- Thrust Fault, Concealed
- Fold, Accurate

**Gunnedah Coalfield Rock Unit (1:100K)**

- Qx - Quaternary Sediments
- Tn - Tertiary Nandewar Volcanics
- Tv - Tertiary Volcanics
- Rns - Napperby Formation
- Rdc - Digby Formation
- Pb - Pamboola Formation
- Pwf - Watermark Formation
- Pps - Porcupine Formation
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pwb - Werrie Basalt
- Pbr - Boggabri Volcanics
- Cbc - Currabubula Formation
- Crc - Rocky Creek Conglomerate

Groundwater Impact Assessment
Boggabri Coal Mine Modification 10 (BCO5002.001)

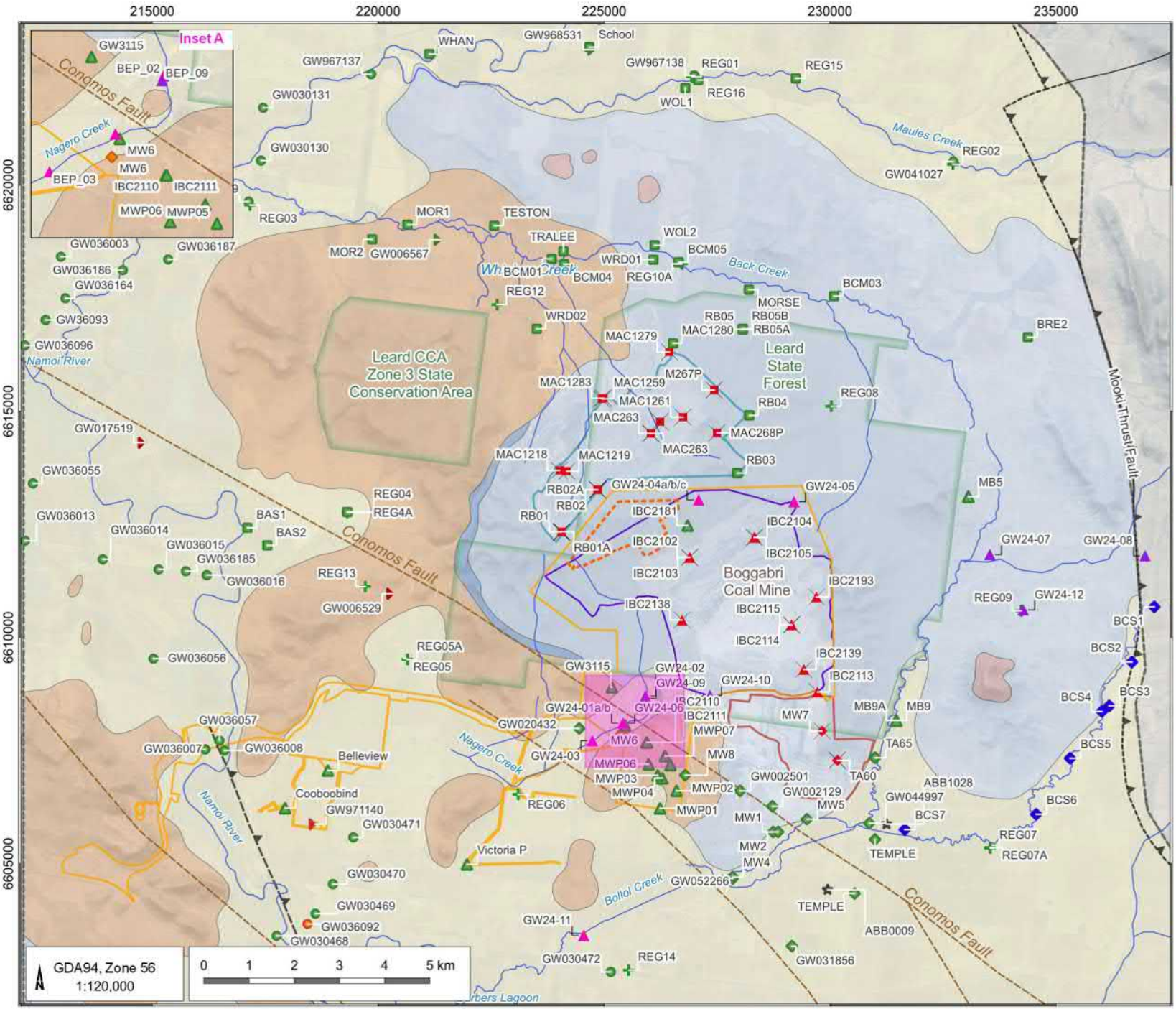
## Regional groundwater monitoring network

AGE

DATE 31/03/2025

FIGURE No: 6.2

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G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\06.02_BCO5002.001_Regional groundwater monitoring network.qgz




LEGEND

- Drainage
- Locally Mapped Faults
- Thrust Fault, Accurate
- Thrust Fault, Concealed
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent
- State Forest
- BTM Complex Model Extent

**Gunnedah Coalfield Rock Unit (100K)**

- Qx - Quaternary Sediments
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pbr - Boggabri Volcanics

**Monitoring Bores Network**

- BCM - Planned
- BCM - Installed in 2024
- ABB Series Bores
- BCM - Active
- BCM - Inactive
- BCM - Destroyed
- BCM - Unknown
- Cumulative - Active
- DPI Water - Active
- DPI Water - Inactive
- Government - Active
- Government - Inactive
- Government - Destroyed
- MCCM - Active
- MCCM - Destroyed
- TCM - Active
- TCM - Inactive
- TCM - Destroyed
- TCM - Unknown

Groundwater Impact Assessment
Boggabri Coal Mine Modification 10 (BCO5002.001)

## Regional groundwater monitoring network - zoomed

DATE
22/05/2025

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FIGURE No:
**6.3**

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# 7 Conceptual groundwater model

The objective of the conceptual model is to describe how water enters, moves through and exits the model area and the interaction with surface water and other water-dependent features. The conceptual model has the following elements:

- Hydrogeological domain (Section 7.1).
- Hydrostratigraphic units (Section 7.2).
- Hydraulic (aquifer and aquitard) properties (Section 7.3).
- Geological structures and boundary conditions (Section 7.6).
- Groundwater levels and flow directions (Section 7.5).
- Groundwater-surface water interaction (Sections 7.6).
- Groundwater recharge, discharge, and conceptual water balance (Sections 7.8, 7.9 and 7.10)
- Groundwater quality (Section7.11).
- Environmental receptors (Section 7.12).
- Overview of Conceptual Hydrogeological Model (CHM) (Section 7.13).

## 7.1 Hydrogeological domain

The BCM is located within the BTM complex, surrounded by the highly productive alluvial aquifers of the Namoi Valley Groundwater Sources (Figure 3.2), Maules Creek Formation and Boggabri volcanics. The Upper Namoi Zone 4, Namoi Valley (Keepit Dam to Gin's Leap) Groundwater Source, is the most proximal and, therefore, has the highest potential to be affected[1] by mining at Boggabri. Within the Upper Namoi Zone 4, an alluvial tongue extends along the length of Nagero Creek, providing a potential connection between mining and the alluvial aquifer. The Namoi River and its alluvium form the western extent of the hydrogeological domain.

To the east, the BCM is situated on the Gunnedah-Oxley Basin subdivision of the WSP for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2020. This subdivision includes all rocks of Permian, Triassic, Jurassic, Cretaceous, and Tertiary age, and alluvial sediments within outcropped areas.

The Hunter-Mooki Thrust Fault constrains the hydrogeological domain to the east. The left lateral strike-slip fault system separates the Maules Creek Sub-basin from the New England Fold Belt. The Nandewar ranges, located west of the fault, provide a source of inflow into the catchment.

The Conomos fault, striking in a northwest-southeast direction, is located southwest of the BCM and is reported to have a vertical displacement of 60 m to 100 m, with the north block rising. Bore logs ABB0009 and ABB1028 (Figure 5.8) located on either side of the Conomos fault, support this interpretation. The hydraulic properties of the fault, however, are unknown. Conceptually, given the low hydraulic conductivity of the interburden in the Maules Creek Formation and the associated vertical displacement, it is likely that the fault reduces geological interconnectivity, with coal seams abutting the less permeable interburden, thereby limiting groundwater flow. Although assumed to be a flow barrier, a level of uncertainty remains. Further monitoring is planned as part of the monitoring bore network expansion (Section 6.1), a set of two bores are planned for installation either side of the Conomos fault to further examine connectivity across the fault.

[1] Within this report, we use the words 'impact' and 'effect', or the verb formed 'affected', and note these words cannot be used interchangeably. 'Impact' is defined for the purposes of this report as 'a marked effect or influence'. 'Effect' is defined as 'a change which is a result or consequence of an action or other cause.' Therefore, it is possible to have an 'effect', without having an 'impact'. A hypothetical example of this would be a circumstance where the level of the water table is affected by an abstraction bore, but it does not have a marked effect or influence on the ability of adjacent bores to abstract water. In this case, there would be an effect on the groundwater regime, but not an impact. Therefore, whilst Zone 4 Groundwater Source is the most proximal to mining and may be affected by mining, it also may not be impacted.

## 7.2 Hydrostatigraphic units

Local stratigraphy can be grouped into four distinctive hydrostratigraphic units:

- Quaternary alluvium;
- Regolith/weathered volcanics;
- Permian coal-bearing sediments; and
- Late Carboniferous/early Permian volcanics.

Tertiary volcanics and the Lower Permian Leard Formation are also present in the study area. Neither formation forms a significant component of the groundwater system and is therefore not included in the hydrostratigraphic review. Table 7.1 summarises the hydrogeological characteristics of the hydrostratigraphic units. Information on the thickness and lateral extent of these units is in Section 5.2 and aquifer properties in Section 7.3.

Table 7.1 Overview of hydrogeological regime

| Hydrostratigraphic unit | Lithological Formation | Lithology | Hydrogeological characteristics |
|---|---|---|---|
| Quaternary Alluvium | Narrabri Formation | Alluvium | Surface alluvial cover comprises extensive overbank clays with lesser channel sands/gravels. Relative to the underlying Gunnedah Formation, a more substantial presence of clay results in higher salinity and lower yields. Not present within the BCM mining footprint. |
| | Gunnedah Formation | Alluvium | Basal paleochannel alluvium, comprising sands/gravel with interbedded clay. It can provide extremely high yields of fresh water to bores. Groundwater abstraction from this aquifer is significant. Not present within the BCM mining footprint. |
| Regolith / weathered volcanics | Maules Creek Formation and Boggabri volcanics | Regolith / weathered zone | Variable in thickness, with deeper weathering profiles found along fractures and potential fault zones. Interpreted to be more permeable than fresh rock, although still hydrogeologically 'tight'. Limited information is available on water quality, as it is commonly found above the water table. |
| Permian Maules Creek Formation | Maules Creek Formation | Coal seams | Main water-bearing lithology of the Maules Creek Formation. Coal seams vary in thickness, with a cumulative thickness exceeding 35 meters. Low to moderately permeable and generally fresh to brackish within the mining areas. |
| | | Cemented conglomerate and sandstone (interburden) Coal seam | Cemented conglomerate and sandstone comprise most of the Maules Creek Formation, which is hydrogeologically 'tight' and, therefore, very low in yielding to dry. |
| Late Carboniferous / early Permian volcanics | Boggabri volcanics | Silicic volcanics | A small amount of outcrop in the study area, generally forms the basement of Maules Creek Sub-basin. Considered to be of very low permeability/impermeable, particularly at depth. Where present, groundwater is likely stored in fractures and/or weathered material. Brackish to moderately saline water quality. |

Bore yields and field measurements of hydraulic parameters indicate that the area's most productive groundwater system is the deeper alluvium of the Gunnedah Formation. Less productive groundwater systems are also found within the overlying alluvium of the Narrabri Formation and the Permian coal seams. Permian interburden, which is comprised mainly of cemented conglomerate and sandstone, is of lower permeability and serves as a confining layer, retarding groundwater flow between individual coal seams and the overlying alluvium. Unweathered basal volcanics also act as a relatively impermeable unit and are found outcropping along the Boggabri Ridge and underlying the alluvium and the Maules Creek Formation.

## 7.3 Hydraulic properties

A high-level summary of all in-field hydraulic parameter testing utilised for the modelling is provided in Table 7.2. Pumping tests completed for the 2022 BTM Complex model update have been used to inform hydraulic properties, as well as lugeon tests and core permeability tests collated from previous studies. This information has been sourced from the MOD 8 GIA (AGE 2022) (which relied upon the BTM Complex model update (AGE 2022)) along with data sourced from AGC (1981), Coffey & Partners (1983), Heritage Computing (2012), Parsons Brinkerhoff (PB) Australia Pty Ltd (2015), and alluvial conductivity values from Aryal et al. (2018a) in Aryal et al., (2018b).

Table 7.2 Summary of hydraulic testing

| Hydrostratigraphic unit | Types of testing[a] | Summary of results |
|---|---|---|
| Quaternary alluvium | Pumping tests and RHT/FHT | The underlying Gunnedah Formation forms the more productive unit, with higher hydraulic conductivity (6.18 m/day), compared to the overlying Narrabri Formation (0.09 m/day). Although less permeable, data suggests that the Narrabri Formation still has the potential to store and transmit appreciable volumes of groundwater. |
| Permian Maules Creek Formation | Pumping tests, lugeon tests, core permeability testing, and RHT/FHTs | Coal seam hydraulic conductivity is highly variable, with approximately four orders of magnitude separating the highest and lowest estimates (1 m/day to $1x10^{-4}$ m/day). There is insufficient data to provide confidence in an inverse relationship with depth.<br>The interburden hydraulic conductivity is variable, with approximately three orders of magnitude separating the maximum and minimum (1 m/day to $1x10^{-3}$ m/day). A reasonably strong relationship exists between hydraulic conductivity and depth, with lower values observed in deeper tests. |
| Boggabri volcanics | Core permeability testing and RHT/FHT | Limited testing to date, with results indicating relatively impermeable rock (horizontal hydraulic conductivity values less than $10^{-4}$ m/day). |

**Note:** [a] RHT/FHT – rising head tests/falling head tests.

### 7.3.1 Alluvium

Within the study area, measurements of alluvial hydraulic conductivity are available from 19 pumping tests, with calculated values ranging from $1.2\times10^{-3}$ m/day to $3.6\times10^{2}$ m/day (Coffey & Partners, 1983; Heritage Computing, 2012; Parsons Brinkerhoff Australia, 2015; and Aryal, 2018a). Although targeted lithologies are challenging to determine from some reports, the significant variability of hydraulic conductivity suggests tests were undertaken in a wide range of alluvial sediments.

On a larger scale, hydraulic testing of alluvium within the Gunnedah Basin has been collated as part of the Namoi bioregional assessment (Aryal et al., 2018a). General statistics for alluvial hydraulic conductivity for the entire Namoi region are presented in Table 7.3. The entire dataset is considered appropriate for conceptualisation, as the hydraulic properties of the alluvium are likely to be relatively consistent, given the regionally consistent depositional environment. Statistics highlight the impact of alluvial heterogeneity, with the median hydraulic conductivity of the finer-grained Narrabri Formation sediments two orders of magnitude less than that of the sands and gravel of the Gunnedah Formation.

Local bore yields are consistent with the lithology-driven variability of hydraulic conductivity. Within the study area, yields taken from 18 bores range from less than 1 L/s up to a maximum of 175 L/s (AGE, 2014).

Table 7.3 Hydraulic conductivity of alluvium (after Aryal et al. 2018)

| Hydrostratigraphic unit | Hydraulic conductivity (m/day) | | |
|---|---|---|---|
| | Median | Min | Max |
| All alluvium* | 0.003 | 0.0001 | 259 |
| Narrabri Formation | 0.09 | 0.002 | 3.14 |
| Gunnedah Formation | 6.18 | 1.79 | 28.5 |

**Note:** (*) Stratigraphy is not known for all locations.

### 7.3.2 Maules Creek Formation

Measurements of hydraulic conductivity for the Maules Creek Formation are available from a range of studies conducted for mining projects within the BTM Complex. An overview of these testing programs and their methodology is provided below:

- Herring (1979) – conducted tests on a selection of exploration holes that encountered sufficient groundwater flow to enable pumping at the proposed BCM site;
- Coffey and Partners (1983) – performed lugeon tests in the coal seams and interburden at the site of the proposed MCCM;
- Parsons Brinkerhoff (2005) – tested discrete profiles using inflatable packers in the coal seams and interburden at the BCM site;
- AGE (2011) – tested discrete profiles with inflatable packers in the coal seams and interburden at MCCM;
- RPS Aquaterra (2011) – conducted permeability tests on interburden core samples, pumping tests and slug tests at TCM;
- AGE (2017) – conducted core permeability tests on samples of interburden from the MCCM;
- Douglas Partners (2020) – conducted packer tests on two bores within the Maules Creek Formation at multiple depths down hole within both interburden and coal seams; and
- AGE (2020) – conducted core permeability tests on interburden samples from three BCM bores.

Figure 7.1 and Figure 7.2 present a summary of hydraulic conductivity measurements taken at multiple depths within the Maules Creek Formation, including the coal seams (Figure 7.1) and interburden (Figure 7.2). The graphs show data from the BTM complex and data from the Vickery and Rocglen mines contained within the Namoi bioregional assessment (Aryal, et al., 2018b).

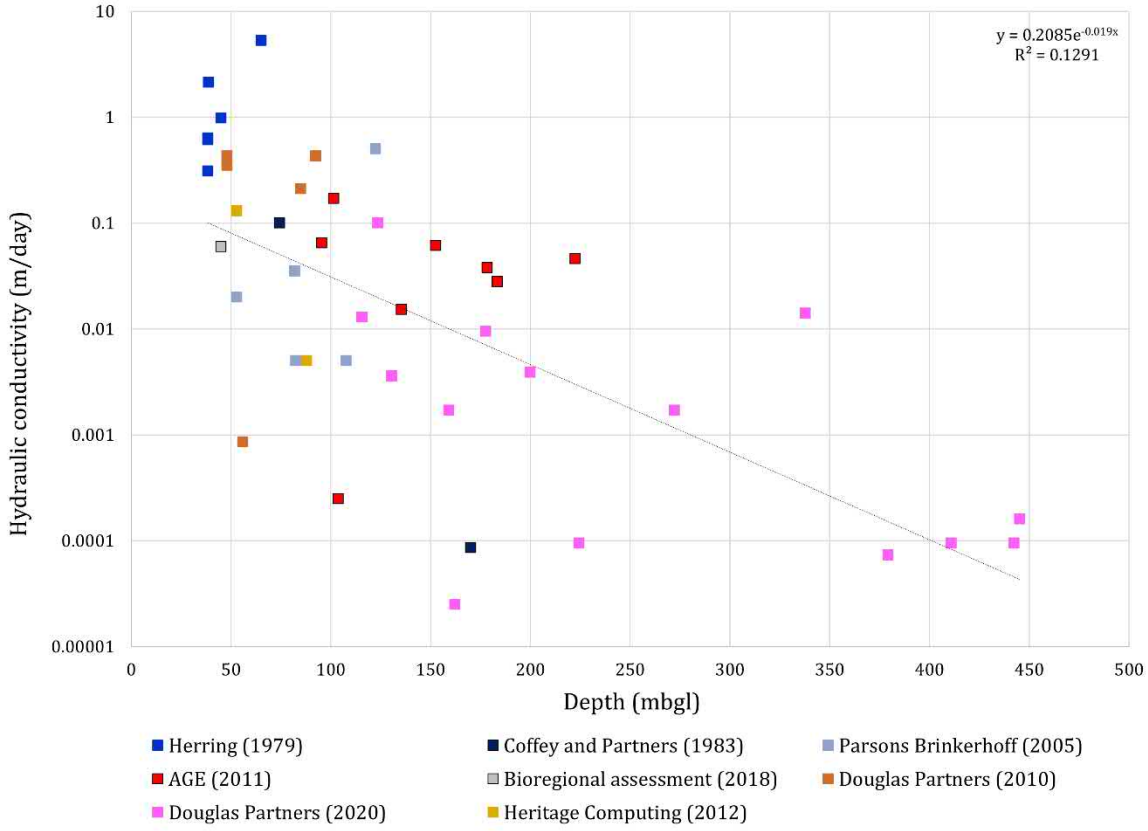



Figure 7.1 Hydraulic conductivity vs depth – coal seams

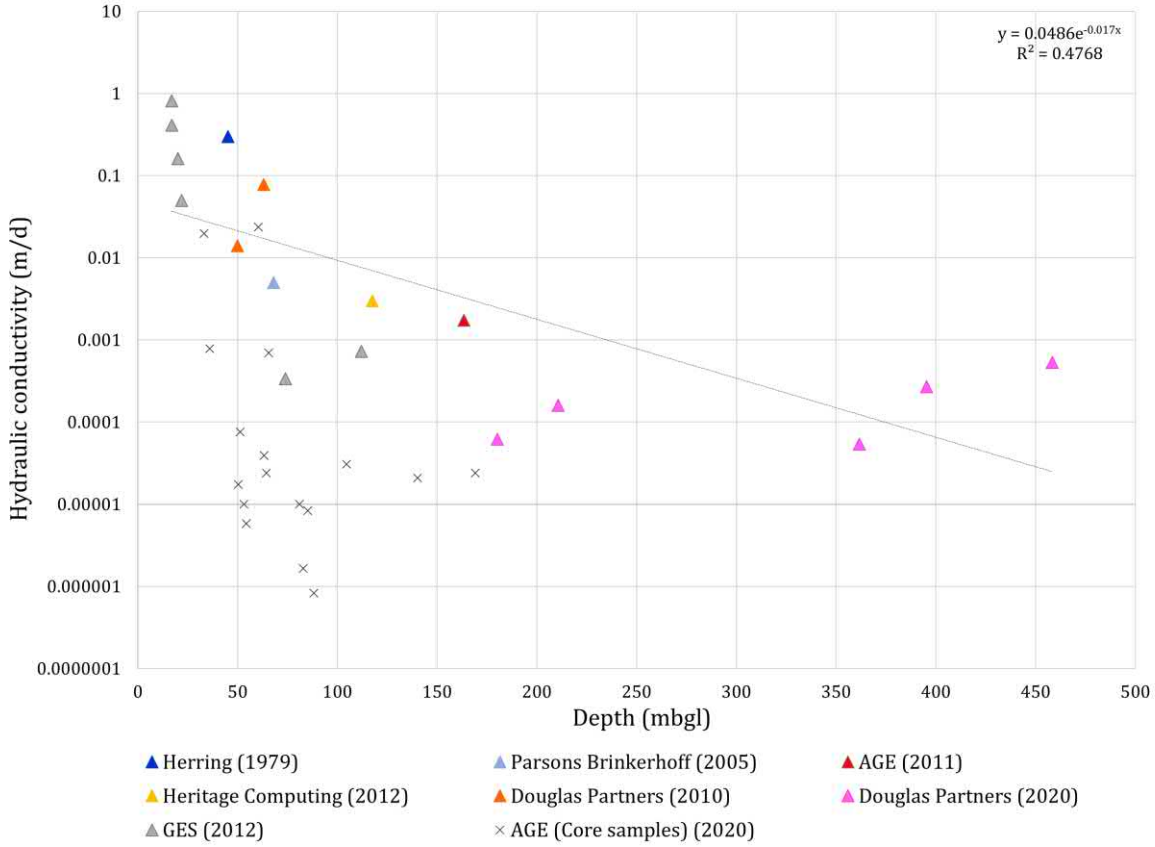



Figure 7.2 Hydraulic conductivity vs depth – interburden (AGE 2020 core samples not included in trend line)

Coal seam hydraulic conductivity is highly variable, with approximately five orders of magnitude separating the highest and lowest estimates. The data show a poorly defined trend, where increases in depth may correlate with a decrease in hydraulic conductivity. There is insufficient data to provide confidence in this relationship, and it should be noted that the maximum depth of investigation (~220 m) is roughly only a quarter of what is estimated to be the maximum thickness of the Maules Creek Formation.

The interburden hydraulic conductivity is variable, with approximately four orders of magnitude separating the maximum and minimum. A reasonably strong relationship exists between hydraulic conductivity and depth, with lower values found in deeper tests. However, it should be noted that only twelve tests were included in the analysis, eight of which were completed in Vickery and Rocglen mines.

Results of core permeability tests in core samples of interburden (RPS Aquaterra, 2011 and AGE, 2017) are not included in Figure 7.2, core permeability from the most recent testing (AGE, 2020) is included in the plot but not in the trend. Estimates of permeability in these tests are solely attributed to the texture of the rock and do not consider secondary permeability, which is associated with rock fractures, joints, and foliation. As such, core permeability tests usually underestimate total permeability. Hydraulic conductivity values determined during core permeability tests are consistent with those from other testing methods, as the interburden has low to very low permeability. Vertical permeability was also tested during core analysis, and similarities in vertical and horizontal permeability were observed in many sample pairs (AGE, 2017).

Coal seams are generally more permeable than the interburden, with an average hydraulic conductivity of 0.6 m/day, based on 39 tests (compared to 0.03 m/day, based on 11 tests, excluding core permeability test results).

### 7.3.3 Boggabri volcanics

To date, hydraulic testing of the Boggabri volcanics is limited, with two core permeability tests completed as part of the Vickery EIS (Groundwater Exploration Services Pty Ltd, 2012) and two rising head tests with inflatable packers attempted as part of the Maules Creek EIS (AGE, 2011).

Core permeability testing indicated a mean horizontal hydraulic conductivity of $2.4\times10^{-6}$ m/day and a mean vertical hydraulic conductivity of $4.0\times10^{-6}$ m/day. These findings are consistent with attempted rising head tests, where analysis was not possible due to a lack of flow. AGE (2011) concluded that these failed tests indicated a very low hydraulic conductivity of less than $10^{-4}$ m/day.

Hydraulic testing of the Boggabri volcanics indicates relatively impermeable rock. To the west of the BTM Complex, regular groundwater monitoring demonstrates that groundwater is present in the system. Although still low, appreciable inflows at these locations are likely attributed to their relatively shallow depth, where the Boggabri volcanics are likely to be weathered.

## 7.4 Geological structures

A summary of geological structures within the region is provided in Section 5.3. No direct or indirect testing of geological structures has been undertaken in the region. However, the fault categories described by Murray and Power (2021) (Figure 7.3) provide an opportunity to consider the potential influence of faults on groundwater flow based on collated information.

The Hunter-Mooki Fault Thrust system forms the eastern structural boundary of the Sydney and Gunnedah basins. The fault is reported to be caused by contractional deformation in the Permian and mid-Triassic formations. A series of associated sub-parallel faults have been mapped. The extent of the fault and propagation of the associated faults suggest a combined conduit-barrier behaviour.

The northwest striking Conomos fault has a reported displacement of 60 m to 90 m (Figure 5.8), north block up and is mapped to be approximately 34 km long. No information exists regarding the condition of the damage zone; however, given the displacement and cross-cutting lithology types, it is likely to form a combined conduit-barrier.

Multiple northwest striking normal faults have been mapped within the mine disturbance area. Offset ranges typically range from 1 m to 5 m, and no significant damage zones have been reported. The faults are localised conduits.

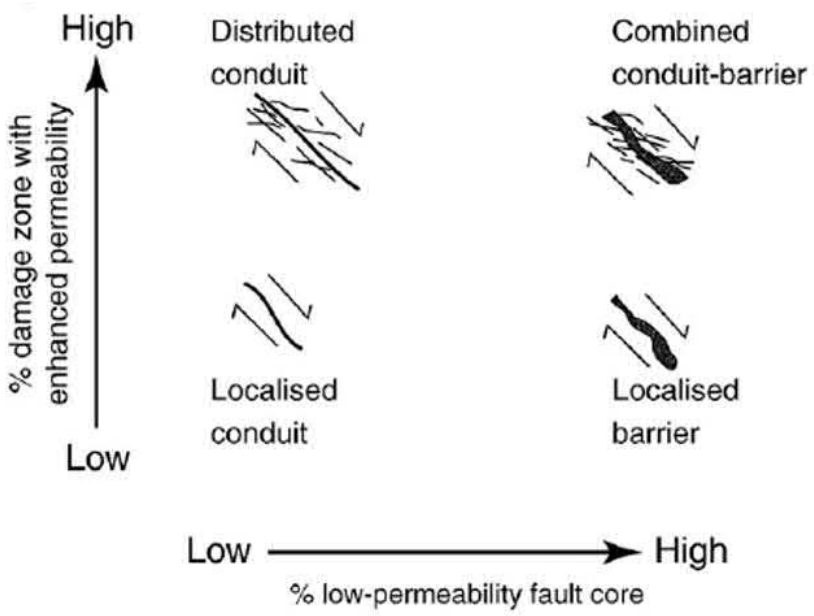



Figure 7.3 Groundwater flow categories for faults (from Murray and Power, 2021)

## 7.5 Groundwater levels, hydraulic gradients and flow direction

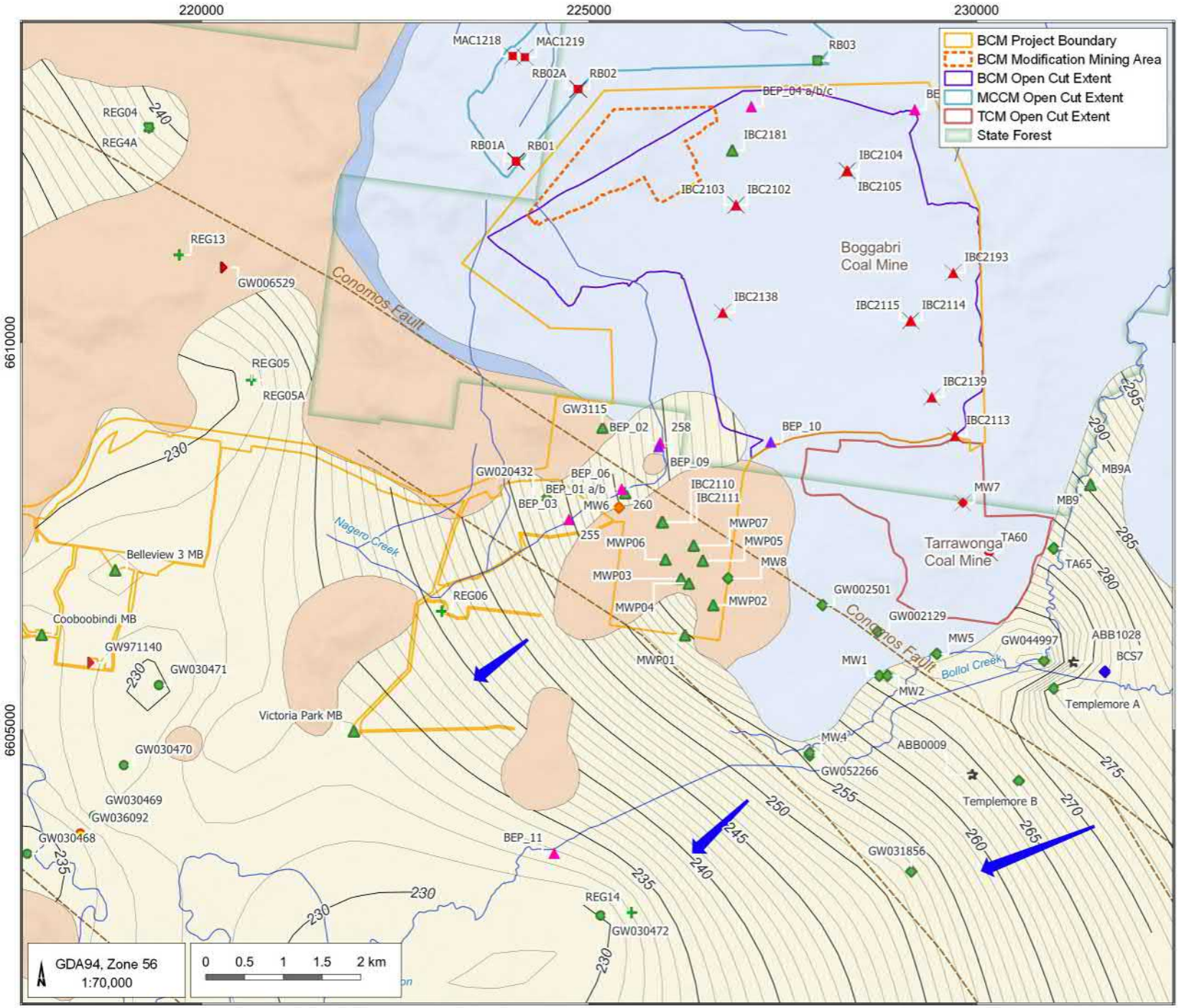
Groundwater in the alluvium surrounding BCM and TCM, which includes the Bollol Creek/Driggle Draggle Creek alluvial plain and the Nagero Creek alluvium, generally flows towards the southwest, where it joins with the Namoi River alluvial groundwater system (Figure 7.4). Regional groundwater flow within the Namoi River alluvium follows in the same direction of the river, either to the northwest or north (McNeilage, 2006). Current groundwater flow directions are consistent with pre-mining groundwater flow directions.

Pre-mining groundwater flow within the Maules Creek Formation is predominantly from east to west (AGE, 2010). Existing mining activities have led to localised areas of depressurisation around the BTM Complex mines, resulting in the mining areas acting as local groundwater sinks.

Groundwater flow within the Boggabri volcanics is generally a subdued reflection of topography with hydraulic gradients from east to west (AGE, 2022).

### 7.5.1 Alluvium

The alluvial sediments closest to BCM form a thin tongue-shaped area to the southwest of the mine associated with the ephemeral Nagero Creek (Figure 7.4). This creek is fed from the catchment area occupied by BCM. Groundwater in this alluvium flows northeast to southwest toward the highly productive paleochannel zone of the Namoi River alluvium.




LEGEND

- Drainage
- Groundwater Contours
- Groundwater Flow Direction

**Monitoring Bores**

- BCM - Active
- BCM - Inactive
- BCM - Destroyed
- BCM - Unknown
- Cumulative - Active
- DPI Water - Active
- DPI Water - Inactive
- Government - Active
- Government - Inactive
- Government - Destroyed
- MCCM - Active
- MCCM - Destroyed
- TCM - Active
- TCM - Inactive
- TCM - Destroyed
- TCM - Unknown

BCM GW24 Series Bores

**Gunnedah Coalfield Rock Unit (100k)**

- Qx - Quaternary Sediments
- Pmx - Maules Creek and Goonbri formations
- Plf - Leard Formation
- Pbr - Boggabri Volcanics

Groundwater Impact Assessment
Boggabri Coal Mine Modification 10 (BCO5002.001)

## Alluvial groundwater levels and flow direction

DATE
22/05/2025

AGE

FIGURE No.
**7.4**

©2025 Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) - www.ageconsultants.com.au; Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006
G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\07.04_BCO5002.001_Alluvial groundwater levels and flow direction.qgz

Groundwater in the Nagero Creek alluvium is monitored by open standpipe monitoring bores MW6 installed from 18 to 22 mbgl and recently installed bores BEP_01a, BEP_01b, BEP_02 and BEP_03. Groundwater levels within the Nagero Creek alluvium are near the surface, ranging from 4 to 13 mbgl, and show some influence from changes in rainfall. Figure 7.5 shows that fluctuations in water levels are generally consistent with changes in rainfall. A period of increasing water levels was recorded from 2012 to 2019, inconsistent with the decreasing pattern of CRD. It is unclear what is causing the increasing trend in water levels from 2012 to 2019. From 2019 to 2020, bore MW6 was blocked. In 2020, the bore was redrilled, and water level trends resumed, showing a better agreement with the CRD, albeit with an increasing trend. In late 2024 and early 2025, four additional Nagero Creek alluvial monitoring bores were installed: BEP_03, which is located downstream along Nagero Creek approximately 500 m from MW6. Initial water levels recorded prior to development are 4.9 mbgl. Additionally, water levels recorded at MW6 and BEP_01a and b are 4.4 mbgl, 4.9 mbgl and 4.8 mbgl, respectively. Approximately 730 m upstream of MW6 and BEP_01a and b is BEP_02, which is installed from 12 to 15 mbgl. BEP_02 recorded a standing water level of 13.1 mbgl 24 hours after drilling.

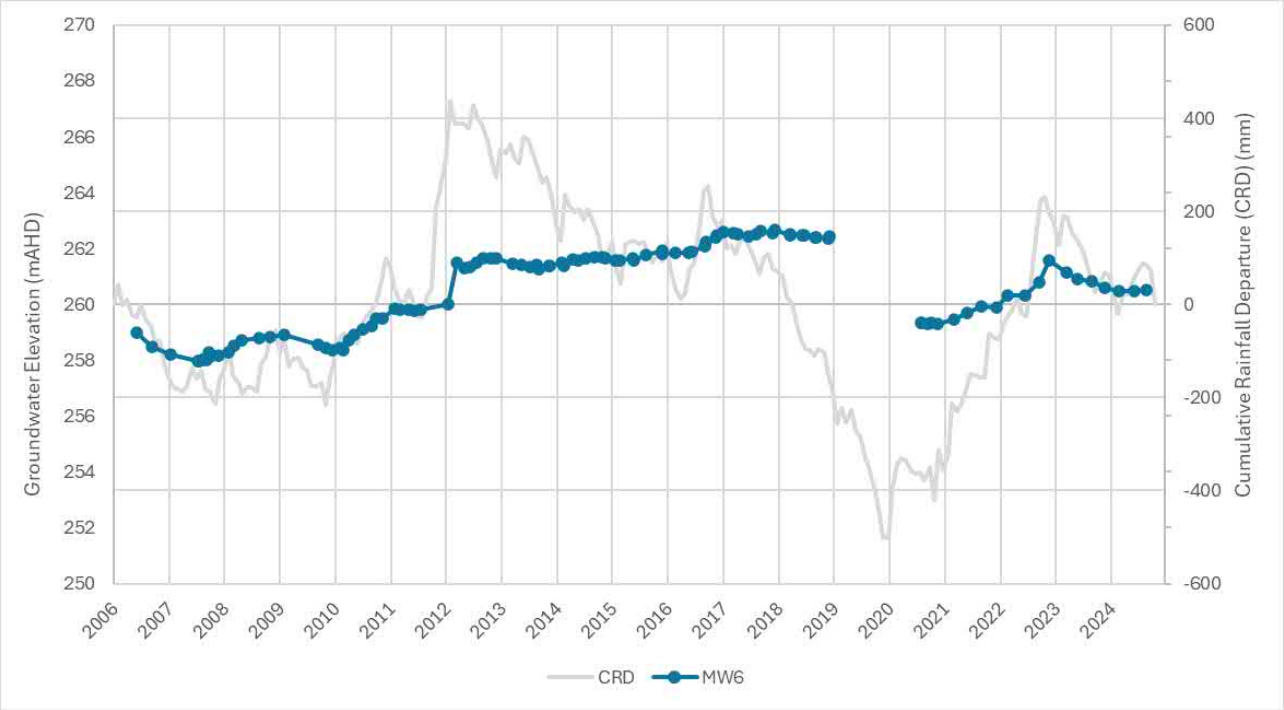



Figure 7.5 Nagero Creek hydrograph (MW6)

Alluvial groundwater monitoring bores have been installed within the Bollol Creek Alluvium, south of TCM and BCM. Bores are managed and monitored by TCM, which undertakes quarterly groundwater level and quality monitoring in accordance with the TCM Water Management Plan (Whitehaven Coal, 2023). Groundwater level variations for these bores (Figure 7.6) are generally consistent with CRD. Mining activities occur near the floodplain and its associated alluvial aquifer; however, no measurable drawdown has been recorded.

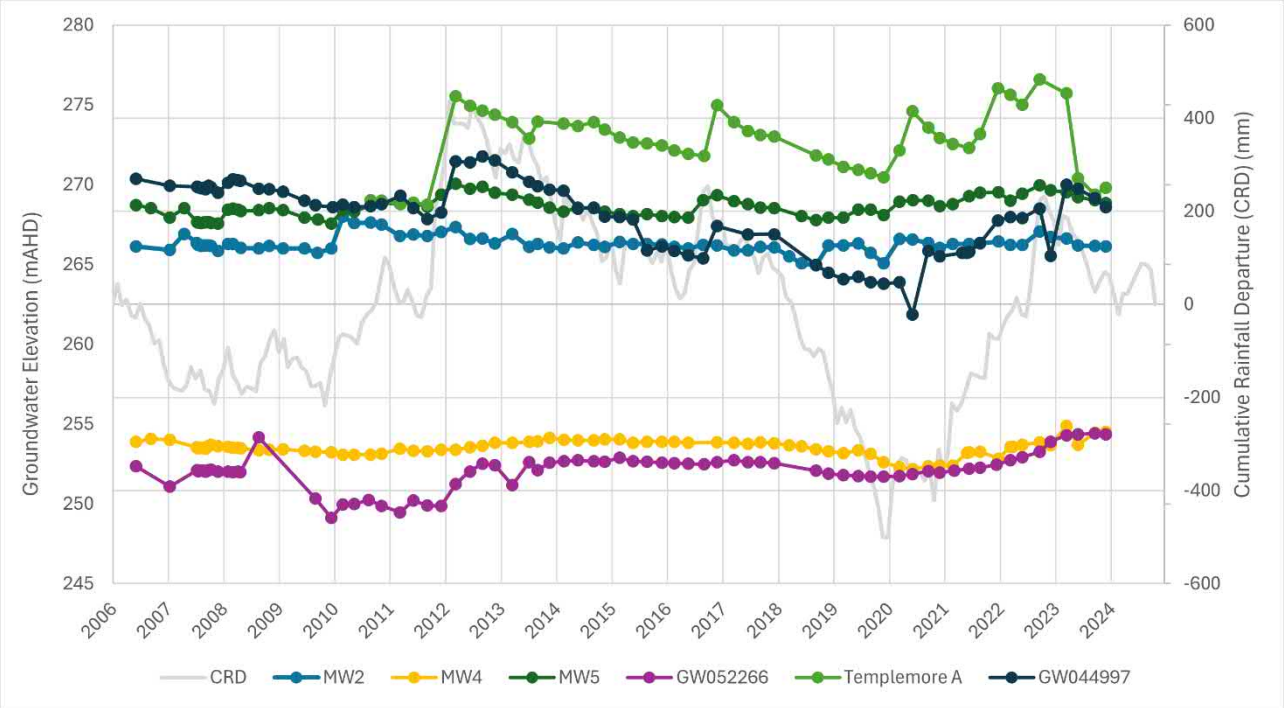



Figure 7.6 Bollol Creek hydrographs, results from TCM Annual Review (2023)

The Namoi River alluvium is an important groundwater source for irrigation in the region. Groundwater extraction predominantly occurs from the deeper Gunnedah formation in the paleochannel zone, aligned with the Namoi River. Registered bore GW036016 is located approximately 7.5 km west of BCM alongside the Namoi River (Figure 6.3) and has been monitored by WaterNSW since 1974. The bore has recorded a decline in groundwater levels over time, with an increase in seasonal pumping (Figure 7.7). Before 1993, groundwater levels at all three depths were very similar, with a slight downward gradient observed and only small (<1 m) changes in levels consistent with the CRD. All three monitoring points show a consistent decline in groundwater elevation, indicating a long-term groundwater depletion with localised fluctuations consistent with variations in rainfall. Since 1993, groundwater level variations have demonstrated the influence of seasonal extraction to support agriculture, with large spikes associated with pumping becoming increasingly evident, resulting in an overall downward trend, particularly in the deeper bores.

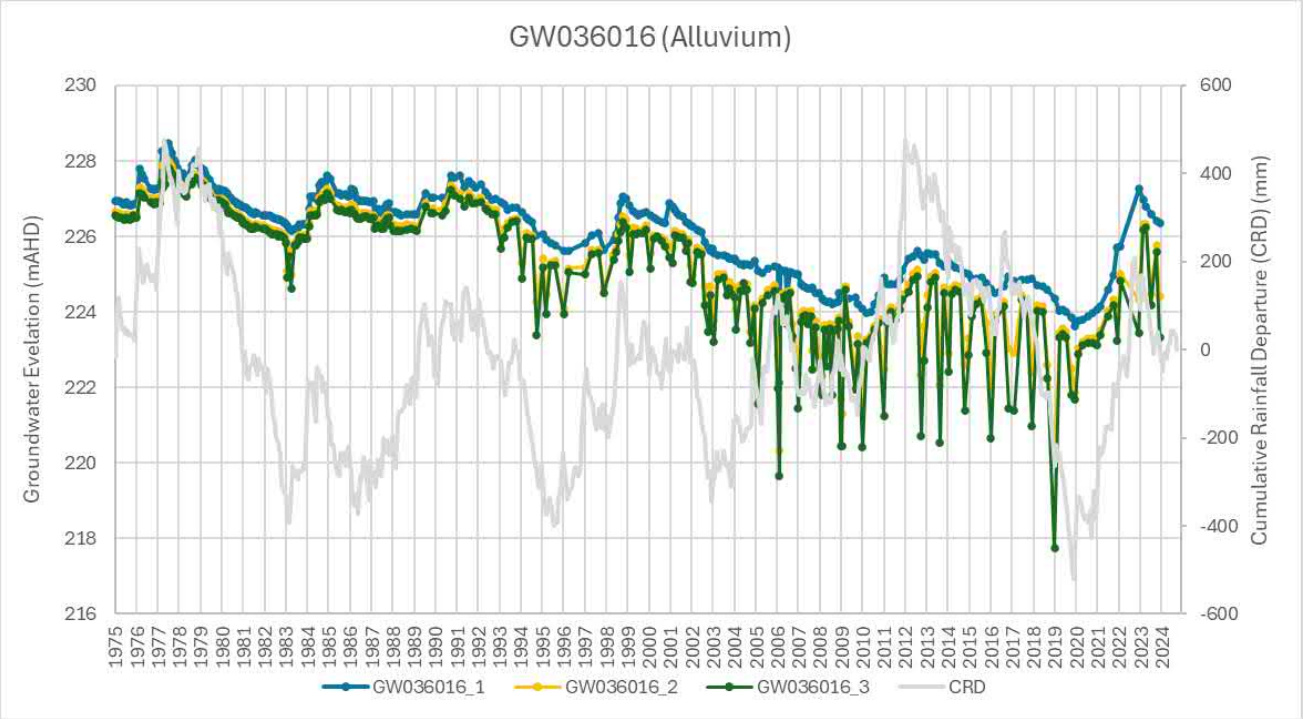



Figure 7.7 GW036016 bore installed in the Namoi alluvium at depths (pipe 1) 27.4 mbgl, (pipe 2) 45.7 mbgl, and (pipe 3) 76.2 mbgl

### 7.5.2 Maules Creek Formation

The Maules Creek Formation comprises multiple laterally continuous coal seams, with interburden consisting of cemented conglomerate and sandstone. The coal seams, particularly the Merriown seam, are transmissive with minor intergranular permeability. The groundwater flow direction in the Maules Creek Formation is south-westward, consistent with regional topographic gradients. Groundwater levels are relatively deep, from 40 to 70 mbgl, up to 148 mbgl at BEP_04. BEP_04 was drilled and installed in 2024 and is located at higher elevations north of mining between BCM and MCCM (Figure 6.3). Bores installed in the coal seam proximal to mining experience depressurisation associated with dewatering the seam as mining progresses (Figure 7.8). All IBC series bores installed in the Maules Creek Formation, excluding IBC2181, have been destroyed due to the progression of mining. IBC2181, which was installed from 105 to 111 mbgl in the Merriown seam, remains active; however, it has been recorded as dry since June 2023.

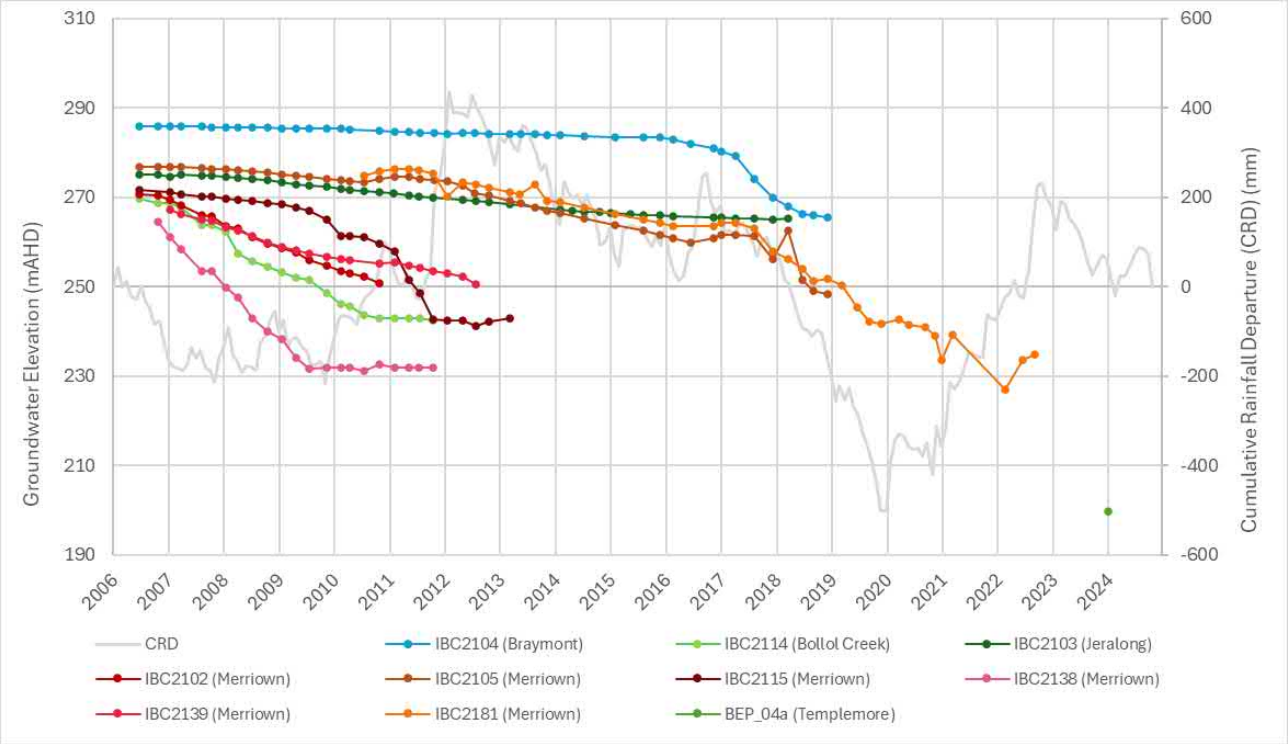



Figure 7.8 Maules Creek formation hydrographs

A network of regional monitoring bores is located north, east, and south of the BTM complex, which monitors cumulative impacts and depressurisation propagating away from the mines. Bores REG07 (southeast of BCM), REG08 (northeast of BCM) and REG09 (west of BCM) (Figure 6.3) are installed in the Braymont, Merriown and Nagero coal seams.

REG07 is located southeast of BCM and monitors the Braymont (67.5 mbgl), Merriown (148.2 mbgl) and Nagero (242.5 mbgl) coal seams. Water levels in the Braymont seam (Figure 7.9) do not show any indications of drawdown, while sensors installed in the Merriown and Nagero seams initially show a declining trend and have more recently stabilised water levels.

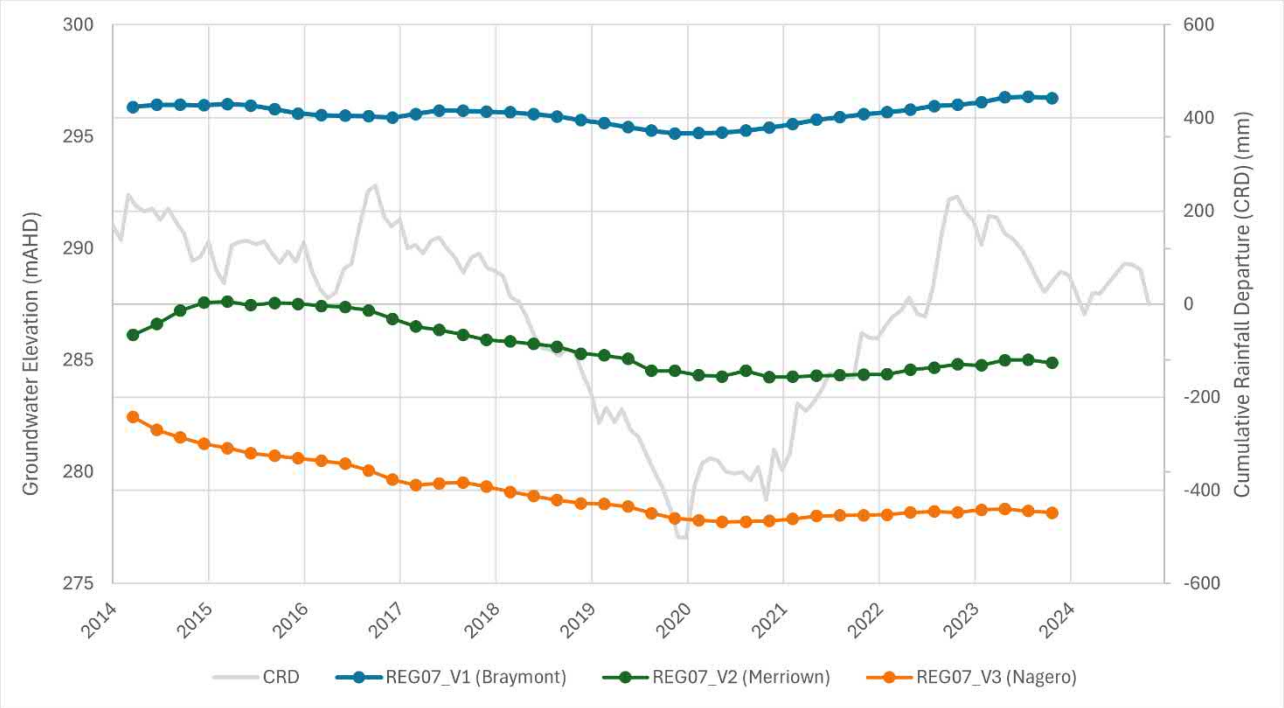



Figure 7.9 REG07 hydrograph: the Braymont (67.5 mbgl), Merriown (148.2 mbgl) and Nagero (242.5 mbgl) coal seams

REG08 (Figure 7.10) is installed approximately 2.6 km northeast of the BCM-approved Mine Disturbance Boundary, east of MCCM (Figure 6.3). Depressurisation is recorded at REG08, showing a declining trend, consistent with the progression of mining of the Braymont, Merriown, and Nagero seams within the BTM complex.

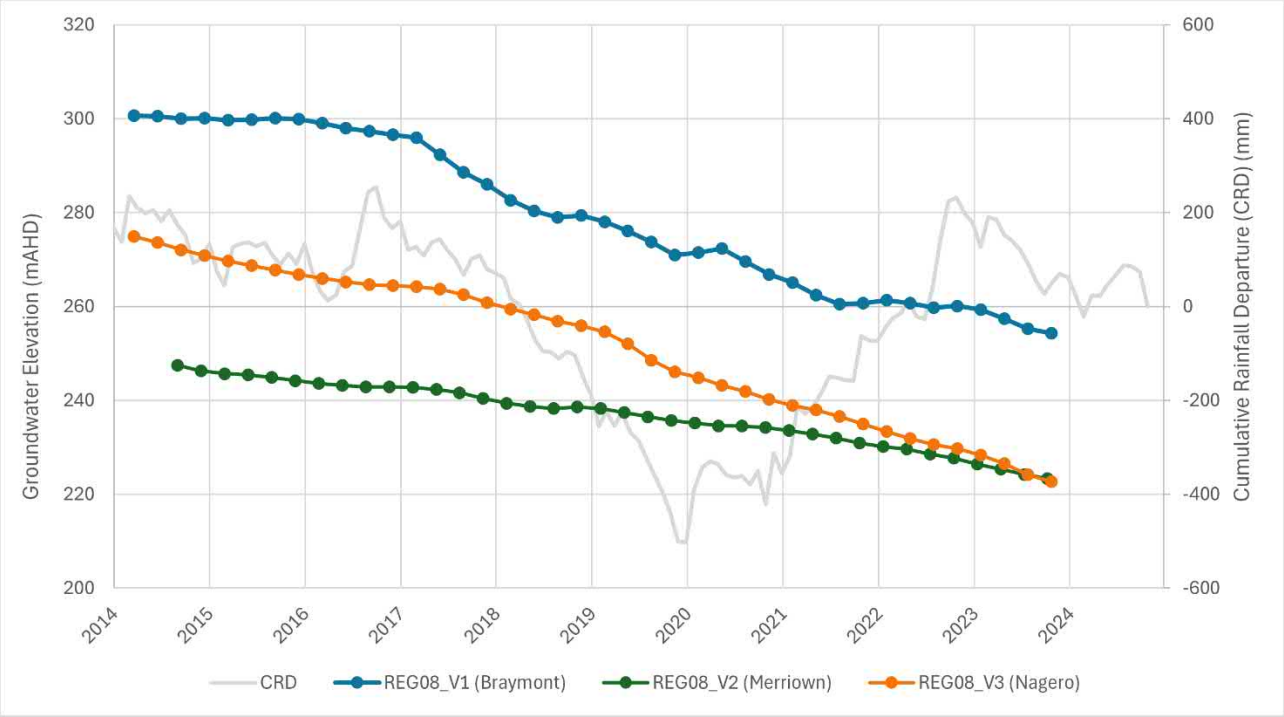



Figure 7.10 REG08 hydrograph: the Braymont (92 mbgl), Merriown (221 mbgl) and Nagero (274 mbgl) coal seams

REG09 is located six kilometres east of BCM (Figure 6.3) and monitors the Braymont (115.8 mbgl), Merriown (175.2 mbgl), and Nagero (268 mbgl) coal seams (Figure 7.11). Groundwater levels recorded show minor signs of depressurisation and minor variations associated with changes in rainfall, with recent water level trends stabilising.

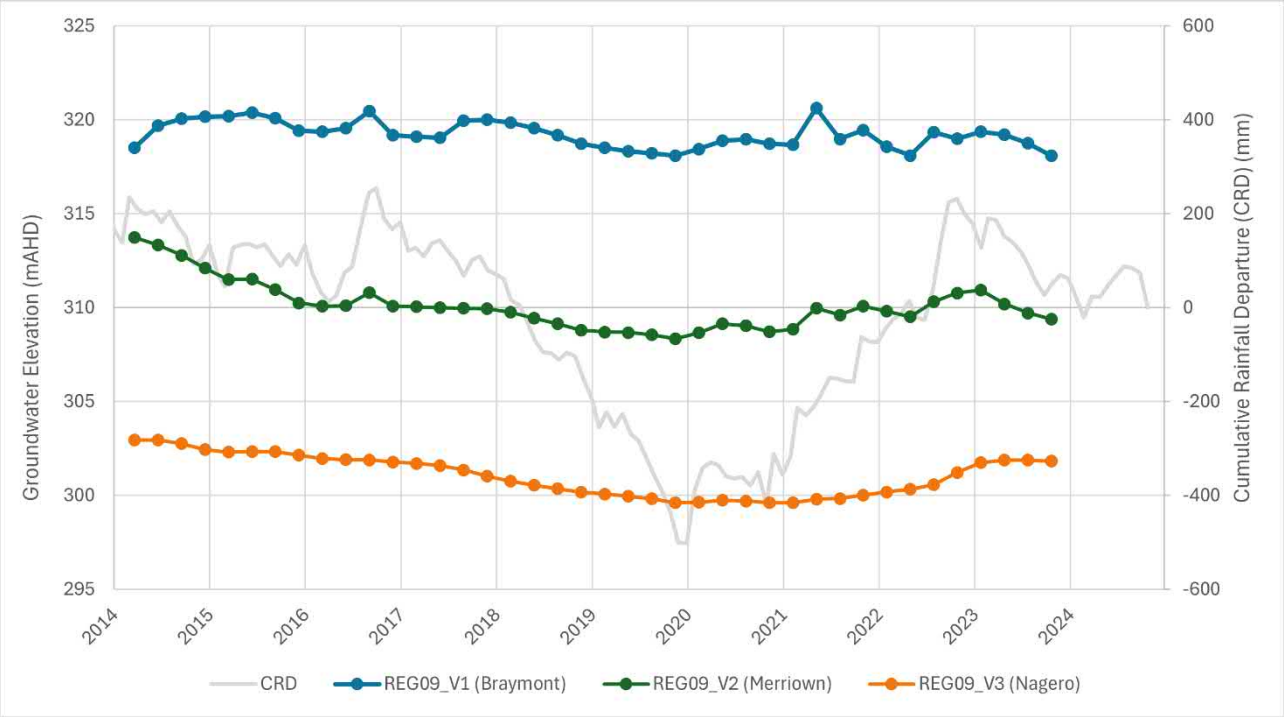



Figure 7.11 REG09 hydrograph: Braymont (115.8 mbgl), Merriown (175.2 mbgl) and Nagero (268 mbgl) coal seams

### 7.5.3 Boggabri volcanics

The propagation of drawdown to the west in the Boggabri volcanics is monitored by three bores southwest of BCM (GW3115, IBC2110, and IBC2111). Groundwater levels at GW3115, installed in the weathered volcanics at 42 mbgl, have remained stable. On the contrary, bores IBC2110 and IBC2111 installed south of the alluvial tongue, into weathered volcanics at 91 to 97 mbgl and 36 to 42 mbgl, respectively, show some fluctuations with rainfall and an overall steadily increasing trend (Figure 7.12).

The fluctuations recorded at IBC2110 and IBC2111 indicate that variations in climate partially affect water levels. The reasons for this partial effect of climate at these bores and not GW3115 are not well known; however, it is likely due to more substantial fracturing within the immediate area around the Conomos fault (Figure 6.3).

The overall increasing trend could be attributed to the proximity of these bores to surface water storage as bores are located approximately 300 m south of water storage dams SD6 and SD10, and 600 m north of MW3 (Figure 6.1 – inset A). If seepage is a likely cause of increasing water levels, a subsequent change in EC or sulfate would be expected; however, EC (Figure 7.26) and sulfate (Figure 7.29) trends remain stable, indicating that the increasing water levels are unlikely to be related to seepage from surrounding dams.

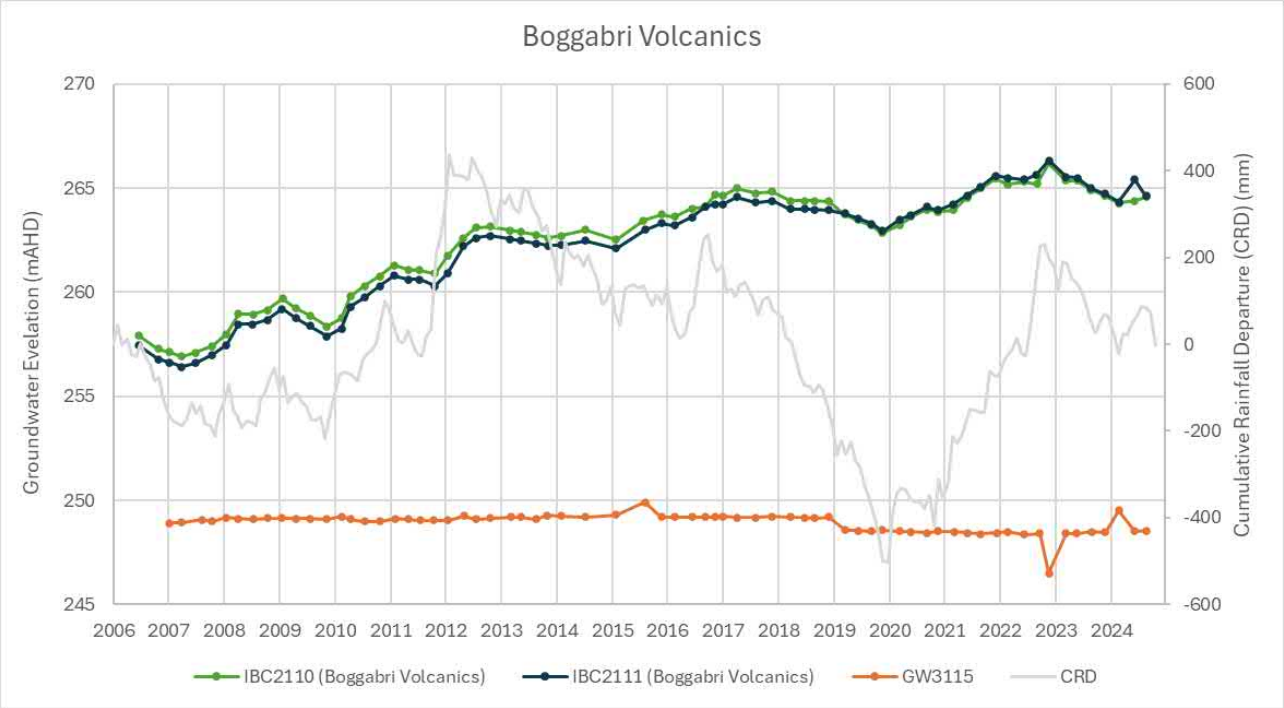



Figure 7.12 BCM hydrographs - Boggabri volcanics: GW3115 (42 mbgl), IBC2110 (97 mbgl), and IBC2111 (42 mbgl)

The Boggabri volcanics is also monitored by regional bores REG03, REG04, REG05, REG06, REG12, and REG13, which are located to the west of the BTM complex, between the mining complex and the Namoi River. Hydrographs (Figure 7.13) for these bores indicate no mining-related drawdown. It is worth noting that bores REG12, REG13, REG03, and REG06 exhibit a recent increasing trend in water levels, which may be a delayed response to above-average rainfall rates, as indicated in the CRD for the period 2020-2023.

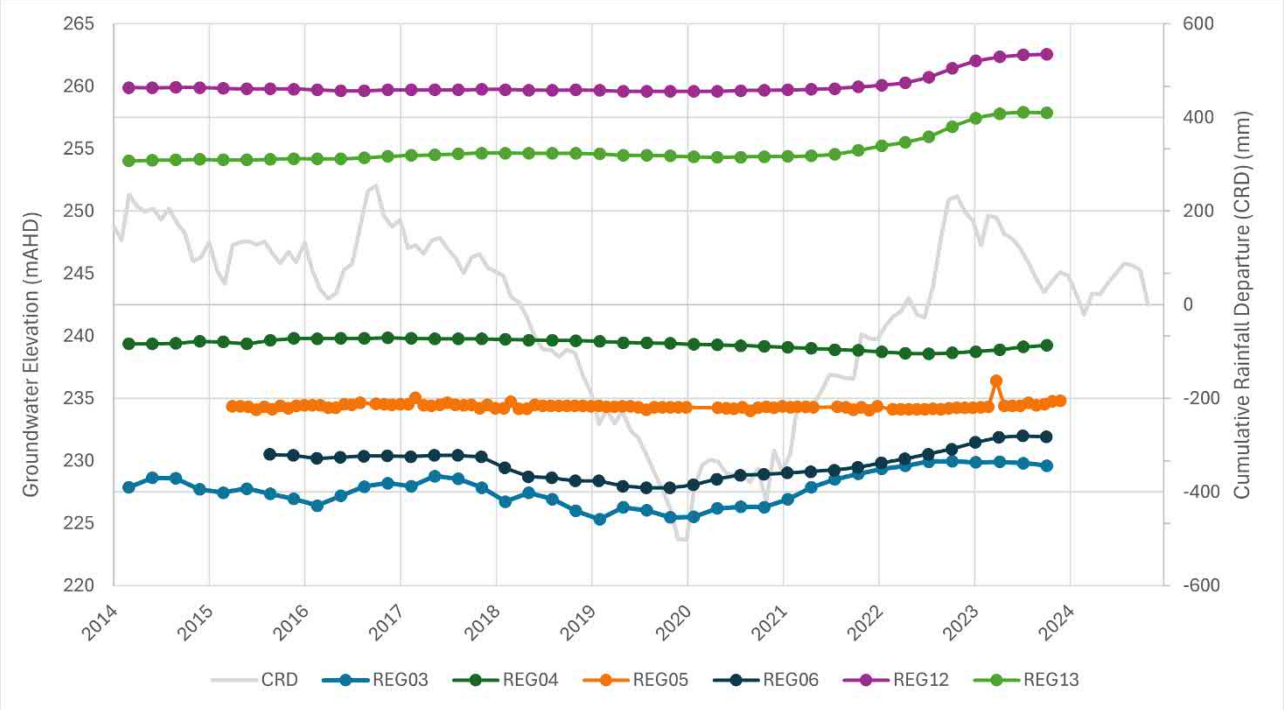



Figure 7.13 Regional hydrographs - Boggabri volcanics

A comparison of the groundwater elevation and topographic elevation (Figure 7.14) shows a strong correlation, with an $R^2$ of 0.84. This indicates that groundwater levels within the volcanics correlate well with topography. Additionally, Figure 7.15 (piezometric map during mining in 2023) confirms that groundwater flows generally east to west.

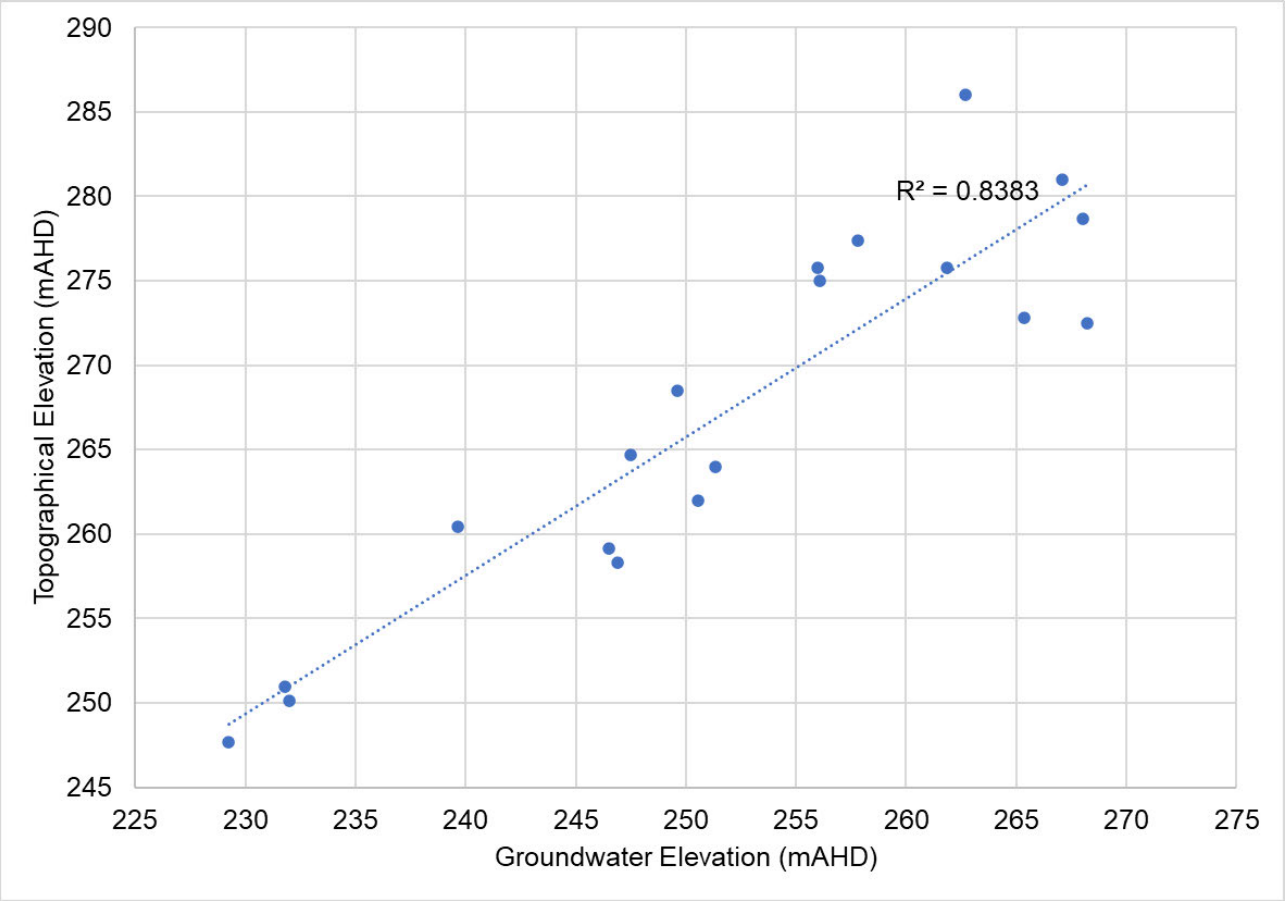
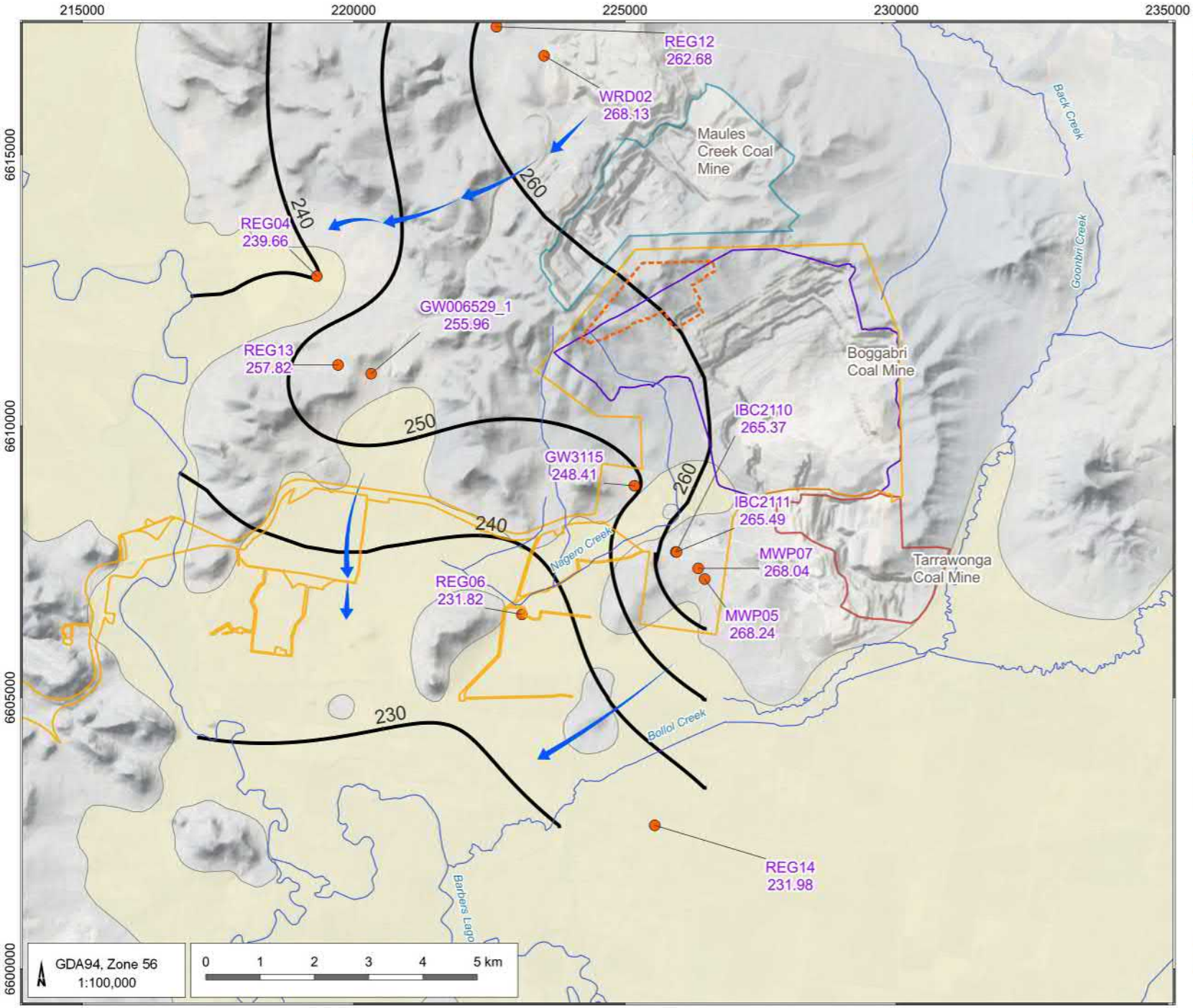



Figure 7.14 Correlation between groundwater elevation and topographic elevation in the volcanics




LEGEND

- Drainage
- Groundwater Elevation Contours
- Groundwater Flow Direction
- BCM Volcanics Bores
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

Groundwater Impact Assessment Boggabri Coal Mine Modification 10 (BCO5002.001)

**Boggabri volcanics groundwater flow**

DATE
11/03/2025

AGE

FIGURE No.
**7.15**

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## 7.6 Alluvial connectivity to coal measures

Multi-level monitoring that extends through the alluvium and the coal measures is limited in the immediate area around BCM. Cumulative monitoring bores REG07 and REG07A are co-located southeast of TCM, with sensors installed in the Bollol Creek alluvium (REG07A) and the Braymont, Merriown, and Nagero coal measures (REG07). Hydrographs (Figure 7.16) show an upward hydraulic gradient between the Braymont seam and the alluvium. A similar behaviour was observed for the Merriown seam up to 2020, after which it was depressurised sufficiently to reverse the hydraulic gradient (downward) from the alluvium to the Merriown seam.

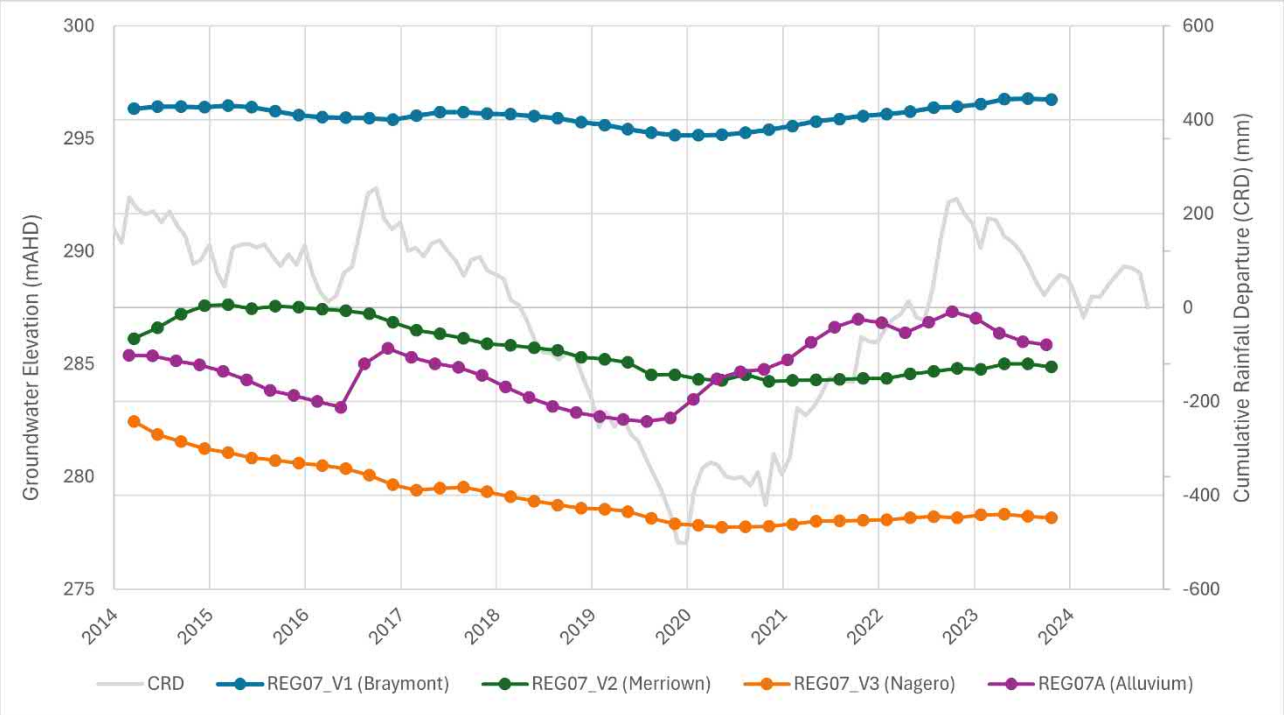



Figure 7.16 REG07 and REG07A hydrographs

## 7.7 Groundwater-surface water interaction

Three small ephemeral creeks surround BCM, including the Nagero, Bollol, and Goonbri creeks, which are located southwest, south and southeast of BCM, respectively (Figure 1.1). The creek beds are above the water table level and can be defined as losing streams that recharge the underlying water table during flow events.

The largest river in the study area is the Namoi River, located approximately 12.5 km west of BCM. In the vicinity of the study area, the river flows southeast to northwest.

### 7.7.1 Namoi River

Comparisons between the river stage from WaterNSW Namoi River at Boggabri gauging station (station 419012) and select alluvial groundwater levels from nearby bores (GW030469, GW030468, GW036092) indicate that water levels in the river are highly variable and have a larger range than the groundwater levels (Figure 7.17). Groundwater levels were typically over 1 m higher than the river stage between 1979 and 2005, with the Namoi River expected to gain flow during this period. Conversely, since 2005, periods where groundwater levels are lower than the river stage have occurred more frequently, with the Namoi River losing to groundwater during these periods. This change in connectivity is likely linked to the gradual decline in groundwater levels, which has been observed since the onset of monitoring and is in full agreement with the recent analysis by Crosbie et al. (2023) on surface water–groundwater connectivity in the Murray-Darling Basin. During periods of above-average rainfall, groundwater flows into the Namoi River and the lower reaches of the Maules Creek when the water table is relatively high.

Seasonal pumping and an overall groundwater decline is evident in hydrographs for bore GW036016 (Figure 7.7). From 2000 onwards, an increasing seasonal drawdown trend is evident, which coincides with an overall decreasing trend. The commencement of the declining trend before the commencement of mining indicates that the overall decreasing trend is in some part attributable to an increase in irrigation in the area.

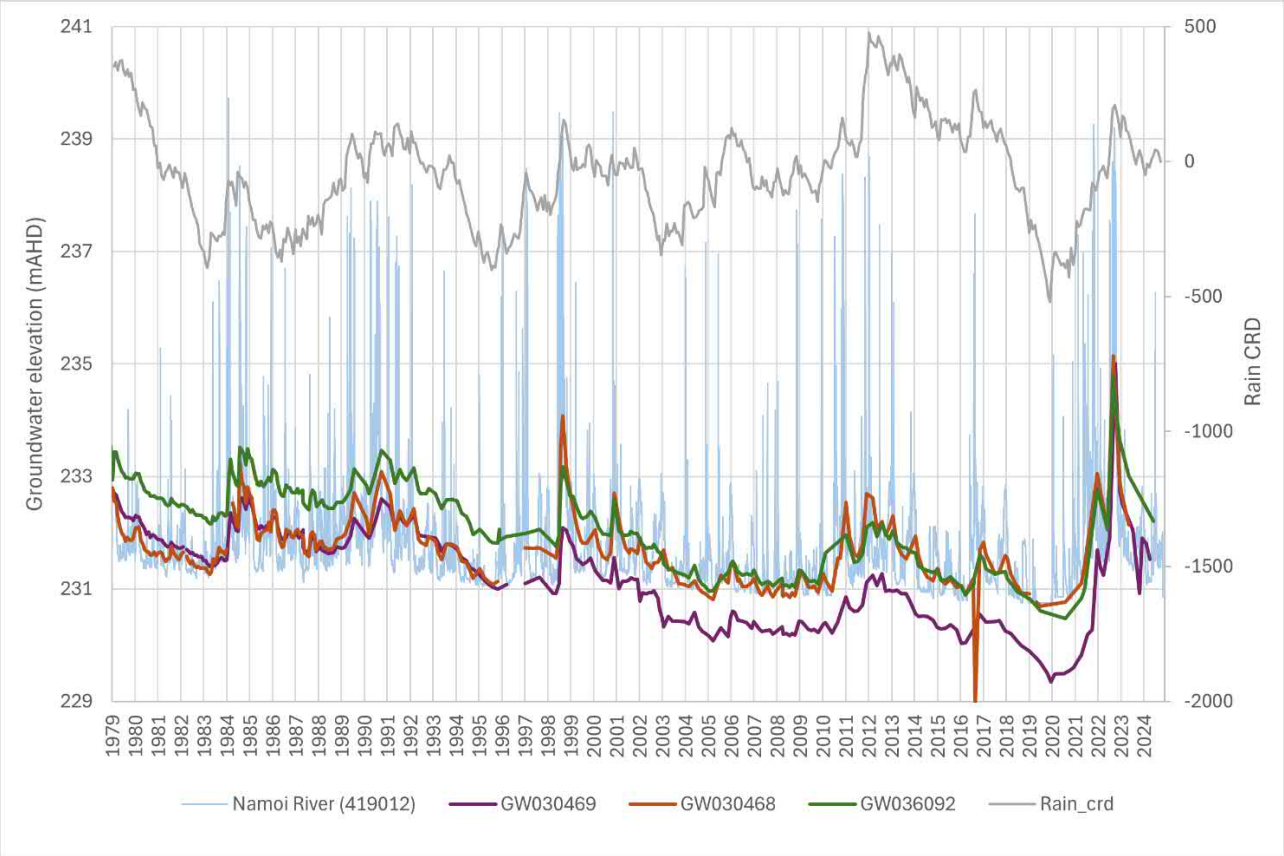



Figure 7.17 Namoi River level and surrounding groundwater hydrographs

## 7.7.2 Nagero Creek

Nagero Creek flows from its source in the catchment within the Leard State Forest and BCM operations to the west through agricultural lands, where it joins the Cooboobindi Creek and its confluence with the Namoi River. The creek is ephemeral with no permanent groundwater discharge or baseflow due to the creek beds being higher than the water table. The creek flows only after significant or prolonged rainfall (Engeny, 2021) and is not heavily incised into the landscape. During these rainfall and flow events, it is conceptualised that short-term recharge to the underlying water table should be provided through creek bed seepage.

As discussed in Section Figure 6.1 further groundwater monitoring bores have been installed along Nagero Creek in the upper and lower alluvium to further monitor groundwater levels and quality.

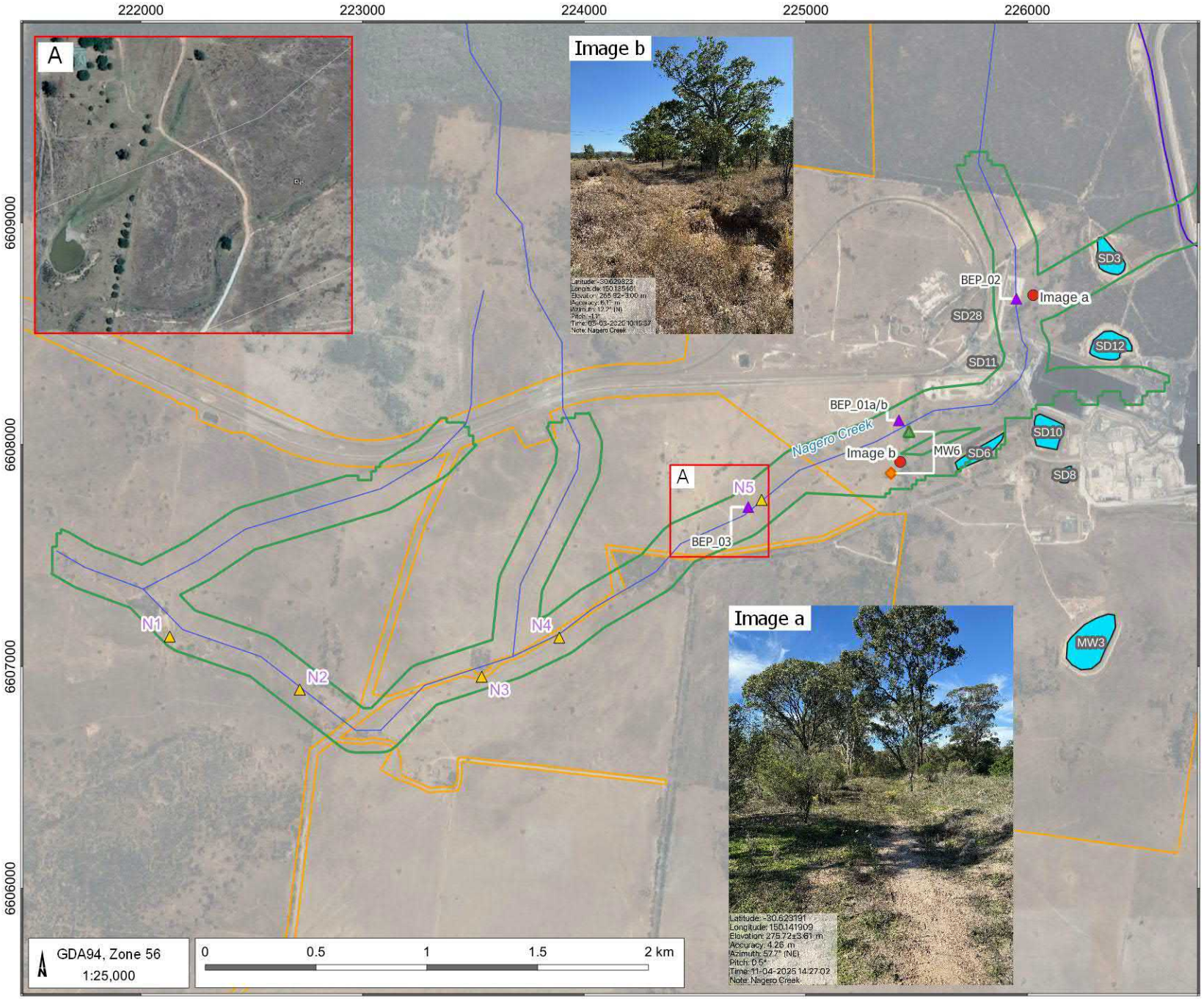
Available monitoring data at Bore MW6 and BEP_03 are plotted in Figure 7.18. MW6 is located in the southern alluvial fringe of the Nagero Creek, just south of the Conomos fault. The hydrograph for MW6 indicates that water levels generally fluctuate in response to variations in rainfall. However, from 2012 to 2019, an overall increasing trend was observed, contrary to the decreasing trend in rainfall rates reported by the CRD; the reasons for this behaviour are unclear. In 2019, MW6 was reported as blocked and subsequently re-drilled. Since the new bores were installed in 2020, groundwater levels have resumed fluctuating, aligning more closely with variations in rainfall, albeit with an increasing trend over time. Water level measurements have consistently been recorded below 4 mbgl.




Figure 7.18 Nagero Creek alluvial monitoring bores

Previous work completed by AGE (2021) analysed satellite imagery (Figure 7.19) and found a few isolated potential seep areas along Nagero Creek. These occurrences are limited and sporadic, and no clear evidence links them to groundwater discharge. Simulated water levels at potential seeps (Figure 7.20) conducted with the previous BTM Complex groundwater model found that simulated levels are responsive to recharge, although water table levels remain below the ground surface.

Human activities have significantly altered the hydrology of Nagero Creek. Numerous dams and reservoirs constructed along the creek appear to capture surface runoff (Figure 7.19), further disrupting any potential natural connectivity between surface water and groundwater.




LEGEND

- Potential Seeps
- Review Area
- Drainage

**Existing Alluvial Monitoring Bores**

- BCM - Active
- TCM - Inactive

**BEP Series Alluvial Monitoring Bores**

- Installed 2024/2025

- BCM Project Boundary
- BCM Open Cut Extent

Groundwater Impact Assessment Boggabri Coal Mine Modification 10 (BCO5002.001)

## Nagero Creek study area and potential seeps (AGE, 2021)

DATE
26/05/2025

AGE

FIGURE No:
**7.19**

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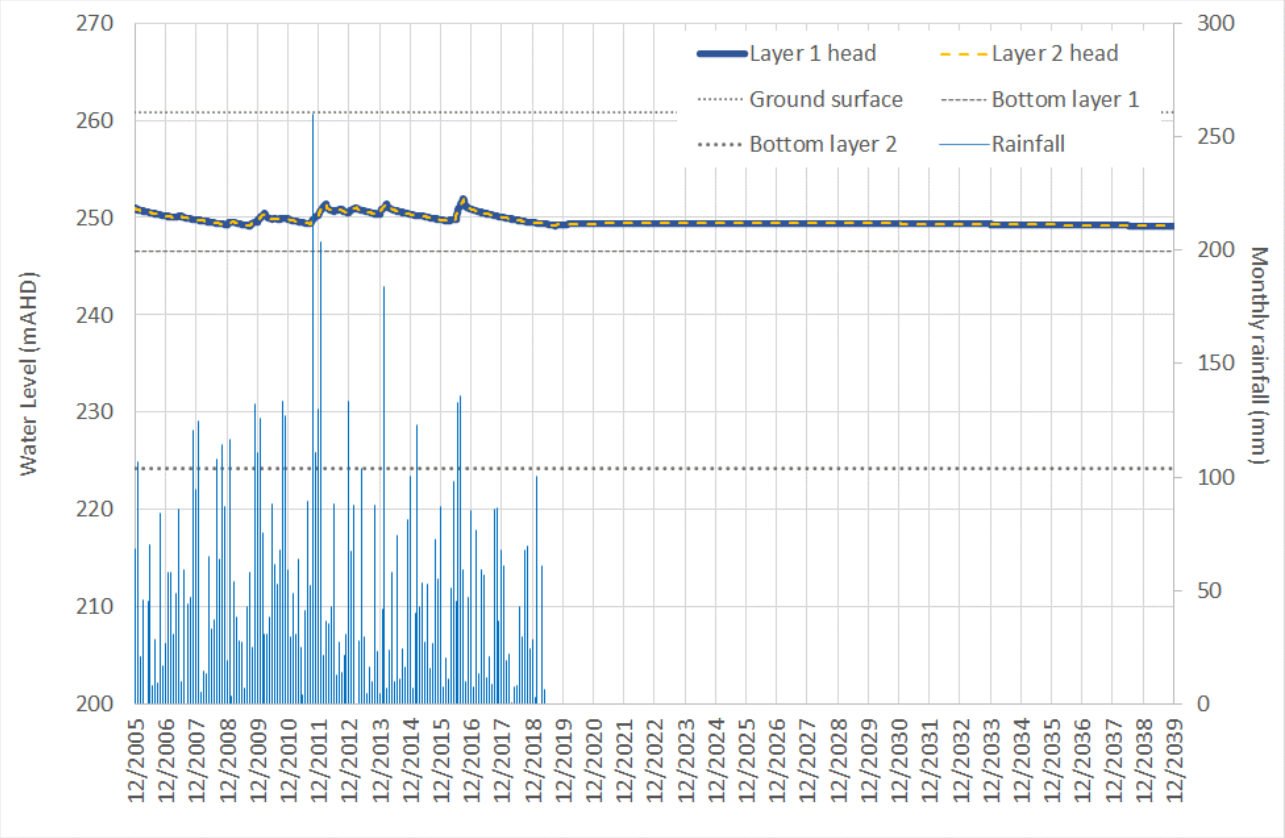



Figure 7.20 Modelled heads adjacent to potential groundwater seep – Nagero Creek N5 (AGE, 2021)

### 7.7.3 Bollol Creek

The headwaters of Bollol Creek originate in a forested, hilly region about 20 km east of TCM. Monitoring is conducted by TCM, BCM and the BTM complex along the length of the creek. Groundwater levels fluctuate in response to changes in rainfall, varying in amount (Figure 7.21). Bores located upstream (REG7A, Templemore A, and GW044997) demonstrate a strong correlation with variations in rainfall; however, water levels are generally greater than 5 mbgl. Bores MW2 and MW5, located south of TCM and installed in the shallow alluvium between 4 mbgl and 8 mbgl, record shallower depths to water averaging between 2 and 4 mbgl. Bores MW4 and GW052266, located further downstream, demonstrate a more subdued response to rainfall and water levels consistently below 7 mbgl.

AGE (2021) identified potential groundwater seeps within the Bollol Creek downstream of the BTM Complex (Figure 7.22). Two additional monitoring bores (BEP_11a and b) have been installed by BCOPL adjacent to these potential seeps in the upper and lower alluvium. The screened interval in the upper alluvium is dry, while the screen interval in the lower alluvium contains moisture held within the rock material but not flowing water. Simulated water levels at potential seeps (Figure 7.23) conducted with the previous BTM complex groundwater model found that simulated levels are responsive to recharge, although water table levels remain below the ground surface.

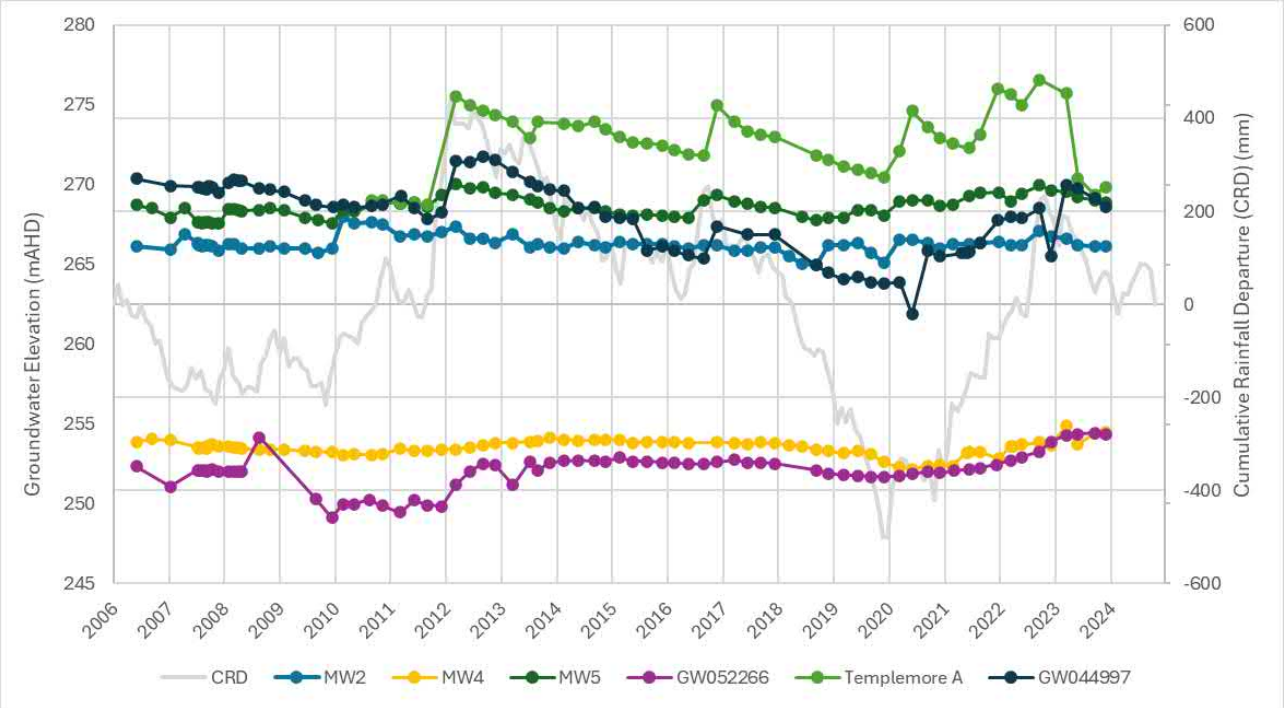
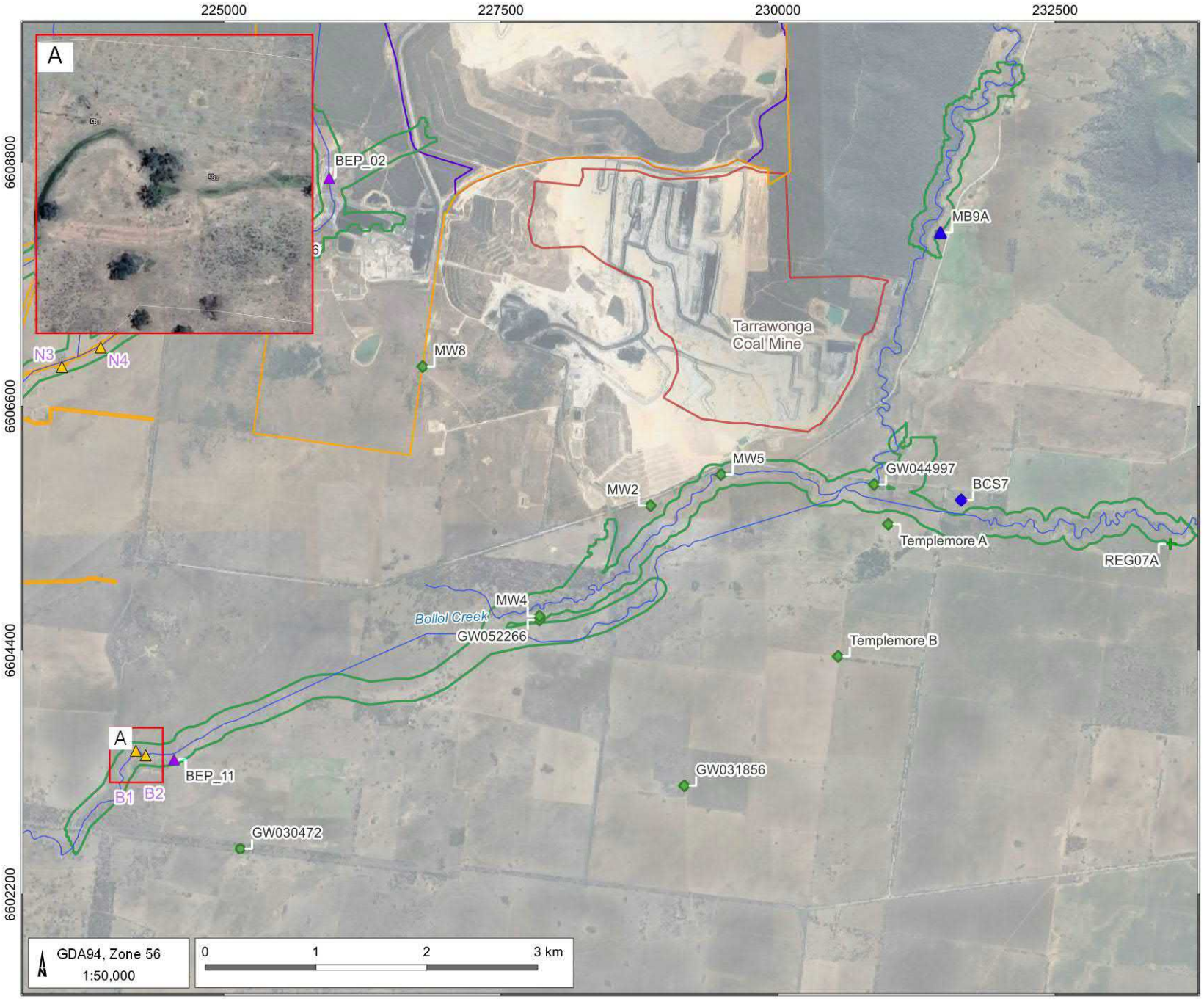



Figure 7.21 Bollol Creek alluvial monitoring bores




LEGEND

- Potential Seeps
- Review Area
- Drainage

**Existing Alluvial Monitoring Bores**

- BCM - Active
- BCM - Unknown
- Cumulative - Active
- DPI Water - Active
- TCM - Active
- TCM - Inactive
- TCM - Unknown

**BEP Series Alluvial Monitoring Bores**

- Installed 2024/2025

- BCM Project Boundary
- BCM Open Cut Extent
- TCM Open Cut Extent

Groundwater Impact Assessment Boggabri Coal Mine Modification 10 (BCO5002.001)

## Bollol Creek study area and potential seeps (AGE, 2021)

DATE
26/05/2025

AGE

FIGURE No:
**7.22**

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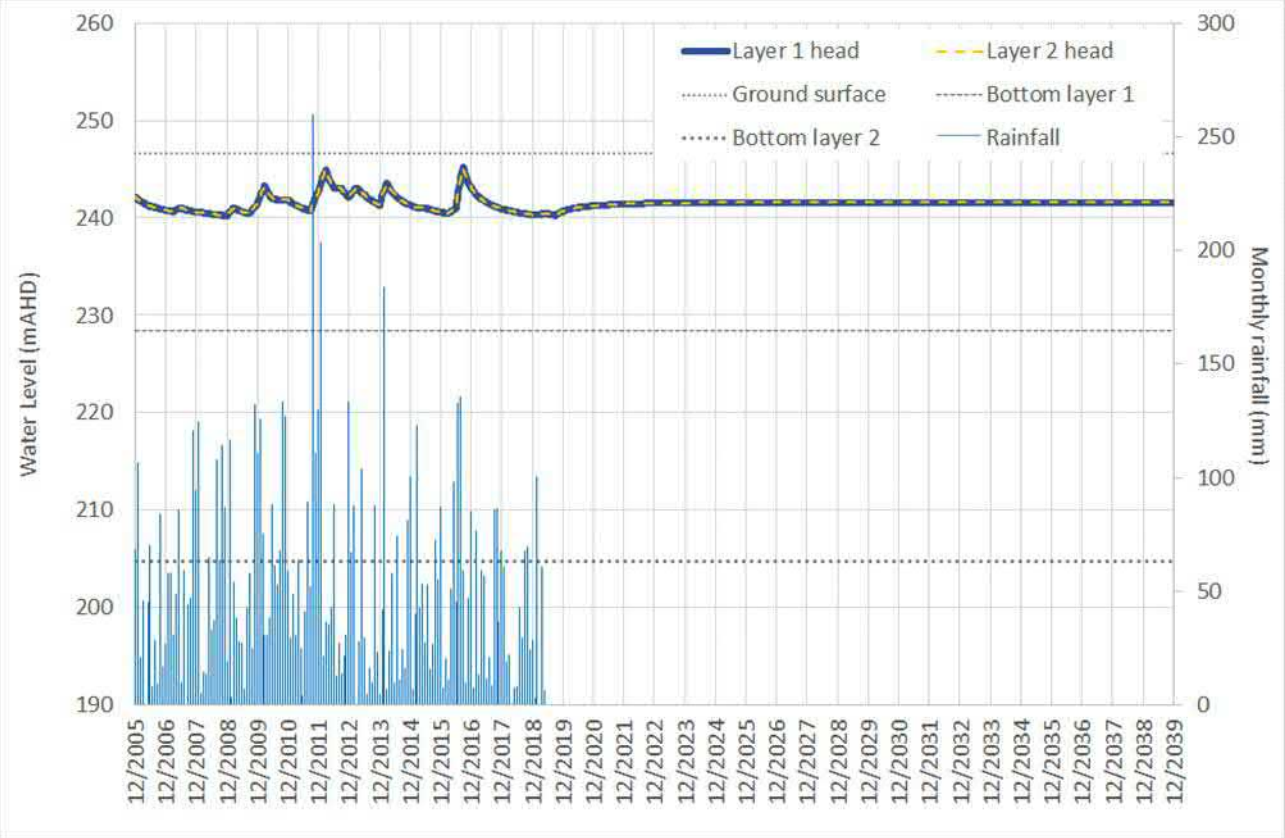



Figure 7.23 Modelled heads adjacent to potential groundwater seep – Bollol Creek B1/B2

## 7.8 Recharge

Rainfall is the principal means for diffuse recharge to the groundwater regime in the study area. The amount of water that eventually reaches underlying groundwater systems depends on various factors, including climate, soil, vegetation, geology, and terrain characteristics. Rainfall recharge cannot be directly measured, but can be indirectly estimated. AGE (2022) used several methods to estimate rainfall recharge, including a soil moisture balance, chloride mass balance (CMB), and water table fluctuation.

The chloride mass balance method provides an estimate of long-term average recharge. The method indicated that long-term recharge rates are relatively modest, at less than 1% of annual rainfall within the alluvium and less than 1.3% in the Permian coal measures and volcanics. The Namoi bioregional assessment (Aryal et al., 2018b) also used the chloride mass balance method to estimate rainfall recharge. Estimates of groundwater recharge were similar, ranging from less than 1% to 6% of annual rainfall, for the Maules Creek Formation/Boggabri Volcanics and the Namoi Valley alluvial aquifer, respectively.

In contrast to the chloride mass balance method, the soil moisture balance method described by AGE (2020) provides a daily time series of estimated recharge. The time series highlights episodic recharge and its relationship to climatic conditions, particularly during the La Niña and El Niño periods. During El Niño droughts, recharge can be zero in the alluvial aquifer and up to approximately 10% of rainfall in wetter La Niña years.

Previous numerical modelling efforts documented by AGE (2020) estimates recharge from the soil moisture balance method were applied to two zones in the model, representing the geology and terrain. The zones represented the main geological formations of the alluvial plain, Permian coal measures, and Boggabri volcanics, as well as a zone at the break of slope around the edge of the alluvial plain and a zone along creek beds where enhanced recharge occurred.

As part of the BTM Complex model update utilised for MOD 10, an enhanced soil moisture balance method was utilised to provide a spatially varying time series recharge estimate. The technique maps the spatial distribution of rainfall, evapotranspiration, soil characteristics, land use and geology and is described fully in Appendix F. The method provided a recharge time series for numerical modelling, with the average recharge rates for each zone shown in Appendix F. The updated spatial recharge model highlights episodic recharge and its relationship to climatic conditions, particularly during the La Niña and El Niño periods. During La Niña droughts, recharge can occur across the entire region and then exceed 50 GL/yr in wetter La Niña years. Variability in recharge rates due to climate change has been further explored in Appendix F.

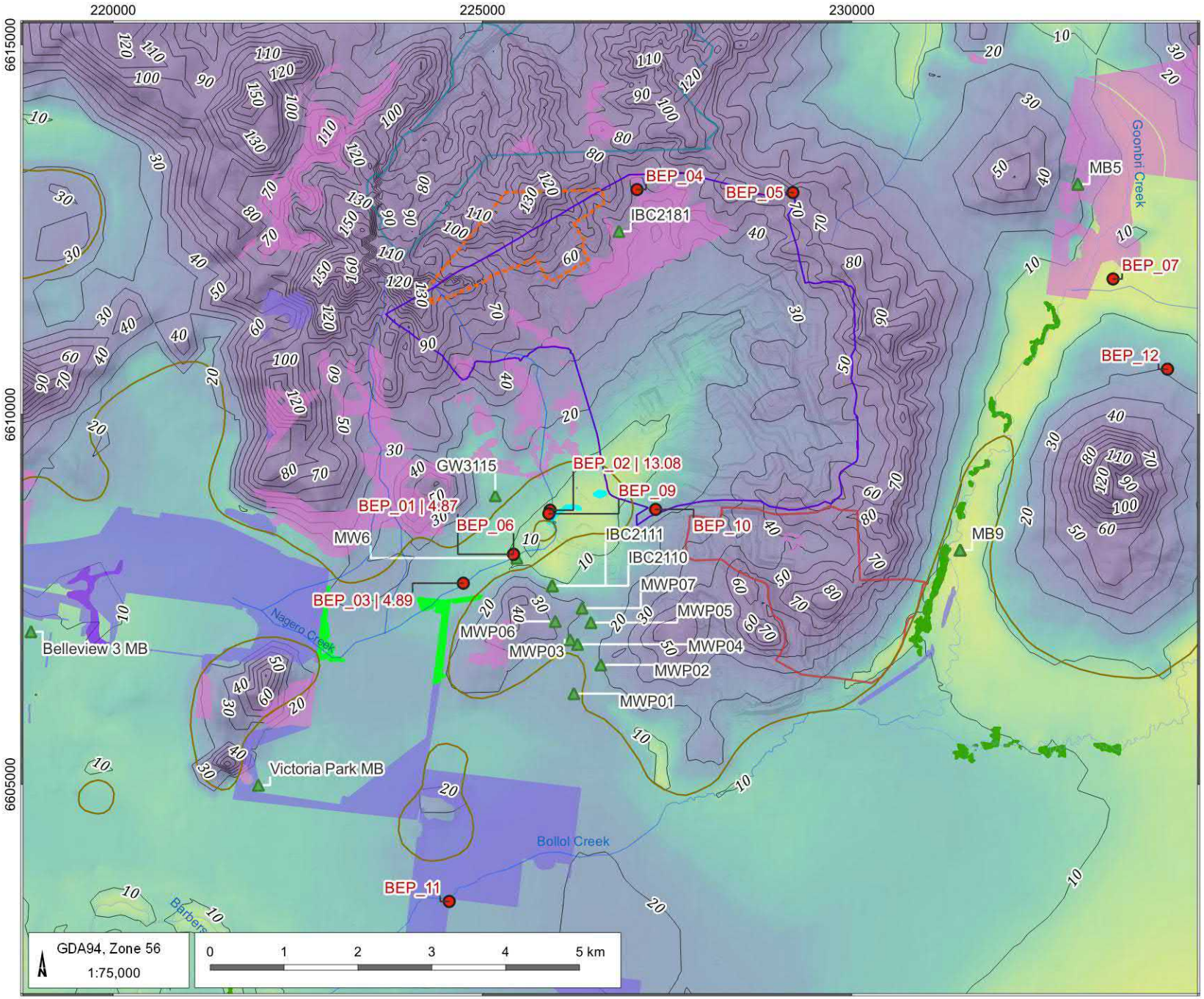
## 7.9 Discharge

Discharge from the groundwater regime occurs via a number of mechanisms, including:

- evapotranspiration via deep-rooted riparian vegetation stands;
- pumping via stock, domestic and irrigation bores;
- interception of groundwater in mining areas; and
- discharge as baseflow to the Namoi River and ephemeral creeks.

### 7.9.1 Evapotranspiration

Recent drilling on the ridge north of BCM at BEP_04a recorded a water level greater than 140 mbgl, with other areas around the BTM complex recording depth to water table from 50 to 100 mbgl. Depth to water (Figure 7.24) is controlled in parts by topography, with high elevations having a higher depth to water. The water table is closer to the surface in the low-lying alluvial plains, with water levels commonly below 2 mbgl at plains cleared of deep-rooted vegetation. Therefore, evapotranspiration is not considered significant. Evapotranspiration is likely to occur along vegetated creeks and riverbeds, where the water table is closer to the surface. Evapotranspiration methods applied to the model are included in Appendix F.




LEGEND

- Planned monitoring network
- Current monitoring network
- Drainage
- Contour lines
- MCCM open cut extent
- BCM Open Cut Extent
- TCM Open Cut Extent
- BCM Modification Mining Area
- Alluvium

**EPBC mapped and WSP field verified GDEs**

- Poplar Box Grassy Woodland on Alluvial Plains
- White Box – Yellow Box – Blakely's Red Gum Grassy Woodland
- Natural grasslands on basalt and fine-textured alluvial plains
- Poplar Box Grassy Woodland on Alluvial Plains
- White Box-Yellow Box-Blakely's Red Gum Grassy Woodland

**GDEs Priority**

- High
- Medium

**Depth to water (m**

| | |
|---|---|
| 0 | 16 |
| 5 | 20 |
| 9 | 30 |
| 10 | 50 |
| 12 | 305 |
| 15 | |

Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

## Simulated depth to water (no mining)

DATE
28/04/2025

AGE

FIGURE No:
**7.24**

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### 7.9.2 Groundwater abstraction from production bores

Groundwater abstraction for irrigation (and mining) purposes occurs predominantly within the alluvium, with most bores located within the Namoi River alluvium. BCOPL is licenced to take groundwater from supply bores approximately 7 km west of the mine in Zone 4 of the Upper Namoi Groundwater Source. The water allocation for this activity and the incidental take from mining is 1,028 ML/year. Methods applied to include abstraction are outlined in Appendix F.

### 7.9.3 Interception of groundwater in mining areas

BCM does not directly intersect any highly productive aquifers. Therefore, groundwater entering the mining area is not substantial compared to mining operations in more permeable and porous environments. Groundwater is not a concern for mining activities at BCM, and advanced dewatering prior to mining is unnecessary. The groundwater intersected in the mining areas is commonly evident only as damp evaporating seeps in active mine faces. Since the onset of mining, groundwater inflow to the BCM void has peaked at approximately 600 ML/year in 2020. Between 2017 and 2023, groundwater inflow ranged from about 250 to 400 ML/year, with the most recent reported inflow being 321 ML/year in 2023 (Idemitsu, 2023). The water allocation for the Gunnedah Oxley Basin Murray Darling Basin Groundwater Source is 842 ML/year.

## 7.10 Water balance

The estimates of recharge and discharge provided in Section 7.8 and Section 7.9 can be used to prepare a conceptual water balance for the area. Table 7.4 presents a summary of the water balance components. It shows that an estimated 15 GL to 27 GL of water enters and leaves the groundwater regime annually.

Table 7.4 Conceptual model water balance

| Water balance components | IN megalitres per year | OUT megalitres per year |
|---|---|---|
| Rainfall recharge | <1,000 – 50,000 (average – 12,500) | - |
| Evapotranspiration | - | 2,400 |
| Irrigation bores | - | 2,000 – 10,000 |
| Stock/domestic bores | - | 100 – 300 |
| Namoi River baseflow | 0 | 0 – 1,000 |
| Namoi alluvium inflow/outflow | 7,000 | 12,000 |
| New England Fold Belt fractured rock inflow | 1,100 | - |
| Mining interception | - | 600 – 1,000 |
| **Total** | **<9,100 – 58,100** | **17,100 – 26,700** |

## 7.11 Groundwater quality

Salinity has a significant influence on the beneficial use of groundwater. Generally, it correlates to electrical conductivity (EC), which can be used to categorise groundwater quality using the following ranges (FAO, 2013):

- Fresh water <700 µS/cm
- Brackish (slightly saline) 700 to 2,000 µS/cm
- Moderately saline 2,000 to 10,000 µS/cm
- Saline 10,000 to 25,000 µS/cm
- Highly saline 25,000 to 45,000 µS/cm
- Brine >45,000 µS/cm

Pena-Arancibia et al. (2016) show that the salinity of the investigation area is variable, with fresh groundwater generally limited to bores adjacent to the Namoi River, Barbers Lagoon, and Maules Creek. Moving away from these drainage features shifts groundwater salinity to brackish or moderately saline. Regionally, the alluvial groundwater quality of the Namoi subregion is characterised by a median electrical conductivity (EC) value of 1,013 µS/cm. EC values through time in the alluvial aquifer (Figure 7.25) show that the groundwater sampled is brackish to moderately saline, with relatively stable trends over time. Bores Bellevue 3 and Cooboobindi are both located some distance away (approximately 2,800 m and 1,700 m, respectively) from their closest fresh surface water source, the Namoi River, which may be why the EC values for these bores are higher than the median EC value for the alluvial system more generally. Monitoring in alluvial bore MW6, located directly southwest of BCM, reveals that the bore has been moderately saline on average, with a median electrical conductivity (EC) of approximately 2,250 µS/cm. This bore lies adjacent to Nagero Creek, a relatively small surface water drainage, and its catchment is partially occupied by BCM.

In the Boggabri volcanics, groundwater sampling (Figure 7.26) indicates that groundwater is moderately saline. Bore GW3115 recorded a fresh groundwater sample in 2023, which shows a significant deviation from the otherwise stable electrical conductivity (EC) trend. This bore shows the highest recorded EC out of the monitoring bores, with a mean EC value of 3,270 µS/cm.

Salinity within the Merriown coal seam (Bore IBC2181) (Figure 7.27), which was dry and has not been sampled since 2022, shows that groundwater is fresh to brackish and did not change significantly during the sampling period.

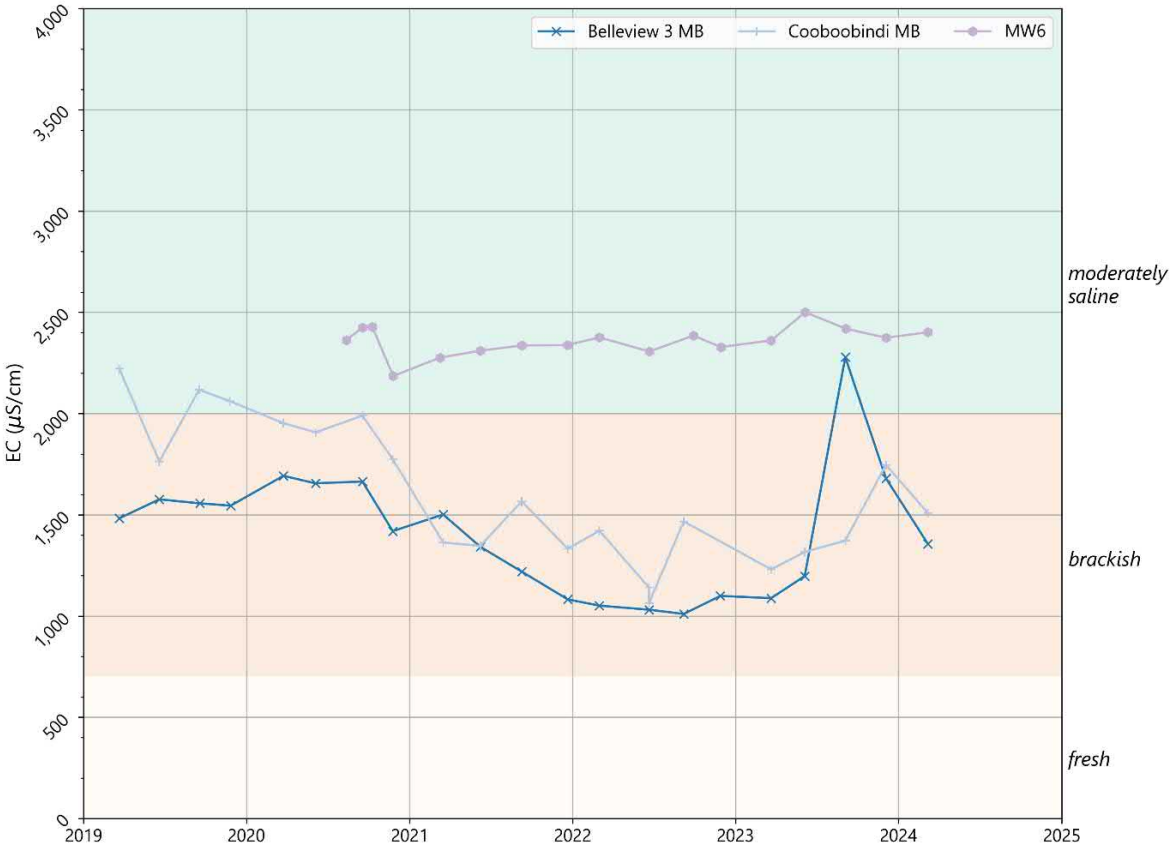



Figure 7.25 Salinity (EC) over time alluvial monitoring bores

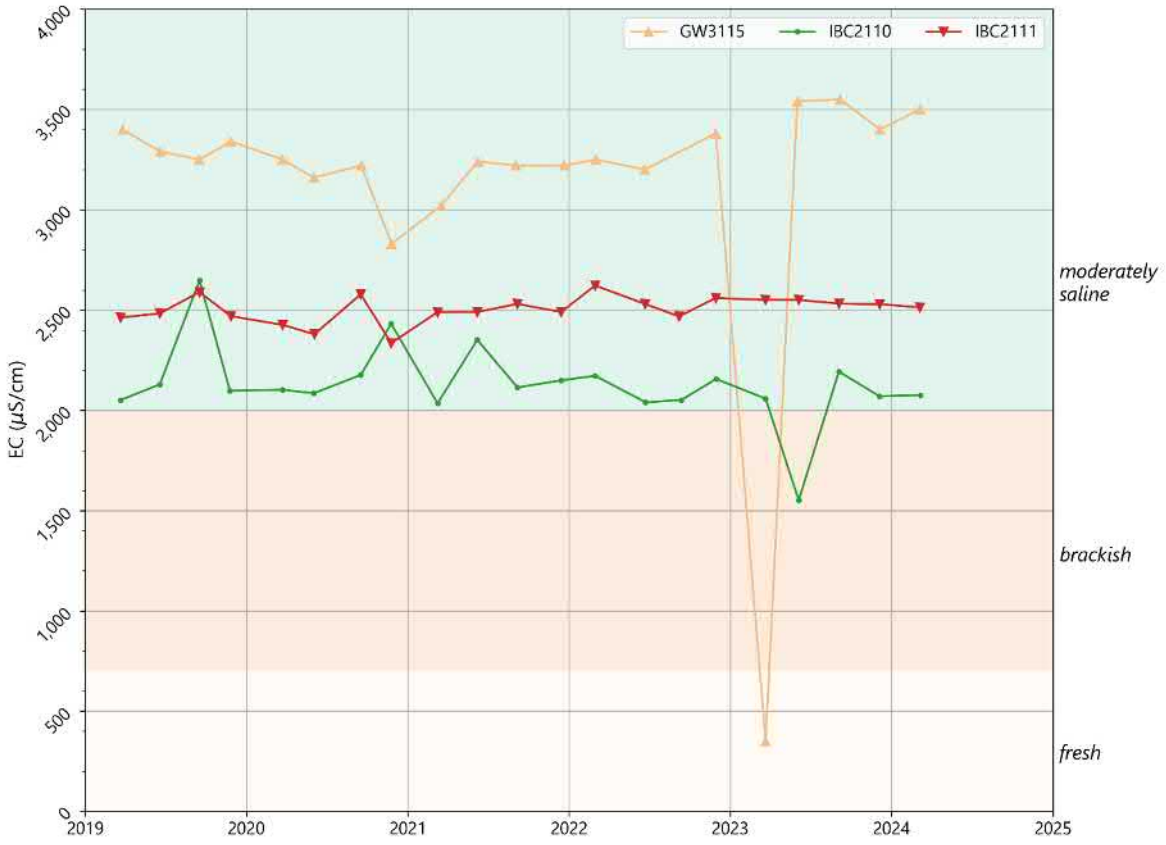



Figure 7.26 Salinity (EC) trends through time for bores sampling the Boggabri volcanics




Figure 7.27 Salinity (EC) trends through time for bores sampling the Merriown coal seam

Sulfate concentrations sampled across the site in the alluvial aquifer (Figure 7.28), Boggabri volcanics (Figure 7.29) and the Merriown coal seam (Figure 7.30) are all relatively low (< 250 mg/L). Sulphate trends in the alluvial aquifer show some variability through time. However, it is not clearly increasing or decreasing, and the cause of the variability is not clear.

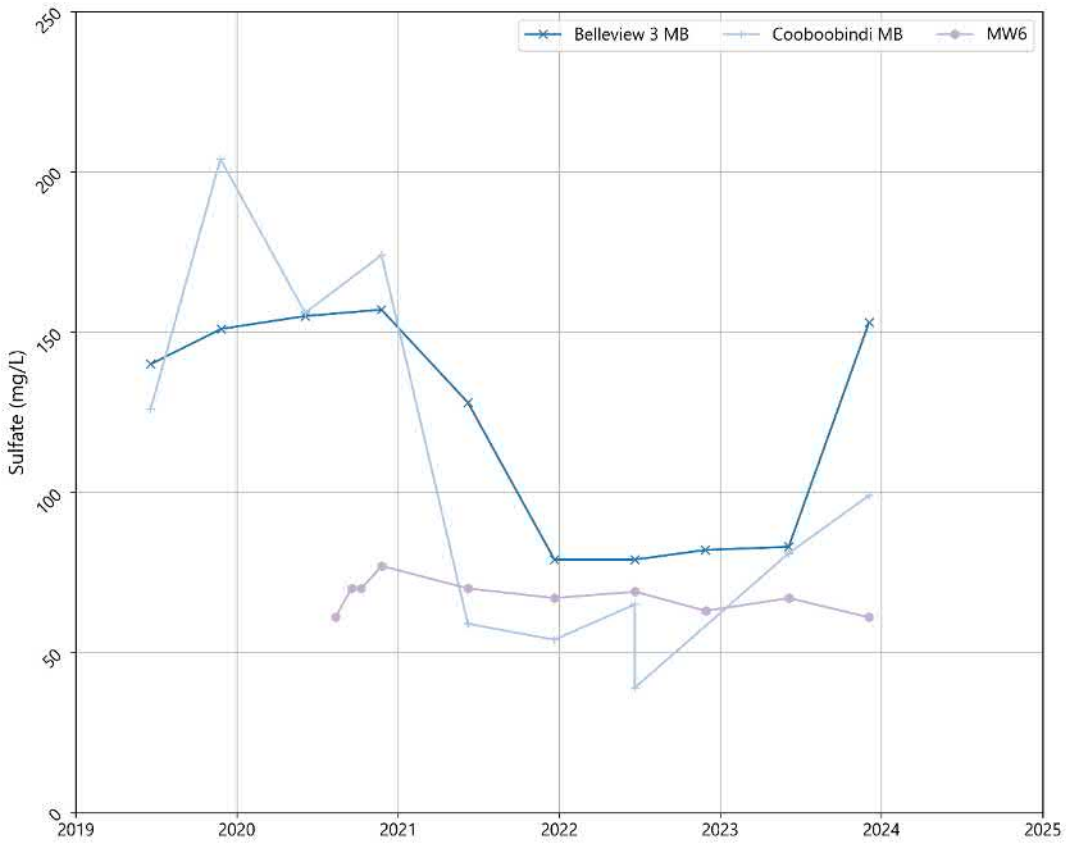



Figure 7.28 Sulfate trends through time for bores sampling the alluvial aquifer

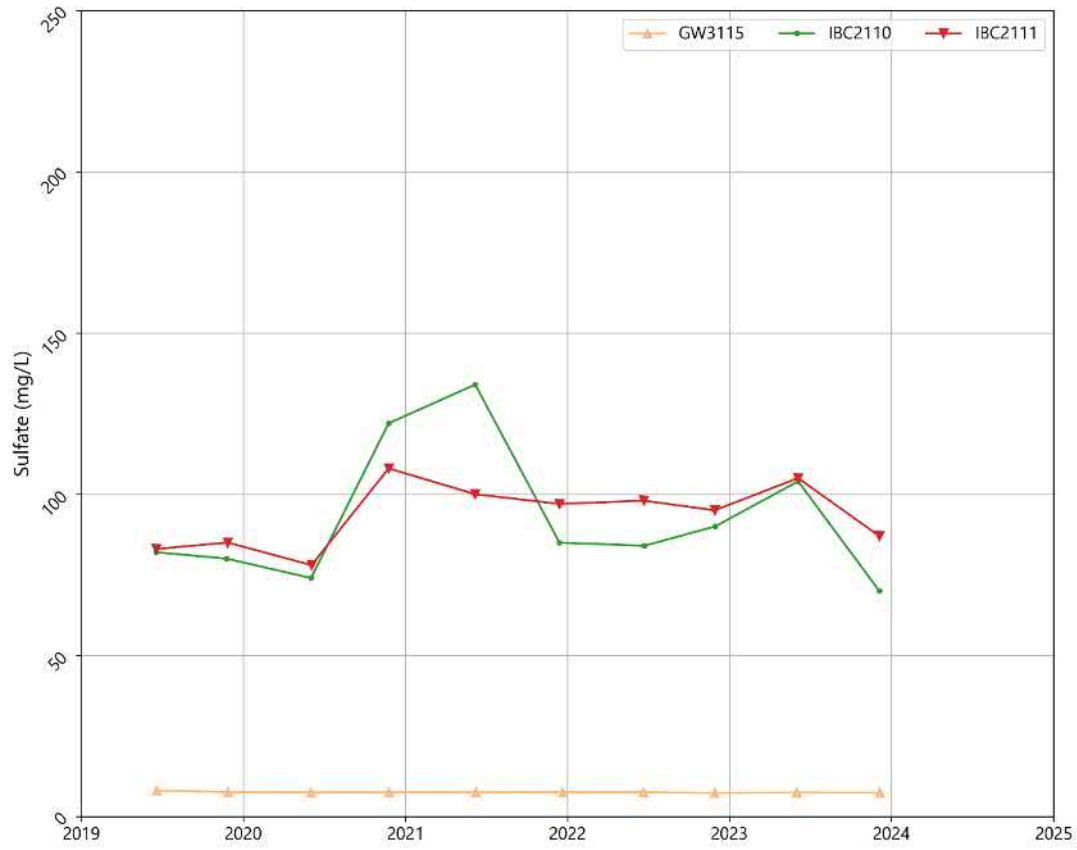



Figure 7.29 Sulfate trends for bores sampling the Boggabri volcanics

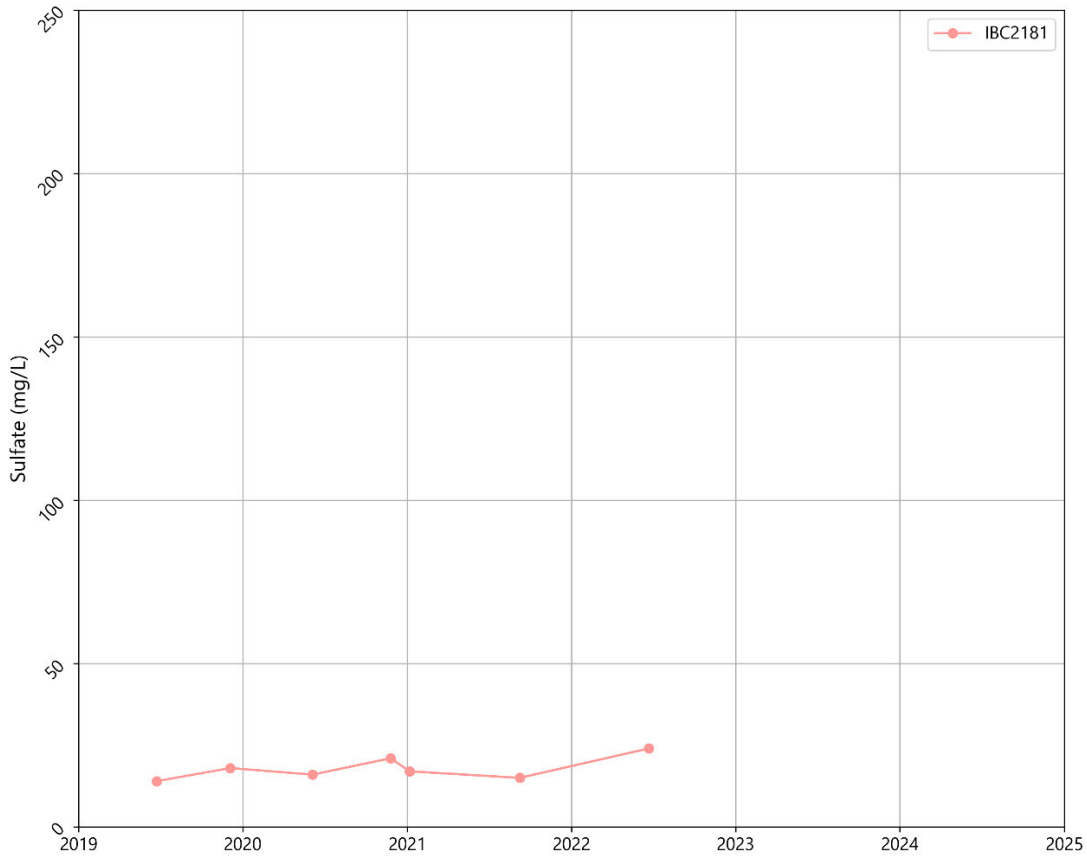



Figure 7.30 Sulfate trends for bores sampling the Merriown coal seam

Across the site, the pH of groundwater predominantly ranges from neutral to slightly alkaline. No notable trends in pH are present. In the alluvial aquifer (Figure 7.31), the lowest pH was measured in bore MW6, close to the BCM. The other two bores, Belleview 3 and Cooboobindi, are slightly more alkaline and closer to the Namoi River. Within the Boggabri volcanics (Figure 7.32), groundwater is generally close to neutral but exhibits some variability, likely due to the highly heterogeneous nature of the Boggabri volcanics. Bores IBC2111 and IBC2110 show different pH values even though they are located very close to one another; this difference in pH is, therefore, potentially related to their screen depths with IBC2111 shallower (36 to 42 mbgl) and slightly more acidic (but still close to neutral) compared to IBC2110 (91 to 97 mbgl). Groundwater in the Merriown coal seam (Figure 7.33) shows a similar trend, with neutral conditions remaining relatively stable over time.

Further details on the locations, frequency, and analytes sampled by BCOPL can be found in the BCM groundwater management plan (BCOPL, 2017c) and the BTM Complex water management strategy (Resource Strategies, 2019).

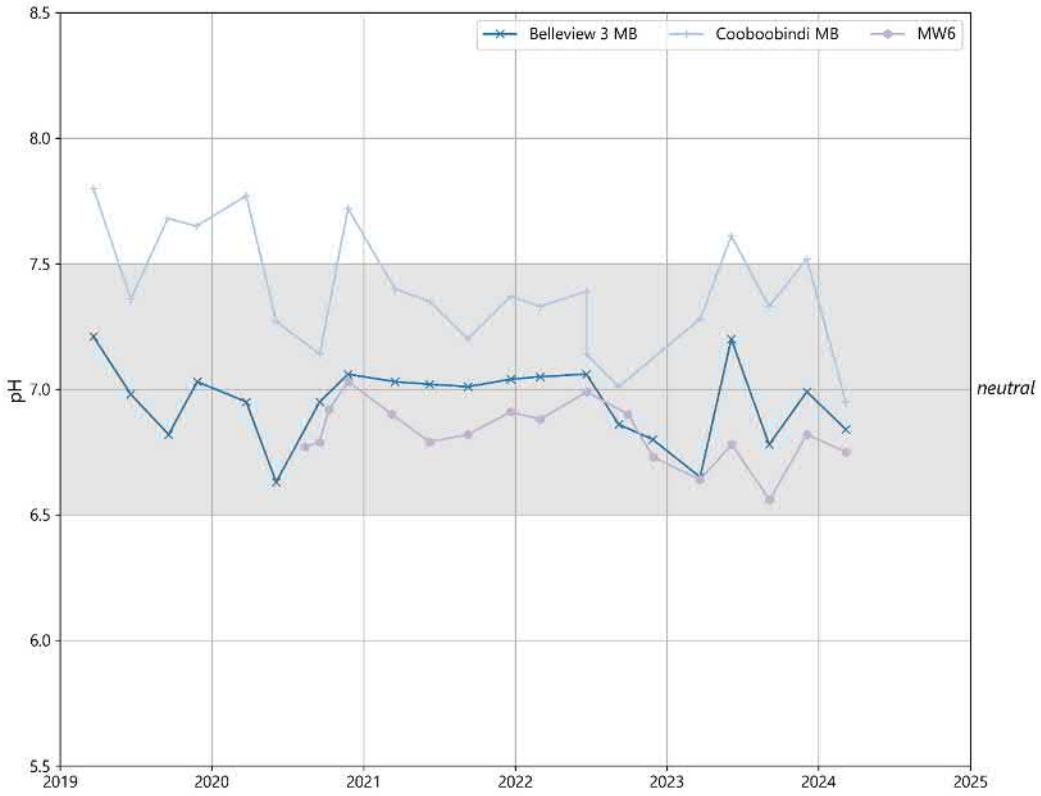



Figure 7.31 pH trends for bores sampling the Alluvium aquifer

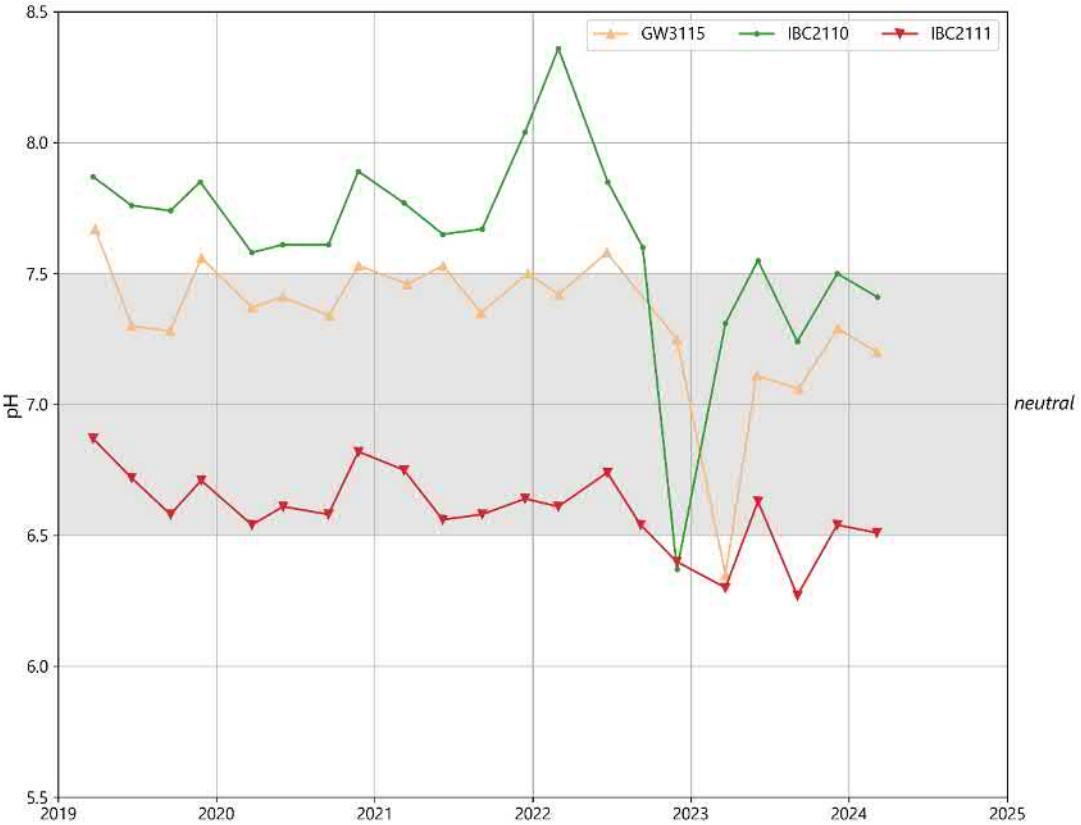



Figure 7.32 pH trends for bores sampling the Boggabri volcanics




Figure 7.33 pH trends for bores sampling the Merriown coal seam

## 7.12 Environmental Receptors

Potentially sensitive environmental receptors identified in the minimum groundwater modelling requirements (NSW Department of Planning and Environment, 2022c) likely associated with the groundwater regime are:

- Culturally Significant Sites;
- water supply bores utilised for agriculture; and
- aquatic, terrestrial and subterranean GDEs.

### 7.12.1 Culturally Significant Sites

The WSP for the Namoi Alluvial Groundwater Sources and the WSP for the NSW Murray Darling Basin Porous Rock Groundwater Sources do not identify any Culturally Significant Sites in the project area.

### 7.12.2 Private groundwater bore users and bore census

There are 1,060 registered bores (Figure 7.34) within the BTM model extent (NGIS 2024), these bores are categorised as follows:

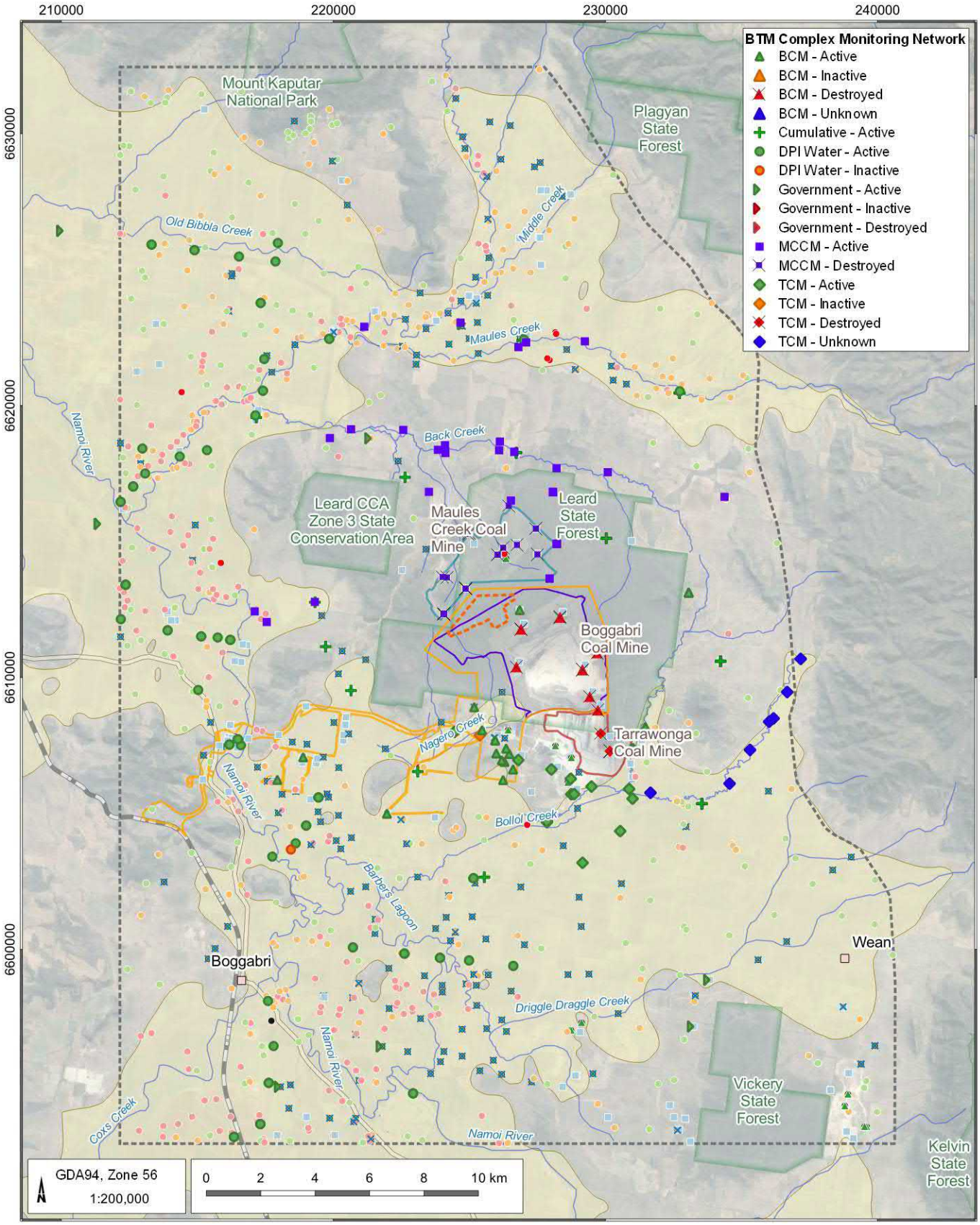
- 279 monitoring bores;
- 202 water supply bores;
- 200 irrigation bores;
- 183 stock and domestic bores;
- 1 commercial and industrial bore;
- 11 exploration bores;
- 183 bores with an unknown purpose; and
- 1 bore listed as other.

Bores licensed to extract groundwater are located primarily across the alluvial aquifers. The most substantial volumes of water are extracted from bores adjacent to the Namoi River. These areas of high extraction generally coincide with identified irrigation areas (Janardhanan et al., 2018).

A field hydrocensus was conducted within a ±13 km radius of the BTM complex in 2023 to identify groundwater users within the predicted zone of influence of the mine. This survey included registered bores from the NGIS and WaterNSW databases and unregistered bores identified by landowners during the census. A total of 190 bores were surveyed in 2023. The locations of these are shown in Figure 7.35. Data collected during the bore census is provided in Appendix D.

The field data indicate that 59% of the surveyed boreholes are functional, 27% are abandoned, and 14% could not be located. The bores identified in the study area were predominantly shallow, typically less than 15 m deep, and were primarily used for stock and domestic purposes. Factors influencing groundwater usage, as discussed with the local landowners, included the following:

- Several landowners reported that their bore/well went dry during the 2017/2018 drought or that the bores no longer produce a similar yield. Many landowners drilled additional boreholes in 2018 to supplement their yield; in many cases, these new bores were drilled adjacent to the dry bore.
- Some bores were drilled through a coal seam, and the quality was considered unsatisfactory.
- Several properties visited, primarily north of Maules Creek, had not been actively farmed for a significant period.
- The equipment installed in the bores was non-operational.




LEGEND

- Populated Place
- Principal Road
- Railway
- Drainage
- BCM Project Boundary
- BCM Open Cut Extent
- BCM Modification Mining Area
- MCCM Open Cut Extent
- TCM Open Cut Extent
- BTM Complex Model Extent
- Alluvium Extent
- State Forest

**Registered Bores**

- Commercial and Industrial
- Exploration
- Irrigation
- Monitoring
- Other
- Stock and Domestic
- Unknown
- Water Supply

Groundwater Impact Assessment
Boggabri Coal Mine Modification 10 (BCO5002.001)

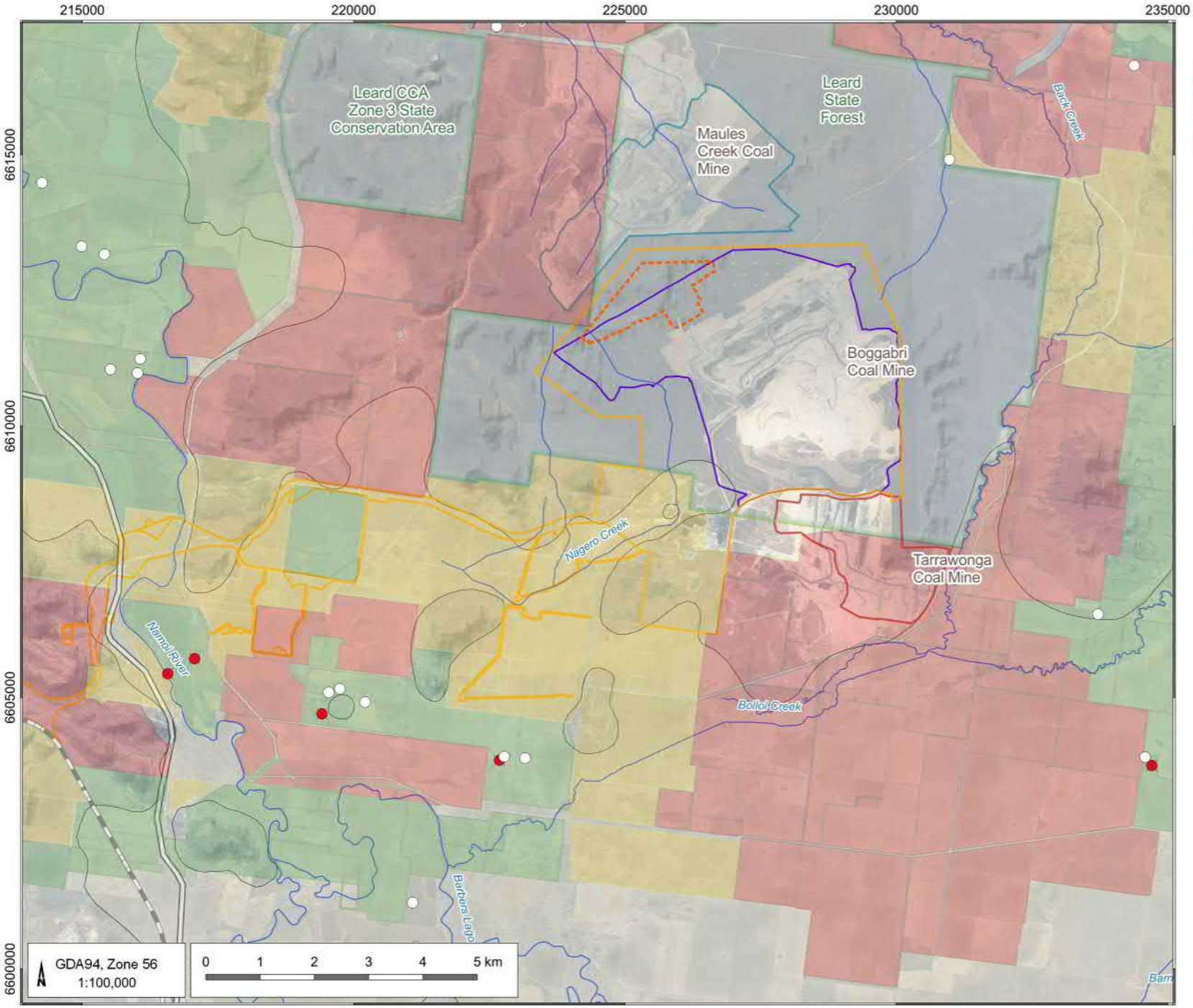
## Registered groundwater bores

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DATE 02/05/2025

FIGURE No: **7.34**

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LEGEND

- Drainage
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent
- State Forest

**Landholders**

- BCM
- Whitehaven or Aston Coal
- Private

**Bore Census**

- Abandoned
- Existing

Groundwater Impact Assessment Boggabri Coal Mine Modification 10 (BCO5002.001)

## Bore census (2023) locations and status

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### 7.12.3 Groundwater-dependent ecosystems (GDEs)

High-priority GDEs are specified in both the WSP for the Namoi Alluvial Groundwater Sources 2020 (NSW Government 2020a) and the WSP for the Murray Darling Basin Porous Rock Groundwater Sources 2020 (NSW Government, 2020b). High and moderate priority GDEs have been identified along northeastern sections of Bollol and Goonbri Creeks, as well as along Namoi River to the west of BCM (Figure 7.36).

Previous mapping, completed in accordance with the EPBC Act, identified threatened ecological communities that may be groundwater dependent. Ecological communities considered in this mapping include:

- Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland;
- Poplar Box Grassy Woodland on Alluvial Plains; and
- White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland.

Natural grasslands have been mapped on the Namoi River floodplain, where the water table is 5 mbgl to 10 mbgl. Given the shallow root systems, which are unlikely to reach the water table, the vegetation is not considered groundwater dependent.

Small patches of Poplar Box Woodland and Box Gum Woodland are mapped along Nagero Creek (Figure 7.37), which is immediately adjacent to the existing BCM mine infrastructure area within the alluvial tongue. The depth to the groundwater at this location is estimated to be less than 10 mbgl (see Figure 7.5). Investigations conducted during MOD 8 (WSP, 2022) and again for MOD 10 (WSP, 2025) concluded that the Box Gum Woodland communities associated with Nagero Creek have no apparent dependency on groundwater.

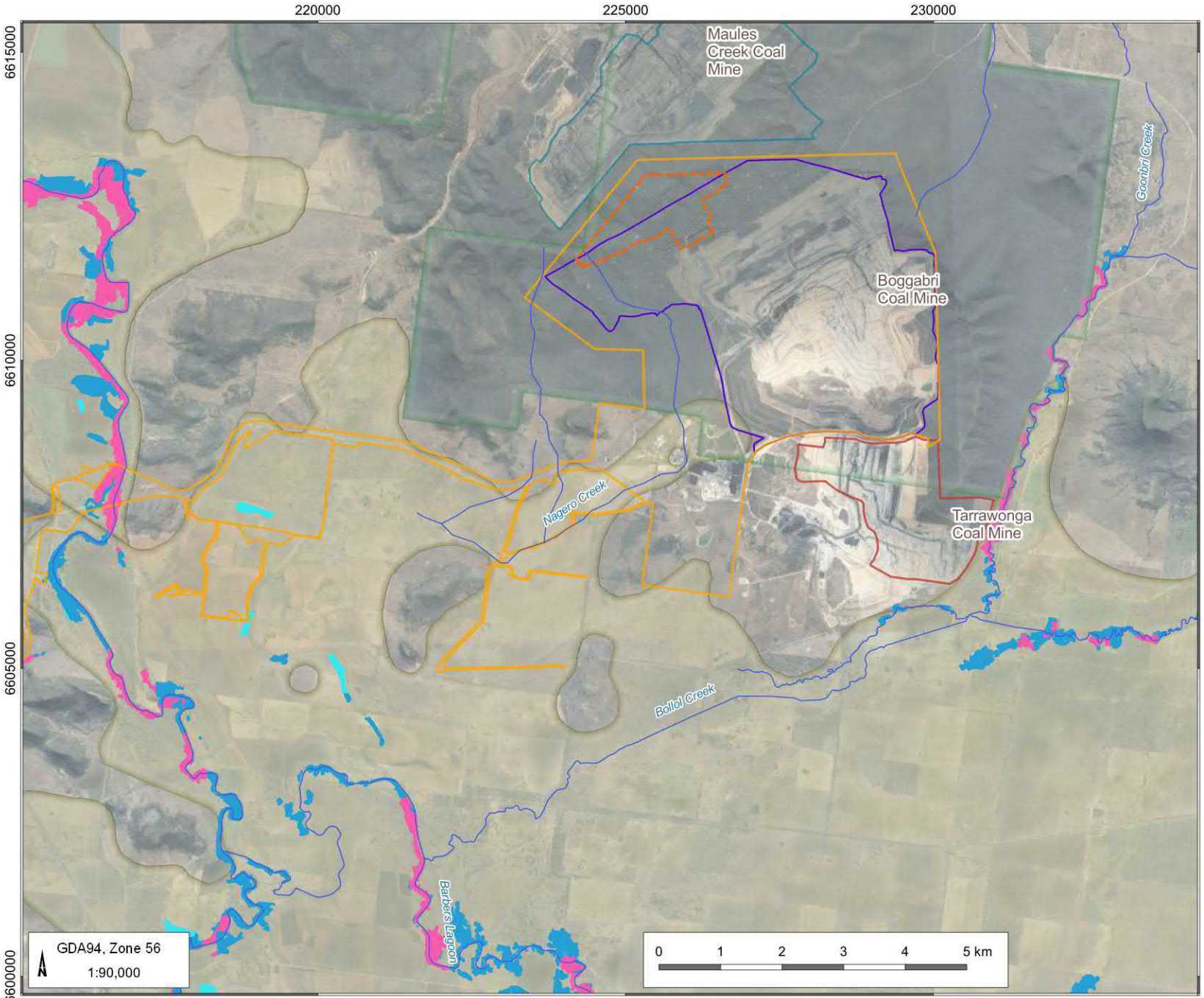
The Poplar Box Grassy Woodland is considered the only community with potential groundwater reliance associated with the Nagero Creek alluvium. Analysis of the leaf green index of Poplar Box (WSP, 2021) indicated reliance on surface/soil moisture. WSP (2025) reported that although they access soil water and perched aquifers, their extensive tap roots mean they are likely to use groundwater proportionally.

BCOPL has committed to installing additional groundwater monitoring bores in the Nagero Creek alluvium (Section 6.1) to track potential changes during mining operations. BCOPL also proposes to complete monitoring at terrestrial GDE monitoring sites along Nagero Creek to observe changes in vegetation conditions, specifically focusing on tree canopy health.

Bollol and Goonbri creeks are conceptualised as losing streams. The depth of the water table beneath the creeks suggests that groundwater drawdown would not affect their flow regimes or the associated GDEs and stygofauna.

According to BCM approved MOD 8, the IESC recommended collecting additional field data to increase confidence in the predicted impacts on GDEs along Nagero, Bollol, and Goonbri Creeks, including stygofauna. In response to these concerns, BCOPL included further studies prepared by WSP and Austral Research and Consulting in its submissions report. These studies incorporated updated native vegetation mapping, field verification of potential GDE terrestrial vegetation, remote sensing analysis of the green leaf index (across dry and wet periods), and targeted surveys of threatened aquatic fauna and stygofauna.

To address the IESC's concerns following the approved MOD 8, Austral Research and Consulting also conducted additional monitoring of aquatic fauna at 22 sites and stygofauna at 18 sites around the mine, within the Namoi River, and in Barbers Lagoon (a significant anabranch of the Namoi River). The stygofauna monitoring confirmed species at two sites and potential species at several other locations.




LEGEND

- Drainage
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent
- Alluvium Extent

**GDE HEVAE (WSP)**

- High
- Moderate
- Low

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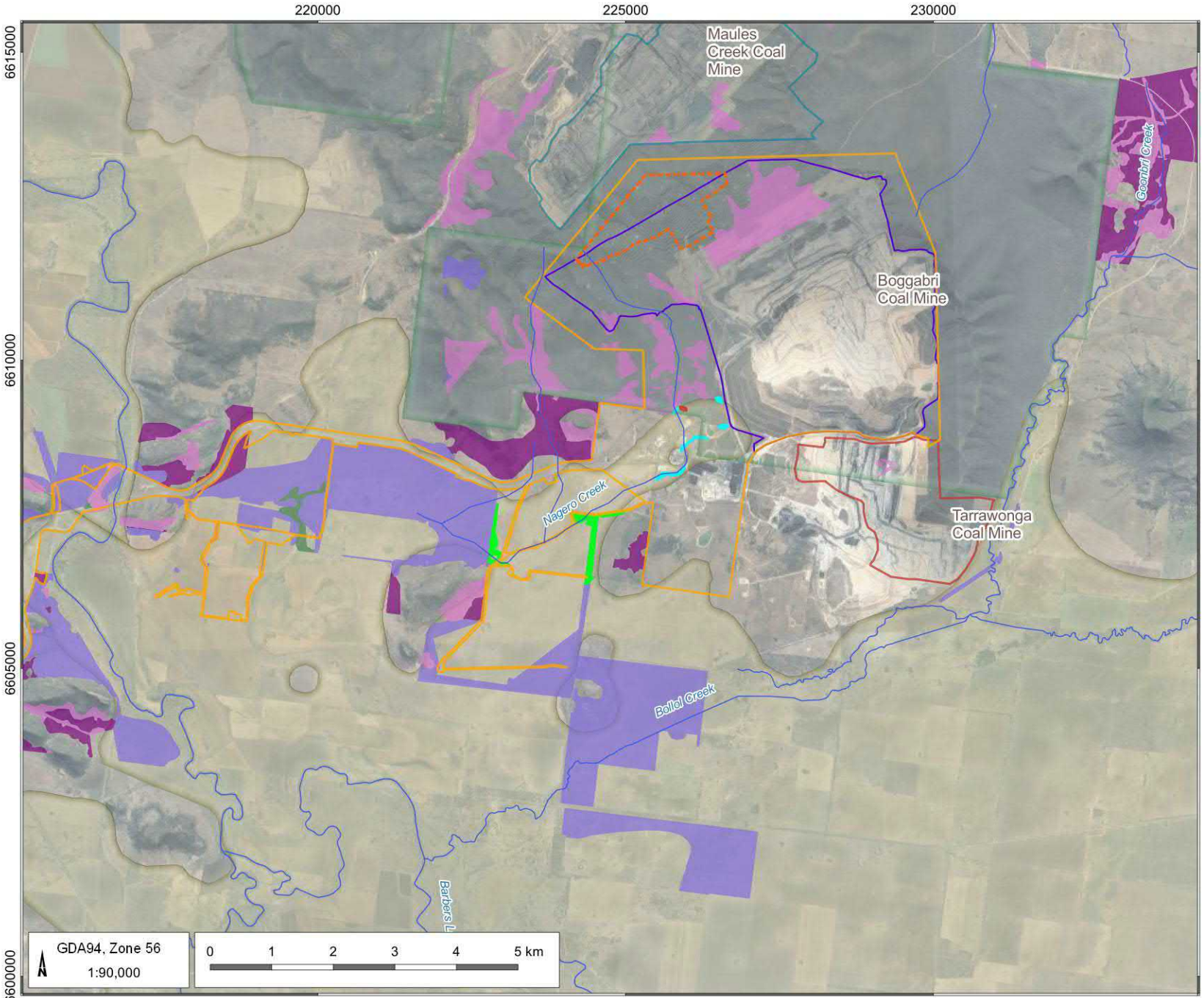
Groundwater Impact Assessment Boggabri Coal Mine Modification 10 (BCO5002.001)

## GDEs identified in the Water Sharing Plan for the Namoi Groundwater Source (NSW 2020)

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FIGURE No:
**7.36**




LEGEND

- Drainage
- Minor_250k
- BCM Project Boundary
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent
- Alluvium Extent

**GDEs (EPBC classification) Source WSP (2022) mapping**

- Natural grasslands
- Poplar Box Grassy Woodland
- Box Gum Woodland
- Box Gum Woodland and Derived Native Grassland
- White Box grassy woodland of the Nandew
- White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland
- Poplar Box Grassy Woodland on Alluvial Plains Class A1 Highest Quality Condition

Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

## EPBC nominated ecological communities

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FIGURE No:
**7.37**

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## 7.13 Conceptual model overview

As discussed in Section 7.2, the local geology can be divided into hydrostratigraphic units based on the ability to store and transmit groundwater (Table 7.5).

Table 7.5 BTM Complex - Hydrostratigraphy units summary

| Hydrostratigraphic units | Groundwater bearing type |
|---|---|
| Alluvial groundwater system (Narrabri and Gunnedah Formations) | Aquifer |
| Regolith/weathered Maules Creek Formation and Boggabri volcanics groundwater system | Aquifer/aquitard |
| Maules Creek Formation-Coal seams | Aquifer |
| Maules Creek Formation-Interburden | Aquitard |
| Fresh Boggabri volcanics | Aquitard |

Bore yields and field estimations of hydraulic parameters (Section 7.3) indicate that the Gunnedah Formation's deeper alluvium is the most productive groundwater system. This formation is highly productive, with high bore yields and low to modest salinity, allowing a range of beneficial uses.

Less productive groundwater systems are within the overlying alluvium of the Narrabri Formation and the Permian coal measures of the Maules Creek Formation. Interburden, comprised mainly of cemented conglomerate and sandstone, is relatively impermeable and serves as a confining layer, partially restricting groundwater flow between individual coal seams and the overlying alluvium. Basal volcanics also act as a relatively impermeable unit and are found underlying the alluvium and the Maules Creek Formation. A claystone formation at the contact between the Boggabri volcanics and the Maules Creek Formation may also retard groundwater flow between these formations.

### 7.13.1 Geological structures

Regional geological structures significant to the hydrogeological regime include the north-south striking Hunter-Mooki Thrust Fault System east of the BTM Complex and the northwest-southeast striking Conomos Fault south of the TCM (Figure 5.8). Groundwater flow is conceptualised to move across the Hunter-Mooki fault zone from the upgradient catchments of the Nandewar Range in the east into the Maules Creek Formation in the west. Depending on its local characteristics, the Hunter-Mooki fault zone is conceptualised as a conduit and a barrier.

The Conomos Fault is reported to have a vertical displacement of 60 m to 100 m, with the north block rising. Conceptually, given the low hydraulic conductivity of the interburden in the Maules Creek Formation and the associated vertical displacement, the fault likely reduces geological interconnectivity, with coal seams abutting the less permeable interburden, thereby limiting groundwater flow. Alternatively, faults can act as conduits through increased permeability or upthrow, resulting in a greater propensity for coal seams to be connected with more transmissive alluvial aquifers. The fault has, therefore, been conceptualised as a potential conduit and a barrier depending on its local characteristics.

Multiple minor northwest-striking normal faults have been mapped within the mine disturbance area, with offsets ranging from 1 m to 5 m, and no significant damage zones have been reported. These faults are expected to be local conduits but with limited regional influence. As is common in hydrogeological studies, there is uncertainty around the behaviour of faults and their influence on the conceptual model.

Appendix F outlines the approach to representing the faults in the numerical model based on the understanding developed from the conceptual model.

### 7.13.2 Groundwater levels and flow directions

Observed water level data indicate that the water table elevation and flow direction within the Namoi Formation alluvium are generally a reflection of topography, with groundwater in the higher elevation areas flowing towards the Namoi River. Groundwater discharge or outflow occurs via a series of different mechanisms:

- Under natural conditions, prior to mining and agricultural development, groundwater would have discharged into low-lying water bodies and drainage lines that intersected the water table, predominantly the Namoi River and downstream areas of Maules Creek. Groundwater discharge would also have occurred via evapotranspiration from deep-rooted vegetation.
- With the mining and agricultural development of the catchment, groundwater discharge also occurs via seepage and evaporation at the open cut mine face and through bores that abstract groundwater for agricultural and water supply purposes.

The natural groundwater system has been modified due to agricultural and mining activities. Historically, clearing land for agriculture and groundwater abstraction for stock, domestic, or irrigation purposes has altered and disrupted the natural groundwater flow and discharge pathways. This impact on the alluvial system is prominent in alluvial monitoring bores, where an overall decline in water levels has been observed in almost all bores. More recently, mining activities at the BTM Complex have altered the groundwater system of the Permian coal measures, with a significant reduction in water levels observed in bores near mined areas, as predicted during the approvals process for each mine. The magnitude of the drawdown diminishes with distance from the mining areas and up the hydraulic gradient east of the BTM Complex.

Water levels in most of the alluvial bores correlate to rainfall patterns, with rising water levels following above-average rainfall periods and falling water levels following periods of below-average rainfall. Seasonal abstraction of groundwater from the alluvium is frequently observed through large water level fluctuations in the deeper alluvial monitoring bores closer to irrigation areas along the Namoi River.

A prolonged decline in water levels, which goes beyond the usual seasonal variations, can also be observed in the alluvial areas. This long-term decrease is likely linked to the historical over-extraction of groundwater from these regions. This will also have caused interruptions to the natural flow and discharge pathways within the alluvium, e.g., lower groundwater discharge to the Namoi River as groundwater moving towards the river is intercepted by abstraction bores. In contrast, there are some areas where shallow groundwater levels have been observed to rise within the alluvium, potentially related to irrigation and/or a long-term increase in recharge due to clearing and land laser levelling.

Natural groundwater levels within the Permian coal measures are influenced by topography and the permeability of the different geological units. Groundwater recharged into areas at the highest topographical elevations typically flows towards regions with lower topographical elevations along the most permeable pathways. Therefore, flows are expected to be most significant within the more permeable and transmissive geological units and lower in the less permeable units. Multi-level bores installed in the eastern areas of the Maules Creek and Bollol Creek catchments typically show a vertically downward gradient through the entire profile monitored. This indicates that the east catchment is primarily a recharge area. The natural discharge of the Permian coal measures is inferred to occur further west at the interface with the Boggabri volcanics ridge, where the contrast in permeability and the influence of the Namoi River discharge zone are expected to promote an upward gradient from the bedrock to the alluvial aquifer. Groundwater is also discharged into the mined areas of the BTM Complex, where the mining depth exposes the coal seam face.

Bores along the outcropping Boggabri volcanics ridge typically show minimal water level fluctuations over the monitoring period. This suggests that the unweathered Boggabri volcanics have low permeability and will limit the propagation of any pressure changes generated in the coal measures during mining.

### 7.13.3 Hydrogeological conceptual cross-sections

The main hydrostratigraphic units and conceptual model elements are illustrated in hydrogeological sections in Appendix A. Some cross-sections are aligned to allow consideration of the mining areas, the intervening geology, the highly productive aquifers and receptors, including GDEs and water supply bores.

Potential connections between BCM and the alluvial groundwater system exist southwest of active mining, where a tongue of alluvium extends along the Nagero Creek. Coal seams are likely to subcrop beneath the easternmost section of the alluvium, where the alluvium extends beyond the Boggabri ridge.

Mining activities have altered the recharge pathways and groundwater flow paths in the vicinity of active mining areas. Pre-mining hydraulic gradients within the Permian coal measures would be expected to be similar to those still observed at the more peripheral monitoring sites. However, near the mines, the lowest pressures are observed in sensors located within the target coal seams, unlike the deeper sensors installed below the mining floors. Groundwater flows into the mining void along open fractures in the interburden and higher-permeability coal seams. Inflows are typically removed through pumping from in-pit sumps as required to keep the pits dry enough for safe working. Groundwater is also removed from the mining areas, tied up into the damp spoil or ROM coal, and via evaporation from pit wall seepages or in-pit storages and sumps.

A summary of the conceptual water balance is provided in Section 7.10. The primary inflows to the groundwater system are diffuse recharge from rainfall events, losing conditions from creeks and river reaches, and groundwater connectivity through the eastern thrust fault system. The main outflows to the system are evapotranspiration, groundwater abstraction and groundwater interception by the mine footprint.

### 7.13.4 Ecohydrological conceptual model

An ecohydrological conceptual model (ECM) integrates information on surface water and groundwater with ecological information on animal and plant species, communities and ecosystems to understand and communicate their interactions. In 2024, the IESC released a document providing guidance for specialist teams on the preparation of ECM for the impact assessment process (IESC, 2024). The recommended process involves a specialist team preparing an initial ECM and using it to generate an impact pathway diagram (IPD) of the proposed Project to predict potential impacts on environmental assets. This understanding then guides the data collection and impact assessment process.

In preparation for the BTM Complex modelling and project approvals, water and aquatic ecology specialists prepared an ECM and an IPD. This ECM is an extended version that covers the whole BTM Complex. In this assessment, the focus is on QoIs specific to BCM. Figure 7.38 shows the extended ECM/IPD that evolved from the original work. This figure illustrates:

- orange boxes: elements of the surface water and groundwater hydrological regimes;
- grey boxes:  water bodies and associated environmental receptors;
- yellow boxes: sources of potential stress on the environmental receptors;
- blue lines: linkages between elements of ECM; and
- red lines: linkages between the hydrological regime and receptors with labels indicating the type of stressor.

For this particular assessment, the ECM/IPD illustrates the potential risks MOD 10 poses to environmental receptors within the Nagero Creek alluvial aquifer. These risks were identified as:

- drawdown and reducing yield for water supply bores; and
- reduced groundwater availability for terrestrial GDEs.

Given Nagero Creek's ephemeral regime, the third potential risk depicted in Figure 7.38, i.e., drawdown reducing flow duration, is considered absent.

The impacts on terrestrial GDEs and water supply bores are considered QoIs for the numerical modelling and are further described in Section 9. Section 9.5 describes impacts on water supply bores and the Section 9.6 describes impacts at the site of terrestrial GDEs. The Groundwater Dependent Ecosystem Assessment by WSP (2025) discusses the potential impacts of reduced groundwater availability for terrestrial GDEs.

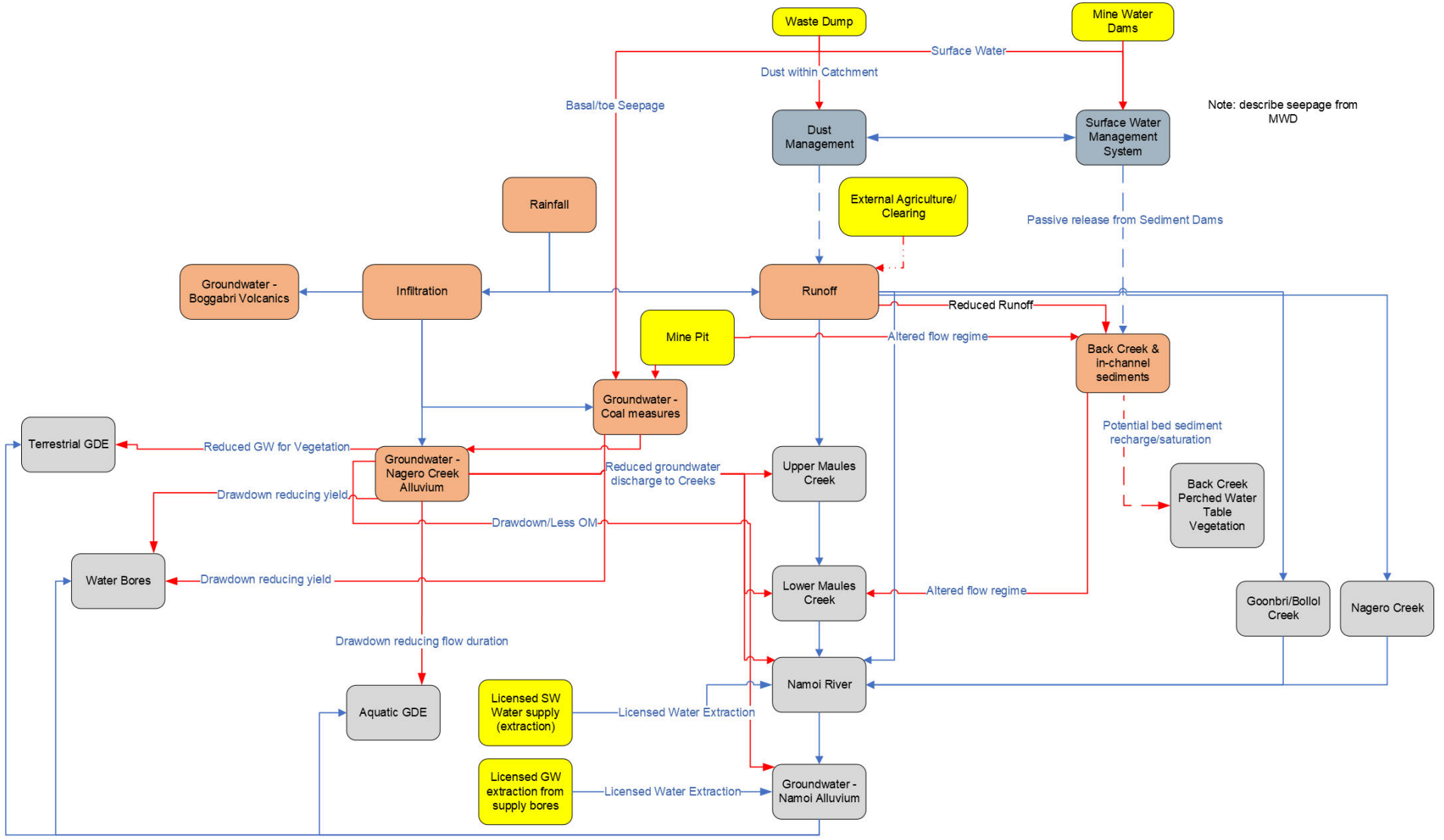



Figure 7.38 Ecohydrological conceptual model

# 8 Numerical model

The recently updated (2025) BTM Complex numerical model was used to assess the potential impacts of MOD 10 on the QoIs. A detailed description of the numerical modelling is provided in Appendix F which is intended to inform technical specialists in groundwater modelling. The report describes the model setup, calibration, predictions, and uncertainty analysis undertaken, as well as predictions of drawdown and water take for all three mines within the BTM Complex. This includes a proposed project at the adjacent MCCM, which is a foreseeable project within the BTM Complex, for which Whitehaven is preparing an application to support an SSD application at the time of writing this report.

The numerical model technical report presents model predictions for the BTM Complex and its surrounding region, as its purpose is to consider regional cumulative impacts. In contrast, Section 9 of this report focuses on the region immediately surrounding the BCM, including adjacent creeks and alluvial deposits. The Nagero Creek and Namoi River alluvial systems have been the main area of interest for MOD 10, as they are defined as QoIs following the IESC Guidelines: Explanatory Note on Uncertainty Analysis in Groundwater Modelling (Peeters & Middlemis, 2023). This provides a focus where potential receptors occur along Nagero Creek, and the Namoi River alluvial system to the west of the mine may be impacted as a result of MOD 10. For reference to the technical details of the numerical model, the reader should refer to Appendix F. The following paragraphs summarise the model setup, calibration, predictions, and uncertainty analysis.

The modelling process considered various guidance documents on groundwater modelling, including the Groundwater Assessment Toolbox (DPE 2022), the Australian Groundwater Modelling Guidelines (Barnett, et al., 2012), the Groundwater Modelling Decision Support Initiative (GMDSI) and uncertainty analysis guidelines prepared for the IESC (Peeters & Middlemis, 2023).

The 3D groundwater flow model was developed using MODFLOW-USG. The model represents the main hydrostratigraphic layers in the region, including:

- Quaternary alluvium and regolith;
- coal seams/interburden of the Permian Maules Creek sub-basin; and
- Permian Boggabri volcanics, which form the basement.

The model is approximately 30 km wide in an east to west direction, and 28 km long north to south. The spatial scale refers to the model's representation of the coal measures of the Maules Creek sub-basin, extending to the eastern boundary with the New England Fold Belt, the underlying volcanic basement, and the overlying alluvial groundwater systems associated with the Namoi River, Maules Creek, and Bollol Creek. The model represents a regional structure known as the Conomos Fault directly, with hydraulic properties along the fault face varying spatially based on history matching.

The model has 34 layers and comprises up to 18,920 cells per layer, making it spatially a large and complex model. Systems stresses represented by the model are:

- zones of spatially varying diffuse rainfall recharge and recharge through porous creek beds;
- flow of groundwater to ephemeral creeks as baseflow where the water table intersects the creek bed;
- dynamic interaction between alluvial aquifers and the surface water systems of the Namoi River;
- evapotranspiration of groundwater when the water table rises to within 2 m of the land surface;
- abstraction of groundwater from registered irrigation water supply bores installed within the Namoi valley alluvial aquifer; and
- incidental interception of groundwater associated with approved mining activities within the BTM complex.

A history-matching process was used to determine the optimal hydraulic properties to assign to each layer in the numerical model. Parameter estimation software was used to automate the adjustment of hydraulic properties and recharge rates, thereby replicating the water level observations from the BTM Complex groundwater monitoring network as closely as possible. Particular focus was on replicating drawdown trends resulting from mining conducted to date while constraining hydraulic properties within known, plausible ranges.

Once the history matching and calibration process was completed, the model was used to simulate the influence of the approved and proposed mining within the BTM Complex. The model was used to simulate groundwater flow from 2006, when mining commenced in the area, until the proposed completion of mining in 2045. The model also included a post-mining period to simulate the recovery of the groundwater regime over 200 years, from 2045 to 2245.

Fifteen separate model scenarios were prepared and used in combination to assess the marginal impacts of each mine as well as the cumulative impacts for the BTM Complex for both the approved and proposed mining (Table 8.1). The predictions provided by the model scenarios were used to assess the impacts of the approved and proposed mining on the groundwater regime and to compare them with the AIP's minimal impact considerations. The scenarios consider both currently approved and proposed mining operations for all mines in the BTM Complex, enabling the improved apportionment of impacts to QoIs from each mine.

Table 8.1 Model scenarios

| Number | Scenario | Description |
|---|---|---|
| 1 | Null | Assumes no mines in operation. Used as a reference for the impact on QoI calculation. |
| 2 | All cumulative approved | Simulates all mines with currently approved mine and closure plans. |
| 3 | Cumulative approved ex MCCM | Similar to scenario 2 but excludes all MCCM operations. |
| 4 | Cumulative approved - excluding BCM | Similar to scenario 2 but excludes all BCM operations. |
| 5 | Cumulative approved - excluding TCM | Similar to 2 but excludes all TCM operations. |
| 6 | All cumulative proposed | Simulates all mines with proposed mine and closure plans (MCCM Continuation Project and BCM MOD 10). |
| 7 | Cumulative proposed - excluding MCCM | Similar to scenario 6 but excludes all MCCM operations. |
| 8 | Cumulative proposed - excluding BCM | Similar to scenario 6 but excludes all BCM operations. |
| 9 | Cumulative proposed - excluding TCM | Similar to scenario 6 but excludes all TCM operations. |
| 10 | Proposed MCCM only | Simulates MCCM proposed mine plan in isolation. |
| 11 | Proposed BCM only | Simulates BCM proposed mine plan in isolation. |
| 12 | Approved TCM only | Simulates TCM approved mine plan in isolation. |
| 13 | Approved MCCM only | Simulates MCCM approved mine plan in isolation. |
| 14 | Approved BCM only | Simulates BCM approved mine plan in isolation. |
| 15 | Cumulative approved and BCM proposed | Cumulative approved MCCM and TCM, with proposed BCM MOD 10 project. |

The differences between proposed and approved scenario simulations affect the following in each simulation:

- Mine progression – changes to timing and location of dewatered Permian formation.
- Recharge – different areas of the Permian assigned enhanced recharge associated with spoil emplacement.
- Hydraulic properties – different areas of the Permian transition to spoil or void properties at different times.
- Pit lake stages – different locations and timing of pit lake development.
- Evapotranspiration surface plus extinction depth – different areas and timing for final landforms post-mining operations.

The uncertainty in model predictions associated with the model parameters was assessed to consider risks to the QoIs, primarily the water supply bores in the alluvial aquifer (Namoi River) and high-priority GDEs in Nagero Creek. The model used for uncertainty analysis simulates post-closure conditions and captures the variability anticipated due to climate change in the main driver of recharge rates, rainfall and evaporation rates. Further details are provided in Appendix F.

# 9 Impact Assessment

This section describes the model predictions of MOD 10 during operations and post-closure. The cumulative impacts of all approved mining operations in the BTM Complex and the predicted impacts for MOD 10 are included. The impact assessment focuses on the QoIs identified in the conceptual model in Section 7. The QoIs for the BCM MOD 10 include:

- Drawdown and reductions in yield for water supply bores; and
- Drawdown reducing groundwater availability to the Poplar Box Woodland ecological communities within the Nagero Creek alluvium.

Discussion of incremental changes from the original approval SSD09_0182 (under Modification 7), herein referred to as MOD 7, MOD 8 (increase in depth of mining) and MOD 10 (this Modification) are included in each section and are summarised in Table 9.6. Further details on incremental changes from MOD 7 to MOD 8 are outlined in the Groundwater Impact Assessment Boggabri Coal Mine MOD 8 Amendment (AGE, 2022).

## 9.1 Heads and flow direction

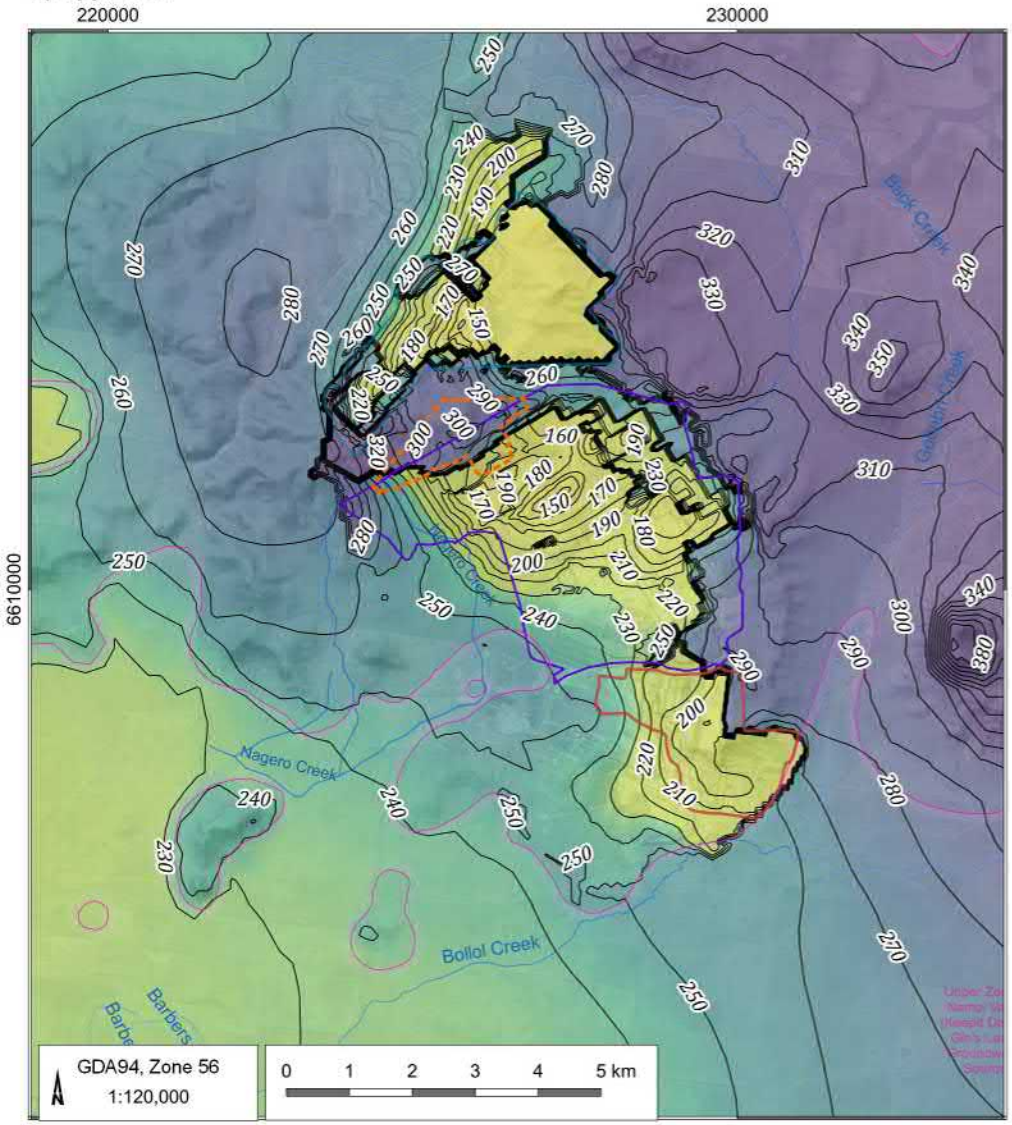
The simulated water table at the end of the Project life and 25, 50 and 100 years post-closure is shown in Figure 9.1 to Figure 9.4. The left window in each figure shows the water table predicted for all approved mining within the BTM Complex (Scenario 2). In contrast, the right-side window displays the cumulative approved mining for MCCM and TCM, with BCM MOD 10 (Scenario 15). The figures illustrate cumulative impacts as all approved and BCM proposed mining is represented. Additional details on the approved and proposed mining scenarios for all mines are provided in the BTM numerical modelling report in Appendix F.

The figures illustrate the influence of the approved mining and MOD 10 on the groundwater regime, characterised by a locally lowered water table and inward hydraulic gradients towards the mining footprint. The inward gradient is consistent with MOD 7 approvals, with the greatest change associated with the deeper mined seam within the Mine Disturbance Boundary and the additional mine area north of the approved Mine Disturbance Boundary.

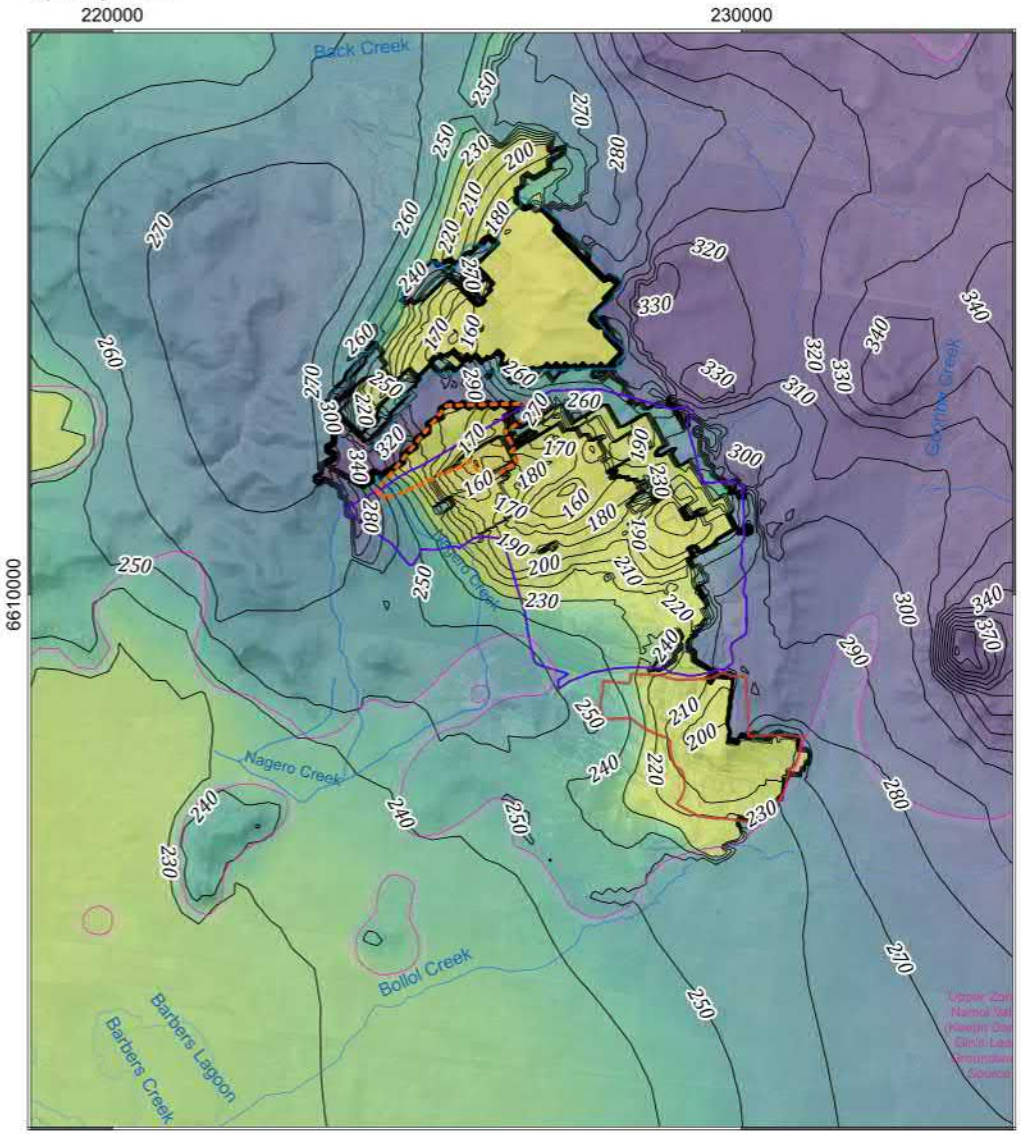
The drawdown in the water table is most significant at the end of mining and then slowly recovers post-mining when dewatering of the mining area ceases. However, this recovery does not reverse the direction of the hydraulic gradients within the assessment period (100 years). The key difference in the water table between the approved and proposed model scenarios is the reduction in the water table north of the currently approved mine within the BCM MOD 10 Modification Mining Area. Similarly, the area of the ridge separating BCM from MCCM and controlling the flow direction between the two mines is reduced in both the approved and proposed scenarios. Thus, groundwater flows towards the MCCM and BCM mining areas, which act as sinks.

Figure 9.1 to Figure 9.4 show that the regional east-to-west flow direction aligned with the alluvial aquifers remains largely unchanged through the operations and closure stages for both the approved and proposed mining. Changes in the water table are largely confined to the bedrock ridge area where mining is situated.

a) Approved




b) Proposed




LEGEND

- Road
- Drainage
- Contours
- Groundwater Management Areas
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

**Water Table (mAHD)**

| | |
|---|---|
| 124 | 265 |
| 228 | 275 |
| 230 | 290 |
| 235 | 315 |
| 245 | 557 |
| 250 | |

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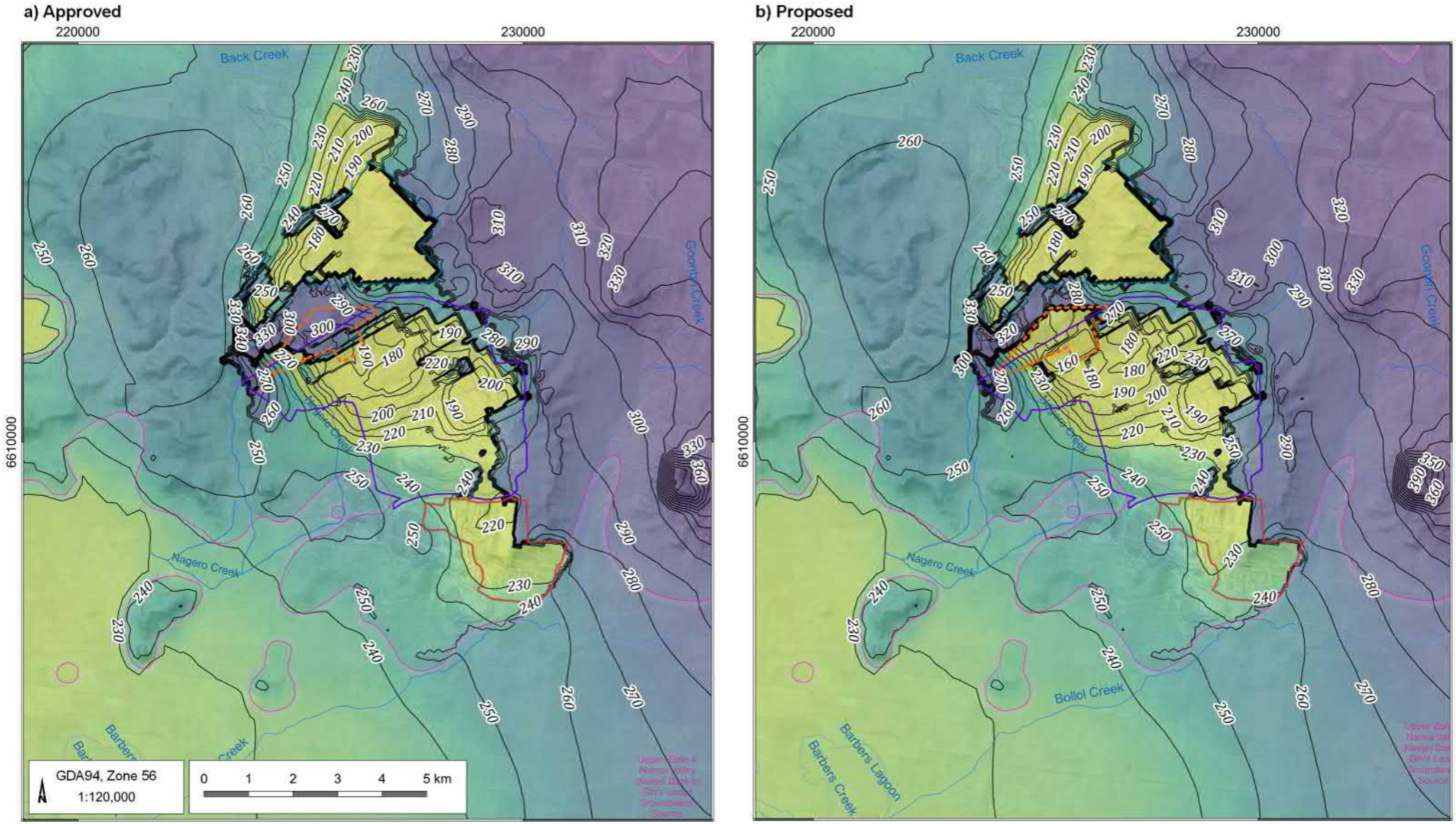
Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Predicted water table - end operations – cumulative approved and BCM MOD 10 with MCCM-TCM approved scenarios**

DATE
30/03/2025

FIGURE No.
**9.1**

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LEGEND

- Road
- Drainage
- Contours
- Groundwater Management Areas
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

AGE

Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Predicted water table - 25 years post closure – cumulative approved and BCM MOD 10 with MCCM-TCM approved scenarios**

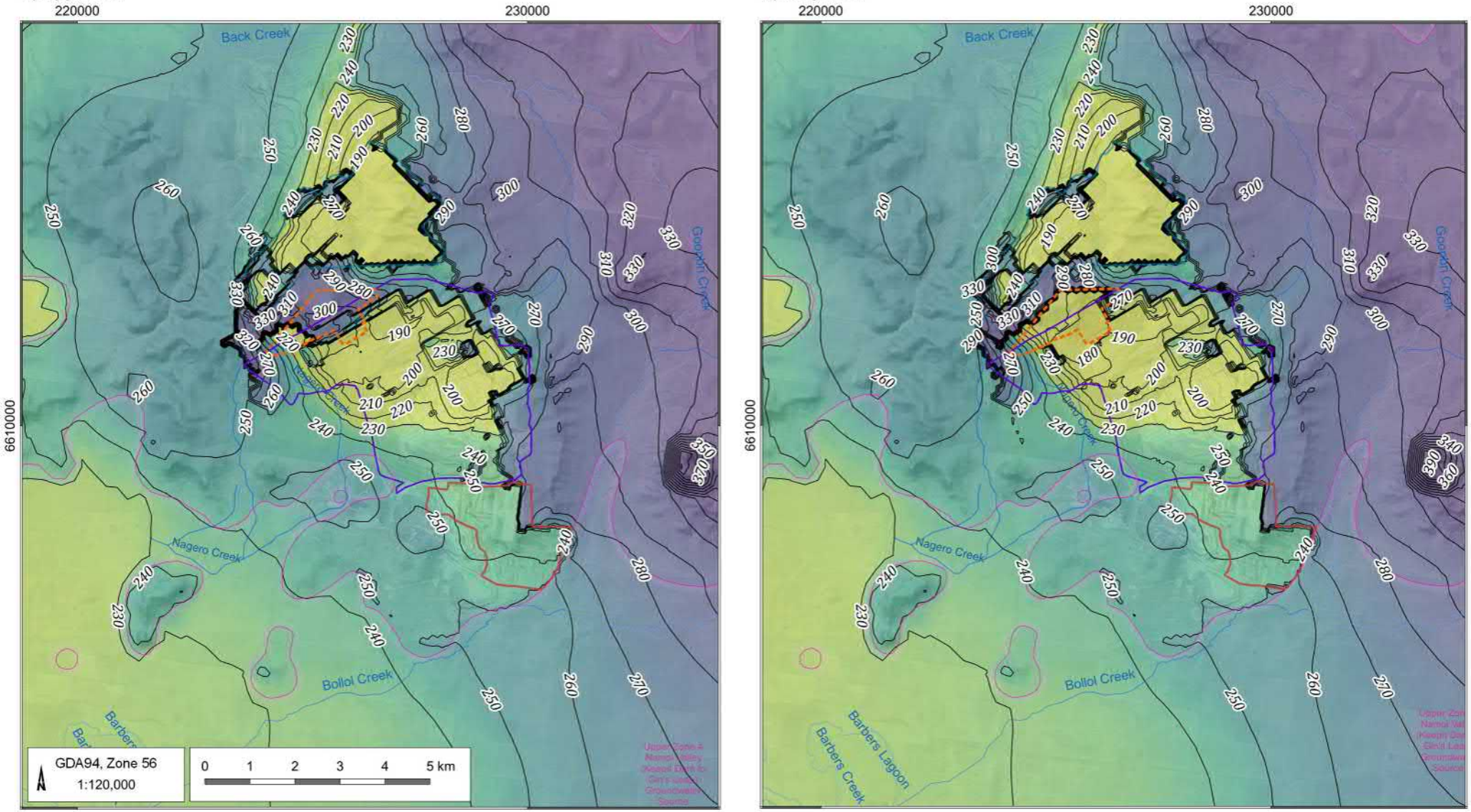
DATE
30/03/2025

FIGURE No.
**9.2**

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G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\09.01_BCO5002.001_Predicted water table - end operations – cumulative approved and BCM MOD 10 with MCCM-TCM approved scenarios.qgz

a) Approved

b) Proposed




LEGEND

- Road
- Drainage
- Contours
- Groundwater Management Areas
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

**Water Table (mAHD)**

AGE

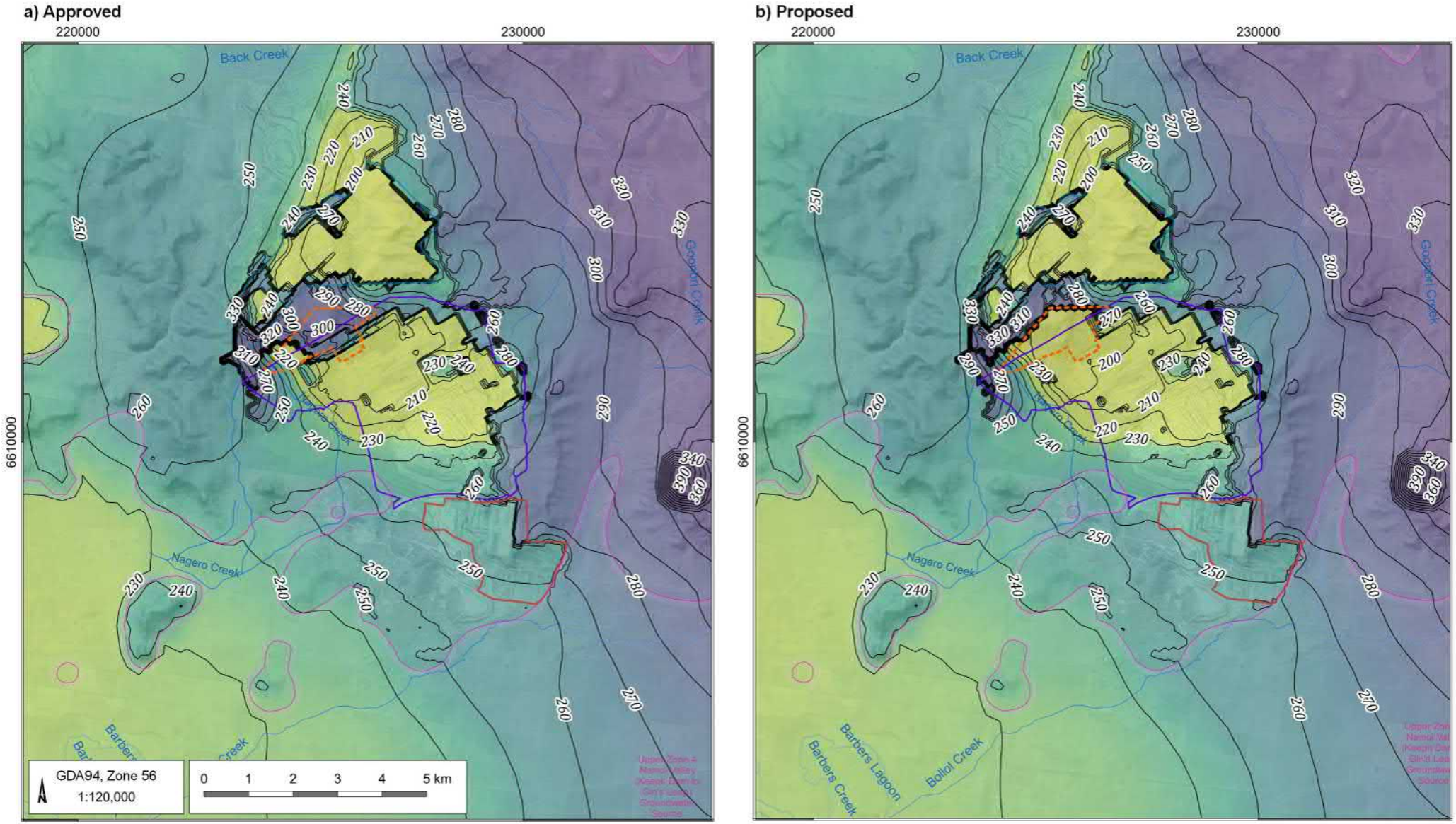
Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Predicted water table - 50 years post closure – cumulative approved and BCM MOD 10 with MCCM-TCM approved scenarios**

DATE
30/03/2025

FIGURE No.
**9.3**

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G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\09.01_BCO5002.001_Predicted water table - end operations – cumulative approved and BCM MOD 10 with MCCM-TCM approved scenarios.qgz




**Water Table (mAHD)**

LEGEND

- Road
- Drainage
- Contours
- Groundwater Management Areas
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

AGE

Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Predicted water table - 100 years post closure - cumulative approved and BCM MOD 10 with MCCM-TCM approved scenarios**

DATE
30/03/2025

FIGURE No.
**9.4**

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G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\09.01_BCO5002.001_Predicted water table - end operations – cumulative approved and BCM MOD 10 with MCCM-TCM approved scenarios.qgz

## 9.2 Drawdown

### 9.2.1 Cumulative drawdown

Predictions of maximum drawdown for the alluvium[2], Merriown seam, Templemore seam and Boggabri volcanics are shown in Figure 9.5 to Figure 9.8. For each of the layers, two sets of predictions are provided, including:

- left window – cumulative drawdown for all approved mining (scenario 2) within the BTM Complex, showing the absolute impact for already approved activities; and
- right window – cumulative drawdown for MCCM and TCM approved, and BCM proposed (scenario 15), showing the absolute impact predicted to occur due to MOD 10 mining.

Cumulative drawdown in the alluvium (Figure 9.5) for both approved and proposed mining is generally less than 2 m. The most significant drawdown predicted is located in the alluvial plains south of TCM, the Goonbri alluvium between TCM and Goobri Creek and the Nagero Creek alluvium immediately southwest of BCM. Cumulative drawdown predicted in the Nagero Creek alluvium closest to mapped GDEs and the Nagero Creek is 3.8 m. A maximum drawdown of up to 5.1 m restricted to the very fringes of the alluvial tongue, where it extends into the currently approved Mine Disturbance Boundary, is predicted. The cumulative drawdown in the Nagero Creek alluvium is generally less than 2 m.

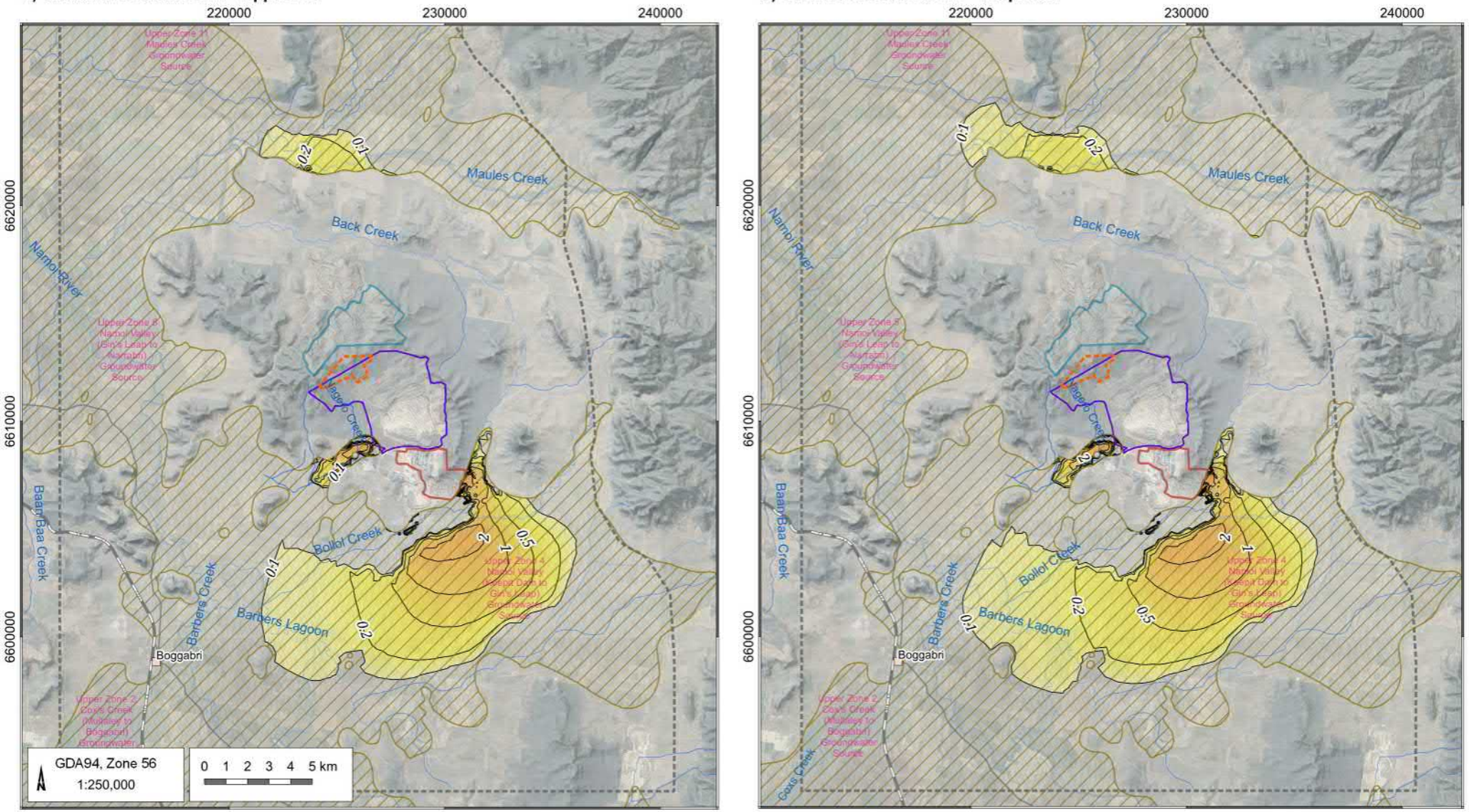
The lateral extent of drawdown in the coal measures shows minimal change between the approved and proposed scenarios. Drawdown in the Merriown seam (Figure 9.6) show little change in the drawdown near mining, a slight increase in drawdown is evident in the area north of mining. Drawdown in the Templemore seam (Figure 9.7), the deepest seam to be mined by approved and proposed mining, increases closer to the Modification Mining Area. This is expected, given the deepening of seams within the approved Mine Disturbance Boundary. Drawdown propagation to the south remains relatively unchanged, with a more evident increase in drawdown to the north of the Modification Mining Area.

Drawdown in the Boggabri volcanics (Figure 9.8) shows minimal change between the approved and proposed mining scenarios. A small increase in drawdown propagating to the west is predicted; at this point, the drawdown reaches a maximum of 0.1 m.

[2] For consistency with the results reported for MOD 8, when the regional water table is above the bottom of the alluvial layer, a drawdown in the water table can be calculated by subtracting values for the water table level from different scenarios. On the contrary, when the regional water table is below the bottom of the alluvial, only a loss of saturated thickness can be estimated in the alluvial system. This is consistent with methods previously used in MOD 8 to calculate the drawdown in alluvial layers in the numerical model.

a) Cumulative drawdown - Approved

b) Cumulative drawdown - Proposed




LEGEND

- Populated place
- Road
- Drainage
- Contour
- Alluvium
- BTM Complex Model Extent
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

**Drawdown (m)**

| | |
|---|---|
| 0 | 10 |
| 0.1 | 20 |
| 0.2 | 50 |
| 0.5 | 100 |
| 1 | 200 |
| 2 | 500 |
| 5 | |

AGE

Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Maximum drawdown in alluvium - cumulative drawdown**

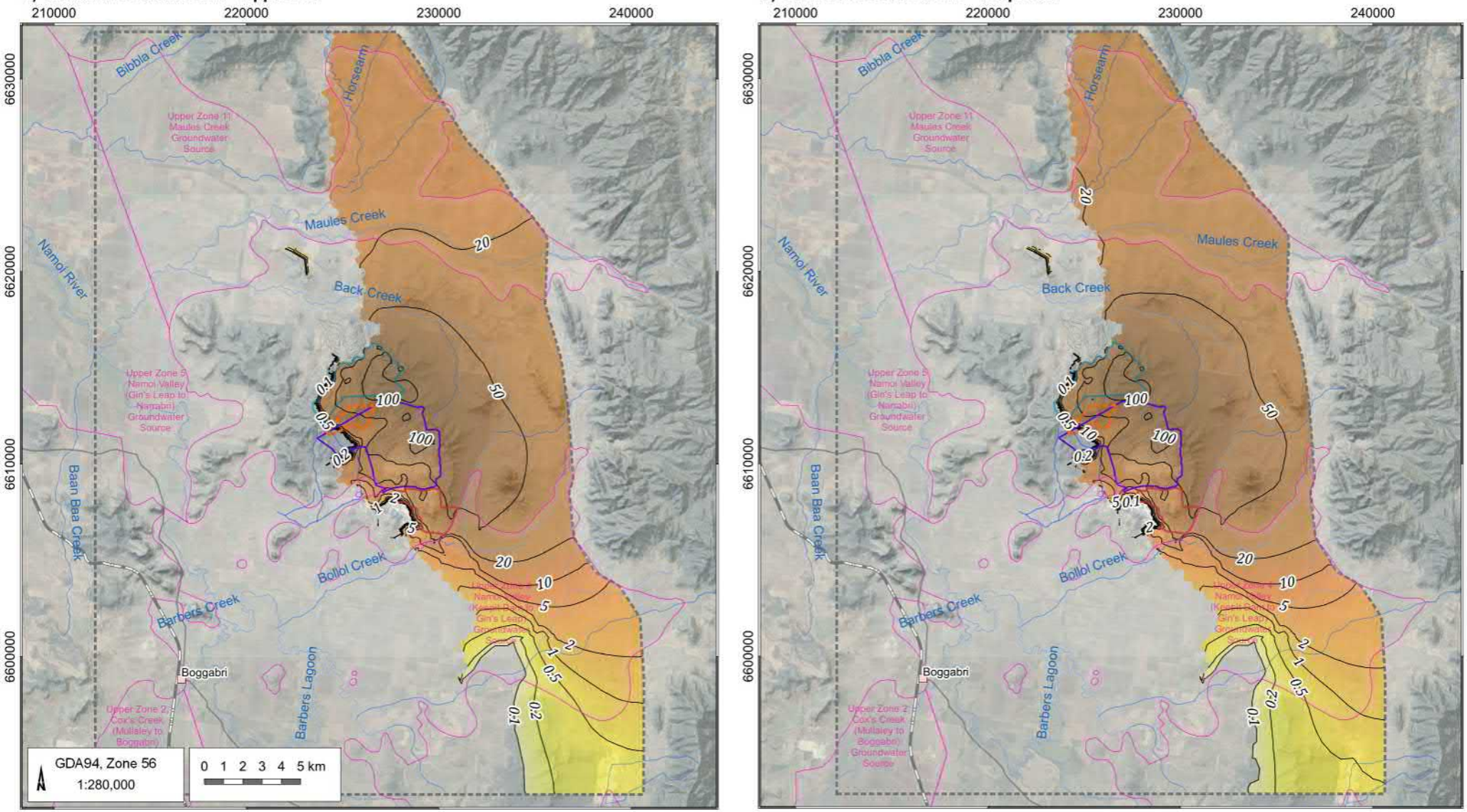
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FIGURE No.
**9.5**

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G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\09.05_BCO5002.001_Maximum drawdowns.qgz

a) Cumulative drawdown - Approved

b) Cumulative drawdown - Proposed




LEGEND

- Populated place
- Road
- Drainage
- Contour
- Groundwater management areas
- BTM Complex Model Extent
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

**Drawdown (m)**

| | |
|---|---|
| 0 | 10 |
| 0.1 | 20 |
| 0.2 | 50 |
| 0.5 | 100 |
| 1 | 200 |
| 2 | 500 |
| 5 | |

AGE

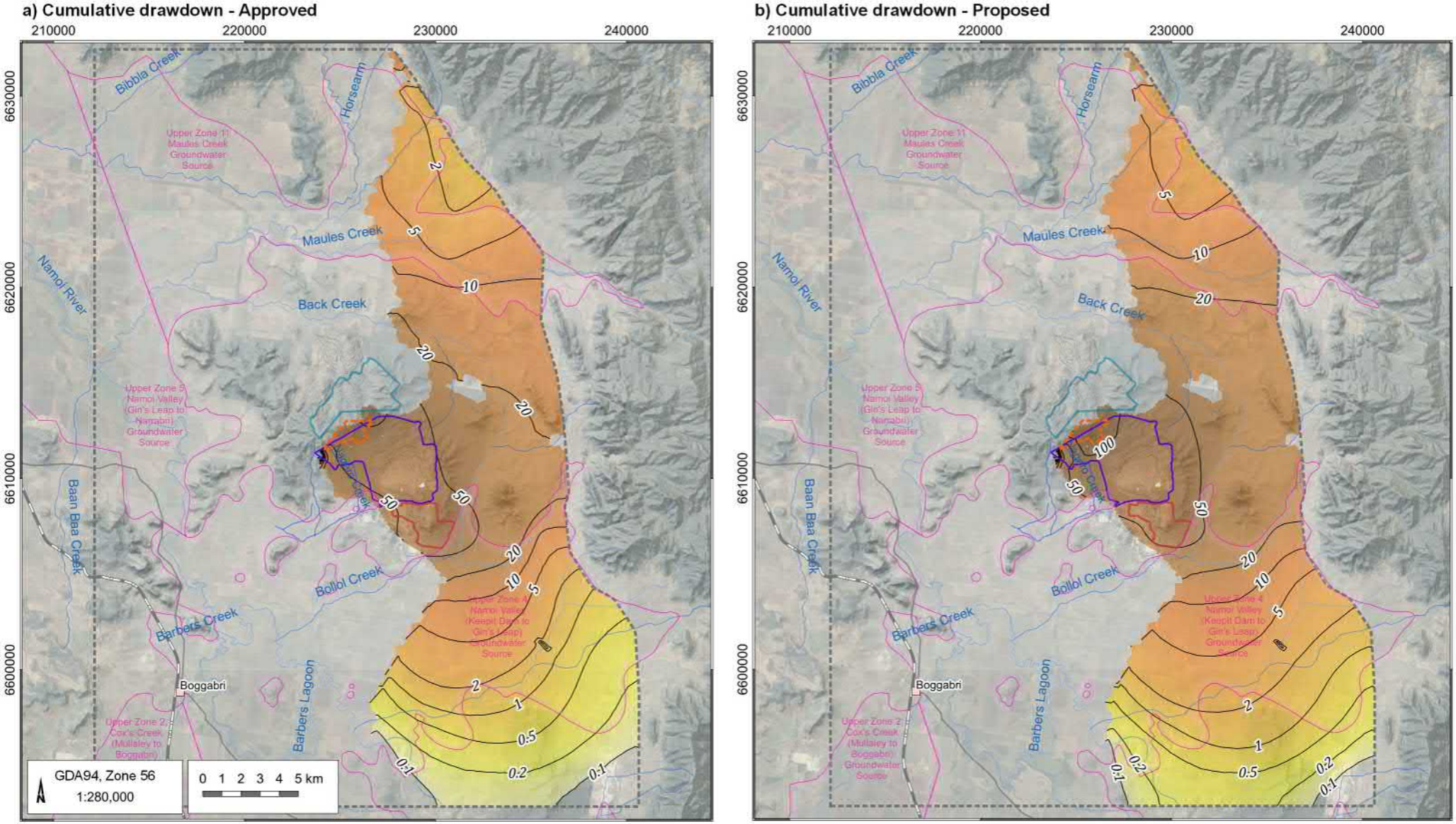
Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Maximum drawdown in Merriown - cumulative drawdown**

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FIGURE No.
**9.6**

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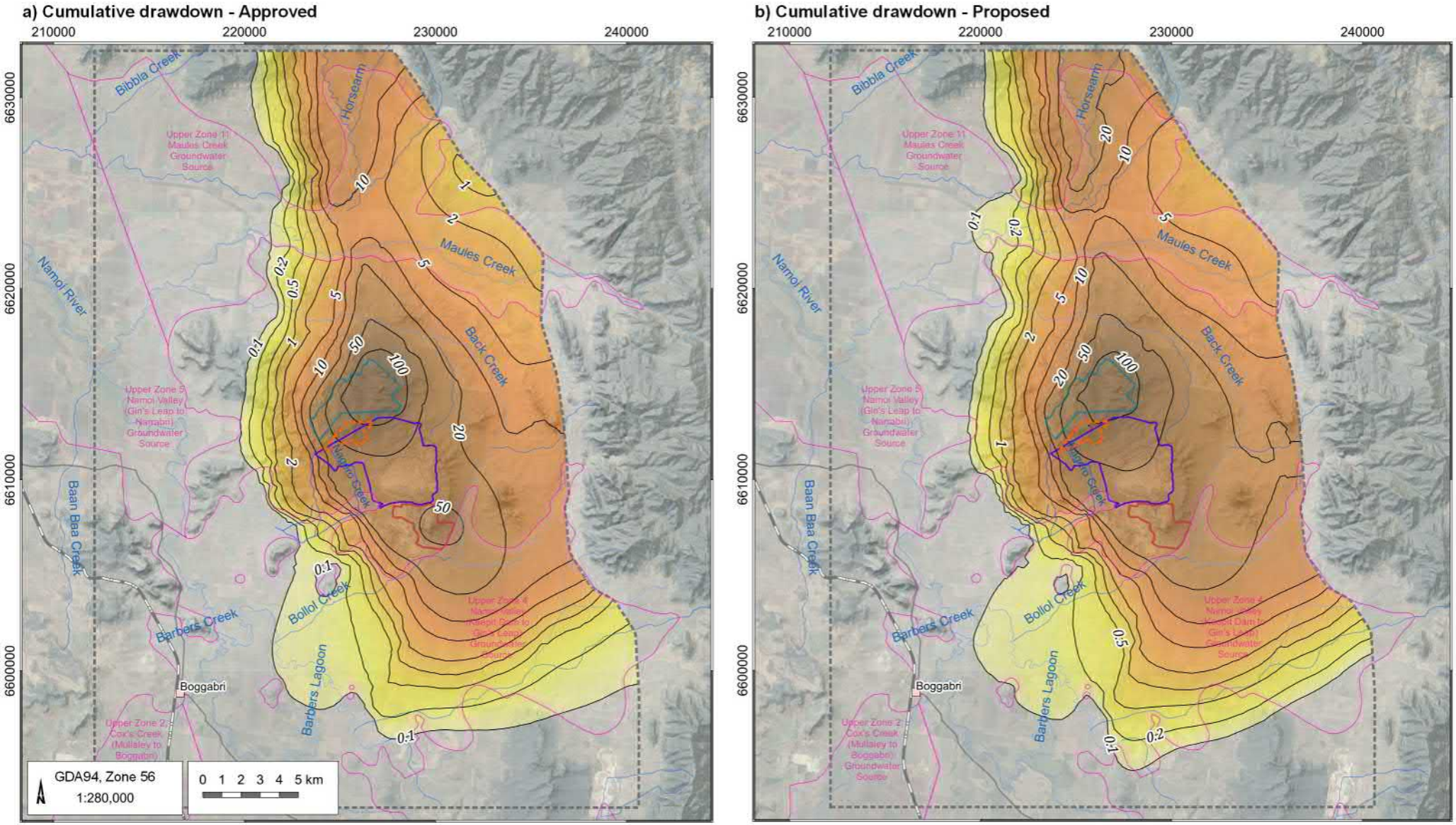

Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Maximum drawdown in Templemore - cumulative drawdown**

DATE
26/05/2025

FIGURE No.
**9.7**

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AGE

Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Maximum drawdown in Boggabri Volcanics - cumulative drawdown**

DATE
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FIGURE No.
**9.8**

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### 9.2.2 BCM specific impact

Simulated maximum drawdown throughout the mining period within the alluvium, Merriown seam, Templemore seam and the Boggabri volcanics are shown in Figure 9.9 to Figure 9.12. The component of drawdown attributed to BCM is created by comparing scenarios with and without BCM. For each layer, the following predictions are presented:

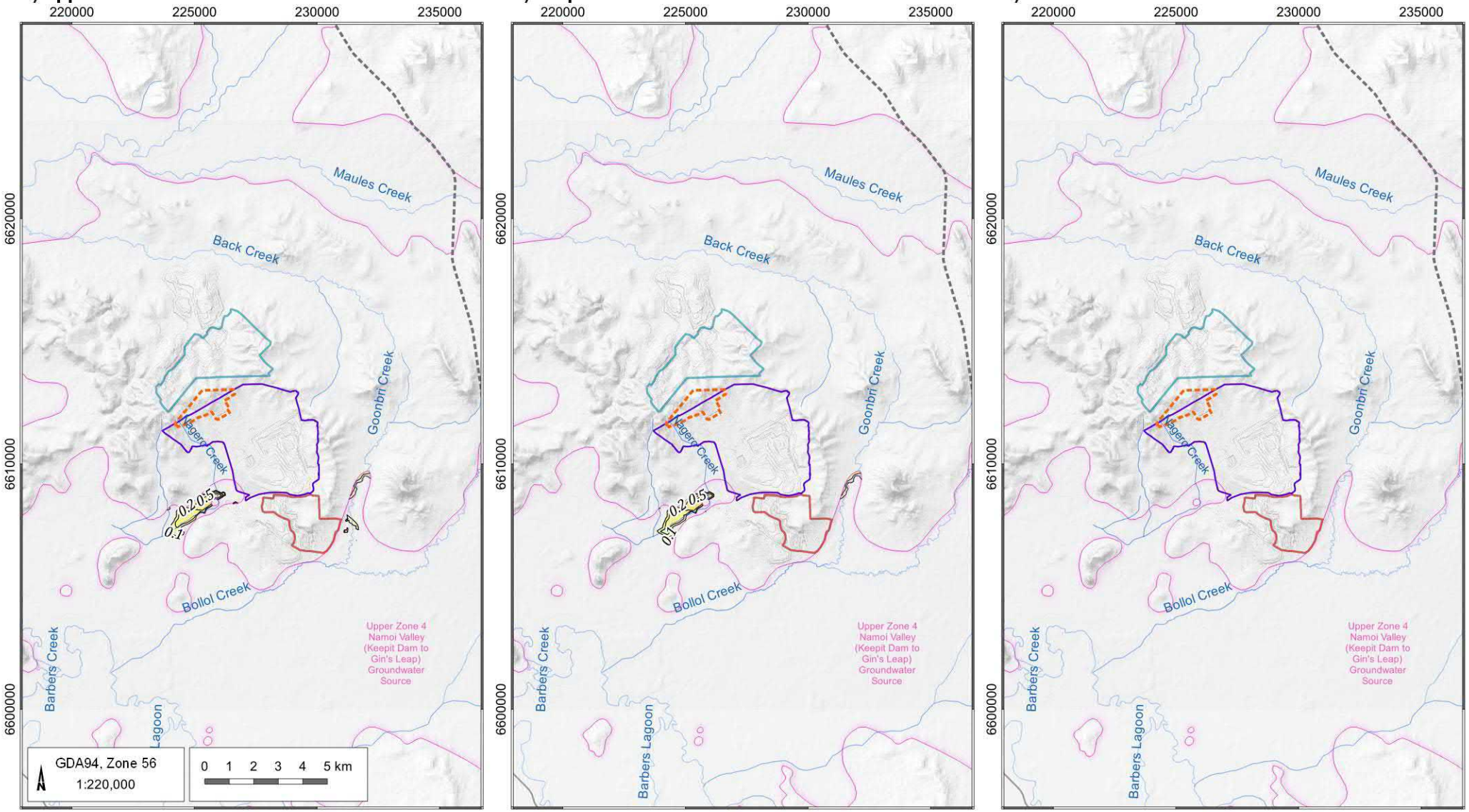
- left window – component of drawdown from all approved mining that is attributed to BCM;
- middle window – component of drawdown that is attributed to BCM MOD 10; and
- right window – incremental drawdown attributed to BCM MOD 10 (MOD 10 minus approved).

One of the QoIs for impact assessment of the BCM operation is the water level drawdown along the alluvial tongue in Nagero Creek. The latter is a shallow (20 m to 40 m thick) and narrow (600 m to 1200 m wide) alluvial section that thins out on the edges and towards the east. It is unlikely to be connected to the regional water table. Within the alluvium, drawdown (i.e., loss of saturated thickness) is confined to a portion of the Nagero Creek alluvial tongue southwest of BCM on BCOPL owned land. The drawdown in this portion of the alluvium attributable to MOD 10 reaches a maximum of 1.3 m, consistent with MOD 8. No incremental change in the alluvium is identified, as expected, given the small relative change in mining and the absence of new mining coal seams (Figure 9.9). Incremental change from MOD 7 to MOD 8 was reported as an additional 0.3 m drawdown. The minimal incremental change from MOD 8 to MOD 10 is attributed to MOD 10 primarily affecting areas proximal to alluvium that were already dewatered by the MOD 8 mined depth increase.

As a result of the approval of MOD 8 in January 2024, BCM is currently approved to mine down to the Templemore seam. MOD 10 will also mine down to the Templemore seam, extracting an additional 15.4 Mt of coal deeper within the currently approved Mine Disturbance Boundary, and an additional 14.5 Mt of coal further north within the BCM Modification Disturbance Footprint. The small relative change in mining is reflected in the spatially constrained increase in drawdown in the Merriown seam, with the maximum drawdown in the Merriown seam located within the Modification area (Figure 9.10).

Figure 9.11 shows that the lateral extent of drawdown is more pronounced in the Templemore seam, with a maximum drawdown of approximately 50 m predicted within the Modification Mining Area. This is anticipated as Templemore is the targeted seam. Further east of the mine footprint, the incremental drawdown in the Templemore seam due to mining is mostly less than 5 m. Incremental drawdown from MOD 8 to MOD 10 is less than previously approved, with a 107 m incremental change reported from MOD 7 to MOD 8. This is expected as prior to MOD 8, the maximum seam approved to be mined was the Merriown. The increased lateral extent of drawdown MOD 10 compared with MOD 8 is associated with increased mining life and Permian hydraulic diffusivity, promoting rapid drawdown.

The predicted drawdown in the Boggabri volcanics attributable to MOD 10 is expected to result in approximate drawdowns between 10 m and 20 m, with up to 26 m maximum drawdown within the Modification Mining Area (Figure 9.12). This is predominantly beneath the Modification Mining Area, with an additional 5 m incremental change predicted for the remainder of the area beneath the BCM. Further east of the Mine Disturbance Boundary, the incremental drawdown in the Boggabri volcanics due to mining is mostly less than 2 m.




LEGEND

- Roadway
- Drainage
- Contours
- Groundwater management areas
- BTM Complex Model Extent
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

**Drawdown (m)**

| | |
|---|---|
| 0 | 10 |
| 0.1 | 20 |
| 0.2 | 50 |
| 0.5 | 100 |
| 1 | 200 |
| 2 | 500 |
| 5 | |

AGE

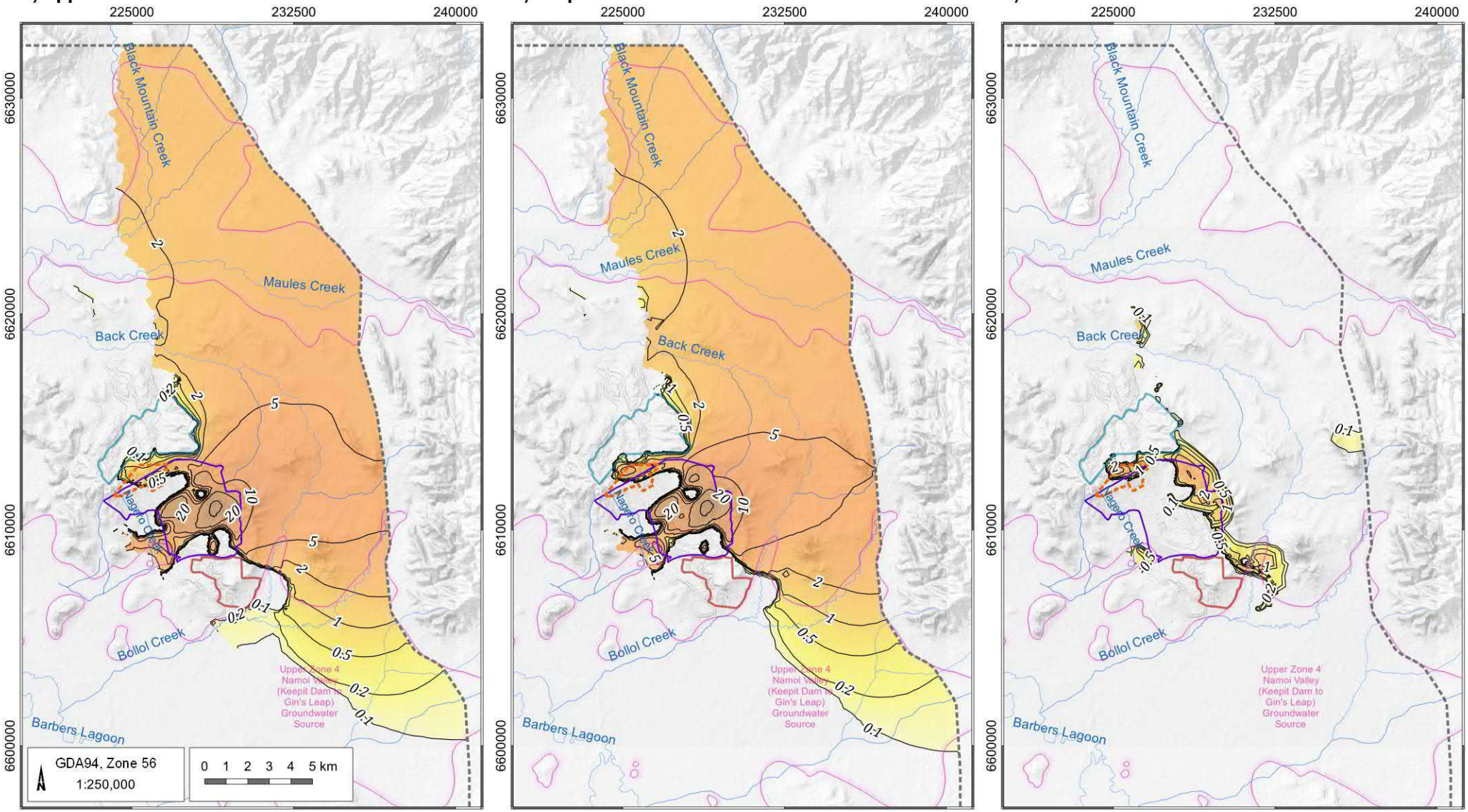
Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Maximum drawdown in alluvium - BCM specific drawdown**

DATE
26/05/2025

FIGURE No:
**9.9**

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LEGEND

- Roadway
- Drainage
- Contours
- Groundwater management areas
- BTM Complex Model Extent
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

**Drawdown (m)**

| | |
|---|---|
| 0 | 10 |
| 0.1 | 20 |
| 0.2 | 50 |
| 0.5 | 100 |
| 1 | 200 |
| 2 | 500 |
| 5 | |

AGE

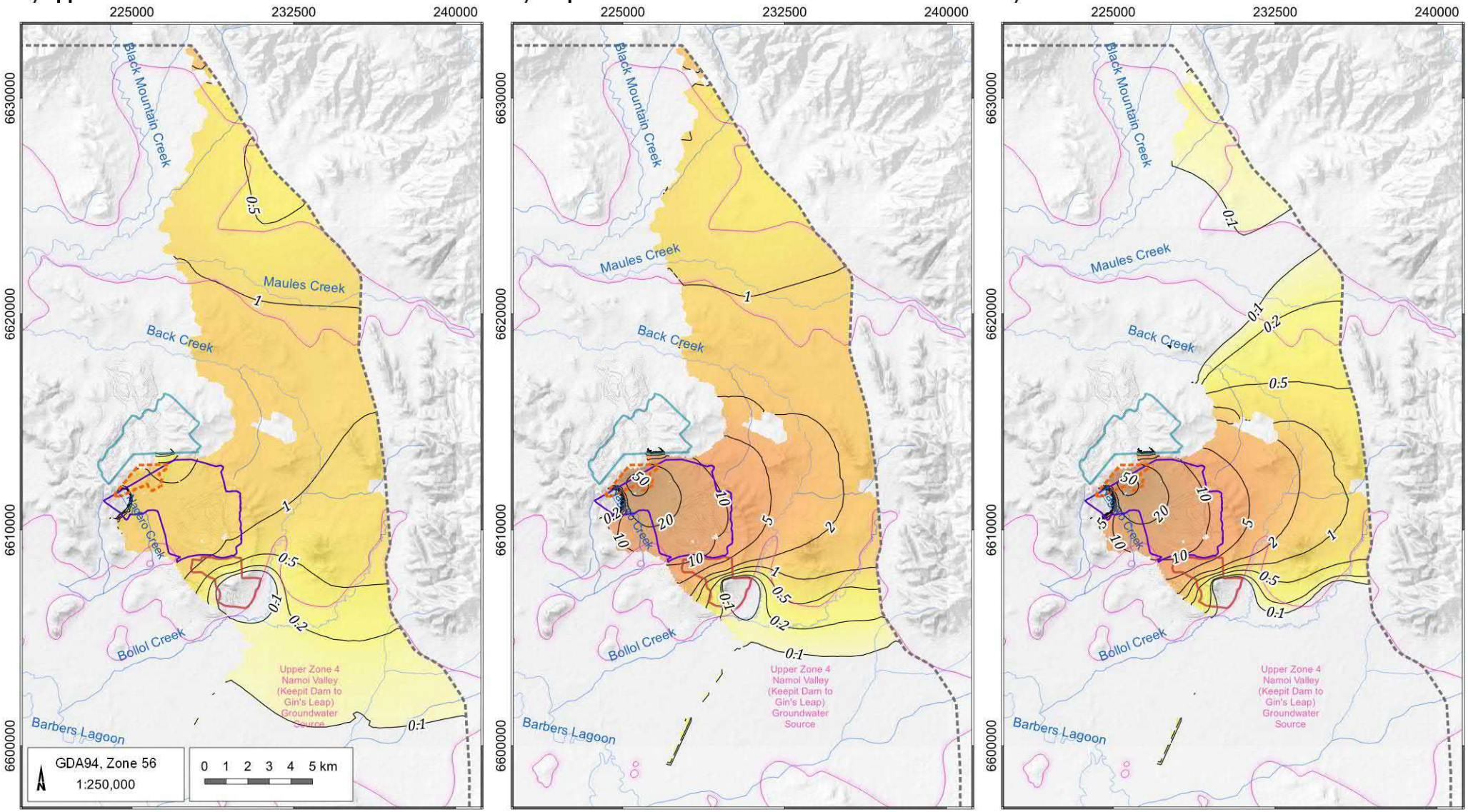
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**Maximum drawdown in Merriown - BCM specific drawdown**

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FIGURE No:
**9.10**

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LEGEND

- Roadway
- Drainage
- Contours
- Groundwater management areas
- BTM Complex Model Extent
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

**Drawdown (m)**

| | |
|---|---|
| 0 | 10 |
| 0.1 | 20 |
| 0.2 | 50 |
| 0.5 | 100 |
| 1 | 200 |
| 2 | 500 |
| 5 | |

AGE

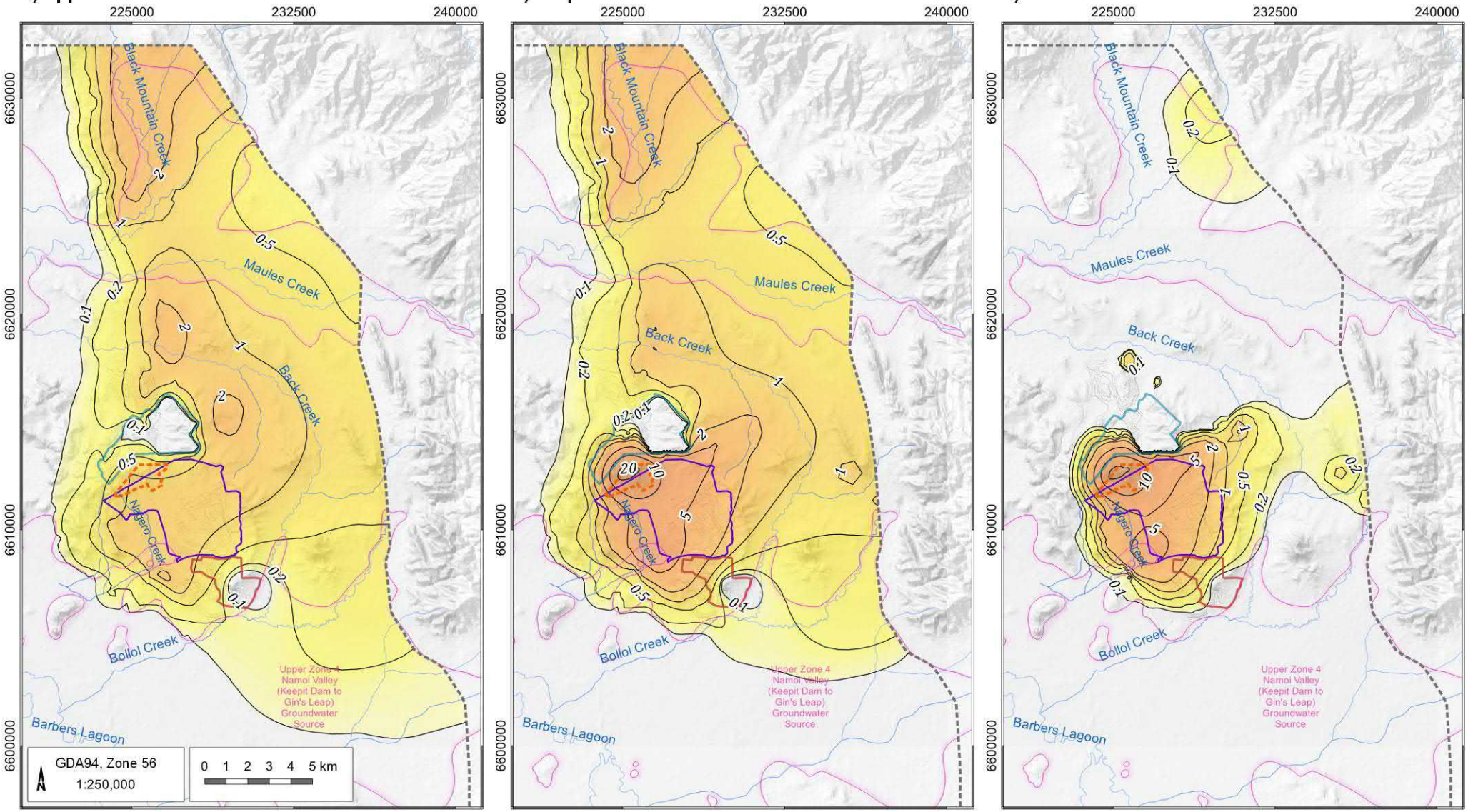
Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Maximum drawdown in Templemore - BCM specific drawdown**

DATE
26/05/2025

FIGURE No:
**9.11**

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LEGEND

- Roadway
- Drainage
- Contours
- Groundwater management areas
- BTM Complex Model Extent
- BCM Modification Mining Area
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

**Drawdown (m)**

| | |
|---|---|
| 0 | 10 |
| 0.1 | 20 |
| 0.2 | 50 |
| 0.5 | 100 |
| 1 | 200 |
| 2 | 500 |
| 5 | |

AGE

Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Maximum drawdown in Boggabri Volcanics - BCM specific drawdown**

DATE
26/05/2025

FIGURE No:
**9.12**

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G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\09.09_BCO5002.001_Maximum drawdown in alluvium - BCM specific impacts.qgz

## 9.3 Mine inflow

Figure 9.13 shows the approved and proposed mine inflows for BCM. The cumulative inflows are included in the BTM Complex numerical model report in Appendix F. Differences in inflow estimates between the approved and proposed scenarios are minimal, with key differences attributable to changes in mine progression. Previous Modification to approved mining from MOD 7 to MOD 8 saw an estimated 30% increase in inflow into the mine associated with deeper extraction and extended operation. The incremental total increase in inflow from MOD 8 approved to MOD 10 is approximately 27%, associated with increasing the footprint and extended mine operations.

The maximum annual inflow for the approved cumulative scenario is 581 ML/year, and for the MOD 10 proposed scenario, it is 613 ML/year. From 2037 to 2040, when mining continues beyond the BCM approved (MOD 8), the maximum inflow is 189 ML/year in 2040. BCM inflows increase from 2035 as dewatering from surrounding approved mines progressively ceases on closure from 2030 for TCM and 2034 for MCCM (as approved). The peak recorded in 2036 is likely attributed to the end of mining at MCCM, which is related to the property changes in the spoil at MCCM, plus increased recharge through that spoil. This happens within a single stress period in the model when MCCM hits closure.

Cumulative inflows for the BTM Complex for approved MCCM and TCM with proposed MOD 10 peaks in 2023 and again in 2025 at 1,909 ML/year and 1,746 ML/year, respectively (Figure 9.14).

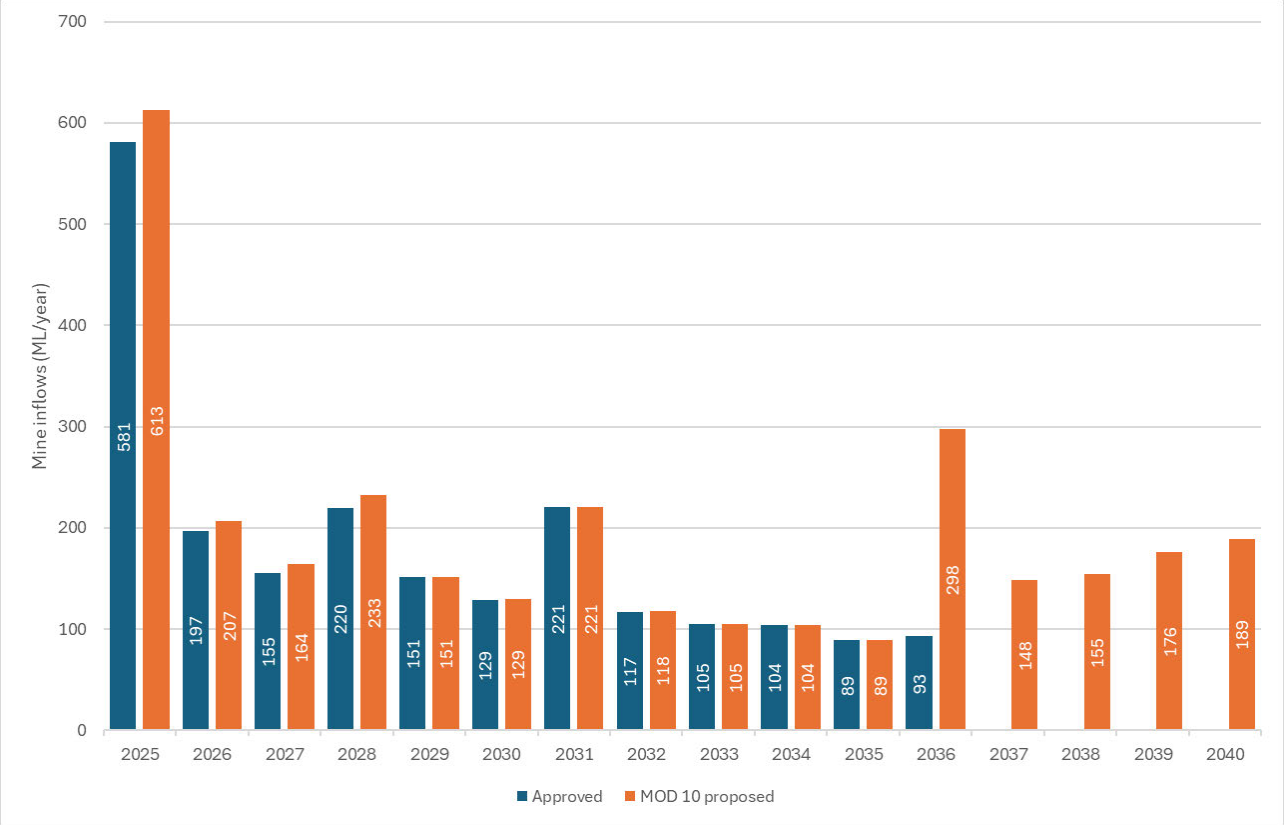



Figure 9.13 Simulated inflows at BCM - approved mining and MOD 10

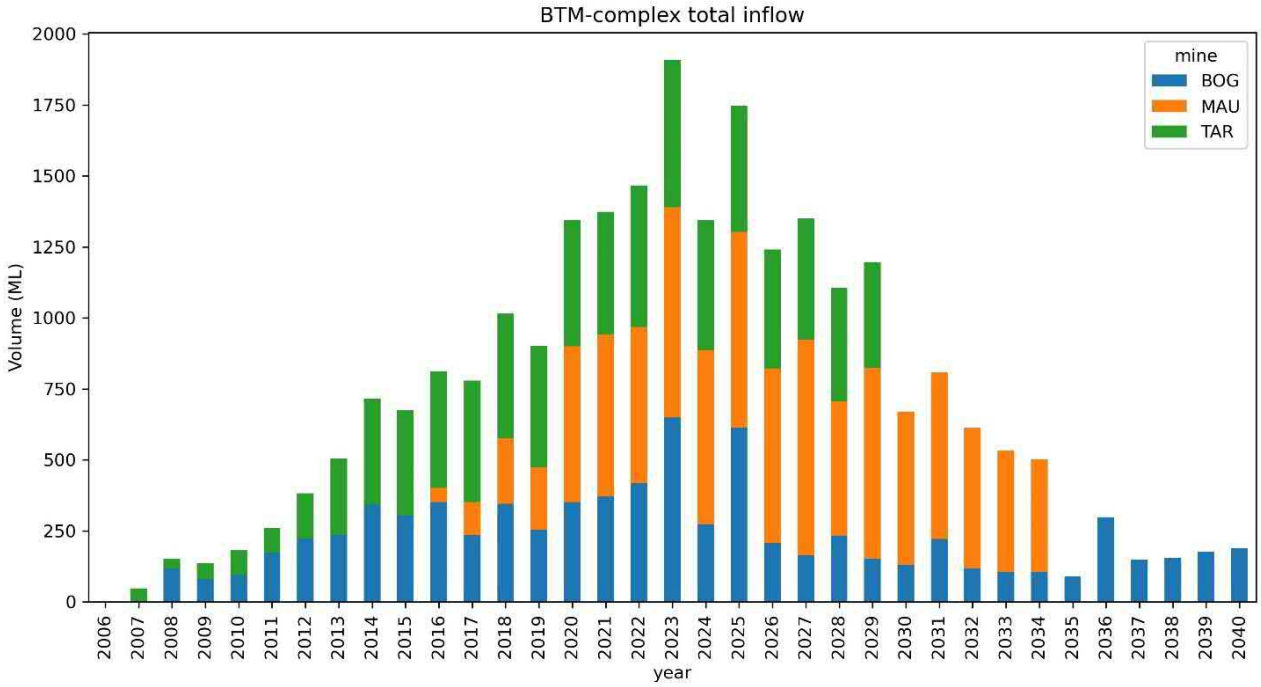



Figure 9.14 Cumulative inflows for MCCM and TCM approved and BCM MOD 10 proposed mining scenario

## 9.4 Water take and water licensing

Estimates of consumptive, passive and incidental water take are provided for the approved mining in Appendix F. A summary of the WALs held by the proponent to account for water take estimates is contained within Appendix B. Table 9.1 provides a summary of the estimated peak water take for the MOD 10 proposed mining, based on the cumulative proposed scenario (Scenario 15) and the total number of units held by BCOPL, to account for incidental, passive, and consumptive take.

BCOPL holds sufficient WALs for the Gunnedah-Oxley Basin Porous Rock Groundwater Source, and the Namoi Alluvium Groundwater Sources zones 4 and 5 for the duration of the operation. For the Namoi Alluvium Groundwater Source Zone 11, BCOPL holds sufficient WAL units for each year of operation, excluding 2040, when the predicted take is expected to exceed the WALs by 2 ML/year.

Table 9.1 Estimated peak water take and water access licences

| Water sharing plan | Water Source | Category of water take | Year | Predicted peak water take (ML/year) | WAL units held by the proponent (ML) |
|---|---|---|---|---|---|
| NSW Murray Darling Basin Porous Rock Groundwater Sources | Gunnedah-Oxley Basin Porous Rock | incidental take within pits | 2025 | 479 | 842 |
| Namoi Alluvial Groundwater Sources | Zone 4 alluvium | passive indirect take | 2026 | 144 | 1,028 |
| Namoi Alluvial Groundwater Sources | Zone 5 alluvium | passive indirect take | - | n/a | - |
| Namoi Alluvial Groundwater Sources | Zone 11 alluvium | passive indirect take | 2040 | 22 | 20 |

It is worth noting that the predicted water take from the Porous Rock Groundwater Source includes rainfall-derived water flowing through spoil, which does not require licensing. Given that apportioning inflows among ultimate sources is difficult, a conservative approach has been followed by comparing the predicted peak take (including water flowing through spoil) (479 ML/year) against the WALs held by the proponent (842 ML/year).

## 9.5 Impact on water supply bores

The AIP indicates 'minimal impact considerations' as described in Section 3.1.2. For water supply bores installed within the highly productive alluvial water sources, such as the Nagero Creek and Bollol Creek alluvium, the Level 1 minimal impact consideration threshold is stated in the AIP as *"a maximum of a 2 m decline cumulatively at any water supply work."*

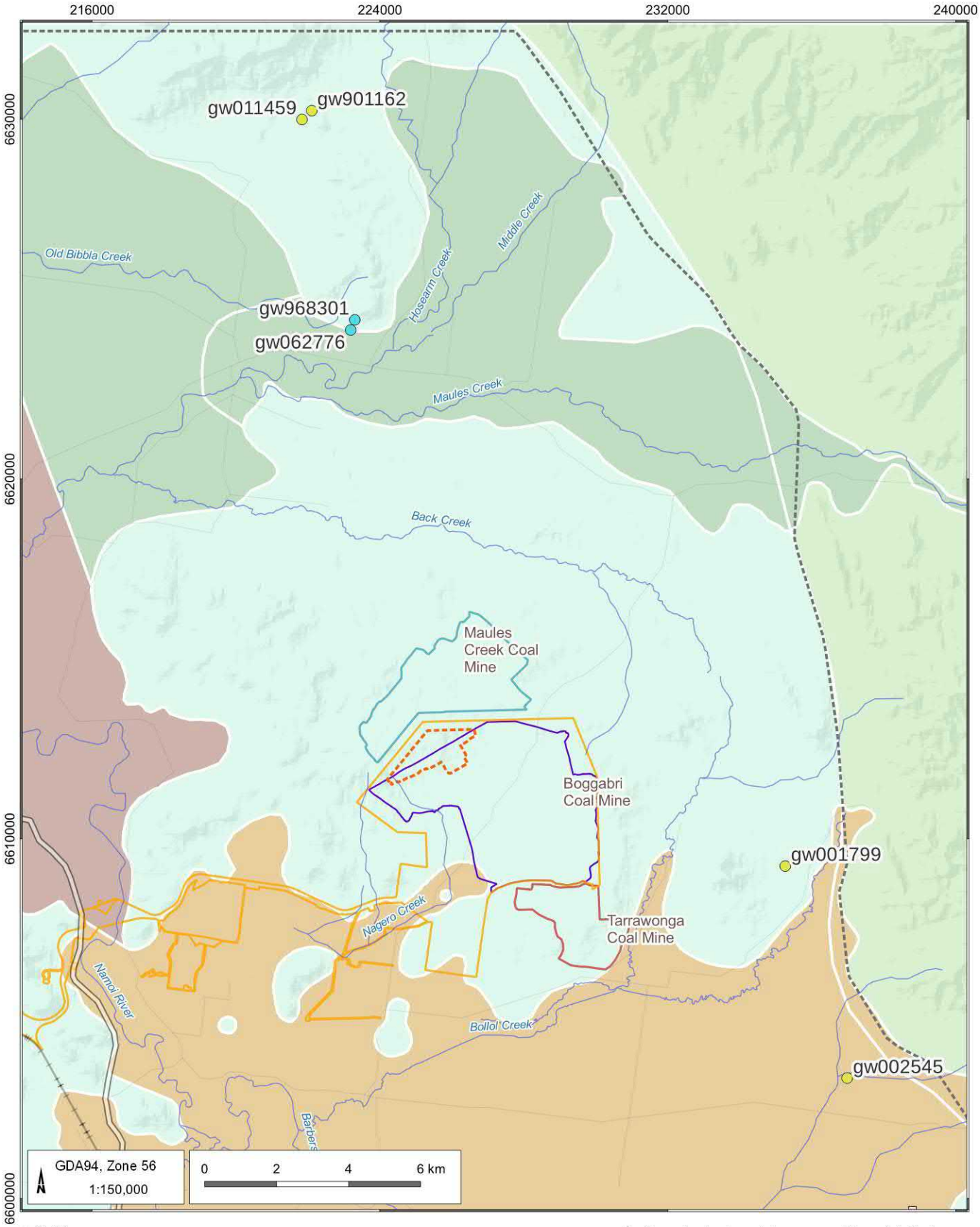
The private water supply bores with predicted maximum drawdown from the numerical model of more than 2 m are summarised in Table 9.2 and plotted in Figure 9.15. Drawdown is not predicted to exceed the AIP minimal impact considerations Level 1 threshold of 2 m within the highly productive alluvium at any known water supply bore site for the approved or proposed mining scenarios. This is consistent with previous investigations for MOD 7 and MOD 8, which did not predict any bores to be impacted with greater than 2 m drawdown.

Water supply bores predicted to be impacted by both approved and proposed mining scenarios are screened within the Maules Creek Formation and Boggabri Volcanics, which are in the AIP less-productive aquifer within the Gunnedah-Oxley Basin WSP. The predicted maximum drawdown between the approved and proposed mining scenarios is similar, and no additional private water supply bore is identified as being impacted by MOD 10 compared to the approved MOD 8. Modelling conducted for MOD 8 identified only one bore on private land to experience drawdown greater than 2 m, with the modelling assuming drawdown in layer 20 to be representative of all drawdown in the hard rock aquifer.

Table 9.2 Private water supply bore sites predicted to experience more than 2 m drawdown

| Private bore ID | Estimated Screened lithology | Bore status | Bore Purpose | Cumulative approved (Scenario 2) | | Cumulative proposed (Scenario 15) | |
|---|---|---|---|---|---|---|---|
| | | | | Maximum predicted drawdown (m) | Year of maximum drawdown | Maximum predicted drawdown (m) | Year of maximum drawdown |
| gw001799 | Interburden | Unknown | Stock and Domestic | 2.38 | 2240 | 2.38 | 2240 |
| gw002545 | Interburden | Unknown | Stock and Domestic | 3.35 | 2043 | 3.35 | 2043 |
| gw011459 | Interburden | Unknown | Water Supply | 3.26 | 2095 | 3.26 | 2095 |
| gw062776 | Volcanics | Functioning | Unknown | 2.43 | 2075 | 2.44 | 2075 |
| gw901162 | Interburden | Unknown | Stock and Domestic | 3.40 | 2145 | 3.41 | 2145 |
| gw968301 | Volcanics | Functioning | Stock and Domestic | 2.72 | 2075 | 2.73 | 2080 |

In accordance with the AIP, BCOPL would implement 'make good' provisions at any privately owned water supply bore experiencing more than 2 m of drawdown as a result of MOD 10. 'Make good' provisions would be assessed on a case-by-case basis and implemented in consultation with the affected landholder. Any make good provisions would be undertaken in consideration of the proportion of drawdown from all three mines (MCCM, BCM and TCM) at the impacted supply bore.




LEGEND

- Railway
- Principal Road
- Drainage
- BCM Modification Mining Area
- BCM Open Cut Extent
- BCM Project Boundary
- BTM Complex Model Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

**Water sharing sources**

- Gunnedah-Oxley Basin MDB Groundwater Source
- New England Fold Belt MDB Groundwater Source
- Upper Namoi Zone 11, Maules Creek Groundwater Source
- Upper Namoi Zone 4, Namoi Valley (Keepit Dam to Gin's Leap) Groundwater Source
- Upper Namoi Zone 5, Namoi Valley (Gin's Leap to Narrabri) Groundwater Source

**Water supply bores**

- Interburden
- Volcanics

Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Existing water supply bores where predicted drawdown exceeds 2m**

AGE

DATE 01/04/2025

FIGURE No: **9.15**

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Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\09.11_BCO5002.001_Existing water supply bores where predicted drawdown exceeds 2m.qgz

## 9.6 Groundwater dependent ecosystems

The Water Sharing Plans for the Namoi Alluvial Groundwater Sources and the NSW Murray Darling Basin Porous Rock Groundwater Sources identify several high-priority Groundwater Dependent Ecosystems (GDEs) located within the BTM Complex model domain. These have been discussed in Section 7.12.3 and shown in Figure 7.36 and Figure 7.37. Several studies have been conducted previously to investigate the occurrence of GDEs within the model area. These include:

- FloraSearch (2011) identified the presence of potentially groundwater-dependent Melaleuca bracteate along Goonbri and Bollol creeks. This work was conducted as part of the TCM environmental assessment (EA), and the mapping was consistent with the mapping by BoM (2019);
- Resource Strategies (2011) reviewed the potential impacts on the vegetation communities as part of TCM EA and found no significant impacts were anticipated;
- EcoLogical (2018) surveyed sedgeland proximal to Driggle Draggle Creek as part of the work to support the Vickery Extension Project, they noted that the surrounding environment was already modified from the natural environment due to cattle grazing;
- BoM (2019) mapping of sedgeland proximal to Driggle Draggle Creek was consistent with EcoLogical work;
- WSP (2021) conducted a desktop assessment of the regional high-priority GDE mapping, concluding that cumulative impacts are unlikely;
- WSP (2022) conducted a desktop study of leaf green index for two EPBC threatened species located in the Nagero Creek alluvium, including the Poplar Box and Blakey's red gum. Soil Adjusted Vegetation Index (SAVI) results indicated that only the Poplar Box has the potential to be connected to the groundwater system;
- WSP (2022) conducted field surveys, which confirmed the work of FloraSearch (2011); and
- WSP (2025) conducted a desktop assessment of the regional high-priority GDE mapping.

The AIP provides tables of 'minimal impact considerations' with threshold criteria for Level 1 impacts for GDEs. For groundwater-dependent ecosystems within highly productive alluvial water sources, the Level 1 minimal impact consideration threshold is:

> *"Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan…"*

The value adopted as the Level 1 threshold for high-priority groundwater-dependent vegetation was based on the observed water table variability associated with post-WSP climatic conditions in each alluvial zone (Zone 4 and 11) and the Gunnedah-Oxley Basin MDB Groundwater Source. Table 9.3 to Table 9.5 show observed seasonal water table fluctuations at each representative bore within the potential GDE area for each groundwater source. Figure 9.16 shows the predicted depth to water at the end of mining for no-mining (scenario 1) and all-approved (scenario 2) scenarios.

Table 9.3 Observed seasonal water table fluctuation within the Gunnedah – Oxley Basin Porous Rock Groundwater Source WSP zone

| Bore ID | Pumping affected? | Data period | Observed water level range (m AHD) | Observed seasonal fluctuation (m) |
|---|---|---|---|---|
| BRE2 | no | 30/01/2014 - 01/08/2023 | 331.6 to 337.9 | 6.3 |
| GW001869 | no | 30/01/2014 - 06/02/2019 | 280.1 to 280.4 | 0.3 |
| IBC2110 | no | 21/06/2006 - 12/11/2009 | 256.9 to 259.7 | 2.8 |
| MAC1280 | no | 22/12/2010 - 15/10/2023 | 263.4 to 273.2 | 9.8 |
| MOR1 | no | 30/01/2014 - 01/08/2023 | 244.6 to 246.9 | 2.2 |
| MORSE | no | 26/06/2014 - 21/08/2023 | 275.9 to 278.9 | 3.0 |
| REG01_V1 | no | 20/03/2014 - 29/10/2023 | 273.9 to 277.5 | 3.5 |
| REG02_V1 | no | 20/03/2014 - 29/10/2023 | 307.8 to 313.7 | 5.9 |

Table 9.4 Observed seasonal water table fluctuation within WSP Zone 4

| Bore ID | Pumping affected? | Data period | Observed water level range (m AHD) | Observed seasonal fluctuation (m) |
|---|---|---|---|---|
| GW030052_1 | no | 18/01/2006 - 09/05/2024 | 234.8 to 236.0 | 1.1 |
| GW030472_1 | no | 18/01/2006 - 09/05/2024 | 227.0 to 228.7 | 1.8 |
| GW030049_1 | no | 17/01/2006 - 09/05/2024 | 226.2 to 231.6 | 5.4 |
| GW031856 | no | 02/06/2006 - 17/03/2020 | 239.9 to 250.6 | 10.7 |
| BCS7 | no | 01/09/2007 - 28/01/2009 | 275.5 to 279.0 | 3.5 |
| BCS3 | no | 01/09/2007 - 28/01/2009 | 322.0 to 325.0 | 3.0 |

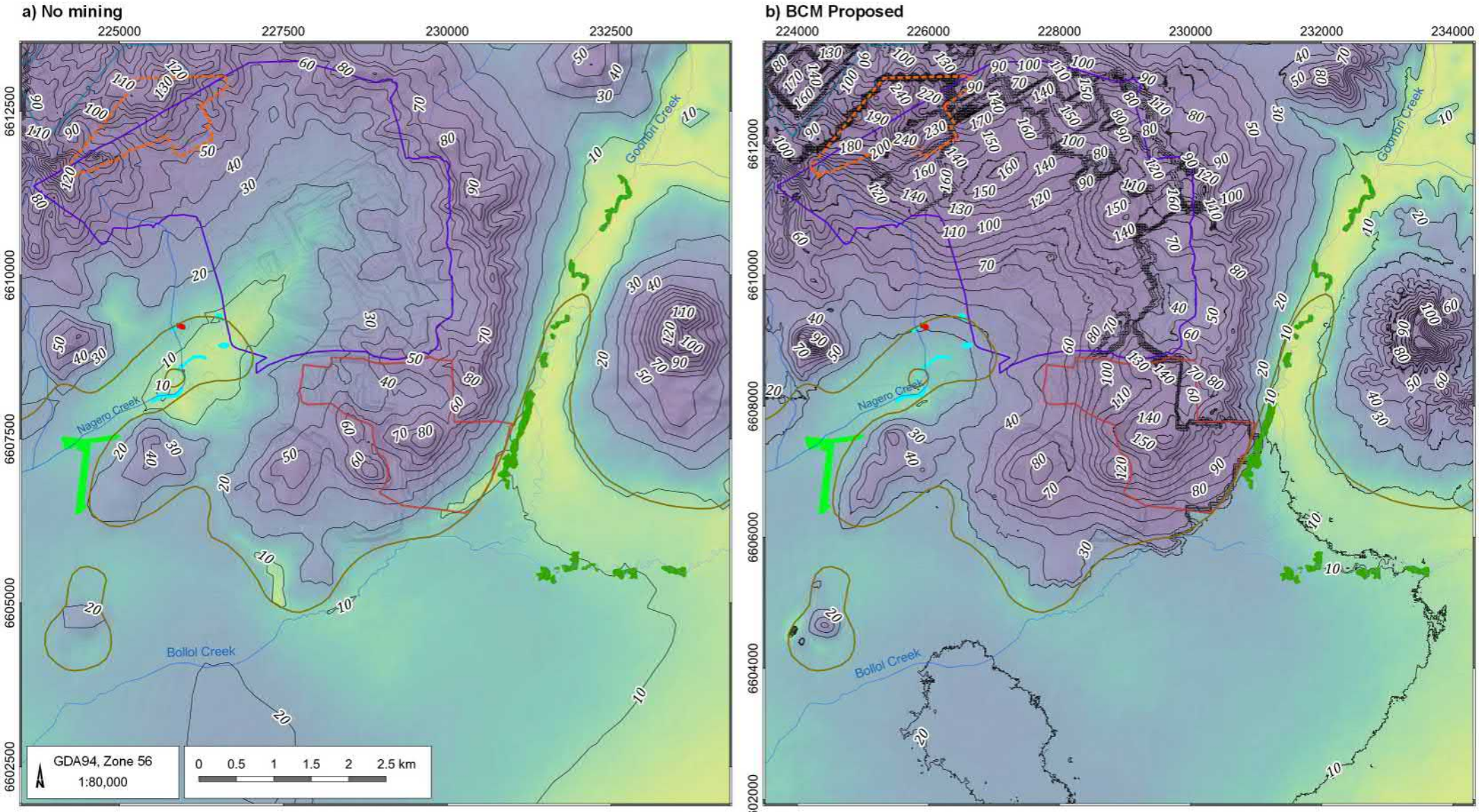
Table 9.5 Observed seasonal water table fluctuation within WSP Zone 11

| Bore ID | Pumping affected? | Data period | Observed water level range (m AHD) | Observed seasonal fluctuation (m) |
|---|---|---|---|---|
| GW041027_1 | no | 14/06/2006 - 12/12/2023 | 307.6 to 314.5 | 6.9 |
| GW967137_1 | no | 01/01/2006 - 07/04/2022 | 250.2 to 252.7 | 2.5 |
| GW967138_1 | no | 01/01/2006 - 28/12/2023 | 279.6 to 284.6 | 5.0 |
| GW968531_1 | no | 02/09/2008 - 12/11/2020 | 269.3 to 277.4 | 8.1 |
| GW030133_1 | no | 19/01/2006 - 14/05/2024 | 241.6 to 247.0 | 5.4 |
| GW030134_1 | no | 19/01/2006 - 14/05/2024 | 241.1 to 247.3 | 6.2 |

The median seasonal fluctuation in each WSP region is adopted for use with the AIP 10% change threshold. Based on the data reported in Table 9.3, Table 9.4, and Table 9.5 AIP thresholds for assessing impacts on GDEs were estimated as follows:

- Potential GDEs within WSP Zone 4 threshold = 0.3 m (from a median fluctuation of 3.2 m rounded down).
- Potential GDEs within WSP Zone 11 threshold = 0.5 m (from a median fluctuation of 5.8 m rounded down).
- Potential GDEs within Gunnedah Oxley Basin Porous Rock Groundwater Sources threshold = 0.3 m (from a median fluctuation of 3.2 m rounded down).

Depth to water beneath mapped GDEs for the no mining scenario and the cumulative BCM proposed and MCCM/TCM approved scenario (scenario 15) are plotted in Figure 9.16. For the no mining scenario, the depth to water beneath the Nagero Creek alluvium ranges from 7 mbgl to 10 mbgl in the northeastern section of the alluvium beneath mapped populations of White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (PCT599). Further downstream, the depth to water ranges from 14 mbgl to 17 mbgl. Depth to water along the Goonbri Creek ranges from approximately 3 mbgl to 15 mbgl. The depth to water beneath high priority GDE mapped along the Bollol Creek is generally greater than 10 mbgl up to 17 mbgl.




LEGEND

- Drainage
- Contour lines
- MCCM open cut extent
- BCM Open Cut Extent
- TCM Open Cut Extent
- BCM Modification Mining Area
- Alluvium

**EPBC mapped and WSP field verified GDEs**

- White Box grassy woodland of the Nandew
- Poplar Box Grassy Woodland on Alluvial Plains
- White Box – Yellow Box – Blakely's Red Gum Grassy Woodland
- Natural grasslands on basalt and fine-textured alluvial plains
- Poplar Box Grassy Woodland on Alluvial Plains
- White Box-Yellow Box-Blakely's Red Gum Grassy

**GDEs Priority**

- High
- Medium

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**Depth to water with EPBC mapped (WSP, 2022) field verified and high priority GDEs**

DATE
26/05/2025

FIGURE No.
**9.16**

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G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\09.16_BCO5002.001_Depth to water with EPBC mapped (WSP, 2022) field verified and high priority GDEs.qgz

### 9.6.1 Cumulative impact

High-priority GDEs, as identified by DCCEEW using the Australian Government's Guidelines for High Ecological Value Aquatic Ecosystems (HEVAE) (AETG, 2012), are mapped along drainage features, including the Namoi River, Barber's Lagoon, Maules Creek, Back Creek, Goonbri Creek, and the upper reaches of Bollol Creek. The location of these GDEs is plotted with the maximum predicted drawdown in the alluvium and the maximum predicted drawdown in the coal seams and volcanics in Figure 9.17. The maximum cumulative drawdown predicted to occur beneath high-priority GDEs include:

- Goonbri Creek:
  - up to 3.8 m drawdown in the alluvium and up to 11.9 m drawdown in the water table underlying GDEs;
  - drawdown is maximum at GDEs adjacent to mining at TCM; and
  - less than 1 m drawdown in the alluvium at GDEs away from mining at TCM.
- Bollol Creek:
  - up to 1.5 m drawdown in the alluvium underlying GDEs.
- Barbers Lagoon:
  - up to 0.16 m drawdown in the alluvium underlying GDEs.
- Maules Creek:
  - up to 0.3 m drawdown in the alluvium underlying GDEs.
- Back Creek:
  - up to 43 m drawdown in the water table underlying GDEs adjacent to MCCM.

Predicted cumulative drawdowns are similar to those predicted and reported in the approved MOD 8 GIA (AGE, 2022). Based on thresholds calculated from median water fluctuations, cumulative impacts at Goonbri Creek, Bollol Creek and Back Creek exceed the AIP minimal impact threshold of less than or equal to 10% cumulative variation in the water table.

Related to the potential impacts of the predicted drawdowns at Goonbri and Bollol Creeks, previous work by FloraSearch (2011) and WSP (2022) identified the presence of potentially groundwater-dependent Melaleuca bracteate communities. This assessment was consistent with the mapping conducted by BoM (2019), which served as the basis for the GDE Atlas. The potential impacts on these communities were investigated as part of the Tarrawonga Mine EA (Resource Strategies, 2011).

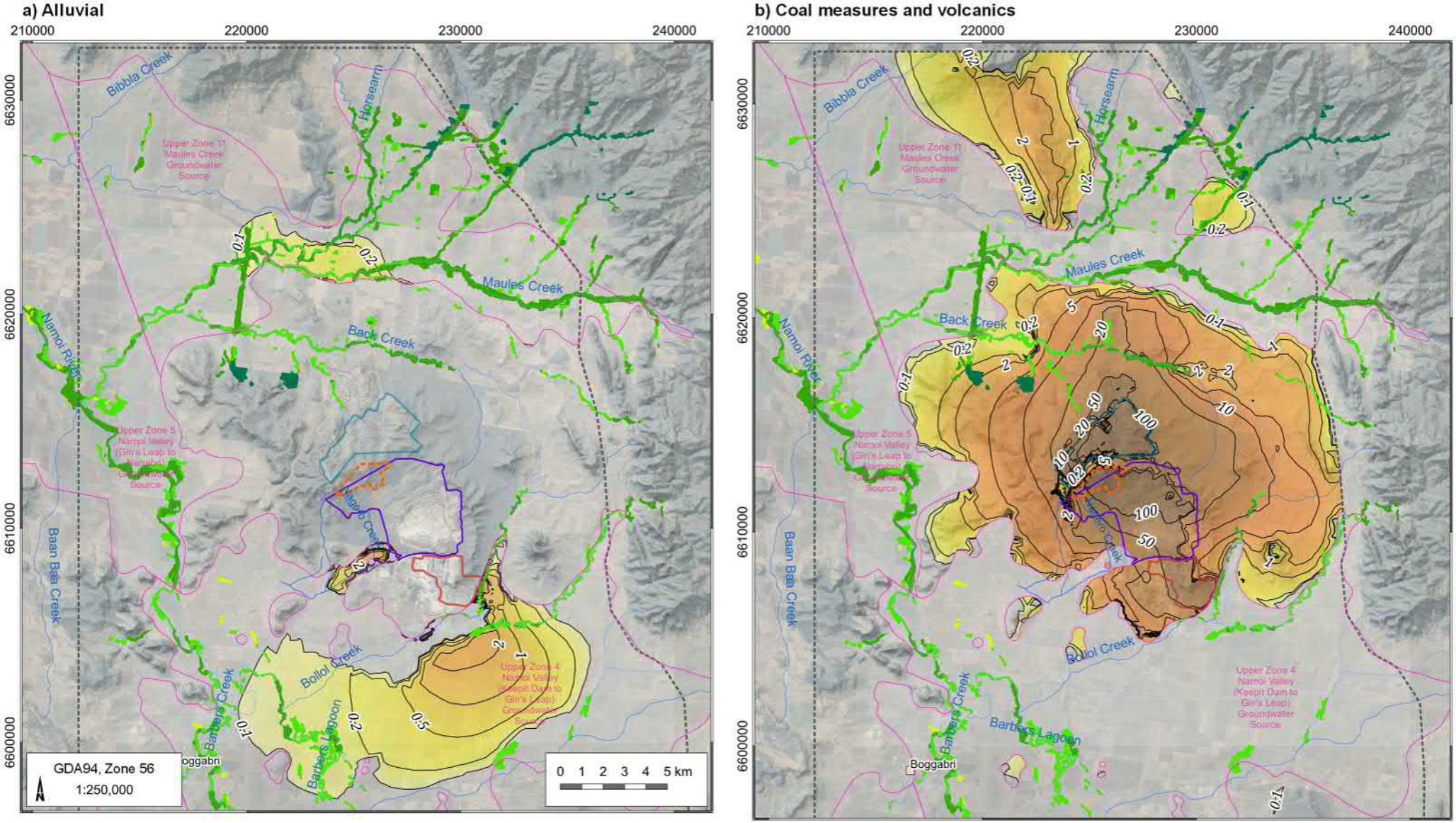
Work by Cumberland Ecology (2011) found that the presence of GDEs along Back Creek is unlikely due to the identified vegetation having a root zone of 2 mbgl to 3 mbgl and water table below 10 mbgl. Predicted depths to water for no mining indicate the water table at Back Creek is consistently below 10 mbgl (Figure 9.16).

Ecological communities listed under the EPBC Act and mapped by WSP (2022) along the Nagero Creek alluvium and within the potential zone of drawdown include (Figure 9.18):

- Poplar Box Grassy Woodland on Alluvial Plains (PCT101) - to the southwest of BCM and directly east/southeast of the Tarrawonga mining footprint; and
- White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (PCT599) - to the southwest of BCM.

Predicted drawdown within the Nagero Creek alluvium is expected to reach a maximum of 5.1 m at the fringes of the alluvial tongue (Section 9.2.1) with a predicted maximum drawdown of 3.8 m in areas near the Nagero Creek. Drawdown of up to 0.7 m is predicted at the location of field-verified mapped populations of PCT101 (WSP, 2021) (Figure 9.18). Based on previous modelling (AGE, 2022), which predicted a maximum drawdown of 4.3 m in Nagero Creek, WSP (2021) concluded that the risk of the predicted cumulative drawdown impacting the ecological community Poplar Box Woodland (PCT101) in Nagero Creek was low. This conclusion still holds as the predicted maximum drawdown under MOD 10 (3.8 m) is lower than the previously predicted drawdown (4.3 m) (AGE, 2022).

For the second ecological community listed in the EPBC Act, field-verified mapped populations of PCT599 (WSP, 2021) were identified within the Nagero Creek alluvium, close to mining activities on BCOPL-owned land. The maximum drawdown in the alluvium beneath these communities is approximately 3.6 m for the proposed mining scenario (Figure 9.16). Studies conducted by WSP (2022) compared soil-adjusted vegetation index (SAVI) values between PCT599 and the Leard State Forest, a non-groundwater-dependent control site. This comparison confirmed that PCT599 was unlikely to be connected to the groundwater system, with no apparent groundwater dependency (WSP, 2025).




LEGEND

- Drainage
- Contour lines
- MCCM open cut extent
- BCM Open Cut Extent
- TCM Open Cut Extent
- BCM Modification Mining Area
- Model Extent
- Groundwater Management Areas

**HEVAE GDEs**

- Very High
- High
- Medium
- Low

**Drawdown (m)**

| | |
|---|---|
| 0 | 10 |
| 0.1 | 20 |
| 0.2 | 50 |
| 0.5 | 100 |
| 1 | 200 |
| 2 | 500 |

AGE

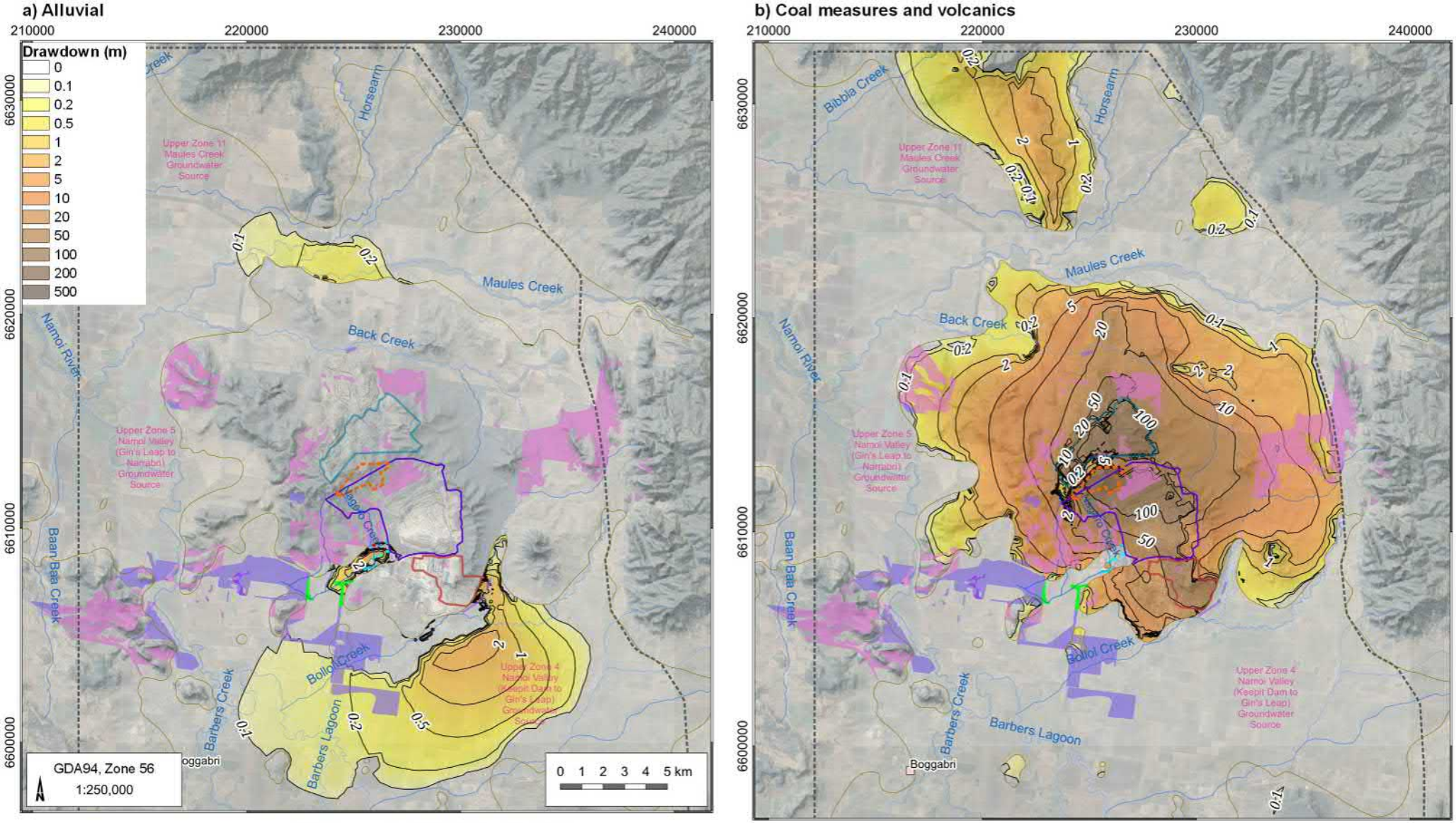
Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Maximum predicted drawdown (proposed) with WSP HEVAE mapped GDEs**

DATE
01/04/2025

FIGURE No.
**9.17**

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G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\09.16_BCO5002.001_Maximum predicted drawdown (proposed) with WSP HEVAE mapped GDEs.qgz




LEGEND

- Drainage
- Contour lines
- MCCM open cut extent
- BCM Open Cut Extent
- TCM Open Cut Extent
- BCM Modification Mining Area
- Model Extent
- Groundwater Management Areas

**EPBC mapped and WSP field verified GDEs**

- White Box grassy woodland of the Nandew
- Poplar Box Grassy Woodland on Alluvial Plains - Class A1 Highest Quality Condition
- White Box – Yellow Box – Blakely's Red Gum Grassy Woodland Derived Native Grassland
- Natural grasslands on basalt and fine-textured alluvial plains
- Poplar Box Grassy Woodland on Alluvial Plains
- White Box-Yellow Box-Blakely's Red Gum Grassy

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Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

**Maximum predicted drawdown (proposed) with EPBC mapped and (WSP) field verified GDEs**

DATE
21/05/2025

FIGURE No.
**9.18**

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G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\09.18_BCO5002.001_Maximum predicted drawdown (proposed) with EPBC mapped and (WSP) field verified GDEs.qgz

### 9.6.2 Incremental impact

As discussed in Section 9.2.2, no BCM-specific incremental impact in the Nagero Creek alluvium is predicted to occur when compared to the approved cumulative BTM Complex operations. The incremental, cumulative impact is present within a small area at the eastern edge of the Nagero Creek alluvial tongue. Incremental loss of saturation in the alluvium reaches a maximum of 0.3 m at the fringes of the alluvial tongue, noting that at this point, the water table is greater than 10 mbgl, and the alluvium is within the Mine Disturbance Boundary. The remainder of the incremental drawdown is approximately 0.1 m and is unlikely to be discernible from climate fluctuations.

## 9.7 Groundwater quality

Groundwater quality varies across the study area. Salinity ranges from freshwater near the Namoi River to brackish water closer to mining operations, whereas pH levels vary from neutral to slightly alkaline. A summary of key groundwater quality parameters is summarised in Section 7.11

Groundwater flow predictions for MOD 10 indicate that mining will continue to act as a groundwater sink, as previously predicted (AGE, 2022; AGE, 2010). Groundwater inflow into mining voids is treated as contaminated water, which is pumped by BCM to water storage dams and mining voids and, where possible, reused on-site for coal washing and dust suppression (Idemitsu, 2017).

Previous geochemical studies conducted by RGS (2009; 2020, 2025) concluded that the potential risk to the groundwater from water in contact with mining waste is low. These studies found that the coal reject material is generally non-acid forming (NAF), with salinity levels equivalent to or lower than those found in the surrounding groundwater systems, and concentrations of dissolved trace metals in groundwater are likely to be low. Recent geochemical sampling (RGS, 2025) identified material from the Herndale and Onavale seams to have elevated Sulfur content and, as such, are potentially acid-forming (PAF). The total amount of PAF material is considered a low fraction of the total NAF overburden. PAF coal reject material will be strategically managed by deep in-pit burial, which will be covered by inert NAF overburden materials, as described in the BCM Rehabilitation Management Plan. The acid mine drainage (AMD) risk associated with PAF materials from the MOD 10 project is considered low (RGS, 2025).

## 9.8 Impact assessment summary

To further understand incremental impacts associated with Modifications to the originally approved SSD 09_0182 a summary has been collated in Table 9.6. This table includes the original baseline impacts reported as part of the approved MOD 7 to SSD 09_0182, with incremental changes from MOD 7 to MOD 8 and MOD 8 to MOD 10.

Table 9.6 Summary of baseline impacts (MOD 7) and incremental change to last modification that altered impacts to the groundwater regime (MOD 8) and proposed (MOD 10)

| | MOD 7 (baseline) | MOD 7 to MOD 8 | MOD 8 to MOD 10 |
|---|---|---|---|
| Deepest seam mined | Merriown | Templemore | Templemore |
| End of operations (year) | 2033 | 2036 | 2040 |
| Mine disturbance area | - | No change | An additional 85 Ha |
| Heads and flow direction | Inward hydraulic gradient towards mining, no change outside mined areas | Lowered water table within the mining area attributable to the increased depth of mining and mine life | Lowered water table in the Modification Mining Area |
| Drawdown | The zone of influence largely remains within the Permian outcrop zone, a small valley of drawdown in the Nagero Creek alluvial tongue up to approximately 5 m | Alluvium – 0.3 m increase in drawdown from MOD 7<br>Coal seams – minimal incremental change down to Merriown (2 m), Maximum drawdown in Templemore 107 m | Alluvium – no increase in drawdown from MOD 7<br>Coal seams – 50 m incremental increase in Templemore seam |

| | MOD 7 (baseline) | MOD 7 to MOD 8 | MOD 8 to MOD 10 |
|---|---|---|---|
| Mine inflow | Maximum simulated inflows 457 ML per year (AGE, 2010) | Approximately 30% more inflow to the mine is associated with deeper excavation and extended operation | Approximately 27% more inflow to the mine is associated with increasing the footprint and extending the mining operation |
| Water take | Maximum predicted annual take:<br>- alluvial zone 4: 86 ML,<br>- alluvial zone 11: 4 ML | Estimated average increase:<br>- alluvial zone 4: ~40 %<br>- alluvial zone 11: ~60 % | Estimated average increase:<br>- alluvial zone 4: ~16 %<br>- alluvial zone 11: ~200 %* |
| Water supply bores | No alluvial or porous rock aquifer bores with predicted drawdown greater than 2 m | No alluvial aquifer bores with predicted drawdown greater than 2 m. One porous rock aquifer bore with a greater than 2 m predicted drawdown | No alluvial aquifer bores with predicted drawdown greater than 2 m. Four porous rock aquifer bores with greater than 2 m predicted drawdown |
| GDEs | GDEs in the vicinity of mining are not expected due to ephemeral creeks and depths to water greater than 2 m. No high-priority mapped GDEs within the expected drawdown | Incremental alluvial drawdown is only predicted to occur in a small portion of the alluvial tongue (Nagero Creek) | Incremental drawdown reaches a maximum of 0.3 m at the fringes of the alluvial tongue (Nagero Creek). However, at this point, the water table is deeper than 10 mbgl |
| Groundwater quality | The concentration of dissolved metals in initial run-off and seepage from potential coal reject materials or overburden is unlikely to present any significant environmental issues associated with surface and ground water quality | No change | No change |

**Note:** *large increase relative to small volumes of water take.

## 9.9 Recovery simulations

### 9.9.1 Heads, flow direction and depth to water

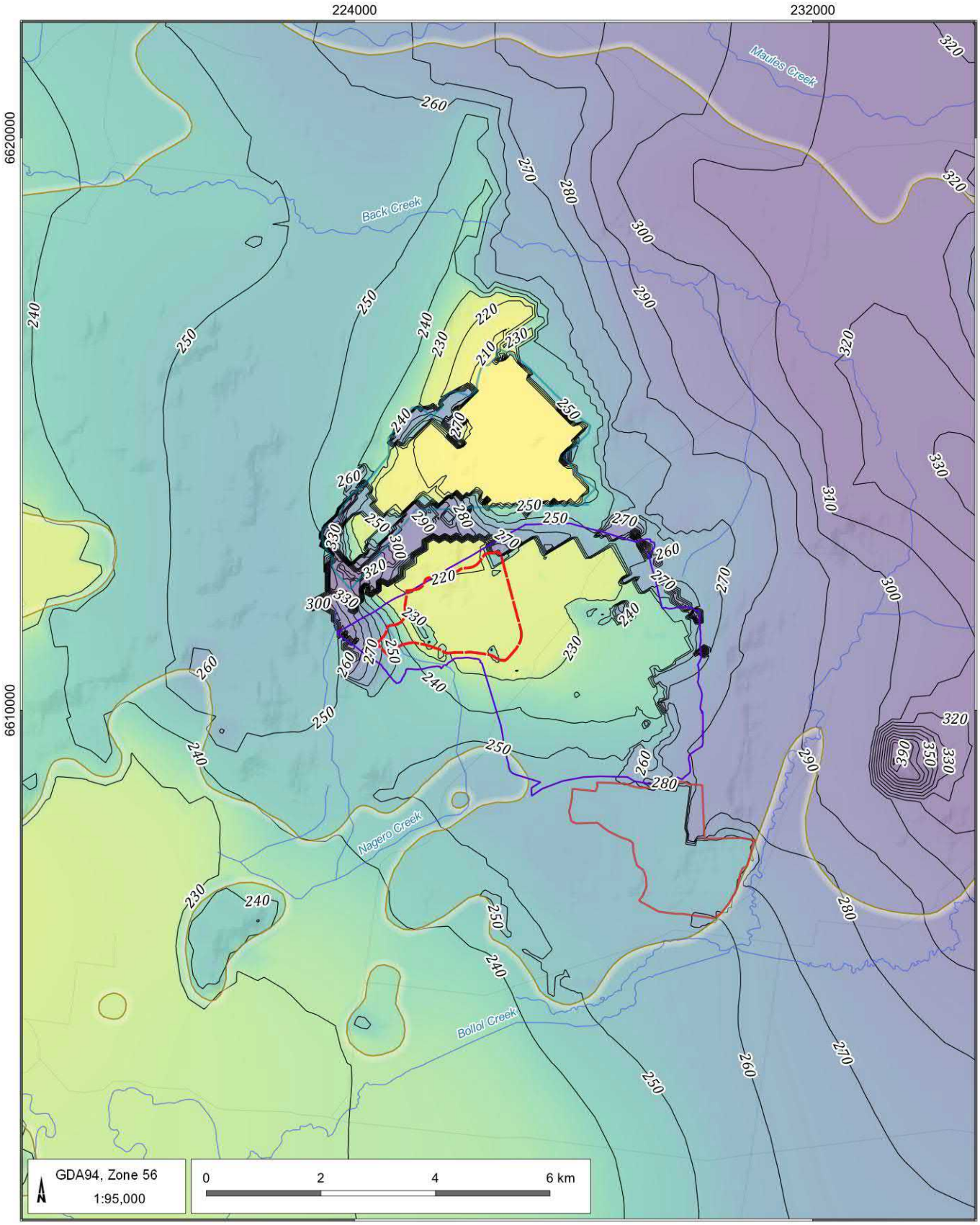
The final landform for MOD 10 is designed to be consistent with the previously approved final landform and with condition 69, Schedule 3 of the Project Approval (SSD 09_0182). As per the rehabilitation objectives outlined in Table 16 of the Project Approval, the final void should *'minimise the size and depth of the final void as far as is reasonable and feasible and ensure that the void contains no retained surface water (i.e., no pit lake)'.*

The final landform is designed with a partially infilled void at the northern edge of the BCM, located at an elevation of 285 m AHD. Although lower than the natural terrain, the partially infilled void is designed to be above the water table, potentially ponding only during significant rainfall events when infiltration capacity is exceeded (BCOPL, 2024; EMM [unpublished], 2025).

The BTM Complex model used in this assessment was modelled up to the end of mining, plus 200 years into the future. A steady-state model was run after the transient model concluded to assess the likely final equilibrium state of the system. This adopted the same mean stresses used in the 200-year post-mining simulation period. Spoil properties used in the steady-state model include horizontal hydraulic conductivity (Kx) of 0.3 m/day and vertical conductivity (Kz) of 0.1 m/day. Note storage properties do not impact a steady-state simulation. The simulated water table shows that groundwater remains below the levels of the final partially infilled void (Figure 9.19). Previous modelling (AGE, 2022) simulated recovery up to 1000 years post-closure. This modelling predicted that the BCM mining area would act as a rainfall recharge groundwater source, with groundwater from the BCM spoil flowing to the void lakes within the adjacent MCCM and TCM mines. These predictions also estimated a component to move southwest towards the adjacent alluvial tongue.

Testing the sensitivity of the water table beneath the void infill was accomplished by varying the properties of the spoil and future recharge in the final steady-state stress period. Horizontal and vertical hydraulic conductivities were reduced to 0.03 m/d and 0.01 m/d, respectively. In addition, recharge through the spoil was increased to 4% of mean rainfall (approximately 12 mm/yr), noting that recharge in the Permian is assumed to be significantly less. Under these conditions, the water table remained below surface elevation.

The reduced water table is related to the change in the aquifer's transmissivity attributed to the infilled void. Even with reduced spoil properties, the transmissivity is much greater than that of the original aquifer, where interburden dominated the hydrostratigraphic profile.




LEGEND

- Populated place
- Drainage
- Railway
- Principal Road
- Contour
- Alluvium
- approximate extent of infilled void
- BCM Open Cut Extent
- MCCM Open Cut Extent
- TCM Open Cut Extent

**Water table (mAHD)**

| | |
|---|---|
| 205 | 255 |
| 230 | 270 |
| 235 | 285 |
| 240 | 310 |
| 250 | 530 |

Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

## Equilibrated post mining piezometric surface – water table

AGE

DATE 22/05/2025

FIGURE No: 9.19

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G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\09.19_BCO5002.001_Equilibrated post mining piezometric surface – water table.qgz

### 9.9.2 Recovery duration

Previous work (AGE, 2022) showed that the recovery duration is within 300 years post-mining. The timing varied with changes to adopted properties for spoil used to fill the voids and recharge. The BTM Complex numerical model includes a 200-year post-mining simulation in which hydraulic heads do not achieve a new equilibrium. This prompted the inclusion of a steady-state simulation as the final stress period of the model. Accordingly, the recovery duration cannot be assessed explicitly but is expected to exceed 200 years, which aligns with the previous assessment in AGE (2022).

### 9.9.3 Groundwater quality

Geochemical studies conducted by RGS (2009, 2020, 2024) assessed the geochemistry of samples from the overburden, roof and floor (top and bottom) of the coal seams and from the interburden. Most of the spoil is expected to be comprised of overburden and interburden material. Overburden, interburden and coal rejects are generally considered to be NAF with the only PAF or unknown material contained in the Herndale and Onavale seams, which is managed in accordance with the BCM Rehabilitation Management Plan. Spoil material is not expected to be significantly enriched in metals/metalloids, and is expected to have neutral to slightly alkaline pH, with low levels of salinity (see Section 9.7).

Considering the material quality of the spoil is similar to that of the groundwater, a long-term change in the groundwater quality that has a material impact on the beneficial use of the surrounding groundwater systems is unlikely.

# 10 Uncertainty analysis (UA)

The magnitude of uncertainty inherent in the numerical model predictions was analysed. An overview of the methods used to address the uncertainty is provided below. Further technical details of the methodology and extended results of the UA are included in Appendix F.

For the uncertainty analysis, the IESC Explanatory Note on Uncertainty Analysis for groundwater modelling (Peeters and Middlemis, 2023) was followed as best practice. This technical document provides guidance on defining the QoIs, developing a fit-for-purpose numerical groundwater model, and using accurate terminology to assess the likelihood of potential impacts.

Two steps were followed to implement the uncertainty analysis in accordance with the IESC guidelines. First, a constrained Monte-Carlo approach was used to produce spatial drawdown probability surfaces of the water table. Second, Data Space Inversion (DSI) was used for assessing uncertainty in value predictions of maximum drawdown at receptors, mine inflow across all mine sites, and cumulative water take from the alluvial zones identified in the Water Sharing Plans (WSPs). The two approaches were required because DSI relies on a surrogate and is, therefore, unable to provide a spatial distribution of drawdown to create a probability surface. DSI is consequently the primary approach for the uncertainty analysis in this project. DSI was selected because it is less prone to the deleterious effects of information loss and/or corruption that can potentially accompany a complex model. The application of both methods, constrained Monte-Carlo and DSI, is fully supported by the IESC Explanatory Note on uncertainty analysis for groundwater modelling (Peeters and Middlemis, 2023). The IESC Note suggests that methods selected for uncertainty analysis should balance model complexity, the number of parameters, and the number of model evaluations required for the assessment. The Bayesian and ensemble-based approaches (using IESC terminology) implemented in this work meet this trade-off and can accommodate the complexity of the model predictions (QoIs) needed for this project.

Key points of the uncertainty analysis results are:

- Likelihood of cumulative water table drawdown exceeding 2.0 m in the alluvium is unlikely. This includes Nagero Creek and other alluvial zones around the BTM-Complex.
- Uncertainty in cumulative mean annual groundwater take from alluvial zones 4 and 11 ranges from 10 to 25 ML/yr.
- Uncertainty in mean annual mine inflows can be as high as 275 ML but is mostly less than 100 ML for BCM.
- Greater than 2.0 m drawdown impacts to private groundwater users attributed to operations at BCM under MOD 10 is very unlikely.

# 11 Regulatory framework requirements

## 11.1 Aquifer interference policy

The BTM Complex numerical groundwater model used to assess the impacts of MOD 10 on the groundwater regime is consistent with the AIP requirements in that it is appropriately calibrated and validated, it has been developed in a manner consistent with the Australian Groundwater Modelling Guidelines, and it has been independently reviewed. As discussed throughout Section 9, for both the 'highly productive' Upper Namoi Alluvium and the 'less productive' Gunnedah-Oxley Basin Porous Rock:

- cumulative impacts generally meet the Level 1 minimal impact considerations (some exceptions noted below); and
- the MOD 10 incremental impacts meet all Level 1 minimal impact considerations.

Drawdown is not predicted to exceed the AIP minimal impact considerations Level 1 threshold of 2 m within the highly productive alluvium at the site of any known private water supply bore for the approved or proposed mining scenarios. Six bores within the 'less productive' Gunnedah-Oxley Basin Porus Rock Water Source were identified as exceeding the Level 1 threshold.

Maximum drawdown is likely to exceed the 10% cumulative drawdown threshold for several GDEs along Goonbri Creek and Bollol Creek These potential impacts have been addressed in previous approvals (FloraSearch, 2011; Heritage Computing, 2012), and no further incremental drawdown has been predicted.

Changes in groundwater quality are not expected to affect the beneficial use of either water source, nor are any long-term salinity increases anticipated in connected surface water bodies. Groundwater fluxes during mining and post-recovery are inferred to be largely constrained within the BTM Complex, whereas the groundwater in contact with mining waste materials is expected to be of comparable quality to that of the surrounding systems.

BCOPL holds sufficient WALs under the WSP Murray Darling Basin Porous Rock Groundwater Sources for the Gunnedah-Oxley Basin Porous Rock Groundwater Source and Zones 4 and 5 of the Namoi Alluvial Groundwater Sources. Currently, BCOPL does not hold sufficient WALs for Zone 11 of the Namoi Alluvial Groundwater Sources, whereby BCOPL holds sufficient licenses for all years, except 2040, when predicted water take exceeds WALs by 2 ML.

## 11.2 Environment Protection and Biodiversity Conservation Act 1999

On 20 August 2024, a delegate of the Federal Minister for the Department of Climate Change, Energy, the Environment and Water (DCCEEW) determined that the Boggabri Coal Mine Modification 10 (MP 09_0182 Mod 10) (EOBC 2024/09887) was a controlled action under section 75 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

As per section 4.3 of the Significant Impact Guidelines 1.3 (DCCEEW 2013);

> *'A significant impact on the hydrological characteristics of a water resource may occur where there are, as a result of the action:*
>
> *a) changes in the water quantity, including the timing of variations in water quantity;*
>
> *b) changes in the integrity of hydrological or hydrogeological connections, including substantial structural damage (e.g. large scale subsidence); and*
>
> *c) changes in the area or extent of a water resource.*
>
> *Where these changes are of sufficient scale or intensity as to significantly reduce the current or future utility of the water resource for third party users, including environmental and other public benefit outcomes.'*

MOD 10 indicates that changes in flow regimes, recharge rates, aquifer pressure or water table levels, groundwater-surface water interactions, river-floodplain connectivity, and inter-aquifer activity are not expected to be of sufficient scale or intensity to significantly reduce the quantity or quality of water resources for third-party users or the environment.

The incremental impacts of MOD 10, relative to approved mining, are minimal, while cumulative impacts are fundamentally equivalent to those for already approved mining activities.

According to the Significant Impact guidelines and in accordance with the impact considerations discussed throughout Section 9, MOD 10 is unlikely to significantly impact the hydrological characteristics of surrounding water sources.

This assessment was completed in consideration of the IESC information guidelines, along with their associated explanatory notes.

# 12 Mitigation, management and monitoring

BCOPL manages the impacts of the BCM in accordance with the approved Water Management Plan (WMP), which was prepared in consultation with NSW government agencies and is consistent with the requirements of the conditions of consent. The WMP is an overarching document that sets out the water management framework, statutory and procedural requirements. Its main components are the site water management strategy (WMS), a surface water management plan (SWMP), a GWMP, and a site water balance (SWB). The SWMP presents a mitigation and response plan defining the actions that must be undertaken if any established triggers are exceeded.

The currently approved GWMP (v06.01, 2017) focuses on assessing, monitoring, and, when necessary, managing impacts on the groundwater regime identified due to BCM activities. The objective of the GWMP is to ensure compliance with consent conditions. The components of the GWMP include groundwater baseline data, performance criteria, monitoring programs, response plans, and groundwater model validation programs. Regarding groundwater quality, a qualified hydrogeologist will review the relevant monitoring information if any trigger level is exceeded. This review will assess trends in monitoring data, mining activities, and climatic conditions, and may suggest management, monitoring, and/or mitigation measures. The GWMP establishes that a similar review process be conducted for groundwater levels to recommend management, monitoring, and mitigation measures for compliance.

BCOPL has established a groundwater monitoring network to assess/monitor impacts from BCM and the BTM Complex, as described in Section 6. The monitoring network comprises standard monitoring bores installed within the alluvial aquifers and the deeper Permian strata, including the coal measures. Monitoring bores currently being installed in the alluvium are considered sufficient to assess any changes in water levels and quality associated with the progression of mining. The network also includes arrays of VWPs cemented into selected drill holes to monitor pressure in deeper strata and provide multilevel monitoring. This includes monitoring sites along Nagero Creek underlying Permian strata, allowing water level observations to be compared with numerical modelling predictions.

Current mining activities have to date and will result in removing some existing groundwater monitoring sites within the approved Mine Disturbance Boundary and Modification Disturbance Footprint as a result of approved and proposed mining operations. Replacement bores have been planned with coal monitoring bore BEP_05a/b/c installed to meet commitments from MOD 8. The remainder of the bores are planned for installation in 2025 and are outlined in Section 6.1.

Currently, groundwater levels and water quality (pH and EC) are measured regularly in the monitoring bores, alongside daily water level readings recorded by dataloggers in selected monitoring bores and VWPs in accordance with the approved GWMP. Continuous monitoring will help distinguish between natural groundwater level fluctuations, such as those occurring in response to rainfall, and potential impacts from groundwater level changes resulting from depressurisation due to proposed mining activities. Additionally, ongoing monitoring of groundwater levels will be used to evaluate the extent and rate of depressurisation compared to model predictions. BCOPL has commenced installing additional monitoring bores to expand the existing monitoring network, meet approved MOD 8 commitments, and further understand the hydraulic properties of the Conomos fault in line with IESC guidelines.

The annual review includes yearly reporting of the water level results from the monitoring network. It will also identify whether additional monitoring sites are required or whether the existing monitoring sites should be optimised.

The GWMP (v06.01, 2017) includes performance measures and Trigger Action Response Plans (TARPs) for changes in groundwater levels and quality. Water level and quality measurements are routinely compared to trigger thresholds, with outcomes documented in the Annual Review. The trigger levels are periodically reviewed in consultation with relevant agencies as more monitoring information becomes available. Specific measures should be implemented in consultation with the relevant regulator when exceedances are detected for water levels and quality. In particular, the GWMP establishes that:

- For groundwater quality, "where any exceedance of a trigger level is confirmed a review of relevant monitoring information will be carried out by a suitably qualified hydrogeologist. The review will consider trends in monitoring data, mining activities, climatic conditions and may recommend management, monitoring and/or mitigation measures. If BCM is confirmed to have caused the impact, recommendations for monitoring or mitigation measures will be provided. BCOPL will consult with the DPIW (or relevant regulator) on the outcomes of the review prior to the implementation of any mitigation measures".
- For groundwater levels, "in the event that groundwater levels readings for these monitoring bores (Table 4.1) fall below the historical 5th percentile (based on all previous data) for more than 30 days, a review of monitoring information will be carried out by a suitably qualified hydrogeologist. The review will consider trends in monitoring data, mining activities and climatic conditions and may recommend management, monitoring and/or mitigation measures".
- For private water supply bores, "where a landowner of a privately registered bore reports that their water supply is adversely and directly impacted by the abstraction of groundwater from the borefield, an investigation will be undertaken by a suitably qualified hydrogeologist. The investigation will consider the potential causes of the impact including, private landowner and mining activities, local groundwater abstraction rates, climatic conditions, condition of water supply works and assess if the impact has occurred as a result of BCOPL's operations…Where the investigation confirms BCOPL has adversely and directly impacted the water supply, other than an impact that is negligible, a compensatory water supply will be provided to the landowner as per Schedule 3, Condition 34 of the Project Approval. The types of compensatory water supply to be made available may include financial provisions, alternative water supply provisions or other 'make good' provisions and will be developed in consultation with the landowner and DPIW."
- For groundwater dependent ecosystems, "if impacts to GDEs are identified through vegetation surveys these will be assessed against groundwater levels in monitoring bores and climatic conditions to identify the causes of the impacts. The results of the assessment will be reported in the Annual Review (refer to Section 7.1)."

The BTM Complex numerical model predictions are reviewed and updated every three years. This version of the BTM Complex model has been reviewed by Dr Noel Merrick, who has provided a detailed independent peer review assessment available in Appendix G.

## 12.1 Monitoring and mitigation measures to address the impacts of MOD 10

Incremental impacts with respect to MOD 8 are limited, and mitigation measures to address potential impacts arising from MOD 10 can be addressed with the current approval conditions of MOD 8. In terms of specific measures to address the incremental impacts of MOD 10, the following actions are suggested:

1. Water take for Namoi Alluvial Groundwater Sources Zone 11 alluvium is predicted to exceed WAL units held by BCM in 2040. A review of the requirement to acquire an additional 2 units should be considered after further iterations of the groundwater model prior to 2040.
2. Utilisation of recently installed bores screened in the upper and lower alluvium, including BEP_01a and b, BEP_02 and BEP_03. These bores are considered sufficient to monitor impacts to the Nagero Creek alluvium associated with the BCM, including changes from MOD 10.

# 13 References


Australasian Groundwater and Environmental Consultants. (2010). *Continuation of Boggabri Coal Mine Groundwater Assessment.* Idemitsu.

Australasian Groundwater and Environmental Consultants. (2010). *Maules Creek Coal Project – Groundwater Impact Assessment prepared for Aston Resources Limited. Project No. G1508.* Brisbane: AGE Consultants.

Australasian Groundwater and Environmental Consultants. (2011). *Maules Creek Coal Project – Groundwater Impact Assessment Project No. G1508.* Brisbane: Aston Resources.

Australasian Groundwater and Environmental Consultants. (2014). *Maules Creek Coal Project Installation of Monitoring Bore Network and Updating Groundwater Model. Prepared for Whitehaven Coal Project No. G1508/B, January 2014.* Brisbane: AGE Consultants.

Australasian Groundwater and Environmental Consultants. (2017). *RE: Maules Creek Interburden, Project No. G1850E.* Whitehaven Coal.

Australasian Groundwater and Environmental Consultants. (2018). *Boggabri, Tarrawonga, Maules Creek Complex – Numerical Model Update, Project No. G1850A.* Boggabri Coal and Whitehaven Coal.

Australasian Groundwater and Environmental Consultants. (2020). *Boggabri Coal Mine - Interburden Permeability Testing.* unpublished.

Australasian Groundwater and Environmental Consultants. (2020). *Boggabri, Tarrawonga, Maules Creek Complex Groundwater Model Update.* Brisbane: Australian Groundwater and Environmental Consultants.

Australasian Groundwater and Environmental Consultants. (2022). *Groundwater Impact Assessment Boggabri Coal Mine MOD 8 Amendment to SSD 09_0182.* Idemitsu.

Aquatic Ecosystems Task Group (AETG). (2012). *Aquatic Ecosystems Toolkit. Module 3: Guidelines for Identifying High Ecological Value Aquatic Ecosystems (HEVAE). Australian Government Department of Sustainability,* Environment, Water, Population and Communities, Canberra.

Aryal, S. K., Northey, J., Slatter, E., Ivkovic, K., Crosbie, R., Peña-Arancibia, J., . . . Bell, J. (2018b). *Observations analysis, statistical analysis and interpolation for the Namoi subregion. Product 2.1-2.2 for the Namoi subregion from the Northern Inland Catchments Bioregional Assessment.* Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia. Retrieved from https://data.bioregionalassessments.gov.au/product/NIC/NAM/2.1-2.2

Aryal, S. K., Pena-Arancibia, J., Viney, N., Yang, A., Wang, B., Hughes, J., . . . Kim, S. (2018a). *Surface water numerical modelling for the Namoi subregion. Product 2.6.1 for the Namoi subregion from the Northern Inland Catchments Bioregional Assessment.* Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. Retrieved from https://data.bioregionalassessments.gov.au/product/NIC/NAM/2.6.1

Barnett, B., Townley, L. R., Post, V., Evans, R. E., Hunt, R. J., Peeters, L., . . . Boronkay, A. (2012). *Australian groundwater modelling guidelines. Waterlines report.* Canberra: National Water Commission.

Barnett, S., & Clancy, J. S. (2012). *Australian groundwater modelling guidelines, Waterlines Report.* Canberra: National Water Commission.

BCOPL. (2024). *ENV-RHB-STR-001 Rehabilitation Strategy.* BCOPL.

Bureau of Meteorology. (2019). *Groundwater Dependent Ecosystems Atlas of Australia*. Retrieved from Bureau of Meteorology: http://www.bom.gov.au/water/groundwater/gde/index.shtml

Cadman, S. J., Pain, L., & Vuckovic, V. (1998). *Bowen and Surat Basins, Clarence-Moreton Basin, Sydney Basin, Gunnedah Basin and other minor onshore basing, Qld, NSW and NT.* Kingston, ACT: Dept. of Primary Industries and Energy, Bureau of Resource Sciences.

Coffey and Partners Pty Ltd. (1983). *Maules Creek Groundwater Investigation Report No. HS62/3-AV.* Kembla Coal and Coke Pty.

Commonwealth of Australia. (2024). *Information Guidelines Explanatory Note Using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessment.* Canberra: Commonwealth of Australia.

Commonwealth of Australia. (2024). *Information Guidelines Explanatory Note: Using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessment.* Department of Climate Change, Energy, the Environment and Water, Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development. Canberra: Commonwealth of Australia.

Cowen Geodata Services. (1995). *Scone-Gunnedah surveys, Narrabri area; Aeromagnetic and radiometric interpretation.* NSW Geological Survey Report 1997/076.

Cuthbert, M. O., Acworth, R. I., Andersen, M. S., Larsen, J. R., McCallum, A. M., Rau, G. C., & Tellam, J. H. (2016). Understanding and quantifying focused, indirect groundwater recharge from ephemeral streams using water table fluctuations. *Water Resources Research, 52*(2), 827-840. doi:https://doi.org/10.1002/2015WR017503

Danis, C., & O'Neil, C. (2013). *The Geology of NSW; The geological characteristics and history of NSW with a focus on coal seam gas (CSG) resources. A report commissioned for the NSW Chief Scientist's Office.*

Danis, C., O'Neill, C., & Lackie, M. A. (2010). Gunnedah Basin 3D architecture and upper crustal temperature. *Australian Journal of Earth Sciences, 57*(4), 483-505.

Douglas Partners. (2020). *Groundwater services packer testing Project no. 102002.00.* unpublished.

EMM [unpublished]. (2025). *Surface Water Impact Assessment.* unpublished.

FloraSearch. (2011). *Tarrawonga Coal Project - Flora Assessment.* Whitehaven Coal.

Food and Agricultural Organisation of the United Nations. (1992). *The use of saline waters for crop production FAO irrigation and drainage paper 48.* Rome: Food and Agricultural organisation of the united nations.

Gates, G. W., & Ross, J. B. (1980). Cainozoic alleviation and hydrogeology of the Namoi River Basin, NSW. *The Cainozoic Evolution of Continental Southeast Australia : abstracts of papers presented at a symposium held in Canberra, November 1980* (pp. 28-30). Canberra: Geological Society of Australia (Commonwealth Territories Division) and the Bureau of Mineral Resources, Geology and Geophysics.

GES. (2012). *A groundwater field investigation program in support of the Vickery Coal Project environmental assessment.* Groundwater Exploration Services Pty Ltd.

Glen, R. A. (2005). The Tasmanides of Eastern Australia. In A. P. Vaughan, P. T. Leat, & R. J. Pankhurst, *Terrane Processes At The Margins Of Gondwana Special Publication 246* (pp. 23-96). London: Geological Society.

GMDSI. (2020). *Groundwater Modelling Decision Support Initiative*. Retrieved from https://gmdsi.org/: https://gmdsi.org/

Government of NSW. (2012). *Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources 2012.* Government of NSW, Minister of Primary Industries.

Government of NSW. (2020). *Water Sharing Plan for the Namoi Alluvial Groundwater Sources Order 2020.* Minister for Water, Property and Housing.

Government of NSW. (2020). *Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources Order 2020.* Government of NSW Minister for Water, Property and Housing.

Government of NSW. (2025). *Draft Water Sharing Plan for the Namoi and Peel Unregulated Rivers Water Sources 2025.* Department of Primary Industries and Environment.

Groundwater Exploration Services Pty Ltd. (2012). *A Groundwater field investigation program in support of the Vickery Coal project environmental assessment.* Whitehaven Coal Limited. Retrieved from https://whitehavencoal.com.au/Documentations/Vickery%20Extension%20Project/Environmental%20Management,%20Monitoring%20&%20Compliance/Environmental%20Assessments/VIC-Environmental%20Impact%20Statement-Appendix%20A%20-%20Groundwater%20Assessment%20-%20Part%

Groundwater Imaging. (2023). *AgTEM Electrical Resistivity Tomography for Groundwater Investigation Maules Creek Coal Mine.*

Gunn, P. J. (2002). *Interpretation of gravity and aeromagnetic data over the Northern Gunnedah Basin, New South Wales.* NSW Department of Mineral Resources.

Hamilton, D. S., Beckett, T., & Weber, C. R. (1989). Gunnedah Basin. In K. H. Wolf, *Permian coals of eastern Australia* (Vol. Bulletin 231, pp. 43-58). Canberra: Bureau of Mineral Resources.

Hansen Bailey. (2010). *Boggabri Mine Environmental Impact Statement.*

Heritage Computing. (2012). *Groundwater Assessment - A Hydrogeological Assessment in Support of the Tarrawonga Coal Project Environmental Assessment. Project number: WHC-04 Report.* Tarrawonga Coal Pty Ltd By Dr N. P. Merrick and Dr M. Alkhatib Heritage Computing Pty Ltd.

Herr, A., Northey, J., Mitchell, P. J., Aryal, S. K., Merrin, L. E., & Slatter, E. (2018). *Conceptual modelling for the Namoi subregion. Product 2.3 for the Namoi subregion from the Northern Inland Catchments Bioregional Assessment.* Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia.

Idemitsu. (2017). *Boggabri Coal Operations Pty Ltd Site water balance .*

Idemitsu. (2024). *Groundwater Management Plan - Final for consultation.* Unpublished.

IESC. (2024). *Infomation guidelines and explanatory notes*. Retrieved from https://www.iesc.gov.au/information-guidelines

IESC. (2024). *Information Guidelines Explanatory Note Using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessmen.* Canberra: Commonwealth of Australia.

Janardhanan, S., Crosbie, R., Pickett, T., Cui, T., Peeters, L., Slatter, E., . . . Herr, A. (2018). *Groundwater numerical modelling for the Namoi subregion. Product 2.6.2 for the Namoi subregion from the Northern Inland Catchments Bioregional Assessment.* Canberra: Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. Retrieved from http://data.bioregionalassessments.gov.au/product/NIC/NAM/2.6.2

JB Mining. (2019). *CL375 Maules Creek Resource Statement.*

JB Mining. (2010). *Interpolation of regional coal seam surfaces.* unpublished.

McNeilage, C. (2006). *Upper Namoi groundwater flow model, model development & calibration.* Parramatta: NSW Department of Natural Resources.

Murray, T. A., & Power, W. L. (2021). *Information Guidelines Explanatory Note: Characterisation and modelling of geological fault zones.* Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Agriculture, Water and the Environment, Commonwealth of Australia.

NSW Department of Planning and Envionment. (2022d). *Cumulative Groundwater Impact Assessment Approaches.* NSW Department of Planning and Envionment.

NSW Department of Planning and Environment. (2022a). *Groundwater assessment toolbox for major projects in NSW - Overview document. Technical guideline prepared for the Water group.* NSW Department of Planning and Environment.

NSW Department of Planning and Environment. (2022b). *Guidelines for Groundwater Documentation for SSD/SSI Projects. Technical guideline.* NSW Department of Planning and Environment.

NSW Department of Planning and Environment. (2022c). *Minimum Groundwater Modelling Requirements for SSD/SSI Projects. Technical Guidelines.* NSW Department of Planning and Environment.

Parsons Brinkerhoff. (2015). *Boggabri Coal Mine – Project Approval Modification Environmental Assessment (MOD 5). Document No. 2200545A-ENV-REP-2 RevF.*

Peeters, L. J., & Middlemis, H. (2023). *Information Guidelines Explanatory Note: Uncertainty analysis for groundwater modelling, A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Climate Change, Energy.* Canberra: Commonwealth of Australia. Retrieved from https://www.iesc.gov.au/sites/default/files/2022-07/information-guidelines-explanatory-note-uncertainty-analysis.pdf

Pena-Arancibia, Slatter, Northey, & Cassel. (2016). *Current water accounts and water quality for the Namoi subregion. Product 1.5 for the Namoi subregion.* Canberra: Northern Inland Catchments Bioregional Assessment, Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia.

Pratt, W. (1998). *Notes to accompant the 1:100,000 scale Gunnedah coalfield regional geology (north and south) maps. Geological survey report No. GS1998/505.* NSW Department of Mineral Resources.

Rau, G., McCallum, A., Anderson, M. S., & Acworth, R. I. (2008). *The Use of Natural Heat as a Tracer to Quantify Surface Water and Groundwater Interactions: Maules Creek, New South Wales, Australia.* UNSW Connected Waters Initiative.

Resource Strategies. (n.d.). *Boggarbi-Tarrawonga-Maules Creek Complex Water Management Strategy.* Whitehaven Coal and Boggabri Coal Operations Pty Ltd.

RGS. (2009). *Continuation of Boggabri Coal Mine Geochemical Assessment.* Hansen Bailey Pty Ltd on behalf of Boggabri Coal Operations Pty Ltd.

RGS. (2020). *Geochemical Assessment of Interburden and Potential Coal Reject.* Hansen Bailey Pty Ltd on behalf of Boggabri Coal Operations Pty Ltd.

RPS Aquaterra. (2011). *Tarrawonga Groundwater Field Investigation Program.*

Scientific Information for Land Owners. (2024, 06 01). *Database of historical climate records for Australia*. Retrieved from The Long Paddock: https://www.longpaddock.qld.gov.au/silo/ date accessed 01/06/2024

Tadros, N. Z. (1993). The Gunnedah Basin, New South Wales. *Memoir 12*.

Tadros, N. Z. (1995). Gunnedah Basin. In C. R. Ward, H. J. Harrington, C. W. Mallett, & J. W. Beeston, *Geology of Australian Coal Basins, Special Publication No. 1* (pp. 247-298). Australia: Geological Society of Australia Incorporated Coal Group.

Whitehaven Coal. (2023). *Annual Review 2023 Tarrawonga Coal Mine.* Whitehaven Coal.

Whitehaven Coal. (2023). *Water Management Plan.* Whitehaven Coal.

Whitehouse, J. (1993). Coal resources of the Maules Creek Sub-basin. In N. Z. Tadros, *The Gunnedah Basin, New South Wales* (Vol. Memoir Geology 12, pp. 523-534). Geological Survey of New South Wales.

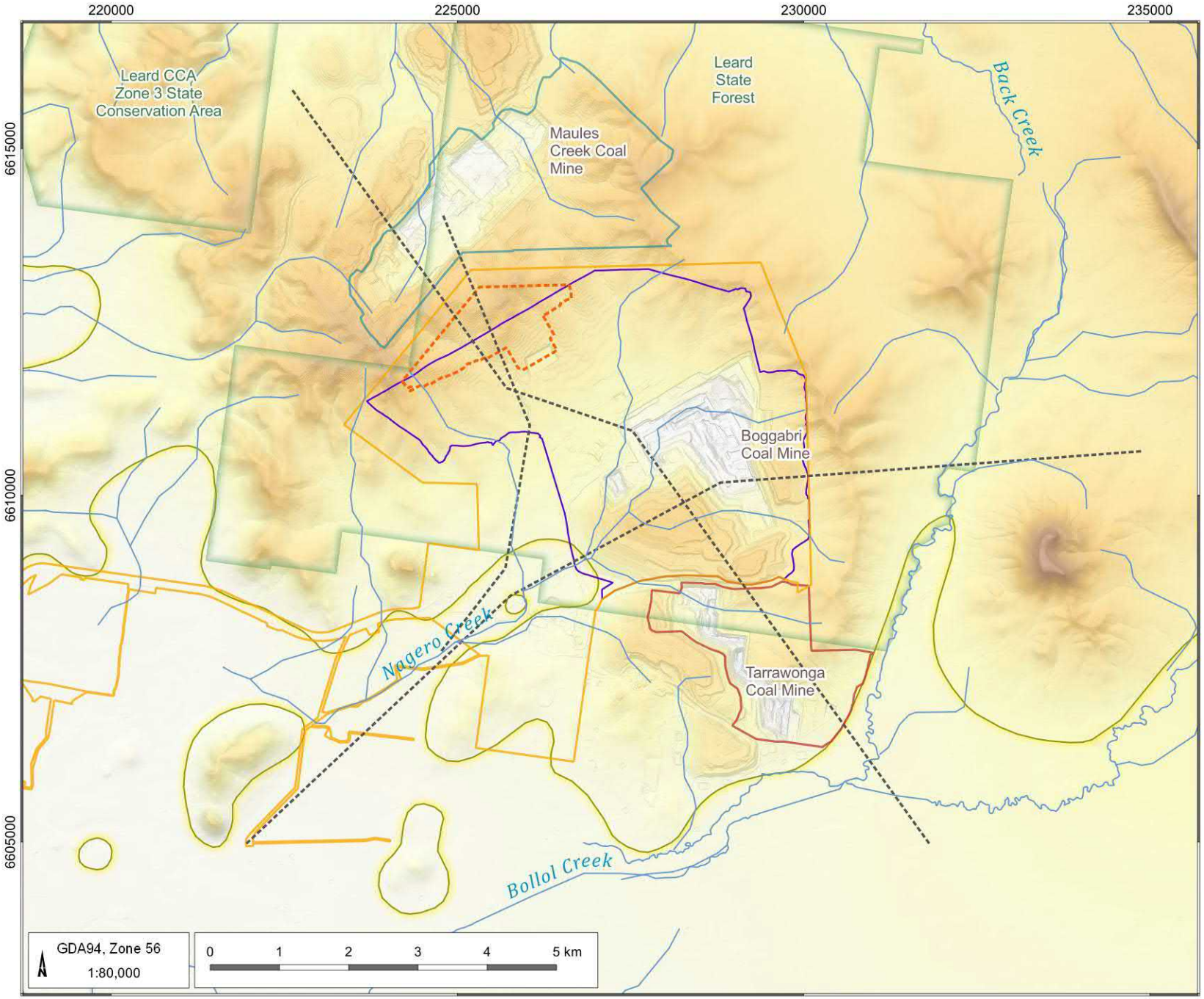
WSP. (2021). *Boggabri Coal Mine Mod 8 Groundwater dependent ecosystem assessment.* Idemitsu .

WSP. (2022). *Boggabri Coal Mine Modification 8 response to Independent Expert Scientific Community.* Idemitsu.

WSP. (2025). *Boggabri Coal Mine Modification 10 Groundwater Dependent Ecosystem Assessment.* Boggabri Coal Operations Pty Ltd.

# Appendix A

# Cross sections




LEGEND

Drainage

Cross section location

**MCCM Open Cut Extent**

**BCM Open Cut Extent**

**TCM Open Cut Extent**

**BCM Modification Mining Area**

Alluviuial extent

**Elevation (mAHD)**

200

300

400

500

600

Groundwater Impact Assessment
Boggabri Coal Mine (BCO5002.001)

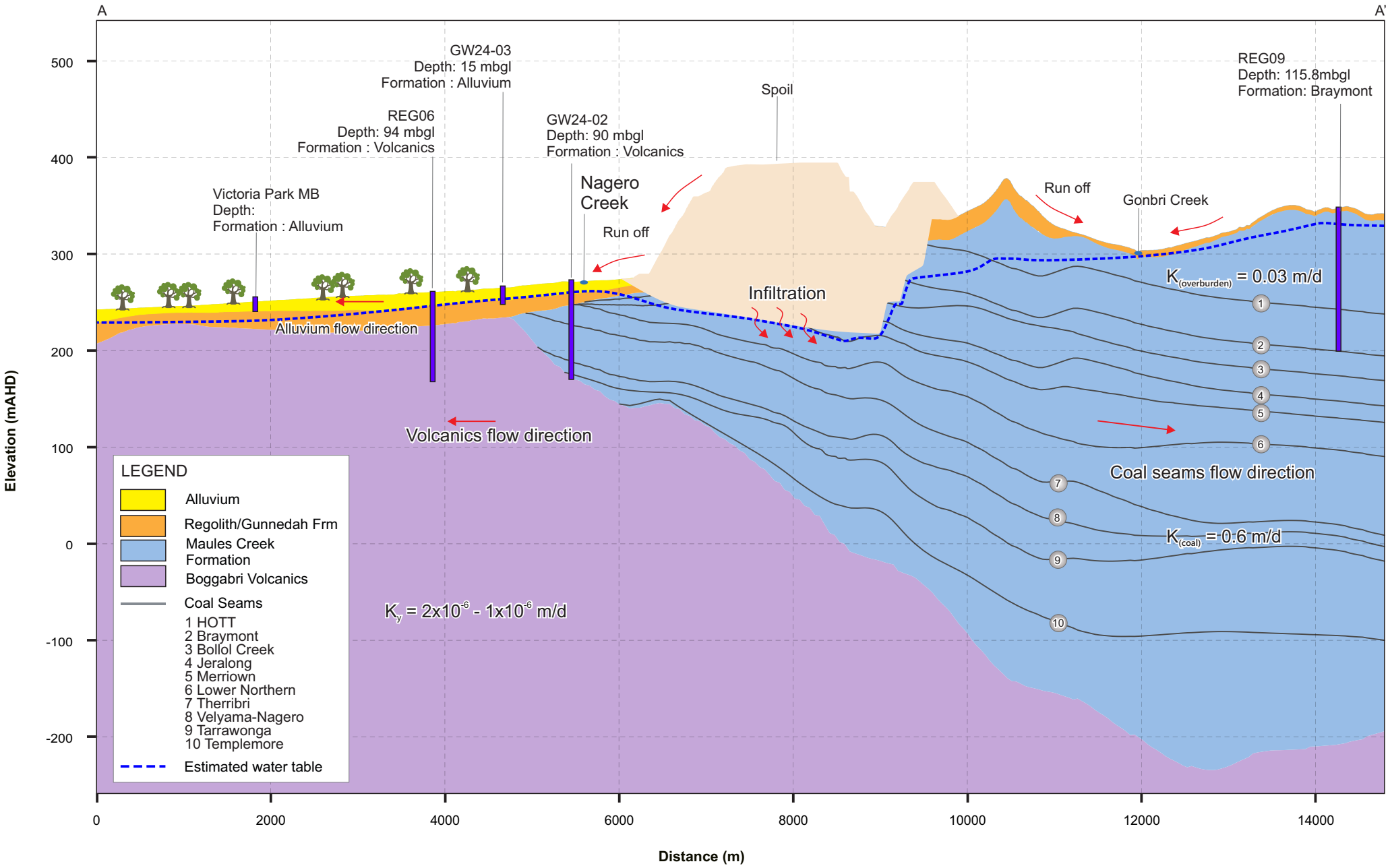
## Cross section locations

DATE
22/05/2025

AGE

FIGURE No:

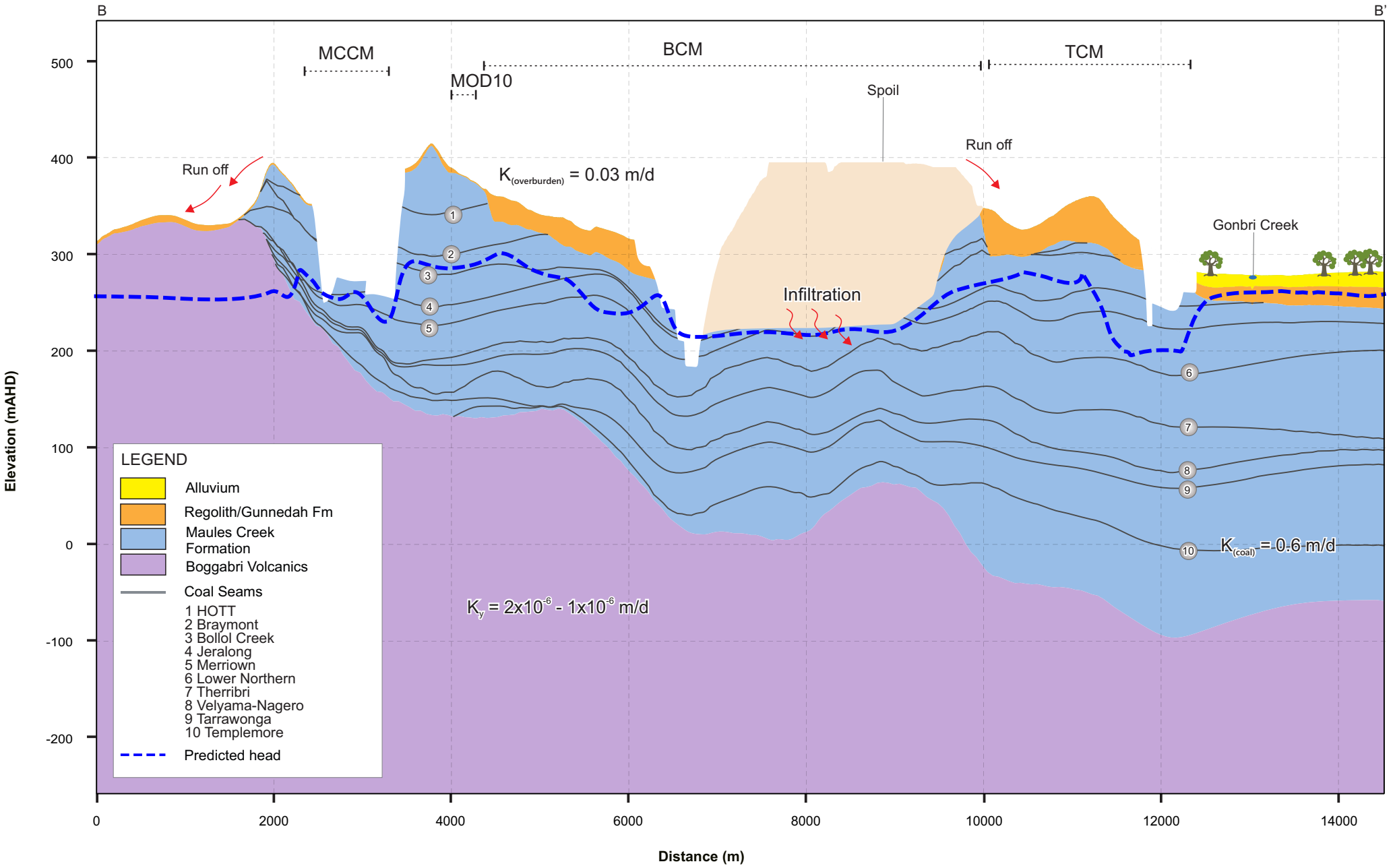
©2025 Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) - www.ageconsultants.com.au; Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006
\\AGE-SRV-DC01\Shared\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\3_GIS\Workspaces\001_GIA_maps\A_01_BCO5002.001_Cross section location.qgz




**Cross section A - A'**

**Figure - 1**

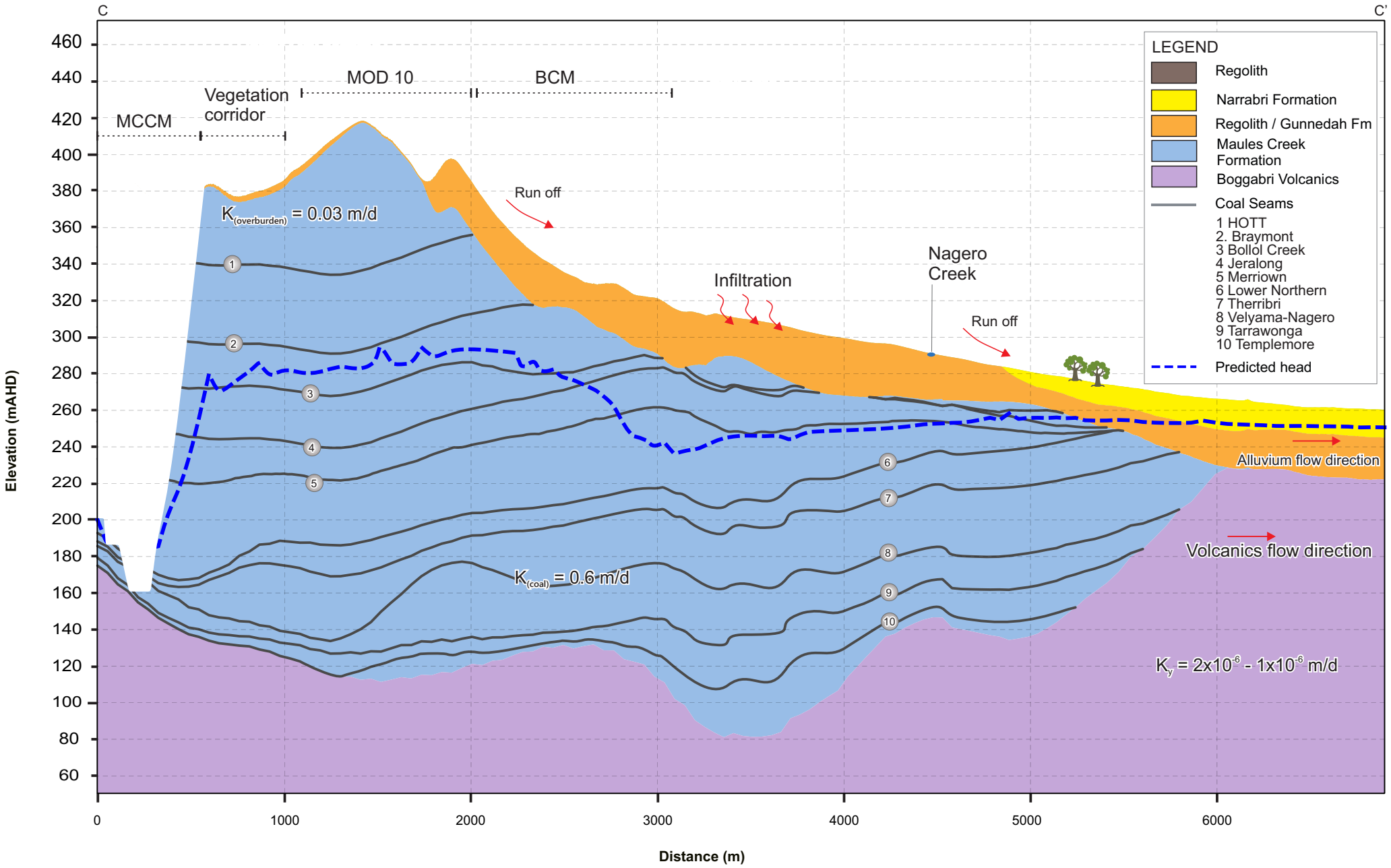
Boggabri Extension Project EIS – Groundwater Assessment (BCO5002.001)




**Cross section B - B'**

**Figure - 2**

Boggabri Extension Project EIS – Groundwater Assessment (BCO5002.001)




**Cross section C - C'**

**Figure - 3**

Boggabri Extension Project EIS – Groundwater Assessment (BCO5002.001)

# Appendix B

# Water access licences and bore licences

# B1 BCM Licenses and approvals

Table B 1 summarises the approved water takes, from the Murray Darling Basin and Namoi Alluvial Groundwater Sources, for BCM. Table B 2 provides a table of the key water access and borehole licences and approvals that have been obtained for BCM.

Table B 1 Water access licence entitlements 2024/25

| Water sharing plan | Water Source | Total entitlement (units) |
|---|---|---|
| NSW Murray Darling Basin Porous Rock Groundwater Sources | Gunnedah-Oxley Basin porous rock | 842 |
| Namoi Alluvial Groundwater Sources | Upper Namoi Zone 2 | - |
| Namoi Alluvial Groundwater Sources | Upper Namoi Zone 4 | 1,028 |
| Namoi Alluvial Groundwater Sources | Upper Namoi Zone 5 | - |
| Namoi Alluvial Groundwater Sources | Upper Namoi Zone 11 | 20 |

Table B 2 BCM licences and approvals (source Boggabri 2023 Annual Review , Idemitsu 2023)

| Approval | Reference | Detail | Issue Date | Expiry Date |
|---|---|---|---|---|
| Water Access Licence | WAL12691 | Upper Namoi Zone 4 Namoi Valley (Keepit Dam to Gin's Leap), Upper and Lower Namoi Groundwater Sources WSP | 01/11/2006 | In perpetuity |
| Water Access Licence | WAL12767 | Upper Namoi Zone 4 Namoi Valley (Keepit Dam to Gin's Leap), Upper and Lower Namoi Groundwater Sources WSP | 01/11/2006 | In perpetuity |
| Water Access Licence | WAL15037 | Upper Namoi Zone 4 Namoi Valley (Keepit Dam to Gin's Leap), Upper and Lower Namoi Groundwater Sources WSP | 01/11/2006 | In perpetuity |
| Water Access Licence | WAL24103 | Upper Namoi Zone 4 Namoi Valley (Keepit Dam to Gin's Leap), Upper and Lower Namoi Groundwater Sources WSP | 29/06/2011 | In perpetuity |
| Water Access Licence | WAL36547 | Upper Namoi Zone 4 Namoi Valley (Keepit Dam to Gin's Leap), Upper and Lower Namoi Groundwater Sources WSP | 14/01/2014 | In perpetuity |
| Water Access Licence | WAL37519 | Upper Namoi Zone 4 Namoi Valley (Keepit Dam to Gin's Leap), Upper and Lower Namoi Groundwater Sources WSP | 16/02/2016 | In perpetuity |
| Water Access Licence | WAL29473 | Gunnedah Oxley Basin Murray Darling Basin Groundwater Source, NSW Murray Darling Basin Porous Rock Groundwater Sources WSP | 16/02/2012 | In perpetuity |
| Water Access Licence | WAL29562 | Gunnedah Oxley Basin Murray Darling Basin Groundwater Source, NSW Murray Darling Basin Porous Rock Groundwater Sources WSP | 16/02/2012 | In perpetuity |
| Water Access Licence | WAL2571 | Lower Namoi Regulated River, Upper Namoi and Lower Namoi Regulated River WSP | 01/07/2004 | In perpetuity |
| Water Access Licence | WAL2572 | Lower Namoi Regulated River, Upper Namoi and Lower Namoi Regulated River WSP | 01/07/2004 | In perpetuity |

| Approval | Reference | Detail | Issue Date | Expiry Date |
|---|---|---|---|---|
| Water Access Licence | WAL2595 | Lower Namoi Regulated River, Upper Namoi and Lower Namoi Regulated River WSP | 01/07/2004 | In perpetuity |
| Water Access Licence | WAL2596 | Lower Namoi Regulated River, Upper Namoi and Lower Namoi Regulated River WSP | 01/07/2004 | In perpetuity |
| Water Access Licence | WAL37067 | Upper Namoi Regulated River, Upper Namoi and Lower Namoi Regulated River WSP | 26/04/2016 | In perpetuity |
| Water Access Licence | WAL42234 | Bluevale Water Source, Namoi and Peel Unregulated Rivers Water Sources 2012 | 21/04/2022 | In perpetuity |
| Water Access Licence | WAL44134 | Upper Namoi Zone 11 Maules Creek Groundwater source. Purchased 9/1/2019 | 21/04/2022 | In perpetuity |
| Bore Licence | 90FW833717 | Production bore | 21/09/2015 | 04/04/2030 |
| Bore Licence | 90FW834023 | Production bore | 21/09/2015 | 04/06/2029 |
| Bore Licence | 90BL254255 | Monitoring bore | 24/04/2007 | In perpetuity |
| Bore Licence | 90BL253832 | Monitoring bore | 17/01/2007 | In perpetuity |
| Bore Licence | 90BL253841 | Monitoring bore | 17/01/2007 | In perpetuity |
| Bore Licence | 90BL253840 | Monitoring bore | 17/01/2007 | In perpetuity |
| Bore Licence | 90BL255765 | Monitoring bore | 18/08/2010 | In perpetuity |

# Appendix C

# Monitoring network construction details

**Australasian Groundwater & Environmental Consultants Pty Ltd**
Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

# BOREHOLE LOG



**GW24-03**

PROJECT No: **BCO5002.001**
PROJECT NAME: **Boggabri Coal Mine**
DATE DRILLED: **30/3/2024**
LOGGED BY: [redacted]

DRILLING COMPANY: **Mannion Drilling**
DRILLER: [redacted]
DRILLING METHOD: **Air Rotary/Mud Air Rotary**
DRILL RIG: **MD65**

EASTING: **224742 mE**
NORTHING: **6607720 mN**
DATUM: **MGA 55 / z56**
RL: **260 m**
TD: **15 mBGL**

COMMENTS: **Casing sticking up is approximately 1 m**

| Stratigraphic Cloumn | Soil or Rock Field Material Description | Graphic Log | Depth (mBGL) / R.L. (mAHD) | Bore Construction | Bore Description |
|---|---|---|---|---|---|
| *Alluvium* | Transported soil | | 261 / 0 | +1.0 m | Stick up: +1.0 m |
| | | | 260 / 0 | -0 m | |
| | Gravelly clay | | 259 / 2 | | 140 mm uPVC surface casing: 0 m to 5.4 m |
| | Silty clay | | 258 / 4 | | 125 mm PCD Bit: 0 m to 8 m air rotary then mud air rotary from 8 m to 15 m |
| | | | 257 / 6 | | 50 mm PN18 uPVC blank casing: 0 m to 10 m |
| | | | 256 / 8 | -5.4 | |
| | Sandy clay | | 255 / 10 | | Bentonite grout (5 %): 0 m to 7.4 m |
| | | | 254 / 12 | -7.4 m | |
| | Gravel | | 253 / 14 | | Bentonite seal: 7.4 m to 10 m |
| | | | 252 / 16 | -10 m | SWL: 10.15 mTOC (31/03/2024) |
| | | | 251 / 18 | | 3 mm Washed, Quartz Bagged, Gravel Pack: 10 m to 13 m |
| | | | 250 / 20 | | 50 mm PN18 uPVC machine slotted casing, slot aperture: 1 mm, 10 m to 12.85 m |
| | | | 249 / 22 | -12.85 m | End cap: 13 m BGL |
| | | | 248 / 24 | | Gravel backfill: 13 m to 15 m (EOH) |
| | | | 247 / 26 | | |
| | | | 246 / 28 | | |
| | | | 245 / 30 | | |

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# BOREHOLE LOG



**GW24-04b**

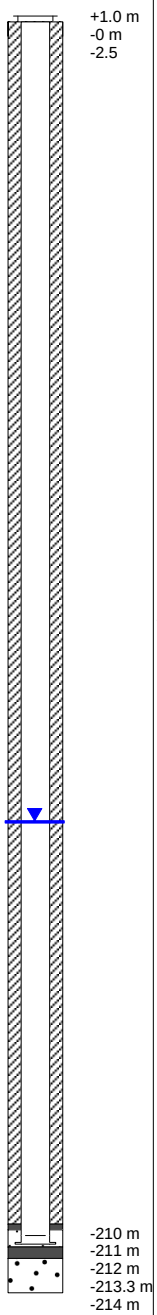
PROJECT No: **BCO5002.001**
PROJECT NAME: **Boggabri Coal Mine**
DATE DRILLED: **19/3/2024**
LOGGED BY: [redacted]

DRILLING COMPANY: **Mannion Drilling**
DRILLER: [redacted]
DRILLING METHOD: **Air Rotary**
DRILL RIG: **MD65**

EASTING: **226994 mE**
NORTHING: **6613000 mN**
DATUM: **MGA 55 / z56**
RL: **340 m**
TD: **222 mBGL**

COMMENTS: **Casing sticking up is approximately 1 m**

| Stratigraphic Cloumn | Soil or Rock Field Material Description | Depth (mBGL) / R.L. (mAHD) |
|---|---|---|
| *Soil* | Soil and Regolith | 0 / 330 |
| *Maules Creek Formation* | Siltstone with minor conglomerate, coaly mudstone and carbonaceous mudstone lens intercalations | 10 / 320 |
| | **THORNFIELD COAL SEAM** | 20 / 310 |
| | Siltstone with minor sandstone lens intercalations | 30 / 300 |
| | Lithic conglomerate with sandstone intercalations and minor coal lens | 40 / 290 |
| | Sandstone with minor intercalations of siltstone and carbonaceous material | 50 / 280 |
| | **BRAYMONT UPPER COAL SEAM** | 60 / 270 |
| | Sandstone with minor intercalations of siltstone and carbonaceous material | 70 / 260 |
| | Lithic conglomerate | 80 / 250 |
| | Sandstone with minor intercalations of siltstone,lithic conglomerate and carbonaceous material | 90 / 240 |
| | Lithic conglomerate with sandstone intercalations | 100 / 230 |
| | Fine to medium sandstone | 110 / 220 |
| | Lithic conglomerate | 120 / 210 |
| | Sandstone with minor intercalations of siltstone,lithic conglomerate and carbonaceous material | 130 / 200 |
| | **BRAYMONT COAL SEAM** | 140 / 190 |
| | Sandstone with minor intercalations of siltstone and carbonaceous material | 150 / 180 |
| | Lithic conglomerate with sandstone and siltstone intercalations | 160 / 170 |
| | **JERALONG COAL SEAM** | 170 / 160 |
| | Fine to medium sandstone with minor carbonaceous mudstone | 180 / 150 |
| | Lithic conglomerate with sandstone lens intercalations | 190 / 140 |
| | Fine to medium sandstone with minor siltstone and carbonaceous mudstone intercalations | 200 / 130 |
| | Lithic conglomerate | 210 / 120 |
| | **MERRIOWN COAL SEAM** | 220 / 110 |
| | Siltstone with sandstone and carbonaceous mudstone intercalations | |
| | Lithic conglomerate with minor sandstone and siltstone lens intercalations | |
| | Fine to medium sandstone | |
| | Lithic conglomerate with minor carbonaceous material, sandstone and siltstone lens intercalations | |
| | Fine to medium sandstone | |
| | Lithic conglomerate with minor carbonaceous material and sandstone lens intercalations | |
| | Fine to medium sandstone with conglomerate and siltstone intercalations | |
| | Lithic conglomerate with minor sandstone lens intercalations | |
| | **VELYAMA COAL SEAM** | |
| | fine to medium sandstone with minor siltstone and carbonaceous material intercalations | |
| | **NAGERO COAL SEAM** | |
| | Carbonaceous siltstone | |
| | **NORTHAM COAL SEAM** | |
| | Siltstone with sandstone intercalations and minor carbonaceous material | |
| | Fine to medium sandstone | |




**Bore Description**

Stick up: +1.0 m

140 mm uPVC surface casing: 0 m to 2.5 m

125 mm PCD Bit: 0 m to 222 m air rotary

50 mm PN18 uPVC blank casing: 0 m to 210 m

SWL: 139.74 mTOC (20/03/2024)

Bentonite grout (5 %): 0 m to 210 m

Bentonite seal: 210 m to 211 m
50 mm PN18 uPVC machine slotted casing, slot aperture: 1 mm, 212 m to 213.35 m
Bentonite seal: 214 m to 216 m
3 mm Washed, Quartz Bagged, Gravel Pack: 211 m to 214 m
End cap: 213.5 m BGL
Gravel backfill: 216 m to 222 m (EOH)

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# BOREHOLE LOG



**GW24-04c**

PROJECT No: **BCO5002.001**
PROJECT NAME: **Boggabri Coal Mine**
DATE DRILLED: **19/3/2024**
LOGGED BY: [redacted]

DRILLING COMPANY: **Mannion Drilling**
DRILLER: [redacted]
DRILLING METHOD: **Air Rotary**
DRILL RIG: **MD65**

EASTING: **226994 mE**
NORTHING: **6613000 mN**
DATUM: **MGA 55 / z56**
RL: **340 m**
TD: **169 mBGL**

COMMENTS: **Casing sticking up is approximately 1 m**

| Stratigraphic Cloumn | Soil or Rock Field Material Description | Graphic Log | R.L. (mAHD) / Depth (mBGL) | Bore Construction | Bore Description |
|---|---|---|---|---|---|
| | | | 340 / 0 | +1.0 m<br>-0 m<br>-2.5 | Stick up: +1.0 m<br><br>140 mm uPVC surface casing: 0 m to 2.5 m |
| ***Soil*** | Soil and Regolith | | 330 / 10<br>320 / 20 | | |
| ***Maules Creek Formation*** | Siltstone with minor conglomerate, coaly mudstone and carbonaceous mudstone lens intercalations | | 310 / 30 | | |
| | **THORNFIELD COAL SEAM** | | | | |
| | Siltstone with minor sandstone lens intercalations | | | | |
| | Lithic conglomerate with sandstone intercalations and minor coal lens | | 300 / 40<br>290 / 50 | | 125 mm PCD Bit: 0 m to 156.5 m air rotary |
| | Sandstone with minor intercalations of siltstone and carbonaceous material | | | | |
| | **BRAYMONT UPPER COAL SEAM** | | 280 / 60 | | |
| | Sandstone with minor intercalations of siltstone,lithic conglomerate and carbonaceous material | | 270 / 70<br>260 / 80<br>250 / 90 | | 50 mm PN18 uPVC blank casing: 0 m to 159.5 m |
| | **BRAYMONT COAL SEAM** | | | | |
| | Sandstone with minor intercalations of siltstone and carbonaceous material | | 240 / 100 | | Bentonite grout (5 %): 0 m to 156.5 m |
| | Lithic conglomerate with sandstone and siltstone intercalations | | 230 / 110<br>220 / 120<br>210 / 130 | | |
| | **JERALONG COAL SEAM** | | | | |
| | Lithic conglomerate with sandstone lens intercalations | | 200 / 140 | | SWL: 144.05 mTOC (27/03/2024) |
| | Fine to medium sandstone with minor siltstone and carbonaceous mudstone intercalations | | 190 / 150 | | Bentonite seal: 156.5 m to 158.5 m<br>50 mm PN18 uPVC machine slotted casing, slot aperture: 1 mm, 159.5 m to 163.35 m |
| | Lithic conglomerate | | | -156.5 m<br>-158.5 m | 3 mm Washed, Quartz Bagged, Gravel Pack: 158.5 m to 163.5 m |
| | **MERRIOWN COAL SEAM** | | 180 / 160 | | |
| | Siltstone with sandstone and carbonaceous mudstone intercalations | | 170 / 170 | -163.3 m<br>-163.5 m<br>-169 m | End cap: 163.5 m BGL<br>Bentonite seal: 163.5 m to 165 m<br>Gravel backfill: 165 m to 169 m (EOH) |

**Australasian Groundwater & Environmental Consultants Pty Ltd**
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# BOREHOLE LOG



**GW24-11**

PROJECT No: **BCO5002.001**
PROJECT NAME: **Boggabri Coal Mine**
DATE DRILLED: **30/3/2024**
LOGGED BY: [redacted]

DRILLING COMPANY: **Mannion Drilling**
DRILLER: [redacted]
DRILLING METHOD: **Air Rotary**
DRILL RIG: **MD65**

EASTING: **224551 mE**
NORTHING: **6603416 mN**
DATUM: **MGA 55 / z56**
RL: **247 m**
TD: **11 mBGL**

COMMENTS: **Casing sticking up is approximately 1 m**

| Stratigraphic Cloumn | Soil or Rock Field Material Description | Graphic Log | Depth (mBGL) / R.L. (mAHD) | Bore Construction | Bore Description |
|---|---|---|---|---|---|
| *Alluvium* | Silty clay | | 247 / 0 | +1.0 m<br>-0 m | Stick up: +1.0 m |
| | Clay | | 246 | | |
| | Gravelly clay | | 245 / 2 | | 125 mm PCD Bit: 0 m to 11 m air rotary |
| | Clayey gravel | | 244<br>243 / 4<br>242<br>241 / 6<br>240<br>239 / 8<br>238<br>237 / 10<br>236 | -5.5 m<br>-10 m<br>-7.8 m<br>-10.65 m<br>-11 m | Bentonite grout (5 %): 0 m to 5.5 m<br>50 mm PN18 uPVC blank casing: 0 m to 7.8 m<br>Bentonite seal: 5.5 m to 6.8 m<br>3 mm Washed, Quartz Bagged, Gravel Pack: 6.8 m to 11 m<br>50 mm PN18 uPVC machine slotted casing, slot aperture: 1 mm, 7.8 m to 10.65 m<br>End cap: 10.8 m BGL<br>SWL: ?? mTOC (31/03/2024) |

# Appendix D

# Water supply bore census records

# D1 Introduction

A field hydrocensus in a ± 13km radius of the BTM complex was conducted in 2023 to identify groundwater users within the predicted zone of influence of the mine. This survey included registered bores through the NGIS and Water NSW databases as well as unregistered bores identified by the landowners during the census. A total of 190 bores were surveyed during three rounds of field investigation conducted over July, August and December 2023. Additionally, one bore was surveyed by Whitehaven in February 2024.

Landowners were contacted prior to the field investigation to assess interest in participating in the survey. Some landowners declined to participate, and their properties were not visited.

The purpose of the survey was to collect baseline data for all identified bores, including water level, in situ water quality, bore information, bore usage and pump details. Where possible, several landowners were able to guide the census team with background information on their properties bores as well as identify unregistered bores. In all other cases, the census team navigated to all WaterNSW and NGIS bores that plotted on the property. Water samples were collected from select bores and submitted to ALS for analysis of general cations and anions.

The census team also had discussions with several landowners to understand water usage, factors affecting supply and the historical relationship between the property and groundwater availability. Individual bore census forms are in Section D3.

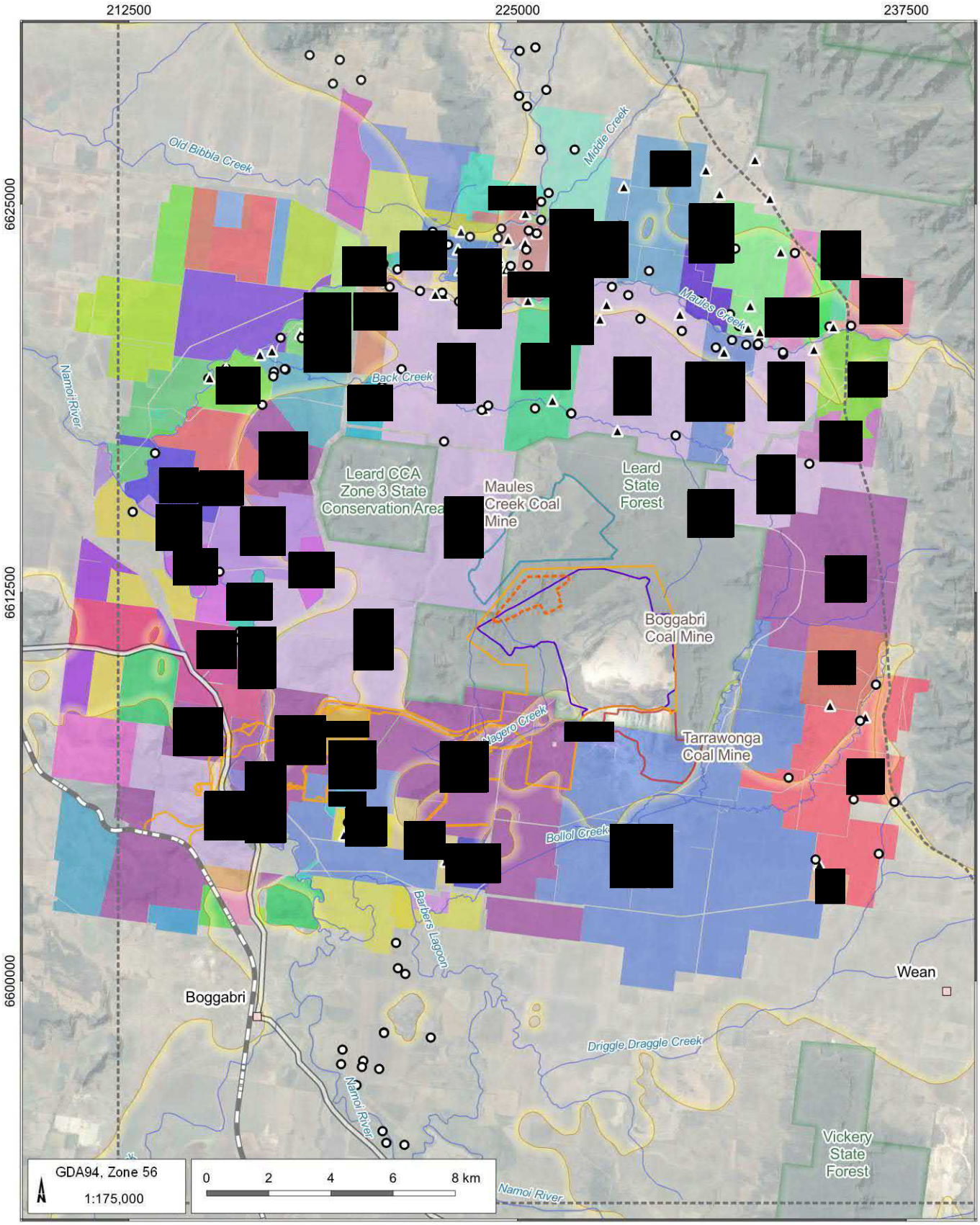
# D2 Bore Census

## D2.1 Landowners

Table D 1 includes a summary of all landowners that participated in the 2023 survey and the total number of bores surveyed on their properties. Figure D 1 shows the locations of all the bores inspected.

Table D 1 Summary of landowners surveyed and their available bores

| Landowner | Bores Surveyed |
|---|---|
| [redacted] | 1 |
| [redacted] | 6 |
| [redacted] | 1 |
| [redacted] | 19 |
| [redacted] | 6 |
| [redacted] | 5 |
| [redacted] | 4 |
| [redacted] | 6 |
| [redacted] | 1 |
| [redacted] | 1 |
| [redacted] | 1 |
| [redacted] | 2 |
| [redacted] | 5 |
| [redacted] | 2 |
| [redacted] | 2 |
| [redacted] | 4 |
| [redacted] | 7 |
| [redacted] | 8 |
| [redacted] | 5 |
| [redacted] | 2 |
| [redacted] | 4 |
| [redacted] | 2 |
| [redacted] | 1 |
| [redacted] | 4 |
| [redacted] | 3 |
| [redacted] | 8 |
| [redacted] | 5 |
| [redacted] | 2 |
| [redacted] | 4 |
| [redacted] | 3 |
| [redacted] | 64 |
| [redacted] | 3 |
| **TOTAL** | **191** |




LEGEND

- Populated place
- Principal Road
- Railway
- Drainage

**BCM Open Cut Extent**

**MCCM Open Cut Extent**

**TCM Open Cut Extent**

**MCCM Continuation Project**

- Quaternary Alluvium

- Existing - Used
- Existing- Abandoned and Disused

Groundwater Impact Assessment Boggabri Coal Mine (BCO5002.001)

## Borehole locations

AGE

DATE 22/05/2025

FIGURE No: **D 1**

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Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.; G:\Projects\BCO5002.001 Boggabri Coal Mine Groundwater Assessment\5_Deliverables\002_Mod10 Groundwater Impact Assessment\Appendices\Appendix D - Water supply bore census records\F_01.00_BCO5002_Borehole locations.qgz

## D2.2 Usage

Of the boreholes surveyed 59% of boreholes were functional, 27% were abandoned and 14% could not be located (refer to Table D 2). The bores identified in the study area were predominantly shallow, typically less than 15 m deep, and were primarily used for stock and domestic. Factors influencing groundwater usage, as discussed with the local landowners included the following:

- Several landowners noted that their bore/well went dry during the 2017/2018 drought or that the bores no longer produce the same yield. Many landowners drilled additional boreholes in 2018 to supplement their yield, in many cases these new bores were drilled adjacent to the dry bore.
- Some bores were drilled through a coal seam and the quality was considered unsatisfactory.
- Several of the properties visited, primarily north of Maules Creek, had not been actively farmed for a significant period.
- Equipment installed in the bores were non-operational.

Table D 2 Bore usage summary

| Usage | Bore Count |
|---|---|
| Existing – Abandoned and Disused | 51 |
| Existing – Used | 114 |
| Not located | 26 |

## Table D 3 Hydrochemistry Results

| Bore ID | - | GW008270 | GW060214 | GW062788 | GW062727 | GW060214 Dup | GW062770 | GW904950 | GW062781 | Old Glenelg 2 (OG2) | GW062771 | GW062772 | Wongalea Bore 2 | GW008266 | GW904727 | GW070540 | Finlay Field Unreg | GW062790 | GW008247 | SB House Bore |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Landowner | - | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| Date Sampled | - | 11/07/2023 | 11/07/2023 | 11/07/2023 | 11/07/2023 | 11/07/2023 | 10/07/2023 | 10/07/2023 | 10/07/2023 | 10/07/2023 | 10/07/2023 | 10/07/2023 | 12/07/2023 | 12/07/2023 | 12/07/2023 | 12/07/2023 | 12/07/2023 | 13/07/2023 | 13/07/2023 | 13/07/2023 |
| **Field Parameters** | | | | | | | | | | | | | | | | | | | | |
| Field pH | - | 6.64 | 6.59 | 6.66 | 6.64 | 6.59 | 6.94 | 6.93 | 6.95 | 6.95 | 6.94 | 6.94 | 6.71 | 6.73 | 6.76 | 7.76 | 6.72 | 6.76 | 6.24 | 6.81 |
| Field Electrical Conductivity (EC) | µS/cm | 1538 | 325.4 | 1403 | 280.3 | 325.4 | 334.3 | 514.8 | 541 | 355.3 | 174.8 | 1447 | 251.8 | 416 | 951 | 1662 | 1220 | 1023 | 1270 | 1210 |
| Field TDS | mg/l | 1101 | 223.7 | 1003 | 187.7 | 223.7 | 221.7 | 337.9 | 365 | 238.2 | 108.7 | 1020 | 176.3 | 300.7 | 719.6 | 1282 | 933 | 776.8 | 968.1 | 911.1 |
| Depth to Groundwater | m TOC | - | 3.56 | 6.2 | - | 3.56 | 7.49 | - | 3.97 | - | 6.87 | 4.95 | 12.68 | 12.57 | - | - | - | 3.72 | 5.53 | - |
| **Physical Parameters** | | | | | | | | | | | | | | | | | | | | |
| pH | pH Units | 7.64 | 7.5 | 7.27 | 7.38 | 7.46 | 7.07 | 7.42 | 7.36 | 7.17 | 6.92 | 7.37 | 7.64 | 7.76 | 7.64 | 7.38 | 8.29 | 7.35 | 8.43 | 7.94 |
| Sodium Absorption Ration (SAR) | - | 4.23 | 1.19 | 2.54 | 1 | 1.15 | 1.07 | 1.36 | 1.89 | 1.2 | 1.1 | 2 | 2.71 | 3.17 | 1.85 | 4.37 | 5.85 | 1.99 | 23 | 6.98 |
| Total Dissolved Solids (calc) | mg/L | 938 | 232 | 886 | 189 | 232 | 195 | 316 | 328 | 240 | 65 | 1110 | 139 | 238 | 564 | 998 | 740 | 674 | 818 | 758 |
| Hydroxide Alkalinity as $CaCO_3$ | mg/L | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as $CaCO_3$ | mg/L | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 20 | <1 |
| Bicarbonate Alkalinity as $CaCO_3$ | mg/L | 525 | 129 | 304 | 111 | 127 | 109 | 190 | 144 | 146 | 20 | 188 | 74 | 196 | 262 | 431 | 476 | 227 | 630 | 565 |
| Total Alkalinity as $CaCO_3$ | mg/L | 525 | 129 | 304 | 111 | 127 | 109 | 190 | 144 | 146 | 20 | 188 | 74 | 196 | 262 | 431 | 476 | 227 | 650 | 565 |
| **Major Ions** | | | | | | | | | | | | | | | | | | | | |
| Sulfate as $SO_4$ - Turbidimetric | mg/L | 16 | 8 | 33 | 3 | 8 | 5 | 19 | 16 | 3 | <1 | 46 | <1 | <1 | 30 | 19 | 10 | 27 | 11 | 27 |
| Chloride | mg/L | 210 | 21 | 275 | 18 | 21 | 22 | 36 | 72 | 26 | 20 | 323 | 38 | 30 | 193 | 377 | 214 | 225 | 83 | 113 |
| Fluoride | mg/L | 0.5 | 0.2 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.5 | 0.1 | 0.1 | 0.2 | 0.1 | 0.4 | 0.4 | 0.5 | 0.2 | 0.2 | 0.4 | 0.6 |
| Calcium | mg/L | 100 | 24 | 113 | 20 | 24 | 19 | 42 | 36 | 26 | 3 | 114 | 11 | 21 | 100 | 146 | 60 | 104 | 6 | 35 |
| Magnesium | mg/L | 40 | 9 | 37 | 8 | 9 | 8 | 14 | 13 | 11 | 2 | 41 | 1 | 6 | 34 | 41 | 39 | 31 | 3 | 24 |
| Sodium | mg/L | 198 | 27 | 122 | 21 | 26 | 22 | 40 | 52 | 29 | 10 | 98 | 35 | 64 | 84 | 232 | 237 | 90 | 277 | 219 |
| Potassium | mg/L | 2 | 1 | 2 | 2 | 1 | 2 | <1 | 1 | 2 | <1 | 4 | 2 | 1 | 1 | 3 | 4 | 2 | 22 | 3 |
| Total Anions | meq/L | 16.7 | 3.34 | 14.5 | 2.79 | 3.3 | 2.9 | 5.21 | 5.24 | 3.71 | 0.96 | 13.8 | 2.55 | 4.76 | 11.3 | 19.6 | 15.8 | 11.4 | 15.6 | 15 |
| Total Cations | meq/L | 16.9 | 3.14 | 14 | 2.62 | 3.09 | 2.61 | 4.99 | 5.15 | 3.52 | 0.75 | 13.4 | 2.2 | 4.35 | 11.5 | 20.8 | 16.6 | 11.7 | 13.2 | 13.3 |
| Ionic Balance | % | 0.59 | 3.06 | 1.67 | ---- | 3.15 | ---- | 2.15 | 0.84 | 2.73 | ---- | 1.46 | ---- | 4.51 | 0.72 | 2.93 | 2.66 | 1.13 | 8.36 | 6.04 |
| **Dissolved Metals** | | | | | | | | | | | | | | | | | | | | |
| Aluminium | mg/L | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Arsenic | mg/L | 0.001 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | 0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | 0.007 | <0.001 | 0.001 | 0.001 | <0.001 |
| Beryllium | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Boron | mg/L | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.16 | 0.13 | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Cadmium | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Chromium | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cobalt | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper | mg/L | <0.001 | 0.013 | <0.001 | 0.049 | 0.008 | 0.002 | 0.002 | <0.001 | 0.001 | 0.002 | 0.065 | <0.001 | <0.001 | <0.001 | 0.004 | <0.001 | <0.001 | <0.001 | 0.004 |
| Iron | mg/L | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 2.93 | <0.05 | <0.05 | <0.05 | 1.41 | 0.13 | 0.06 | 4.03 | <0.05 | <0.05 | <0.05 | <0.05 | 0.05 | 0.93 |
| Lead | mg/L | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Lithium | mg/L | 0.052 | 0.002 | 0.01 | 0.001 | 0.002 | <0.001 | 0.002 | 0.003 | <0.001 | <0.001 | 0.001 | 0.008 | 0.004 | 0.008 | 0.034 | <0.001 | 0.006 | 0.041 | 0.01 |
| Manganese | mg/L | <0.001 | 0.003 | 0.039 | <0.001 | 0.002 | 0.192 | 0.003 | 0.002 | 0.014 | 0.394 | 0.032 | 0.066 | 0.505 | 0.002 | <0.001 | 0.008 | 0.017 | 0.082 | 0.018 |
| Mercury | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

| Bore ID | - | GW008270 | GW060214 | GW062788 | GW062727 | GW060214 Dup | GW062770 | GW904950 | GW062781 | Old Glenelg 2 (OG2) | GW062771 | GW062772 | Wongalea Bore 2 | GW008266 | GW904727 | GW070540 | Finlay Field Unreg | GW062790 | GW008247 | SB House Bore |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Molybdenum | mg/L | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.002 | <0.001 | <0.001 | <0.001 | 0.004 | 0.001 |
| Nickel | mg/L | <0.001 | 0.002 | <0.001 | <0.001 | 0.002 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 |
| Selenium | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Uranium | mg/L | 0.02 | <0.001 | 0.009 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.01 | 0.017 | <0.001 | 0.005 | <0.001 | <0.001 |
| Vanadium | mg/L | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | mg/L | <0.005 | 0.188 | 0.007 | 0.03 | 0.187 | 0.058 | 0.008 | <0.005 | 0.357 | 0.006 | 0.704 | <0.005 | 0.044 | <0.005 | 0.006 | <0.005 | <0.005 | <0.005 | <0.005 |

## Table D 4 Hydrochemistry Results

| Bore ID | - | Stoneybrook 2 | Back Stoneybrook | GW965941 | GW062780 | Billyena MP2 | Billyena BMC (GW062730) | GW062753 | GW062778 | GW901090 | GW062749 | GW059053 | GW062749 Dup | GW037705 | GW037338 Dup | GW037338 | GW003489 | GW003489DUP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Landowner | - | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| Date Sampled | - | **13/07/2023** | **13/07/2023** | **14/07/2023** | **14/07/2023** | **14/07/2023** | **14/07/2023** | **2023-08-08** | **2023-08-08** | **2023-08-07** | **2023-08-07** | **2023-08-07** | **2023-08-07** | **2023-08-07** | **2023-08-07** | **2023-08-07** | **2023-08-09** | **2023-08-09** |
| **Field Parameters** | | | | | | | | | | | | | | | | | | |
| Field pH | pH units | 6.81 | 6.82 | 6.89 | 6.9 | 6.88 | 6.88 | 6.91 | 6.93 | 7.2 | 7.23 | 7.22 | 7.23 | 7.25 | 7.24 | 7.24 | 6.96 | 6.96 |
| Field Electrical Conductivity (EC) | µS/cm | 1377 | 475.2 | 370.4 | 586.5 | 239.5 | 275.8 | 350.90 | 708.30 | 525.30 | 1158.00 | 9293.00 | 1158.00 | 291.50 | 700.60 | 700.60 | 1639.00 | 1639.00 |
| Field TDS | mg/l | 1045 | 345.6 | 536 | 407.3 | 157.2 | 181.6 | 230.20 | 476.00 | 389.20 | 886.90 | 8522.00 | 886.90 | 211.00 | 531.70 | 531.70 | 1136.00 | 1136.00 |
| Depth to Groundwater | m TOC | 7.15 | 16 | - | 4.64 | 6.61 | 5.4 | 3.93 | 2.39 | - | 5.00 | 4.81 | 5.00 | 3.56 | 4.40 | 4.40 | 18.90 | 18.9 |
| **Physical Parameters** | | | | | | | | | | | | | | | | | | |
| pH | pH Units | 8.1 | 7.95 | 7.77 | 7.52 | 7.23 | 7.33 | 7.27 | 7.4 | 7.38 | 7.54 | 8.04 | 7.45 | 7.35 | 7.6 | 7.6 | 8.33 | 8.39 |
| Sodium Absorption Ration (SAR) | - | 5.83 | 1.82 | 1.22 | 0.99 | 0.92 | 0.91 | 1.03 | 1.17 | 1.03 | 2.15 | 17.4 | 2.15 | 1.03 | 1.9 | 1.9 | 8.55 | 8.45 |
| Total Dissolved Solids (calc) | mg/L | 858 | 284 | 492 | 316 | 144 | 144 | 162 | 396 | 279 | 784 | 7270 | 790 | 164 | 436 | 406 | 721 | 726 |
| Hydroxide Alkalinity as $CaCO_3$ | mg/L | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as $CaCO_3$ | mg/L | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 22 | 25 |
| Bicarbonate Alkalinity as $CaCO_3$ | mg/L | 554 | 239 | 208 | 184 | 86 | 97 | 118 | 185 | 168 | 306 | 385 | 306 | 125 | 209 | 208 | 574 | 564 |
| Total Alkalinity as $CaCO_3$ | mg/L | 554 | 239 | 208 | 184 | 86 | 97 | 118 | 185 | 168 | 306 | 385 | 306 | 125 | 209 | 208 | 596 | 589 |
| **Major Ions** | | | | | | | | | | | | | | | | | | |
| Sulfate as $SO_4$ - Turbidimetric | mg/L | 12 | <1 | 31 | 28 | 1 | 1 | 3 | 50 | 29 | 114 | 1840 | 118 | 3 | 56 | 55 | 11 | 11 |
| Chloride | mg/L | 199 | 24 | 111 | 35 | 18 | 18 | 22 | 87 | 43 | 206 | 2820 | 214 | 20 | 112 | 113 | 78 | 79 |
| Fluoride | mg/L | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.3 | 0.2 | 0.3 | 0.2 | 0.2 | 0.3 | 0.4 | 0.4 |
| Calcium | mg/L | 34 | 42 | 82 | 54 | 19 | 20 | 23 | 62 | 44 | 119 | 489 | 119 | 23 | 66 | 67 | 29 | 28 |
| Magnesium | mg/L | 39 | 15 | 28 | 18 | 6 | 8 | 9 | 24 | 23 | 46 | 237 | 46 | 9 | 24 | 25 | 22 | 21 |
| Sodium | mg/L | 210 | 54 | 50 | 33 | 18 | 19 | 23 | 43 | 34 | 109 | 1870 | 109 | 23 | 71 | 72 | 251 | 243 |
| Potassium | mg/L | 23 | 4 | 1 | 1 | 1 | 1 | 2 | <1 | 2 | 2 | 14 | 2 | 1 | 2 | 2 | 6 | 5 |
| Total Anions | meq/L | 16.9 | 5.45 | 7.93 | 5.25 | 2.25 | 2.47 | 3.04 | 7.19 | 5.17 | 14.3 | 126 | 14.6 | 3.12 | 8.5 | 8.49 | 14.3 | 14.2 |
| Total Cations | meq/L | 14.6 | 5.78 | 8.6 | 5.64 | 2.25 | 2.51 | 2.94 | 6.94 | 5.62 | 14.5 | 126 | 14.5 | 2.91 | 8.41 | 8.58 | 14.3 | 13.8 |
| Ionic Balance | % | 7.3 | 2.93 | 4.02 | 3.59 | ---- | ---- | 1.68 | 1.78 | 4.12 | 0.76 | 0.02 | 0.31 | 3.47 | 0.55 | 0.56 | 0.03 | 1.43 |
| **Dissolved Metals** | | | | | | | | | | | | | | | | | | |
| Aluminium | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Arsenic | mg/L | <0.001 | <0.001 | 0.002 | 0.002 | 0.003 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.004 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Beryllium | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

| Bore ID | - | Stoneybrook 2 | Back Stoneybrook | GW965941 | GW062780 | Billyena MP2 | Billyena BMC (GW062730) | GW062753 | GW062778 | GW901090 | GW062749 | GW059053 | GW062749 Dup | GW037705 | GW037338 Dup | GW037338 | GW003489 | GW003489DUP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Boron | mg/L | 0.1 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.11 | <0.05 | <0.05 | <0.05 | <0.05 | 0.1 | 0.1 |
| Cadmium | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0002 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0007 | 0.0007 |
| Chromium | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cobalt | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper | mg/L | <0.001 | <0.001 | 0.072 | <0.001 | 0.018 | 0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.004 | 0.002 | <0.001 | 0.002 | 0.002 | 0.002 | 0.002 |
| Iron | mg/L | 0.36 | <0.05 | <0.05 | <0.05 | 23.7 | 5.58 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 1.88 | 2.22 |
| Lead | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Lithium | mg/L | 0.001 | <0.001 | 0.003 | 0.002 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | 0.002 | 0.012 | 0.002 | <0.001 | 0.002 | 0.002 | 0.015 | 0.014 |
| Manganese | mg/L | 0.54 | 0.077 | <0.001 | <0.001 | 0.112 | 0.712 | 0.01 | <0.001 | 0.014 | <0.001 | 0.004 | <0.001 | 0.004 | 0.012 | 0.012 | 0.5 | 0.476 |
| Mercury | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Molybdenum | mg/L | 0.002 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | 0.003 | 0.002 |
| Nickel | mg/L | 0.003 | <0.001 | 0.001 | <0.001 | <0.001 | 0.006 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.002 |
| Selenium | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Uranium | mg/L | 0.003 | <0.001 | 0.003 | 0.002 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | 0.008 | 0.013 | 0.008 | <0.001 | 0.001 | 0.001 | 0.002 | 0.002 |
| Vanadium | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | mg/L | <0.005 | <0.005 | 0.244 | <0.005 | 0.125 | 0.035 | 0.023 | 0.025 | 0.025 | 0.007 | 0.107 | 0.027 | 0.025 | 0.096 | 0.096 | 0.01 | 0.03 |

Table D 5 Hydrochemistry Results

| Bore ID | - | GW31340 | GW060920 | GW032249 | GW016140 | GLENHOPE NEW | GW970797 | GW062798 (Alistair House) | GW014213 (Todd House Bore) | Bungulla Unreg | GW035920 | GW902849 | Kil 1 | W4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Landowner | - | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| Date Sampled | - | **2023-08-10** | **2023-08-10** | **2023-08-10** | **2023-08-09** | **2023-08-10** | **2023-08-10** | 6/12/2023 | 6/12/2023 | 6/12/2023 | 6/12/2023 | 04/12/2023 | 04/12/2023 | 04/12/2023 |
| **Field Parameters** | | | | | | | | | | | | | | |
| Field pH | pH units | 6.98 | 6.98 | 6.99 | 6.98 | 7.00 | 6.91 | 6.53 | 7.24 | 8.53 | 7.37 | 6.72 | 6.49 | 6.77 |
| Field Electrical Conductivity (EC) | µS/cm | 2534.00 | 1646.00 | 1310.00 | 2284.00 | 2601.00 | 650.30 | 248.00 | 186.00 | 1479.00 | 906.00 | 1209.00 | 934 | 1898.00 |
| Field TDS | mg/l | 1806.00 | 1135.00 | 900.80 | 1614.00 | 1853.00 | 432.30 | 124.00 | 93.00 | 741.00 | 453.00 | 665.00 | 467 | 949.00 |
| Depth to Groundwater | m TOC | - | - | 6.94 | - | - | - | 5.19 | 4.00 | 8.07 | - | - | ~11 | - |
| **Physical Parameters** | | | | | | | | | | | | | | |
| pH | pH Units | 8.32 | 8.11 | 8.46 | 8.16 | 8.16 | 8.37 | 7.15 | 6.95 | 8.51 | 7.8 | 7.66 | 7.78 | 7.97 |
| Sodium Absorption Ration (SAR) | - | 9.58 | 4.04 | 5.18 | 6.82 | 7 | 3.65 | 1.25 | 0.79 | 16.5 | 1.82 | 1.18 | 1.49 | 2.2 |
| Total Dissolved Solids (calc) | mg/L | 1540 | 924 | 837 | 1250 | 1590 | 344 | 189 | 135 | 784 | 510 | 852 | 503 | 1220 |
| Hydroxide Alkalinity as $CaCO_3$ | mg/L | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as $CaCO_3$ | mg/L | 10 | <1 | 37 | <1 | <1 | 10 | <1 | <1 | 26 | <1 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as $CaCO_3$ | mg/L | 363 | 467 | 619 | 255 | 723 | 268 | 99 | 58 | 351 | 205 | 175 | 190 | 244 |
| Total Alkalinity as $CaCO_3$ | mg/L | 374 | 467 | 657 | 255 | 723 | 278 | 99 | 58 | 377 | 205 | 175 | 190 | 244 |
| **Major Ions** | | | | | | | | | | | | | | |
| Sulfate as $SO_4$ - Turbidimetric | mg/L | 216 | 23 | 23 | 4 | 283 | 8 | 1 | <1 | 140 | 67 | 134 | 63 | 265 |
| Chloride | mg/L | 468 | 256 | 59 | 570 | 301 | 11 | 10 | 7 | 120 | 98 | 208 | 107 | 328 |
| Fluoride | mg/L | 0.6 | 0.2 | 0.4 | 0.1 | 0.3 | 0.3 | 0.2 | 0.2 | <0.1 | 0.3 | 0.2 | 0.2 | 0.1 |
| Calcium | mg/L | 76 | 98 | 60 | 59 | 120 | 25 | 18 | 11 | 10 | 66 | 92 | 54 | 136 |
| Magnesium | mg/L | 44 | 53 | 39 | 66 | 73 | 11 | 6 | 4 | 8 | 26 | 56 | 30 | 70 |

| Bore ID | - | GW31340 | GW060920 | GW032249 | GW016140 | GLENHOPE NEW | GW970797 | GW062798 (Alistair House) | GW014213 (Todd House Bore) | Bungulla Unreg | GW035920 | GW902849 | Kil 1 | W4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sodium | mg/L | 424 | 200 | 210 | 321 | 394 | 87 | 24 | 12 | 288 | 69 | 58 | 55 | 127 |
| Potassium | mg/L | <1 | <1 | 4 | 2 | 2 | <1 | 1 | 1 | 11 | <1 | 1 | 2 | 2 |
| Total Anions | meq/L | 25.2 | 17 | 15.3 | 21.2 | 28.8 | 6.03 | 2.28 | 1.36 | 13.8 | 8.26 | 12.2 | 8.13 | 19.6 |
| Total Cations | meq/L | 25.8 | 18 | 15.4 | 22.4 | 29.2 | 5.94 | 2.46 | 1.42 | 14 | 8.43 | 11.7 | 7.61 | 18.1 |
| Ionic Balance | % | 1.34 | 2.63 | 0.56 | 2.6 | 0.61 | 0.79 | ---- | ---- | 0.48 | 1.07 | 1.7 | 3.3 | 4.03 |
| **Dissolved Metals** | | | | | | | | | | | | | | |
| Aluminium | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | 0.02 | 0.23 | 0.04 | 0.01 | 0.02 | 0.04 | 0.03 |
| Arsenic | mg/L | 0.005 | 0.005 | 0.003 | <0.001 | 0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Beryllium | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Boron | mg/L | <0.05 | 0.08 | 0.12 | <0.05 | 0.09 | 0.06 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Cadmium | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0002 | <0.0001 | <0.0001 |
| Chromium | mg/L | <0.001 | 0.003 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cobalt | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper | mg/L | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | 0.003 | <0.001 | 0.034 | <0.001 | 0.027 | 0.002 | <0.001 |
| Iron | mg/L | <0.05 | <0.05 | 0.13 | 7.34 | <0.05 | <0.05 | 0.07 | 0.19 | 13 | <0.05 | <0.05 | 1.12 | <0.05 |
| Lead | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.01 | 0.001 | <0.001 |
| Lithium | mg/L | 0.012 | 0.004 | 0.004 | 0.011 | 0.008 | 0.003 | 0.001 | <0.001 | 0.002 | 0.003 | 0.003 | 0.004 | 0.004 |
| Manganese | mg/L | 0.002 | 0.007 | 0.735 | 0.621 | 0.05 | 0.008 | 0.014 | 0.002 | 2 | <0.001 | 0.003 | 0.02 | 0.002 |
| Mercury | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Molybdenum | mg/L | 0.001 | <0.001 | 0.002 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Nickel | mg/L | <0.001 | 0.01 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | 0.004 | 0.002 | <0.001 |
| Selenium | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Uranium | mg/L | 0.016 | 0.01 | 0.007 | <0.001 | 0.042 | 0.003 | <0.001 | <0.001 | <0.001 | 0.003 | <0.001 | <0.001 | 0.002 |
| Vanadium | mg/L | 0.02 | 0.04 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | mg/L | 0.028 | 0.048 | 0.041 | 0.021 | 0.037 | <0.005 | 0.025 | <0.005 | 0.285 | <0.005 | 1.26 | 0.04 | <0.005 |

Table D 6 Hydrochemistry Results

| Bore ID | - | - | GW017285 | W9 | W5 | GW053032 | GW900039 | N1 | GW965517 | GW032422 | GW003451 | Roslyn Unreg | GW62747 | GW062737 | GW062742 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Landowner | - | - | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| Date Sampled | - | - | 04/12/2023 | 04/12/2023 | 04/12/2023 | 04/12/2023 | 04/12/2023 | 04/12/2023 | 04/12/2023 | 04/12/2023 | 05/12/2023 | 05/12/2023 | 05/12/2023 | 05/12/2023 | 05/12/2023 |
| **Field Parameters** | | | | | | | | | | | | | | | |
| Field pH | pH units | - | 6.89 | 6.91 | - | 6.52 | 6.78 | 6.75 | 6.92 | 7.33 | 8.23 | 7.96 | 7.32 | 7.69 | 6.76 |
| Field Electrical Conductivity (EC) | µS/cm | - | 655.00 | 1248.00 | - | 1157 | 1149.00 | 558.00 | 3743.00 | 4058.00 | 1936.00 | 1477.00 | 431.00 | 349.00 | 427.00 |
| Field TDS | mg/l | - | 328.00 | 625.00 | - | 578 | 574.00 | 279.00 | 1872.00 | 2029.00 | 982.00 | 738.00 | 216.00 | 174.00 | 213.00 |
| Depth to Groundwater | m TOC | - | - | - | 9.68 | ~11 | ~11 | - | - | - | ~6 | - | 8.00 | 4.46 | - |
| **Physical Parameters** | | | | | | | | | | | | | | | |
| pH | pH Units | 0.1 | 7.92 | 7.86 | 6.97 | 8.05 | 7.79 | 7.82 | 7.32 | 8.27 | 8.46 | 8.28 | 7.51 | 7.77 | 7.34 |
| Sodium Absorption Ration (SAR) | - | 0.01 | 1.3 | 2.94 | 1.15 | 2.2 | 1.56 | 1.35 | 4.37 | 13.8 | 36.7 | 11.5 | 1.23 | 1.35 | 1.46 |
| Total Dissolved Solids (calc) | mg/L | 1.00 | 382 | 1660 | 315 | 702 | 726 | 310 | 2350 | 2130 | 1150 | 843 | 247 | 208 | 277 |
| Hydroxide Alkalinity as $CaCO_3$ | mg/L | 1.00 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as $CaCO_3$ | mg/L | 1.00 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 31 | <1 | <1 | <1 | <1 |

| Bore ID | - | - | GW017285 | W9 | W5 | GW053032 | GW900039 | N1 | GW965517 | GW032422 | GW003451 | Roslyn Unreg | GW62747 | GW062737 | GW062742 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bicarbonate Alkalinity as $CaCO_3$ | mg/L | 1.00 | 171 | 250 | 207 | 247 | 279 | 172 | 310 | 411 | 828 | 596 | 173 | 140 | 184 |
| Total Alkalinity as $CaCO_3$ | mg/L | 1.00 | 171 | 250 | 207 | 247 | 279 | 172 | 310 | 411 | 859 | 596 | 173 | 140 | 184 |
| **Major Ions** | | | | | | | | | | | | | | | |
| Sulfate as $SO_4$ - Turbidimetric | mg/L | 1 | 42 | 566 | <1 | 111 | 99 | 56 | 415 | 243 | 27 | 34 | 2 | 2 | 2 |
| Chloride | mg/L | 1 | 65 | 346 | 28 | 143 | 148 | 35 | 842 | 892 | 142 | 107 | 20 | 15 | 21 |
| Fluoride | mg/L | 0.1 | 0.2 | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 0.2 | 0.5 | 0.4 | 0.2 | 0.2 | 0.3 | 0.2 |
| Calcium | mg/L | 1 | 48 | 146 | 44 | 76 | 81 | 39 | 209 | 100 | 6 | 29 | 28 | 22 | 31 |
| Magnesium | mg/L | 1 | 19 | 88 | 18 | 43 | 46 | 21 | 135 | 38 | 4 | 11 | 14 | 11 | 14 |
| Sodium | mg/L | 1 | 42 | 182 | 36 | 97 | 71 | 42 | 330 | 641 | 473 | 286 | 32 | 31 | 39 |
| Potassium | mg/L | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 3 | 5 | 2 | 2 | 1 | 3 | 1 |
| Total Anions | meq/L | 0.01 | 6.12 | 26.5 | 4.92 | 11.3 | 11.8 | 5.59 | 38.6 | 38.4 | 21.7 | 15.6 | 4.06 | 3.26 | 4.31 |
| Total Cations | meq/L | 0.01 | 5.84 | 22.5 | 5.27 | 11.6 | 11 | 5.55 | 36 | 36.1 | 21.2 | 14.8 | 3.97 | 3.43 | 4.42 |
| Ionic Balance | % | 0.01 | 2.4 | 8.25 | 3.36 | 1.41 | 3.7 | 0.33 | 3.51 | 3.09 | 1.11 | 2.59 | 1.19 | 2.48 | 1.27 |
| **Dissolved Metals** | | | | | | | | | | | | | | | |
| Aluminium | mg/L | 0.01 | 0.01 | <0.01 | 0.75 | <0.01 | 1.32 | 0.02 | 0.04 | <0.01 | 0.06 | 5.44 | 0.04 | 0.08 | 0.02 |
| Arsenic | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.002 | <0.001 | 0.016 | <0.001 | <0.001 | <0.001 |
| Beryllium | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Boron | mg/L | 0.05 | <0.05 | <0.05 | 0.23 | 0.07 | <0.05 | <0.05 | <0.05 | 0.05 | 0.12 | 0.06 | <0.05 | 0.05 | <0.05 |
| Cadmium | mg/L | 0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0008 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Chromium | mg/L | 0.001 | 0.016 | 0.002 | 0.002 | <0.001 | 0.002 | <0.001 | 0.008 | 0.001 | <0.001 | 0.004 | <0.001 | <0.001 | 0.007 |
| Cobalt | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | 0.004 | <0.001 |
| Copper | mg/L | 0.001 | 0.01 | 0.022 | 0.003 | 0.002 | 0.035 | 0.076 | 0.006 | 0.004 | 0.034 | 0.016 | 0.004 | 0.002 | 0.026 |
| Iron | mg/L | 0.05 | 0.47 | 0.33 | 22.1 | 1.67 | 13.4 | 1.8 | 4.56 | 0.09 | 0.56 | 17.1 | 0.38 | 0.28 | 6.65 |
| Lead | mg/L | 0.001 | <0.001 | 0.001 | <0.001 | <0.001 | 0.028 | 0.006 | <0.001 | <0.001 | 0.005 | 0.005 | <0.001 | <0.001 | 0.005 |
| Lithium | mg/L | 0.001 | 0.002 | 0.003 | 0.002 | 0.003 | 0.004 | 0.002 | 0.006 | 0.004 | 0.019 | 0.014 | <0.001 | 0.003 | <0.001 |
| Manganese | mg/L | 0.001 | 0.012 | 0.154 | 0.744 | 0.02 | 0.164 | 1.28 | 0.085 | 0.002 | 0.017 | 0.094 | 0.006 | 0.078 | 0.027 |
| Mercury | mg/L | 0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Molybdenum | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.002 | 0.001 | <0.001 | 0.002 | <0.001 |
| Nickel | mg/L | 0.001 | 0.004 | 0.004 | 0.002 | <0.001 | 0.002 | 0.004 | 0.023 | <0.001 | <0.001 | 0.002 | <0.001 | 0.003 | <0.001 |
| Selenium | mg/L | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Uranium | mg/L | 0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.016 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 |
| Vanadium | mg/L | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.03 | <0.01 | <0.01 | <0.01 |
| Zinc | mg/L | 0.005 | <0.005 | <0.005 | 0.011 | <0.005 | 0.052 | 0.14 | <0.005 | 0.031 | 0.055 | 0.012 | 0.02 | 0.01 | 0.037 |