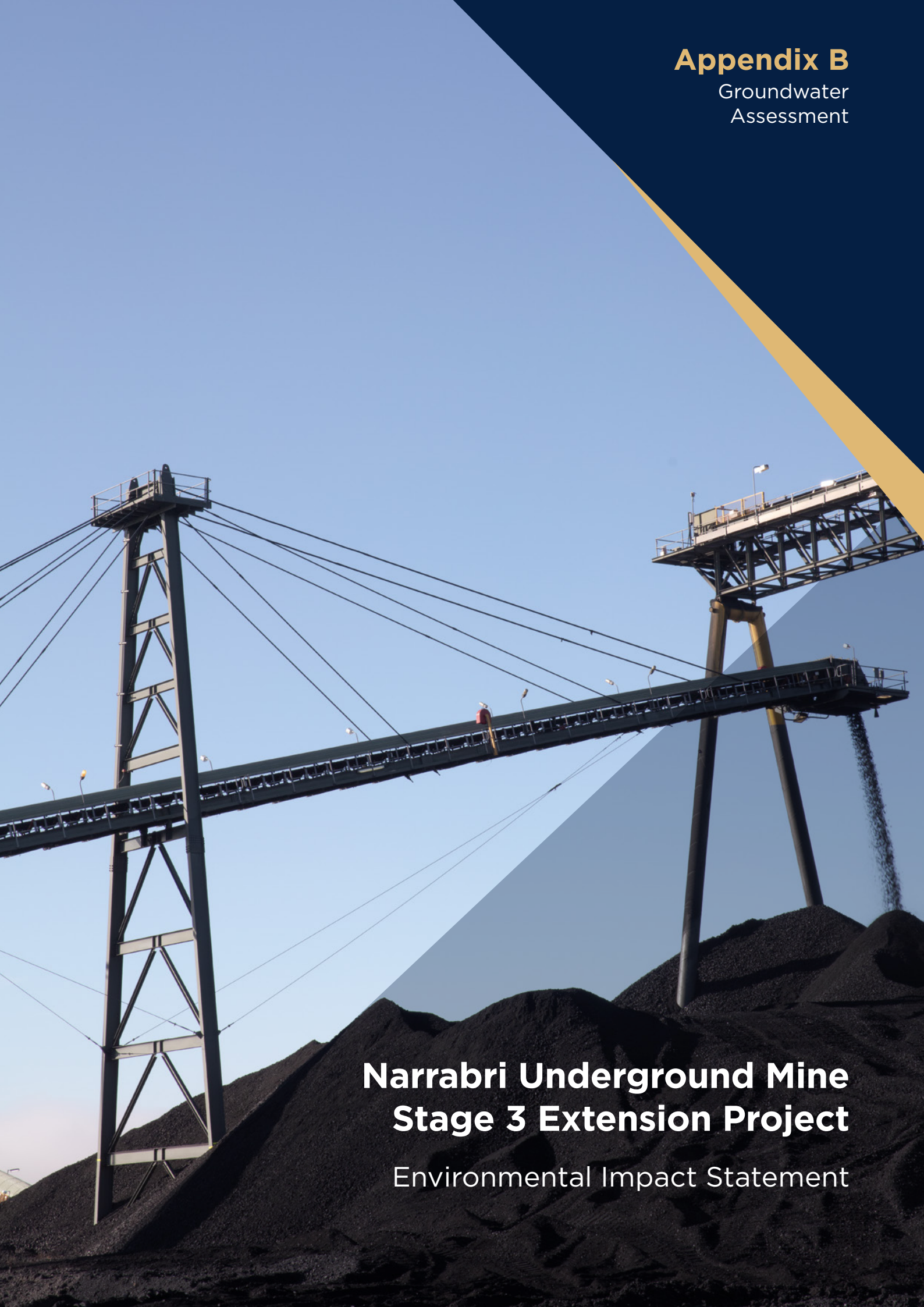
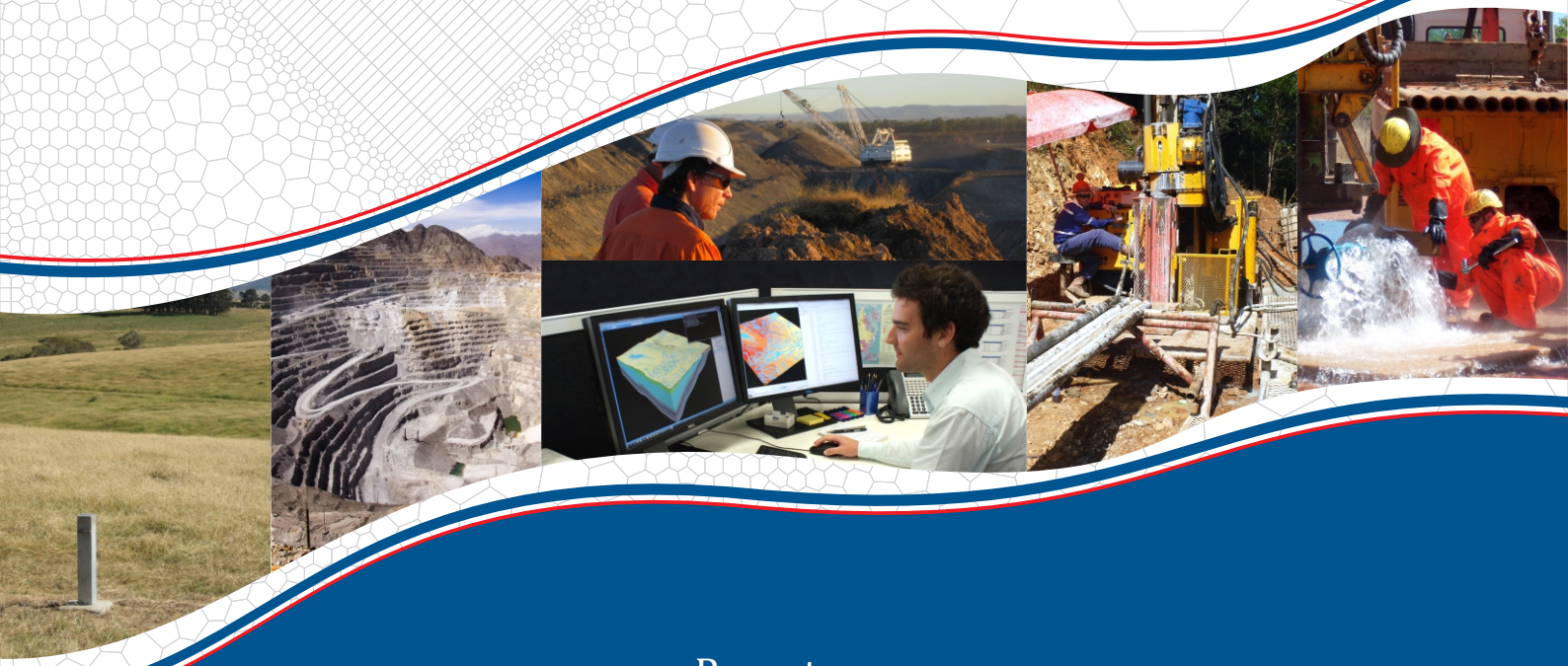
# Appendix B
Groundwater Assessment



# Narrabri Underground Mine Stage 3 Extension Project

Environmental Impact Statement

Australasian Groundwater and
Environmental Consultants Pty Ltd



Report on

# Groundwater Assessment
# Narrabri Mine
# Stage 3 Extension Project

Prepared for
Narrabri Coal Operations Pty Limited

Project No. G1972 October 2020
www.ageconsultants.com.au ABN 64 080 238 642

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*Report on*

# Groundwater Assessment
# Narrabri Underground Mine Stage 3 Extension Project

## 1 Introduction

The Narrabri Mine is located approximately 25 kilometres (km) south-east of Narrabri and approximately 60 km north-west of Gunnedah within the Narrabri Shire Council Local Government Area of New South Wales (NSW) (Figure 1.1). The Narrabri Mine is operated by Narrabri Coal Operations Pty Limited (NCOPL).

NCOPL is seeking a new Development Consent under the State Significant Development provisions of Part 4 of the NSW *Environmental Planning and Assessment Act, 1979* (EP&A Act) for the Narrabri Underground Mine Stage 3 Extension Project (the Project).

This groundwater assessment forms part of the Environmental Impact Statement (EIS) which has been prepared to accompany a Development Application for the Project.

The Project has also been declared a 'controlled action' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) following referral of the Project to the Commonwealth Department of Environment and Energy (DoEE) (now the Department of Agriculture, Water and the Environment [DAWE] (Whitehaven Coal Limited [Whitehaven], 2019).

### 1.1 Objectives and scope of work

The objective of this groundwater assessment is to assess the impact of the Project on the groundwater regime, and address the requirements of the NSW and Commonwealth government legislation and policies. The report comprises two parts: a description of the existing hydrogeological environment, and an assessment of the likely impacts of the Project on that environment.

Tasks completed in undertaking this assessment included:

- review of existing background data and previous hydrogeological investigations, including the *Narrabri Underground Mine Stage 3 Extension Project: Gateway Application Preliminary Groundwater Assessment* (HydroSimulations, 2019a) (the Gateway Application Preliminary Groundwater Assessment), and the *Narrabri Mine Modification Groundwater Assessment* (HydroSimulations, 2015) (the Approved Mine Groundwater Assessment);
- a site visit including a field reconnaissance of parts of Kurrajong, Pine and Tulla Mullen creeks;
- extensive revision of the existing Narrabri Mine model, used to predict impacts in the Gateway Application Preliminary Groundwater Assessment (HydroSimulations, 2019a), in accordance with the National Groundwater Modelling Guidelines (Barnett *et al*., 2012) and relevant State and Commonwealth guidelines;
- assessment of impacts resulting from the Project, including impacts on regional groundwater levels and baseflow;
- assessment of predicted drawdown at known and potential groundwater dependent ecosystem (GDE) locations resulting from short and/or long-term changes in groundwater;
- assessment of the potential third party impacts (i.e. private bores) resulting from changes to the regional groundwater system;

- assessment against the Aquifer Interference Policy (DPI – Office of Water, 2012a) (AIP);
- assessment of cumulative impacts;
- assessment of post-mining recovery; and
- provision of recommendations for the management of groundwater impacts including monitoring.

The scope of the groundwater assessment has been designed to address the following recommendations and requirements that relate to groundwater, from the following sources:

- Department of Planning, Industry and Environment (DPIE) Secretary's Environmental Assessment Requirements (SEARs) (issued on 20 November 2019);
- outcomes of the NSW Gateway Process, including the Mining & Petroleum Gateway Panel (MPGP) report, the MPGP Conditional Gateway Certificate (issued on 4 June 2019), the Technical assessment by the Department of Industry (DoI) – Lands and Water, and the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) advice;
- AIP; and
- Information guidelines for proponents preparing coal seam gas and large coal mining development proposals (the Information Guidelines) (IESC, 2018).

Table 1.1 reproduces the SEARs and recommendations from the Gateway Panel Report and DoI – Lands and Water relating to groundwater and indicates where these requirements are addressed within this report. Appendix H reconciles the MPGP, DoEE (now the DAWE) and IESC requirements relating to groundwater and where these requirements are addressed in this report.

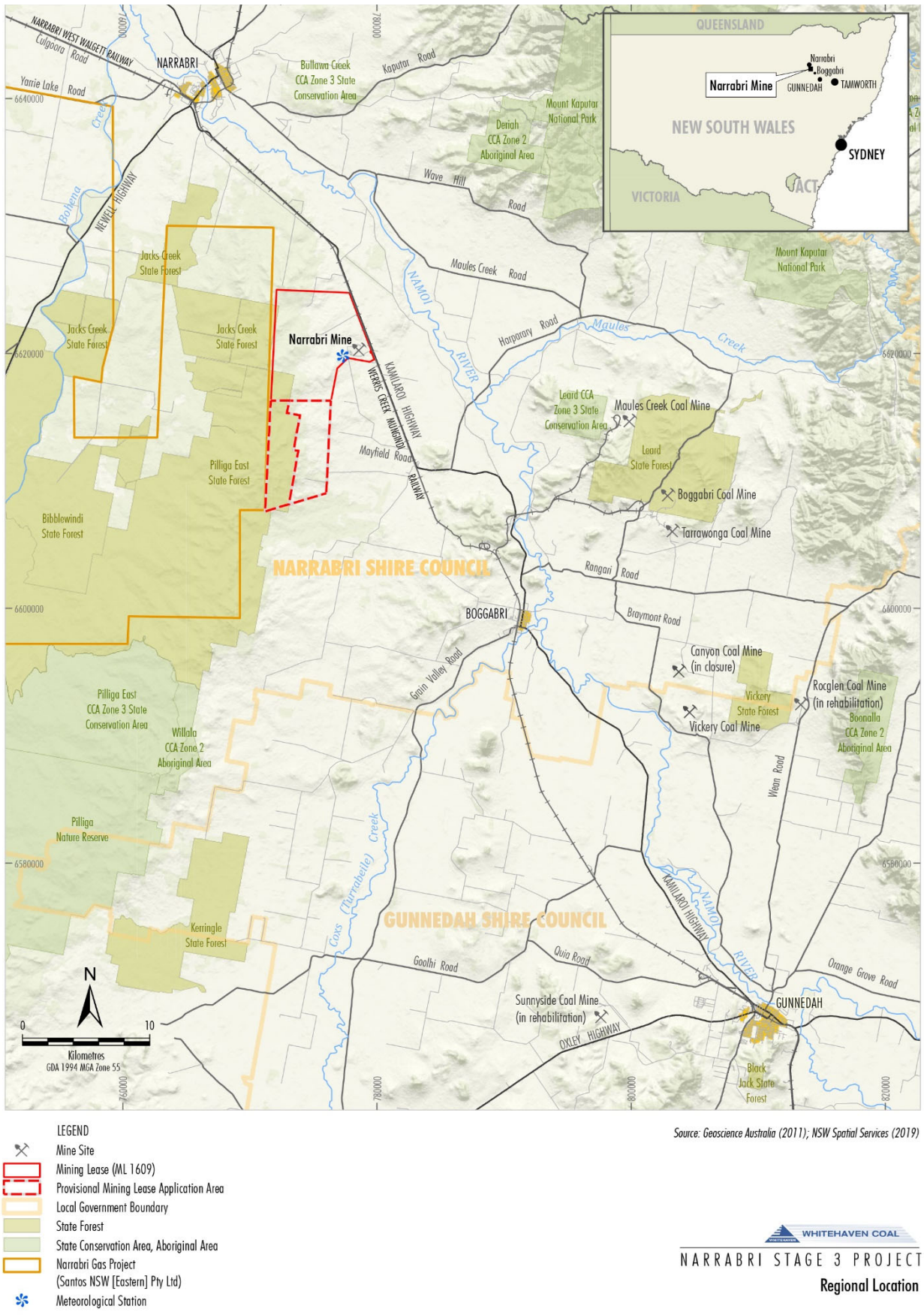
The Project involves an extension to the south of the approved underground mining area to gain access to additional coal reserves within Mining Lease Application (MLAs) 1 and 2 (Figure 1.2), an extension of the mine life to financial year (FY) 2044 and development of supporting surface infrastructure. Run-of-mine (ROM) coal production would occur at a rate of up to 11 million tonnes per annum (Mtpa), consistent with the currently approved limit. The Project Area includes Mining Lease (ML) 1609 and MLAs 1 and 2.

A detailed description of the Project is provided in Section 2 in the Main Report of the EIS.

## Table 1.1 Secretary's Environmental Assessment Requirements and Recommendations from the Conditional Gateway Certificate relating to groundwater

| Requirement / recommendation | Addressed in report sections |
|---|---|
| **Revised SEARs (issued 20 November 2019)** | |
| An assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources; having regard to the Mining & Petroleum Gateway Panel's requirements and (Commonwealth) Department of Environment and Energy requirements under the Environment Protection and Biodiversity Conservation Act 1999; | Section 7<br>A table reconciling how the MPGP and DoEE requirements relating to groundwater have been met is provided in Appendix H |
| An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, groundwater dependent ecosystems, water-related infrastructure, and other water users; | Section 7 |
| A detailed description of the proposed water management system (including sewerage), beneficial water re-use program and all other proposed measures to monitor and mitigate surface water and groundwater impacts; | A review of the current groundwater management plan and additional monitoring recommendations are presented in Section 8. Other requirements addressed in the Surface Water Assessment (WRM, 2020). |
| **Gateway panel report (dated 4 June 2019)** | |
| The Panel considers the conceptualization of the regional geology and hydrogeology to be plausible and adequate at this early stage of assessment and that the processes of groundwater flow from one water source to another have been identified at a broad scale. At a local scale there are still uncertainties such as the extent to which fracturing, caused by mine subsidence, will modify groundwater flow and also the impacts of faults and a basalt intrusion on flow. | Sections 5.2.11, 6.2 and 7.2 |
| The Panel agrees with the IESC and DoI Water that if the project progresses to an EIS, the 2013 monitoring program should be updated with additional monitoring bores. In particular, the spatial coverage of the groundwater monitoring network should be expanded to where there are currently no monitoring bores i.e. to the west and south of the proposed extension | Section 5.2.1 and Section 8 |
| The Panel requires more geological detail and baseline data acquisition in any upgraded groundwater model that is to be used in an EIS. Additional studies are required to more fully identify and evaluate cracking formed from the effects of mining and the possible loss of water in ephemeral streams due to surface cracking; | Geological detail - Section 4<br>Baseline data - Section 5.2.1 |
| **Recommendations (DoI – Land and Water)** | |
| The proponent should confirm in the EIS detail on the significant drawdown in the vicinity of the proposed mine footprint including the potential impact to the nearby state forest and other users including BSAL and private bores as identified in the preliminary groundwater assessment document. | Section 7.6 |
| The preliminary assessment shows that the drawdown will impact on two private groundwater works. In accordance with the Aquifer interference Policy, make good provisions are required for all bores where a cumulative pressure head decline of more than 2 m occurs. | Section 7.6.1 |
| The proponent should confirm in the EIS the risk of potential connective fracturing to surface with reference to the predicted distance between mining induced fracturing. | Section 7.2 |

| Requirement / recommendation | Addressed in report sections |
|---|---|
| The proponent should clarify in the EIS the impact assessment against the Aquifer Interference Policy relating to the Southern Recharge Groundwater Source. This should include:<br>• Ensuring the correct minimal impact considerations have been quoted and applied in the assessment – specifically the 'Water Pressure' criteria for the Southern Recharge Groundwater Source<br>• Clearly identifying and justifying which formations the 'Water Table' and 'Water Pressure' criteria apply to, noting the Pilliga Sandstone is considered unconfined in this area.<br>• Addressing the prediction of a 4 m decline in the water table post mine closure in the Pilliga Sandstone as part of the minimal impact consideration which should include applying the Level 2 criteria | Sections 7.4, 7.6.1 and 7.7 |
| The proponent should commit to updating the Water Management Plan to include mitigation and/or remediation actions to cover any predicted impacts and contingency planning to address impacts greater than predicted | A review of the current groundwater management plan and additional monitoring recommendations are presented in Section 8. Other requirements addressed in the Surface Water Assessment (WRM, 2020) |
| The proponent should qualify with evidence the statement that pumping effects from private bores are observed in the monitoring data – specifically relating to the Southern Recharge and Gunnedah – Oxley Basin MDB Groundwater Sources. The proponent needs to investigate and report on this in the EIS. | Section 5.2.4 |
| The proponent predicts that the project will result in maximum additional groundwater take of 0.38 megalitres per day (ML/d) from the Upper Namoi Zone 5 Namoi Valley groundwater sources, 0.85 ML/d from the Southern Recharge Groundwater Source and 0.5 ML/d from the Lower Namoi Regulated River Water Source. The proponent will need to acquire additional water entitlement from the relevant water source to account for the estimated take from each source. | Predicted additional takes from water sharing plan areas are detailed in Section 7.7 |
| The potential for cumulative impact to water resources in relation to other nearby projects, including the proposed Narrabri Gas Project. This was not considered in the preliminary groundwater assessment and will need to be addressed in detail at the EIS stage. | Sections 7.1, 7.4, 7.5 and 7.6 |




## Figure 1.1 Regional Location

## 1.2 Report structure

This report is structured as follows:

- Section 1 – Introduction: provides an overview of the Project and the assessment scope;
- Section 2 – Regulatory framework: describes the regulatory framework relating to groundwater;
- Section 3 – Environmental setting: describes the environmental setting of the Project including the climate, terrain, land uses and other environmental features relevant to groundwater;
- Section 4 – Geological setting: describes the regional geology and local stratigraphy;
- Section 5 – Conceptual model: describes the groundwater regime within and surrounding the Project;
- Sections 6 and 7 – Impact Assessment: describes the numerical model and the predicted impacts on groundwater users and the receiving environment;
- Section 8 – Groundwater Monitoring and Management Plan: describes the measures for monitoring and management of groundwater impacts including recommendations for additional monitoring;
- Section 9 – Summary and Conclusions;
- Appendix A provides key construction details for each of the Project groundwater monitoring points;
- Appendix B shows time series groundwater level data used for conceptual and numerical model development and calibration;
- Appendix C summarises the available water quality data used in the current study;
- Appendix D provides a detailed description of the numerical modelling undertaken for the Project, including details on model construction, calibration, validation and uncertainty, and the peer review report;
- Appendix E includes a series of cross sections extracted from a lithological model of the Namoi Alluvium;
- Appendix F provides further details of existing registered water supply bores which have the potential to be impacted by the Project;
- Appendix G includes a bore census report prepared by Environment & Natural Resource Solutions (ENRS, 2020); and
- Appendix H presents a reconciliation of how the MPGP and DoEE requirements and recommendations relating to groundwater have been met.

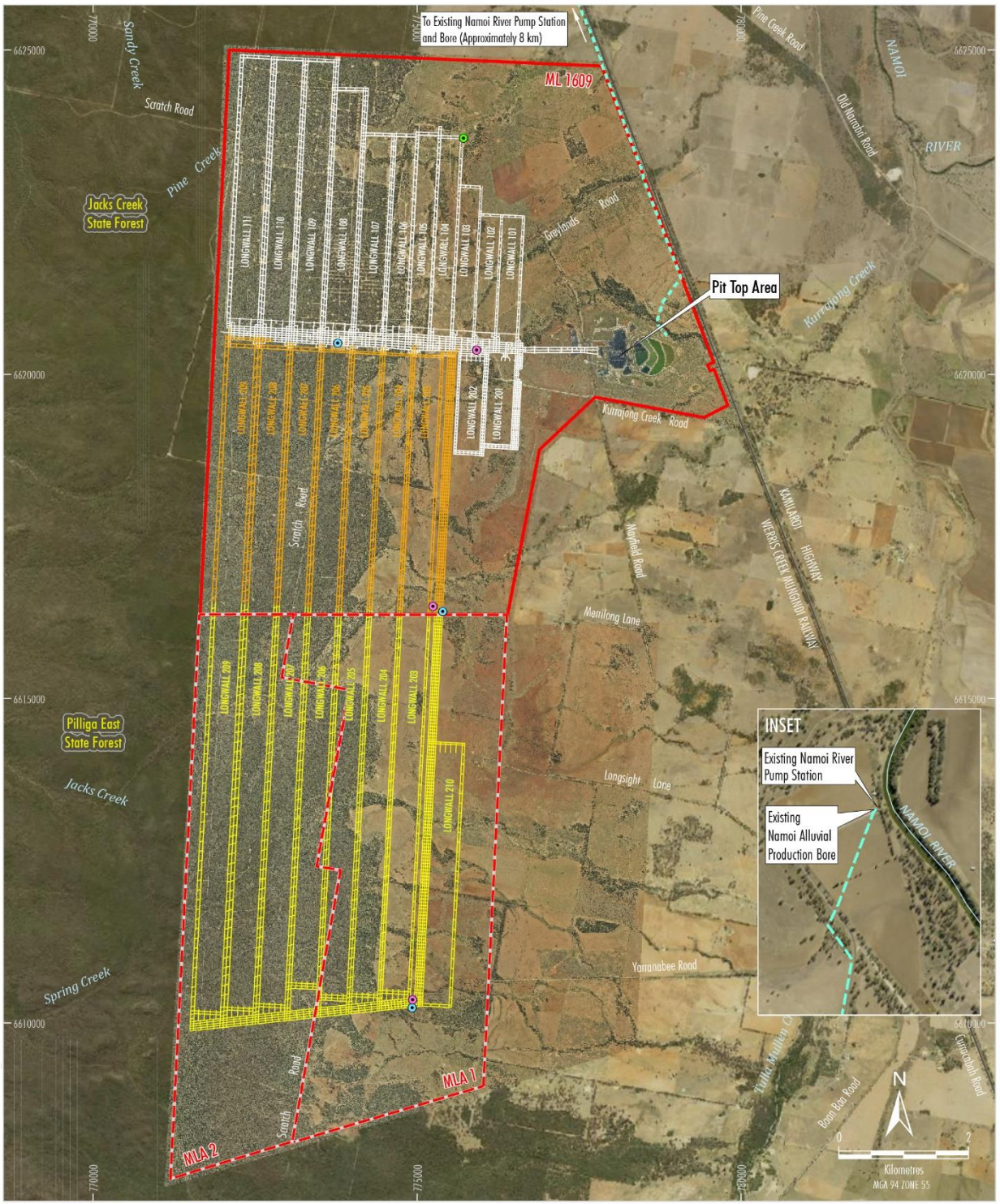



**Figure 1.2 Approved and Project General Arrangement**

# 2 Regulatory framework

This Section outlines the regulatory framework of relevance to the Project EIS and the current groundwater impact assessment report.

This report has been prepared considering the following legislation, policy and guidelines relating to groundwater:

- NSW Government:
    - Legislation:
        - EP&A Act; and
        - *Water Management Act 2000, Water Management (General) Regulation 2018* and the associated Water Sharing Plans (WSPs).
    - Policy and Plans:
        - AIP;
        - State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007;
        - Groundwater Quality Protection Policy (1998);
        - Groundwater Dependent Ecosystems Policy (2002);
        - Groundwater Quantity Management Policy (Policy Advisory Note No. 8);
        - Strategic Regional Land Use Policy (2012); and
        - Strategic Regional Land Use Plan – Upper Hunter (2012).
- Commonwealth Government:
    - Legislation:
        - EPBC Act.
    - Guidelines and explanatory notes:
        - the Information Guidelines (IESC, 2018);
        - Australian Groundwater Modelling Guidelines (Barnett et al., 2012);
        - Uncertainty analysis – Guidance for groundwater modelling within a risk management framework (Middlemis and Peeters, 2018); and
        - Assessing Groundwater Dependent Ecosystems (Doody et al., 2019).

The sections below summarise the intent of the key legislation, policy and guidelines above and how they apply to the Project.

## 2.1 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 the granting of approvals. Aquifer interference approvals are not to be granted unless the Minister is satisfied that adequate arrangements are in force such that no more than minimal harm will be done to any water source, or its dependent ecosystems, as a consequence of it being interfered with in the course of the activities to which the approval relates.

The EP&A Act, sections 4.41 1(g) stipulates that State Significant Development authorised by a development consent does not require a water use approval, a water management work approval or an activity approval under the *Water Management Act 2000*.

## 2.2 NSW Environmental Planning and Assessment Act 1979

The EP&A Act provides a system of environmental planning and assessment for the State of NSW. Section 4.12(8) of the EP&A Act requires that a development application for a State Significant Development is to be accompanied by an EIS prepared by or on behalf of the applicant in the form prescribed by the regulations.

This Groundwater Assessment will be used in support of the EIS for the Project.

## 2.3 State groundwater policy

### *2.3.1 Aquifer Interference Policy*

The *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, injection of water, and commercial, industrial, agricultural and residential activities that intercept the water table or interfere with aquifers.

The AIP states that:

"*all water taken by aquifer interference activities, regardless of quality, needs to be accounted for within the extraction limits defined by the water sharing plans. A water licence is required under the WM Act (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. "*

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. These predictions need to occur prior to approval. After approval and during operations, these volumes need to be measured and reported in an annual review or environmental management reports. The WAL must hold sufficient share component and water allocation to account for the take of water from the relevant water source when the take occurs.

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. Activities may induce flow from adjacent groundwater sources or connected surface water. Flows induced from other water sources also constitute take of water. In all cases, WALs are required to account for the take from all individual water sources.

In addition to the volumetric water licensing considerations, the AIP requires details of potential:

- *"water level, quality or pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right;*
- *water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources;*
- *water level, quality or pressure drawdown impacts on groundwater dependent ecosystems;*
- *increased saline or contaminated water inflows to aquifers and highly connected river systems;*
- *to cause or enhance hydraulic connection between aquifers; and*
- *for river bank instability, or high wall instability or failure to occur."*

In particular, the AIP describes minimal impact considerations for aquifer interference activities based upon whether the water source is highly productive or less productive and whether the water source is alluvial or porous/fractured rock in nature.

A "highly productive" groundwater source is defined by the AIP as a groundwater source which has been declared in regulations and datasets, based on the following criteria:

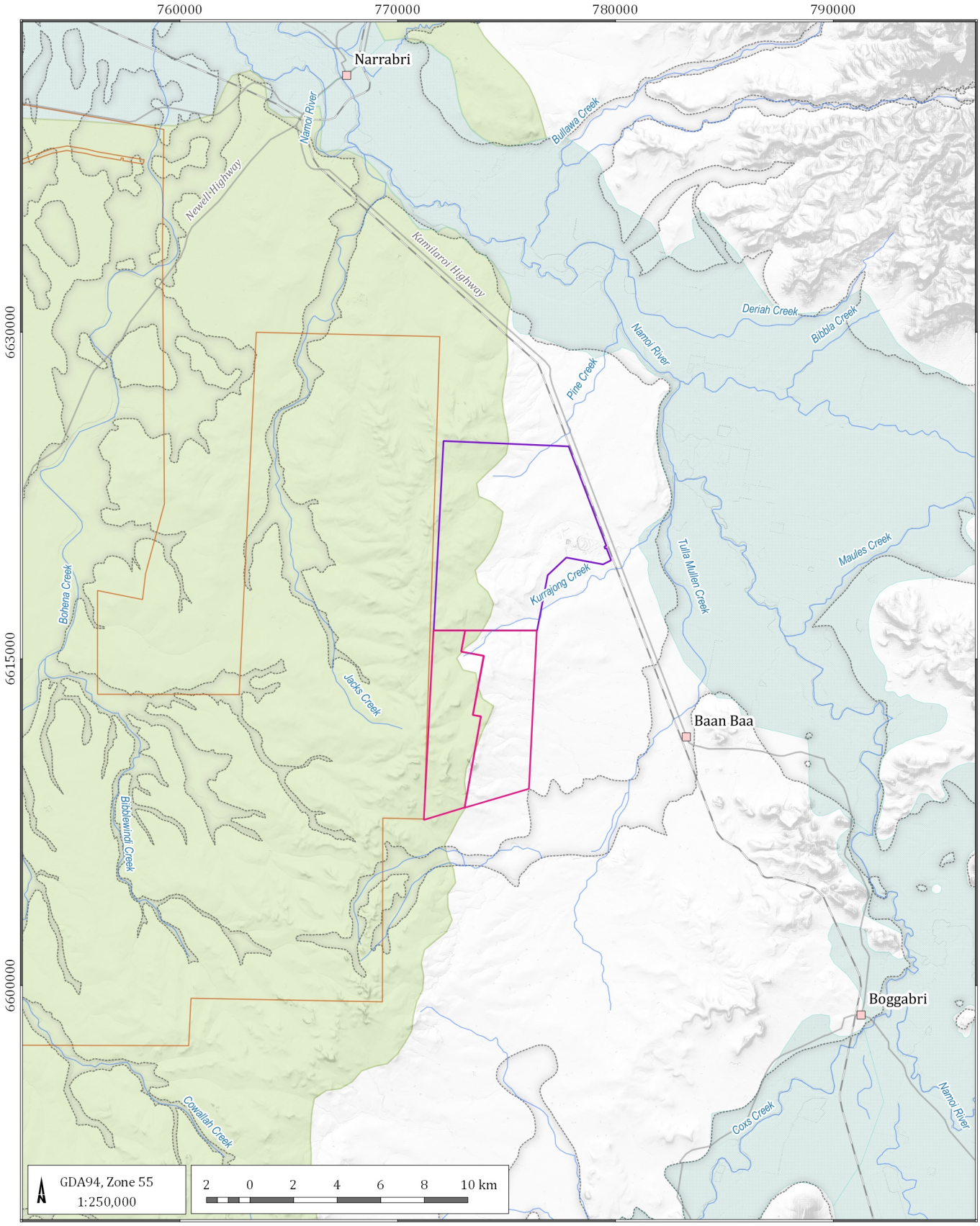
a) has a total dissolved solids (TDS) concentration less than 1,500 milligrams per litre (mg/L); and

b) contains water supply works that can yield water at a rate greater than 5 litres per second (L/s).

Highly productive groundwater sources are further grouped by geology into alluvial, coastal sands, porous rock, and fractured rock. "Less productive" groundwater sources are all other aquifers that do not satisfy the "highly productive" criteria for yield and water quality.

The NSW Department of Planning, Industry and Environment – Water (DPIE-Water) has mapped areas of groundwater productivity across NSW, which shows areas classified as either highly or less productive.

Figure 2.1 shows the DPIE-Water groundwater productivity map, which indicates the alluvium associated with the Namoi River and its tributaries has been classified as highly productive alluvial aquifer. The area west of the Project is also mapped as containing a highly productive porous rock aquifer (i.e. the Pilliga Sandstone), however, the Project longwall mining would occur beneath this within less productive aquifers.




LEGEND

- Populated place
- Drainage
- Road
- Rail
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Mapped alluvium extent (see Figure 4.5)

**Highly productive groundwater**

- Alluvial
- Porous rock

Narrabri Stage 3 Extension GIA (G1972)

## Highly productive groundwater areas

DATE 17/06/2020

FIGURE No: **2.1**

©2020 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\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\02.01_G1972_Highly productive groundwater areas.qgs

The extent and characteristics of the Quaternary alluvium and porous rock units are further discussed in Sections 4.2.1 and 5.1.1 respectively. Section 5.1 and Section 5.3 provide further information on the properties of the aquifers and if they are considered "highly productive". As shown in Figure 2.1, there are some discrepancies between the DPIE-Water mapped extent of the Namoi alluvial aquifer and the extent of the Quaternary alluvium based on current geological data. In particular, the DPIE mapping shows the alluvial aquifer extending further west towards the Narrabri Mine in places. Where such discrepancies occur, preference has been given to the geological mapping throughout the current assessment, on the basis that this is considered to be the most contemporary dataset and since the groundwater flow model structure (Section 6) is also based on the geological mapping data.

The minimal impact considerations are a series of threshold levels defining minimal impact on groundwater sources, connected water sources, groundwater dependent ecosystems, culturally significant sites and water users. The thresholds specify water table and groundwater pressure drawdown as well as groundwater and surface water quality changes. Section 7.5.2 presents the Project impacts and compares these with AIP thresholds where relevant.

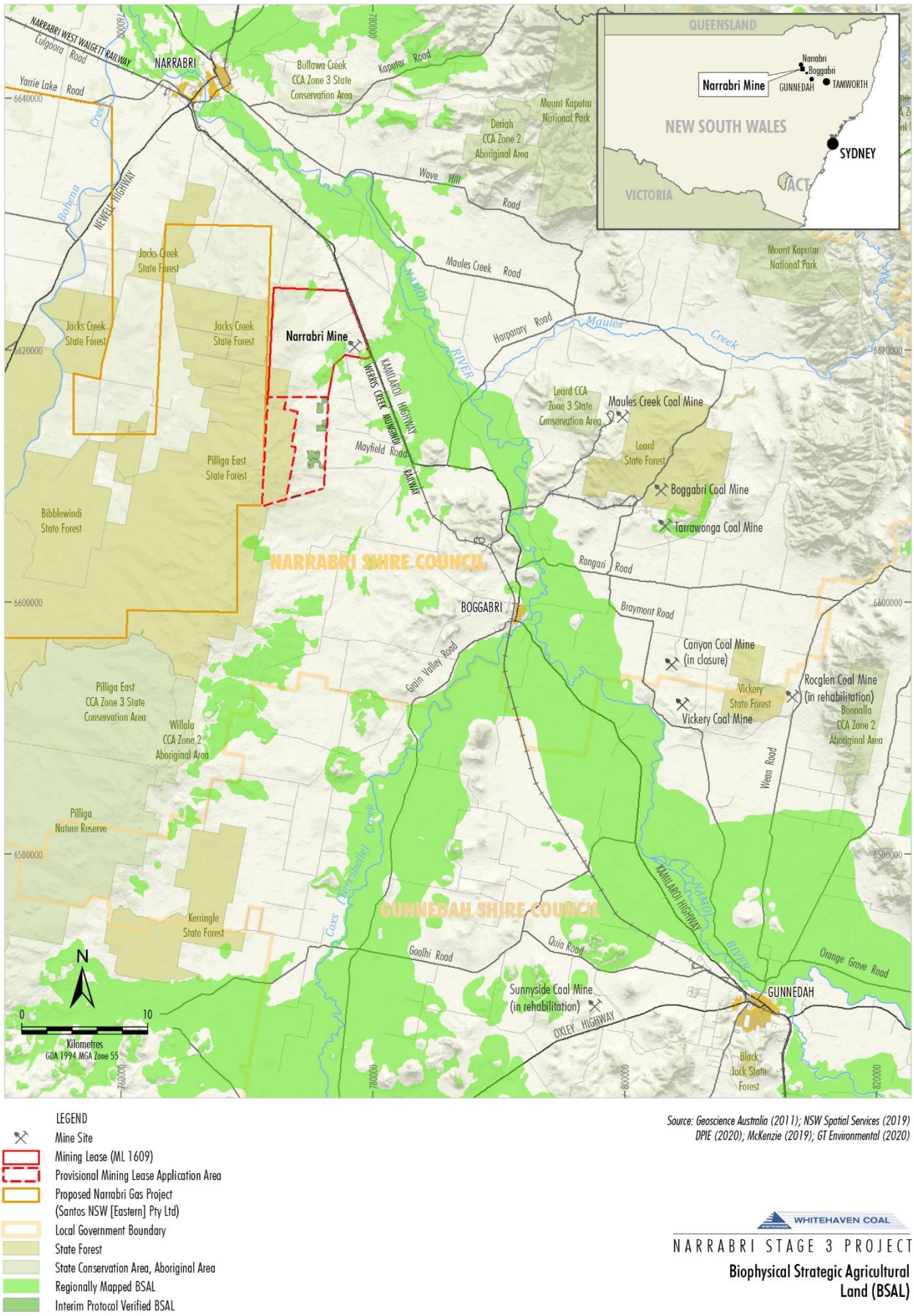
### *2.3.2 State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*

Pursuant to clause 17H of the State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007, the Gateway Panel determined the Gateway Application made by NCOPL by issuing a Conditional Gateway Certificate for the Project on 4 June 2019.

The revised SEARs (issued 20 November 2019) consider the recommendations of the Gateway Panel.

### *2.3.3 NSW Strategic Regional Land Use Policy*

The NSW Strategic Regional Land Use Policy applies to the area in which the Project resides. Biophysical Strategic Agricultural Land (BSAL) is land with high quality soil and water resources capable of sustaining high levels of productivity. BSAL is regionally mapped by the NSW Government within parts of ML 1609 (Figure 2.2). An assessment of BSAL occurrence within the Project has found that the actual occurrence of BSAL (i.e. based on a program of soil tests) within MLAs 1 and 2 is more limited, comprising approximately 5.7 percent (%) of the Project Area (2rog Consulting, 2020).




LEGEND

- Mine Site
- Mining Lease (ML 1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos NSW [Eastern] Pty Ltd)
- Local Government Boundary
- State Forest
- State Conservation Area, Aboriginal Area
- Regionally Mapped BSAL
- Interim Protocol Verified BSAL

*Source: Geoscience Australia (2011); NSW Spatial Services (2019) DPIE (2020); McKenzie (2019); GT Environmental (2020)*

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

**Biophysical Strategic Agricultural Land (BSAL)**

**Figure 2.2**

## Figure 2.2 Biophysical Strategic Agricultural Land (BSAL) Areas

## 2.4 Water sharing plans

NSW WSPs establish rules for sharing water between the environmental needs of rivers and aquifers, and water users, as well as between different types of water use such as town supply, rural domestic supply, stock watering, industry and irrigation.

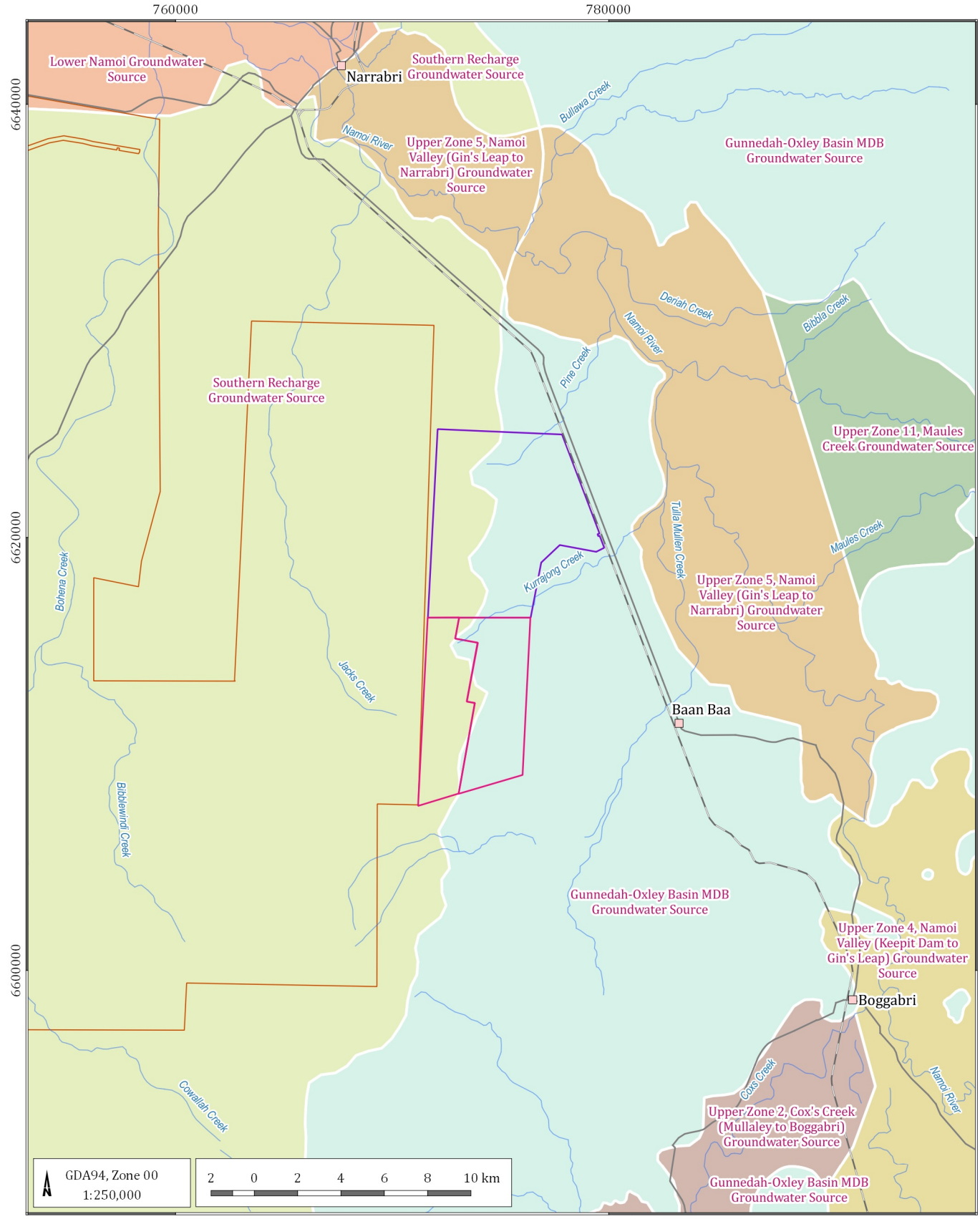
The DPIE-Water is progressively developing WSPs for rivers and groundwater systems across NSW following the introduction of the *Water Management Act 2000*. The purposes of the WSPs are to protect the health of rivers and groundwater, while also providing water users with perpetual access licences, equitable conditions, and increased opportunities to trade water through separation of land and water.

Four WSPs apply to the aquifers and surface waters in the vicinity of the Project Area – these are the WSPs for the:

- NSW MDB Porous Rock Groundwater Sources 2020 – Gunnedah-Oxley Basin MDB Groundwater Source (Gunnedah Oxley Basin MDB [Other] Management Zone);
- NSW Great Artesian Basin (GAB) Groundwater Sources 2020 – Southern Recharge Groundwater Source;
- Namoi Alluvial Groundwater Sources 2020 – Upper Namoi Zones 2, 4 and 5 and the Lower Namoi Groundwater Sources; and
- Upper and Lower Namoi Regulated River Water Sources 2016 – Lower Namoi Regulated River Water Source.

As discussed in Section 2.4.1 some units which are associated with the Lachlan Fault Belt MDB Groundwater Source are present at outcrop within the Project Area. However, these areas are assigned to the Gunnedah-Oxley Basin source and hence the Lachlan Fault Belt WSP is not considered relevant.

Figure 2.3 shows the extent of the relevant groundwater sources in plan view, and Figure 2.4 shows a schematic cross section identifying which aquifers are covered by each WSP in the vicinity of the Project.




LEGEND

- Populated place
- Drainage
- Road
- Rail
- Mining Lease Boundary (ML 1609)
- Provisional Mining Lease Application
- Proposed Narrabri Gas Project (Santos)

**Water sharing sources**

- Gunnedah-Oxley Basin MDB Groundwater Source
- Lower Namoi Groundwater Source
- Southern Recharge Groundwater Source
- Upper Zone 11, Maules Creek Groundwater Source
- Upper Zone 2, Cox's Creek (Mullaley to Boggabri) Groundwater Source
- Upper Zone 4, Namoi Valley (Keepit Dam to Gin's Leap) Groundwater Source
- Upper Zone 5, Namoi Valley (Gin's Leap to Narrabri) Groundwater Source

Narrabri Stage 3 Extension GIA (G1972)

## Water sharing plan areas

DATE 12/08/2020

FIGURE No: **2.3**

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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.;
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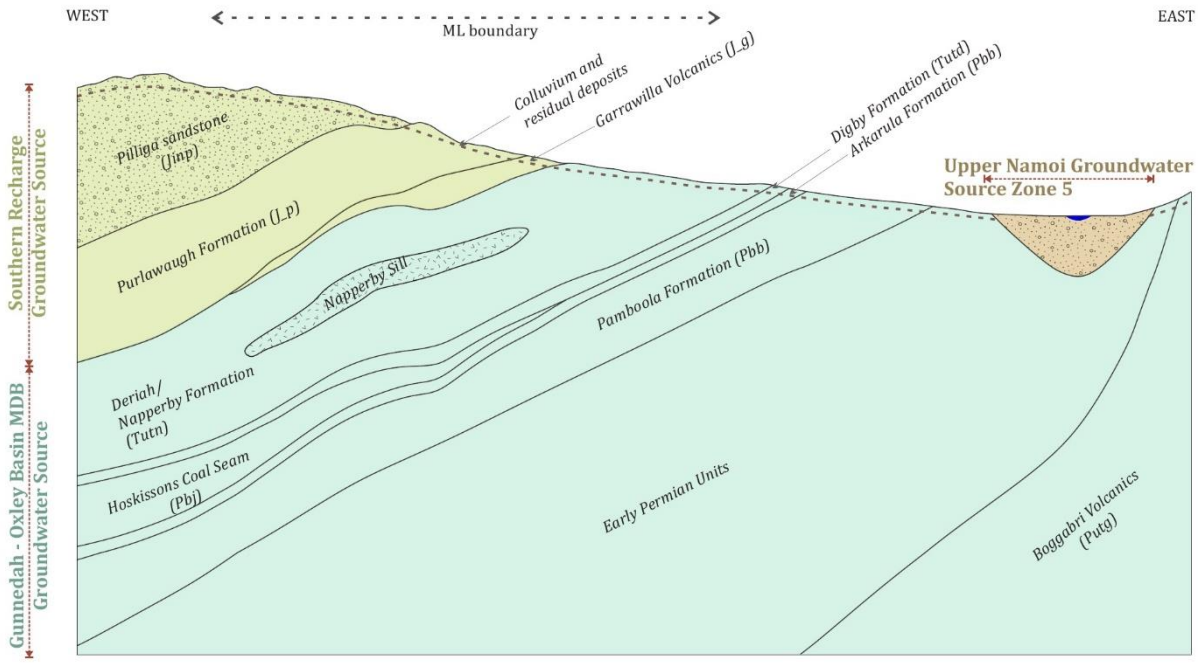



**Figure 2.4 Schematic water sharing plan cross section**

### *2.4.1 Lachlan Fault Belt MDB Groundwater Source*

Reference to geological mapping of area suggests that the Boggabri Volcanics, which form part of the Lachlan Fault Belt MDB groundwater source (within the WSP for the NSW MDB Fractured Rock Groundwater Sources 2020), are present at outcrop towards the east of the Project Area. However, these areas plot within the boundary the Gunnedah-Oxley Basin MDB Groundwater Source and reference clause 3 in the WSP document confirms that the Gunnedah_Oxley Basin source includes all rocks of Permian, Triassic, Jurassic, Cretaceous and Tertiary age within the mapped area. Accordingly since none of the groundwater resources within the Project Area form part of the Lachlan Fault Belt MDB Groundwater Source there is no potential for impact on this source and it is not discussed further in the remainder of this report.

### *2.4.2 Gunnedah-Oxley Basin MDB Groundwater Source*

As shown in Figure 2.3, the Project is located within the Gunnedah-Oxley Basin MDB Groundwater Source area (within the WSP for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2020) which comprises Permian and Triassic rocks associated with the Gunnedah Basin and the overlying younger Jurassic and Cretaceous rocks associated with the Oxley Basin. As shown in Figure 2.3 this plan therefore covers all the consolidated sedimentary units underlying the sandstone units which form part of the GAB Southern Recharge Groundwater Source (Section 2.4.3). The WSP suggests that GDEs associated with this groundwater source are at relatively high risk (DPI-Office of Water, 2012c). In response to which 50% of estimated recharge has been reserved for the environment, a relatively high proportion. The recent 2020 update of the WSP plan for this source also identifies a large number of priority GDEs within the plan area. These GDEs are understood to be based on 'high potential' GDE areas identified in The National Groundwater Dependent Ecosystem Atlas (GDE Atlas, BoM, 2018). As such the majority of the areas identified are potential GDE areas identified using satellite image analysis with limited ground truthing. Further discussion and description of potential GDEs site which have been identified in the area is provided in Section 5.7.

Despite the recharge reserved for the environment, the long-term average annual extraction limit for the Gunnedah-Oxley Basin MDB Groundwater Source is 127,500 megalitres per year (ML/year). In the July 2019 to June 2020 water year, 23,872 aquifer and local water utility shares were allocated, indicating the groundwater source is significantly under-allocated. In addition, the NSW Government gazetted a controlled allocation order in 2017 which included shares in the Gunnedah-Oxley Basin MDB Groundwater Source. In 2019, the controlled allocation entered a third Registration of Interest period which included 16,742 shares available in the Gunnedah-Oxley Basin MDB Groundwater Source. In 2020, there has again been a gazetted Controlled Allocation Order Registration of Interest period for this groundwater source of 4,043 unit shares.

### *2.4.3 GAB Southern Recharge Groundwater Source*

As shown in Figure 2.3, the eastern boundary of the Southern Recharge Groundwater Source area (within the WSP for the NSW GAB Groundwater Sources 2020) runs from north to south through the centre of ML 1609 and MLAs 1 and 2. The WSP for the area covers all water contained in the Cretaceous and Jurassic age sandstone aquifers of the GAB in the area (Department of Water and Energy [DWE], 2009a). This plan requires that water be allocated for the fundamental health of a water sources and its dependent ecosystems as a priority. Accordingly, the plan reserves the long-term storage component of the Eastern and Southern Recharge groundwater sources for the environment and also sets aside 30% of the average annual net recharge for the environment to protect GDEs. As discussed above in relation to the Gunnedah Oxley Basin source the recently updated WSP for the GAB Southern Recharge Source identifies a large number of high priority GDE areas which are understood to be based on potential GDE areas identified in the GDE Atlas (BoM, 2018). Few if any of these areas are understood to have been field verified and hence they may not be actual GDEs. The Hardys and Eather Springs which are located approximately 3.5 km and 5.5 km south of MLAs 1 and 2, respectively are also listed as high priority spring GDE sites in the latest revision of the WSP plan. Further discussion and description of these springs and other potential GDE areas which have been identified in the Project Area is provided in Section 5.7.

Groundwater from the Southern Recharge Groundwater Source is predominantly used for irrigation where the water quality is suitable (DWE, 2009b).

The distribution of water allocations for the Southern Recharge Groundwater Source indicates that the more productive region is located to the west of the Project Area, and that water use in the vicinity of the Project comprises a small component of the overall use for the groundwater source (Figure 2.5).

### *2.4.4 Namoi Alluvial Groundwater Sources*

Groundwater resources within the unconsolidated alluvial sediments associated with the Namoi River and its tributaries are the subject of the WSP for the Namoi Alluvial Groundwater Sources 2020. The Upper Namoi Zone 5, Namoi Valley (Gin's Leap to Narrabri) Groundwater Source (Zone 5) is located approximately 6 km east of the Project underground mining area. NCOPL is approved to extract water from Zone 5 from its bore located near the Namoi River (work approval 90WA812891) (Figure 1.2). As discussed above in relation to the other WSP areas the recently updated WSP for this source identifies a large number of high priority GDE areas which are understood to be based on potential GDE areas identified in the GDE Atlas (BoM, 2018). Few if any of these areas are understood to have been field verified and hence they may not be actual GDEs. Further discussion and description of potential GDEs site which have been identified in the area is provided in Section 5.7.

Groundwater from Zone 5 is predominantly used for irrigation.

Other groundwater sources associated with this WSP located further from the Project but which could be impacted to some degree include the Upper Namoi Zone 2, Cox's Creek (Mullaley to Boggabri) Groundwater Source (Zone 2), Upper Namoi Zone 4, Namoi Valley (Keepit Dam to Gin's Leap) Groundwater Source (Zone 4), Upper Namoi Zone 11, Maules Creek Groundwater Source (Zone 11), and the Lower Namoi Groundwater Source.

### *2.4.5 Upper and lower Namoi Regulated River Water Sources*

Both the volume and pattern of flows in the Namoi River have been significantly altered by water extraction and the operation of two main water storages, the Split Rock Dam (completed 1987) on the Manilla River (a tributary of the Namoi River) and the Keepit Dam (completed 1960) on the Namoi River itself. Both of these storages are located some distance upstream of the Project Area. The frequency of all but the largest flood events in the river catchment has been reduced and flows at the downstream end of the system are also reduced. Regulation has led to increased average monthly flows in the summer but reduced average flows during the winter. These changes have impacted on the environmental health of the river and its wetlands and are thought to have contributed to some reductions in water quality (Department of Infrastructure, Planning and Natural Resources, 2004).

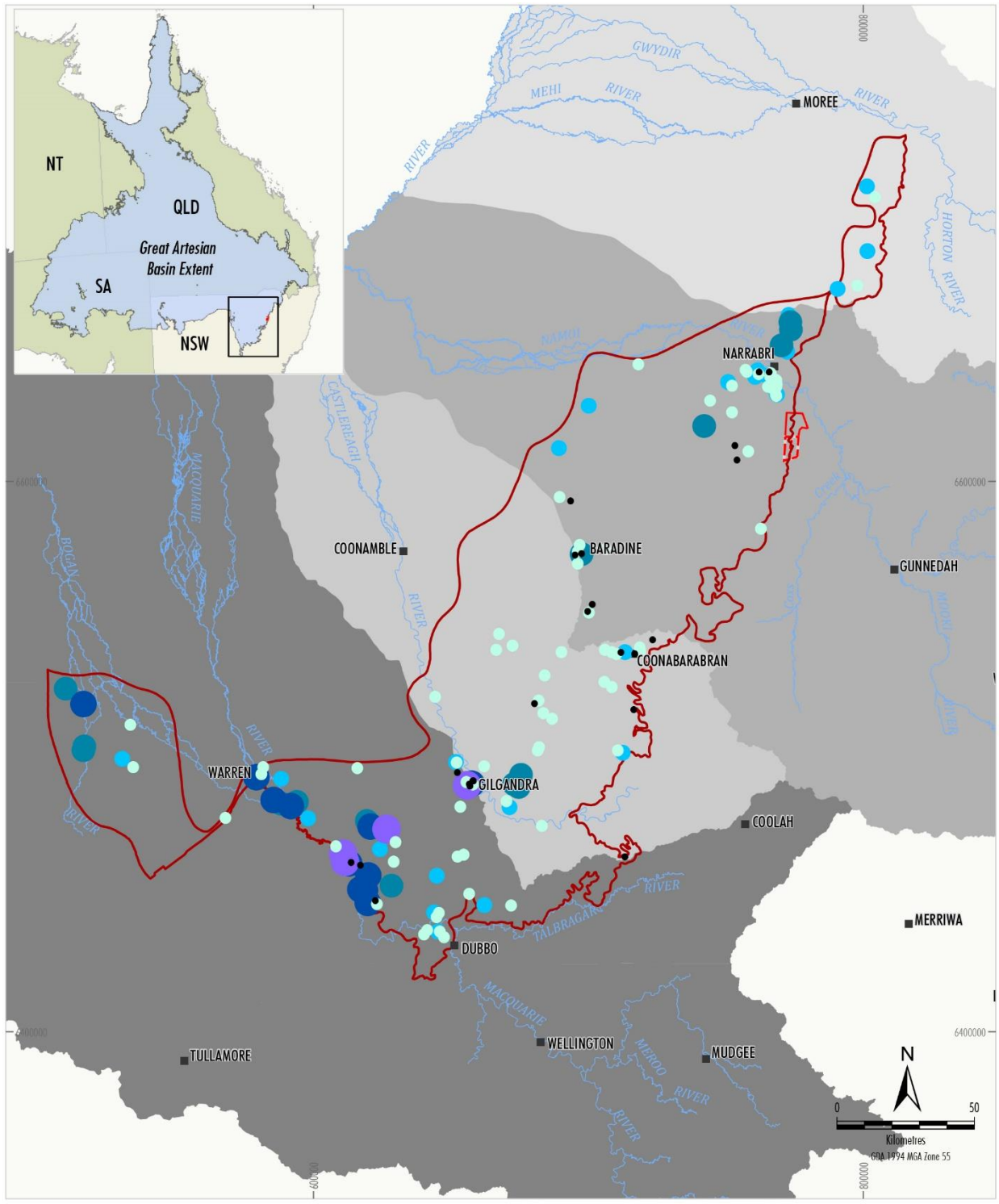



**Figure 2.5 Southern Recharge Groundwater Source WALs**

The WSP splits the Namoi into two regulated water sources: The Upper Namoi water source which includes river sections between the Split Rock and Keepit Dam; and the Lower Namoi water source which includes river sections downstream of the Keepit Dam to the Barwon River. The Lower Namoi water source is therefore of most relevance to the Project. NCOPL is approved to extract water from the Namoi River from its pump located at the Namoi River (Figure 1.2). However, no future external raw water is predicted to be required at the Narrabri Mine as groundwater inflows are expected to exceed the site water demand (WRM, 2020).

### *2.4.6 Water licences by source*

Table 2.1 summarises the number of WALs and the surface water and aquifer licence shares available for each water source.

**Table 2.1 Water licensing for each water source**

| Water Sharing Plan | Water source | Access licence category | Water access licence units | |
|---|---|---|---|---|
| | | | No. of WALs | Total units |
| NSW Murray Darling Basin Porous Rock Groundwater Sources 2020 | Gunnedah – Oxley Basin MDB Groundwater Source | Aquifer | 144 | 23,109 |
| NSW GAB Groundwater Sources 2020 | GAB Southern Recharge Groundwater Source | Aquifer | 156 | 24,462 |
| Namoi Alluvial Groundwater Sources 2020 | Zone 2 | Aquifer | 30 | 7,141 |
| | Zone 4 | Aquifer | 166 | 21,032 |
| | Zone 5 | Aquifer | 76 | 15,992 |
| | Zone 11 | Aquifer | 29 | 2,223 |
| | Lower Namoi | Aquifer | 216 | 81,586 |
| Upper and Lower Namoi Regulated River Water Sources | Lower Namoi Regulated River Source | Regulated River (High Security and General Security) | 614 | 122,684 |

***Note:*** *based on information within NSW Water register accessed on 20 August 2019.*

The water sharing rules are implemented through WALs and relate to:

- environmental water;
- access licence dealing;
- access licences;
- water supply work approvals;
- making available water determinations; and
- water allocation accounts.

## 2.5 Water licensing

Water entitlements currently held by NCOPL are listed in Table 2.2.

**Table 2.2 Existing NCOPL water licences by water source**

| Water Sharing Plan | Water source | Access licence category | Licence | Nominal units |
|---|---|---|---|---|
| NSW Murray Darling Basin Porous Rock Groundwater Sources 2020 | Gunnedah-Oxley Basin MDB Groundwater Source | Aquifer | WAL 29549 | 818 |
| | | | WAL 43017 | 403 |
| NSW GAB Groundwater Sources 2020 | GAB Southern Recharge Groundwater Source | Aquifer | WAL 15922 | 248 |
| Namoi Alluvial Groundwater Sources 2020 | Zone 5 | Aquifer | WAL 12833 | 67 |
| | | | WAL 20131 | 150 |
| | | | WAL 12822 | 43 |
| Upper and Lower Namoi Regulated Water Sources | Lower Namoi Regulated River Water Source | Regulated River (High Security) | WAL 6762 | 20 |
| | | Regulated River (General Security) | WAL 2671 | 48 |
| | | | WAL 2728 | 10 |
| | | | WAL 20152 | 600 |

## 2.6 Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act is Commonwealth legislation administered by the DoEE. The EPBC Act 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 *Significant Impact Guidelines 1.3: Coal Seam Gas and Large Coal Mining Developments – Impacts on Water Resources* (Significant Impact Guidelines for Water Resources) (Commonwealth Department of the Environment [DotE], 2013) has been developed in order to assist CSG and large coal mining development applicants determine whether a development is likely to have significant impacts on water resources.

The bilateral agreement under the EPBC Act with the NSW Government notes that NSW should seek and consider expert advice from the IESC in relation to CSG or large coal mining developments that are likely to have a significant impact on water resources. The IESC (2018) Information Guidelines and advice for the Project are discussed in Section 2.6.2.

### 2.6.1 EPBC Act Referral

On 30 September 2019, a delegate of the Federal Minister for Environment and Energy determined that the Project was a 'controlled action' under the EPBC Act. The EPBC Act controlling provisions for the Project are:

- EPBC Act listed threatened species and communities; and
- water resources.

Therefore, the EIS, including this Groundwater Assessment, provides an assessment of potential impacts to the controlling provisions identified by the Minister's delegate. A summary checklist against the SEARs, including the DoEE (now DAWE) requirements, is presented in Appendix H.

### 2.6.2 IESC Guidelines and IESC Advice

The Information Guidelines (IESC, 2018) developed by the IESC outline the information considered necessary 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 (IESC, 2018) have been considered during the preparation of this Groundwater Assessment, as well as associated explanatory notes including:

- uncertainty analysis – Guidance for groundwater modelling within a risk management framework (Middlemis and Peeters, 2018);
- assessing groundwater-dependent ecosystems (Doody et al., 2019);
- deriving site-specific guideline values for physico-chemical parameters and toxicants (Huynh and Hobbs, 2019); and
- environmental water tracers in environmental impact assessments for coal seam gas and large coal mining developments (Office of Water Science, 2020).

In addition, the MPGP requested the IESC provide advice on the Project Gateway Application. The advice was based on the Gateway Application Preliminary Groundwater Assessment (HydroSimulations, 2019a) and was assessed against the Information Guidelines (IESC, 2018).

The full list of comments provided in the IESC Advice have been noted and addressed. A reconciliation of the IESC comments and requirements is also provided in Appendix H.

# 3 Environmental setting

## 3.1 Location, land use and groundwater studies

The Project is located in the North West Slopes and Plains region of NSW approximately 25 km south-east of the Narrabri township. Land use in the region is primarily for agriculture cropping and grazing, with a number of coal mining operations, the Narrabri Gas Project and managed State Forests and National Parks (Figure 1.2).

The majority of the Project Area comprises cleared agricultural land used for cattle grazing and State Forest.

### *3.1.1 Current and historical mining at the Project site*

Underground longwall mining commenced in 2012. The currently approved Stage 1 and Stage 2 operations at the Narrabri Mine (the Approved Mine) occur within ML 1609 (Figure 1.2). A number of groundwater assessments have been previously prepared for the various stages of the Approved Mine:

- initial project approval and boxcut operations, Stage 1 (GHD, 2007);
- development of longwall mining operations, Stage 2 (Aquaterra, 2009); and
- modification to longwall panels, Stage 2 Modification 5 (HydroSimulations, 2015) (i.e. the Approved Mine Groundwater Assessment).

As part of the Project approval process, a Preliminary Groundwater Assessment was prepared by HydroSimulations (2019a) as part of a Gateway Certificate Application. Groundwater modelling undertaken as part of this study provided a preliminary assessment of the impacts of the proposed Project but did not assess the cumulative impacts of development of the adjacent Narrabri Gas Project (Section 3.1.3).

### *3.1.2 Nearby existing coal mining*

Several other operating open cut mines exist in the region, the nearest being the Boggabri, Maules Creek and Tarrawonga coal mines approximately 25 km to the east of the Project on the opposite side of the Namoi River (Figure 1.2).

Construction of the Boggabri Coal Mine commenced in 2005. The current method of open cut mining allows coal extraction to occur in the uppermost seams in the Maules Creek sequence including the Braymont, Bollol Creek, Jeralong and Merriown. The Boggabri Coal Mine is currently approved to extract up to 8.6 Mtpa ROM coal until 31st December 2033.

The Maules Creek Coal Mine is located to the north of the Boggabri Coal Mine. Commercial production started from the Maules Creek Coal Mine in mid-2015. The Maules Creek Coal Mine is currently approved to extract up to 13 Mtpa ROM coal until the end of December 2034. The Maules Creek Coal Mine is approved to extract from the Maules Creek sequence down to the Templemore seam.

The Tarrawonga Coal Mine is located immediately to the south of the Boggabri Coal Mine. The Tarrawonga Coal Mine commenced coal production during 2006. Extraction occurs from the Braymont to Nagero seams in the Maules Creek sequence using truck and excavator methods. The Tarrawonga Coal Mine is currently approved to extract up to 3 Mtpa ROM coal until the end of December 2030.

The cumulative groundwater impacts of these mines including other mines in the Namoi subregion have been regionally modelled and assessed by the Bioregional Assessment for the Namoi subregion (Janardhanan et al., 2018). The predicted impacts of these three developments were shown to be limited to area east of the Namoi River.

### *3.1.3 Other developments*

As shown in Figure 1.2, a pilot scale CSG development by Santos is currently operating in the area immediately west of the Project and further development of this area is proposed. The Narrabri Gas Project comprises a progressive development of a CSG field comprising up to 850 gas wells on up to 425 well pads over 20 years by Santos. The groundwater impact assessment for the Narrabri Gas Project (CDM Smith, 2016) included the development of a regional scale groundwater flow model, the domain of which included the Project Area and the Namoi River alluvium to the east. This study included an assessment of the cumulative impacts of concurrent operation of the Approved Mine and the Narrabri Gas Project as well as the predicted impact of both of these projects individually. The Narrabri Gas Project was approved by the Independent Planning Commission of NSW on 30 September 2020.

Other developments near the Project include the Inland Rail project, the Narrabri South Solar Farm and the Silver Leaf Solar Farm. None of these projects are likely to generate groundwater impacts which have the potential to overlap with those of the Project.

## 3.2 Climate

### *3.2.1 Rainfall*

Climate data was sourced from the Scientific Information for Land Owners (SILO) Dataset, for the coordinates 30.4445° S, 149.939° E for station #55058 TURRAWAN (WALLAH). The SILO dataset is used to obtain location specific infilled and quality-controlled climate data and is calculated from surrounding weather stations and interpolated through splining and kriging techniques. Climate data for the 1961 to 2019 period was analysed in order to provide seasonal rainfall variations over the long-term.

The mean annual rainfall recorded over the analysed period was 616 millimetres per year (mm/year), most of which falls in the warmer months of the year (November to March). Potential evaporation rates (pan evaporation) exceed rainfall throughout the year, with the highest moisture deficits occurring in summer (Table 3.1).

Weather monitoring has also been conducted at the Narrabri Mine Meteorological Station, with rainfall recorded from 2013 to 2020. The location of the rainfall station is shown on Figure 1.1. Data for this station suggests a lower average annual rainfall of 516 mm/year, consistent with the shorter period of record for this gauge and the predominantly dry conditions which have prevailed during the recent period. The Bureau of Meteorology (BoM) derived SILO data has been adopted for numerical modelling purposes in the Groundwater Assessment due to the longer period of record.

**Table 3.1 Summary of climate averages (1961 to 2019)**

| Month | Mean monthly rainfall (mm) | Mean monthly pan evaporation (mm) |
|---|---|---|
| January | 94 | 267 |
| February | 60 | 217 |
| March | 44 | 200 |
| April | 33 | 139 |
| May | 44 | 90 |
| June | 39 | 62 |
| July | 40 | 68 |
| August | 37 | 96 |
| September | 40 | 137 |
| October | 51 | 191 |
| November | 64 | 227 |
| December | 70 | 268 |
| **Annual** | **616** | **1962** |

***Source:*** *BoM (2019).*

In order to place rainfall in the recent years into a historical context, the cumulative rainfall departure (CRD) (also referred to as the residual rainfall mass) was calculated. The CRD is calculated by subtracting the long-term average monthly rainfall from the actual monthly rainfall, providing a monthly departure from average conditions. 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 to compare the water level hydrographs with the CRD. The CRD can be used to assess if changes in groundwater levels are correlated with climatic conditions or other factors such as resource extraction, mining, irrigation, etc.

Variations in CRD for station #55058 (TURRAWAN [WALLAH]) for the 1961 to 2019 period are provided in Figure 3.1. The site experienced an increasing rainfall trend since the onset of mining in 2007 up until 2012, when a period of significantly higher rainfall occurred throughout most of Australia. After the record 2012 rainfall event, there has been a notable long-term decline and below average rainfall. The long-term variations demonstrate the cyclic nature of climate, noting that current declines are among the most severe since 1961.

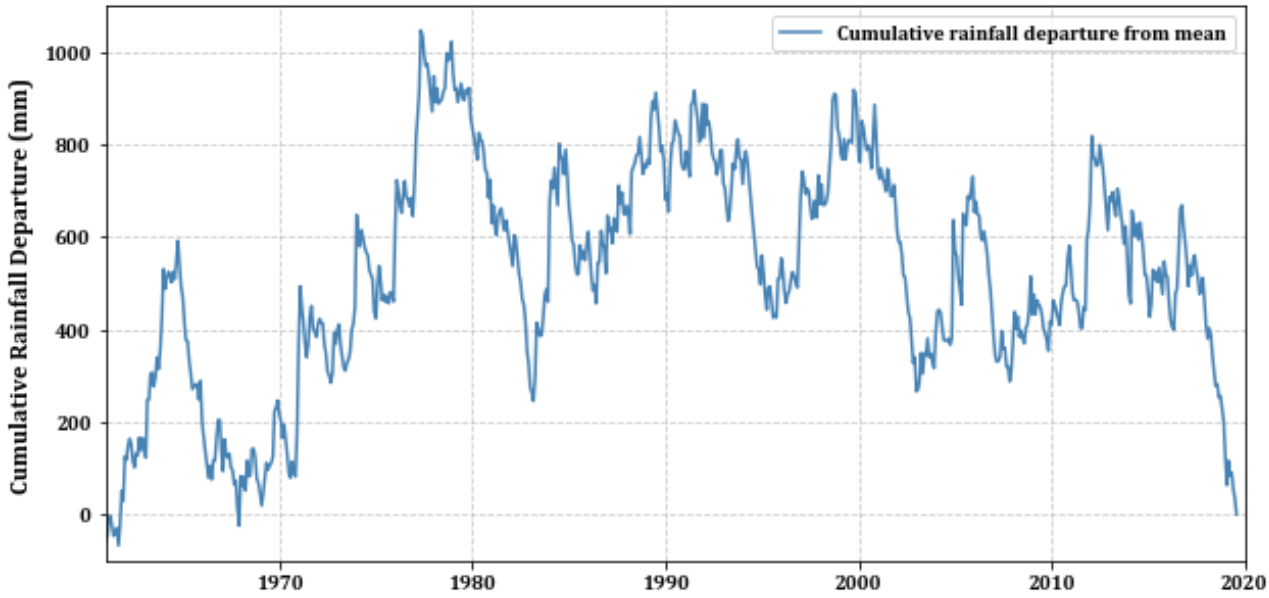



**Figure 3.1 Cumulative rainfall deficit**

### *3.2.2 Evapotranspiration*

Evapotranspiration (ET) is a collective term for the transfer of water, as water vapour, to the atmosphere from both vegetated and un-vegetated land surfaces. It is affected by climate, availability of water and vegetation. ET is sometimes reported only as based on the condition of unlimited water supply (e.g. irrigated area, wetland) and therefore reflects a conservative upper value of water loss to the atmosphere.

The actual loss of water through evapotranspiration for the Project region is approximately 580 mm/year to 680 mm/year, which is derived from 1961 to 1990 climatology data from the BoM. The definition of areal actual evapotranspiration according to BoM:

*" … the ET that actually takes place, under the condition of existing water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average. For example, this represents the evapotranspiration which would occur over a large area of land under existing (mean) rainfall conditions."*

Both potential ET and actual ET are somewhat higher than long-term average annual rainfall (Table 3.1), reflecting the arid conditions which prevail within the Project Area. Groundwater recharge is therefore only likely to occur during periods of intense rainfall since soil moisture deficits are likely to persist most of the time.

## 3.3 Terrain and drainage

### *3.3.1 Project Area*

The western boundary of the Project Area is located close to a topographic divide, as shown in Figure 3.2. Ground elevations therefore gradually decline from around 350 to 400 metres above Australian Height Datum (mAHD) in the west to around 275 mAHD in the east toward the wide and flat alluvial river valley of the Namoi River.

As shown in Figure 3.2, ML 1609 is located within the catchments of Kurrajong and Pine Creeks. MLAs 1 and 2 are located in the Kurrajong Creek and Tulla Mullen Creek tributary catchments, which drain to Tulla Mullen Creek to the east of the Project (Figure 3.2). These creeks are all ephemeral with minimal to no baseflow (WRM, 2020).

Kurrajong Creek originates to the west of the Project within the Pilliga East State Forest and drains in a north-easterly direction across the Project Area. Across the Project Area, the main Kurrajong Creek channel is a third order watercourse under the Strahler stream ordering system. Pine Creek and its tributaries traverse through the northern part of ML 1609, before entering the Namoi River 4.7 km downstream of the Turrawan gauging station (WRM, 2020). Tulla Mullen Creek Tributary 1 also originates to the west of the Project within the Pilliga East State Forest and drains in a north-easterly and then easterly direction across MLAs 1 and 2 before it drains into Tulla Mullen Creek upstream of the Kamilaroi Highway. The tributary channel is a first order watercourse under the Strahler stream ordering system as it drains into the most western longwall panel (Longwall 209) and becomes a third order watercourse as it crosses Longwall 207 (WRM, 2020).

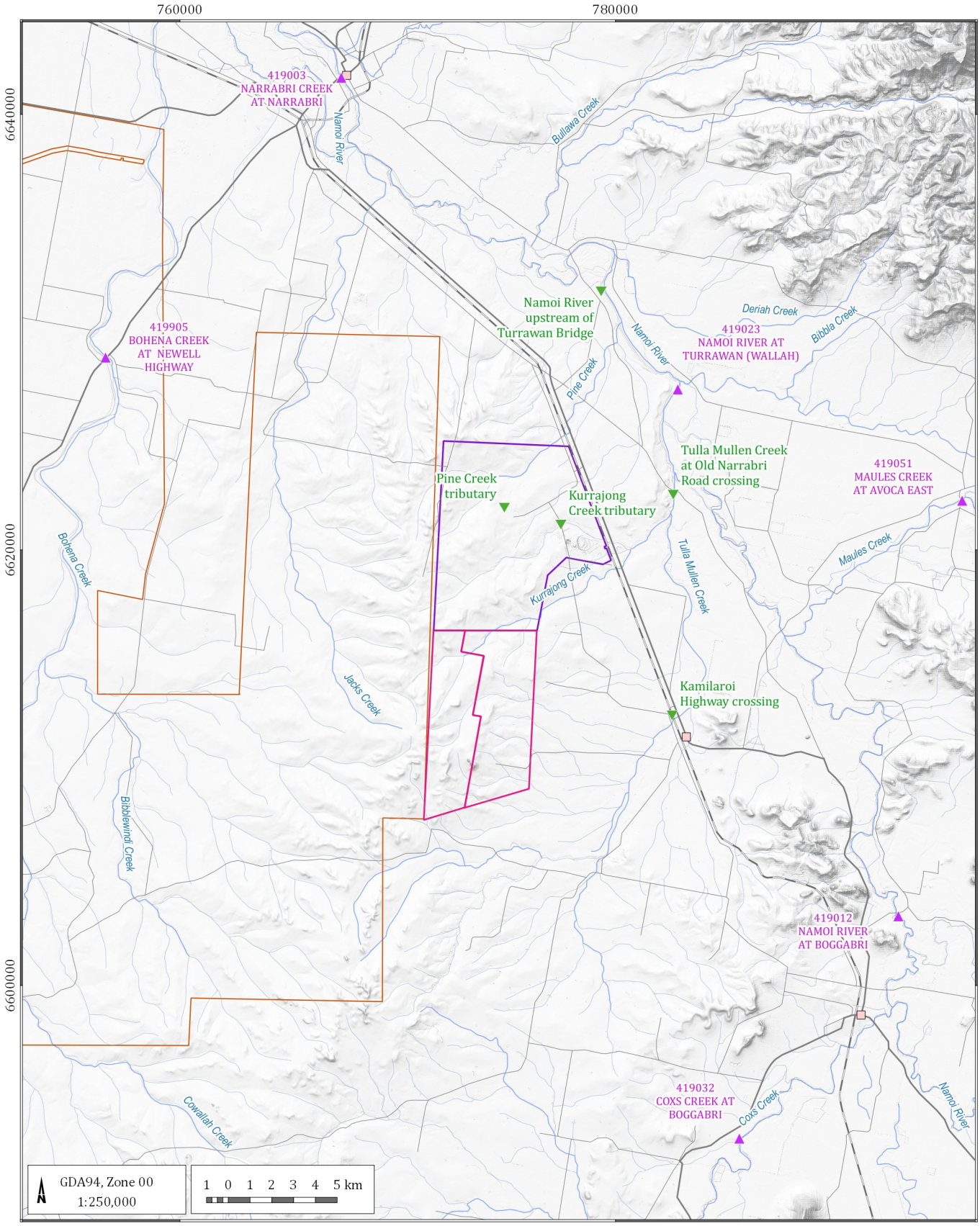
A number of other first and second order unnamed watercourses drain to Kurrajong Creek and the Tulla Mullen Creek tributaries across the Project Area (WRM, 2020).

Due to the highly intermittent nature of flow and frequent changes in the channel geometry, it has not been possible to accurately gauge levels or flows in the various creeks within ML 1609 (Whitehaven, 2017). Surface water quality monitoring however has been undertaken by NCOPL at eight sites on watercourses draining the Narrabri Mine since July 2007 in accordance with the Water Management Plan (WMP) (Whitehaven, 2017) and the Extraction Plan Water Management Plan LW107 to LW110. In addition, NCOPL established surface water monitoring sites on tributaries of Tulla Mullen Creek in 2017 to establish background water quality in the MLA 1 and MLA 2 areas (WRM, 2020).

Sampling has been undertaken during or immediately following flow events, for Electrical Conductivity (EC), pH, total suspended solids (TSS), oil and grease and total organic carbon (TOC). The surface water quality in the watercourses draining the Project Area can be characterised as follows (WRM, 2020):

- slightly alkaline, with median laboratory measured pH values ranging from 7.0 to 7.7 (within the 'Ecosystem' trigger value range);
- fresh, with median EC values ranging from approximately 54 microsiemens per centimetre (µS/cm) to 218 µS/cm (within the 'Ecosystem' trigger values range);
- variable levels of TSS, with median values ranging from approximately 20 mg/L to 127 mg/L;
- not affected by oil and grease contamination; and
- exhibiting low levels of TOC, with median values ranging from approximately 10 mg/L to 15.5 mg/L.

There appears to be no significant difference in water quality between undisturbed monitoring locations and those located downstream of the Narrabri Mine (WRM, 2020).




LEGEND

- Surface water monitoring sites
- Site inspected Sept 2019
- Populated place
- Road
- Rail
- Drainage
- Mining Lease Boundary (ML 1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)

Narrabri Stage 3 Extension GIA (G1972)

## Surface drainage

DATE 17/06/2020

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\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\03.02_G1972_Surface drainage.qgs

### 3.3.2 Namoi River

The Namoi River is a major watercourse that flows in a north-westerly direction approximately 5 km to the east of the Narrabri Mine (Figure 3.2). The areas adjacent to the Namoi River have been extensively developed for irrigation, supporting significant cotton and broad area cropping (primarily sorghum, wheat, sunflower) and grazing activities.

Flow in the river is heavily regulated by upstream water storage in Keepit, Chaffey and Split Rock dams supporting significant licenced extraction from the river itself and from the alluvial aquifer associated with the river. Accordingly, reference to flow gauging data for the Namoi River upstream and downstream of the Project, at Boggabri (419012) and Turrawan (419023) respectively, suggest consistent flow losses within the river between the two sites. As shown in Table 3.2, long-term average flow at Turrawan is 1,306 megalitres per day (ML/d), around 141 ML/d less than at Boggabri. Taking into account an additional inflow of 55 ML/d on average from Maules Creek, which joins the Namoi River between the two gauges, then this suggests an average loss of around 196 ML/d.

Flow duration curves for the Boggabri and Turrawan gauges and combined gauged flow at Turrawan and Avoca East are shown in Figure 3.3. In addition to confirming that flow appears to be consistently lost from the Namoi River within the Project Area these plots tend to confirm that some flow occurs most of the time. However, no flow events do occasionally occur in this stretch of the Namoi River. As shown in Table 3.2 monthly average flows of zero have been recorded on 10 occasions at Turrawan (i.e. around 4% of the time) and on three occasions at Boggabri (around 1% of the time).

**Table 3.2 Flow gauging station data summary**

| Site number | Water Course and Station Name | Catchment Area ($km^2$) | Long-term average flow (ML/d) | Number of no flow months (% of record) |
|---|---|---|---|---|
| 419012 | Namoi River at Boggabri | 22,600 | 1,447 | 3 (1%) |
| 419023 | Namoi River at Turrawan | 24,500 | 1,306 | 10 (4%) |
| 419051 | Maules Creek at Avoca East | 739 | 55 | 28 (10%) |
| 419003 | Narrabri Creek at Narrabri | 25,400 | 1,435 | 8 (3%) |

***Note:*** *Statistics based on monthly average flow data for the period July 1995 to July 2019 inclusive (i.e. the period over which data is available at all four gauge locations)*

Downstream of Turrawan and just upstream of Narrabri the Namoi River appears to bifurcate. Reference to satellite imagery suggests that the majority of the flow in the river appears to enter Narrabri Creek and flow through Narrabri, rather than continuing in the Namoi River which runs to the west of Narrabri. Consistent with this, as shown in Table 3.2, data for the flow gauge on Narrabri Creek at Narrabri suggests higher flows than in the Namoi River at Turrawan, suggesting a reversion to gaining conditions downstream in the Namoi River / Narrabri Creek downstream of Turrawan. In fact, as shown in Table 3.2 and Figure 3.3, flows at Narrabri are similar to those observed at Boggabri, indicating that the volume of flow lost between Boggabri and Turrawan is similar to the volume gained between Turrawan and Narrabri. Possible explanations for this pattern of gains and losses include: under-reporting of flows at Turrawan; and/or that flow lost through the river bed between Boggabri and Turrawan re-appear as baseflow discharge further downstream.

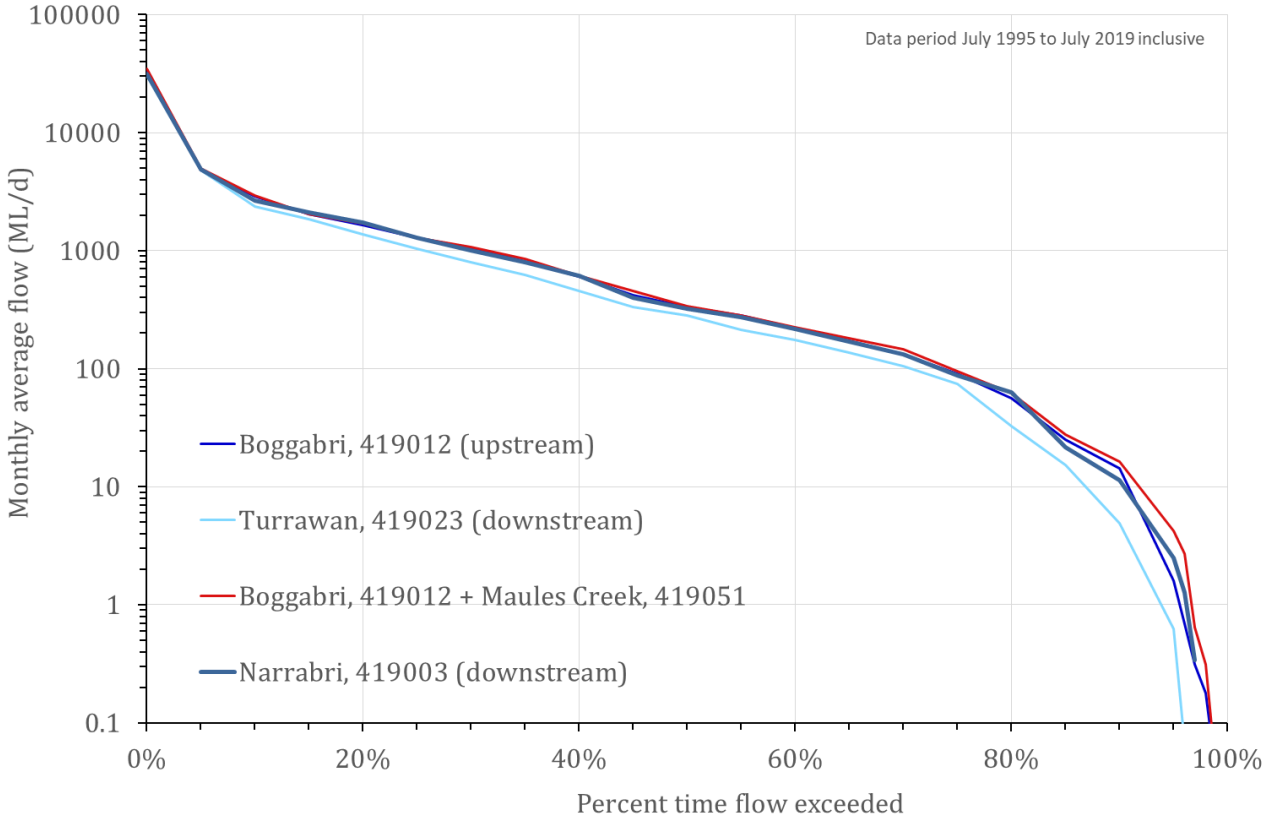



**Figure 3.3 Flow duration curves, Namoi River**

# 4 Geological setting

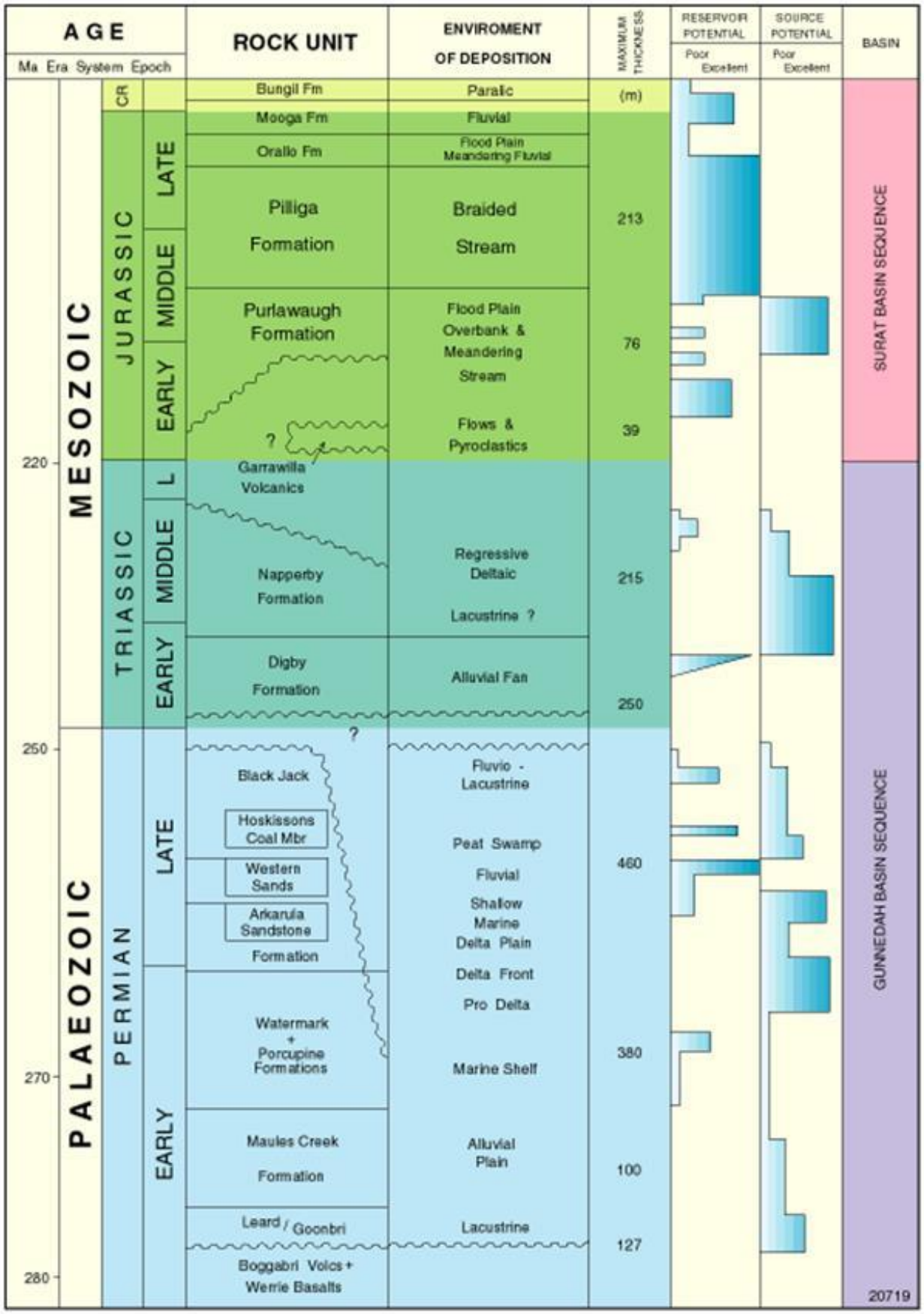
## 4.1 Regional geology

The main stratigraphic units (Figure 4.1) occurring in the vicinity of the Project Area and the dominant lithology within each are:

- Quaternary alluvium – unconsolidated clays, silts, sands and gravels associated with the Namoi River and its associated tributaries.
- Jurassic age Surat Basin units – Pilliga Sandstone, Purlawaugh Formation and the intrusive Garrawilla Volcanics.
- Gunnedah Basin units:
    - Triassic age Napperby and Digby formations; and
    - Permian age coal bearing formations which comprise multiple coal seams, within claystones, siltstones, sandstones and conglomerates.

The Project is located within the Mullaley Sub-basin, which forms part of the larger Gunnedah Basin. It is separated from the Maules Creek Sub-basin to the east by a north-south trending volcanic ridge (termed the Boggabri Ridge), with the Mooki Thrust Fault System forming the eastern boundary. The Boggabri Ridge also forms the basement of the Gunnedah Basin and occurs as outcrop along the Namoi River.

The western half of the Project Area comprises of Jurassic formations of the Surat Basin, which overlie much of the Permian and Triassic sequence. In general, the Surat and Gunnedah Basin units are characterised by a dip to the west at an angle of less than 10 degrees (Aquaterra, 2009) and outcrops to along the Namoi River valley.




***Source:*** *From Totterdall et al. (2009).*

**Figure 4.1 Sequence stratigraphy of the Bowen-Gunnedah and Surat Basins**

## 4.2 Local geology

The following sections provide a description of the geology in the immediate Project Area and surrounds drawing on exploration drilling results, detailed geological modelling and fault mapping undertaken by NCOPL geologists as well as local published geological mapping.

A map of the solid geology showing the outcrop of consolidated formations on the surface, after removal of the overlying superficial strata, is provided in Figure 4.4. A number of structural features have been identified within the study area and include:

- regional faults and folds – after Pratt (1998) – coloured red in Figure 4.4; and
- other minor faults affecting the coal resources identified by NCOPL geologists based on exploration logs and mapping underground – coloured dark blue in Figure 4.4.

The faults mapped by site geologists within the Project Area are commonly oriented northwest-southeast, including a secondary set of subsidiary faults oriented north-east to south-west. These faults are typically characterised by displacements of less than 5 metres (m), but larger displacements of up to 15 m have been mapped north of the existing longwall panels LW101 to LW104 and near the southern boundary of ML 1609. The site mapped faults with larger throws generally overlap and are in good agreement with the regional mapped faults.

Only two larger faults have been mapped in MLAs 1 and 2 based on the available drilling records, a northwest-southeast trending fault with throws less than 5 m and another directly perpendicular with throws greater than 10 m. Further faults are likely to be identified as the underground mine expands into this area. However, experience gained from mining the northern area suggests that these are small faults characterised by displacements of generally less than 5 m. The larger faults in the northern area were identified during the pre-mining period based on exploration drilling results.

Information on the lithological composition of geological formations present within the Project Area has been derived from an extensive lithological dataset developed by NCOPL geologists. This dataset comprises over 400,000 m of geological logs in over 1,900 exploration holes. The average lithological composition of each of the main hydrostratigraphic units present is shown in Figure 4.2 and discussed in the sections below.

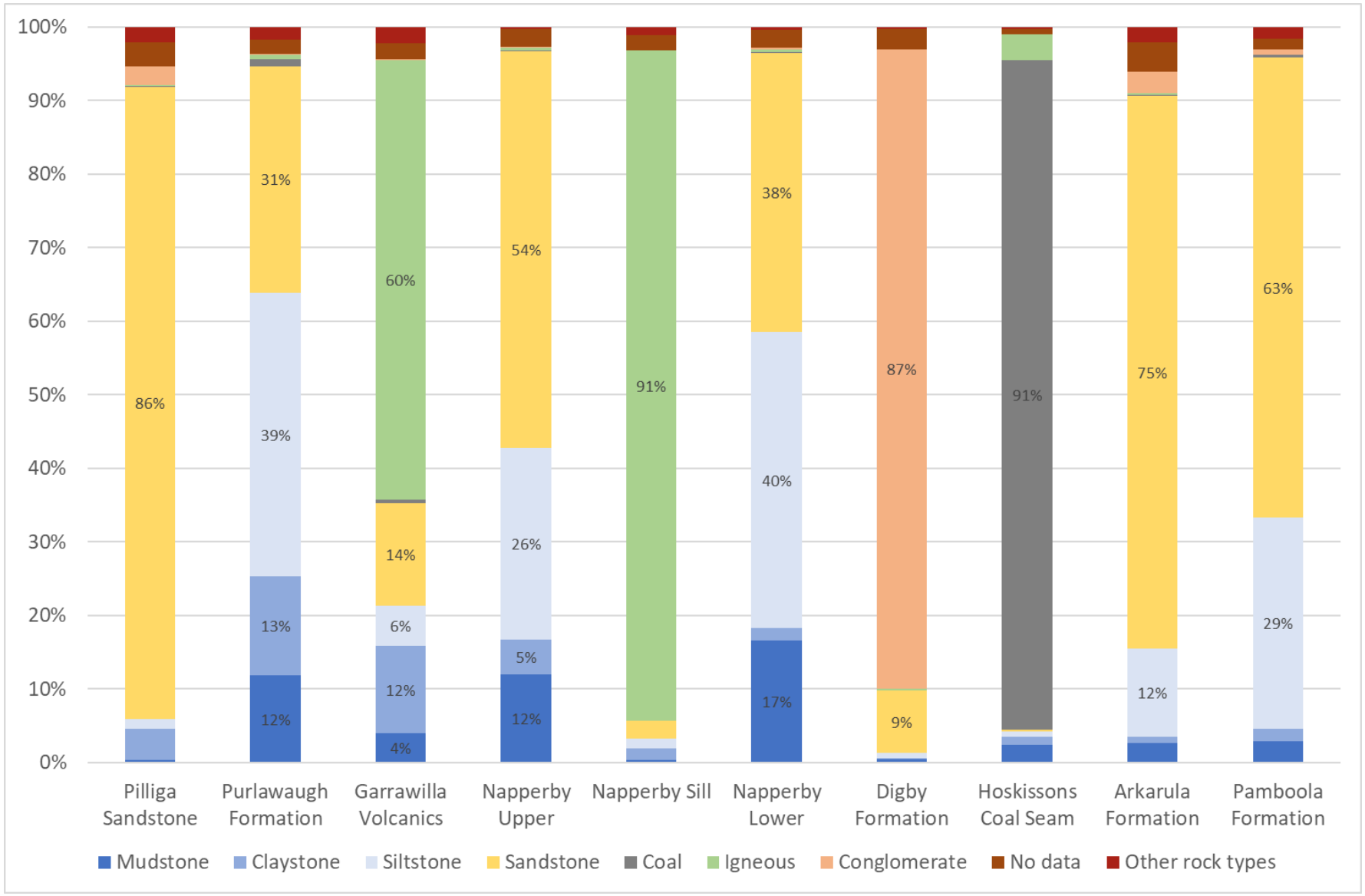



**Figure 4.2 Average lithological composition of the main hydrostratigraphic units from NCOPL exploration drilling results**

### *4.2.1 Quaternary alluvium, colluvium and regolith*

Expanses of Quaternary alluvium associated with Tulla Mullen Creek, Maules Creek and the Namoi River occur beyond the Project to the north, east and south. A map showing the location of these watercourses and mapped areas of Quaternary alluvium is provided in Figure 4.3. Reference to detailed descriptions of the Quaternary geology of the area (Geological Survey of NSW, 2002) suggest that the depositional environment was somewhat different in the tributary streams than in the main Namoi River channel.

To the south-east of the Project Area, a notable constriction of the Namoi River can be seen north of Boggabri at Gin's Leap, where the presence of outcropping Boggabri Volcanics limits the expanse of alluvium. To the north and east of the Project Area, the Quaternary alluvium is more extensive in particular in areas close to the confluence of Namoi River with major tributary creeks such as Tulla Mullen Creek and Maules Creek.

The extent of alluvium shown in Figure 4.3 has been taken from the NSW statewide seamless geology data package (Colquhoun et al., 2019) which is in turn sourced from contemporary geological mapping (on a variety of scales) across NSW.

Figure 4.3 also shows the thickness of Quaternary alluvium included in the groundwater model developed as part of the Gateway Application (HydroSimulations, 2019a) and is consistent with other available estimates including the Upper Namoi Alluvium Groundwater Model (McNeilage, 2006). As shown in Figure 4.3, the alluvium is generally thickest (greater than 100m) to the east of the current path of the Namoi River, thinning towards the edges of the mapped alluvium and along the tributaries (McNeilage, 2006).

Alluvium associated with the Tulla Mullen Creek are thought to have been deposited in alluvial fans (i.e. areas where confined streams emerge from elevated areas into relatively flat zones with reduced stream power). Where multiple alluvial fans coalesce then piedmont plains are formed. The Quaternary alluvium associated with Tulla Mullen Creek is one of a number of such features mapped in the area (Geological Survey of NSW, 2002).

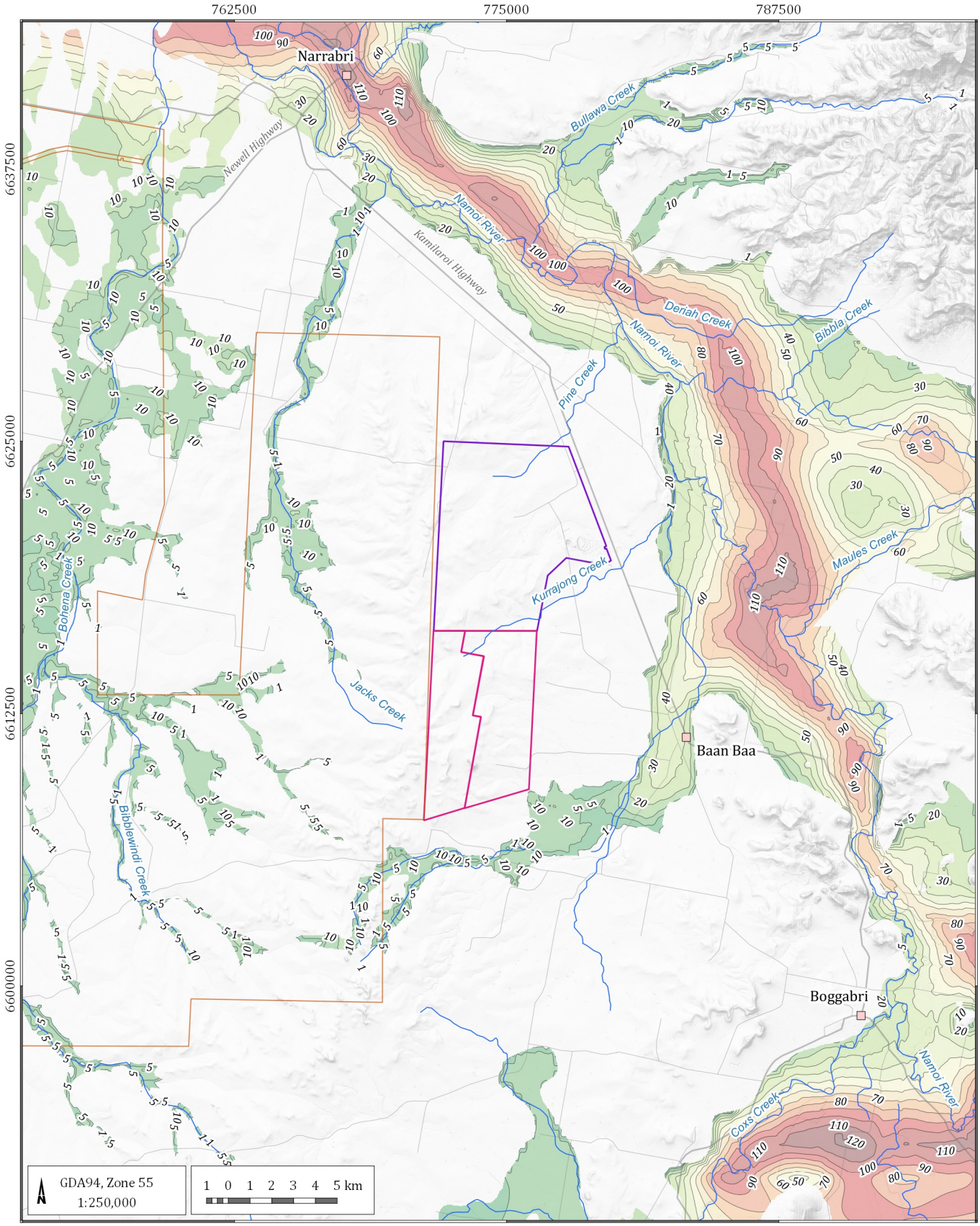
Alluvium associated with the Namoi River is often vertically divided into two different geological units, namely the Narrabri Formation at surface and the underlying Gunnedah Formation. This distinction is adopted in order to characterise differences in alluvial sediments, which are generally upward-fining (Herron 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, likely deposited by leveed meandering streams; and
- the underlying Gunnedah Formation fills the main palaeovalley floors and consists of moderately well sorted sands/gravel, with interbedded clays, likely deposited by braided streams.

More recent studies of Namoi Alluvium suggest that this differentiation may be an oversimplification and that the boundary between the two units can be difficult to identify in the field (Acworth et al., 2015).

As shown in Figure 4.5, outside of the areas mapped as Quaternary alluvium the dominant surface cover material is undifferentiated Quaternary colluvium and residual soils (or regolith). Evidence from exploration drilling at the Narrabri mine site suggests that residual soils dominate, rather than colluvium. Colluvium was not recorded in any of the over 1,900 exploration holes drilled in and around the mine. *In situ* weathering of consolidated strata at outcrop is also an important process in most Australian landscapes. The regolith material formed, which is typically clay dominated, forms a cap over the underlying fresher strata. Whilst this material is typically not shown on geological maps its thickness has been estimated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Wilford et al., 2015) who have developed a depth of regolith product which estimates the thickness of the Quaternary cover (i.e. alluvium, colluvium and regolith) across the whole of Australia. Reference to this CSIRO dataset suggests that the depth of regolith over consolidated formations in the area varies between 5 to 15 m below the ground, but can be as deep as 20 m towards the major creek lines east of the Project Area.

Elsewhere some minor areas of Quaternary colluvium have also been mapped in the area. This is material that, unlike the adjacent alluvium, has not been deposited by fluvial processes but has instead been transported by gravity, typically over relatively short distances, to the base of slopes. Where information is provided on local geology maps the colluvium is described as comprising a polymitic conglomerate within a medium to coarse grained sand matrix interspersed with clayey and silty sand layers. In most cases, however, the colluvium is simply described as undifferentiated with no description provided.




LEGEND

- Populated place
- Drainage
- Road
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Contour line (m)

Narrabri Stage 3 Extension GIA (G1972)

## Thickness of Quaternary alluvium

DATE 27/04/2020

FIGURE No: **4.3**

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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.;
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### 4.2.2 Jurassic geology

The Pilliga Sandstone is the youngest consolidated formation in the immediate Project Area and outcrops across the western half of the Project Area. The sandstone thickness varies from zero at the mapped limit of the formation to approximately 80 to 120 m at the western margin of the Project Area, and up to around 300 m within the adjacent Narrabri Gas Project (CDM Smith, 2016). The sandstone is predominantly a well sorted, fine to coarse grained quartz sandstone in medium cross beds (Aquaterra, 2009). As shown in Figure 4.2, lithological logging of NCOPL exploration drilling in and around the Project Area suggests that the Pilliga Sandstone comprises around 86% sandstone with only around 5% of finer grained sediments including mudstone, claystone and siltstone.

Underlying the Pilliga Sandstone is the Purlawaugh Formation, which outcrops within a thin (< 1,000 m), north-south trending strip towards the middle of the Project Area. The formation typically comprises fine to medium grained lithic to labile sandstone, thinly interbedded with siltstone, mudstone and thin coal seams. Consistent with this exploration drilling results (Figure 4.2) suggest that siltstone is the most abundant lithofacies (39%), followed by sandstone (31%), Claystone (13%) and mudstone (12%).

The Purlawaugh Formation unconformably overlies the Garrawilla Volcanics, a layer of alkali basalt rocks, trachytes and interbedded pyroclastis. The volcanics form the basal unit of the Surat Basin in the area and unconformably overlie the Triassic formations of the Gunnedah Basin. They tend to occur as sills and plugs which infill relic topographical lows (CDM Smith, 2016) and thus vary in thickness within the Project Area from entirely absent to up to 90 m in places. As shown in Figure 4.4, the volcanics are present at subcrop towards the east of the ML 1609 and MLAs 1 and 2 but are for the most part overlain by Quaternary colluvium or residual soils and hence are largely not mapped as being present at outcrop (Figure 4.5). Lithological data derived from exploration drilling (Figure 4.2) suggest around 60% igneous strata on average but also show relatively significant proportions of sandstone (14%) and claystone (12%).

### 4.2.3 Triassic and Permian geology

As shown in Figure 4.5 current geological mapping of the area shows the Deriah Formation at outcrop within the Project Area, although this unit is not differentiated from the underlying Napperby Formation in the site geological model or identified in the Bowen-Gunnedah sequence stratigraphy (Totterdell et al., 2009). Accordingly, information about this formation is limited. It is described on the geological map as typically comprising fine to medium grained lithic sandstone rich in volcanic fragments with common mudstone clasts overlain by off white lithic sandstone and dark grey mudstone.

The Deriah Formation is unconformably underlain by the Napperby Formation, which consists of coarsening up sequence of siltstone and sandstone laminate interbedded with quartzose sandstone beds. The Napperby Formation can be up to 170 m thick and is intruded by a dolerite sill about 40 m above the base of the formation. The dolerite sill is between 10 to 30 m thick and is not thought to extend beyond the boundaries of ML 1609. Consistent with the coarsening upwards description above, exploration drilling results (Figure 4.2) suggest a higher proportion of sandstone (54% versus 38%) and lower proportions of finer materials (43% versus 59%) in the Napperby Formation above the sill than below.

Underlying the Napperby formation is Digby Formation, which can be lithologically categorised into a lower sandstone and an upper conglomerate unit. The lower sandstone unit is only present towards the north-west of the Project Area and is generally less than less than 5 m thick, but thickens abruptly to the north up to a maximum of 20 m. The thickness of the upper conglomerate unit is similarly about 15 m to 20 m thick but is present extensively within the Project Area. The conglomerate unit consists mainly of thickly bedded, polymictic, lithic, pebble conglomerate with clasts of volcanics, meta-sediments and jasper in a lithic rich matrix (Aquaterra, 2009). Exploration drilling results (Figure 4.2) tend to confirm this description, suggesting 87% conglomerate and 9% sandstone on average.

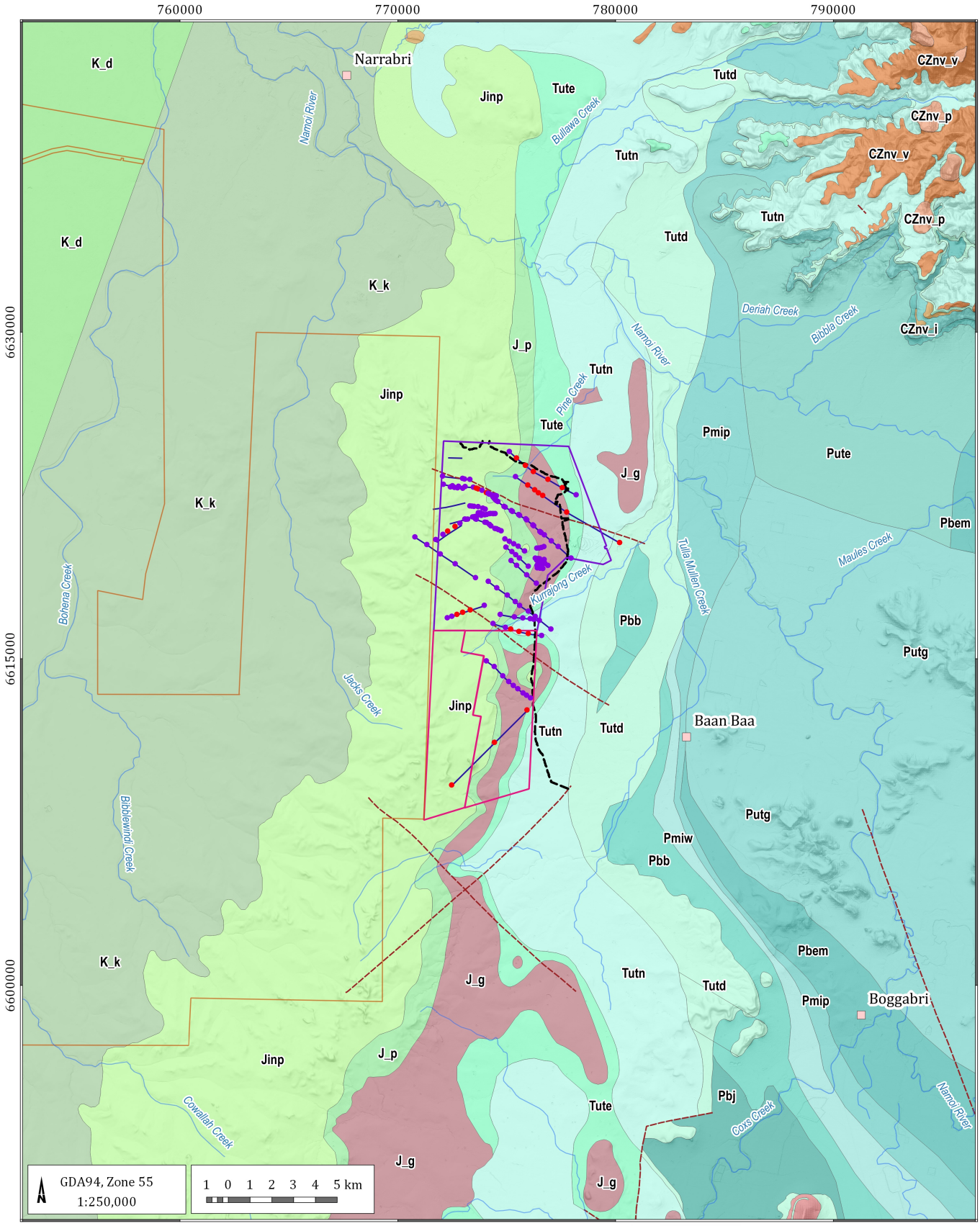
The Digby Formation unconformably overlies the coal bearing Permian formations within the Project Area. The Permian formations are best known and mapped in the area as Black Jack Group, which consists of the Trinkey Formation, Clare Sandstone, Benalabri Formation, Hoskissons Seam, Arkarula Formation and Pamboola Formation. Coal seams have been mapped in all the formations of the Black Jack Group except for Clare Sandstone and Arkarula Formation.

The target for both the existing and proposed operations at the Narrabri Mine is the Hoskissons Seam within the Black Jack Group. Thickness and quality characteristics of the coal seams present within the Black Jack Group in the Project Area are such that only the Hoskissons Seam is currently considered to contain coal resources with mining potential. The seam is generally 7 to 10 m thick over the western half of the Project Area. The Hoskissons Seam is also the shallowest of a number of seams which are the target for CSG extraction as part of the adjacent Narrabri Gas Project. As would be expected, exploration drilling results for logged sections interpreted to be part of the Hoskissons Coal Seam (Figure 4.2) suggest 91% coal with only minor proportions of mudstone, claystone and sandstone and other lithologies.

As shown in Figure 4.5, the nearest outcrop of the Black Jack Group is approximately 15 km south-east of the Project Area in the vicinity of Coxs Creek. An unconformity beneath the Digby formation truncated the underlying Permian Black Jack Group including the Hoskissons seam. As a result, the Hoskissons Seam does not extend beyond the eastern boundary of the Project Area and does not therefore subcrop underneath the alluvium of the Namoi River (Aquaterra, 2009) or Tulla Mullen Creek, based on review of the current regional geological mapping (Colquhoun et al., 2019) and current site geological model. As such, there is no direct connection between the mined coal seams and alluvium in either the Namoi River or Tulla Mullen Creek. Thinner (~10 centimetre [cm]) coal beds associated with Black Jack Group beneath the Hoskissons and Arkarula have been encountered in exploration holes towards the eastern boundary of the Project. Review of the mapped geology suggests that these coal bearing formations are deeper than the Hoskissons Seam (Pamboola Formation of the Black Jack Group, Watermark Formation and Maules Creek Formation of the Millie Group) and subcrop underneath Tulla Muleen Creek (Figure 4.4).

Underlying the Hoskissons Seam is the Arkarula Formation which forms part of the Brothers sub-group and typically comprises an upward fining sequence of medium grained quartzose sandstone and siltstone. The Arkarula Formation is generally around 25 m thick (HydroSimulations, 2019a); its extent closely follows the extent of the Hoskissons Seam and similarly it does not subcrop underneath either Tulla Mullen Creek or Namoi River alluvium. Exploration drilling results tend to confirm the lithological description above suggesting 75% sandstone and 12% siltstone with only minor proportions of other lithofacies reported (Figure 4.2).

The Pamboola Formation is the oldest unit within the Permian Black Jack Group. It consists of sporadic upward fining sequence of lithic sandstone, siltstone, claystone and conglomerate with intercalated coals. The formation is reported to be between 55 to 75 m thick (Aquaterra, 2009) within the Project Area. Exploration drilling results suggest 63% sandstone and 29% siltstone on average (Figure 4.2).




LEGEND

- Populated place
- Drainage
- Regional fault
- Site mapped fault
- Mining Lease Boundary (ML1609)
- Proposed Narrabri Gas Project (Santos)
- Provisional Mining Lease Application Area

**Surface geology ( NSW seamless geology)**

- (CZnv_p) - Trachyte intrusives
- (CZnv_v) - Volcanics
- (K_k) - Keelindi beds
- (K_d) - Drildool beds
- (Jinp) - Pilliga Sandstone
- (J_p) -Purlawaugh Formation
- (J_g) - Garrawilla Volcanics
- (Tute) - Deriah Formation
- (Tutn) - Napperby Formation
- (Tutd) - Digby Formation
- (Pbj) - Black Jack Group
- (Pbb) - Brothers Subgroup
- (Pmiw) - Watermark Formation
- (Pmip) - Porcupine Formation
- (Pbem) - Maules Creek Formation
- (Pute) - Werrie Basalt
- (Putg) - Boggabri Volcanics
- Boundary extent of Hoskinson Coal Seam

**Site mapped fault**

- ≤ 5 m throw
- ≥ 5 m throw

Narrabri Stage 3 Extension GIA (G1972)

## Solid geology

DATE 27/04/2020

FIGURE No: **4.4**

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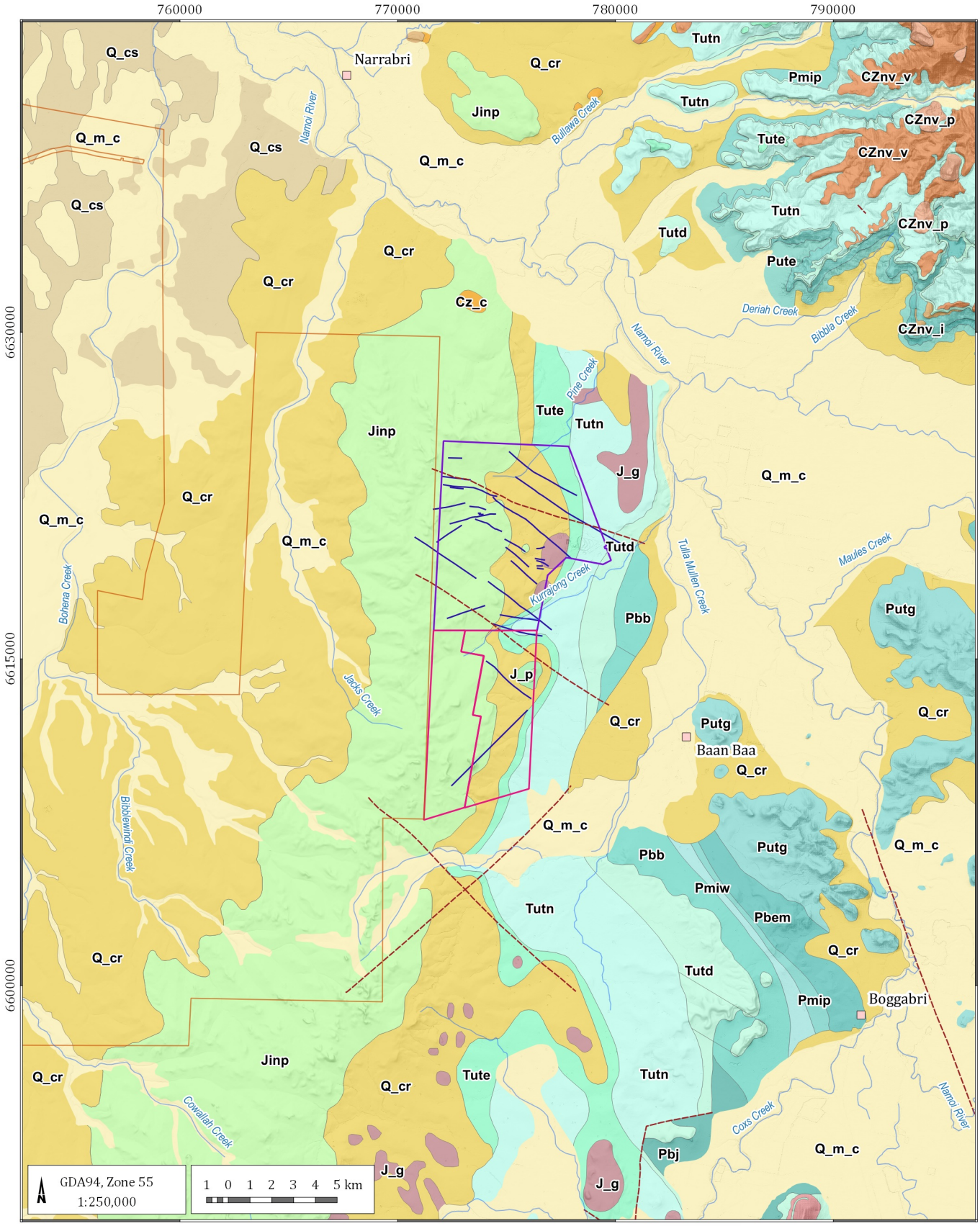
G:\Projects\G1972.Narrrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\04.04_G1972_Solid geology.qgs




LEGEND

- Populated place
- Drainage
- Mining Lease Boundary (ML1609)
- Proposed Narrabri Gas Project (Santos)
- Provisional Mining Lease Application Area
- Regional fault
- Site mapped fault

**Surface geology ( NSW seamless geology)**

- (Q_m_c) - Alluvium
- (Q_cr) - Colluvium and residual deposits
- (CZ_c) Colluvial deposits
- (Q_cs) Colluvial sheetwash
- (CZnv_p) - Trachyte intrusives
- (CZnv_v) - Volcanics
- (Jinp) - Pilliga Sandstone
- (J_g) - Garrawilla Volcanics
- Jinp (Pilliga Sandstone)
- J_p ) Purlawaugh Formation)
- (Tute) - Deriah Formation
- (Tutn) - Napperby Formation
- (Tutd) - Digby Formation
- (Pbj) - Black Jack Group
- (Pbb) - Brothers Subgroup
- (Pmiw) - Watermark Formation
- (Pmip) - Porcupine Formation
- (Pbem) - Maules Creek Formation
- (Pute) - Werrie Basalt
- (Putg) - Boggabri Volcanics

Narrabri Stage 3 Extension GIA (G1972)

## Surface geology

DATE 27/04/2020

FIGURE No: **4.5**

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# 5 Conceptual model

## 5.1 Hydrostratigraphic units

The key hydrostratigraphic units controlling the transmission of impacts from the Hoskissons Coal Seam to other surrounding units and which may be impacted by the development are as follows:

- Quaternary alluvium and regolith;
- Pilliga Sandstone;
- Purlawaugh Formation;
- Garrawilla Volcanics;
- Napperby Formation;
- Digby Formation;
- Hoskissons Coal Seam;
- Arkarula Formation; and
- Pamboola Formation.

Of these units only the Namoi Alluvium and Pilliga Sandstone are considered to be regionally consistent aquifers (noting that at its closest point, the Namoi Alluvium is located approximately 6 km east of the Project underground mining area). Whilst the remaining units can support water supply extractions in some areas, they are generally considered to be poor aquifers. The MPGP (2019) states:

*"There are two important groundwater sources in the vicinity of the mine within the hydrogeological regime described above that are considered as 'highly productive' under the AIP. They are the Quaternary Upper Namoi Alluvial aquifer (Upper Namoi Zone 5 Groundwater source) and the Jurassic Pilliga Sandstone aquifer (part of the Great Artesian Basin Southern Recharge Groundwater source."*

A general hydrogeological description of each of the above units is provided below in sections 5.1.1 to 5.1.9 with further details of the hydrogeological characteristics of each unit (i.e. groundwater monitoring, recharge, water levels and flow directions, water quality, etc.) provided in subsequent sections.

### *5.1.1 Quaternary alluvium, colluvium and regolith*

The Quaternary alluvium associated with the Namoi River and its major tributaries forms the most important aquifer in the region. As discussed previously (Section 4.2.1) the alluvium is often vertically divided into two different geological units, namely the Narrabri Formation at surface and the underlying Gunnedah Formation. This distinction is adopted in order to characterise differences in alluvial sediments, which are generally upward-fining (Herron et al., 2018) although the boundary between the two units is not always obvious. The Gunnedah Formation occurs towards the base of the alluvium, which typically comprises well sorted sand and gravel interbedded with clay, is therefore the target for most water supply bores in the area. The overlying Narrabri Formation typically comprises extensive overbank clays, and fewer sand and gravel units suggesting generally lower permeability and aquifer potential.

However, the alluvial sequences as described generally under-represent the complexity of the sequence and the interplay between clay, sand and gravel beds (Kelly et al., 2007). The dominant lithology of the upper and lower formations may be reversed with clays in the Gunnedah Formation and gravels dominant in the upper Narrabri formation. In some areas there is no hydraulic distinction between the alluvial formations, and they act as a single aquifer. On the other hand, in other areas, there is sufficient difference in hydraulic characteristics that observed water level responses suggest minimal connectivity between the two formations (Welsh et al., 2014).

As shown in Figure 4.5, extensive areas of undifferentiated Quaternary colluvium and residual soils (or regolith) are mapped across the Project Area. As discussed previously in Section 4.2.1 these areas are thought to be predominantly regolith. CSIRO mapping also suggests a regolith cap over the various consolidated units mapped at outcrop over the remainder of the area. Both the colluvium and regolith cover, where present, are thought to be relatively thin and dominated by low permeability clay strata which are the result of weathering and decomposition of the underlying consolidated strata.

The extent of groundwater associated with the Namoi River alluvium that is considered "highly productive" under the AIP is shown on Figure 2.1.

### *5.1.2 Pilliga Sandstone*

As shown in Figure 4.5, the Pilliga Sandstone is present at or close to outcrop across the majority of ML 1609 and MLAs 1 and 2 and can attain thicknesses of up to around 300 m in places. The Pilliga Sandstone is an important regional aquifer dominated by well sorted, fine to coarse grained sandstones which are typically highly porous and permeable, and producing high yields of good quality groundwater (Radke et al., 2000). It also represents the main GAB aquifer in the Namoi sub-region and forms part of the Southern Recharge Groundwater Source under the NSW GAB Water Sharing Plan. However, modelling by CSIRO's Gas Industry Social and Environmental Research Alliance indicates that recharge to the Great Artesian Basin in the vicinity of the Project is relatively low (less than 5 mm/year) (DPIE, 2020). Primary recharge in the region (i.e. more than 40 mm/year) occurs predominantly via the Warrumbungles (DPIE, 2020). The independent Water Expert Panel for the Narrabri Gas Project concluded that the area in the vicinity of the Project is not a significant recharge zone for the Great Artesian Basin (DPIE, 2020).

The Pilliga Sandstone is the only Jurassic formation that is considered "highly productive" under the AIP in the vicinity of the Project. The extent of groundwater associated with the Pilliga Sandstone that is considered "highly productive" is shown on Figure 2.1, noting that the Project would involve longwall mining within less productive Permian age units which underlie the Pilliga Sandstone. Furthermore, as shown on Figure 2.5, the majority of licences held in the Southern Recharge Groundwater Source are located west of the Project, suggesting that there is limited productivity in the vicinity of the Project Area, towards the eastern limit of the Pilliga Sandstone.

Consistent with the definition of the Pilliga Sandstone as a highly productive unit, exploration drilling results (Figure 4.2) suggest 86% sandstone on average with only around 5% of finer grained sediments including mudstone, claystone and siltstone.

Reference to the solid geology map for the area (Figure 4.4) suggests that the Pilliga Sandstone is overlain by the Keelindi Beds around 3 km west of ML 1609, although it would appear that this strata are entirely overlain by Quaternary colluvium and/or residual soils. This Keelindi Beds sub-crop area is located within a different surface water catchment and some distance hydrogeologically upgradient of the proposed underground mining area. Consistent with previous assessments (Aquaterra, 2009; HydroSimulations, 2015; and HydroSimulations, 2019a) no impacts are expected on the Keelindi Beds or any overlying younger units. Accordingly, the Pilliga Sandstone represents the youngest consolidated hydrostratigraphic unit included in the current assessment.

### 5.1.3 Purlawaugh Formation

The Pilliga Formation is underlain by the Purlawaugh Formation which is dominated by fine grained lithic to labile sandstone and siltstone (Figure 4.2) and as such does not typically support significant groundwater extraction. As shown in Figure 4.5 the Purlawaugh Formation does not occur at or close to outcrop since it is overlain by Quaternary alluvium, colluvium and/or residual deposits but is present across the eastern half of Project Area at thicknesses of up to 120 m. The Purlawaugh Formation is identified as a "less productive" unit under the AIP. The Namoi Bioregional Assessment (Herron et al., 2018) describes that the Purlawaugh Formation has a lower hydraulic conductivity than the Pilliga Sandstone and acts as an aquitard.

### 5.1.4 Garrawilla Volcanics

The Garrawilla Volcanics unconformably underlies the Purlawaugh Formation. As a result, the thickness of the volcanics is highly variable since it was subject to erosion prior to deposition of the overlying stata and can therefore range from 90 m to being fully absent. The volcanics layer is the basal unit for the Surat Basin and is thought to be a 'less significant transmissive unit' considered as an aquitard (CDM Smith, 2016).

Consistent with this, reference to information on the degree of weathering held within the NCOPL geology database suggests that 72% of the material attributed to the Garrawilla Volcanics has been logged as fresh (Figure 5.1). Such material would normally be expected to be characterised by very low permeability. However, as shown in Figure 5.1 the remainder of the material logged shows some degree of weathering and reference to hydraulic tests (Section 5.3) and water quality data (Section 5.5) suggests that the Garrawilla Volcanics can form a reasonably productive layer in some instances.

### 5.1.5 Napperby Formation

The Napperby Formation typically comprises an upwards-coarsening sequence of siltstone and sandstone laminate interbedded with quartzose sandstone beds. Accordingly, as shown in Figure 4.2 the proportion of sandstone is somewhat higher in the upper part of the unit (above the Napperby Sill than below it). As shown in Figure 4.5 the Napperby Formation is present at outcrop close to eastern boundary of the Project Area at thicknesses of up to around 170 m.

The Napperby Formation is also identified as a "less productive" unit under the AIP.

Updated geological mapping of the area also shows the Deriah Formation at outcrop within the Project Area. This formation unconformably overlies the Napperby Formation and is thought to typically comprise fine to medium grained lithic sandstones rich in volcanic fragments. This unit is not differentiated from the underlying Napperby Formation by the mine site geologists and hence no information is available on the thickness of this unit in the Project Area.

As shown in Figure 5.1 reference to geological logs for the Napperby Sill suggests that 97% of the sill material logged shows little or no weathering and hence is likely to be characterised by very low permeability and porosity values.

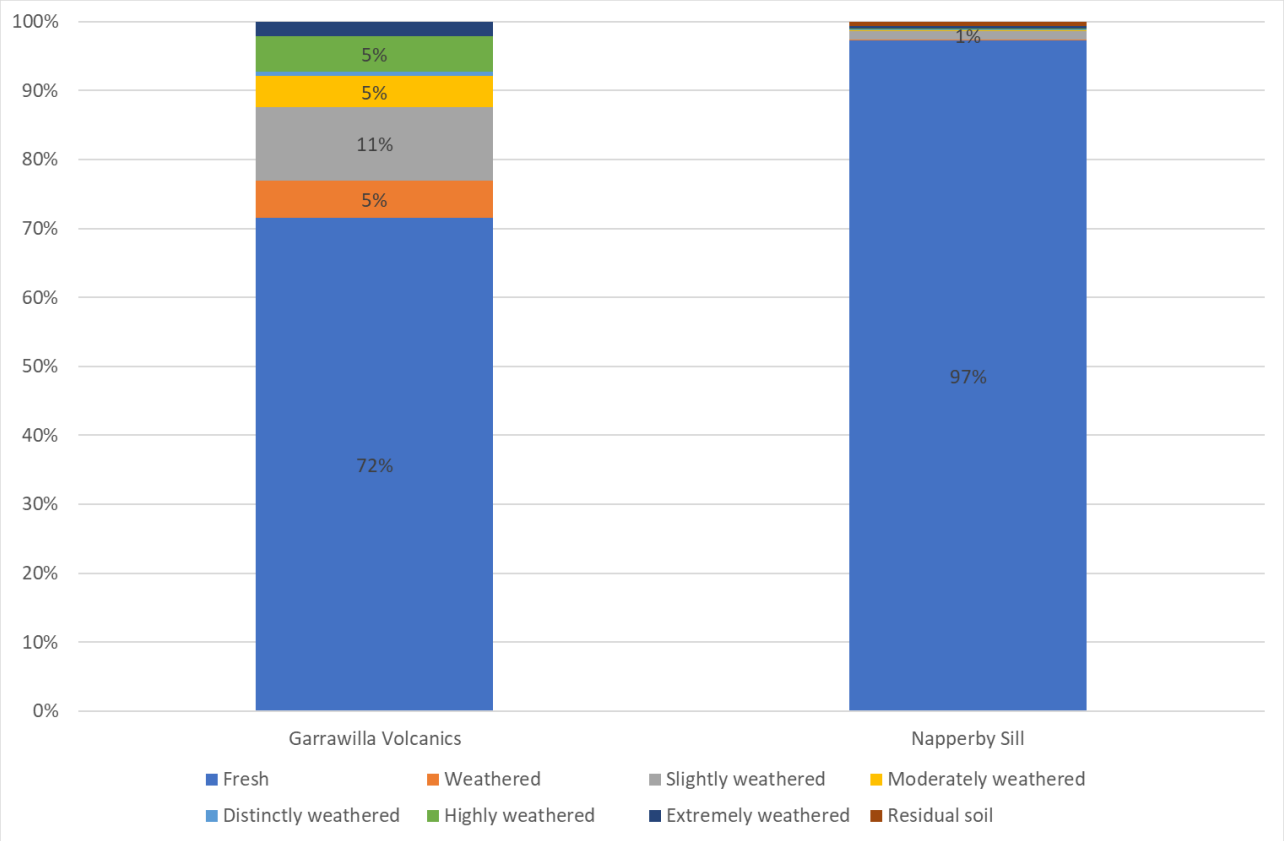



**Figure 5.1 Logged degree of weathering Garrawilla Volcanics and Napperby Sill from NCOPL exploration drilling results**

### *5.1.6 Digby Formation*

The Digby Formation unconformably overlies the coal bearing Permian formations within the Project Area and occurs at or close to outcrop to the east of ML 1609. The formation typically comprises a 15 m to 30 m thick conglomerate overlying a basal sandstone, although the sandstone is only present towards the north of the Project Area. The conglomerate unit therefore sits directly above the Hoskissons Seam across the majority of the current and proposed mining area. Un-disturbed by mining, the conglomerate would be expected to be characterised by very low permeability and this is consistent with exploration drilling results which suggest that around 98% of the conglomerate material tested in characterised by medium to high strength rock.

Consistent with these drilling results the Digby Formation is identified as a "less productive" unit under the AIP.

### *5.1.7 Hoskissons Coal Seam*

As discussed previously (Section 4.2.3) the Hoskissons Coal Seam represents the sole target for both the existing and proposed mining operations. The seam is generally 7 m to 10 m thick and present at depths of between 160 and 420 metres below ground level (mBGL) within the Project Area. Extensive drilling by Whitehaven Coal in the region suggests that the thickness of the Hoskissons Coal Seam reduces to zero close to the eastern boundary of ML 1609 and MLAs 1 and 2. This is consistent with current geological mapping (see Figure 4.4) which shows the Digby Formation directly overlying the Brothers sub-group to the east of the Project Area. Accordingly, there is no direct contact between the Hoskissons Coal Seam and the alluvial strata associated with the Namoi River or Tulla Mullen Creek.

Operation of the Narrabri Mine results in direct dewatering of the Hoskissons Coal Seam. Actual groundwater inflows to the existing Narrabri Mine have been substantially lower than predicted either by Aquaterra (2009) or HydroSimulations (2015). Pre-development de-gassing and dewatering of the coal seam at Narrabri has also required a number of closely spaced horizontal wells. The hydraulic properties of the Hoskissons Coal Seam are discussed further in Section 5.3.

The Hoskissons Coal Seam is identified as a "less productive" unit under the AIP.

### *5.1.8 Arkarula Formation*

As discussed in Section 4.2.3, the Arkarula Formation immediately underlies the Hoskissons Coal Seam and generally comprises an upward fining sequence of medium grained quartzose sandstone and siltstone. However, within the mine itself, a 10 m thick highly porous sandstone is more typical (Figure 4.2) which can lead to groundwater ingress through the longwall panel floor since, unlike the overlying coal seams, this sandstone has not been de-pressurised prior to mining.

The Arkarula Formation is identified as a "less productive" unit under the AIP.

### *5.1.9 Pamboola Formation*

The Arkarula Formation is underlain by the Pamboola Formation which typically comprises lithic sandstone, siltstone, claystone and conglomerate, although as shown in Figure 4.2 sandstone and siltstone tend to dominate in and around the Narrabri Mine area. It can also include minor coal seams. However, these seams are not targeted by operations at the Narrabri Mine, and previous assessments (Aquaterra, 2009; HydroSimulations, 2015; and HydroSimulations, 2019a) suggest no significant impact on any older underlying units. Accordingly, the Pamboola Formation represents the oldest hydrostratigraphic unit included in the current assessment. It is identified as "less productive" unit under the AIP.

## 5.2 Water levels and flow directions

### *5.2.1 Groundwater monitoring network*

Groundwater level data for monitoring bores in and around the Project Area are available from three monitoring networks associated with the Narrabri Mine, the Narrabri Gas Project and the State groundwater monitoring network. Groundwater monitoring bore locations are shown in Figure 5.2. A summary of the number of monitoring bores for which data has been collated for the current study is presented in Table 5.1.

As shown in Table 5.1 data have been collated for 262 monitoring points, around 40% of which are thought to be monitoring groundwater levels in the Quaternary alluvium associated with the Namoi River and its major tributaries. Since information on the formation monitored for the State monitoring bores are not included in the National Groundwater Information System (NGIS) (BoM, 2018), this has been estimated by intersecting the bore screen with surfaces developed for groundwater modelling purposes. Accordingly, data for 43 state monitoring bores for which no screen information or subsurface information is available have not been used for conceptualisation and/or model development since the formation monitored cannot be estimated. For the most part the monitoring networks generally comprise standpipe monitoring bores for shallow installations and vibrating wire piezometers (VWPs) for monitoring of deeper formations.

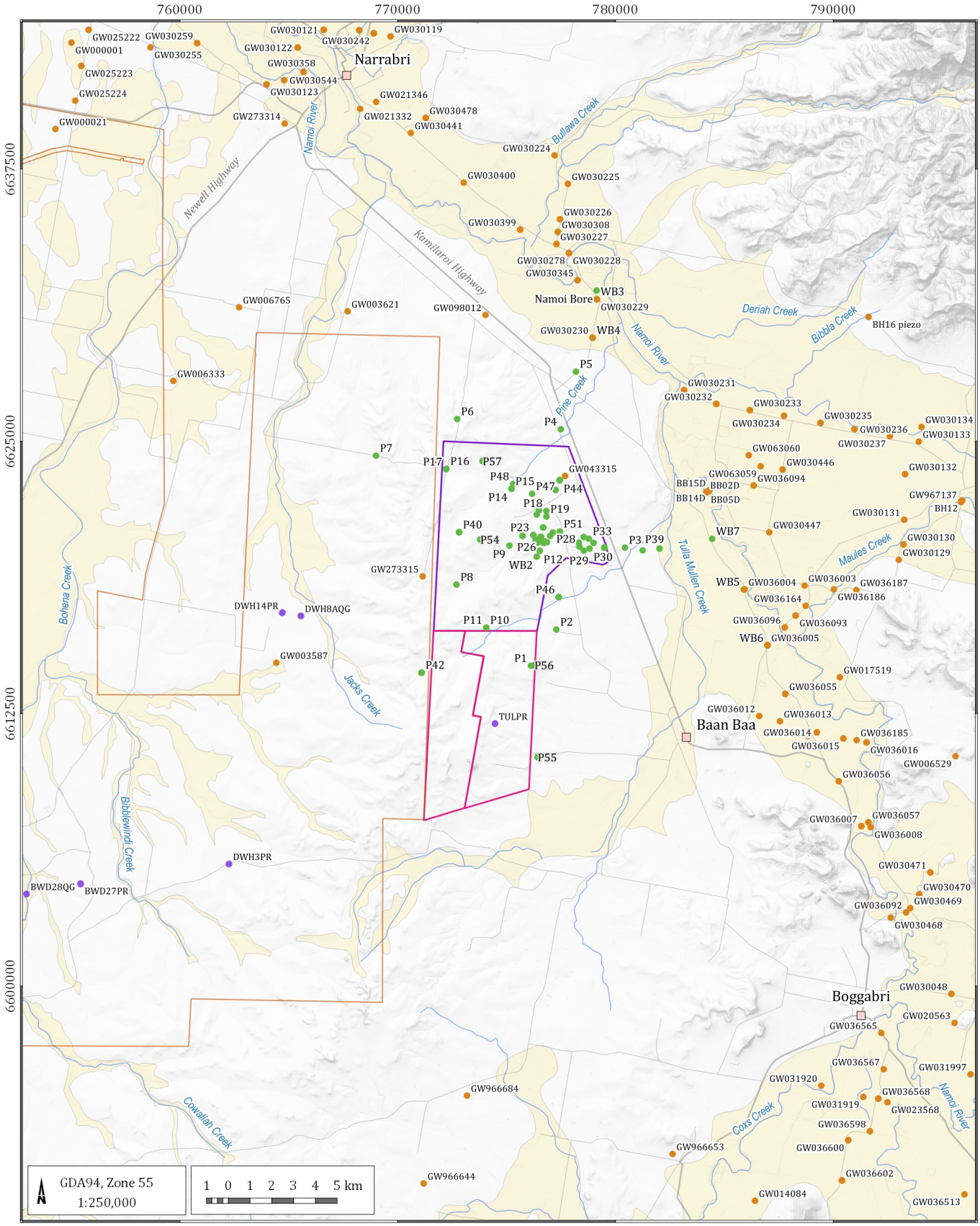
Data have been collated and analysed for a substantially larger network of monitoring points than that assessed as part of the Gateway Application Preliminary Groundwater Assessment (HydroSimulations, 2019a). Of the 262 monitoring bores used for development of the current conceptual and numerical model 82, of the Narrabri Mine monitoring points were used in the Gateway Application Preliminary Groundwater Assessment.

The dataset for the Project has therefore been significantly expanded through the use of data for NSW State Monitoring bores and the Narrabri Gas Project (Figure 5.2). Data are also available for a further 33 Narrabri Mine monitoring points in and around ML 1609 and MLAs 1 and 2. This includes a key nest of VWPs and extensometer installed immediately above longwall panel LW108A prior to mining this panel. As discussed in Section 5.2.11 interpretation of this monitoring site provides key information on likely actual fracture heights above the existing workings.

Further construction and other details for each the Narrabri Mine monitoring points are presented in Appendix A.

**Table 5.1 Groundwater monitoring locations by formation and operator**

| Formation | Narrabri Mine | Narrabri Gas Project | NSW State Monitoring bores | Total |
|---|---|---|---|---|
| Alluvium | 9 | - | 91 | 101 |
| Pilliga Sandstone | 4 | 12 | 4 | 21 |
| Purlawaugh Formation | 13 | 2 | 2 | 13 |
| Garrawilla Volcanics | 11 | - | 3 | 16 |
| Napperby Formation | 27 | 1 | 4 | 26 |
| Digby Formation | 7 | 2 | 5 | 14 |
| Hoskissons Coal Seam | 13 | - | 1 | 15 |
| Arkarula Formation | 7 | 1 | 18 | 23 |
| Pamboola Formation | 10 | - | - | 5 |
| Older units | 14 | - | 1 | 3 |
| **Total** | **115** | **18** | **129** | **262** |




LEGEND

- Populated place
- Drainage
- Road
- Mining Lease Boundary (ML 1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Alluvium extent

**Groundwater moitoring sites**

- Narrabri coal mine
- NSW state monitoring
- Narrabri Gas project

Narrabri Stage 3 Extension GIA (G1972)

## Groundwater level monitoring locations

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FIGURE No: **5.2**

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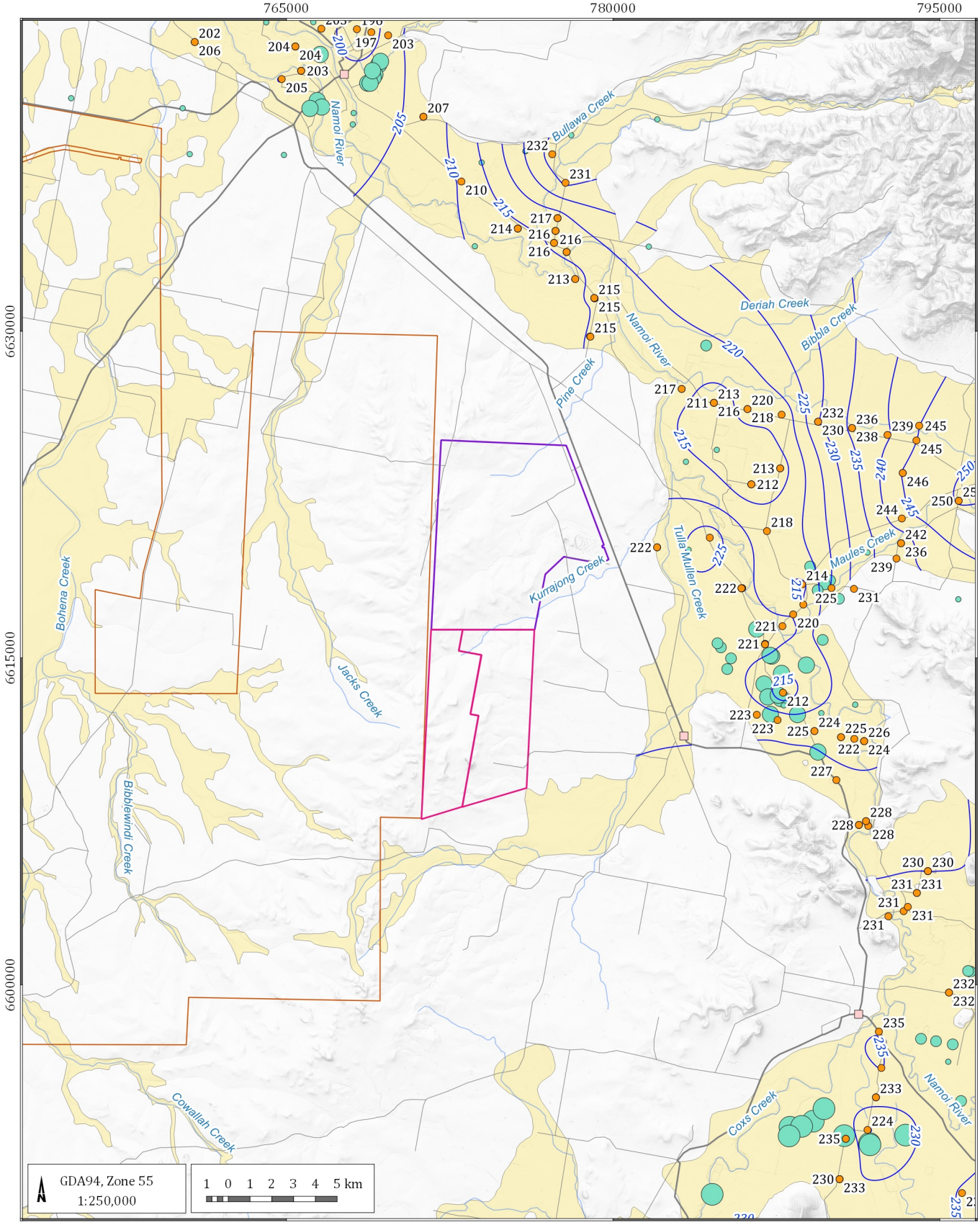
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\05.02_G1972_Groundwater level monitoring locations.qgs

### *5.2.2 Namoi Alluvium*

Current groundwater levels in the Namoi alluvium are shown in Figure 5.3 and range between 250 mAHD towards the east of the area shown to around 200 mAHD in the vicinity of Narrabri. Consistent with the topography and flow direction in the river groundwater appears to flow generally south to north along the main Namoi River. However, groundwater gradients appear to be very flat upstream of Baan Baa suggesting possible disconnection of groundwater and surface water in this area. Conversely, relatively steep gradients are evident in the vicinity of some tributaries suggesting groundwater and surface water connectivity and/or significant groundwater flow contributions in these areas.

Intensive groundwater use for irrigation in this area generally results in seasonal water table drawdown of up to 5 m in the alluvium (DPI-Office of Water, 2017). As shown in Figure 5.3 there is an extensive groundwater monitoring network currently in place in the Namoi River alluvium and as a result, there is sufficient spatial resolution to observe localised areas of groundwater drawdown. Groundwater drawdown can be observed around Narrabri, south of Boggabri near Cox's Creek and north-east of Baan Baa along the Namoi River (Figure 5.3) and coincide with areas where numerous licensed groundwater bores are located. Similarly, reference to data for the Narrabri monitoring bore (WB6B, see Figure B 1), which is located close to the depression seen in the groundwater level contours north-east of Baan Baa (shown in Figure 5.3) also shows 5 to 10 m drawdown cycles which are almost certainly due to the intensive extraction which appears to be occurring in this area. Data for some monitoring points (including WB6b, see Appendix B, Figure B 1) show seasonal pumping effects in excess of 15m.

As mentioned previously, whilst the Namoi Alluvium itself is relatively well monitored there are relatively few monitoring bores located in many of the tributary channels, including the Tulla Mullen Creek to the south and east of the Project Area. However, assuming that the Quaternary alluvium associated with this creek is saturated, it is likely that the groundwater flow direction closely mirrors topography and flows from the west to east towards the Namoi River.




LEGEND

- Populated place
- Road
- Drainage
- Mining Lease Boundary (ML 1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Alluvium extent
- Site monitoring bores

**Licensed extraction bore (ML/year)**

- < 1000
- 1000 - 2000
- 2000 - 4000
- 4000 - 6000
- > 6000
- Groundwater level contour (mAHD)

Narrabri Stage 3 Extension GIA (G1972)

## Current groundwater levels - Quaternary alluvium

DATE 27/04/2020

FIGURE No: **5.3**

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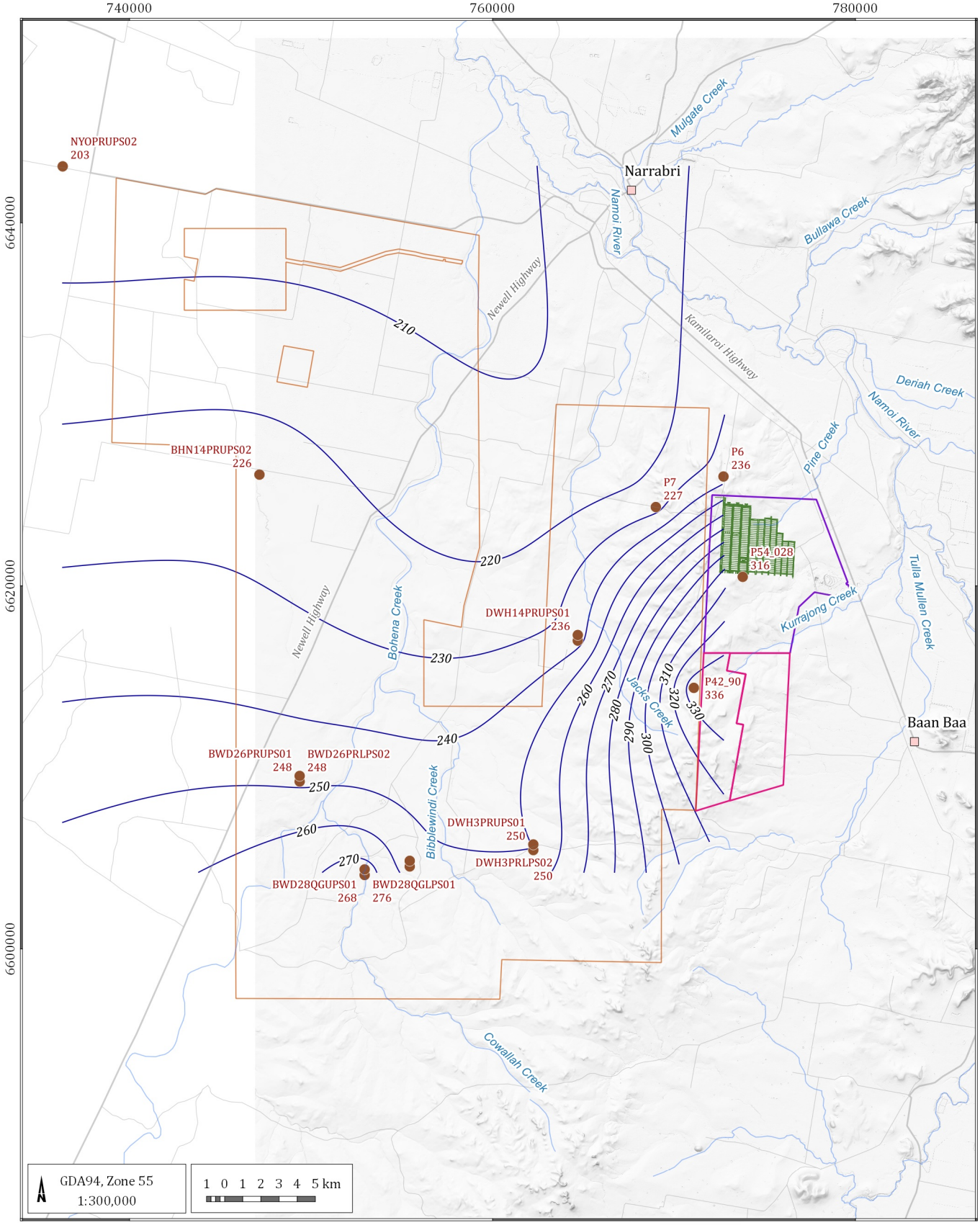
### *5.2.3 Pilliga Sandstone*

As shown in Figure 5.4, groundwater monitoring bores in the Pilliga Sandstone are predominantly located to the west of the Narrabri Mine. In part, this reflects the distribution of the formation, as discussed previously (Section 5.1.2) the Pilliga Sandstone is not present in the eastern part of ML 1609 and MLAs 1 and 2. Data are available for four monitoring points (P6, P7, P42_90 and P54_28) which are located close to the northern and western boundary of ML 1609 and MLAs 1 and 2 (see Figure 5.2) and hence any drawdown in the aquifer to the west of ML 1609 and MLAs 1 and 2 is being monitored.

As shown in Figure 5.4 and Appendix B, Figure B 2, observed groundwater levels in the Pilliga Sandstone range between approximately 336 mAHD close to the western boundary of MLAs 1 and 2, to around 203 mAHD north and north-west of the Project Area. Regional groundwater flow directions in the Pilliga Sandstone therefore appear to be towards the north-west, generally consistent with the topography, but somewhat at odds with the dip of the strata which is towards the west.

As shown Figure B 2, observed groundwater levels including the four monitoring points installed close to the Narrabri Mine (P6, P7, P42_90 and P54_28) show little or no temporal variation and hence do not appear to be affected by climate, mine dewatering operations and/or other extraction from the Pilliga Sandstone for water supply or other purposes.




LEGEND

- Populated place
- Monitoring bore
- Interpolated groundwater level contour (mAHD)
- Drainage
- Road
- Existing longwall panel
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)

P7: BoreID
227 : Water level (mAHD)

Narrabri Stage 3 Extension GIA (G1972)

## Current groundwater levels - Pilliga Sandstone

DATE
27/04/2020

FIGURE No:
**5.4**

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### 5.2.4 Purlawaugh Formation

As shown in Appendix B, Figure B 35, nine of the eleven monitoring points within the Purlawaugh Formation are located in and around the Project Area and hence there is not considered to be sufficient information to generate meaningful regional groundwater level contours. Reference to time series data for the eleven available monitoring points (Figure B 3 and B 35) suggests groundwater levels which vary from around 236 mAHD at DWH14PR_PUR03 to the west of Jacks Creek to around 285 mAHD at P42_185 close to the western boundary of the Project Area. The hydrographs also show a variety of responses including P11, which shows a possible delayed response to climate since it appears to correlate relatively well with the CRD curve.

Data for monitoring point P9 show a decline of around 15 m since early 2014 which, given its location close to the existing workings, may be mine related. Although, as shown in the CRD curve, the recent period has also been relatively dry and hence a component of this observed drawdown may be related to climate. In support of this, as shown in Figure B 3, recent data for monitoring point BWD28QG located more than 25 km south-west of the mining area (and therefore not likely to be affected by mining operations), shows a similar rate of decline to that observed at P9. This observation suggests that a large proportion of the observed decline at P9 may be attributed to prevailing dry conditions.

Data for the nested monitoring point P40_95 initially show a sharp 20 m level decline in 2013 followed by a gradual recovery until 2016. This pattern and some variability in levels in P7 and P17 was previously attributed to pumping effects from an existing nearby property bore (HydroSimulations, 2019a). As shown in Figure 5.10, there are three registered water supply bores to the north-west of ML 1609 which could be causing impacts at nearby monitoring bores. However, P40 is also located close to the existing Narrabri Mine and hence the observed decline in 2013 may be mining related. As discussed in Section 5.2.11, more recent monitoring in deeper units at this nested monitoring facility suggest substantial mining impact. However, levels in the Purlawaugh Formation have remained relatively static recently as nearby longwall panels have been mined out, which suggests that another non-mining influence may be affecting levels. Unfortunately, DPIE-Water have been unable to provide actual extraction data for any of the nearby water supply bores which might assist with determining the cause of the observed variation in monitoring points P17 and P40_95.

Significant de-pressurisation of the Purlawaugh Formation can also be observed in the recently installed P57 nested monitoring point which is located above longwall panel LW108A. Data for this important nested monitoring facilities is discussed further in Section 5.2.11 below.

### 5.2.5 Garrawilla Volcanics

As shown in Appendix B, Figure B 4 and Figure B 36, time series data are currently available for 11 monitoring points in the Garrawilla Volcanics, including one monitoring point (P1) in the proposed mining extension to the south.

As shown in Figure B 4, groundwater levels in the Garrawilla Volcanics in the vicinity of the Narrabri Mine vary from around 294 mAHD in monitoring point P1 to around 194 mAHD in the nested monitoring point P57. As per the Purlawaugh monitoring point (P40_95) discussed above, data for P40_135 show substantial variability although levels have generally been declining in the Garrawilla Volcanics, rather than increasing. Given the proximity of a number of monitoring points which show recent declines (e.g. P16, P13, P40_135 and P57_100) to the existing workings, then de-pressurisation impacts in the Garrawilla Volcanics cannot be ruled out. Although, as discussed previously in relation to P9 (Section 5.2.4), a component of the observed de-pressurisation in each of these monitoring points is likely to be climate related. In contrast, P47 which is also located in close proximity to the existing longwall panels shows little or no drawdown.

### 5.2.6 Napperby Formation

The available time series groundwater level for monitoring points completed into the Napperby Formation are shown in Appendix B, Figure B 5 and Figure B 37. As per other formations the majority of these monitoring points are located in and around the existing mining area and there is insufficient coverage to allow meaningful regional groundwater level contours to be developed. In particular, there are no monitoring bores in the Napperby Formation west of the Project Area. However, this is in part due to the depth of the formation in this part of the area. Three nested monitoring points are located within the proposed expansion area.

As shown in Figure B 5 and Figure B 37, groundwater levels in the Napperby Formation range between 280 mAHD in monitoring point P10 near the southern boundary of ML 1609 to around 206 mAHD in the nested monitoring point P57_160 and P44_95 located to the north within and near the existing underground mining area.

Hydrographs for monitoring points installed into the Napperby Formation can be split into three broad groups. Many monitoring points including P28, P29 and P31 show stable or slightly rising trends. A number of other monitoring points including P12, P32, P52 and P44_95 show relatively minor recent declines which may be a reflection of recent dry conditions and/or minor depressurisation impacts. Whilst the third group of monitoring points, which includes the nested monitoring points P40_307, P46_70 and P24_112; show highly variable levels and more substantial recent depressurisation.

### 5.2.7 Digby Formation

The available time series groundwater level for monitoring points completed into the Digby Formation are shown in Appendix B, Figure B 6. As per other formations and as shown in Figure B 38, the majority of these monitoring points are located in and around the existing mining area. One monitoring point (DWH8AQG_DGY01) is, however, located west of the existing lease area in the vicinity of Jacks Creek and a two further nested monitoring points (TULPR_DGY02 and P55_110) are located in the Project Area. Nevertheless, there is considered to be insufficient data coverage to allow meaningful regional groundwater level contours to be developed, contours are however shown within the Narrabri Mine and Project Area.

Groundwater levels in the Digby Formation range between around 330 mAHD in DWH8AQG_DYG01 near Jacks Creek to around 170 mAHD in three nested monitoring points P24_148, P40_322 and P42_345 within and to the south of the Narrabri Mine. Observed groundwater levels in three nested monitoring points P24_148, P42_322 and P44_134 have also declined steadily since the start of monitoring in each bore. Data for a further nested monitoring point P40_322 have declined by around 80 m recently. Given the proximity of these monitoring points to the existing workings it is considered likely that the majority of the observed depressurisation is related to the extraction of coal from the Hoskissons Coal Seam which immediately underlies the Digby Formation within the Narrabri Mine area. Of the eight monitoring points with time series data only three are considered likely to be unaffected by mining operations at this stage. Two of the unaffected bores, P46_87 and TULPR_DGY02, are located within the Project Area and the third, DWH8AQG_DGY01, is located close to Jacks Creek around 5 km from the western boundary of ML 1609.

### 5.2.8 Hoskissons Coal Seam

The available time series groundwater level for monitoring points completed into the Hoskissons Coal Seam are shown in Figure B 7. As per other formations and shown in Figure B 39 the majority of these monitoring points are located in and around the existing mining area. Consequently, the majority of the monitoring points show substantial depressurisation of the Hoskissons Coal Seam due to ongoing dewatering operations in the current underground mining area.

As shown in Figure B 7, pre-mining water levels in the Hoskissons Coal Seam appear to have been in the range between 220 mAHD to 260 mAHD. Current levels of as low as 100 mAHD are recorded in a number of monitoring points suggesting significant depressurisation in some locations. Data for the nested monitoring location P40_346 shows a relatively late dewatering response consistent with the location of this bore within longwall panel LW110, which has yet to be fully developed. Groundwater levels as low as 50 mAHD were recorded in this monitoring point prior to it ceasing operation in late 2018.

### *5.2.9 Arkarula Formation*

The available time series groundwater level for monitoring points completed into the Arkarula Formation are shown in Figure B 8. As shown in Figure B 40, seven of the eight monitoring points are located in and around ML 1609, with a single point (DWH8AQG_ARK02) located close to Jacks Creek to the west.

Observed groundwater levels in the Arkarula Formation range between around 50 mAHD in the nested monitoring point P40_357 close to the existing longwall panel 110 and 277 mAHD in DWH8AQG_ARK02 close to Jack's Creek.

As would be expected given the location of the Arkarula Formation sandstones immediately below the Hoskissons Coal Seam data, four of the five Arkarula Formation monitoring points located close to the current mining area show substantial de-pressurisaton. However, data for the nested monitoring point P45_80, which is located around 2 km east of the underground mining area, close to the Kamilaroi Highway, show relatively static levels suggesting the drawdown cone in this formation and in this direction may be quite restricted. Conversely, data for monitoring point P42_415, which is located around 5 km south of the existing workings shows around 6 m of recent drawdown which may be related to mining since there is no other known extraction from the Arkarula Formation in the vicinity of the Narrabri Mine.

### *5.2.10 Pamboola Formation*

Time series groundwater level monitoring data for the Pamboola Formation are shown in Figure B 9. As shown in Figure B 41, data are available for seven monitoring points all located in and around ML 1609. Consistent with the generally lower permeability of this formation and its location beneath the Arkarula sandstone, data for the Pamboola Formation shows substantially less apparent de-pressurisation than observed in the overlying layers. As shown in Figure B 9, groundwater levels of between 210 mAHD and 260 mAHD are observed, 100 – 160 m higher than in the Hoskissons Coal Seam. Data for two monitoring points P19 and P46_151 show possible mine related drawdown. However, levels at the remaining three monitoring points have remained relatively static or increased slightly during the monitoring period.

### *5.2.11 Nested monitoring facilities*

Data are currently available for eleven nested monitoring facilities (P24, P38, P40, P42, P44, P45, P46, P54, P55, P56 and P57) installed in and around the existing Narrabri Mine. These sites comprise multiple VWPs cemented into a single drill hole at a number of different levels. Analysis of data for such sites typically provides valuable insights into the rate at which de-pressurisation of the Hoskissons Coal Seam propagates into overlying and underlying strata. Grouped hydrographs for each of the nested monitoring locations are presented in Appendix B, Figure B 10 to Figure B 33. Hydrographs for the three nested facilities closest to the current underground mining area, P24, P40 and P57 are shown in Figure B 10, Figure B 13 and Figure B 21 respectively and are discussed in the sections below.

P24 is located around 80 m east of the first longwall panel LW101. Monitoring takes place at four different levels within the facility – the Napperby Formation at 112 mBGL, the Digby Formation at 148 mBGL, the Hoskissons Coal Seam at 166 mBGL and the Arkarula Formation at 180 mBGL. As shown in Figure B 10, substantial drawdown can be observed in each formation monitored, commencing in early 2009 in the Hoskissons Coal Seam, Arkarula and Digby formations.

Drawdown during this period is thought to be associated with construction of the drift tunnel and the main development headings as none of the longwall panels had been developed at this time.

Development of longwall panel LW101 adjacent to P24 occurred in March 2013 and can be clearly seen in all the hydrographs at this location, as spike in groundwater level as the longwall passes. Data for the monitoring point in the Napperby Formation at 112 mBGL (around 54 m above the Hoskissons coal seam) show only minor drawdown prior to March 2013 but then declined rapidly to around 195 mAHD as the longwall passed and have remained relatively stable since. As would be expected current levels suggest substantial gradients have been established between the Hoskissons Coal Seam and both under and overlying units.

P40 is located close to southern end of longwall panel LW110 which has yet to be mined, but has seen the installation of a number of Underground in-seam (UIS) boreholes which are used to depressurise the panel prior to mining. Monitoring takes place at six different levels within the facility:

- the Purlawaugh Formation at 95 mBGL;
- the Garrawilla Volcanics at 135 mBGL;
- the Napperby Formation at 307 mBGL;
- the Digby Formation at 322 mBGL;
- the Hoskissons Coal Seam at 346 mBGL; and
- the Arkarula Formation at 357 mBGL.

As shown in Figure B 13, recent data suggests likely mining related drawdown in all the overlying units apart from the upper most unit monitored, the Purlawaugh Formation. Data at this location also show more drawdown in the Arkarula Formation than in the Hoskissons Coal Seam itself until late 2018. Significant depressurisation of the Hoskissons Coal Seam appears not to have occurred until early 2017, presumably reflecting pre-development de-pressurisation of nearby longwall panels. However, substantial drawdown in the Arkarula Formation can be seen prior to this date suggesting that de-pressurisation impacts spread more rapidly in the sandstones of the Arkarula Formation than in the overlying coal seams. This is consistent with the relatively high expected hydraulic conductivity of the Arkarula sandstone unit in the Project Area.

P57 is located close to the northern end of longwall panel LW108A, the mining of which commenced in mid September 2018. The monitoring points at this location were installed in April 2018 (i.e. around five months prior to development of the panel beneath). Monitoring takes place at eight levels:

- at 40, 60 and 80 mBGL within the Purlawaugh Formation;
- at 100 and 120 mBGL in the Garrawilla Volcanics; and
- at 140, 160 and 180 mBGL in the Napperby Formation.

The Hoskissons Coal Seam at this location is around 275 mBGL and hence the deepest monitoring point in this array (P57_180) is around 95 m above the coal seam. As shown in Figure B 21 groundwater levels were relatively static in each monitoring point just before mining of longwall panel commenced around 300 m north of P57 on 16 September 2018. Interestingly the majority of the piezometers show some de-pressurisaton prior to this date, which likely reflects ongoing activities in the mine nearby, such as roadway construction or UIS borehole operations. Furthermore, whilst the deepest monitoring point closest to the coal seam (P57_180), as would be expected, shows the largest response in the longer term, this response is somewhat later than observed at other shallower levels. Groundwater levels in the two shallowest monitoring points (P57_40 and P57_60) in the Purlawaugh Formation show relatively subdued and delayed responses, whilst data for P57_80 shows a similar characteristic response to other deeper piezometers with multiple sudden upward and downward changes in level as mining approaches. All piezometers from P57_80 and deeper show multiple 'events' as longwall mining approaches the piezometer location.

As expected, these piezometers failed at around the same time as the longwall panel directly beneath was mined out. The failure of all of the sensors below 80 m therefore tends to confirm that the limit of physical disturbance of the mining operations at this location extends to at least P57_80 (i.e. 80 m below ground level or 215 m above the Hoskissons Coal Seam). As shown in Figure B 21, data for P57_60 also show a significant response and the data suggest temporary de-saturation of the strata (i.e. levels below the level of the sensor) as the longwall passed directly beneath the piezometers. Groundwater levels appear to have recovered to above the level of the sensor recently, however, the rapid response and temporary de-saturation of the strata suggests that the zone of physical disturbance may extend to P57_60 (i.e. 60 mBGL or 235 m above the Hoskissons Coal Seam). Accordingly, a review of this same piezometer alongside data for a nearby extensometer array as part of a separate detailed subsidence assessment concluded that longwall induced sub-surface cracking extends to around 236 m above the longwall panel at this location (Ditton Geotechnical Services [DGS], 2020).

## 5.3 Hydraulic properties

### *5.3.1 Horizontal hydraulic conductivity*

Hydraulic conductivity data for the Project Area have been collated from previous reports by Sigra (2006), GHD (2007), Aquaterra (2009), Weatherford (2009), Kamenar and Associates (2016), Core Laboratories Australia (2018) and Bioregional Assessments (2016a). Hydraulic conductivity data available via these sources are as follows:

- 26 slug tests undertaken in Narrabri coal groundwater monitoring bores installed in and around the Project Area;
- 28 drill stem tests (DSTs) undertaken in coal exploration holes primarily in the Hoskissons Coal Seam;
- 48 laboratory core tests undertaken on samples extracted from coal exploration holes above and below the Hoskissons Coal Seam. Core recovery in coal seams is typically poor and hence *in situ* DST tests are typically undertaken to confirm coal properties; and
- 2 pumping tests reported by Aquaterra (2009) in the Garrawilla Volcanics (Claremont Bore) and a multi-formation pumping test undertaken in the P13 monitoring bore.

Summary statistics based on DST, slug and laboratory core test results for each formation tested are summarised in Table 5.2, Table 5.3 and Table 5.4 respectively below, and in Figure 5.5.

As shown in Figure 5.5, relatively high hydraulic conductivity values are returned for the Pilliga Sandstone and the porous sandstone at the top of the Arkarula Formation. In both cases, laboratory core test results are higher in both of these units than slug test results. Hydraulic conductivity test results typically increase with the scale of the test and hence tests of core samples (which are typically only around 10 cm long) are usually lower than slug tests which test the entire bore screen. In this case the average test length of the slug tests summarised in Table 5.3 is around 8 m. Typically, the longer the test length, then the higher the chance of encountering a permeable sandstone unit or fracture. Hence, as shown in Figure 5.5, results for slug tests completed in the Purlawaugh Formation, Garrawilla Volcanics and Napperby Formation are substantially higher than the values returned for laboratory core tests undertaken in the same strata. The significant differences between the median values returned by the laboratory core tests and slug tests results particularly in the Purlawaugh Formation, Garrawilla Volcanics and Napperby Formation suggest that the development of secondary porosity and permeability via fractures may be a feature of these units.

With regard to the two pumping tests undertaken in the Claremont bore, information on the location and test interval of this is not available and hence hydraulic conductivity cannot be estimated from the transmissivity which is reported to be in the range 75-150 square metres per day. Analysis of the pumping test data related to P13 suggests hydraulic conductivities in the range 0.016 to 0.44 metres per day (m/d) (GHD, 2007; Aquaterra, 2009) at the boundary between the Garrawilla Formation and underlying Napperby Formation.

This estimate is towards the upper range of values estimated from slug tests undertaken in these strata (Table 5.3 and Figure 5.5).

## Table 5.2 Hydraulic conductivity data – DST tests

| | | | Horizontal hydraulic conductivity, Kh (m/d) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Formation** | **No of Bores tested** | **No of Tests** | **Mean** | **Harmonic Mean** | **Min** | **25%** | **50%** | **75%** | **Max** |
| Garrawilla Volcanics | 1 | 1 | 8.0 | | | | | | |
| Napperby Formation | 1 | 1 | $8.3 \times 10^{-6}$ | | | | | | |
| Napperby Formation (Dolerite Sill) | 2 | 2 | $4.1 \times 10^{-1}$ | $1.8 \times 10^{-4}$ | $9.1 \times 10^{-5}$ | - | | | $8.3 \times 10^{-1}$ |
| Digby Formation | 3 | 3 | $2.1 \times 10^{-2}$ | $1.7 \times 10^{-4}$ | $9.1 \times 10^{-5}$ | $1.1 \times 10^{-4}$ | $1.4 \times 10^{-4}$ | $3.1 \times 10^{-2}$ | $6.3 \times 10^{-2}$ |
| Hoskissons Coal Seam | 6 | 8 | $8.7 \times 10^{-3}$ | $4.1 \times 10^{-4}$ | $1.7 \times 10^{-4}$ | $2.0 \times 10^{-4}$ | $8.6 \times 10^{-4}$ | $3.9 \times 10^{-3}$ | $5.4 \times 10^{-2}$ |
| Arkarula Formation | 1 | 1 | $1.1 \times 10^{-5}$ | | | | | | |

## Table 5.3 Hydraulic conductivity data – slug tests

| | | | Horizontal hydraulic conductivity, Kh (m/d) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Formation** | **No of Bores tested** | **No of Test** | **Mean** | **Harmonic Mean** | **Min** | **25%** | **50%** | **75%** | **Max** |
| Pilliga Sandstone | 2 | 2 | $1.1 \times 10^{-1}$ | $5.0 \times 10^{-2}$ | $2.9 \times 10^{-2}$ | - | | | $1.9 \times 10^{-1}$ |
| Purlawaugh Formation | 4 | 5 | $9.2 \times 10^{-2}$ | $3.7 \times 10^{-3}$ | $1.1 \times 10^{-3}$ | $2.8 \times 10^{-3}$ | $1.7 \times 10^{-2}$ | $3.2 \times 10^{-2}$ | $4.1 \times 10^{-1}$ |
| Garrawilla Volcanics | 3 | 3 | $5.3 \times 10^{-2}$ | $8.3 \times 10^{-3}$ | $3.0 \times 10^{-3}$ | $2.5 \times 10^{-2}$ | $4.7 \times 10^{-2}$ | $7.8 \times 10^{-2}$ | $1.1 \times 10^{-1}$ |
| Napperby Formation | 5 | 7 | $2.9 \times 10^{-2}$ | $1.7 \times 10^{-3}$ | $5.5 \times 10^{-4}$ | $1.1 \times 10^{-3}$ | $4.0 \times 10^{-3}$ | $5.3 \times 10^{-2}$ | $9.0 \times 10^{-2}$ |
| Hoskissons Coal Seam | 1 | 2 | $1.0 \times 10^{-2}$ | $1.0 \times 10^{-2}$ | $8.6 \times 10^{-3}$ | - | | | $1.3 \times 10^{-2}$ |
| Arkarula Formation | 1 | 1 | $1.2 \times 10^{-2}$ | | | | | | |
| Pamboola Formation | 3 | 5 | $7.8 \times 10^{-3}$ | $2.8 \times 10^{-3}$ | $2.0 \times 10^{-3}$ | $2.1 \times 10^{-3}$ | $2.3 \times 10^{-3}$ | $2.8 \times 10^{-3}$ | $3.0 \times 10^{-2}$ |

## Table 5.4 Hydraulic conductivity data – laboratory core tests

| Formation | No of Bores tested | No of tests | Horizontal hydraulic conductivity, Kh (m/d)[a] | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean[b] | Min | 25% | 50% | 75% | Max |
| Pilliga Sandstone | 2 | 4 | 2.88 | 1.05 | 1.21 | 1.93 | 3.60 | 6.59 |
| Purlawaugh Formation | 1 | 4 | $2.28 \times 10^{-5}$ | $5.60 \times 10^{-7}$ | $6.71 \times 10^{-6}$ | $2.15 \times 10^{-5}$ | $3.76 \times 10^{-5}$ | $4.79 \times 10^{-5}$ |
| Garrawilla Volcanics | 2 | 4 | $3.68 \times 10^{-5}$ | $1.57 \times 10^{-7}$ | $2.70 \times 10^{-7}$ | $3.07 \times 10^{-6}$ | $3.96 \times 10^{-5}$ | $1.41 \times 10^{-4}$ |
| Napperby Formation | 2 | 7 | $1.12 \times 10^{-2}$ | $3.82 \times 10^{-7}$ | $1.54 \times 10^{-5}$ | $1.91 \times 10^{-4}$ | $1.44 \times 10^{-2}$ | $4.94 \times 10^{-2}$ |
| Digby Formation | 1 | 2 | $1.00 \times 10^{-4}$ | $7.37 \times 10^{-5}$ | - | | | $1.27 \times 10^{-4}$ |
| Arkarula Formation | 1 | 2 | $2.34 \times 10^{-1}$ | $4.42 \times 10^{-6}$ | - | | | $4.69 \times 10^{-1}$ |
| | | | Vertical hydraulic conductivity, Kv (m/d)[a] | | | | | |
| Pilliga Sandstone | 1 | 2 | $5.1 \times 10^{-2}$ | $8.04 \times 10^{-3}$ | - | | | 1.01 |
| Purlawaugh Formation | 2 | 4 | $9.7 \times 10^{-7}$ | $1.09 \times 10^{-7}$ | $3.36 \times 10^{-7}$ | $9.74 \times 10^{-7}$ | $8.14 \times 10^{-4}$ | $3.25 \times 10^{-3}$ |
| Garrawilla Volcanics | 2 | 4 | $1.9 \times 10^{-7}$ | $1.27 \times 10^{-7}$ | $1.27 \times 10^{-7}$ | $1.53 \times 10^{-7}$ | $3.98 \times 10^{-5}$ | $1.59 \times 10^{-4}$ |
| Napperby Formation | 2 | 8 | $4.4 \times 10^{-7}$ | $1.27 \times 10^{-7}$ | $5.45 \times 10^{-7}$ | $2.42 \times 10^{-6}$ | $1.03 \times 10^{-4}$ | $5.65 \times 10^{-3}$ |
| Digby Formation | 1 | 1 | $2.77 \times 10^{-5}$ | | | | | |
| Arkarula Formation | 1 | 2 | $3.0 \times 10^{-5}$ | $1.52 \times 10^{-5}$ | - | | | $4.04 \times 10^{-1}$ |

***Notes:*** *[a] Conductivities calculated using from brine permeability reported in millidarcies. Conversion rate of 1 mD = $1.27 \times 10^{-3}$ m/d (OGIA, 2016).*

*[b] mean values shown represent arithmetic means for Kh and harmonic values for Kv.*

Test data from other similar sedimentary basins within Australia confirms that the *in situ* permeability of most strata tends to reduce with depth (Office of Groundwater Impact Assessment [OGIA], 2019). This is particularly true of coal seams since the permeability is derived almost entirely from small fractures or cleats which are particularly prone to closure as the weight of the material overlying increases. Whilst there is insufficient coal permeability data available from which to develop a project specific permeability versus depth relationship for the Project Area sufficient data is available for coal seams within the wider Gunnedah Basin (Figure 5.6). As shown in Figure 5.6, this data, which predominantly relates to tests undertaken in the Boggabri, Tarrawonga and Maules Creek coal mines (BTM complex mines) to the east of the Namoi River, suggests a reduction in coal hydraulic conductivity of around an order of magnitude every 100 m. Comparison of the data shown in Figure 5.6 with the Narrabri DST test results (Table 5.2) also suggests that the coal at Narrabri which occurs at depths of between 160 and 320 mBGL at Narrabri is towards the bottom of the range of values recorded in the BTM complex mines.

Laboratory testing of sandstone, mudstone and siltstone samples taken from the Surat Basin in Queensland by CSIRO (Pervukhina et al., 2016) shows much more subtle reductions in permeability with depth of less than around an order of magnitude every 1,000 m. Hence, significant reductions in permeability with depth are not expected within other non-coal lithologies within the anticipated cone of influence of the Narrabri Mine.

No hydraulic property data relating to alluvium strata in the immediate vicinity of Narrabri Mine are available from the sources listed above. However, data are available for the Namoi Alluvium from other projects including Watermark, Sunnyside and Tarrawonga coal mines, and from pumping tests undertaken in a number of water supply bores. This information has previously been collated as part of the Namoi bioregional assessment (Aryal et al., 2018). General statistics for alluvial hydraulic conductivity for the entire Namoi region are presented below in Table 5.5. These statistics highlight the impact of alluvial heterogeneity, with median hydraulic conductivity of the finer grained Narrabri Formation sediments two order of magnitude less than the sands and gravel of the Gunnedah Formation.

**Table 5.5 Hydraulic conductivity of alluvium (after Aryal et al., 2018)**

| Hydrostratigraphic unit | Hydraulic conductivity (m/d) | | | |
|---|---|---|---|---|
| | Min | Median | Max | Count |
| All alluvium* | 0.0001 | 0.003 | 29 | 78 |
| Narrabri Formation | 0.002 | 0.09 | 3 | 20 |
| Gunnedah Formation | 2 | 6 | 29 | 9 |

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

Further information on the hydraulic properties of the Quaternary alluvium in the Project Area are available via a detailed modelling study of the Upper Namoi Alluvium undertaken by the NSW Department of Natural Resources (McNeilage, 2006). Of most relevance to the Narrabri Mine are the results for Zone 5 of the Namoi River which are shown below in Table 5.6 and are generally consistent with the test data shown in Table 5.5.

**Table 5.6 Namoi Alluvium Zone 5, modelled hydraulic conductivity (McNeilage, 2006)**

| Hydrostratigraphic unit | Hydraulic conductivity (m/d) | | |
|---|---|---|---|
| | Min | Mean | Max |
| Narrabri Formation (Layer 1) | 0.3 | 5.7 | 20 |
| Gunnedah Formation (Layer 2) | 0.5 | 7.4 | 30 |

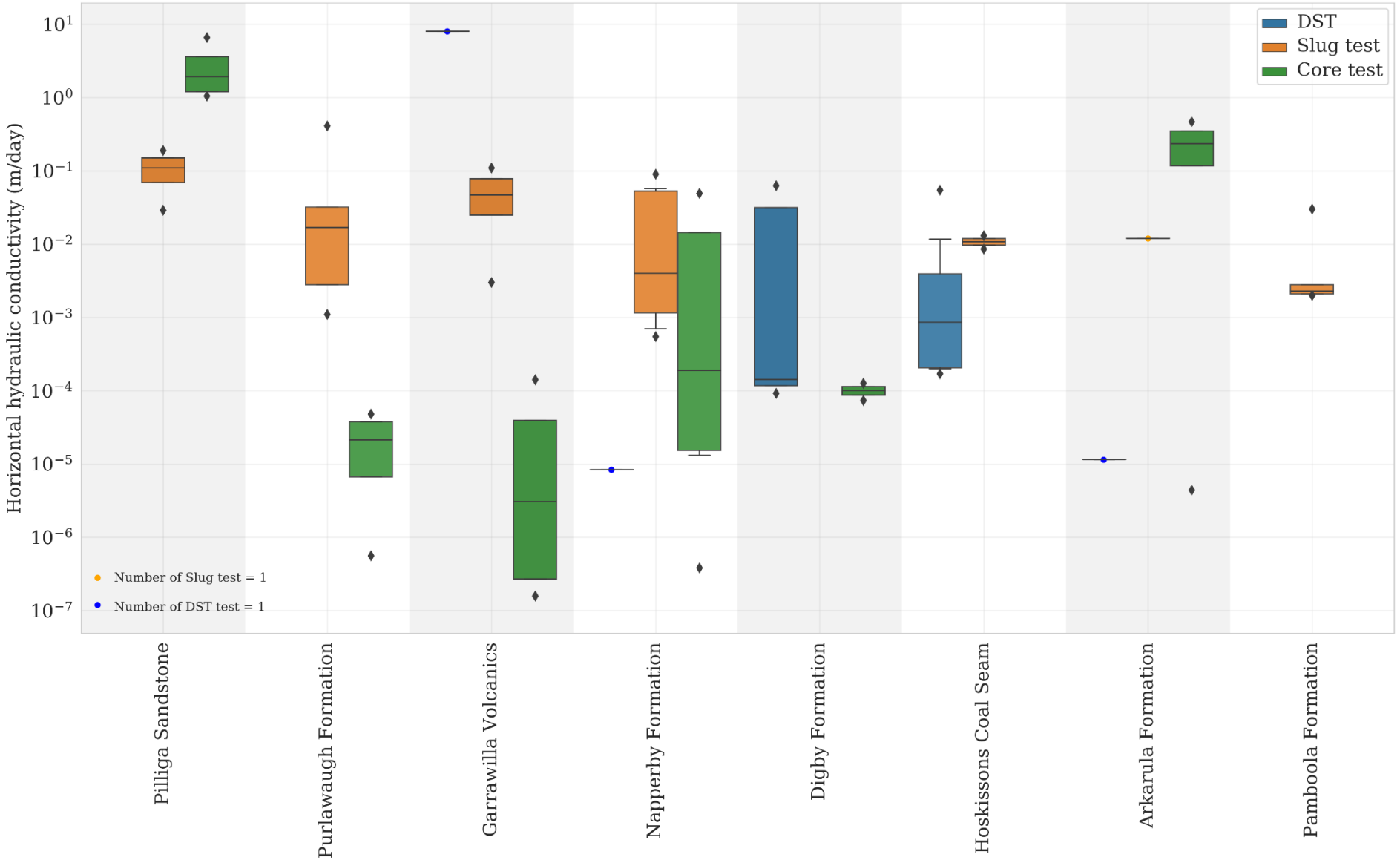



**Figure 5.5 Hydraulic conductivity test data**

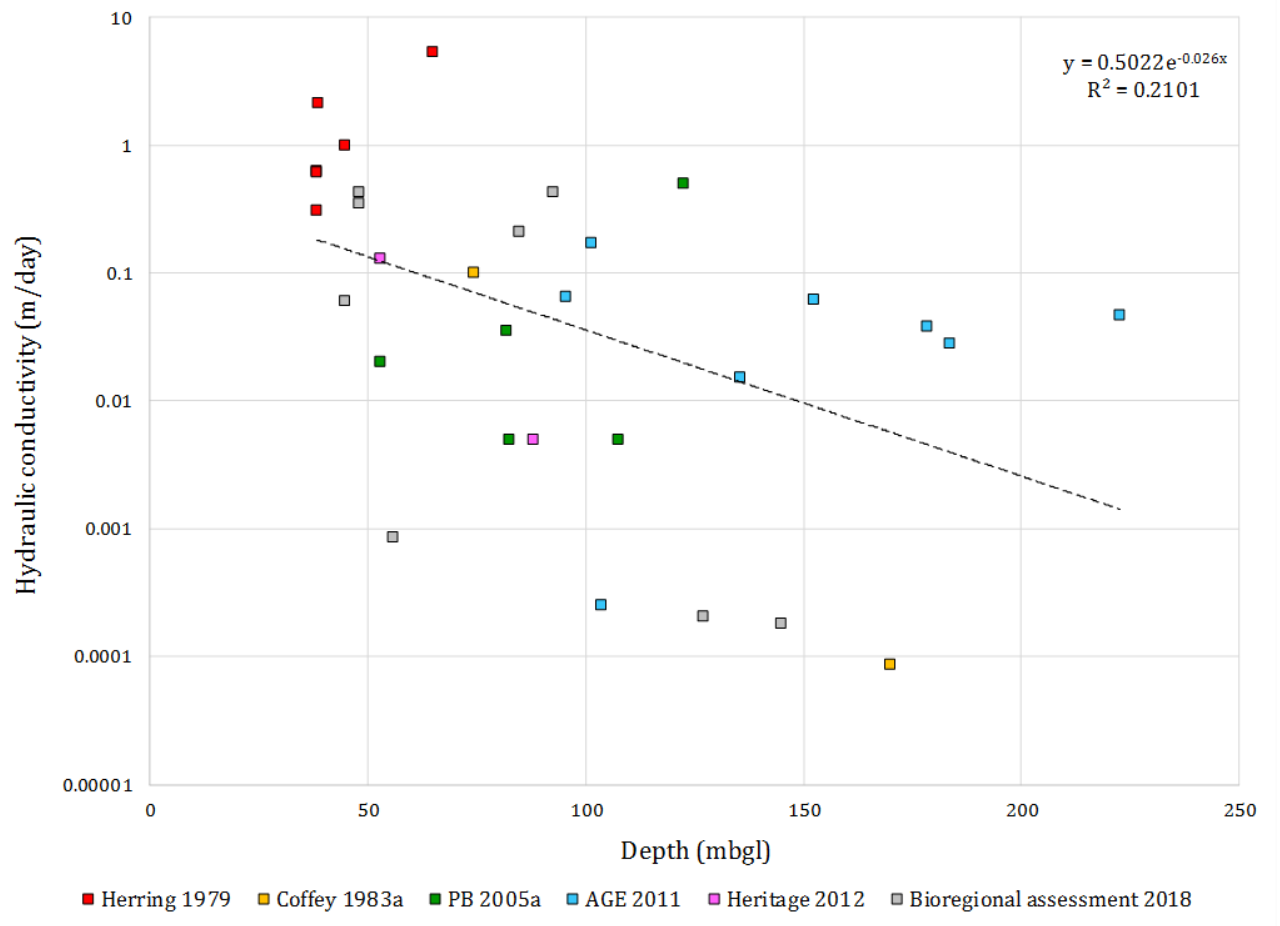



**Figure 5.6 Hydraulic conductivity versus depth, BTM complex coals**

### *5.3.2 Vertical hydraulic conductivity and anisotropy*

Due to the nature of their deposition, sedimentary formations are typically characterised by substantially higher hydraulic conductivity in the horizontal direction (Kh) than in the vertical (Kv). DST and slug test results therefore tend to be dominated by the horizontal hydraulic conductivity of fractured sandstone or other high hydraulic conductivity units which are encountered within the test interval. Intervening low hydraulic conductivity siltstone or mudstone strata, which form a key control on the vertical hydraulic conductivity at the formation scale, often have little effect on the test results. Hence slug and DST tests typically provide little or no reliable information on the potential vertical hydraulic conductivity of the tested formation unless the entire test section happens to intersect a low permeability siltstone or mudstone unit. This is highly unlikely to happen in a bore constructed for groundwater monitoring purposes which would typically target more permeable strata.

However, some useful information on vertical hydraulic conductivity and anisotropy (i.e. the ratio between Kh and Kv) can typically be obtained from laboratory core tests especially where the core samples are tested in both the horizontal and vertical directions.

As shown in Table 5.4 estimates of the vertical hydraulic conductivity are available for 21 core samples. These results suggest quite similar and generally very low median values in the range $1x10^{-7}$ to $2x10^{-6}$ m/d for the Purlawaugh Formation, Garrawilla Volcanics and Napperby Formation suggesting that these formations in particular include a relatively high proportion of low permeability strata.

A histogram of anisotropy values (i.e. the ratio Kh:Kv) for all core samples which have been tested in both directions is shown in Figure 5.7. As would normally be expected the majority of the values calculated exceed 1 (i.e. Kh typically exceeds Kv).

The median of the available estimates is 2.6 and as shown in Figure 5.7 the majority of the data sit in the range 1 to 5. It should be stressed that since these data relate to short (generally around 10 cm) test samples, rather than the entire formation, they are likely to represent an under-estimate of anisotropy at the formation scale. The chances of encountering both a high permeability sandstone and a continuous low permeability siltstone layer within a 10 cm test sample are much reduced compared to the probability of the same occurring in the formation as a whole. A more representative value for formation scale anisotropy is considered to be provided by the ratio between the median value from slug or DST tests (Table 5.2 and Table 5.3) and the median vertical hydraulic conductivity value from core tests (Table 5.4). Other authors have identified that taking the harmonic mean of the available hydraulic conductivity values can also return a representative formation scale Kv value. Anisotropy values estimated using both these approaches to estimating Kv are summarised in Table 5.7. Whilst it is recognised that the amount of data used to calculate the values shown in Table 5.7 is limited, the resulting values, which are very high in some cases using either set of Kv values used, are consistent with values estimated for similar sedimentary units in the Surat Basin in Queensland (OGIA, 2016).

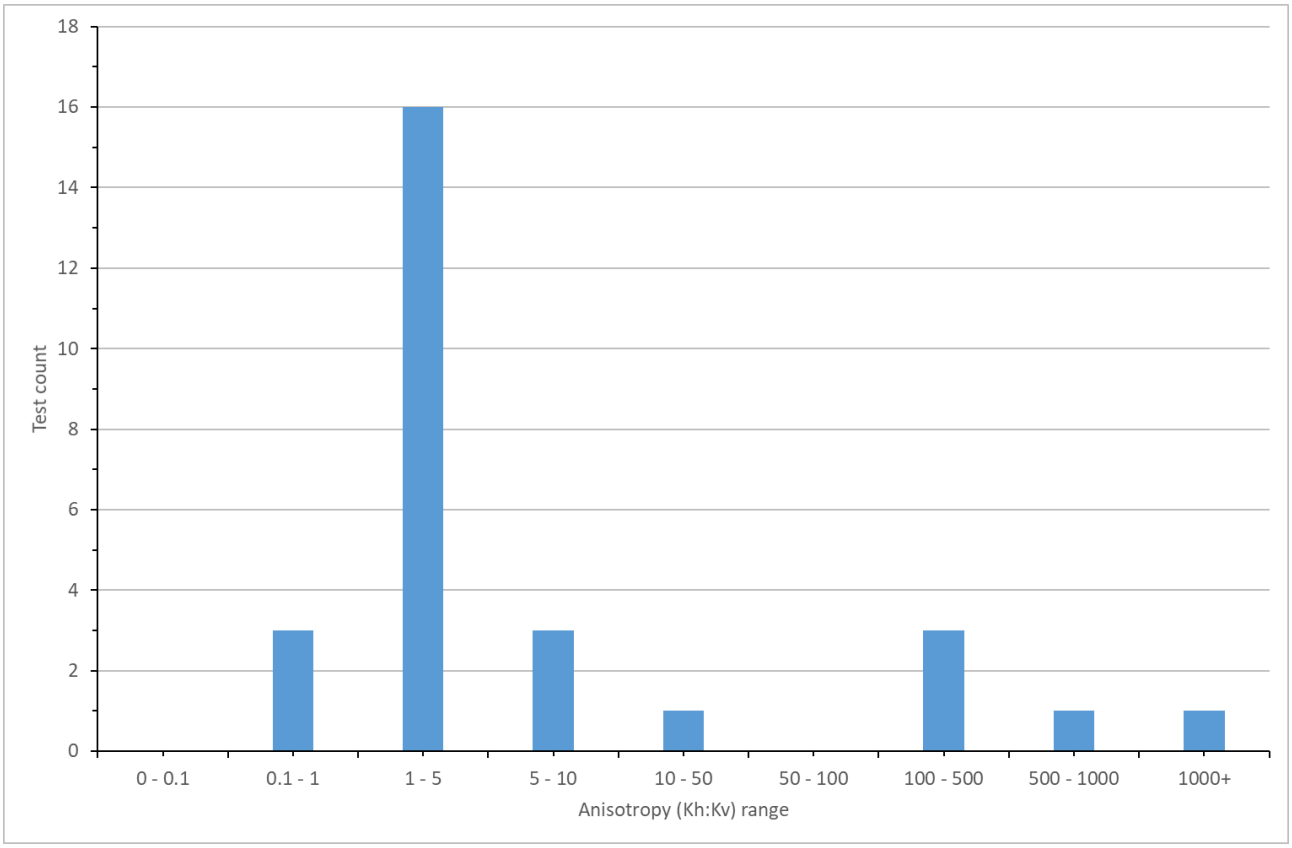



**Figure 5.7 Estimated anisotropy (ratio Kh:Kv), laboratory core tests**

**Table 5.7 Estimated formation scale anisotropy**

| Formation | Estimated Kh (m/d) | Estimated Kv (m/d) – median core test value | Estimated Kv (m/d) – harmonic mean of core test value | Estimated Formation Scale anisotropy (Kh:Kv) | Notes |
|---|---|---|---|---|---|
| Pilliga Sandstone | $1.1x10^{-1}$ | $8.0x10^{-3}$ | $5.1 x 10^{-2}$ | 2-14 | Kh = mean of 2 slug test results<br>Kv = mean/harmonic mean of 2 core test results |
| Purlawaugh Formation | $1.7x10^{-2}$ | $9.7x10^{-7}$ | $9.7 x 10^{-7}$ | 17,525 | Kh = median of 5 slug test results<br>Kv = median/harmonic mean of 4 core test results |
| Garrawilla Volcanics | $4.7x10^{-2}$ | $1.5x10^{-7}$ | $1.9 x 10^{-7}$ | 247,000 - 313,000 | Kh = median of 3 slug test results<br>Kv = median/harmonic mean of 4 core test results |
| Napperby Formation | $4.0x10^{-3}$ | $2.4x10^{-6}$ | $4.4 x 10^{-7}$ | 1,667 – 9091 | Kh = median of 7 slug test results<br>Kv = median/harmonic mean of 8 core test results |
| Digby Formation | $1.4x10^{-4}$ | $2.8 x 10^{-5}$ | $2.8 x 10^{-5}$ | 5 | Kh = No slug test data, median of 3 DST test results<br>Kv = single core test result |
| Hoskissons Coal Seam | $8.6x10^{-4}$ | No data | No data | 3 | Kh = median of 8 DST test results<br>Kv = no data<br>Anisotropy = assumed based on median of core test values |
| Arkarula Formation | $1.2x 10^{-2}$ | $1.5x10^{-5}$ | $3.0 x 10^{-5}$ | 400-800 | Kh = single slug test result<br>Kv = mean/harmonic mean of 2 core test results |
| Pamboola Formation | $2.3x10^{-3}$ | No data | - | 1000 | Kh = median of 5 slug test results<br>Kv = no data<br>Anisotropy assumed |

### *5.3.3 Storage parameters*

Specific yield and specific storage for the Namoi Alluvium have previously been estimated as part of detailed modelling study of the Upper Namoi Alluvium undertaken by the NSW Department of Natural Resources (McNeilage, 2006). Statistics for the Namoi Alluvium Zone 5 are shown in Table 5.8. It should be noted that the specific storage values quoted are above the theoretical ranges estimate by Rau et al. (2018), which suggests an upper bound for specific storage of $1.3x10^{-5}$ per metre ($m^{-1}$). It is understood that these modelled values are largely based on a small number of pumping test analyses undertaken in the alluvium. It is quite common for such tests to specific storage values in excess of $1.3x10^{-5}$ $m^{-1}$ due to the semiconfined nature of the aquifer, hence the material tested is not fully confined and the results can therefore tend towards specific yield.

**Table 5.8 Namoi Alluvium Zone 5, modelled storage parameters**

| Statistic | Specific Yield, Narrabri Formation – Layer 1 | Specific Storage ($m^{-1}$), Gunnedah Formation – Layer 2 |
|---|---|---|
| Min | 0.01 | $1x10^{-4}$ |
| Average | 0.044 | $3.5x10^{-4}$ |
| Maximum | 0.10 | $5.0x10^{-4}$ |

***Source:*** *McNeilage (2006).*

## 5.4 Groundwater recharge

As described below initial estimates of groundwater recharge for numerical modelling purposes has been estimated through reference to chloride data for local groundwater bores and by undertaking a soil moisture balance. The resulting estimates are similar to those estimated as part of the recharge rates included in the Bioregional Assessment Namoi subregion (Bioregional Assessment Programme, 2016b). Consideration was also given to estimating recharge using the ''watertable fluctuation method' outlined in Leaney et al. (2011). However, insufficient detailed (daily or sub-daily) water level observations in bores thought to be monitoring the water table were available to make this application of this methodology worthwhile.

### *5.4.1 Chloride mass balance (CMB)*

Groundwater quality datasets can also be used to indirectly estimate recharge using the chloride mass-balance method (CMB). Chloride concentrations of rainfall-runoff water generally increase as the water infiltrates through the root zone due to evapotranspiration, with concentrations remaining constant below the root zone (Scanlon et al., 2002). As such, differences between the chloride deposition rate (D) and the chloride concentration of groundwater ($C_{gw}$) can be used to estimate groundwater recharge (R) as per Equation 1 (Leaney et al., 2011).

*Equation 1* $$R = D / C_{gw}$$

The assumptions behind application of the CMB are that (Wood, 1999):

- chloride in groundwater is sourced from rainfall (not from rock weathering or interactions with streams or deeper aquifers);
- chloride is conservative in the system (no sources or sinks);
- chloride flux does not change over time (steady state conditions);
- there is no recycling of chloride in the system (e.g. due to irrigation drainage); and
- the chloride imported/exported via runoff or runon can be accounted for (Leaney et al., 2011).

Recharge was estimated for the Project Area using this method, with results presented in Table 5.9. The average chloride deposition rate was extracted from a national dataset (Leaney et al., 2011), while chloride concentrations of groundwater were sourced from the Project's existing groundwater monitoring network dataset. The calculated results are also compared to recharge estimates included in the Bioregional Assessment Namoi subregion (2016b).

**Table 5.9 Recharge – calculated site chloride mass balance vs Bioregional Assessment (2016b)**

| Formation | Number of bores* | Samples | Minimum recharge (mm/year) | Average recharge (mm/year) | Maximum recharge (mm/year) | Bioregional Assessment recharge range (mm/year)^ |
|---|---|---|---|---|---|---|
| Alluvium | 9 | 29 | 11.3 | 11.9 | 13.1 | < 1.0 – 68.7 |
| Pilliga Sandstone | 1 | 23 | 6.2 | 16.1 | 22.8 | 16.5 |
| Purlawaugh Formation | 3 | 54 | 3.1 | 5.0 | 12.7 | 0.1 |
| Garrawilla Volcanics | 9 | 105 | 2.3 | 2.9 | 10.6 | 0.3 – 6.6 |
| Napperby Formation | 9 | 117 | 0.9 | 2.0 | 16.3 | 0.1 – 4.3 |
| Digby Formation | - | - | - | - | - | 0.2 – 6.2 |
| Hoskissons Coal Seam | 1 | 4 | 0.7 | 2.0 | 7.3 | - |
| Arkarula Formation | 1 | 4 | 0.4 | 0.9 | 3.3 | - |
| Pamboola Formation | 3 | 53 | 0.2 | 0.3 | 0.5 | 0.2 – 0.4 |

***Note:*** **Includes bores located in both subcrop and outcrop areas.*

***Source:*** *^Bioregional Assessment (2016b).*

As shown in Table 5.9, recharge rates calculated by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) using the CMB method and values reported in the Namoi Bioregional Assessment (2016) using a similar method are generally broadly consistent. The range of recharge in the alluvium reported from the bioregional assessment dataset is much more variable and reflect the localised availability of site chemistry data compared to the regional coverage of the bioregional assessment. The bioregional assessment also reports a substantially lower value for the Purlawaugh Formation than suggested by the CMB data.

### *5.4.2 SWAT model*

Recharge to the Project Area has also been estimated using a simple Soil & Water Assessment Tool (SWAT) model (Arnold et al., 2012). Global Food and Agriculture Organisation of the United States (FAO) soil and static land use were assumed, and weather was applied using SILO climate data. SWAT calculated percolation rates to the Quaternary alluvium of about 81 mm/year and around 4 mm/year elsewhere. The SWAT estimated recharge rates to the Quaternary alluvium are therefore higher than those estimated by the Bioregional Assessment (Aryal et al., 2018) or using the CMB method.

On the other hand, the SWAT estimate of 4 mm/year recharge to other strata is within the range of values suggested by other methods.

Results from the SWAT modelling suggest a long-term average potential evaporation rate of 397 mm/year, somewhat lower than the 580-680 mm/year estimated by BoM.

## 5.5 Water quality

### *5.5.1 Salinity*

This section describes the groundwater within the hydrostratigraphic units. Salinity is often the key constraint to groundwater use and can be assessed through reference to TDS concentrations and/or EC. EC can be used to estimate TDS concentrations by multiplying by 0.67 (Australian and New Zealand Environment and Conservation Council, 2000). Salinity is commonly described on a scale ranging from fresh to extremely saline. The FAO (2013) provide a useful set of categories for assessing salinity based on TDS concentrations, and is categorised here using EC as follows:

- 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

EC data is collected routinely from the Narrabri monitoring bore network. Figure 5.8 presents EC measurements in monitoring bores from hydrostratigraphic units from the existing mine as a box and whisker plot which shows the spread of the data and a range of statistics (including min, max, median, interquartile range [25th percentile to 75th percentile] and any outliers). The plot is used here to illustrate the distribution of salinity data within each of the hydrostratigraphic units. No EC data are currently available for Digby Formation. The salinity categories described previously are shown with equivalent EC measurements. Summary statistics of the field EC data is also presented in Table 5.10.

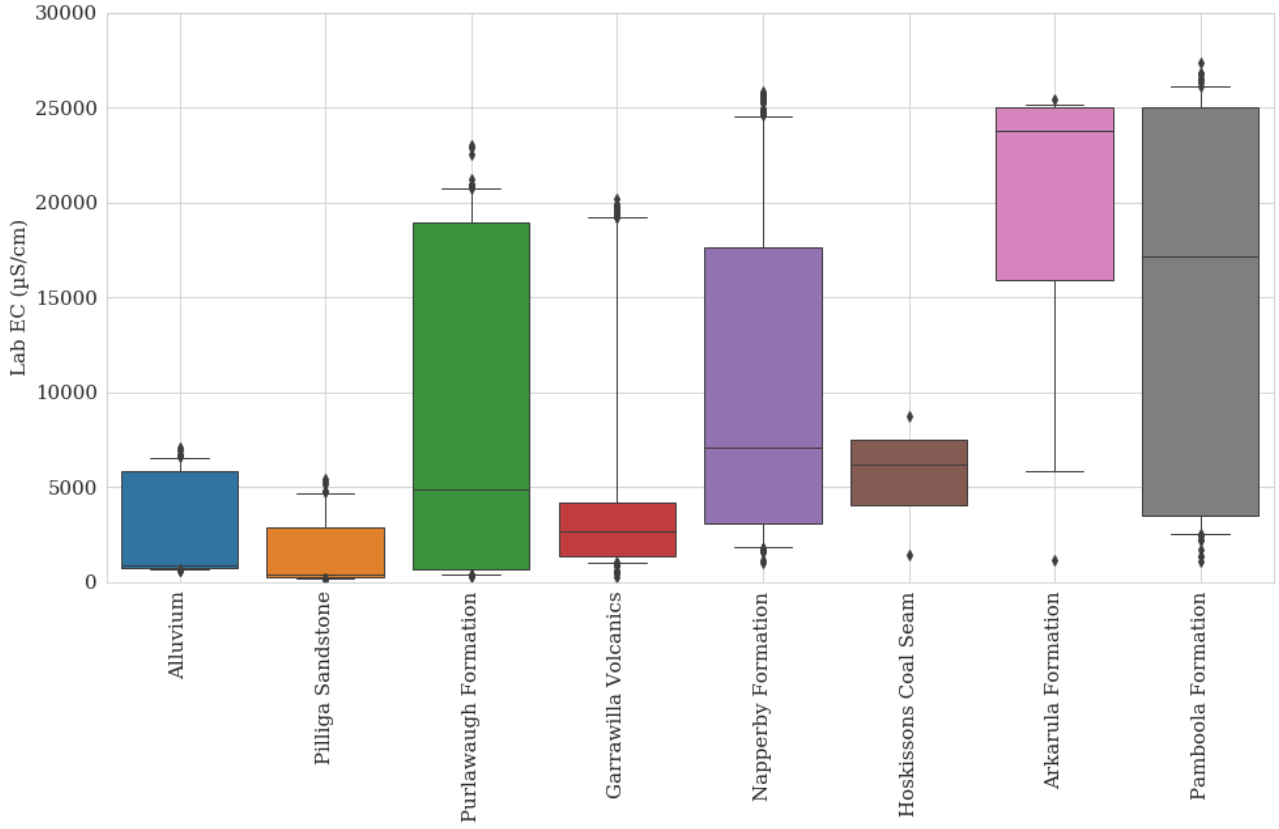



**Figure 5.8 Distribution of groundwater field EC data by hydrostratigraphic unit**

## Table 5.10 Summary statistics, field EC data by hydrostratigraphic unit

| | | | Field EC (µS/cm) | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Formation** | **No of bores** | **No of tests** | **Mean** | **Min** | **25%** | **50%** | **75%** | **Max** |
| Alluvium | 9 | 92 | 2292 | 597 | 704 | 853 | 5860 | 7050 |
| Pilliga Sandstone | 4 | 93 | 1410 | 129 | 256 | 393 | 2900 | 5440 |
| Purlawaugh Formation | 4 | 181 | 8343 | 293 | 674 | 4880 | 18960 | 34900 |
| Garrawilla Volcanics | 9 | 360 | 4606 | 274 | 1379 | 2630 | 4158 | 20200 |
| Napperby Formation | 9 | 438 | 9632 | 1020 | 3083 | 7040 | 17628 | 33100 |
| Hoskissons Coal Seam | 1 | 5 | 5580 | 1410 | 4070 | 6180 | 7490 | 8750 |
| Arkarula Formation | 1 | 15 | 19230 | 1140 | 15915 | 23770 | 25015 | 25420 |
| Pamboola Formation | 3 | 174 | 14785 | 1050 | 3468 | 17175 | 25025 | 27340 |

All sub-surface strata will show some degree of variability since salinity can be affected by a range of factors including sampling depth, aquifer residence time and evapo-concentration processes occurring in near surface areas. However, in general, higher permeability aquifer units (especially where they occur at shallow depths) are typically characterised by relatively low salinity, whilst relatively high salinity and variability would normally be expected in low permeability aquitard units. As expected, both the main aquifers in the area the Namoi Alluvium and the Pilliga Sandstone are characterised by relatively low salinities and variability (Figure 5.8). The median EC for both of these aquifers is less than 700 µS/cm suggesting relatively fresh water predominates. Data for the Garrawilla Volcanics also suggest relatively fresh water and return a median EC of 2,630 µS/cm, suggesting brackish to moderately saline.

Median EC values for the Purlawaugh and Napperby Formations suggest moderately saline conditions on average, but show a high degree of variability and relatively fresh waters in some cases, suggesting that potentially useful fresh water aquifers can be encountered within these formations.

Data for the Hoskissons Coal Seam suggest moderately saline conditions based on the median EC value of 6,180 µS/cm, whilst data for the two deepest units monitored in the Project Area, the Arkarula and Pamboola Formation, suggest median EC values of in excess of 15,000 µS/cm suggesting saline groundwater. The relatively high salinity values recorded in samples taken from the Arkarula Formation may reflect the depth of this unit and the lack of any known outcrop areas. Residence times with the strata may therefore be substantial resulting in relatively high salinity groundwater.

The statistics shown in Figure 5.8 summarise all of the available salinity data over different time periods into a single plot. To examine trends over time, a series of water quality over time plots, one for each hydrostratigraphic unit, were prepared and presented in Appendix C.

The shallowest bores in each formation (P51 in Garrawilla volcanics, P4 in Napperby Formation, P5 in Pamboola Formation and P9 in Purlawaugh Formation) consistently show higher EC values than the deeper bores in each formation. This suggests that the lithology in the shallower sections are generally finer grained and therefore less permeable, and/or that near surface evapotranspiration is concentrating salts in groundwater especially in areas with shallower water table. Data for several monitoring points also show a marked reduction in EC during the relatively wet period which occurred in early 2012.

### 5.5.2 *Groundwater types*

Groundwater chemistry from groundwater bores in the Project Area are grouped into hydrostratigraphic units and plotted using a piper diagram (Figure 5.9). Piper diagrams are useful to visualise the dominant chemistry and identify to 'groundwater types' in each hydrostratigraphic unit.

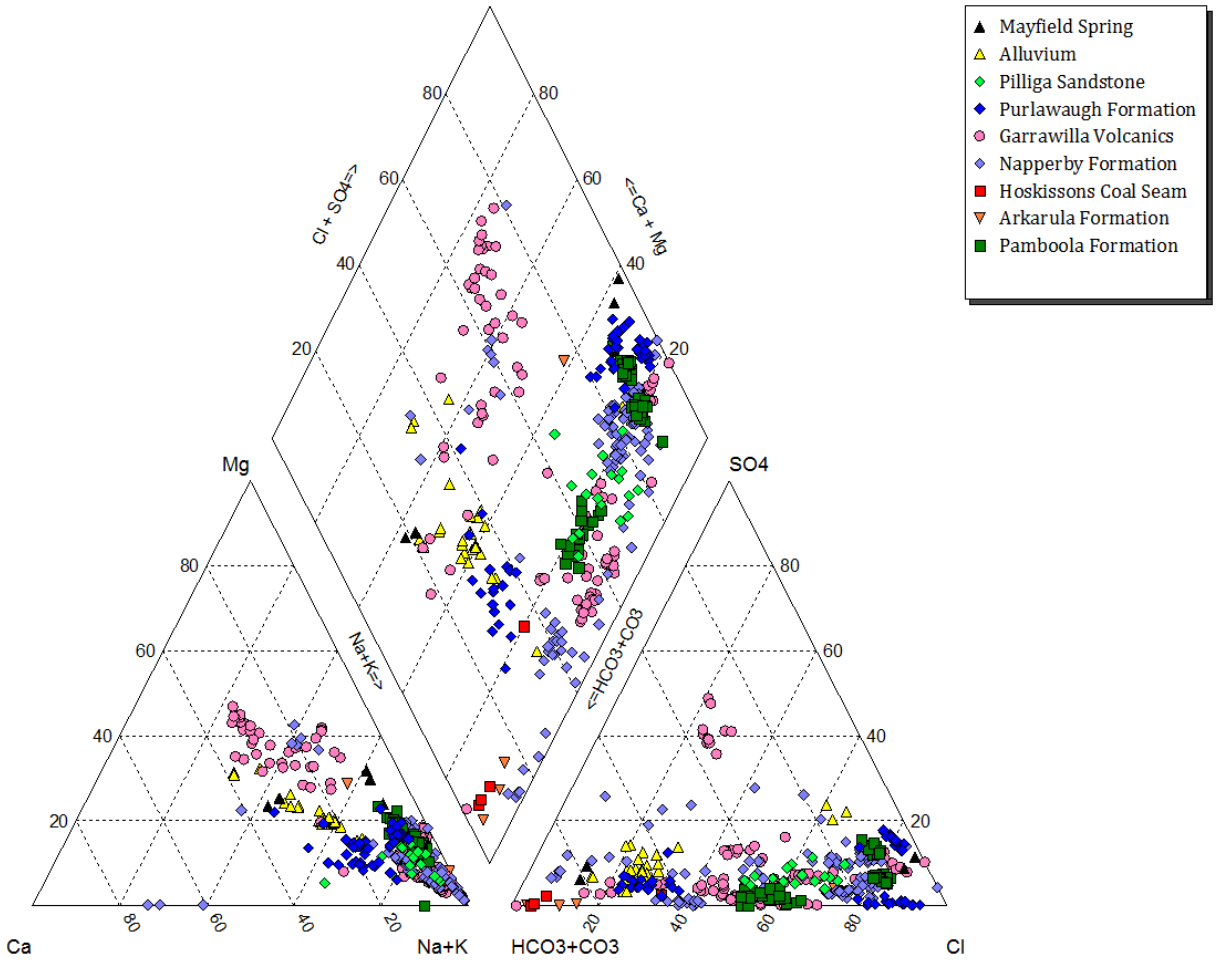



**Figure 5.9 Piper plot of groundwater chemistry by hydrostratigraphic unit**

Results for the majority of the samples tested suggest relatively low proportions of sulphate, but a broad distribution from bicarbonate to chloride dominance among the other anions. Chloride dominances tend to occur in higher salinity waters from deeper formations, with bicarbonate dominance more prevalent in fresher groundwater samples from shallower formations. However, as shown in Figure 5.9 some water samples from the Hoskissons Seam and Arkarula Formation suggest bicarbonate dominance, which may be indicative of mineralisation source in the Permian sequence (Aquaterra, 2009).

Surface water samples taken for the WMP from the Mayfield Spring suggest variable hydrochemistry with two samples characterised by relatively high proportions of bicarbonate and two further samples suggesting relatively low bicarbonate but high proportions of Chloride. Importantly none of the four samples plot close to other samples from the Pilliga Sandstone, which was reported to be a potential source for this spring (Eco Logical, 2016). However, two samples shown in the piper plot, as well as a sample taken as part of the Bore Census Report (Appendix G) and a sample presented in Aquaterra (2009), suggest that the water chemistry of the Mayfield Spring is most similar to that of the Purlawaugh Formation.

## 5.6 Groundwater use

### *5.6.1 Private water users*

Information on groundwater use within the study area has been extracted from two sources:

- the NSW DPI-Office of Water PINNEENA groundwater archive (Version 11.1, DPI-Office of Water, 2016); and
- the BoM NGIS (BOM, 2019).

Of these two datasets the PINNEENA groundwater archive is considered to be the primary data source. However, the NGIS database has been populated using information from PINEENA and has been updated more recently than the version of the PINNEENA database currently available. Accordingly, additional borehole records held within the NGIS database have been included in the project database of private water users. Reference to this combined database suggests the presence of some 2,215 registered works within the domain of the groundwater model developed for this groundwater assessment, many of which may no longer be present. This total also includes some 682 works which were drilled for other non-water supply purposes such as dewatering, exploration or groundwater monitoring and/or are no longer in use. Accordingly, there are thought to be up to 1,533 existing water supply bores within the groundwater model domain, the locations of which are shown in Figure 5.10. It should be noted, however, that this total includes some 205 registered works for which the bore purpose is marked as "unknown" and hence which may not be water supply bores.

Registered water supply bores in the model domain are primarily identified as being used for irrigation or stock & domestic purposes or for other undefined purposes. As shown in Table 5.11 only around 73 of these bores are associated with groundwater licences with stated volumes, the current total licensed volume from which is approximately 147 gigalitres per year. Furthermore, information on the hydrostratigraphic unit (or aquifer) targeted by each bore is not typically provided in either the PINNEENA or NGIS systems. The breakdown of licensed extraction by unit shown in Table 5.11 have therefore been estimated by intersecting the recorded depth of each bore with the geological surfaces developed for this assessment. This analysis suggests that around 82% of the licensed volume is extracted from relatively shallow bores targeting the Quaternary alluvium (predominantly the Namoi Alluvium). As shown in Table 5.11, the majority of the remainder of the licensed extraction within the model domain is from the Pamboola Formation or older units (14%), with only small amounts of extraction licensed from bores thought to be extracting from the Pilliga Sandstone and Purlawaugh Formation.

Overall, registered water supply bores in the broader region are located predominantly within the Namoi Alluvium, and include a number of bores used for irrigation purposes which tap into this highly productive aquifer. Closer to the Project however, groundwater use is less prevalent and less intensive. Privately-owned registered water supply bores in the immediate vicinity of ML 1609 and MLAs 1 and 2 are predominantly used for stock and domestic purposes, which reflects the lack of highly productive formations immediately to the east (outside of the extent of Namoi alluvium), and lack of development to the west (i.e. within the Pilliga East State Forest).

A bore census was conducted by ENRS in 2019 and 2020 to confirm the location and use of groundwater bores in the vicinity of the Project and surrounds. The results of the bore census confirmed that groundwater use near the Project is predominantly stock and domestic. The Bore Census Report is provided in Appendix G.

### Table 5.11 Registered water supply bores with licensed quantities within the groundwater model domain

| Hydrostratigraphic Unit | Commercial and Industrial (ML/yr) | Irrigation (ML/yr) | Stock and Domestic (ML/yr) | Other water supply (ML/yr) | Total volume (ML/yr) | No of bores |
|---|---|---|---|---|---|---|
| Alluvium | - | 85,948 | 158 | 39,452 | 125,558 | 60 |
| Pilliga Sandstone | - | 246 | - | 3994 | 4,240 | 5 |
| Purlawaugh Formation | - | 383 | - | - | 383 | 1 |
| Garrawilla Volcanics | - | - | - | - | - | - |
| Napperby Formation | - | 15 | - | - | 15 | 1 |
| Digby Formation | - | - | - | - | - | - |
| Hoskissons Coal Seam | - | - | - | - | - | - |
| Arkarula Formation | - | - | - | - | - | - |
| Pamboola Formation or older | - | 14704 | - | 2546 | 17,250 | 6 |
| **Total** | **-** | **101,296** | **158** | **45,992** | **147,446** | **73** |

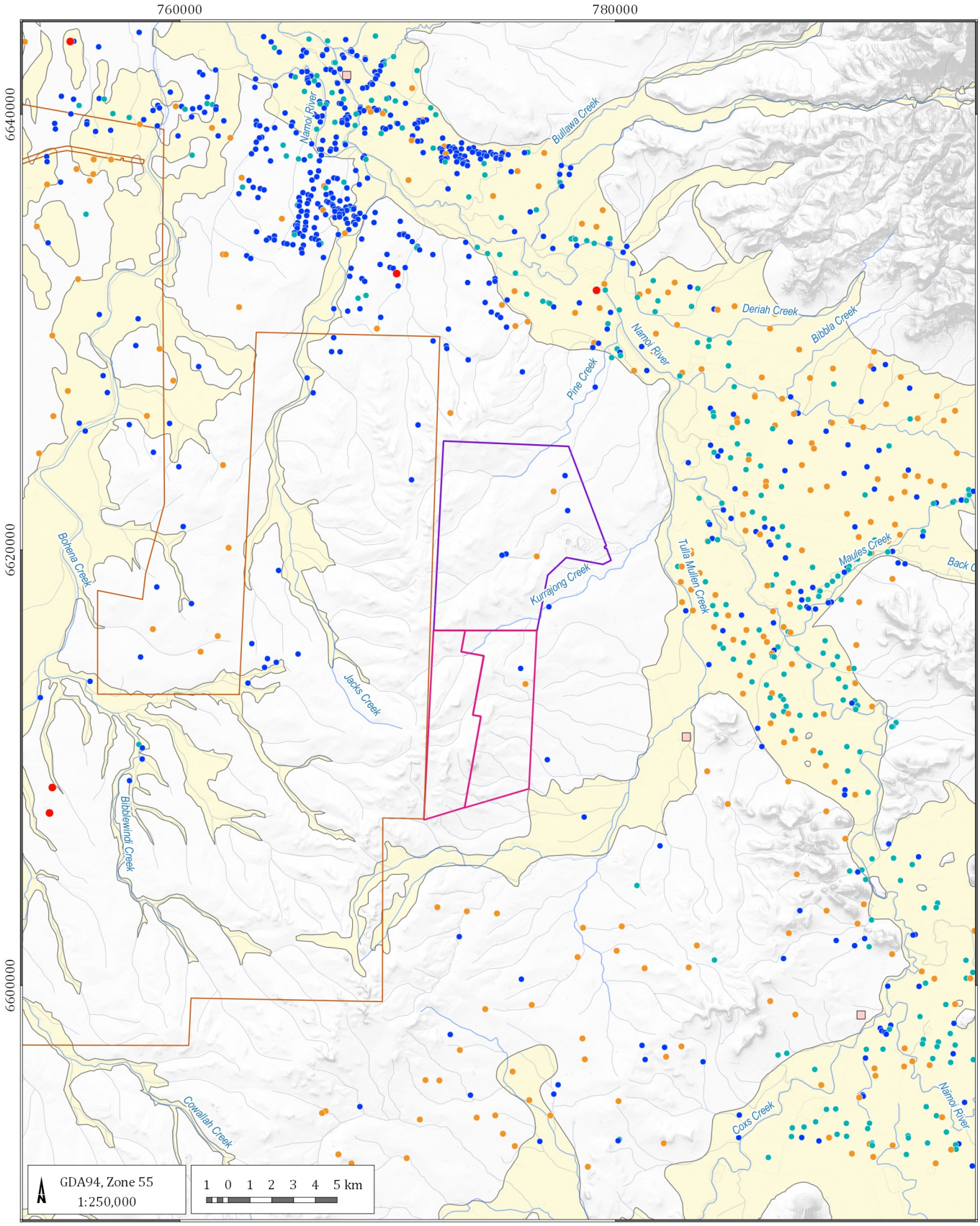
***Note:*** *Bore location, depth and licensed volumes as provided in the combined PINNEENA and NGIS databases. Hydrostratigraphic units identified based by intersecting the recorded depth of each bore with the geological surfaces developed for this assessment*

As shown in Table 5.12 a further 1,460 water supply bores in the groundwater model domain are not associated with licensed quantities.

### Table 5.12 Registered water supply bores with no licensed quantities within the groundwater model domain

| Hydrostratigraphic Unit | Commercial and Industrial (No of bores) | Irrigation (No of bores) | Stock and Domestic (No of bores) | Other water supply (No of bores) | Total No of bores |
|---|---|---|---|---|---|
| Alluvium | 2 | 197 | 190 | 519 | 908 |
| Pilliga Sandstone | 4 | 28 | 34 | 263 | 329 |
| Purlawaugh Formation | - | 1 | 2 | 14 | 17 |
| Garrawilla Volcanics | - | - | 9 | 6 | 15 |
| Napperby Formation | - | 3 | 7 | 12 | 22 |
| Digby Formation | - | - | 2 | - | 2 |
| Hoskissons Coal Seam | - | - | 4 | - | 4 |
| Arkarula Formation | - | - | 4 | 4 | 8 |
| Pamboola Formation or older | 1 | 32 | 51 | 71 | 155 |
| **Total** | **7** | **261** | **303** | **889** | **1,460** |

***Note:*** *Bore location, depth and licensed volumes as provided in the combined PINNEENA and NGIS databases. Hydrostratigraphic units identified based by intersecting the recorded depth of each bore with the geological surfaces developed for this assessment*




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Mining Lease Boundary (ML 1609)
- Proposed Narrabri Gas Project (Santos)
- Provisional Mining Lease Application Area
- Quaternary alluvium

**Registered water supply bores**

- Commercial and Industrial
- Irrigation
- Stock and Domestic
- Water Supply

Narrabri Stage 3 Extension GIA (G1972)

## Registered water supply bores

DATE 27/04/2020

FIGURE No: **5.10**

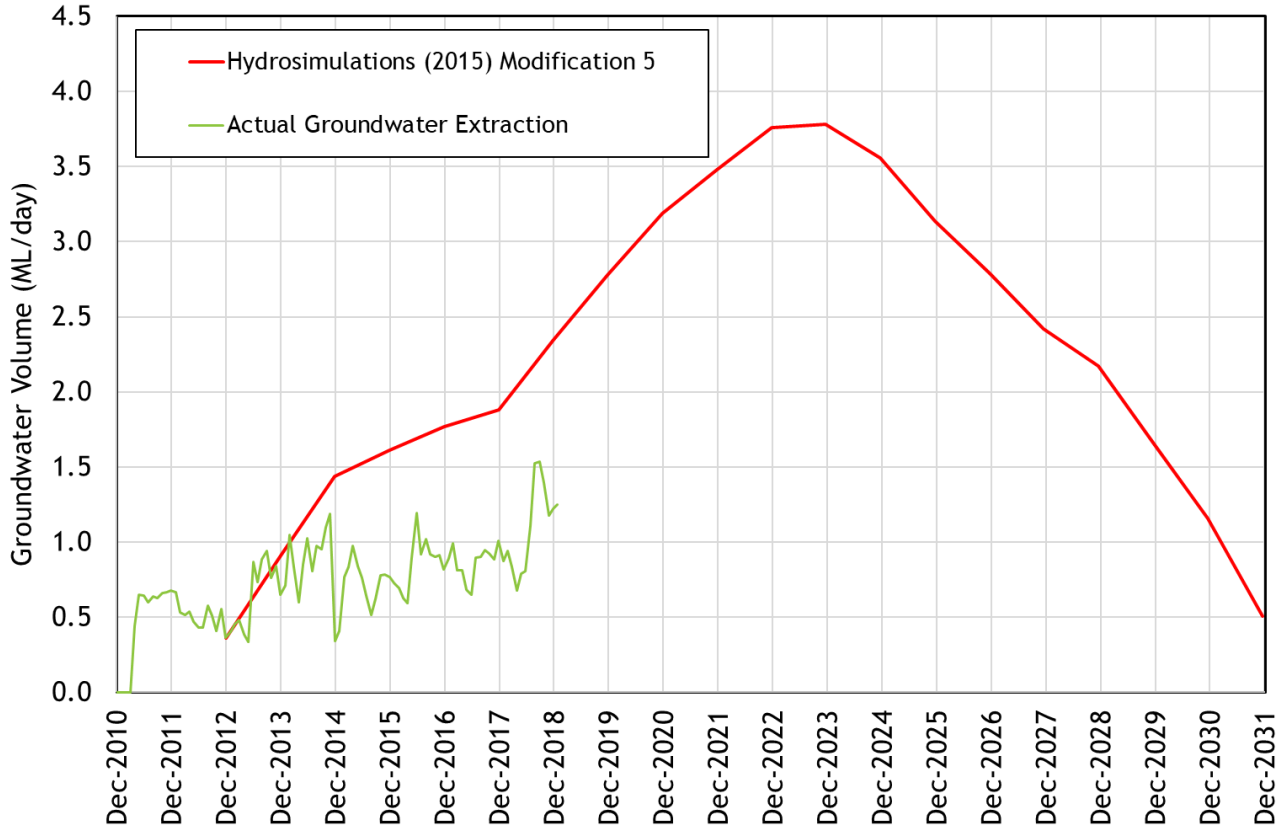
©2020 Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) - www.ageconsultants.com.au
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\05.10_G1972_Registered water supply bores.qgs

### 5.6.2 *Groundwater inflows and mine use*

Groundwater interception by the Narrabri Mine mainly occurs from dewatering of the coal seam, humidity lost due to ventilation fans, and water trapped as moisture in ROM coal. The volume of groundwater inflows is presented in Figure 5.11. The estimates reported by WRM (2019) show that actual water volumes extracted are generally less than 1 ML/d until the second half of 2018, where volumes extracted have increased to between 1 to 1.5 ML/d. Estimated water volumes are based on flowmeter readings from the underground into the surface boxcut plus gas drainage extraction, less the demand for underground returns (with other losses such as ventilation fans and water in extracted ROM coal being sufficiently low to warrant exclusion).

Figure 5.11 shows that actual extracted volumes have been consistently below predicted groundwater inflows by HydroSimulations (2015). For example, actual groundwater inflows in December 2018 and January 2019 were approximately 1.25 ML/d, whereas HydroSimulations (2015) predicted groundwater inflows should be approximately 2.5 ML/d at this time. The lower actual inflows than those predicted are predominantly due to the underground mine development and associated ROM coal production rate to date, which has been lower than what was simulated in modelling by HydroSimulations (2015). Actual ROM coal production in 2018 was approximately 5 Mtpa, compared to the ROM coal production rate of approximately 10 Mtpa in 2018 simulated by HydroSimulations (2015). The reduced ROM coal production in 2018 reflects the slower rate of mine development that has occurred to date, leading to lower groundwater inflows to the mine.

Current water take for dewatering purposes is well within current licensed volumes (Section 2.5).




***Source:*** *WRM (2019).*

**Figure 5.11 Comparison of predicted and actual groundwater inflows**

In addition to groundwater inflows to the underground mining area, groundwater is extracted from NCOPL's existing alluvial bore located adjacent to the Namoi River (Figure 1.2) when required (i.e. when supply from the underground mining area is insufficient to meet water demand and water cannot be extracted direct from the Namoi River using NCOPL's existing Namoi River pump).

The existing alluvial bore (work approval 90WA812891) is located within the Upper Namoi Zone 5 groundwater source (within the WSP for the Namoi Alluvial Groundwater Sources). Water is extracted in accordance with the relevant WALs held by NCOPL and the rules prescribed in the WSP.

## 5.7 Groundwater dependent ecosystems

GDEs are defined as *ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis, so as to maintain their communities of plants and animals, ecosystem processes and ecosystem services* (Richardson *et al*., 2011).

GDEs can be classified into the following types (Doody et al., 2019):

- **Subterranean ecosystems** – stygofauna in cave and aquifer ecosystems.
- **Aquatic ecosystems** – ecosystems dependent on surface expressions of groundwater, e.g. river baseflow, springs, swamps.
- **Terrestrial ecosystems** – ecosystems dependent on subsurface expressions of groundwater, e.g. some vegetation and riparian communities.

The National Groundwater Dependent Ecosystem Atlas (GDE Atlas) was developed by BoM as a national dataset of Australian GDEs to inform groundwater planning and management (BoM, 2018). The GDE Atlas contains information about aquatic, terrestrial and subterranean ecosystems. GDEs derived in the GDE Atlas are mapped according to the following classifications:

- high potential for groundwater interaction;
- moderate potential for groundwater interaction; or
- low potential for groundwater interaction.

The GDE Atlas identifies potential and known aquatic and terrestrial GDEs in the vicinity of the Project, which are shown on Figure 5.12 and described in the relevant subsections below. The GDE Atlas has not analysed the presence of subterranean ecosystems in NSW.

As discussed previously in Section 2.4 as of 30 June 2020 a number of the WSPs of relevance to the Project now identify high priority GDE areas which are included in the GDE Atlas as 'high potential' GDE areas. The June 2020 iteration of the WSP for the GAB Southern Recharge Groundwater Source now also lists the Hardys and Eather Springs (Section 5.7.1.3) as high priority spring GDE sites. Predicted impacts on these springs and other potential GDE sites identified in relevant WSPs are discussed in Section 7.6.2.

### *5.7.1 Aquatic ecosystems*

#### *5.7.1.1 Namoi River*

The Namoi River is located approximately 5 km to the east of the Narrabri Mine.

As shown in Figure 5.12, high potential aquatic GDEs identified in the GDE Atlas (BoM, 2018) have been mapped along the Namoi River from Boggabri to Turrawan.

### *5.7.1.2 Mayfield Spring*

The Stage 2 Hydrogeological Assessment (Aquaterra, 2009) identified the Mayfield Spring as a spring discharging to the surface which has been utilised for stock watering. Aquaterra (2009) described the flows rate from the spring as very low (<0.1 L/s), emanating within a low-lying area in a valley, and likely derived from the Purlawaugh Formation (Aquaterra, 2009). Aquaterra concluded that the Mayfield Spring was not expected to be impacted by the Approved Mine, although it may be at risk if drawdowns in the Purlawaugh Formation are greater than predicted (Aquaterra, 2009).

The Mayfield Spring was also assessed in the Narrabri Gas Project GDE (Springs) Risk Assessment Report (Eco Logical, 2016). Given the proximity of this spring site to the interface between the Pilliga Sandstone and the Purlawaugh Formation, the Mayfield Spring was identified in this report as being most likely to be a water table spring sourced from the Pilliga Sandstone (Eco Logical, 2016). However, no sampling was undertaken at the time to confirm the source aquifer attribution. Subsequent laboratory testing of samples taken from Mayfield spring by NCOPL staff suggests that the water chemistry at the site is quite different to that observed in water bores completed into the Pilliga Sandstone, but is similar to samples taken from the Purlawaugh Formation (Figure 5.9). In addition, it is noted that the location of the Mayfield Spring assessed in Eco Logical (2016) is inconsistent with the location inspected by ENRS in 2019. The location of the Mayfield Spring, inspected by ENRS in 2019, is shown on Figure 5.12. This site is situated some distance from the Pilliga Sandstone in an area where the Deriah Formation (part of the Napperby Formation) is mapped as being present at outcrop but relatively close to the boundary with the underlying underlying Garrawilla Volcanics and Purlawaugh Formation.

As described in the Bore Census report (Appendix G), the Mayfield Spring was inspected on 16 August 2019. The Mayfield Spring had visible discharge and was determined to be a potential groundwater feature (Appendix G). A water sample taken at the time of inspection indicates that the water chemistry of the Mayfield Spring had a similar signature to the water chemistry of the Mayfield Spring presented by Aquaterra (2009) (i.e. water chemistry had a similar signature to Purlawaugh Formation groundwater). Accordingly, both the chemistry and geological mapping tend to support the Aquaterra (2009) source aquifer attribution of the Purlawaugh Formation, rather than Eco Logical (2016) assessment. Irrespective of the source aquifer, physical inspection of the site by ENRS (Appendix G) suggests that the feature has formed in an area where the water table (or phreatic surface) intersects the ground surface, rather than being fed by a deeper confined aquifer. The feature is also being actively used for livestock watering and has been modified for this purpose.

The Mayfield Spring is not mapped on the GDE Atlas (BoM, 2018) or listed as a high priority GDE in the relevant WSPs (DWE, 2009b; DPI–Office of Water, 2012c).

### *5.7.1.3 Hardys Spring and Eather Spring*

Aquaterra (2009) also identified two other potential springs, Hardys Spring and Eather Spring, located further south of the Narrabri Mine (approximately 3.5 km and 5.5 km south of MLAs 1 and 2, respectively). The location of these potential springs was based on information provided by the NSW Office of Water (now DPIE-Water). Modelling from Aquaterra indicated that predicted drawdown within the upper geological units would be extremely small in the vicinity of the potential springs and therefore no adverse impacts were expected (Aquaterra, 2009).

Hardys Spring and Eather Spring are identified as high priority GDEs in the WSP for the NSW Great Artesian Basin Groundwater Sources 2020. Furthermore, both sites are identified as high priority GDEs in a 2010 State of the Catchments (Department of Environment, Climate Change and Water, 2010) report, in the GDE Atlas (BoM, 2018) and in the related Namoi bio-regional report asset register. The original source for all of these documents appears to be an unpublished desktop assessment undertaken by the DWE (2008). It would appear therefore that these springs may not have been field verified prior to the current study.

Hardys Spring and Eather Spring were also assessed in the Narrabri Gas Project GDE (Springs) Risk Assessment Report (Eco Logical, 2016), although neither site was inspected as part of this study. Given the proximity of the spring sites to the interface between the Pilliga Sandstone and the Purlawaugh Formation, Hardys Spring and Eather Spring were identified in this report as being most likely to be water table springs sourced from the Pilliga Sandstone (Eco Logical, 2016).

As described in the Bore Census report (Appendix G), Hardys Spring and Eather Spring were inspected by ENRS on 20 May 2020 and their confirmed locations are shown on Figure 5.12.

During the field visit, the Hardys Spring feature was observed to be a moist, grass lined drainage channel with no surface ponding, flow or visible seepage. Anecdotal evidence provided by the landholder suggests that significant discharge from the spring has not occurred for around 10 years (ENRS, 2020). Based on the confirmed location of the Hardys Spring, it is likely that any historical flows were sourced from the Pilliga Sandstone (consistent with the aquifer attribution suggested by Eco Logical [2016]).

The Eather Spring feature was identified as two adjacent dams associated with a drainage line (herein referred to as Eather Spring [Dam 1] and Eather Spring [Dam 2]). Whilst some erosional features were observed which may be indicative of historic flow, no visible soil seepage or moisture was observed within the drainage lines during the visit. Furthermore, the landholder reported that the Eather Spring had also not flowed in approximately 10 years (ENRS, 2020). At the time of inspection, both dams contained rainwater thought to be derived from a recent rainfall event (ENRS, 2020). Based on the location of the Eather Spring dams, it is likely that any historical flows were sourced from the Pilliga Sandstone (supporting the aquifer attribution assessed in Eco Logical [2016]). However, samples taken from both Eather Spring dams during the site visit (see Appendix G, Figure 3) suggest quite different major ion chemistry from that observed in most Pilliga Sandstone bores and recently observed at Mayfield Spring. Conversely, the major ion chemistry is quite similar to that observed at three creek sites which were also sampled during the recent visit and are thought most likely to be indicative of ponded surface water rather groundwater seepage (Section 5.8.2) (consistent with the landholder's statements that the Eather Spring had not flowed in approximately 10 years).

#### *5.7.1.4 Other Features of Interest*

The Bore Census report (Appendix G) also identifies a number of dams that had no observable flow or distinguishing geology observed during the field visit, which led ENRS to conclude that these dams are unlikely to be groundwater features. Accordingly, these dams have not been assessed further in this report.

### *5.7.2 Terrestrial ecosystems*

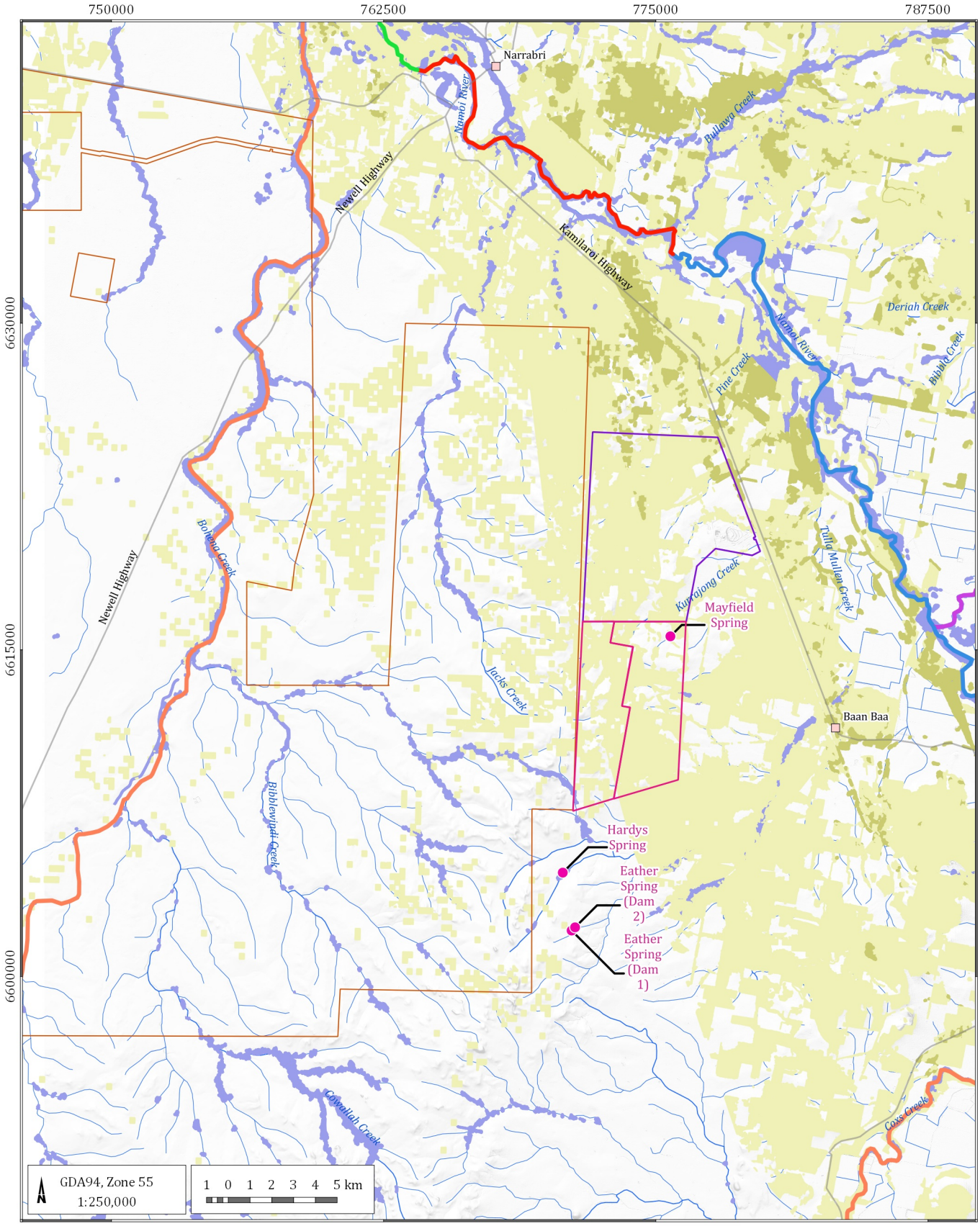
As shown in Figure 5.12, high potential terrestrial GDEs, which are also identified as high priority GDEs in updated WSP documents, are mainly mapped along the Namoi River, Pine Creek, Kurrajong Creek, Tulla Mullen Creek and other water courses to the south of MLAs 1 and 2 which eventually discharge into the Bohena Creek.

### *5.7.3 Subterranean ecosystems*

Eco Logical (2016) conducted stygofauna sampling within coal seams in the Black Jack Group (which includes the Hoskissons Coal Seam), the Maules Creek Formation, the colluvium at Leewood and Bohena Creek alluvium as part of the adjacent Narrabri Gas Project. No stygofauna were found in any of the 19 samples collected as part of this study. Santos (2017) considered that the proposed CSG production bores within the Black Jack Group were too deep and isolated from surface sources of organic matter, and had water with an electrical conductivity generally too high for most stygofauna. It was also considered unlikely that stygofauna would be present within the shallower sandstone aquifers, such as the Pilliga Sandstone. This was on the basis that for these aquifers to be suitable for stygofauna they would have to be fractured or weathered enough to allow stygofauna movement, have a sufficient flux of water and organic matter, and be well connected to a colonising aquifer such as the Namoi Alluvium (Eco Logical, 2016). The lack of any stygofauna within the minor alluvium and colluvium sites sampled was attributed to the aquifers being thin, drying frequently and having no permanent hydrological connection to a larger alluvial aquifer (Santos, 2017).

Santos (2017) went on to conclude that although stygofauna are known to occur within the Namoi Alluvium, based on sampling conducted by Korbel (2012) in bores near Wee Waa, the thin sedimentary aquifers associated with Bohena, Cowallah and Bibblewindi Creeks which traverse the Narrabri Gas Project area are only likely to provide stygofauna habitat in permanently saturated parts which have an occasional hydrological connection to the Namoi Alluvium. Accordingly of the creeks present in the immediate vicinity of the Project neither the Pine or Kurrajong creeks are considered likely to provide stygofauna habitat, on the basis that there is no mapped alluvium along these creeks and they are highly ephemeral creeks which are either entirely disconnected (or possibly only very occasionally connected) to the Namoi Alluvium. Conversely, the Tulla Mullen Creek piedmont may provide a stygofauna habitat since the Quaternary strata associated with this creek are more substantial. Furthermore whilst this creek is also ephemeral, standing water has been observed in the bed of this creek (Section 5.8.2) suggesting a possible sub-surface connection to the adjacent Namoi Alluvium.

Consistent with the Santos (2017) findings, the Black Jack Group in the vicinity of the Project is not considered to be suitable habitat for stygofauna given the depth at which the aquifers within it are located and the relatively high salinity of the groundwater. Likewise, the overlying Jurassic and Triassic units in the vicinity of the Project are unlikely to provide suitable habitat given they would need to be fractured or weathered to allow for stygofauna movement, have a sufficient flux of water and organic matter, and be well connected to the Namoi Alluvium, as noted by Eco Logical (2016). In particular whilst the relatively high permeability of the Pilliga Sandstone suggests that it may be sufficiently fractured or weathered to provide a habitat there is no connection with the Namoi Alluvium in the vicinity of the Narrabri Mine since the Pilliga Sandstone is not present east of the Narrabri Mine.




LEGEND

- Populated place
- Potential groundwater feature
- Road
- Drainage
- Provisional Mining Lease Application Area
- Mining Lease Boundary (ML 1609)
- Proposed Narrabri Gas Project (Santos)

**Aquatic GDEs**

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

**Terrestrial GDEs**

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

Narrabri Stage 3 Extension GIA (G1972)

## Springs and other groundwater dependent ecosystems

DATE 24/06/2020

FIGURE No: **5.12**

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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.;
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## 5.8 Groundwater – surface water interaction

### *5.8.1 Namoi River*

Groundwater-surface water connectivity in the Namoi River catchment has been previously reviewed by Ivkovic (2006) and CSIRO (2007) and more recently in the Bioregional Assessment (Aryal et al., 2018). As shown in Figure 5.13, Ivkovic (2006) classifies the entire stretch of the Namoi River from upstream of Gunnedah to downstream of Narrabri as being directly connected to the water table but generally losing flow. This is broadly consistent with actual flow data for the river over this stretch of the river which suggest minor average losses of 12 ML/d between Boggabri and Narrabri (Section 3.3.2).

Contrary to this, CSIRO (2007) mapped the same stretch as gaining based on a snapshot in time of the magnitude and hydraulic flux from the river. The seemingly variable assessments of connectivity between the two studies have been attributed to variability in natural climate related and human induced factors (e.g. pumping, stream regulation and water extraction) (Aryal et al., 2018). Consistent with this, as discussed in Section 3.3.2, the observed flow data also suggests losses of 141 ML/d on average between Boggabri and Turrawan, which appear to largely re-gained downstream between Turrawan and Narrabri.

Flow in the Namoi River may also be supported to some extent by discharge from the Pilliga Sandstone. Herczeg (2008) suggest that the Surat basin units which includes the Pilliga Sandstone provides baseflow into the Namoi River to the north of the Project close to Narrabri.

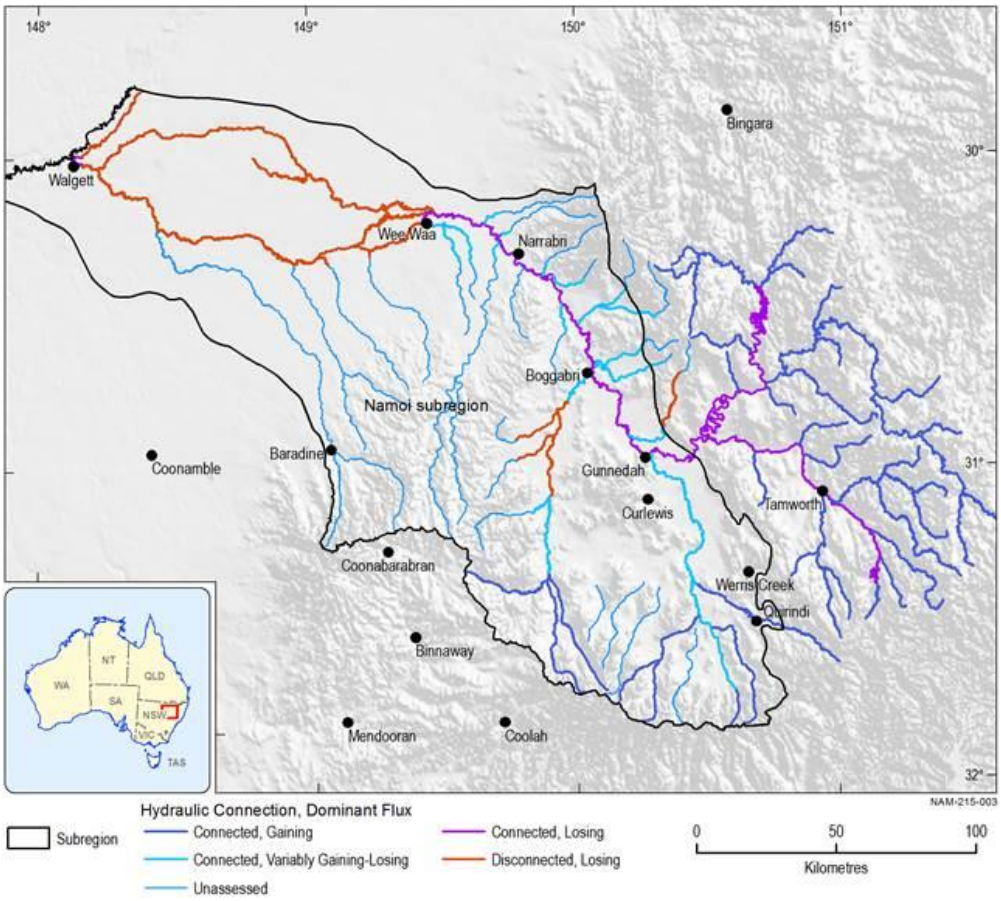



**Figure 5.13 Groundwater-surface water connectivity in the Namoi River catchment (after Ivkovic, 2006)**

Figure 5.14 shows the Namoi River, at the location of the river water offtake (and nearby to the Namoi Bore) used to supply additional water into the mine, taken during a field visit on 12 September 2019. Whilst the recorded flow in the Namoi River at this time was zero, as shown there is a substantial body of standing water in the river.



**Figure 5.14 Namoi River upstream of Turrawan Bridge**

### *5.8.2 Other creeks*

A number of minor creeks within ML 1609 were inspected during a field visit on 12 September 2019 to understand the potential for connectivity between surface water and groundwater resources in the area. The locations visited are presented in Figure 3.2. The last significant rainfall at the site is understood to have occurred in early May 2019 (i.e. around four months prior to the visit). Prior to the site visit, land features where potential groundwater-surface water interaction may occur were identified using the water observation from space dataset (Mueller et al, 2016). This dataset displays and summarises historical surface water observations from satellite imagery for all of Australia between 1987 to the present. The majority of the areas of inundation identified by this dataset were farm dams adjacent to drainage lines and were therefore not further considered. However, a number of other potential sites were identified and visited. The findings of this field visit are summarised below.

As shown below, standing pools of water were observed in a tributary of the Kurrajong Creek in the existing mining area (Figure 5.15) and on Tulla Mullen Creek where it crosses the Kamilaroi Highway and Old Narrabri Road (Figure 5.16), although no actual flow was observed at any of these locations. Conversely, a tributary of the Pine Creek within the mining area (Figure 5.15) was observed to be completely dry.

Based on this site inspection, both the Kurrajong Creek and Tulla Mullen Creek at the Kamilaroi Highway crossing sites are considered most likely to be predominantly ponded surface water runoff. Conversely the Tulla Mullen Creek at Old Narrabri Road appears more likely to be groundwater supported to some degree. All three sites have been recently sampled (Appendix G) and major ion chemistry for each site is shown in a piper plot presented in Appendix G (see Figure 3). Major ion chemistry at the two Tulla Mullen Creek sites appears to be similar to a number of alluvium samples shown in Figure 5.9, whilst the Kurrajong Creek sample is more similar to a number of groundwater samples associated with the Narrabri Formation. This data suggests a possible groundwater component in all three cases, although given the extremely variable groundwater chemistry reported in the area, it is difficult to draw any definitive conclusions from the hydrochemistry alone.

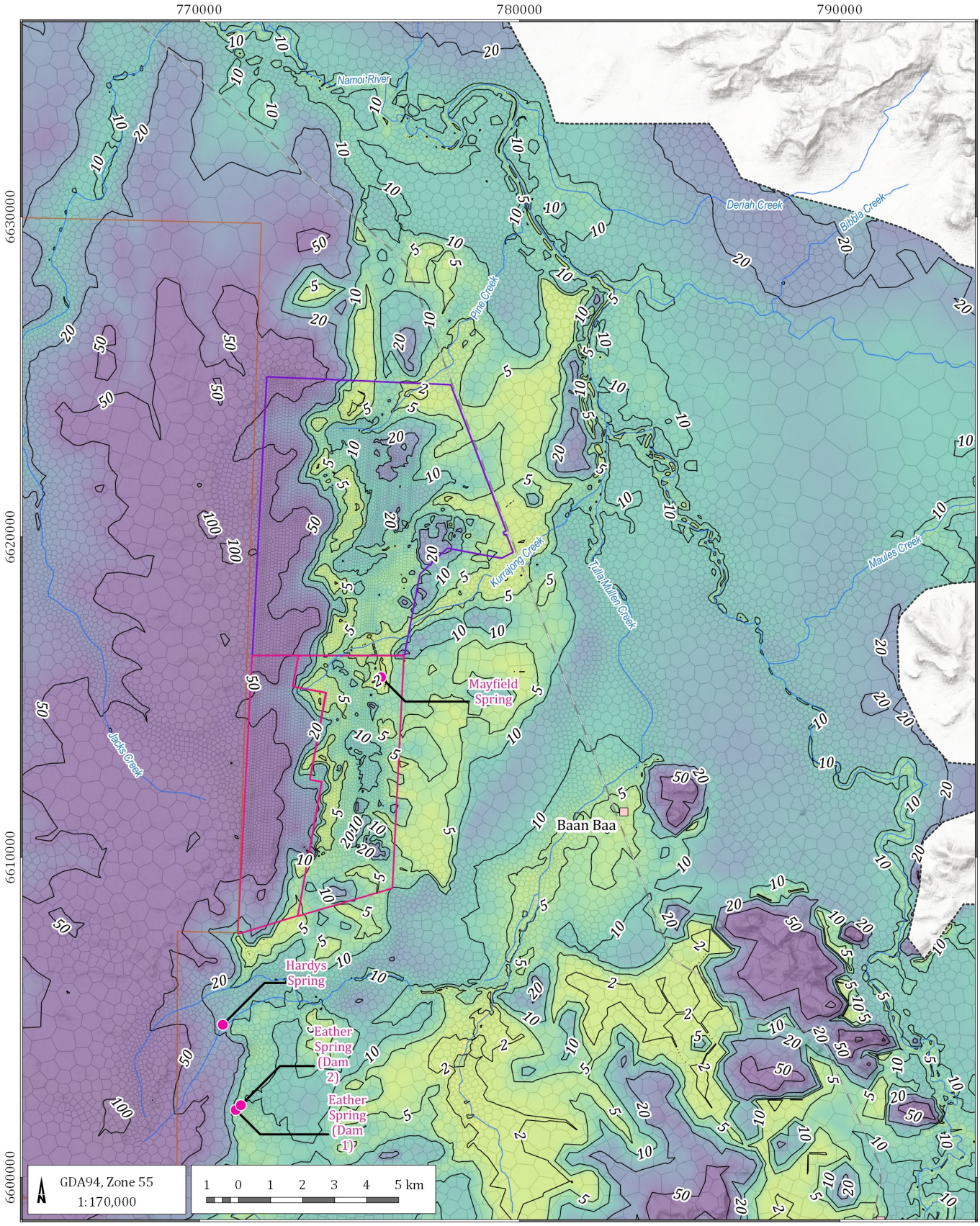
Overall, however, the parts of the Project Area which were inspected during the field visit appeared to be extremely dry with little evidence of significant surface water groundwater interaction or GDEs. Consistent with this observation, modelled depths to water table (Figure 5.17) vary from 2 m to 5 m close to the eastern boundary of ML 1609 to more than 50 m in places along the western boundary.



**Figure 5.15 Kurrajong Creek tributary (left) and Pine Creek tributary (right)**



**Figure 5.16 Tulla Mullen Creek at Old Narrabri Road crossing (left) and Kamilaroi Highway crossing (right)**




LEGEND

- Populated place
- Potential groundwater feature
- Drainage
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary
- Model mesh

**Depth (m)**

- 0 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- Water table contour line (m)

Narrabri Stage 3 Extension GIA (G1972)

## Modelled depth to water table - December 2019

DATE 24/06/2020

FIGURE No: 5.17

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## 5.9 Conceptual model description

This section summarises the processes that control and influence the storage and movement of groundwater in the hydrogeological systems occurring in the Project Area. It is based on geological and hydrogeological data presented in the preceding sections as well as previous groundwater studies undertaken in the region. Table 5.13 shows a summary of hydrostratigraphic units of relevance to assessing the impacts of the proposed development. The aquifer and aquitard classifications presented are based predominantly on the proportion of aquifer material (i.e. sandstone or weathered basalt) present in each formation derived from local drilling data (Figure 4.2 and Figure 5.1), site specific hydraulic testing data and whether or not each unit is targeted locally for water supply purposes (Section 5.6). It is noted that many of the units listed below including the Napperby, Arkarula and Pamboola formations were identified as aquitards in the Narrabri Gas Project EIS (CDM Smith, 2016). However, this classification does not appear to be consistent with the available data for the Narrabri Mine, which suggests relatively high proportions of sandstone, and a number of local extractions which appear to target these units (i.e. since neither the Namoi Alluvium or Pilliga Sandstone are present at many bore locations).

**Table 5.13 Summary of hydrostratigraphic units**

| Basin | Period | Hydrostratigraphic Unit | Aquifer/Aquitard definition |
|---|---|---|---|
| | Quaternary | Namoi Alluvium | Highly productive aquifer |
| | | Other alluvium | Minor aquifer |
| | | Colluvium | Aquitard |
| | | Regolith | Aquitard |
| Surat | Jurrasic | Pilliga Sandstone | Highly productive aquifer (86% sandstone) |
| | | Purlawaugh Formation | Aquitard/Poor aquifer (64% fine material) |
| | | Garrawilla Volcanics | Aquitard/Poor aquifer (72% fresh) |
| Gunnedah | Triassic | Upper Napperby | Minor aquifer (54% sandstone) |
| | | Napperby Sill | Aquitard (97% fresh) |
| | | Lower Napperby | Aquitard / Poor aquifer (59% fine material) |
| | | Digby Conglomerate | Aquitard (medium/high strength conglomerate) |
| | Late Permian | Hoskissons Coal Seam | Target production seam |
| | | Arkarula Formation | Local aquifer (75% sandstone) |
| | | Pamboola Formation | Minor aquifer (63% sandstone) |
| | Early to Middle Permian | Pre-Pamboola Formation | Basement |

The conceptualisation of hydrostratigraphic units for a site forms the basis for design for a numerical groundwater model. However, the conceptualisation and the related numerical model essentially summarise the main characteristics of a groundwater system that is substantially more complex. Uncertainties that arise from review and assumptions based on limited data invariably exist. Middlemis and Peeters (2018) indicate sources of uncertainty affecting groundwater models can be grouped as follows:

- structural/conceptual – geological structure and hydrogeological conceptualisation assumptions applied to derive a simplified view of a complex hydrogeological reality (any system aspect that cannot be changed in an automated way in a model);
- parameterisation – hydrogeological property values and assumptions applied to represent complex reality in space and time (any system aspect that can be changed in an automated way in a model via parameterisation);
- measurement error – combination of uncertainties associated with the measurement of complex system states (heads, discharges), parameters and variability (3D spatial and temporal) with those induced by upscaling or downscaling (site-specific data, climate data); and
- scenario uncertainties – estimating future stresses, dynamics and boundary condition changes (e.g. mining, climate variability, land and water use change).

**Conceptual geology**

Figure 5.18 shows a conceptual cross section through MLAs 1 and 2 showing the disposition of the hydrostratigraphic units present in the area. Conceptual models always include some uncertainty regarding geology and structure as the sub-surface can only inferred through drilling and modelling. However, in this case, since development of the Narrabri Mine has been ongoing since 2009, the sub-surface is relatively better known than a greenfield site. A detailed high-resolution geological model is available, developed using data for hundreds of exploration bores and underground fault mapping. For this reason, it is considered that the surfaces for the key hydrostratigraphic units within the Project boundary have a relatively low level of residual uncertainty compared to less developed or greenfield areas.

However, the mine geological model does not extend towards the Namoi River or the Narrabri Gas Project to the west and hence these areas are characterised by a higher degree of geological and hydrogeological uncertainty further from the mine. The extent and thickness of formations below the Arkarula Formation has not been mapped in detail and so also contributes to uncertainty in the geological model. Regardless, the outcrop extent of the deeper formation information from high-resolution state geological mapping has been used to constrain the conceptual model, which have helped reduce the uncertainty.

There is also residual uncertainty remaining around the behaviour of faults that are mapped in the Project Area, although again detailed mapping of faults within the existing mine area are available. Investigating the hydrogeological properties of faults through field investigations is challenging and therefore, the influence of this uncertainty is investigated through numerical modelling.

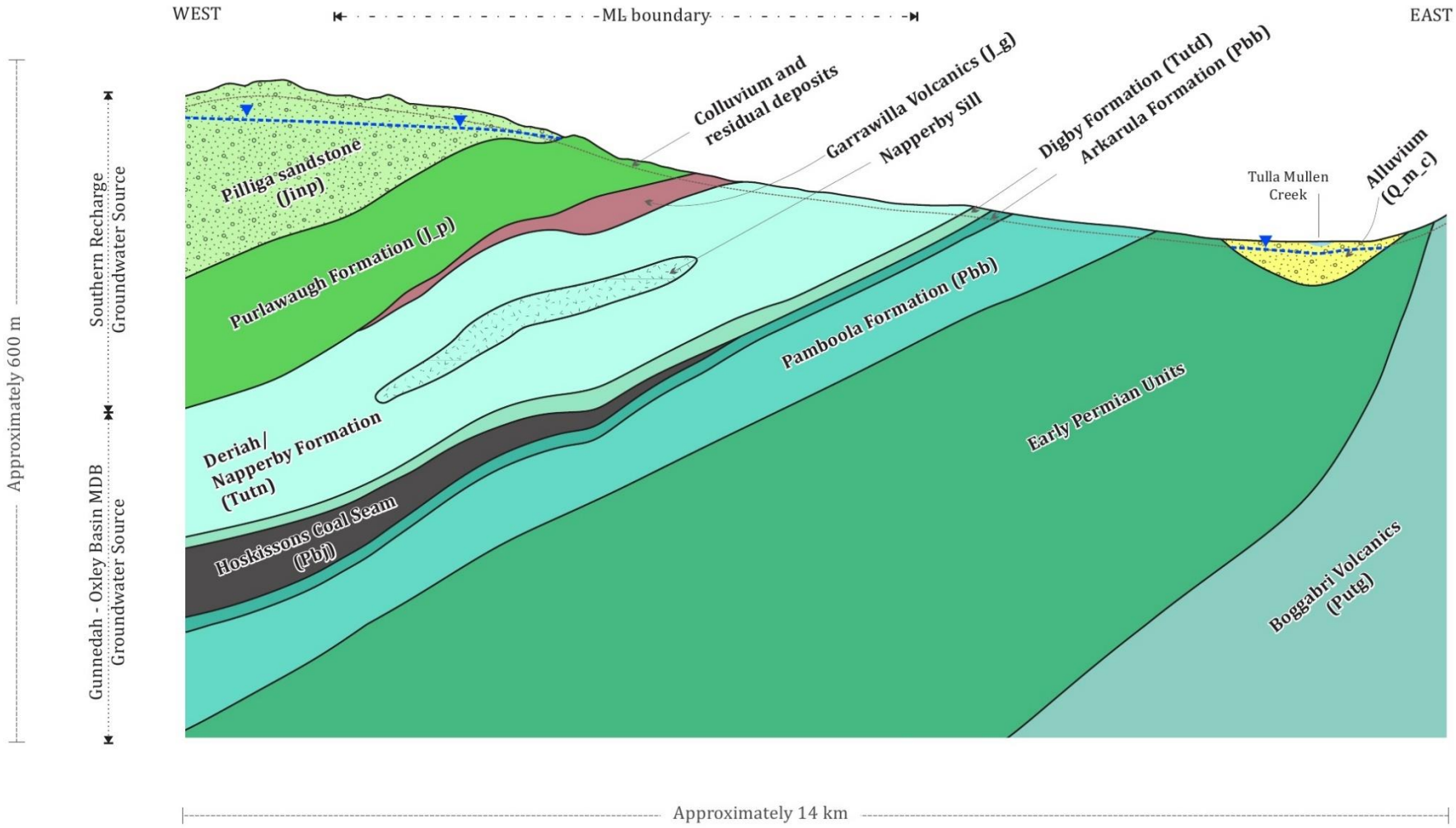



**Figure 5.18 Conceptual schematic**

**Hydrogeological parameters**

A number of direct measurements of hydraulic conductivity and extensive lithological datasets are available for each of the key hydrostratigraphic units present within the Project Area. A substantial dataset of observed groundwater levels and flows into the existing mine is also available and has been used to constrain the numerical model via a calibration process. Accordingly, the number and distribution of the available hydraulic parameter tests is not considered to be a significant source of uncertainty, especially since dewatering of the mine effectively provides an ongoing large-scale pumping test.

**Recharge and discharge**

Groundwater recharge is likely to take place mainly within Pilliga Sandstone and the Alluvium aquifers, directly through exposed outcrop. Accordingly, these formations are characterised by better quality groundwater than other formations. Discharge is thought to be occurring from the Pilliga sandstone via a series of springs close to the boundary with the underlying Purlawaugh Formation, although none are known to occur in the Project Area. Discharge from the Namoi Alluvium is currently thought to be primarily via groundwater extraction bores as the river itself in the vicinity of the Project Area appears to be predominantly losing flow to groundwater.

Post-mining, rainfall recharge may increase within the Project Area due to the increased formation of secondary permeability structures (e.g. cracks, and local depressions) as a result of subsidence. Additionally, dewatering activities that lower the groundwater table may also reduce the amount of water lost via evapotranspiration. These mechanisms have been previously described and are incorporated into the Namoi subregion groundwater model in the Bioregional Assessment Programme (Janardhanan et al., 2018).

**Potential pathways for groundwater impacts**

The main causal pathway for potential impacts on water dependent assets in the Project Area is depressurisation of the Hoskissons Coal Seam resulting in drawdown within overlying units including the Pilliga Sandstone. Previous groundwater modelling results, however, suggest that drawdown in the vicinity of the Namoi Alluvium is likely to be negligible. Furthermore, no actual impacts have been observed in either of the major aquifers (the Pilliga Sandstone and the Namoi Alluvium) outside of ML 1609.

Baseflow impacts on the Namoi River are not expected since significant drawdown is not anticipated in the vicinity of the Namoi River itself and since the river appears to be losing flow. Any reductions in discharge from the underlying bedrock strata to the Namoi Alluvium would lead to potential minor reductions in levels and/or gradients at the edge of the alluvium which, since the river appears to be already losing flow in this reach, would not reduce the baseflow to the river. Some drawdown effects on any water supply bores located in bedrock strata in and around the mine and towards the periphery of the Namoi Alluvium are however possible.

Measurement error is inherent in all hydrogeological datasets. In particular groundwater level records represent a key dataset utilised in developing the conceptual model and which has also been used for calibration of the numerical groundwater flow model.

Where groundwater monitoring bores are appropriately constructed and sealed within the target aquifer, the elevation of bore is accurately surveyed and water level measurement is via modern electronic water level meters, the likely measurement error is considered to be relatively low, potentially less than 0.1 m. This is considered to be the case with the bulk of the available network which has been specifically constructed for groundwater monitoring purposes. Data are also available for a relatively long period which includes around 9 years, this allows data to be corroborated using information for other surrounding bores. The availability of extended datasets for nearby bores is particularly useful for corroborating VWP records. Several such monitoring facilities in the Narrabri Mine network including several nested facilities which provide key data on vertical gradients.

However, one drawback with these kinds of facilities is that they cannot be manually dipped to corroborate logger readings and hence corroborating data for other nearby bores is extremely useful. In general, data collected using the VWP facilities at Narrabri appears to be of good quality and not prone to the long equilibration periods which are sometimes observed in VWPs installed at other sites.

**Inflow into the mine**

A component of groundwater that would report to the underground mining area is reused for the current mining process, evaporates from mine faces, or remains bound by capillary action to spoil and coal materials, and therefore would not flow to sumps for pumping where its volume can be measured. These inherent challenges in measuring groundwater inflow to underground mining areas mean that there is always some residual uncertainty associated with measurements of groundwater inflow. However, this uncertainty has been reduced through the completion of detailed water balance calculations by WRM (2020) which account for the numerous losses in the system to generate a time series of actual inflow to the existing underground workings. Groundwater inflows from detailed water balance calculations by WRM (2020) form a key dataset for calibration of the numerical groundwater flow model.

The majority of the mapped faults encountered in the existing underground mining area are minor features characterised by displacements of less than 5 m and are not a major influence on groundwater inflow during mining. Discussions with the site geologists, confirmed by flow data for nearby de-pressurisation wells, suggest that even the largest faults encountered generate little to no additional flow and therefore do not represent significant conduits for groundwater ingress to the workings.

**Potential cumulative impacts**

The cumulative groundwater impacts of six coal projects that were commercially producing in 2012 (Boggabri, Rocglen, Sunnyside, Tarrawonga and Werris Creek coal mines; and the approved Narrabri Mine) and additional coal resource developments expected to begin production after 2012 (at the time of modelling) (including the Boggabri Coal Expansion Project, Gunnedah Precinct, Maules Creek Coal Mine, Narrabri Mine, Tarrawonga Coal Expansion Project, Vickery Coal Project, Vickery South Extension Project, Watermark Coal Project and the Narrabri Gas Project) have been assessed using a groundwater flow model developed for the Namoi Sub-Region Bio-Regional Assessment program (Janardhanan et al., 2018).

Groundwater impact from the developments were determined to overlap only when they are within 20 km from each other. Additionally, the coal seams targeted in the Narrabri Mine are not continuous across the Boggabri Ridge to the east and hence no overlapping impacts with the nearest mines (BTM complex mines) east of the Namoi River are expected. However, given that the Narrabri Gas Project is located immediately west of the Project Area, some overlapping impacts are anticipated and a cumulative impact assessment has been undertaken (Section 7).

# 6 Numerical groundwater flow model

## 6.1 Previous modelling

A number of numerical models of the Narrabri Mine have been developed to support environmental approvals sought at different stages of the project as follows:

- Initial project approval including boxcut operations, Stage 1 (GHD, 2007). The model consisted of 11 layers and was developed using MODFLOW 2000.
- Development of longwall mining operation, Stage 2 (Aquaterra, 2009). This model adopted the same layering system but was developed using MODFLOW SURFACT v3.
- Longwall panel modification, Stage 2 MOD 5 (HydroSimulations, 2015 and 2016). A further development of the 2009 Stage 2 model developed using MODFLOW SURFACT v4 and incorporating revised layer geometries, fracture zone simulation and re-calibration.
- Stage 3 Gateway Application (HydroSimulations, 2019a). Further re-calibration of the 2015 Stage 2 MOD 5 groundwater model was undertaken for this assessment.

The numerical model developed for the Project represents a further development of the 2019 HydroSimulations model. Aspects of the model design that have been revised and refined are summarised in Section 6.2, based on the revised conceptualisation described previously in Section 5.

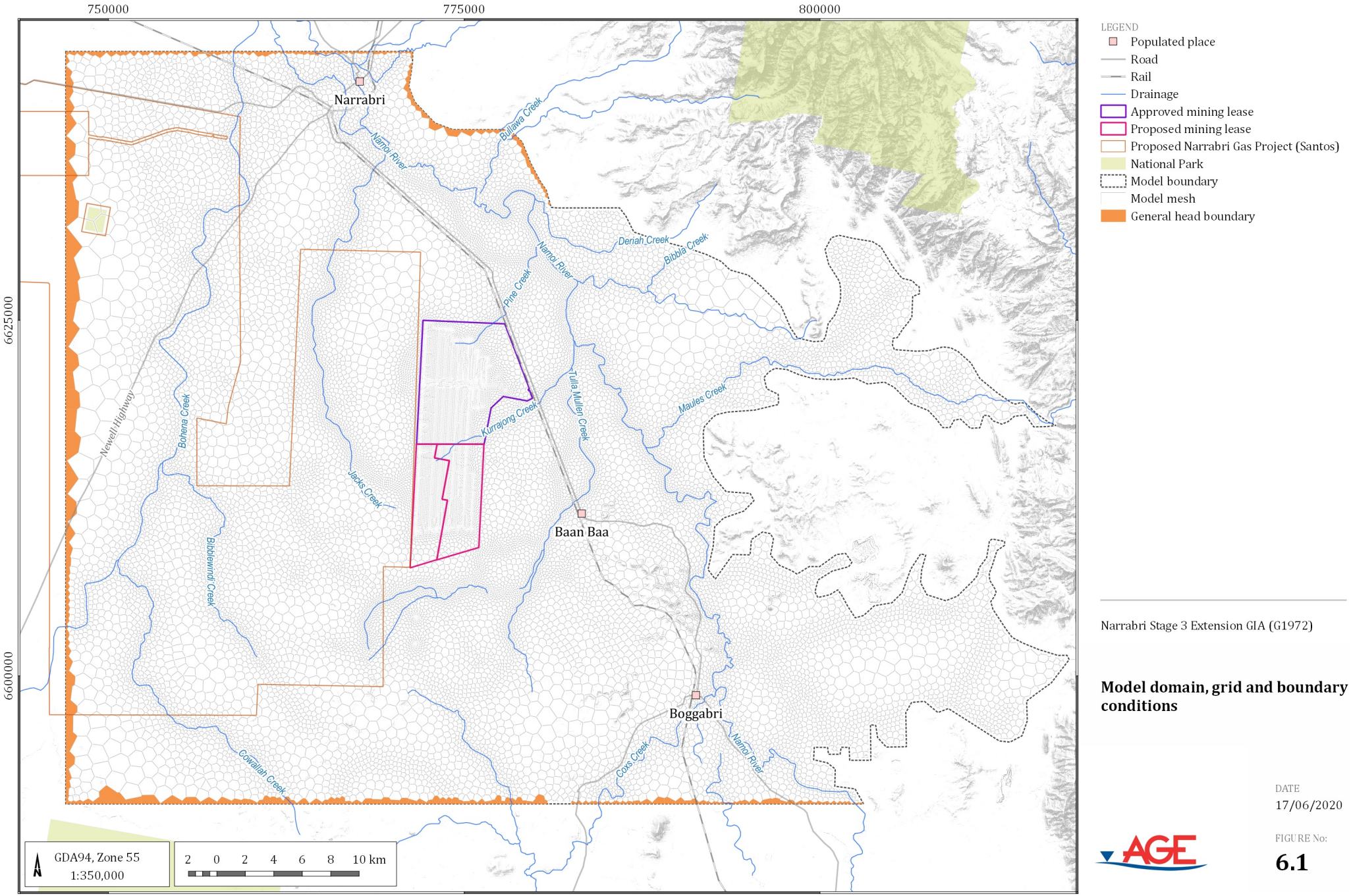
## 6.2 Overview of groundwater modelling

A revised 3D numerical groundwater flow model was developed for the Project using MODFLOW-USG. A detailed description of the modelling logic is provided in Appendix D. The model represents the key geological units using up to 23 layers and covers an area approximately 75 km wide (in the west to east direction) and 53 km long (in the north to south direction). It comprises up to 31,149 cells per layer, making it spatially a relatively large model (Figure 6.1).

As mentioned above (Section 6.1) the numerical model developed for the Project was built upon an existing regional model first developed by Aquaterra (2009), then further updated by HydroSimulations most recently as part of the Stage 3 Gateway Application (HydroSimulations, 2019a). Revisions made to the HydroSimulations model which was used as a starting point include:

- development of new MODFLOW USG model mesh and layers;
- adjusting the numerical model structure based on an updated geological model of the mine site;
- increasing the vertical resolution of model layers to make better use of data for key nested VWP installations;
- revising the approach to estimating drain conductance using the 'Thiem equation' and estimated fracture intensity;
- the inclusion and further calibration of time varying recharge;
- representation of subsidence induced fracturing at the surface using the MODFLOW time varying materials (TVM) package;
- incorporation of height of fracturing predictions derived from an updated geotechnical study based on additional piezometer and extensometer data now available for longwall panel LW108A (DGS, 2020, Section 5.2.11);
- representing major stream and river systems using a coupled streamflow routing package;

- representation of minor mapped faults in and around ML 1609 and MLAs 1 and 2 in the model structure, calibration of cross fault resistance during calibration and further consideration as part of the uncertainty analysis;
- simulating landholder pumping within the Namoi alluvium, Pilliga sandstone and all other underlying consolidated units which have the potential to be impacted by the Project;
- recalibrating the numerical model to updated water level records, mine inflows, and baseflow estimates in the Namoi River;
- representing proposed CSG development from the Narrabri Gas Project;
- representation of potential spatial variability in aquifer parameters using pilot points; and
- completion of a detailed predictive uncertainty analysis.




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Approved mining lease
- Proposed mining lease
- Proposed Narrabri Gas Project (Santos)
- National Park
- Model boundary
- Model mesh
- General head boundary

Narrabri Stage 3 Extension GIA (G1972)

**Model domain, grid and boundary conditions**

DATE
17/06/2020

FIGURE No:
**6.1**

©2020 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
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Further information on the evolution of the regional model over time and the changes made to quantify the impact of the Project are provided in Appendix D.

As described in Appendix D (Section D 3), calibration of the numerical model was undertaken through comparison with observed or estimated:

- groundwater levels;
- head differences between pairs of observations at nested monitoring locations;
- groundwater inflow to the existing underground mining area; and
- baseflow between the surface water flow gauges on the Namoi River at Boggabri and Narrabri.

The objective of the calibration being to replicate observed groundwater levels, net baseflow gains and mine inflows in accordance with Australian Groundwater Modelling Guidelines (Barnett et al. 2012). The transient calibration achieved a 5.0% scaled root mean square (SRMS) error, which is well within acceptable limits (i.e. <10%), recommended by the Australian Groundwater Modelling Guidelines (Barnett et al., 2012). More importantly, the model was able to replicate the observed depressurisation of the Permian strata occurring above the existing underground mining area, and average inflows into the existing underground mining area.

Once calibrated to historic data, the numerical model was then used to quantify the influence of the Project on the groundwater regime by comparing predicted groundwater levels and flows under the following three scenarios:

- a 'baseline' or no development scenario which excludes both the approved Narrabri Mine and the Narrabri Gas Project;
- a 'cumulative' scenario incorporating development of both the Project (including the approved Narrabri Mine) and the Narrabri Gas Project; and
- a 'Narrabri Gas Project only' scenario which excludes the Project (including the approved Narrabri Mine) from the cumulative scenario was also undertaken.

Predicted cumulative and Project only impacts are then calculated by comparing head and flow outputs from two pairs of scenarios as follows:

- Cumulative impacts = baseline scenario minus cumulative scenario; and
- Project only impacts = Narrabri Gas Project only scenario minus cumulative scenario.

## 6.3 Peer review

An external peer review of the Groundwater Assessment, including the groundwater model, was undertaken by Brian Barnett. Brian was the lead author of the current *Australian Groundwater Modelling Guidelines* (Barnett et al., 2012) against which the model was assessed.

The peer review report prepared by Brian Barnett is included within Attachment 6 of the EIS and concludes as follows:

"*The groundwater assessment and supporting groundwater modelling work described in the Report and Appendix have been carried out in a professional and rigorous manner and meet or exceed current industry standards. The modelling work has been completed in line with the Guiding Principles included in the Australian Groundwater Modelling Guidelines and I have not identified any fundamental flaws in the work, both in terms of the approaches and assumptions that have been adopted and the interpretation of the outcomes.*"

# 7 Model predictions and impact assessment

## 7.1 Introduction

This section describes the predicted impacts of the Project including predictions of:

- impacts of goafing on aquifer properties (Section 7.2);
- groundwater directly intercepted by mining of the Hoskissons Coal Seam (Section 7.3);
- groundwater level drawdown in the Permian coal measures and the main aquifers with potential to be impacted by the Project (i.e. Quaternary alluvium and the Pilliga Sandstone [Section 7.4]);
- net changes to groundwater discharge to the Quaternary alluvium and local water courses (Section 7.5);
- groundwater level impacts on private bores (Section 7.6.1), potential GDE locations (Section 7.6.2), BSAL and State Forest (Section 7.6.3) and culturally significant sites (Section 7.6.4);
- additional groundwater take from WSP areas relative to current licences held by NCOPL (Section 7.7); and
- groundwater quality impacts both during operation and post-mining (Section 7.8.1).

Potential uncertainty in predicted impacts, based on the results of a formal predictive uncertainty analysis, are discussed in Section 7.9.

Where relevant, the predicted impacts of both the Project only and the cumulative impacts of development of the Project and Narrabri Gas Project are presented. Impacts which would occur following the completion of mining are also clearly identified.

## 7.2 Impacts of goafing on aquifer properties

Once the longwall mining has removed the targeted coal seams and advanced, the roof strata subsides into the mined area creating a so called goaf zone within each longwall panel. This creates a zone of rubble within the goaf as the roof collapses which in turn also induces fracturing in the material above the spent coal seam. International and Australian research on longwall mining interaction with groundwater systems indicates that the overburden may be divided into four or five zones of surface and sub-surface fracturing with the degree of fracturing gradually decreasing with height above each longwall panel. Forster (1995) and Guo et al. (2007) define the following zones in descending order:

- Surface Zone (D-Zone).
- Elastic Zone (C-Zone).
- Discontinuous Fracture Zone (B-Zone).
- Continuous Fracture Zone (A-Zone).
- Caved Zone (included in the A-Zone).

Definition of the height of the continuous fracture zone (the A zone), the zone of surface subsidence (D zone) and the magnitude of changes to aquifer properties within these zones represents a key component of the Project impact assessment. Further details of the modelling approach adopted to simulate aquifer properties in these zones are presented in Appendix D (Section D.2.5.6). The methodology was initially developed by AGE for use at the Integra mine (AGE, 2017) and subsequently applied to the simulation of underground coal mining operations at a number of other sites, including the Mount Owen Modification 2 (AGE, 2018), Glendell Continued Operations Project (AGE, 2019), and the Dendrobium groundwater model (HydroSimulations, 2019b).

For the most part the approach adopted is the same as that adopted for the Gateway Application modelling (HydroSimulations, 2019a) but also includes:

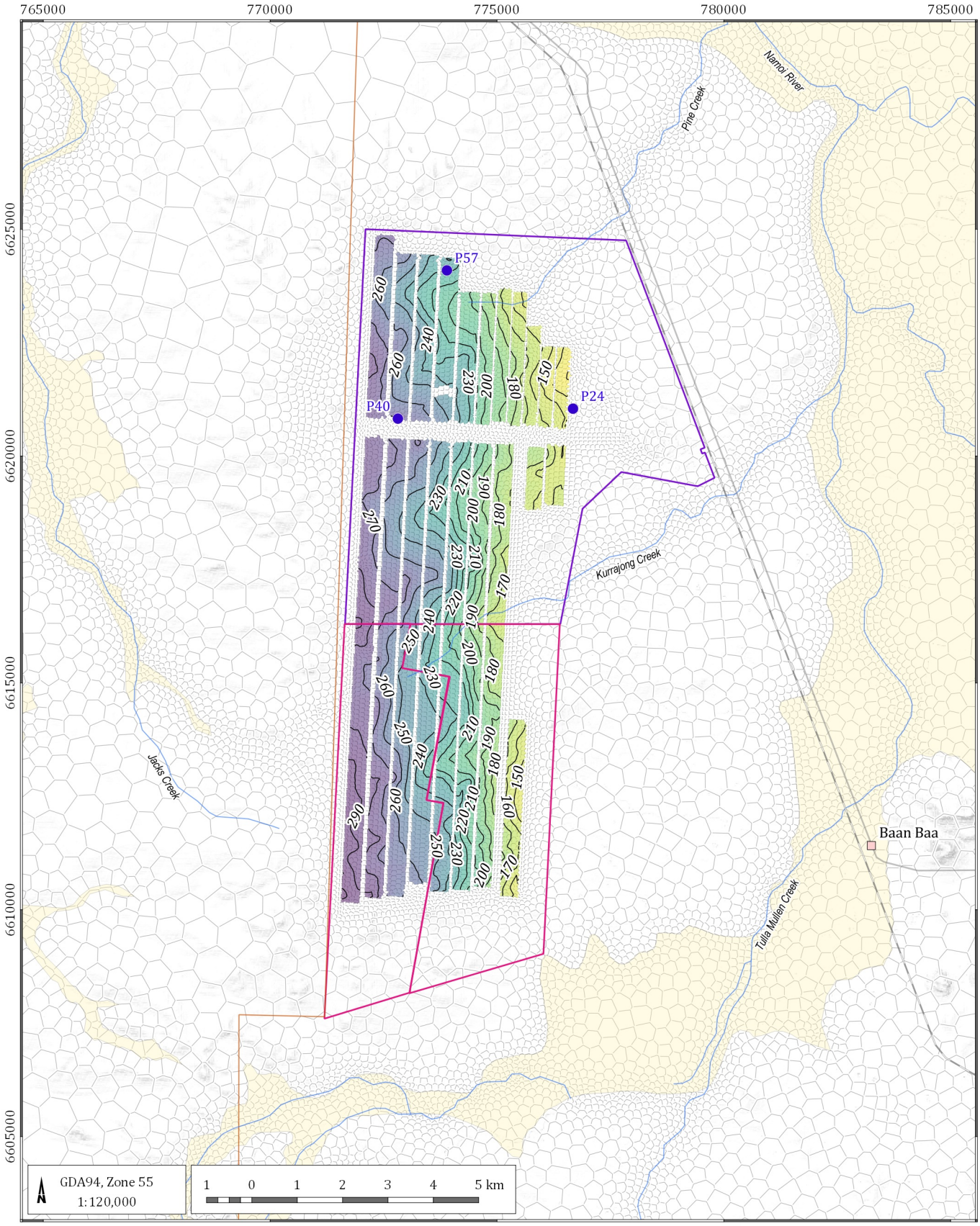
- representation of subsidence induced fracturing in the near surface D Zone (as well as the A Zone);
- increased A zone fracture heights, based on revised geotechnical study results (DGS, 2020); and
- calibration of model parameters which affect the aquifer properties in both the A and D zones.

The sensitivity of predicted impacts to modelled aquifer properties in the A and D zones has also been assessed as part of the predictive uncertainty analysis.

As mentioned above information on the predicted height of fracturing used for groundwater modelling purposes was derived from a detailed subsidence assessment which was initially undertaken at the Gateway Application stage of the Project (DGS, 2019) and has since been updated based on the additional piezometer and extensometer data now available for longwall LW108A (DGS, 2020, Section 5.2.11). This assessment concludes, based on the data available, that an A Zone fracture height of 236 m should be adopted for this panel and calculates fracture heights for all existing and proposed longwall panels (Figure 7.1) based on the proposed depth of cover, panel width and mining height which are all known to affect the height of fracturing. Subsidence induced cracking of the near surface zone (D Zone) to a depth of 43 m (i.e. 10 times the proposed maximum longwall panel height of 4.3 m) has also been simulated. Since estimated A zone heights for longwall panels LW101 to LW108a, LW109, LW201 to LW205 and LW210 extend to within 43 m of the surface, then seam to surface fracturing is simulated above each of these panels. For the remaining longwall panels (i.e. LW108b, LW110 and LW111, and LW 206 to LW 209), there is some separation of the estimated A and D zones and seam to surface fracturing is therefore not predicted.

Modelled horizontal hydraulic conductivity increases above longwall panels vary from up to four orders of magnitude above background immediately above the mining zone and reduce to less than one order of magnitude at the top of the modelled A zone. These increases are consistent with theoretical work undertaken by Guo et al. (2007) and with field measurements undertaken at Dendrobium Mine (HydroSimulations, 2019b). Guo et al. (2007) suggests horizontal hydraulic conductivity increases of between three and four orders of magnitude within 75 m of mined coal seams and generally less than one order of magnitude above 75 m. Similarly, repeat packer testing above Longwall 9 at Dendrobium Mine suggested horizontal hydraulic conductivity increases between one and three orders of magnitude.

Consistent with the work of Guo et al. (2007) modelled hydraulic conductivity increases in the vertical direction are substantially lower than in the horizontal direction. The majority of the calibrated values in the modelled A zone fall in the range 1-2.5 times background, values similar to those estimated by Guo et al. (2007) who suggested values of less than five times background at heights of more than 75 m above coal seams.




LEGEND

- Nested monitoring bores
- Populated place
- Road
- Rail
- Drainage
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model mesh

**Fracture height (mAHD)**

- 100
- 150
- 200
- 250
- 300
- Contour line

Narrabri Stage 3 Extension GIA (G1972)

## Estimated A Zone fracture heights (DGS, 2020)

DATE 29/05/2020

FIGURE No: **7.1**

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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\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.01_G1972_Estimated A Zone fracture heights (DGS, 2020).qgs

## 7.3 Groundwater inflows and other take

Figure 7.2 and Table 7.1 show total predicted inflow to the Project underground mining area from the Hoskissons Coal Seam through time. This take represents groundwater that would be directly intercepted by the Project assuming concurrent development of the Narrabri Gas Project. As shown in Figure 7.2 and Table 7.1, predicted inflows increase relatively rapidly from 2020 due to the commencement of construction of mine roads to allow access to longwall panels LW201 to LW210 to the south of the current workings, although mining of these panels does not commence until 2023. Development of mine roads into MLAs 1 and 2 would commence in 2022. Predicted inflows increase gradually thereafter, peaking at 2,406 ML/year (equivalent to an extraction rate of 6.6 ML/d) in 2040 before falling slightly during the last three years of mining when three relatively small panels (LW201, LW202 and LW108B) would be mined. Average inflows from 2022 to the end of mining would be approximately 1,950 ML/year. The need for additional water licences to account for this water take is discussed in Section 7.7.

It is noted that to date, modelling has over predicted groundwater inflows relative to actual inflows (Figure 5.11). Section 8 provides further discussion regarding ongoing monitoring of actual inflows and comparison to predicted inflows.

Further detail on the modelled mine progression is provided in Appendix D (Section D 2.4.6).

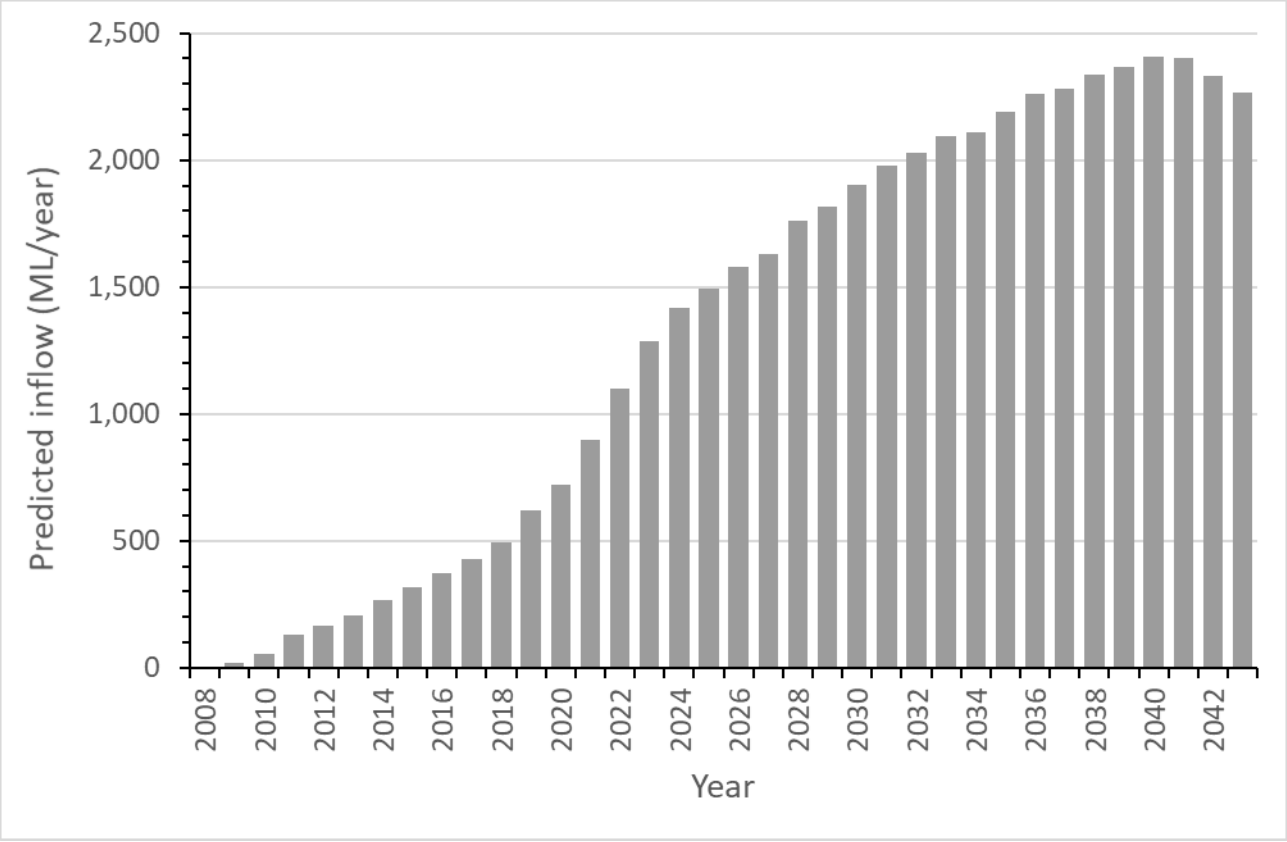



**Figure 7.2 Predicted mine inflow**

## Table 7.1 Predicted mine inflow (ML/year)

| Calendar Year | Longwall panels LW101 to 110 | Longwall panels LW201 to 210 | Other underground development (e.g. roadways) | Total |
|---|---|---|---|---|
| 2008 | 0 | 0 | 0 | 0 |
| 2009 | 0 | 0 | 21 | 21 |
| 2010 | 0 | 0 | 56 | 56 |
| 2011 | 14 | 0 | 115 | 128 |
| 2012 | 33 | 0 | 133 | 165 |
| 2013 | 73 | 0 | 132 | 204 |
| 2014 | 123 | 0 | 143 | 266 |
| 2015 | 171 | 0 | 146 | 317 |
| 2016 | 214 | 0 | 159 | 373 |
| 2017 | 247 | 0 | 180 | 427 |
| 2018 | 287 | 0 | 207 | 494 |
| 2019 | 341 | 0 | 277 | 618 |
| 2020 | 382 | 0 | 342 | 724 |
| 2021 | 448 | 0 | 452 | 900 |
| 2022 | 523 | 0 | 575 | 1099 |
| 2023 | 607 | 19 | 658 | 1284 |
| 2024 | 624 | 122 | 673 | 1420 |
| 2025 | 599 | 253 | 639 | 1491 |
| 2026 | 582 | 372 | 624 | 1578 |
| 2027 | 568 | 444 | 620 | 1631 |
| 2028 | 556 | 542 | 662 | 1760 |
| 2029 | 541 | 599 | 675 | 1815 |
| 2030 | 530 | 682 | 689 | 1901 |
| 2031 | 519 | 770 | 692 | 1981 |
| 2032 | 510 | 827 | 691 | 2029 |
| 2033 | 499 | 913 | 683 | 2096 |
| 2034 | 490 | 961 | 661 | 2112 |
| 2035 | 481 | 1051 | 656 | 2188 |
| 2036 | 473 | 1120 | 665 | 2259 |
| 2037 | 464 | 1171 | 645 | 2279 |
| 2038 | 455 | 1263 | 619 | 2337 |
| 2039 | 448 | 1298 | 620 | 2365 |
| 2040 | 442 | 1380 | 585 | 2406 |
| 2041 | 434 | 1437 | 534 | 2404 |
| 2042 | 428 | 1400 | 504 | 2332 |
| 2043 | 425 | 1352 | 488 | 2265 |

In addition to groundwater inflows to the underground mining area, water would continue to be extracted from NCOPL's existing alluvial bore located adjacent to the Namoi River (Figure 1.2) as and when required (e.g. when supply from the underground mining area is insufficient to meet water demand and water cannot be extracted direct from the Namoi River using NCOPL's existing Namoi River pump). It should be noted that inflows to the underground mining area are predicted to exceed water demands for every year of the Project, and therefore that extraction from the existing Namoi River pump and alluvial bore will not be required in the future (WRM, 2020).

The existing alluvial bore (work approval 90WA812891) is located within the Upper Namoi Zone 5 groundwater source (within the WSP for the Namoi Alluvial Groundwater Sources). Water is extracted in accordance with the relevant WALs held by NCOPL and the rules prescribed in the WSP. As all extraction from the alluvial bore would be conducted in accordance with the licensed entitlements issued by DPIE – Water, and in accordance with the rules in the relevant WSP, minimal impacts to the groundwater source and other users are predicted as a result of the use of the alluvial bore for the Project. Likewise, all extraction from NCOPL's existing pump on the Namoi River would be conducted in accordance with the licensed entitlements and rules associated with the WSP for the Upper and Lower Namoi Regulated River Water Sources.

## 7.4 Regional groundwater level impacts

### *7.4.1 Introduction*

Sections 7.4.2 and 7.4.3 below describe the predicted regional impacts of the Project and cumulatively, assuming concurrent development of the Narrabri Gas Project. For the most part since groundwater levels in the majority of the stratigraphic units present are confined (i.e. they are above the top of the unit in question) and will remain confined post development then the groundwater level impacts described below, and referred to generically as 'predicted drawdown', are limited to partial de-pressurisation. Dewatering is only predicted to occur within the Hoskissons Coal Seam and Napperby Formation immediately overlying the mine and in unconfined units at outcrop within the zone of influence of mine dewatering operations.

### *7.4.2 The Project*

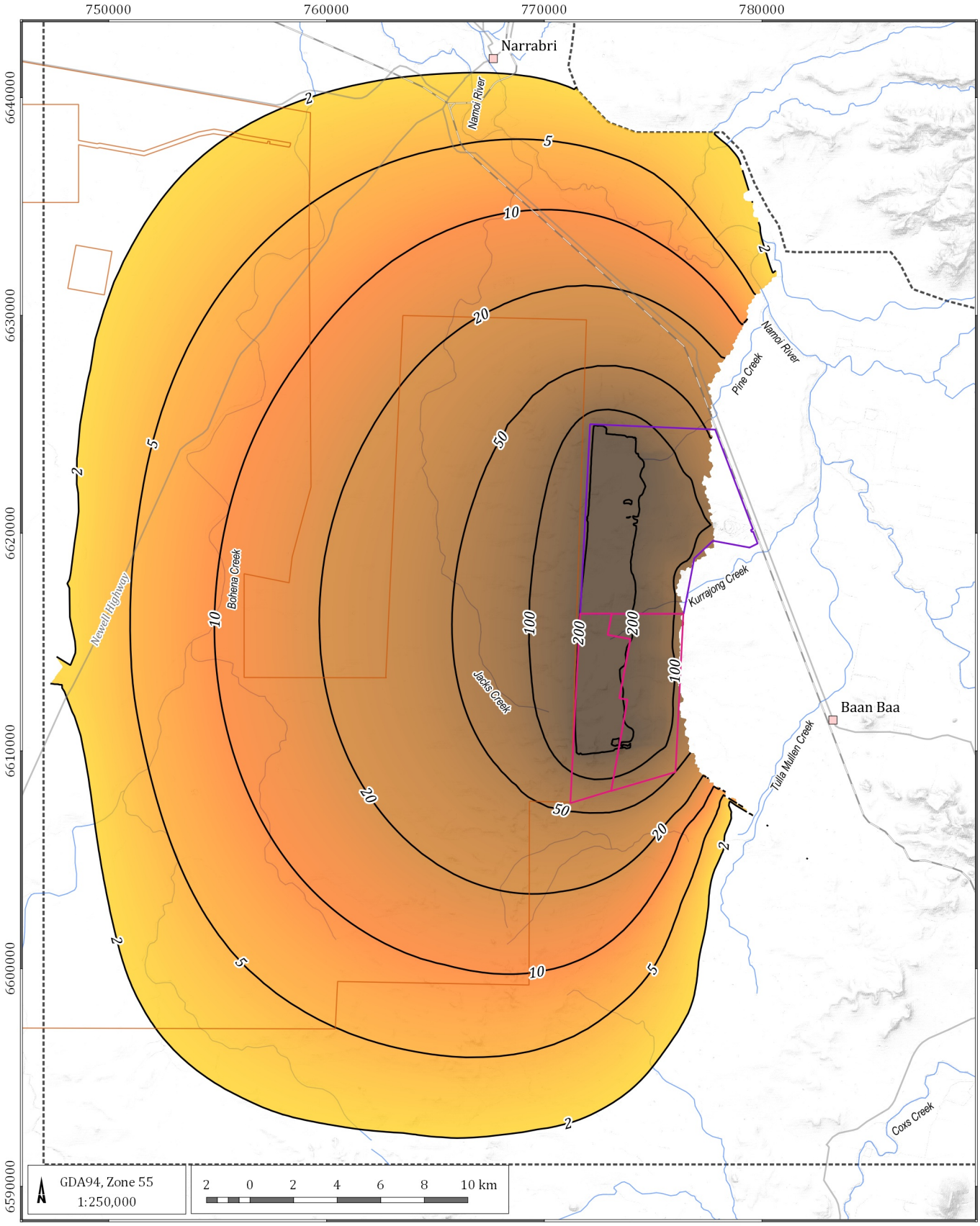
Predicted maximum all-time de-pressurisation impacts in the Hoskissons Coal Seam are shown in Figure 7.3. As expected, given the depth of the underground mining area below ground, predicted drawdown in the Hoskissons Coal Seam is significant within the underground mining area and drawdowns of more than 2 m are predicted up to 23 km from the Project. Maximum impacts in the Hoskissons Coal Seam, particularly close to the mine site, occur towards the end of the proposed mine life.

Predicted maximum all-time drawdown impacts in the Pilliga Sandstone are shown in Figure 7.7. Given that the Pilliga Sandstone is separated from the Hoskissons Coal Seam by the intervening Digby, Napperby, Garrawilla Volcanics and Purlawaugh formation, impacts are substantially reduced compared to those predicted in the coal seam. Impacts of more than 2 m are only predicted over relatively small areas close to the western limit of the proposed underground mining area. Predictions suggest that impacts are also likely to occur sometime after completion of mining due to the time it takes for drawdown impacts to propagate through the strata overlying the coal seams. This is due to the high level of inertia (time-lag) in groundwater systems that are poorly connected to surficial recharge sources.

Predicted maximum all-time drawdown impacts in the uppermost model layer, which represents the Quaternary alluvium and regolith, are shown in Figure 7.8. As shown in Figure 7.8, whilst drawdowns of more than 10 m are predicted in near surface regolith east of the Project, impacts reduce relatively rapidly with distance such that predicted maximum drawdowns do not exceed 2 m in any part of the highly productive Namoi Alluvium aquifer. As shown in the detailed inset maps in Figure 7.8, results suggest that the predicted 2 m drawdown contour overlaps with the GIS polygon showing the extent of the Namoi Alluvium highly productive aquifer in three small areas. However, this polygon extends beyond the boundary of the mapped Quaternary alluvium (Figure 4.5) and therefore appears to over-estimate the extent of the aquifer. Maximum impacts in the near surface strata are therefore predicted to occur in a zone to the east of the underground mining area but to the west of the Namoi Alluvium in areas where the Hoskissons Coal Seam subcrops beneath the regolith. This reflects the fact that impacts tend to preferentially propagate within the coal seam, rather than into overlying units, since the vertical hydraulic conductivity of the strata overlying the mine workings is substantially lower than the horizontal hydraulic conductivity of the coal seams themselves.

Predicted drawdowns in the intervening low productivity aquifers which separate the coal seams from the main aquifers are shown in Figure 7.4 to Figure 7.6. Predicted impacts in all formations represented in the model are presented in Appendix D 4. No drawdown or other predicted impacts are predicted in fractured basement aquifers including the Boggabri Volcanics.

Impacts on GDEs and water supply bores which are connected to the aquifers described above are discussed in Section 7.6.




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown (m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum drawdown impacts, due to the Project - Hoskissons Coal Seam**

DATE 22/06/2020

FIGURE No: **7.3**

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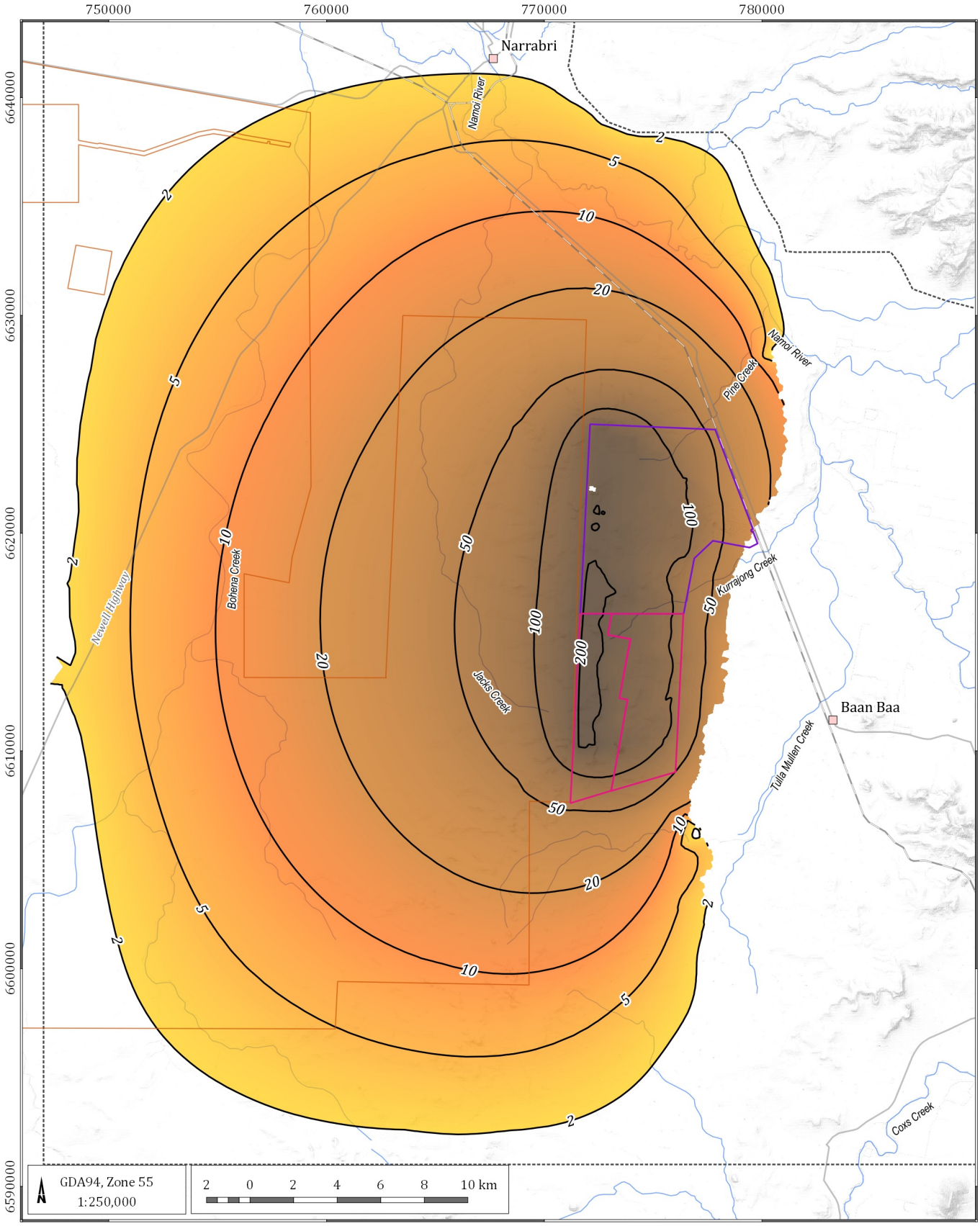
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.03_G1972_Predicted maximum drawdown impacts, due to the Project - Hoskissons Coal Seam.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown (m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum drawdown impacts, due to the Project - Napperby Formation**

DATE 17/06/2020

FIGURE No: **7.4**

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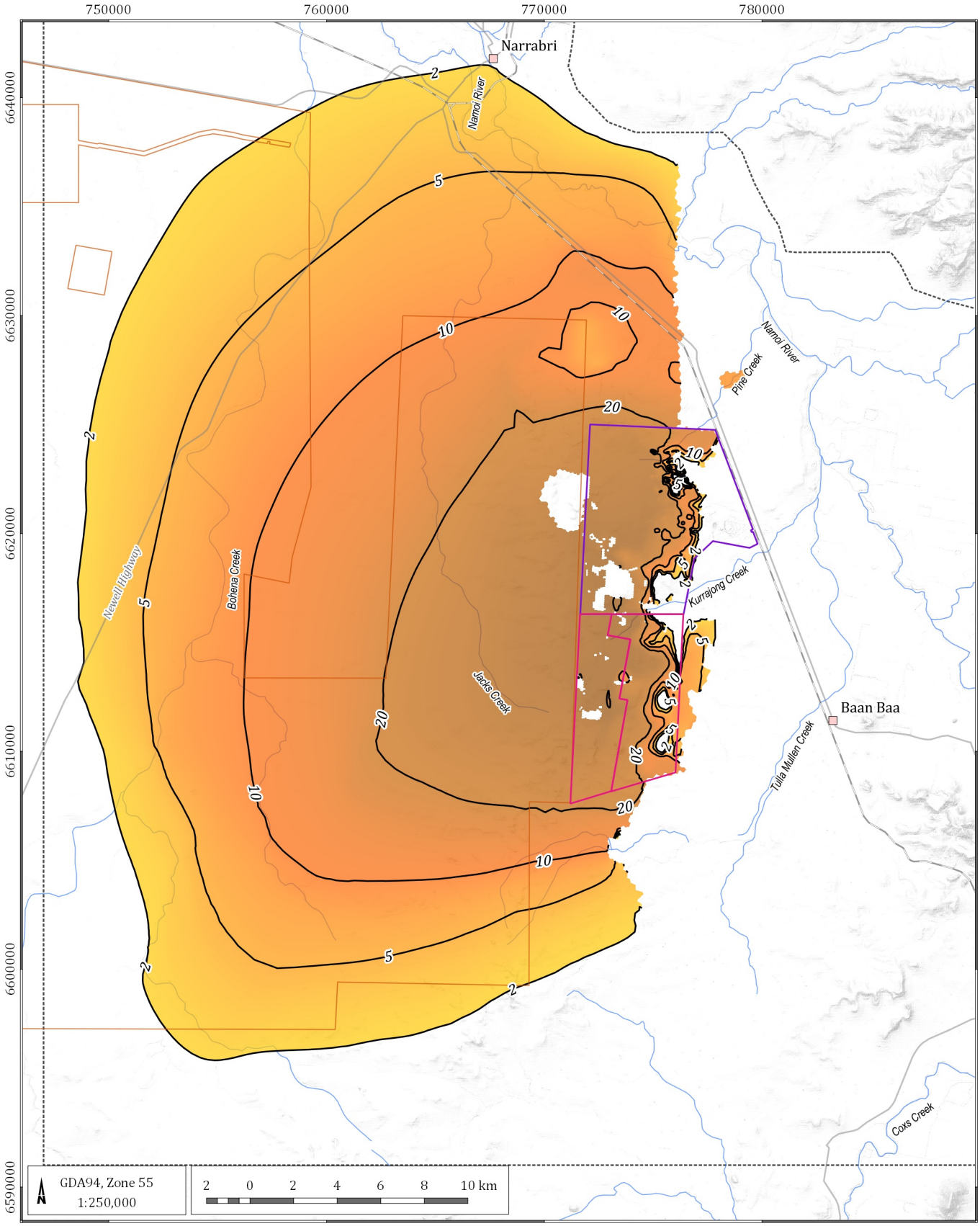
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.04_G1972_Predicted maximum drawdown impacts, due to the Project - Napperby Formation.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown (m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

## Predicted maximum drawdown impacts, due to the Project - Garrawilla Volcanics

DATE 17/06/2020

FIGURE No: **7.5**

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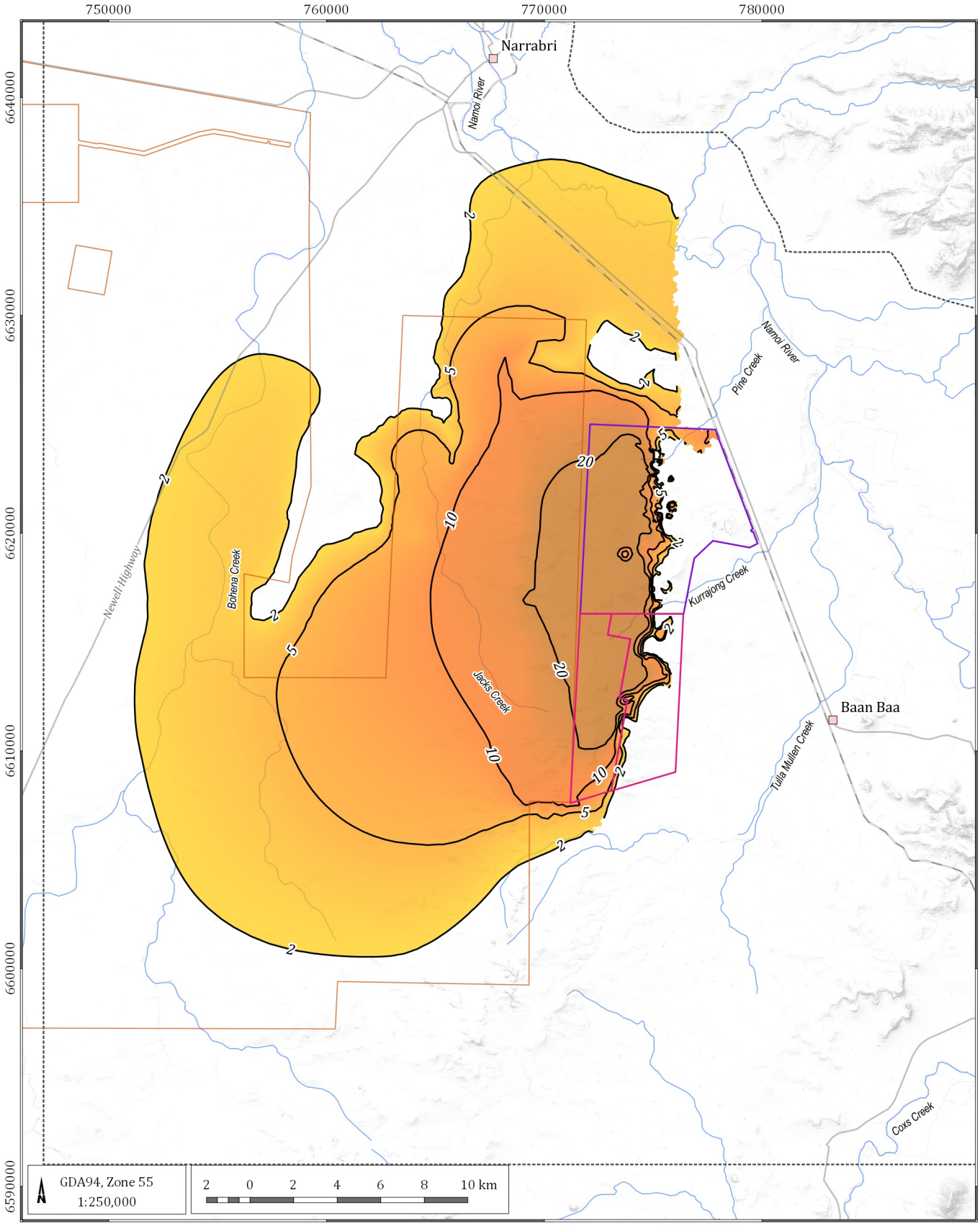
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.05_G1972_Predicted maximum drawdown impacts, due to the Project - Garrawilla Volcanics.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model mesh

**Drawdown (m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum drawdown impacts, due to the Project - Purlawaugh Formation**

DATE 17/06/2020

FIGURE No: **7.6**

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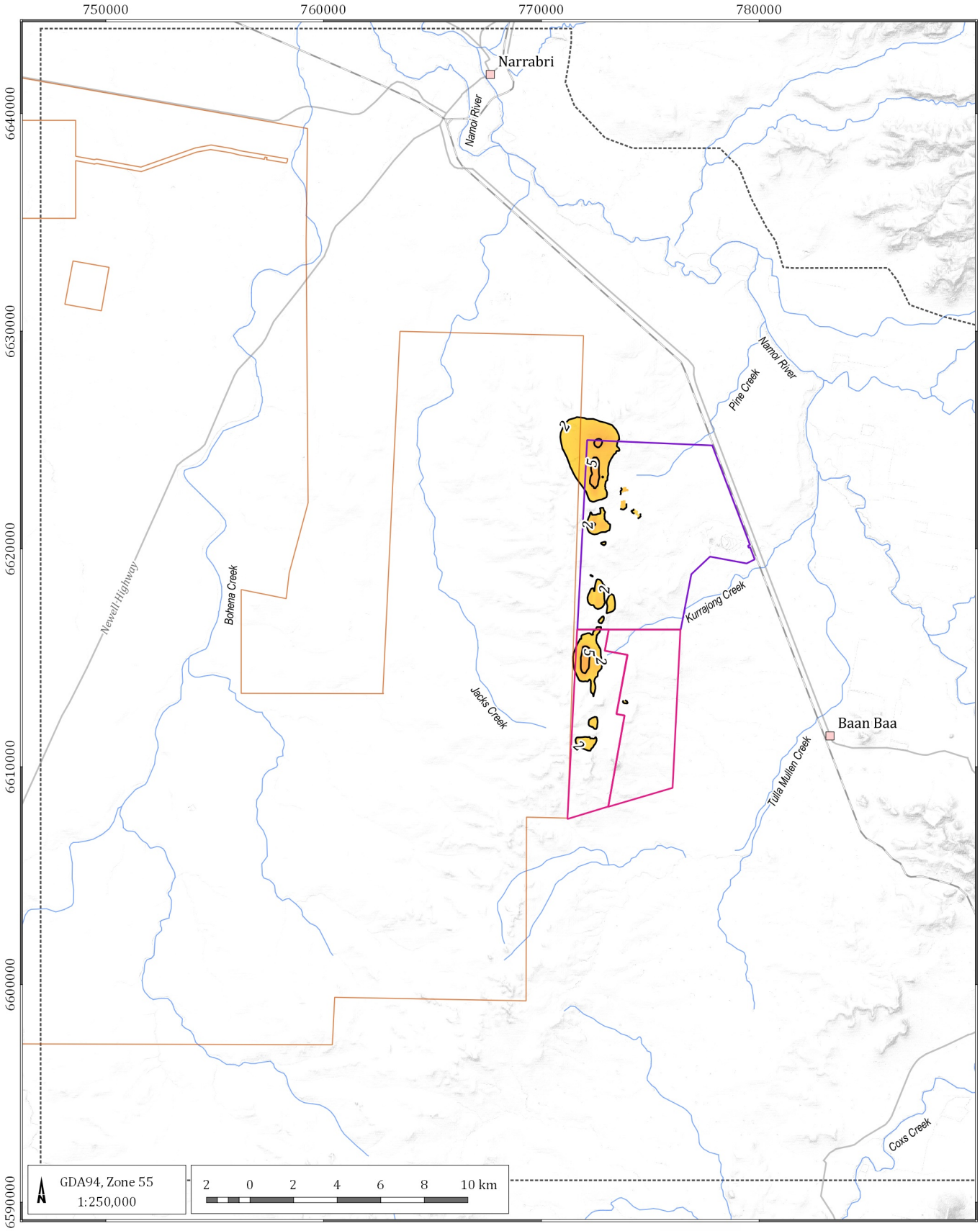
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.06_G1972_Predicted maximum drawdown impacts, due to the Project - Purlawaugh Formation.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown (m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum drawdown impacts, due to the Project - Pilliga Sandstone**

DATE 17/06/2020

FIGURE No: **7.7**

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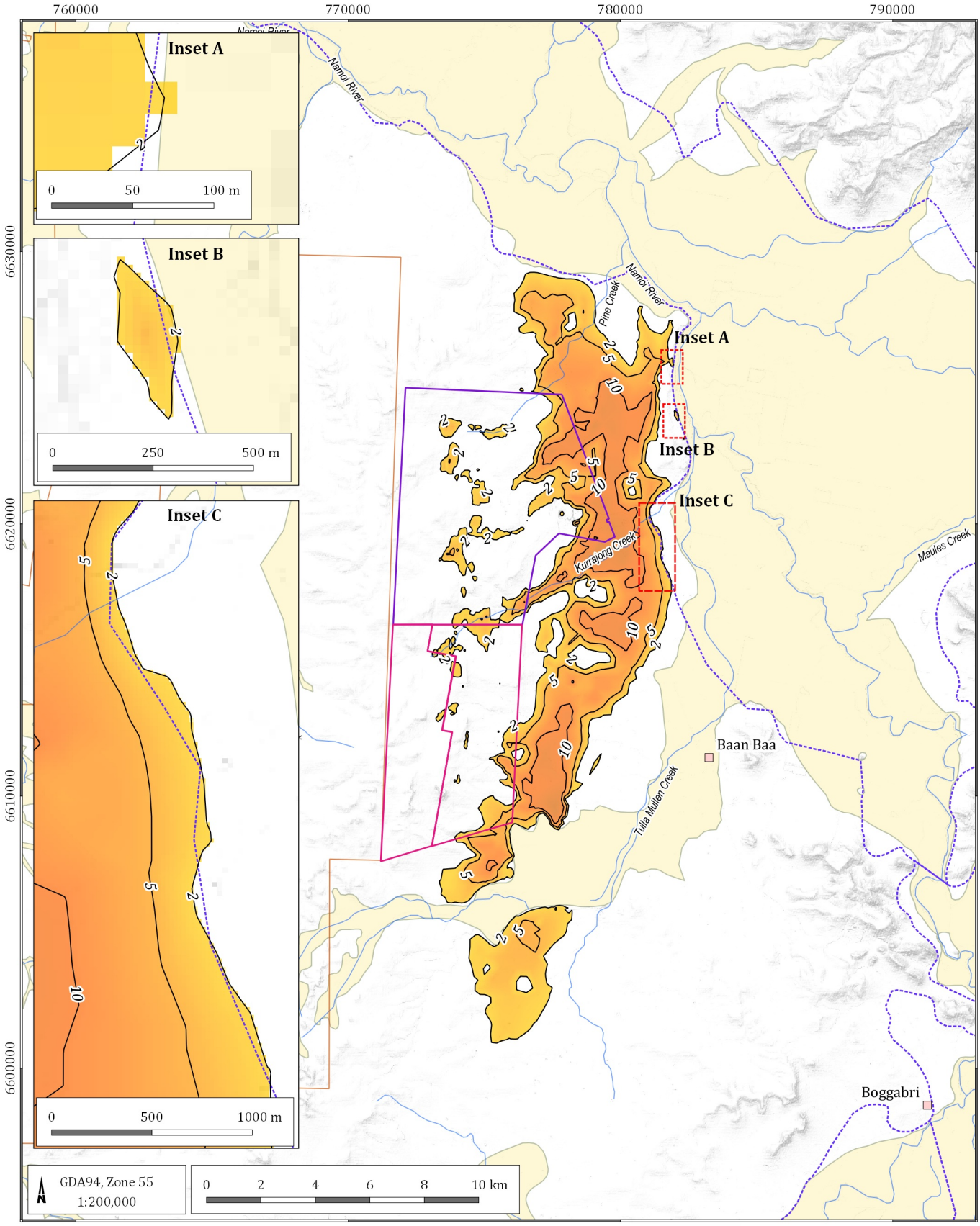
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.07_G1972_Predicted maximum drawdown impacts, due to the Project - Pilliga Sandstone.qgs




LEGEND

- Populated place
- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Highly productive alluvial aquifer
- Quaternary alluvium

**Drawdown (m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

## Predicted maximum drawdown impacts, due to the Project - Quaternary alluvium / regolith

DATE 17/06/2020

FIGURE No: **7.8**

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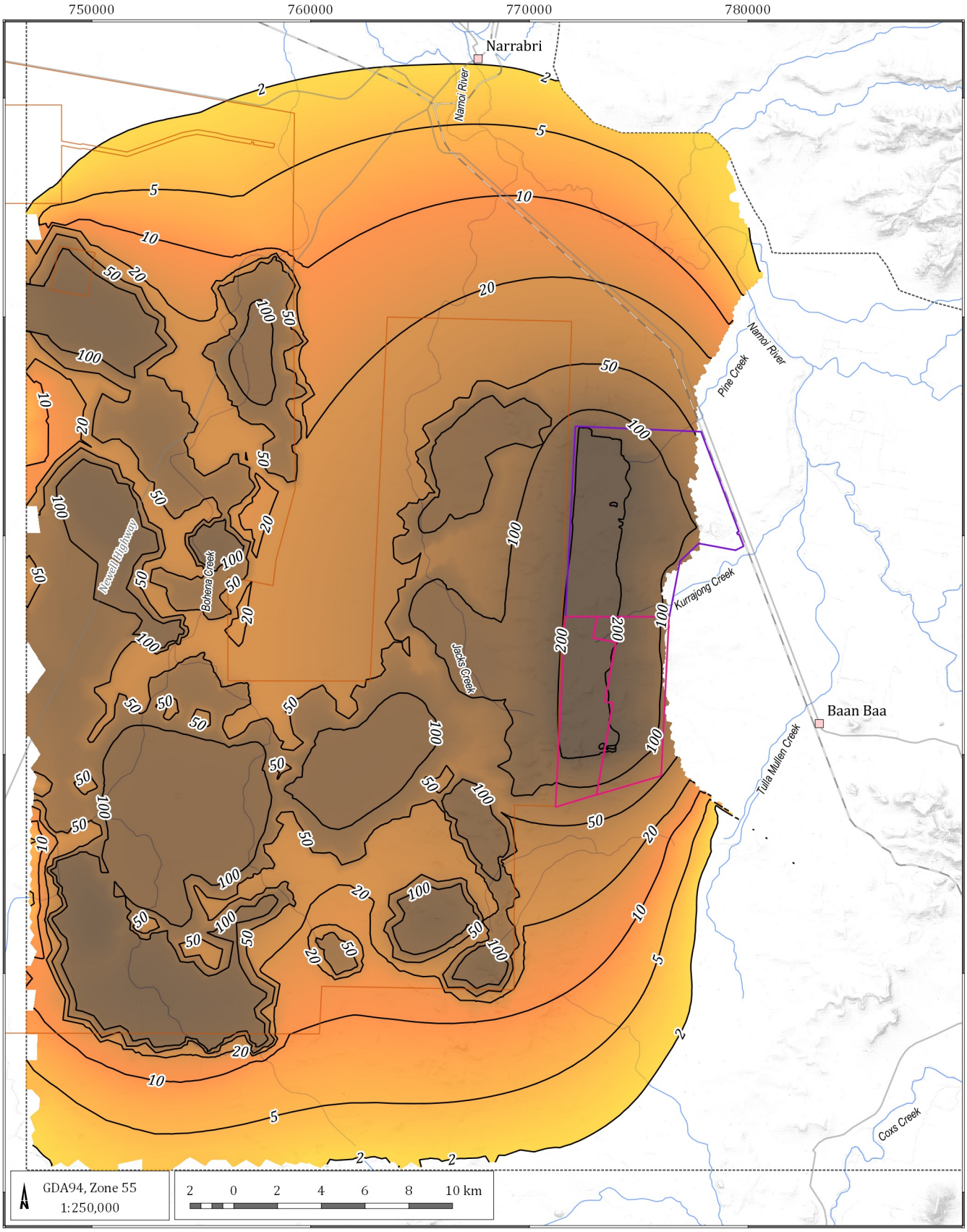
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.08_G1972_Predicted maximum drawdown impacts, due to the Project - Quaternary alluvium_regolith.qgs

### *7.4.3 Cumulative groundwater level impacts – the Project and Narrabri Gas Project*

Predicted maximum drawdown related to development of both the Project (including the approved Narrabri Mine) and the Narrabri Gas Project (i.e. cumulative impacts) in the Hoskissons Coal Seam, Pilliga Sandstone and Quaternary alluvium/regolith are shown Figure 7.9, Figure 7.13 and Figure 7.14 respectively. Drawdowns in the Napperby Formation, the Garrawilla Volcanics and the Purlawaugh Formation are shown in Figure 7.10, Figure 7.11 and Figure 7.12 respectively. As described in Appendix D (Section D 4.3.2), the impacts of the Narrabri Gas Project were simulated in the Project groundwater flow model using extraction rates representing the 'basecase' provided by Santos. Extraction rates were distributed as necessary to account for the different grid resolutions adopted for the Project groundwater model, compared to the Narrabri Gas Project model (CDM Smith, 2016). Predicted groundwater levels in the Narrabri Gas Project area generated by the two models were also compared, to confirm that the Project Groundwater Model was able to accurately replicate the reported impacts of the Narrabri Gas Project (CDM Smith, 2016).

As shown in Figure 7.9, operation of the Narrabri Gas Project in the area to west of the Project leads to additional impacts on the Hoskissons Coal Seam, as would be expected. As shown in Figure 7.13 and Figure 7.14, however, impacts on the Pilliga Sandstone and Quaternary alluvium/regolith are similar to the Project only impacts shown in Figure 7.7 and Figure 7.8. In particular, the area predicted to experience more than 2 m of drawdown is very similar in the two development scenarios assessed. This suggests that the majority of the cumulative impacts on these near surface aquifers are predominantly related to the Project rather than the Narrabri Gas Project which is consistent with the relative depth of these two projects. The Narrabri Gas Project targets the Hoskissons Coal Seam at greater depths than the Project and hence incremental impacts on near surface aquifers including the Pilliga Sandstone and Quaternary alluvium/regolith are reduced.




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown (m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum cumulative drawdown impacts due to the Project and Narrabri Gas Project - Hoskissons Coal Seam**

DATE 17/06/2020

FIGURE No: **7.9**

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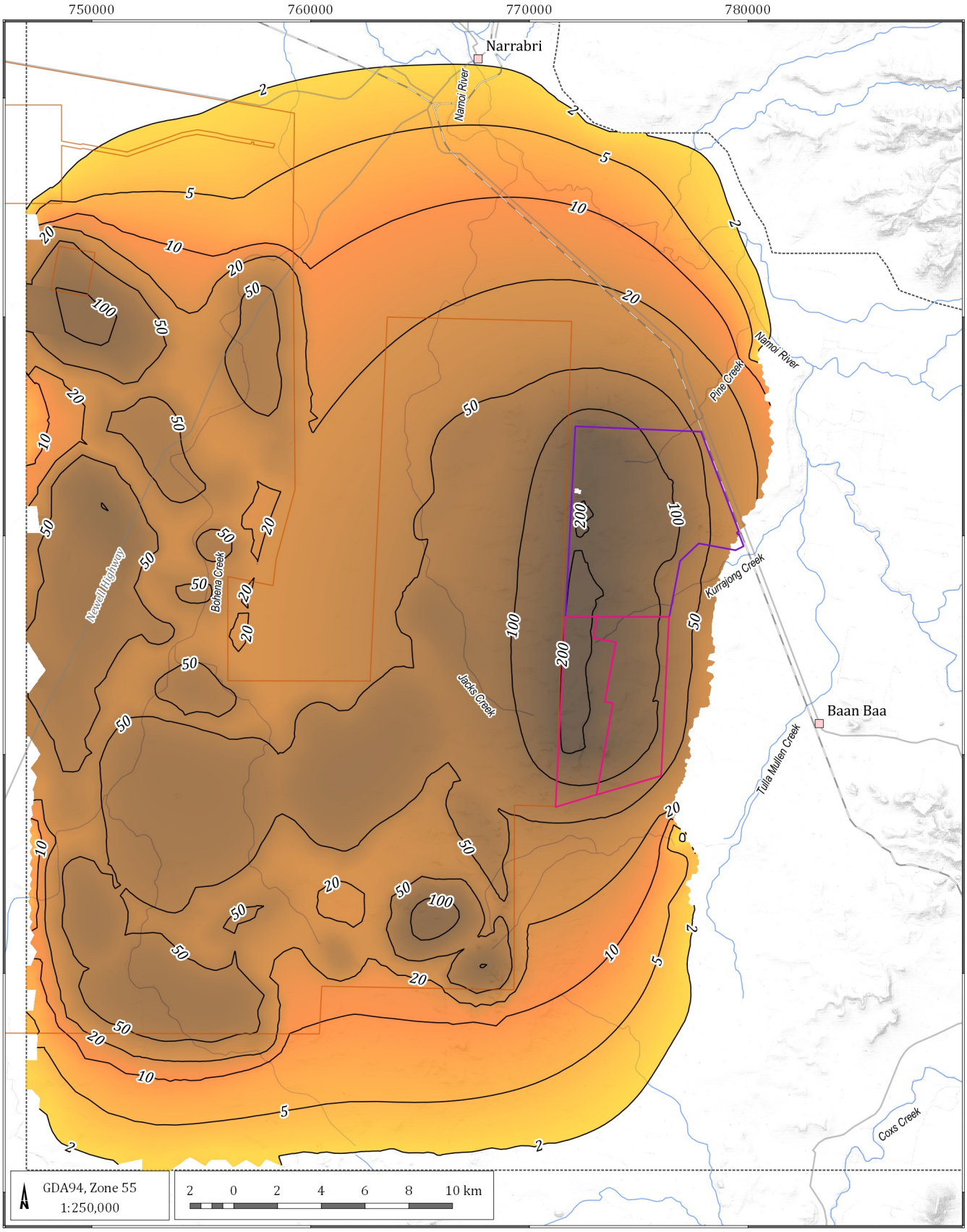
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.09_G1972_Predicted maximum cumulative drawdown impacts, Narrabri Mine and Gas projects – Hoskissons Coal Seam.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown (m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum cumulative drawdown impacts due to the Project and Narrabri Gas Project - Napperby Formation**

DATE 17/06/2020

FIGURE No: **7.10**

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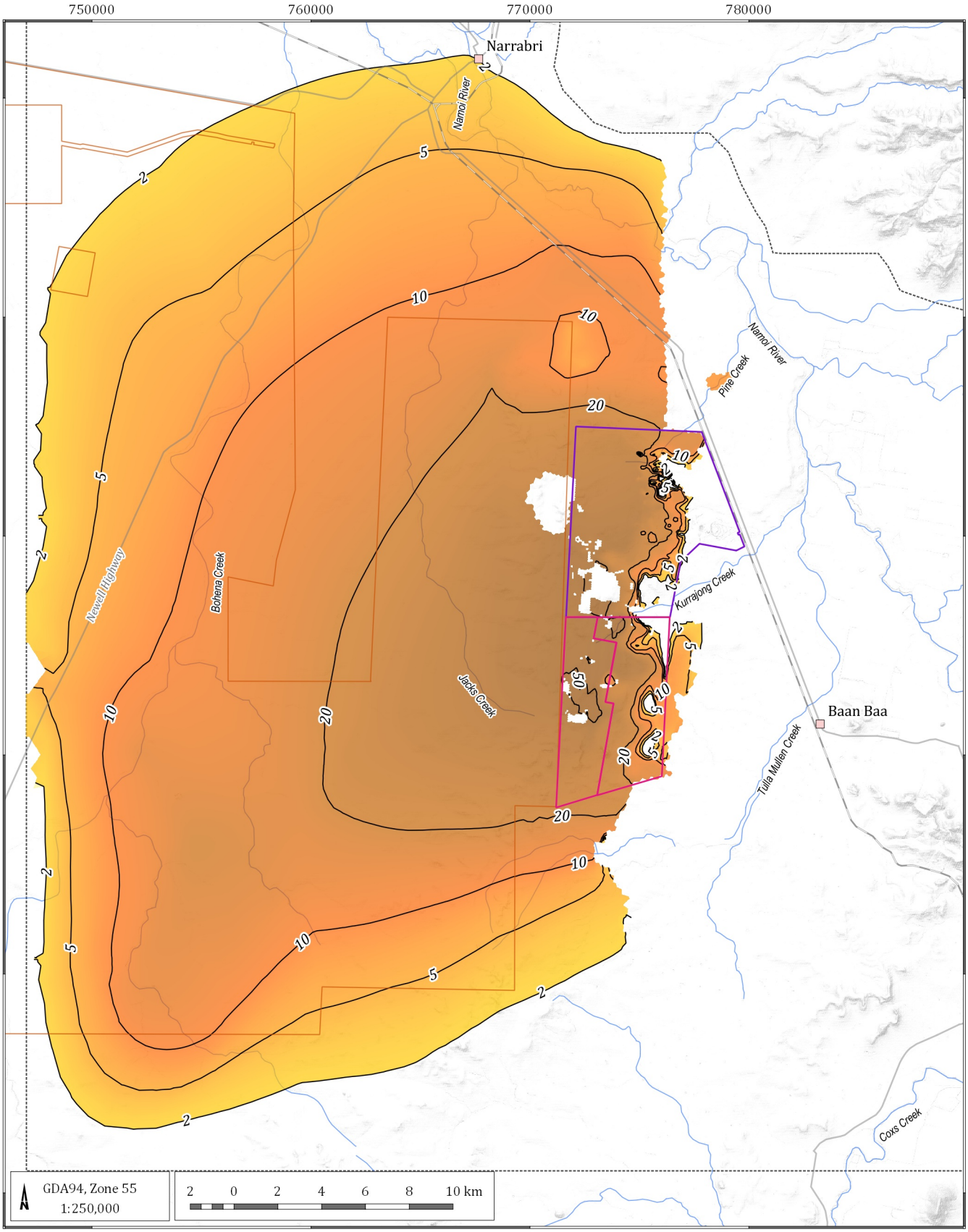
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.10_G1972_Predicted maximum cumulative drawdown impacts, Narrabri Mine and Gas projects - Napperby.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown (m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum cumulative drawdown impacts due to the Project and Narrabri Gas Project - Garrawilla Volcanics**

DATE 17/06/2020

FIGURE No: **7.11**

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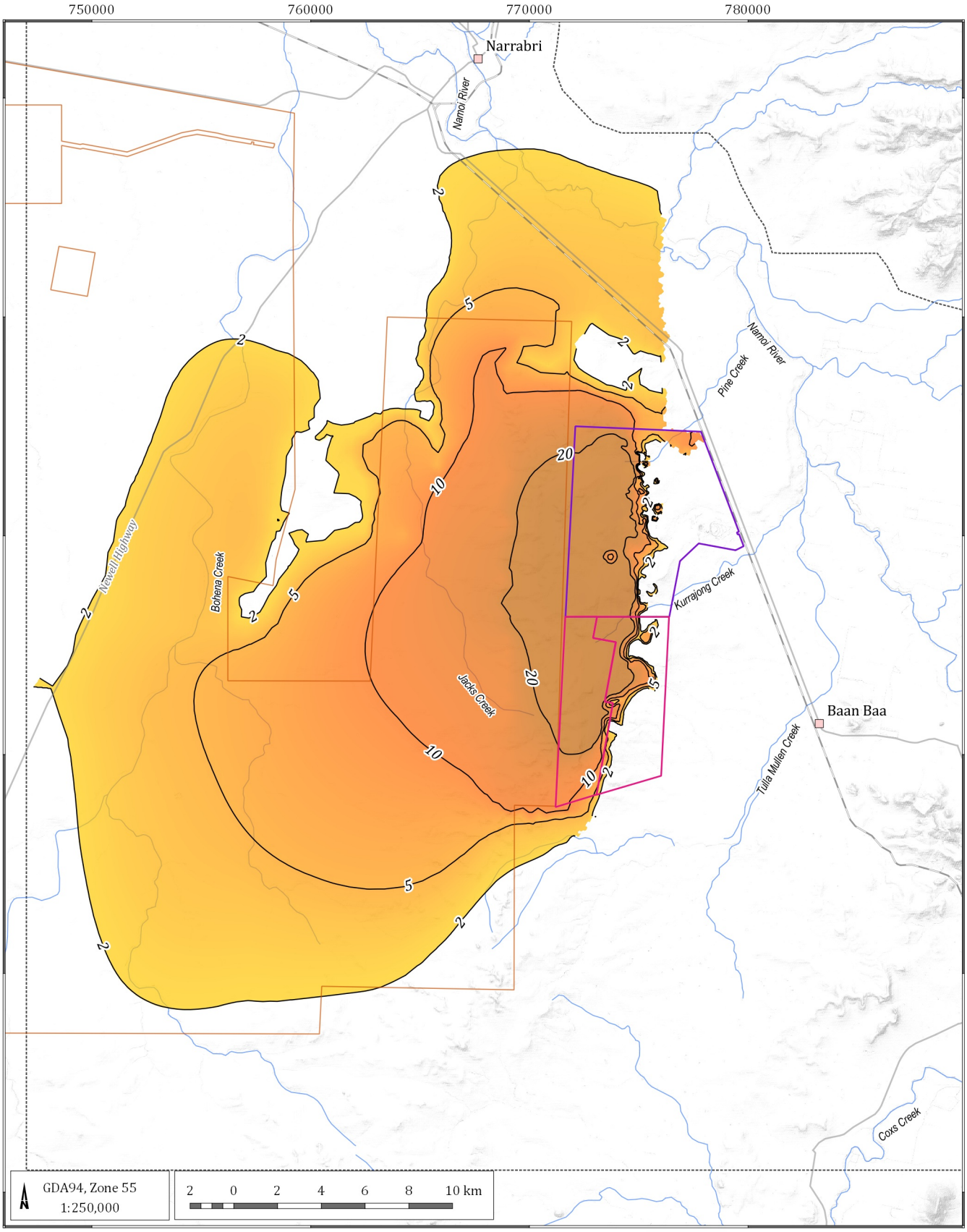
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.11_G1972_Predicted maximum cumulative drawdown impacts, Narrabri Mine and Gas projects - Garrawilla.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drwdown (m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum cumulative drawdown impacts due to the Project and Narrabri Gas Project - Purlawaugh Formation**

DATE 17/06/2020

FIGURE No: **7.12**

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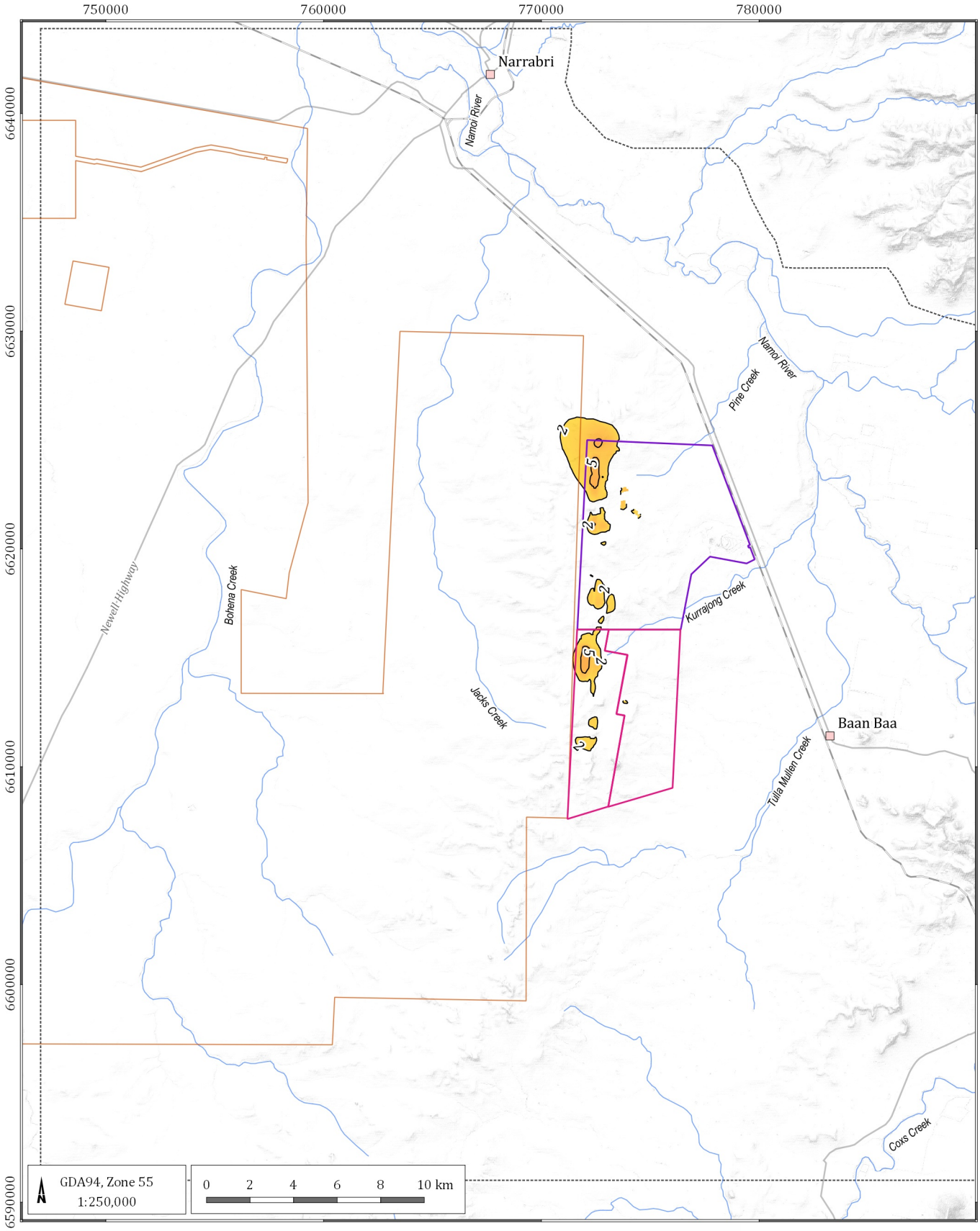
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.12_G1972_Predicted maximum cumulative drawdown impacts, Narrabri Mine and Gas projects - Purlawaugh.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown (m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum cumulative drawdown impacts due to the Project and Narrabri Gas Project - Pilliga Sandstone**

DATE 19/06/2020

FIGURE No: **7.13**

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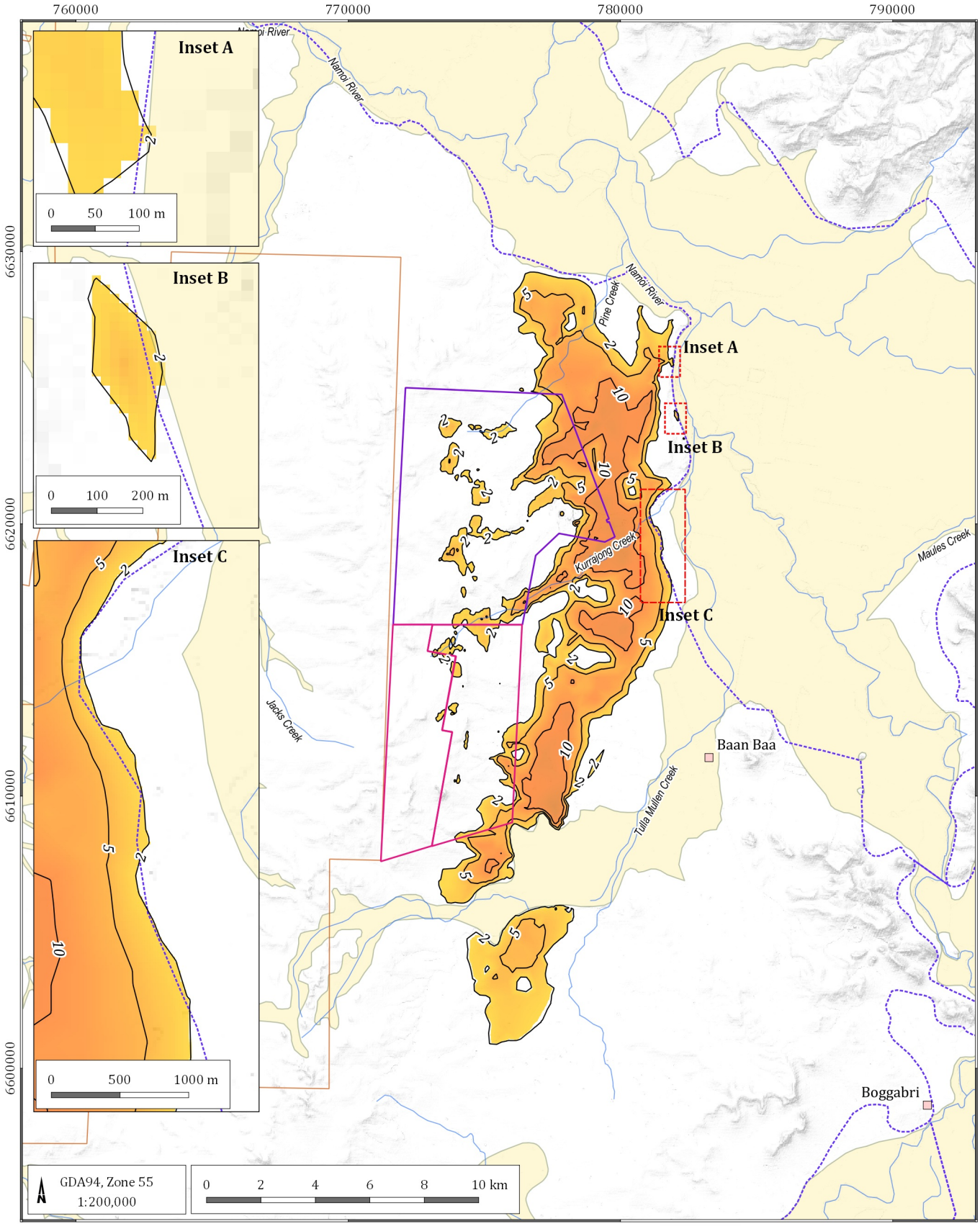
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.13_G1972_Predicted maximum cumulative drawdown impacts, Narrabri Mine and Gas projects - Pilliga.qgs




LEGEND

- Populated place
- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Highly productive alluvial aquifer
- Quaternary alluvium

**Drawdown (m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum cumulative drawdown impacts due to the Project and Narrabri Gas Project - Quaternary alluvium / regolith**

DATE 17/06/2020

FIGURE No: **7.14**

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G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.14_G1972_Predicted maximum cumulative drawdown impacts, Narrabri Mine and Gas projects - Quaternary alluvium.qgs

## 7.5 Impacts on groundwater discharge to surficial aquifers and watercourses

### *7.5.1 Groundwater discharge to Quaternary alluvium*

Predicted discharge to the Quaternary alluvium from underlying hydrostratigraphic units for each of three scenarios described in Section 6.2 are shown in Figure 7.15, although given the very similar flows predicted in each scenario it is difficult to distinguish each of the lines on the graph. Cumulative and Project only impacts calculated by comparison of outputs from these three scenarios therefore are presented in Figure 7.16 and Figure 7.17. As shown in Figure 7.15, model predictions for all three scenarios suggest net flow from underlying strata to the overlying Quaternary alluvium except during wet periods when the net flow direction is reversed. Under long-term average climate conditions which are assumed to apply into the future (i.e. from 2020 onwards) the model predictions show net discharge to the alluvium of around 15 ML/d (or 5,475 ML/year) under the baseline conditions. As shown in Figure 7.16 model predictions suggest that net discharge to the Quaternary alluvium would reduce by around 80 ML/year (or around 1% of predicted discharge to the alluvium within the model domain in the baseline scenario) at the end of the proposed operational period. As shown in Figure 7.17 predictions also suggest that impacts would continue to increase post-mining, due to the time taken for indirect impacts to occur in aquifers other than the Hoskissons Coal Seam. Peak impacts of around 240 ML/year (or around 4.5% of predicted baseline discharge) are predicted to occur in 2192 (i.e. around 150 years after mining ceases).

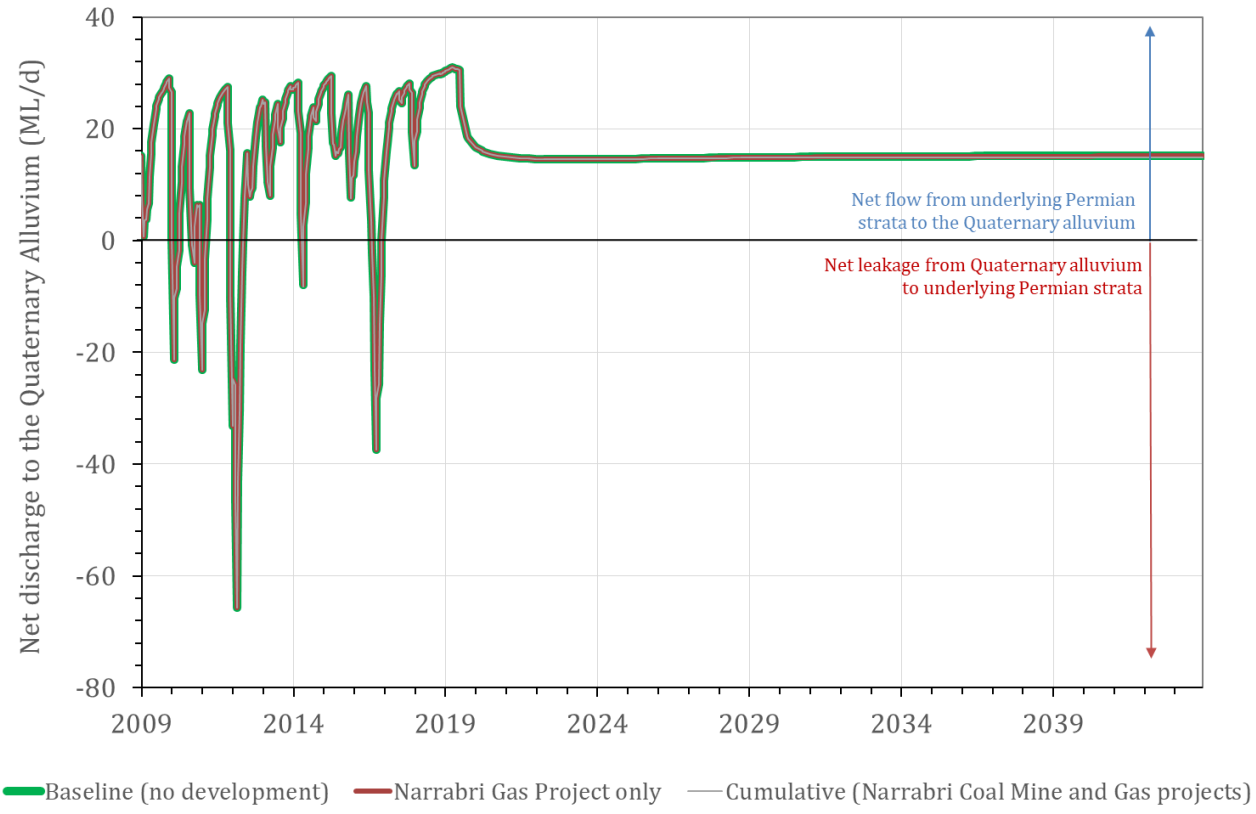



**Figure 7.15 Predicted net discharge to the Quaternary alluvium from underlying Permian strata**

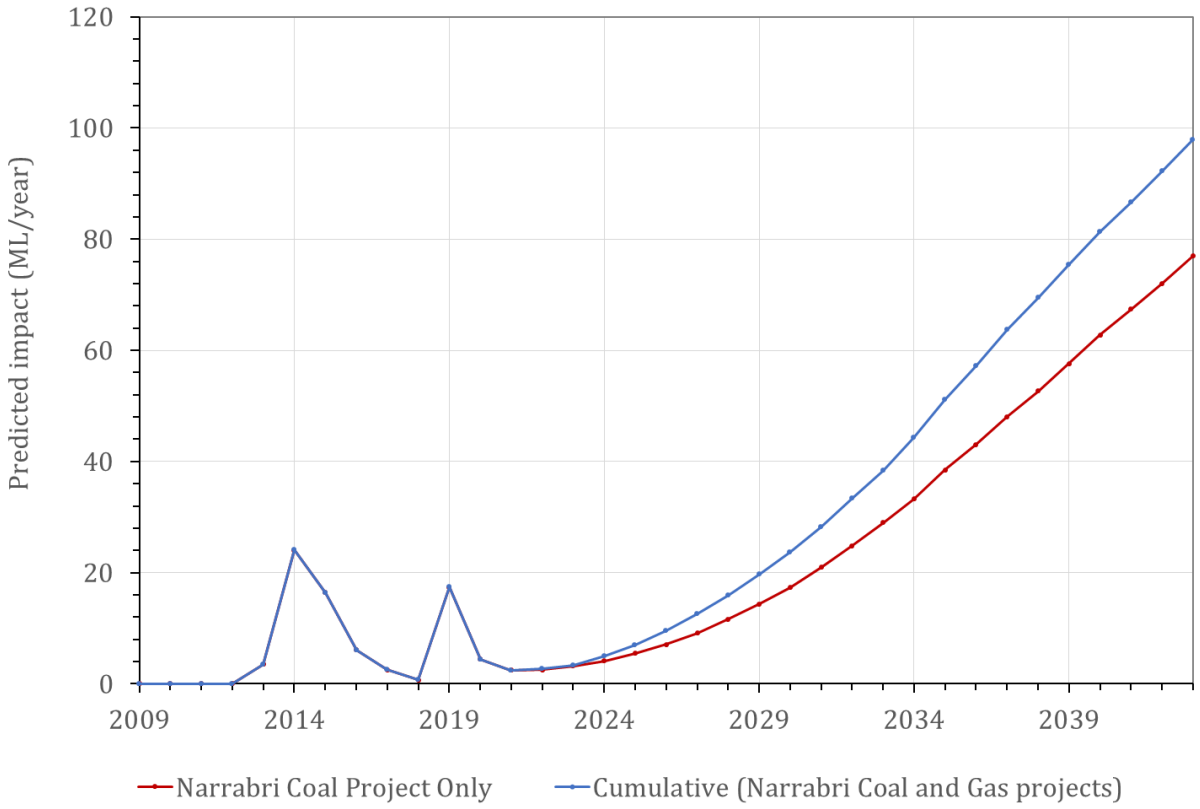



**Figure 7.16 Predicted reduction in net discharge to the Quaternary alluvium, operational period**

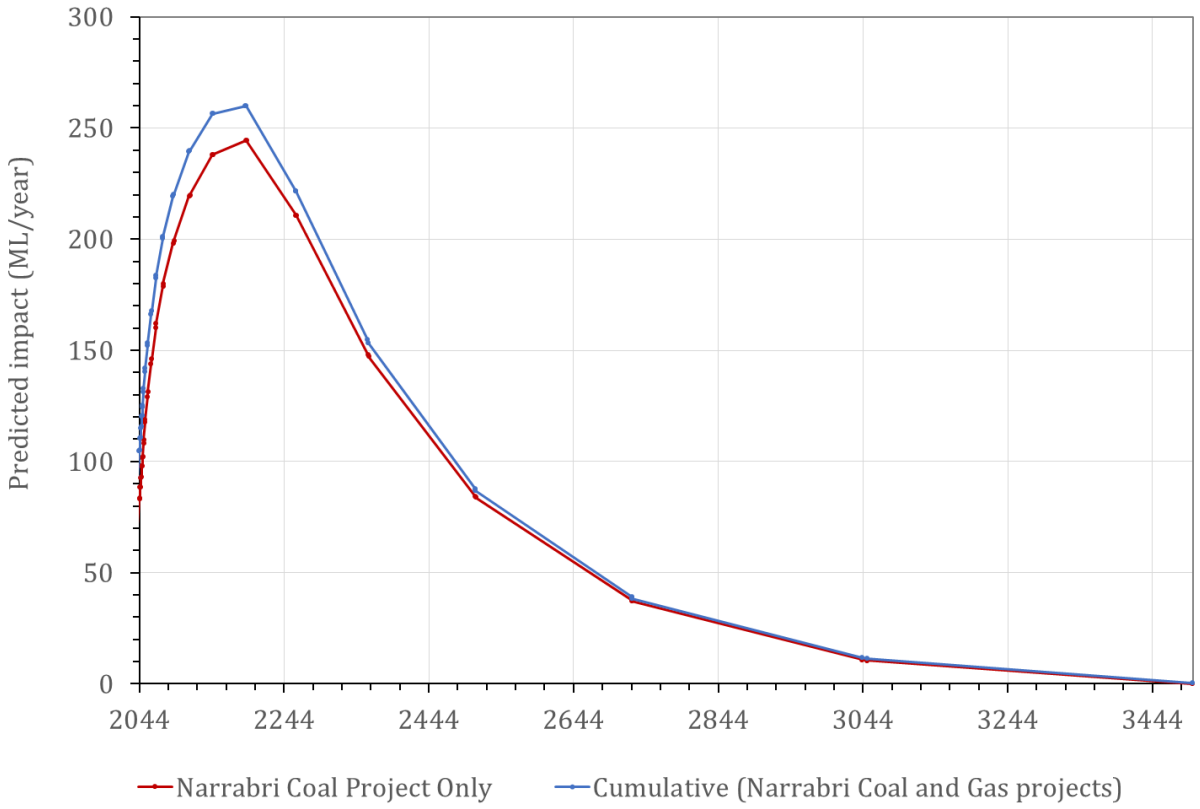



**Figure 7.17 Predicted reduction in net discharge to the Quaternary alluvium, post-mining**

### *7.5.2 Groundwater discharge to surface water courses*

A proportion of groundwater discharging to the Quaternary alluvium would ultimately discharge to the Namoi River. Predicted discharge to the river for each of three scenarios described in Section 6.2 are shown in Figure 7.18, although given the very similar flows predicted in each scenario it is difficult to distinguish each of the lines on the graph. Cumulative and Project only impacts calculated by comparison of outputs from these three scenarios are presented in Figure 7.19 and Figure 7.20.

As shown in Figure 7.18, model predictions for all three scenarios suggest net flow into the river except during dry periods when the net flow direction is reversed. Under long-term average climate conditions which are assumed to apply into the future (i.e. from 2020 onwards) the model predictions show net discharge to the river of around 13 ML/d (or 4,745 ML/year) under the baseline scenario. As shown in Figure 7.19 model predictions suggest that net discharge to the Namoi River would reduce by around 28 ML/year (or around 0.6% of predicted discharge under the baseline scenario) at the end of the proposed mine operational period. As shown in Figure 7.20 predictions also suggest that impacts would continue to increase post-mining with peak impacts of 142 ML/year (or around 3% of predicted baseline discharge) predicted to occur in 2192 (i.e. around 150 years after mining ceases).

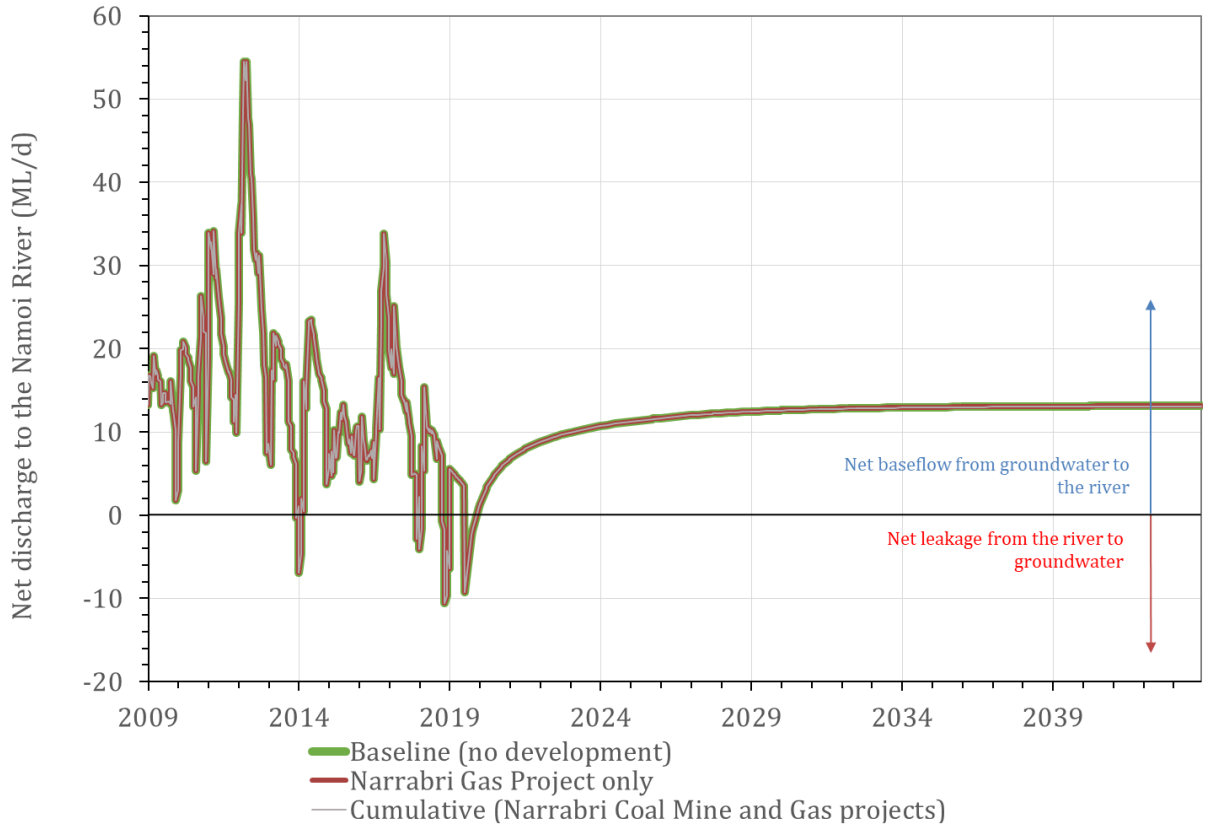



**Figure 7.18 Predicted net groundwater discharge to the Namoi River**

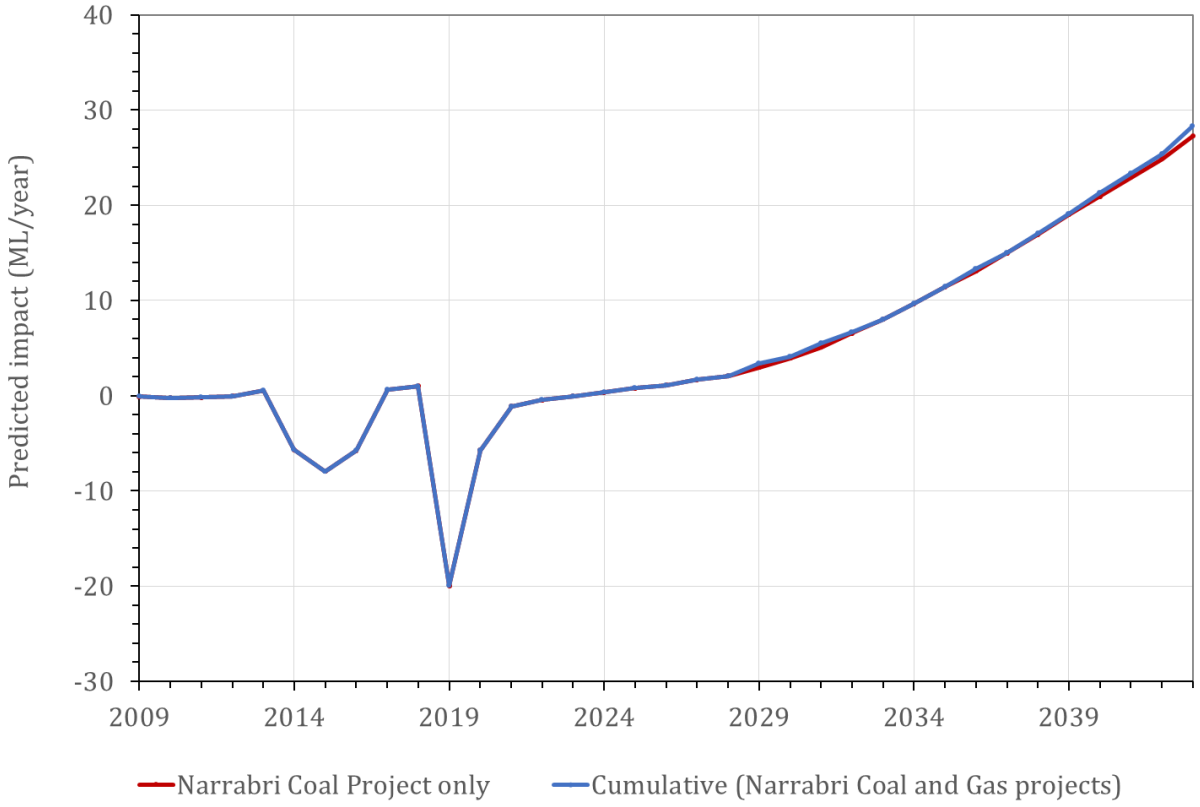



**Figure 7.19 Predicted reduction in net groundwater discharge to the Namoi River, operational period**

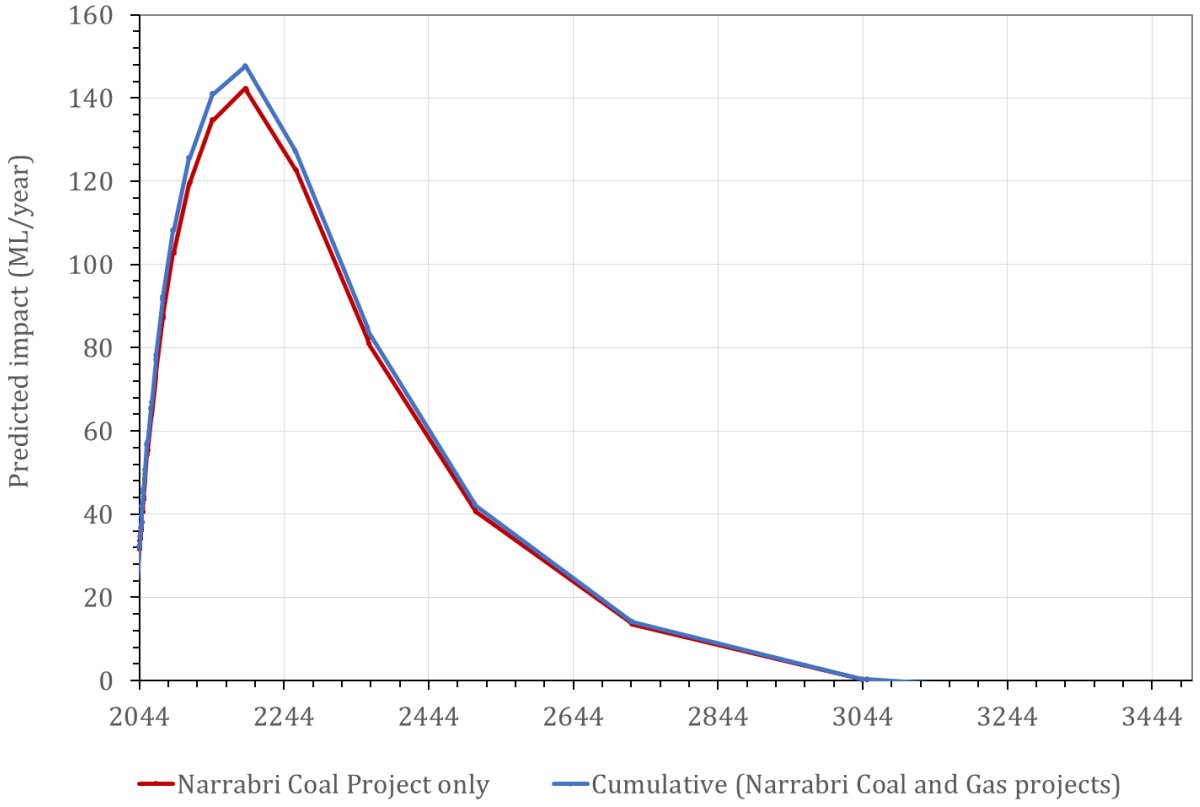



**Figure 7.20 Predicted reduction in net groundwater discharge to the Namoi River, post-mining**

Predictions also suggest minor reductions of up to around 68 ML/year in groundwater discharge to other creeks close to the Project. As shown in Figure 7.21, maximum reductions of around 54 ML/year are predicted in discharge to the Bohena Creek which is located to west of the mine, and smaller predicted reductions in discharge to Tulla Mullen, Kurrajong and Pine creeks to the east. Modelled water balance results suggest that groundwater discharge to minor creeks represents a very small component of the overall water balance (Appendix D, Section D 3.5.7). This is consistent with observations from long-term monitoring at the site and the recent site visit which suggests that the local creeks are highly ephemeral and not likely to be in receipt of substantial groundwater discharge. Accordingly, model predictions show relatively minor impacts on discharge, despite drawdown in the order of 10 m to 15 m predicted in surficial units to the east of the Project (see Figure 7.8), since modelled groundwater levels are already predominantly below ground surface prior to development of the mine.

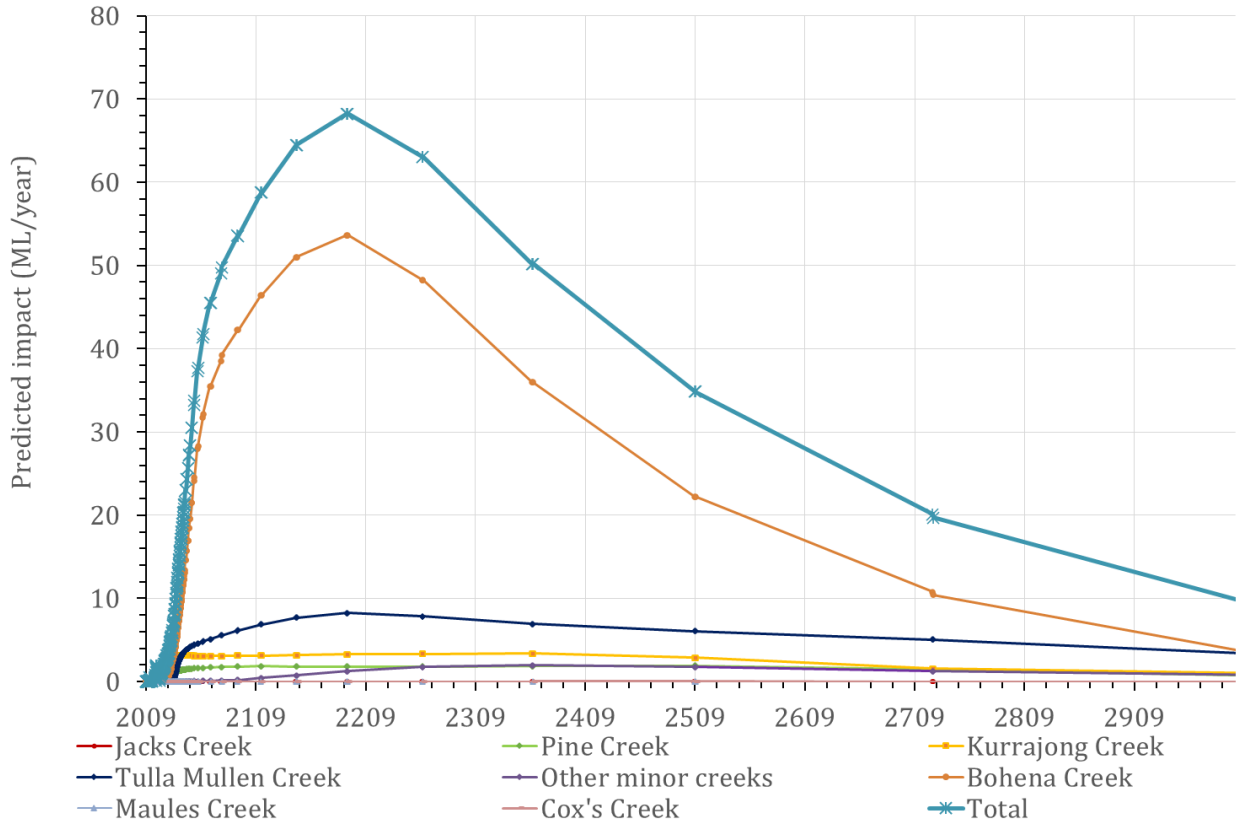



**Figure 7.21 Predicted impacts on net groundwater discharge to minor creeks, due to the Project only**

## 7.6 Impacts to sensitive receptors

### *7.6.1 Drawdown in private water supply bores*

As discussed previously in Section 5.6.1 and shown in Figure 5.10, there up to around 1,533 existing registered water supply bores within the domain of the groundwater flow model developed for the current assessment. A number of un-registered bores were also identified as part of a bore census conducted within ML 1609, MLAs 1 and 2, and surrounding areas (Appendix G).

Initially, each of these bores was attributed to a single hydrostratigraphic unit and groundwater model layer by intersecting the recorded depth of the bore with the modelled surfaces, since neither the stratigraphic unit targeted by each bore or screen information is typically available.

A preliminary assessment was then generated for each bore by extracting modelled drawdown in the model layer present at the base of the bore. Implicit within this preliminary assessment is the assumption that each bore extracts from the aquifer present at the base of the bore. However, where this is not the case, drawdowns tend to be over-predicted since predicted drawdowns increase with depth and since many bores are not screened to the base of the bore. A two stage process was therefore adopted where each bore with more than 2 m of predicted drawdown in the preliminary assessment was subject to a detailed bore by bore review to confirm (as far as possible with the data available) which aquifer(s) or model layer(s) are intersected by each bore. This review process made reference to data from the following sources:

- WaterNSW work summary reports which are typically available for each registered bore and can include information on bore construction, water bearing zones and lithological information from drillers logs; and
- results from the ENRS bore census (Appendix G).

This review process led to the exclusion of a number of registered bores identified in the preliminary list on the basis that:

- the relevant landholder confirmed that the bore did not exist during the bore census (Appendix G);
- the bore census (ENRS, 2020) confirmed that the bore was not in use and that no working pumping infrastructure was installed the bore (i.e. there was no evidence that the bore was currently in use or could easily be brought into production); and/or
- the works summary report indicates that the bore had been backfilled at the time of drilling, or that casing was never installed.

Further details on each bore excluded are provided in Table F1 in Appendix F. Table F1 in Appendix F also includes groundwater bores owned by NCOPL. Groundwater is seldom, if ever, used for agricultural production on NCOPL-owned properties (2rog, 2020). Therefore, drawdown at bores on NCOPL-owned properties would not affect the ongoing use of these properties, which are used predominantly for grazing, during operations or post-mining (2rog, 2020).

A number of other bores were also assessed as likely to be extracting from other shallower units resulting in final predicted drawdowns being less than 2 m. Further details on each of these bores is also provided in Table F1 Appendix F and includes a number of bores which are thought to be extracting from multiple hydrostratigraphic units or model layers. In these cases, drawdowns have been re-assessed by calculating a weighted average water level in each bore based on the transmissivity (i.e. the hydraulic conductivity multiplied by the length of screen) of each unit intersected by the bore. Where this does occur, predicted drawdowns tend to be substantially less than those predicted in the hydrostratigraphic unit or model layer at the base of the bore, especially where a major aquifer is also intersected nearer to the surface.

Privately owned water supply bores predicted to experience more than the 2 m drawdown threshold identified in the AIP are listed below in Table 7.2, and bore locations are shown in Figure 7.22. All of these bores are thought to extract from “less productive” hydrogeological units under the AIP, predominantly the Garrawilla Volcanics and Napperby Formation. As shown in Table 7.2, in all cases drawdowns of more than 2 m are predicted to occur at or following cessation of the Project. Further details of each bore are provided in Table F2 in Appendix F. As summarised in these tables, maximum predicted drawdowns exceed 2 m in eight bores in both the Project only and cumulative scenario (where both the Project and the Narrabri Gas Project proceed to operation). As shown in Table F2, all but one of the bores listed (GW054227) were assessed as part of the bore census survey undertaken by ENRS (Appendix G).

## Table 7.2 Private bores predicted to experience more than 2 m of drawdown

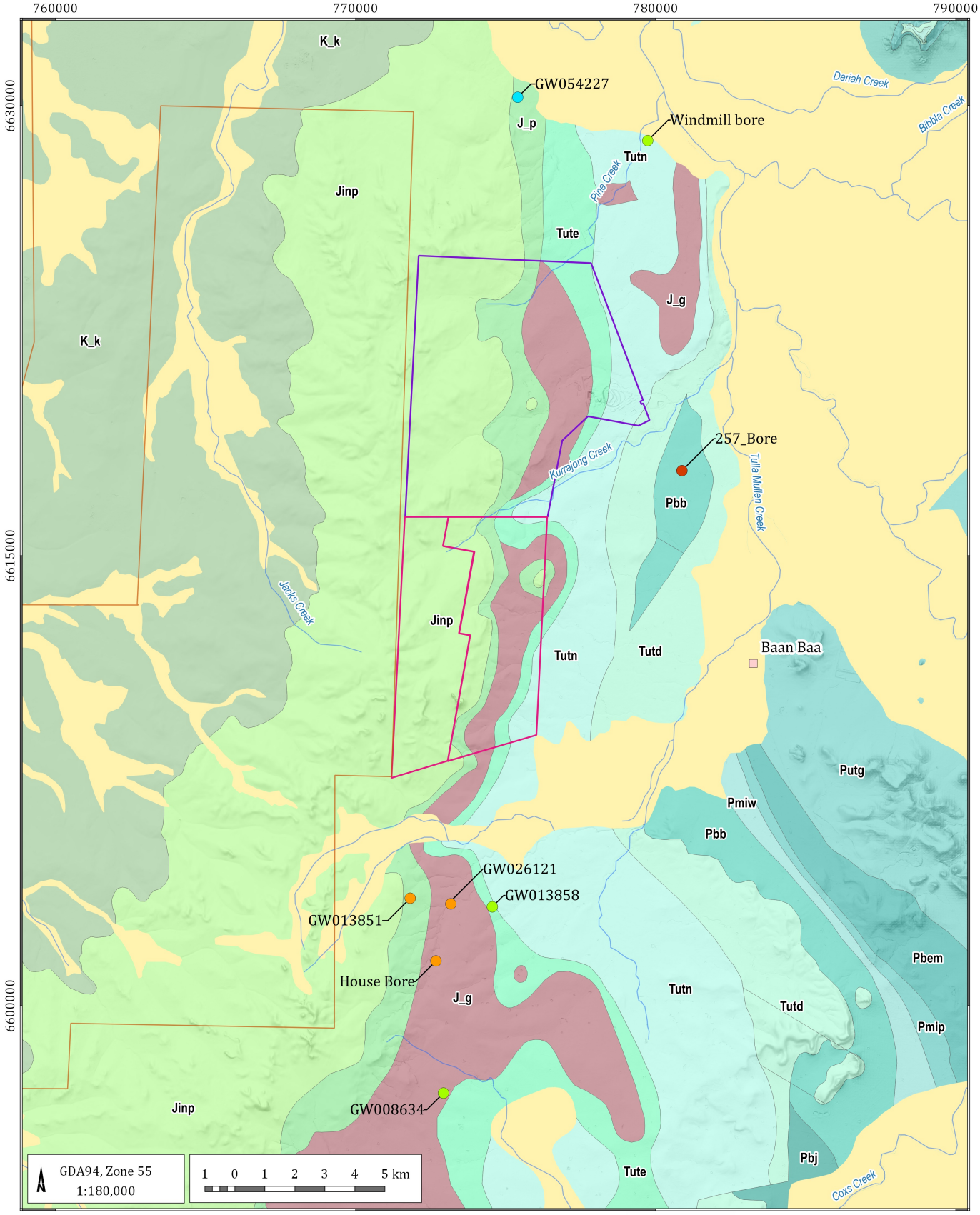
| Private bore ID | Groundwater Extraction Unit | Bore status | Bore Purpose | Project Drawdown | | Cumulative Drawdown | |
|---|---|---|---|---|---|---|---|
| | | | | Maximum predicted drawdown (m) | Year in which drawdown exceeds 2 m | Maximum predicted drawdown (m) | Year in which drawdown exceeds 2 m |
| House Bore | Garrawilla Volcanics | In use | S&D | 2.34 | 2508 | 2.72 | 2360 |
| 257_Bore | Arkarula Fm | In Use | S&D | 12.59 | 2043 | 12.61 | 2043 |
| GW008634 | Napperby Fm[1] | Not in use | S&D | 2.65 | 2191 | 3.35 | 2113 |
| GW013851 | Garrawilla Volcanics | In use | S&D | 5.02 | 2260 | 5.70 | 2191 |
| GW013858 | Napperby Fm | In use | S&D | 9.26 | 2067 | 10.93 | 2055 |
| GW026121 | Garrawilla Volcanics | In use | S&D | 3.98 | 2260 | 4.57 | 2191 |
| GW054227 | Purlawaugh Fm | Not in use | S&D | 3.79 | 2113 | 3.97 | 2113 |
| Windmill Bore | Napperby Fm | In use | S&D | 4.44 | 2050 | 4.61 | 2050 |

***Note:*** *[1] Bore thought to be extracting from multiple "less productive" strata. Strata listed is the lowermost unit thought to be intersected in the bore.*

As shown in Table 7.2, all of the bores listed are thought to be used for stock & domestic (S&D) purposes (i.e. no irrigation bores are predicted to exceed the 2 m AIP minimal impact threshold for drawdown). Consistent with their use for S&D purposes, none of the bores listed are associated with licensed quantities and are likely to represent relatively minor extractions. Consistent with this assessment, as shown in Figure 7.22, all of the bores predicted to experience greater than 2 m of drawdown are located in areas where neither of the highly productive Pilliga Sandstone or Namoi Alluvium aquifers are present at significant thicknesses. These bores therefore extract from other strata which do not typically support large extractions but can support smaller extractions targeting minor sandstone or weathered basalt units which can be present (Figure 4.2 and Figure 5.1).

The majority of the bores predicted to experience more than 2 m of drawdown are thought to terminate in the Garrawilla Volcanics (three bores) or the Napperby Formation (three bores). A single bore in each of the Arkarula and Purlawaugh formations is also predicted to experience more than 2 m of drawdown at some point in the future. As shown in Table 7.2, in almost all cases maximum drawdowns are predicted to occur sometime after mining ceases.

As shown in Figure 7.22 two of the eight bores north of the Narrabri Mine (the Windmill Bore and GW054227) are located close to the edge of the mapped Quaternary Alluvium (Colquhoun et al., 2019). Conversely previous geological mapping of the Gunnedah Coalfields (Pratt, 1998) suggest that Quaternary Alluvium is present at both locations. Reference to regolith mapping developed by CSIRO (Wilford et al, 2015) also suggests 13 m to 16 m of residual soils at the location of these bores. Accordingly, there is some uncertainty about whether or not the Quaternary Alluvium (i.e. the Namoi Alluvial aquifer) is present at these locations and hence whether or not these bores draw water from the alluvium or the underlying consolidated strata. If the bores draw water from the alluvium then actual impacts are likely to be less than predicted since as discussed previously in Section 7.4 given that predicted maximum drawdowns do not exceed 2 m in any part of the highly productive Namoi Alluvium aquifer.




LEGEND

- Populated place
- Drainage
- Mining Lease Boundary (ML1609)
- Proposed Narrabri Gas Project (Santos)
- Provisional Mining Lease Application Area

**Solid geology ( NSW seamless geology)**

- (Qa) - Quaternary alluvium
- (K_k) - Keelindi beds
- (Jinp) - Pilliga Sandstone
- (J_p) -Purlawaugh Formation
- (J_g) - Garrawilla Volcanics
- (Tute) - Deriah Formation
- (Tutn) - Napperby Formation
- (Tutd) - Digby Formation
- (Pbj) - Black Jack Group
- (Pbb) - Brothers Subgroup
- (Pmiw) - Watermark Formation
- (Pmip) - Porcupine Formation
- (Pbem) - Maules Creek Formation
- (Pute) - Werrie Basalt
- (Putg) - Boggabri Volcanics

**Impacted unit**

- Arkarula Formation
- Garrawilla Volcanics
- Napperby Formation
- Purlawaugh Formation

Narrabri Stage 3 Extension GIA (G1972)

## Existing water supply bores where maximum predicted drawdown exceeds 2m

DATE 12/08/2020

FIGURE No: **7.22**

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In accordance with the AIP (DPI-Water, 2012), NCOPL would implement 'make good' provisions at any privately owned water supply bore experiencing more than 2 m of drawdown. 'Make good' provisions would be assessed on a case by case basis and implemented in consultation with the affected landholder, and may include:

- deepening the affected groundwater bore (including lowering the pump set and/or provision of a new pump set and power supply if required);
- construction of a new groundwater bore (including provision of a new pump set and power supply if required); and/or
- provision of an alternative water supply of appropriate quality and quantity.

In many cases, maximum predicted drawdowns at the eight bores listed in Table 7.2 only marginally exceed the 2 m AIP threshold. Predicted maximum Project only drawdowns exceed 5 m in three bores. The potential significance of these generally relatively minor drawdowns has been assessed as described below and summarised in Table 7.3 using information currently available via the bore census (Appendix G) and the PINNEENA database. This assessment involves calculating the available 'headroom' in each bore, i.e. the length of the standing water column above the uppermost recorded water bearing zone. In most instances, submersible and other common pump types are not installed adjacent to or below the main water bearing zones, hence if the standing water level drops below this level then the performance of the bore will likely be significantly affected.

As shown in Table 7.3 predicted drawdowns only exceed the estimated available headroom in one of the six bores assessed (the Windmill Bore). Predicted drawdowns also account for up to 90% of the estimated available headroom at GW013858. However, predicted drawdowns at the remaining four bores assessed represent less than 50% of the available headroom and these bores are therefore considered less likely to be significantly affected. As shown in Table 7.3, no information on the depth of either the bore or water bearing zones is currently available for House Bore and 257_Bore.

**Table 7.3 Estimated available headroom at private bores predicted to experience more than 2 m of drawdown**

| Private bore ID | Bore depth (mBGL) | Depth to standing water level (SWL, mBGL)[a] | Depth to water bearing zone (mBGL) | Available headroom (m)[b] | Predicted maximum drawdown range (m)[c] | Drawdown expressed as a percentage of headroom (%) |
|---|---|---|---|---|---|---|
| House Bore | - | 22.8 | - | _ | 2.34 – 2.72 | Depth unknown |
| 257_Bore | - | 57.2 | - | _ | 12.59 – 12.61 | Depth unknown |
| GW008634 | 78.3 | 7.9 | 28.6 – 74.3 | 20.7 - 62.8 | 2.65 - 3.35 | 4 - 16% |
| GW013851 | 54.8 | 24.3 | 48.7 - 54.7 | 24.4 | 5.02 - 5.70 | 21 - 23% |
| GW013858 | 33.5 | 18.2 | 30.4 - 33.4 | 12.2 | 9.26 – 10.93 | 76 - 90% |
| GW026121 | 20.1 | - | - | 10.1 | 3.98 - 4.57 | 40 - 45% |
| GW054227 | 38.1 | 13.7 | 32.9 - 33.5 | 19.2 | 3.79 - 3.97 | 20 - 21% |
| Windmill Bore | 20.0 | 10.0 | - | 0 | 4.44 – 4.61 | >100% - Bore may dry |

***Notes:*** *[a] Standing or rest water level observed in the bore. Taken from bore census results (where available) or from works summary reports.*

*[b] In this case 'headroom' is defined as the distance between the observed standing water level and the top of the uppermost water bearing zone. For bores where only the bore depth is known then the top of water bearing zone has been assumed to be 50% of the total bore depth.*

*[c] Range of drawdowns predicted for the Project only and assuming concurrent development of the Narrabri Gas Project.*

### 7.6.2 Impacts on groundwater dependent ecosystems

#### 7.6.2.1 Aquatic ecosystems

As discussed in Section 5.7.1, three potential spring sites, the Mayfield, Hardys and Eather springs (Dams 1 and 2), have been previously identified within the potential drawdown area of the Project. The Hardys and Eather springs are also identified as high priority GDEs in the WSP for the Southern Recharge Groundwater Source. Based on their location within the landscape and current understanding of the hydrogeology of the area, the Mayfield Spring is likely to be sourced from the Purlawaugh Formation, while the Hardys Spring and Eather Spring are likely to be sourced from the Pilliga Sandstone. All three features are considered to represent areas where the water table or phreatic surface may express at the ground surface, although anecdotal evidence suggests the Hardys and Eather springs have not discharged for over 10 years. Accordingly, drawdowns have been assessed through reference to predicted drawdowns at the modelled water table (i.e. the uppermost saturated layer). Project only and cumulative predicted maximum all time drawdowns on the water table are shown in Figure 7.23 and Figure 7.24 respectively. Figure 7.25 and Figure 7.26 show the same water table predictions along with the location of known and potential GDE sites including the three springs discussed above. Predicted drawdowns at each individual spring site are also tabulated in Table 7.4 and show predicted maximum all time water table drawdowns ranging from less than 1 cm at Eather Spring (Dams 1 and 2) to less than 5 cm at Hardys Spring. As such it is considered unlikely that discharge from these springs would be significantly affected. The predicted maximum drawdowns are also substantially less than the estimated AIP water table drawdown thresholds of 0.51 m for areas outside of the Namoi Alluvium, as calculated below in Section 7.6.2.2.

The cumulative drawdown of the Project and Narrabri Gas Project predicted at the Mayfield, Hardys and Eather Spring are also all well within the "less than 0.5 m drawdown" predicted at these locations due to the Narrabri Gas project in the Narrabri Gas Project Groundwater Assessment (CDM Smith, 2016).

**Table 7.4 Predicted maximum all time water table drawdown at potential groundwater features**

| Feature | Current modelled depth to water, December 2019 (m) | Predicted maximum drawdown (m) | | Timing of predicted maximum drawdown (year) | |
|---|---|---|---|---|---|
| | | Project only | Cumulative | Project only | Cumulative |
| Hardys Spring | 15.62 | <0.05 | <0.05 | 2360 | 2360 |
| Eather Spring (Dams 1 and 2) | 6.60 (Dam 1)<br>6.72 (Dam 2) | <0.01 | <0.01 | 2725 | 2725 |
| Mayfield Spring | 2.27 | <0.02 | <0.02 | 2360 | 2360 |

As shown in Figure 7.25 and Figure 7.26 negligible maximum all time water table drawdowns of substantially less than 0.2 m are also predicted along in the high potential aquatic GDE area identified in the GDE Atlas (BOM, 2018) along Namoi River from Boggabri to Turrawan.

#### 7.6.2.2 Terrestrial GDEs

As discussed previously in Section 2.4 , the WSPs for the Namoi Alluvial Groundwater Sources 2020, NSW GAB Groundwater Sources 2020 and NSW Murray Darling Basin Porous Rock Groundwater Sources 2020 identify high priority GDEs in the vicinity of the Project. These GDEs are understood to based on 'high potential' GDE areas identified in the National Groundwater Dependent Ecosystem Atlas (GDE Atlas, BoM, 2018). As such the majority of the areas are potential GDE areas identified using satellite image analysis with limited ground truthing.

The WSPs relevant to the Project describe that high priority GDEs may include:

*(a) any instream ecosystem associated with rivers that have a base flow component to their flow regime,*

*(b) vegetation that has a high probability of being groundwater-dependent, and is of very high or high ecological value,*

*I Ramsar wetlands, or wetlands listed in the Directory of Important Wetlands in Australia: Third edition, Environment Australia, 2001 (ISBN 0 642 54721 1).*

The AIP requires that predicted drawdown at high priority GDE sites be assessed against a drawdown threshold which is equal to 10% of the cumulative variation in the water table, allowing for typical climatic "post water sharing plan" variation within 40m. No monitoring of the water table at any of the GDE sites recently added to the relevant WSPs is currently available and hence the first step in identifying impacts at these GDEs is to identify representative water table data from which to identify typical post water sharing plan water table variations. Reference to mapping of groundwater monitoring locations (Figure 5.2) and predicted maximum water table impacts (Figure 7.23 and Figure 7.24) indicates that groundwater level data is available for 16 alluvium monitoring bores in areas where more than 0.05 m of drawdown is predicted (i.e within the predicted zone of influence of the Project). Of these 16 bores only a single monitoring bore (GW030230) is located within a potential GDE area. Estimated seasonal fluctuations at each of these bores are provided below in Table 7.5 and are considered to be representative of likely water table fluctuations at mapped potential GDE sites. The location of these bores are shown in Figure 7.25 and Figure 7.26.

Data is also available for a number of other bores which monitor groundwater levels in outcropping consolidated units within the predicted zone of influence. However, these bores are generally relatively deep and typically monitor groundwater pressures in consolidated confined strata. Accordingly, seasonal fluctuations recorded in these bores are considered unlikely to be representative of water table fluctuations. Furthermore as shown in Figure 5.12 the majority of the mapped high potential GDE areas are located along creek lines and therefore assuming they are actual GDEs are likely to be at least partly sourced from local groundwater held within minor unmapped unconsolidated strata as well as the underlying bedrock strata. Accordingly observed groundwater levels in the nearby alluvium bores listed in Table 7.5 are considered to provide the most reliable available information on likely seasonal fluctuations at the high priority GDE sites. In the absence of any data for observation bores completed into minor alluvium strata data, the Namoi Alluvium bores are also considered to provide the best available information on likely season water table fluctuations in GDE areas along tributary creeks within the MDB Porous Rock Groundwater Sources and GAB Groundwater Sources WSPs..

**Table 7.5 Observed seasonal water table fluctuations within the predicted zone of influence of the Project**

| Bore ID | Pumping affected? | Data period | Observed water level range (mAHD) | Observed seasonal fluctuation (m) |
|---|---|---|---|---|
| GW030230.1.1 | No | 16/03/1972 - 8/01/2018 | 215.08 - 219.28 | 4.20 |
| GW030446.1.1 | No | 5/12/1973 - 8/01/2018 | 224.82 - 232.23 | 7.41 |
| GW030446.1.2 | Yes | 5/12/1973 - 8/01/2018 | 212.01 - 226.75 | 14.74 |
| GW030447.1.1 | Yes | 9/03/1974 - 8/01/2018 | 216.77 - 227.25 | 10.48 |
| GW036004.1.1 | No | 4/10/1974 - 8/01/2018 | 220.94 - 226.26 | 5.32 |
| GW036004.1.2 | No | 4/10/1974 - 8/01/2018 | 220.5 - 226.19 | 5.69 |
| GW036005.1.1 | Yes | 10/09/1974 - 14/07/2019 | 218.3 - 226.68 | 8.38 |
| GW036005.1.2 | Yes | 10/09/1974 - 14/07/2019 | 204.86 - 227.21 | 22.35 |

| Bore ID | Pumping affected? | Data period | Observed water level range (mAHD) | Observed seasonal fluctuation (m) |
|---|---|---|---|---|
| GW036012.1.1 | No | 2/08/1977 - 8/01/2018 | 222.45 - 227.05 | 4.60 |
| GW036013.1.1 | No | 2/08/1977 - 8/01/2018 | 222.75 - 227.32 | 4.57 |
| GW036055.3.3 | Yes | 4/10/1974 - 8/01/2018 | 211.63 - 227.25 | 15.62 |
| GW036093.3.3 | Yes | 6/02/1975 - 8/01/2018 | 218.16 - 229.19 | 11.03 |
| GW036096.2.2 | Yes | 6/02/1975 - 8/01/2018 | 217.76 - 228.86 | 11.10 |
| GW036186.1.1 | No | 7/10/1976 - 14/07/2018 | 224.66 - 233.09 | 8.43 |
| P39B | No | 2/06/2016 - 30/05/2019 | 221.55 - 223.14 | 1.59 |
| WB7 | No | 14/11/2008 24/06/2019 | 225.18 - 228.86 | 3.68 |
| Average observed seasonal fluctuation – all bores (m) | | | | 8.70 |
| Average observed seasons fluctuation – excluding pumping affected bores | | | | 5.05 |

As shown in Table 7.5, since all of the representative monitoring bores are located within the Namoi Alluvium seven of the bores show seasonal fluctuations of up to 22m which are thought to be affected by nearby pumping operations. Hence, depending on whether or not pumping affected bores are included, average seasonal fluctuations vary between 5.1 m and 8.7 m. This difference is particularly important for minor alluvium along tributary creeks outside of the Namoi Alluvium since there is currently little or no groundwater extraction from the areas. Based on these averages AIP thresholds for assessing impacts on potential GDEs have been estimated as follows:

- GDE areas within the Namoi Alluvium WSP area = 0.87 m (i.e. 10% of the observed average seasonal fluctuation in all 16 representative monitoring bores); and
- GDE areas along tributary creeks outside of the Namoi Alluvium WSP area (i.e. in the MDB Porous Rock Groundwater Sources and GAB Groundwater Sources WSPs) = 0.51 m (i.e. 10% of observed average seasonal fluctuation excluding seven pumping affected bores).

As shown in Table 7.5, data for the full period of the available record has been used to estimate AIP thresholds to allow for typical climatic "post water sharing plan" variation. It is noted that the first round of WSPs were published in 2003. Inherent in the AIP thresholds calculated above is therefore an assumption that climate variability and hence seasonal fluctuations in the periods prior to and after 2003 are unchanged (i.e. historic behaviour is a reliable indicator of future behaviour). Given that most predictions of climate change suggest that the climate is becoming more variable this is considered to be conservative.

Predicted maximum water table drawdown within 40 m (Figure 7.23 and Figure 7.24) and predicted depth to water table (Figure 5.17) were then extracted for each of the high priority GDE polygons mapped within the numerical modelling domain. Finally, mapped high priority GDEs, where predicted maximum drawdowns exceed the thresholds identified above were estimated as shown in Figure 7.25 and Figure 7.26 and summarised in Table 7.6. In addition to excluding GDE polygons where predicted water table drawdowns were less than the relevant threshold GDE polygons were also excluded from these maps where minimum depths to water table exceeded 10 m (Figure 5.17). These are areas which are considered unlikely to be receiving groundwater from consolidated units that are represented within the Project numerical model and predicted to be impacted. If these areas are in fact GDEs then they are likely to be sourced from overlying unmapped unconsolidated strata which are not represented in the numerical model but are not predicted to be impacted even if they are present.

### Table 7.6 Mapped high priority GDE areas where predicted water table drawdown exceed the estimated AIP threshold

| Vegetation type | Total mapped area exceeding AIP threshold – Project only (ha) | Total mapped area exceeding AIP threshold – Project and Narrabri Gas Project (ha) |
|---|---|---|
| **Namoi Valley Groundwater Source – Upper Zone 5 (estimated AIP threshold = 0.87 m)** | | |
| Box grassy woodland | 0.5 | 0.5 |
| River Red Gum | 5.9 | 6.9 |
| **Gunnedah Oxley Basin MDB Groundwater Source (estimated AIP threshold = 0.51 m)** | | |
| Narrow leaved Ironbark | 16.1 | 16.1 |
| Box grassy woodland | 19.1 | 19.1 |
| Red Gum | 59.0 | 59.0 |
| River Red Gum | 27.7 | 28.3 |
| Shallow freshwater wetland sedgeland | 29.8 | 31.1 |
| **Total area** | **157.9** | **160.9** |

As shown in Figure 7.23 and Figure 7.24, and summarised in Table 7.6, mapped high priority GDEs where maximum predicted water table drawdowns exceed the relevant estimated AIP threshold are predominantly located within the Gunnedah Oxley Basin MDB Groundwater Source and include areas which are mapped as being dominated by Red Gum, River Red Gum, shallow freshwater wetland sedgeland with smaller areas of Ironbark and Box grassy woodland. The majority of these mapped GDEs are located close to Tulla Mullen Creek to the south east of the Narrabri Mine and in areas close to the Namoi River to the north east. Maximum drawdowns in excess of the estimated AIP threshold are also predicted within very small areas of mapped Box grassy woodland and River Red Gum within the Namoi Alluvial Groundwater Sources – Upper Namoi Zone 5. Predictions suggest that up to 157.9 ha of areas mapped as high priority GDEs could experience drawdowns greater than the estimated AIP threshold due to the Project only and 160.9 ha if the Narrabri Gas Project was to be developed concurrently. These areas represent around 0.22% of the high priority GDE areas mapped in the relevant WSPs within the modelling domain. It is noted that this assessment of high priority GDE's relies on mapping from the recent WSP updates, which is understood to be developed predominantly from satellite image analysis with limited ground truthing.

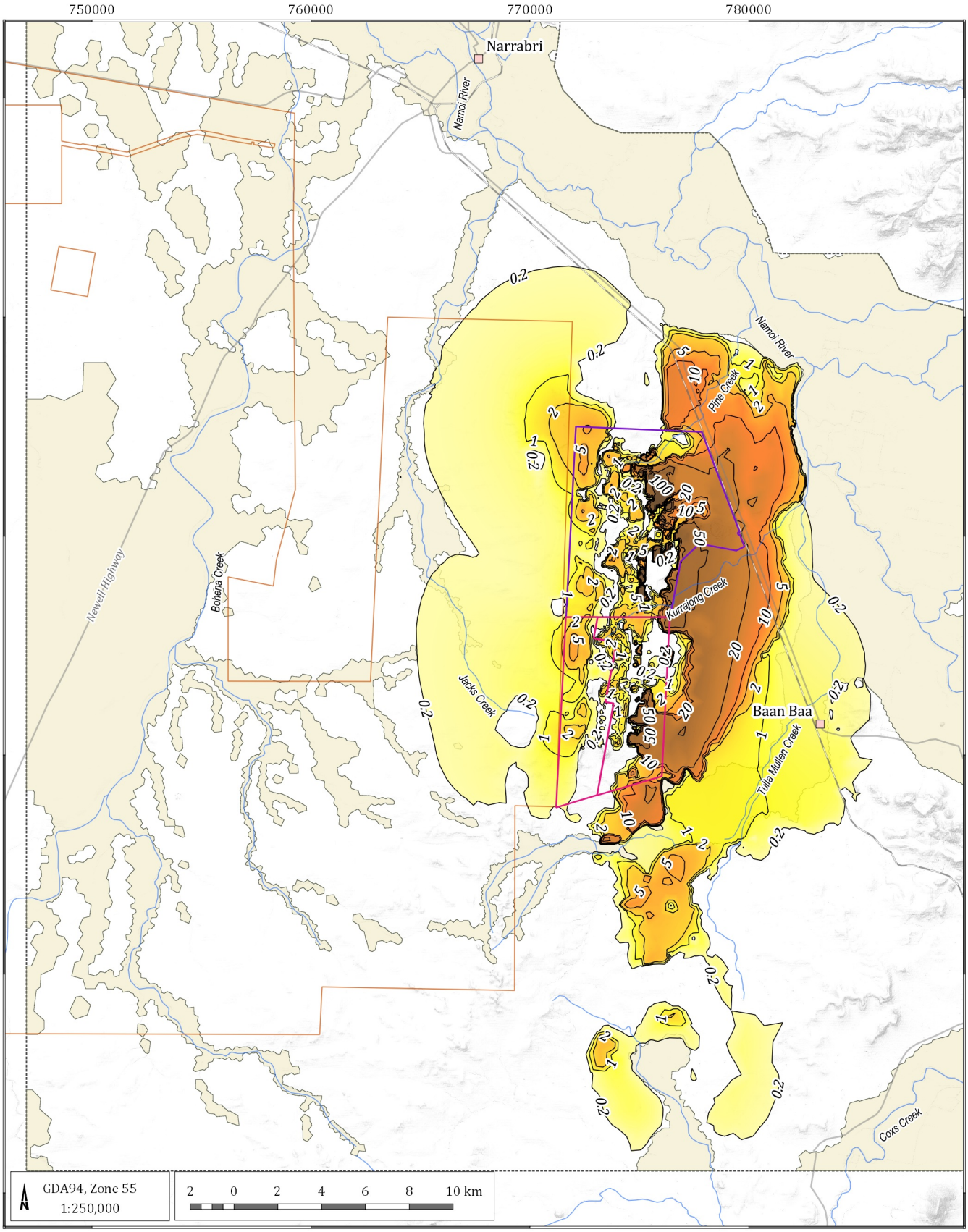
The ecological significance of the predicted water table drawdown at the high priority GDE areas described above (including consideration of whether the high priority GDE definition is met, and the variation in the water levels and long-term viability of the dependent ecosystem) is assessed in Section 6 of the EIS main text and Appendix D of the EIS.

### *7.6.2.3 Subterranean ecosystems*

As discussed previously in Section 5.7.3, of the hydrostratigraphic units present within the Project Area stygofauna are only considered likely to be present within the Quaternary Namoi Alluvium aquifer and the mapped Quaternary piedmont deposits associated with Tulla Mullen Creek. Accordingly since predicted water table impacts (Figure 7.23 and Figure 7.24) are relatively minor within these units (less than 2 m throughout) then no significant changes to the extent of potential stygofauna impacts are predicted. Furthermore, as discussed previously in Section 7.6.2.1 in relation to GDEs, available data for the Namoi Alluvium in particular suggests a high degree of seasonal water table fluctuation, over 20 m in some places where natural variations are amplified by seasonal irrigation extraction. As a result Eco Logical (2016) concluded that if stygofauna were to exist within the water table in the Narrabri Gas Project area, they would likely have evolved to cope with relatively large seasonal and long-term water table fluctuations. Accordingly, further minor long term drawdown associated with development of the Project would likely not substantially affect the viability of stygofauna habitats. It is also noted that the Narrabri Gas Project – Water Expert Panel (2020) concluded that given the extent to which the aquifers in the region have been utilised over many years, there are unlikely to be any significant 'natural' fauna remaining.

As discussed in Section 5.7.3 it is considered unlikely that that stygofauna are present within other consolidated sandstone units, including the Pilliga Sandstone, present within the predicted zone of influence of the Project.

Given the above, there is predicted to be a low risk of any significant impacts to stygofauna habitat as a result of the Project.




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown (m)**

- 0
- 0.2
- 1
- 2
- 5
- 10
- 20
- 50
- 100

Narrabri Stage 3 Extension GIA (G1972)

## Predicted maximum water table drawdown, due to the Project

DATE 09/06/2020

FIGURE No: **7.23**

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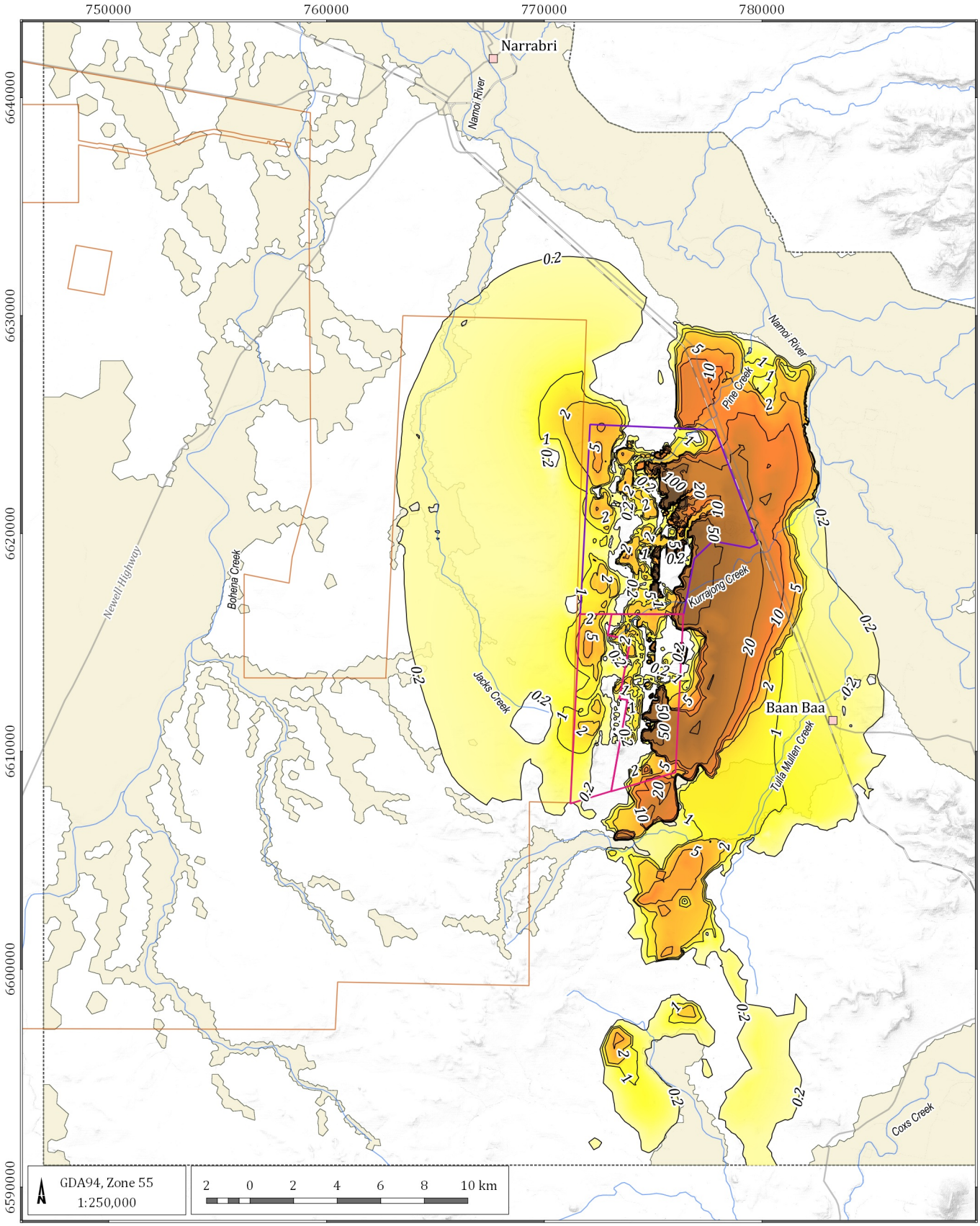
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.23 - 07.24_G1972_Predicted maximum water table drawdown, due to the Project.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown (m)**

- 0
- 0.2
- 1
- 2
- 5
- 10
- 20
- 50
- 100

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum water table drawdown - due to the Project and Narrabri Gas Project**

DATE 09/06/2020

FIGURE No: **7.24**

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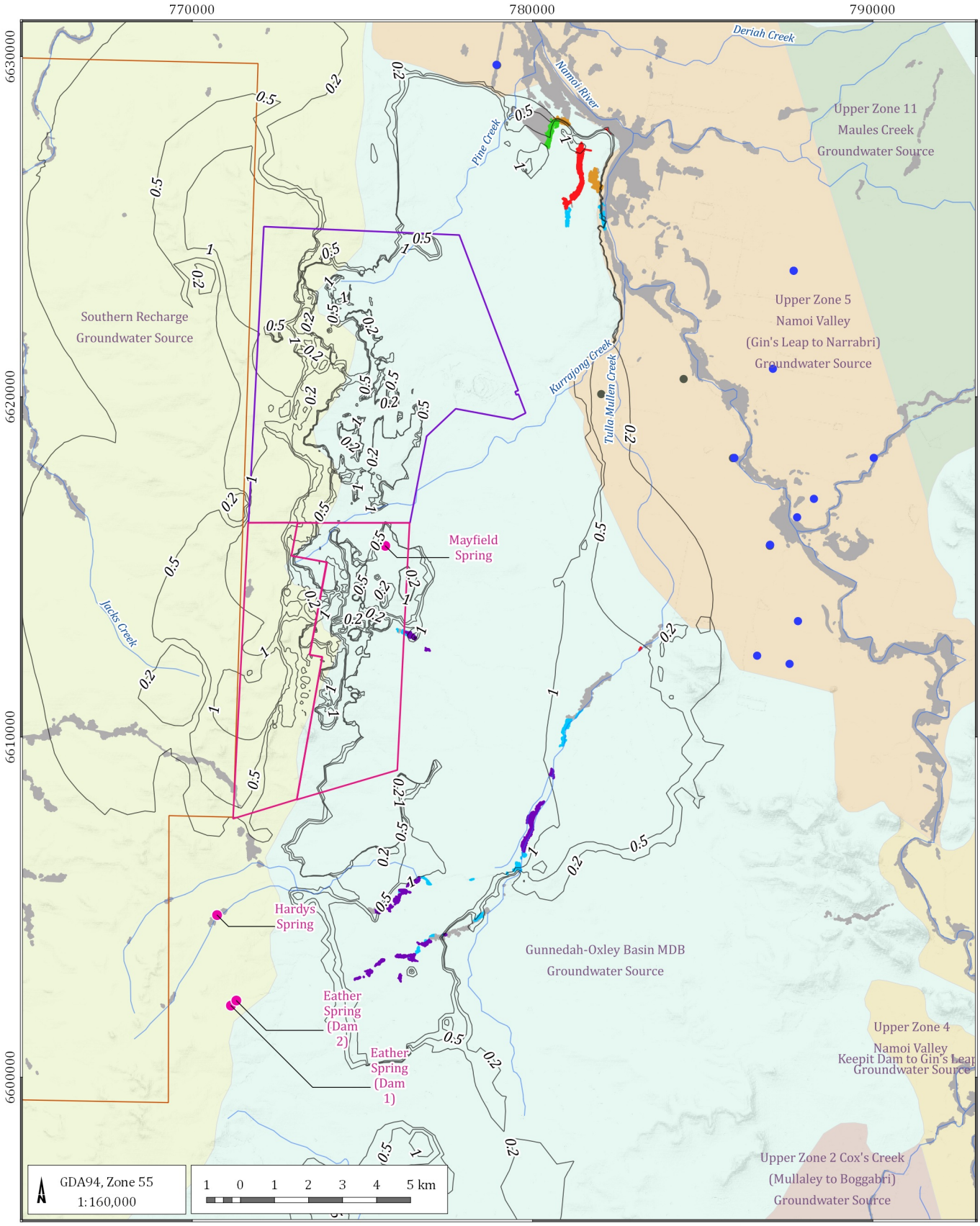
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.23 - 07.24_G1972_Predicted maximum water table drawdown, due to the Project.qgs




LEGEND

**GDEs areas where predicted maximum water table drawdown exceeds AIP threshold**

- Narrow-leaved Ironbark
- Box grassy woodland
- Red Gum
- River Red Gum
- Shallow freshwater wetland sedgeland

- Other High priority GDE areas

- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML 1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Potential groundwater feature

**Water table monitoring sites**

- Narrabri mine
- NSW state monitoring

Narrabri Stage 3 Extension GIA (G1972)

## Water table drawdown at high priority GDE sites, due to the Project

DATE 25/08/2020

FIGURE No: **7.25**

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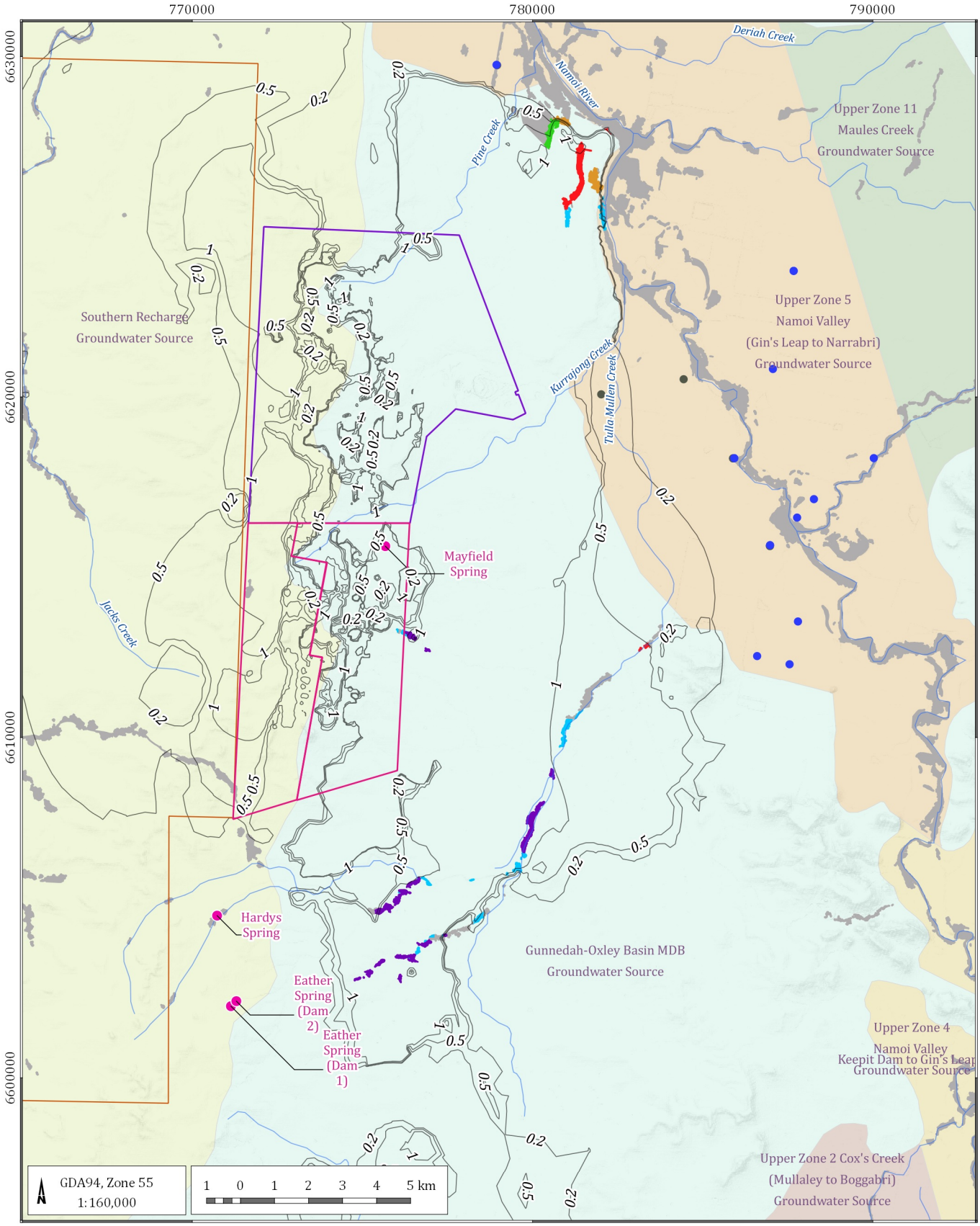
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.25_G1972_Water table drawdown at high priority GDE sites, due to the Project.qgs




LEGEND

**GDEs areas where predicted maximum water table drawdown exceeds AIP threshold**

- Narrow-leaved Ironbark
- Box grassy woodland
- Red Gum
- River Red Gum
- Shallow freshwater wetland sedgeland
- Other High priority GDE areas

- Drainage
- Drawdown contour line (m)
- Mining Lease Boundary (ML 1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Potential groundwater feature

**Water table monitoring sites**

- Narrabri mine
- NSW state monitoring

Narrabri Stage 3 Extension GIA (G1972)

## Water table drawdown at high priority GDE sites, due to the Project and Narrabri Gas Project

DATE 25/08/2020

FIGURE No: **7.26**

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G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\07.26_G1972_Water table drawdown at high priority GDE sites, due to the Project and Narrabri Gas Project.qgs

### 7.6.3 *Impacts on Highly Productive Groundwater in Biophysical Strategic Agricultural Land (BSAL) and State Forest areas*

As required under the AIP, this assessment considers impacts on highly productive groundwater sources with the potential to be impacted by the Project (i.e. the Namoi Alluvium and the Pilliga Sandstone) through reference to the 2 m minimal impact thresholds presented in the AIP. As shown in Figure 7.7, Figure 7.8, Figure 7.13 and Figure 7.14; no drawdowns or more than 2 m are predicted at any water supply works in either the Quaternary alluvium or Pilliga Sandstone. Hence no impact to privately-owned water supply bores in BSAL areas within the Quaternary alluvium or on State Forest areas within the Pilliga Sandstone are also anticipated. The Agricultural Impact Statement for the Project (2rog Consulting, 2020) concludes that "there is no irrigated agriculture in the Project Area. Surface water is the main water source for stock and domestic use. Groundwater is seldom, if ever, used for agricultural production and is generally of poor quality."

### 7.6.4 *Impacts on culturally significant sites*

No high priority culturally significant sites have been listed in the WSP for the Namoi Alluvial Groundwater Sources 2020, the NSW GAB Groundwater Sources 2020 or the NSW Murray Darling Basin Porous Rock Groundwater Sources 2020 in the vicinity of the Project Area.

## 7.7 Additional take from water sharing plan areas

The AIP requires that additional groundwater takes (both direct and indirect) from water sources which feature in WSPs be accounted for. Groundwater reporting to mine drainage systems represents a direct take from Permian age units, which form part of the Gunnedah-Oxley Basin MDB Groundwater Source. Impacts on other water sources which include the Quaternary alluvium, the Namoi River, the Lachlan Fault Belt MDB fractured rock groundwater source (the Boggabri Volcanics) and the GAB Southern Recharge Zone groundwater source (the Pilliga Sandstone and the Purlawaugh Formation) are considered to be indirect since they result from depressurisation of the Permian strata and there is no direct extraction from these units. This section discusses the water licences required to account for the predicted peak direct and indirect takes of groundwater and surface water due to development of the Project.

As discussed in Section 2.4 and shown schematically in Figure 2.4, the following four WSPs apply to the aquifers and surface waters which have the potential to be impacted by the Project:

- Gunnedah-Oxley Basin MDB porous groundwater source, the porous strata lying between the base of the Purlawaugh Formation and the top of the Boggabri Volcanics and including Quaternary Alluvium present within the geographical extent of the groundwater sources;
- Southern Recharge groundwater source, predominantly the Pilliga Sandstone and the Purlawaugh Formation and including Quaternary Alluvium present within the geographical extent of the groundwater source;
- Namoi Alluvial Groundwater Sources 2020, alluvial strata associated with the Namoi River and its major tributaries; and
- Upper and Lower Namoi Regulated River Water Sources 2016.

The peak volume of predicted groundwater inflows due to the Project requiring licensing are provided in Table 7.7. It is noted that the volumes for each water source or management zone represents the net inflow from that source or zone (i.e. outflow from the source/zone, minus inflows to the source/zone from other sources/zones). The sum of the volumes requiring licensing exceeds the maximum predicted annual inflow because the peak take from different water sources are not simultaneous.

## Table 7.7 Groundwater licensing summary for the Project

| Water sharing plan | Water source/ management zone | Aquifers / River | Impacted resource | Peak volume requiring licensing during mining (ML/year) | Peak volume requiring licensing-post-mining (ML/year) | Existing licensed volume (Shares) |
|---|---|---|---|---|---|---|
| Upper and Lower Namoi Regulated River Water Sources | Upper and Lower Namoi | Namoi River (including tributary creeks) | Surface Water (indirect) | 44[a] | 193 | 678 |
| Namoi Alluvial Groundwater Sources | Upper Namoi Zone 5 | Quaternary alluvium | Groundwater (indirect) | 10 | 64 | 260 |
| | Lower Namoi | | | 0 | 1 | Nil |
| NSW GAB Groundwater Sources | Southern Recharge Zone | Pilliga Sandstone, Purlawaugh Formation and outcropping Quaternary alluvium [b] | Groundwater (indirect) | 42 | 88 | 248 |
| NSW Murray Darling Basin Porous Rock Groundwater Sources | Gunnedah-Oxley Basin MDB | Porous strata between the base of the Purlawaugh Formation and top of the Boggabri Volcanics and outcropping Quaternary alluvium [b] | Groundwater (direct and indirect) | 2,310 | 2,310 | 1,221 |

***Notes:*** *[a] modelling from WRM (2020) indicates that no extraction from the Namoi River (using the existing Namoi River pump) would be required for the Project.*

*[b] as required under the relevant WSPs includes predicted take from alluvial sediments which are mapped at outcrop within the boundary of the groundwater source shown on the plan map.*

Based on the peak volumes and existing licenses shown in Table 7.7, NCOPL has sufficient licences to account for the predicted groundwater take from the Upper and Lower Namoi Regulated River Water Sources, the Upper Namoi Zone 5 and the GAB Southern Recharge Zone. Furthermore, since the predicted total take from the Namoi Alluvium (up to 65 ML/year) is substantially less the existing licensed volume (260 ML/year) the Project is considered to align with the Namoi Catchment Action Plan 2010–2020 threshold for alluvial aquifers to never exceed historical maximum drawdown levels (Namoi Catchment Management Authority [CMA], 2011). However, a minor additional water take (less than 1 ML/year) is now predicted from the Lower Namoi Zone and an additional groundwater licence for this zones may therefore be required.

Appropriate additional groundwater licences for the Project would be transferred from other Whitehaven operations, or sought from DPIE-Water under the relevant WSPs.

It is noted that the majority of the additional licensed take would be required under the WSP for the NSW Murray Darling Basin Porous Rock Groundwater Sources (i.e. for the Gunnedah-Oxley Basin MDB Groundwater Source). As described in Section 2.4.2, this groundwater source is significantly under-allocated and has had several controlled allocation periods of interest between 2017 and 2020. Most recently, the Controlled Allocation Order (Various Groundwater Sources) 2020 is offering 4,043 shares of the Gunnedah-Oxley Basin MDB Groundwater Source.

Furthermore, it is noted that NCOPL holds sufficient licenses to commence the Project, and the maximum take from the Gunnedah-Oxley Basin MDB Groundwater Source is predicted to occur towards the end of mining. The current licences held by NCOPL are expected to be sufficient for predicted groundwater take from the Gunnedah-Oxley Basin MDB Groundwater Source until 2023.

Additional licensing requirements for other groundwater sources would peak after the completion of mining as drawdown and depressurisation impacts propagate outwards.

## 7.8 Groundwater quality impacts

### *7.8.1 During operation*

Groundwater reporting to mine water management systems underground is pumped to surface from where it is treated in the water treatment plant. During operations, the concentrated brine waste stream from the reverse osmosis (RO) plant (within the water treatment plant) would continue to be directed to a series of lined brine water storage ponds. The clean water stream from the plant would be re-used on site, or transferred to the Namoi River for controlled release. NCOPL may also investigate options for the beneficial re-use of excess filtered water with other water users in the Project area (e.g. irrigation) or passing the water to local landholders. No groundwater quality impacts are therefore anticipated during operation of the mine since no discharge to groundwater would occur. Furthermore, since hydraulic gradients would be towards the mine, any contamination or poor quality groundwater generated during operation of the mine would likely be captured in the mine dewatering system and pumped to surface for treatment. Given the relatively small volumes of water drawn from other groundwater sources within the Project Area including the Namoi Alluvium and the Pilliga Sandstone, no impacts on groundwater quality in these aquifers are anticipated.

In fact, given that no additional take is predicted to occur from the Namoi Alluvium and Pilliga Sandstone above the volume already licensed, the Project will have no net impact on groundwater quality in these aquifers either during operation or post closure. Accordingly, the Project Area is considered to align with the Namoi Catchment Action Plan 2010–2020 which seeks an improvement in the ability of groundwater systems to support GDEs and designated beneficial uses by 2020 (Namoi CMA, 2011).

### *7.8.2 Post-mining*

Consistent with the Approved Mine, it is intended that any brine stored in the brine storage ponds would be re-injected into the mine goaf at the completion of mining. Mine site water balance calculations (WRM, 2020) indicate that re-injection of 2,367 to 2,830 ML of brine at TDS concentrations of 76,554 mg/L to 91,630 mg/L would be required. Re-injection is likely to occur over a period of three years post-mining via a series of 20 re-injection bores targeting goaf areas towards the southern end of the 100 series and northern end of the 200 series panels.

Theoretically, since the majority of the TDS load in the brine came from underground in the first place then the long-term water quality impacts of re-injecting these solids in a more concentrated form should be negligible. As a cross check on this theory, an additional re-injection scenario was carried out initially, using the project groundwater model. This was then followed by a series of simple mass balance calculations to assess likely long-term TDS concentrations in the mine goaf with and without brine re-injection. The results are summarised below:

- Numerical modelling results suggest that the hydraulic conductivity of the goaf area is likely to be sufficiently high to allow re-injection of the brine at the rates required with only minimal head increases (less than 6 m at the point of injection).
- Furthermore, the total volume of brine to be injected represents less than 2% of the pore space in the goaf, which is estimated to be 137,617 ML at the completion of mining.
- Numerical model predictions indicate that this available pore space would not be filled until around 200 years after mining ceases.

- During this time hydraulic gradients would remain towards the mine leading to the gradual dilution of the brine *in situ* as generally lower TDS groundwater is drawn in from surrounding groundwater units.
- Modelled water balance results suggest that around 60% of inflow would occur from the overlying Digby Formation, 37% via the underlying Arkarula Formation with the remaining 3% of inflow occurring laterally from the Hoskissons Coal Seam itself.

Using these proportions and the baseline water quality data (Table 5.10) mass balance results (Table 7.8) suggest a possible slight increase in TDS concentration from around 8,700 to 10,100 mg/L with and without re-injection. Predicted TDS concentrations are in both cases saline and hence post-mining re-injection is considered unlikely to affect potential groundwater usage in either the short or long-term. In any case, few, if any, water supply bores in the area target the Hoskissons Coal Seam since better quality groundwater sources are available in most locations.

**Table 7.8 Brine re-injection water quality impact assessment**

| Inflow component | With brine re-injection | | Without brine re-injection | |
|---|---|---|---|---|
| | Inflow volume (ML) | TDS Concentration (mg/L) | Inflow volume (ML) | TDS Concentration (mg/L) |
| Re-injection | 2,830 | 76,554 | 0 | NA |
| Lateral inflow (Hoskissons Coal) | 4,367 | 3,739[a] | 4,459 | 3,739[a] |
| Overlying strata (Digby Formation) | 80,171 | 6,453[a] | 81,855 | 6,453[a] |
| Underlying strata (Arkarula Formation) | 50,248 | 12,884[a] | 51,303 | 12,884[a] |
| Total volume and average concentration | 137,617 | 10,157[b] | 137,617 | 8,763[b] |

***Notes:*** [a] TDS estimated from average EC data shown in Table 5.10 and applying a conversion factor of 0.67 to convert from EC to TDS. In the absence of actual EC data for the Digby Formation data for the overlying Napperby Formation has been used.

[b] Long-term average predicted TDS concentration in the goaf. Calculated using the total estimated mass of solids present within the goaf divided by the total volume.

## 7.9 Predictive uncertainty analysis

The uncertainty in the model predictions introduced by model parameters was assessed using a nonlinear uncertainty analysis, where numerous model parameters were changed at the same time. The results of this analysis are presented in Appendix D. In total, some 240 alternative parameter sets were randomly generated initially, 140 of which were then rejected on the basis that they were inconsistent with the available observations for the site. Further statistical analysis of predictions based on the remaining 100 calibration constrained parameter sets allows the sensitivity of key model predictions to possible parameter variability to be determined.

Uncertainty analysis results suggest that peak impacts on discharge to the Quaternary alluvium could range from 210 to 342 ML/year (P10 to P90) compared to the best estimate of around 250 ML/year (Section 7.5.1). Similarly peak impacts on discharge to the Namoi River could range from 61 to 174 ML/year (P10 to P90), compared to the best estimate of around 142 ML/year (Section 7.5.2).

Extreme combinations of recharge, hydraulic conductivity and storage parameters in particular could also lead to more extensive regional groundwater levels impacts than those reported in Section 7.4. Uncertainty analysis results suggest that drawdowns in excess of 1 m could occur at the Mayfield, Hardys and Eather potential spring sites assessed in Section 7.6.2, although this has been assessed as being unlikely to occur. With regard to impacts on highly productive aquifers and existing water infrastructure uncertainty analysis results suggest drawdowns of more than 2 m would be very unlikely to occur within any areas of mapped Quaternary alluvium (which includes the highly productive Namoi Alluvium aquifer) or in any additional water supply bores.

## 7.10 Comparison with predicted groundwater impacts for the Approved Mine

The Approved Mine involves longwall mining operations within ML 1609 at a rate of up to 11 Mtpa of ROM coal until July 2031. Predicted groundwater impacts for the Approved Mine are most recently assessed in the Approved Mine Groundwater Assessment (HydroSimulations, 2015).

### *7.10.1 Groundwater Inflows and Licensing*

The Approved Mine Groundwater Assessment (HydroSimulations, 2015) predicted a peak groundwater inflow of approximately 3.77 ML/d (or around 1,380 ML/year) in water year 2022-2023. It is relevant to note that the Approved Mine Groundwater Assessment simulated mining of the southern longwall panels up-dip (i.e. starting at Longwall 209 and moving east), resulting in inflows decreasing progressively towards the scheduled end of mining due to cessation of dewatering for the down-dip panels. Conversely, the Project would involve mining of the southern longwall panels down-dip (i.e. dewatering activities would continue during the Project life) and therefore peak inflows are predicted towards the end of mining.

As discussed in Section 5.6.2, it is noted that groundwater extraction to date has been below groundwater inflows predicted by HydroSimulations (2015), although the actual ROM coal production rate (and the overall development rate of the underground mining area) has also been lower than the what was simulated by HydroSimulations (2015).

The revised predicted maximum inflow for the Project (approximately 2,406 ML/year in 2040) (Section 7.2) is therefore approximately 1,000 ML/year (or 75%) higher than the predicted maximum inflow to the Approved Mine. This is consistent with the relative sizes of the two mine footprints, which has increased from approximately 31 square kilometres ($km^2$) for the Approved Mine, to approximately 54 $km^2$ for the Project, an increase of approximately 23 $km^2$ (or approximately 75% of the Approved Mine footprint).

It should be stressed, however, that a number of refinements have been made to the project groundwater flow model since 2015 (described in Section 6.2). Furthermore, the current model has also been re-calibrated using a substantially more extensive dataset than was available in 2015. Accordingly, potential Project groundwater impacts are not necessarily expected to be 75% greater than the Approved Mine impact due to the increase in mine footprint, as many other factors and model parameters affect the predictions. Consistent with this discussion, model predictions presented in this Groundwater Assessment suggest generally less impact on flows in overlying and underlying units. This can be illustrated by a comparison of licensing volume summaries taken from the HydroSimulations report and those presented previously in Table 7.7. The results of this comparison are summarised in Table 7.9 and indicate less impact on the Namoi River, Quaternary Alluvium and GAB Southern Recharge Zones than previously predicted (despite the increased predicted take from the Hoskissons Coal Seam).

### *7.10.2 Drawdown at private water supply bores*

One private water supply bore was assessed as being likely to be impacted by more than 2 m in 2015, compared to eight identified in the current assessment. This is predominantly due to the larger footprint of the Project underground mine, resulting in a zone of influence which is larger in some units than previously predicted in 2015 based on the Approved Mine. However, it should also be noted that a more recent and larger database of private water supply bores has been used in the current study (Section 5.6) and that a number of un-registered private bores were also identified via the bore census (Appendix G). In total, impacts have been assessed at some 1,548 private water supply bores for the current study (Section 7.6.1) including over 200 bores within approximately 10 km of the Project

**Table 7.9 Comparison of Stage 2 Mod 5 and Stage 3 predicted groundwater licensing requirements**

| Water sharing plan | Water source/ management zone | Aquifers / River | Impacted resource | Approved Mine peak volume requiring licensing during mining (ML/year)[a] | Project peak volume requiring licensing during mining (ML/year) |
|---|---|---|---|---|---|
| Upper and Lower Namoi Regulated River Water Sources | Upper and Lower Namoi | Namoi River (including tributary creeks) | Surface Water (indirect) | 78 | 44 |
| Namoi Alluvial Groundwater Sources | Upper Namoi Zone 5 | Quaternary alluvium | Groundwater (indirect) | 110 | 10 |
| NSW GAB Groundwater Sources | Southern Recharge Zone | Pilliga Sandstone, Purlawaugh Formation and outcropping Quaternary alluvium | Groundwater (indirect) | 179 | 42 |
| NSW Murray Darling Basin Porous Rock Groundwater Sources | Gunnedah-Oxley Basin MDB | Porous strata between the base of the Purlawaugh Formation and top of the Boggabri Volcanics and outcropping Quaternary alluvium | Groundwater (direct and indirect) | 1,009 | 2,310 |

***Note:*** [a] *HydroSimulations (2015).*

## 7.11 Aquifer Interference Policy considerations

The AIP has been developed by the NSW Government as a component of the NSW Government's Strategic Regional Land Use Policy. The AIP applies state wide and details water licence and impact assessment requirements.

WALs and approvals under the *Water Management Act, 2000* are not to be granted unless the Minister is satisfied that adequate arrangements are in place to ensure that "no more than minimal harm" is caused to a water source. In this regard, the AIP includes minimal impact considerations relating to watertable and groundwater pressure drawdown and changes in groundwater and surface water quality.

The AIP establishes minimal impact considerations for groundwater categories of both "highly productive" and "less productive" groundwater as described in Section 2.3.1.

Table 7.10 to Table 7.13 provide an assessment of the watertable, water pressure and water quality minimal impact considerations for the following water sources associated with the Project:

- highly productive alluvial water source;
- highly productive porous rock water source; and
- less productive porous rock water source.

Based on available data discussed in Section 5.1, the Pilliga Sandstone is the only Jurassic porous rock water source that meets the AIP's definition of "highly productive" (i.e. the Purlawaugh Formation and Garrawilla Volcanics are considered "less productive"). However, all formations within the Southern Recharge Groundwater Source have been assessed against the "highly productive" minimal impact considerations in accordance with the AIP.

## Table 7.10 Minimal Impact Considerations – Namoi Alluvial Groundwater Sources

| Aquifer | Namoi Alluvial Groundwater Sources (WSP for the Namoi Alluvial Groundwater Sources 2020) |
|---|---|
| Type | Alluvial Aquifer |
| Category | Highly Productive |

| Minimal Impact Consideration | Assessment |
|---|---|
| *Watertable*<br>1. Less than or equal to a 10% cumulative variation in the watertable, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:<br>(a) high priority groundwater dependent ecosystem; or<br>(b) high priority culturally significant site;<br>listed in the schedule of the relevant water sharing plan; or<br>A maximum of a 2 m decline cumulatively at any water supply work.<br>2. If more than 10% cumulative variation in the watertable, allowing for typical climatic "post-water sharing plan" variations, 40 m away from any:<br>(a) high priority groundwater dependent ecosystem; or<br>(b) high priority culturally significant site;<br>listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site.<br>If more than 2 m decline cumulatively at any water supply work, then make good provisions should apply. | A large number of high priority GDE areas are listed in the recently updated WSP for the Namoi Alluvial Groundwater Sources based on high potential GDE sites identified in the GDE Water Atlas. Predicted maximum drawdown impacts in two potential GDE areas exceed 10% of estimated cumulative variation in water table.<br>There are no listed high priority culturally significant sites in the WSP for the Namoi Alluvial Groundwater Sources 2020.<br>No privately owned registered water supply works within the Namoi Alluvial Groundwater Sources would incur more than 2 m of drawdown due to the Project (assessed cumulatively with the Narrabri Gas Project).<br>**The Project meets the Level 1 minimal impact consideration classification except for water table drawdown at two potential GDE areas covering an area of approximately 7.4 ha.** |
| *Water Pressure*<br>1. A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.<br>2. If the predicted pressure head decline is greater than requirement 1. above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply. | This criterion is not applicable as only unconfined conditions are present in the alluvial water source.<br>**The Project meets the Level 1 minimal impact consideration classification.** |
| *Water Quality*<br>1. (a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity; and<br>(b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity.<br>Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1.(a) and 1.(b) above.<br>(c) No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the three-dimensional extent of the alluvial water source – whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply".<br>(d) Not more than 10% cumulatively of the three-dimensional extent of the alluvial material in this water source to be excavated by mining activities beyond 200 m laterally from the top of high bank and 100 m vertically beneath a highly connected surface water source that is defined as a "reliable water supply".<br>2. If condition 1.(a) is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works. If condition 1.(b) or 1.(d) are not met then appropriate studies are required to demonstrate to the Minister's satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity. If condition 1. (c) or (d) are not met, then appropriate studies are required to demonstrate to the Minister's satisfaction that:<br>– there will be negligible river bank or high wall instability risks;<br>– during the activity's operation and post-closure, levee banks and landform design should prevent the Probable Maximum Flood from entering the activity's site; and<br>– low-permeability barriers between the site and the highly connected surface water source will be appropriately designed, installed and maintained to ensure their long-term effectiveness at minimising interaction between saline groundwater and the highly connected surface water supply. | There would be no change to beneficial use categories of the alluvial groundwater source as a result of the Project or any predicted increase in the salinity of the Namoi River.<br>No mining activity within the specified proximities to the alluvial water source is proposed.<br>No excavation of the highly productive alluvial sediments associated with the Namoi Alluvial Groundwater Sources is proposed.<br>**The Project meets the Level 1 minimal impact consideration classification.** |

## Table 7.11 Minimal Impact Considerations – Southern Recharge Groundwater (Pilliga Sandstone)

| Aquifer | Southern Recharge Groundwater Source (Pilliga Sandstone) (WSP for the NSW GAB Groundwater Sources 2020) |
|---|---|
| Type | Porous Rock Aquifer |
| Category | Highly Productive |

| Minimal Impact Consideration | Assessment |
|---|---|
| *Watertable*<br>1. Less than or equal to a 10% cumulative variation in the watertable, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:<br>(a) high priority groundwater dependent ecosystem; or<br>(b) high priority culturally significant site;<br>listed in the schedule of the relevant water sharing plan; or<br>A maximum of a 2 m decline cumulatively at any water supply work.<br>2. If more than 10% cumulative variation in the watertable, allowing for typical climatic "post-water sharing plan" variations, 40 m away from any:<br>(a) high priority groundwater dependent ecosystem; or<br>(b) high priority culturally significant site;<br>listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site.<br>If more than 2 m decline cumulatively at any water supply work, then make good provisions should apply. | The updated WSP for the Southern Recharge Source now lists two high priority spring sites to the south of the project (Hardys and Eather springs) However, maximum drawdowns of less than 0.05m are predicted at these two sites, substantially less than 10% of the estimated water table fluctuation in the area. A large number of other potential GDE areas are also now listed as high priority GDEs, based on high potential areas identified in the GDE Water Atlas. However, predicted drawdowns at all such sites are less than 10% of the estimated cumulative variation in the water table or the water table is predicted to be sufficiently deep that they are considered unlikely to be dependent on regional groundwater resources.<br>There are no listed high priority culturally significant sites in the WSP for the NSW GAB Groundwater Sources 2020 in the vicinity of the Project.<br>No privately owned registered water supply works extracting from the Pilliga Sandstone would incur more than 2 m of drawdown due to the Project (assessed cumulatively with the Narrabri Gas Project).<br>**The Project meets the Level 1 minimal impact consideration classification.** |
| *Water Pressure*<br>1. (a) Less than 0.2 m cumulative variation in the groundwater pressure, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:<br>(i) high priority groundwater dependent ecosystem; or<br>(ii) high priority culturally significant site;<br>listed in the schedule of the relevant water sharing plan.<br>(b) A cumulative pressure level decline of not more than 15 m, allowing for typical climatic "post-water sharing plan" variations.<br>(c) The cumulative pressure level decline of no more than 10% of the 2008 pressure level above ground surface at the NSW State border, as agreed between NSW and Qld.<br>2. If the predicted pressure head decline is greater than requirement 1. (a). above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long term viability of dependent ecosystem or culturally significant site.<br>Pressure level decline should not:<br>(a) cause any flowing bore to cease to flow,<br>(b) be any more than 1 m, allowing for typical "post-water sharing plan" variations, at any flowing water supply work unless make good provisions apply, or<br>(c) be any more than 2 m, allowing for typical "post-water sharing plan" variations, at any non flowing water supply work unless make good provisions apply. | This criterion is not applicable as only unconfined conditions are present in the Pilliga Sandstone in the vicinity of the Project.<br>**The Project meets the Level 1 minimal impact consideration classification.** |
| *Water Quality*<br>1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.<br>2. If condition 1. is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works. | There would be no change to beneficial use categories of the Pilliga Sandstone as a result of the Project.<br>**The Project meets the Level 1 minimal impact consideration classification.** |

## Table 7.12 Minimal Impact Considerations – Southern Recharge Groundwater (Other Formations)

| Aquifer | Southern Recharge Groundwater Source (Other Formations) (WSP for the NSW GAB Groundwater Sources 2020) | |
|---|---|---|
| Type | Porous Rock Aquifer | |
| Category | Highly Productive | |
| **Minimal Impact Consideration** | | **Assessment** |
| *Watertable*<br>1. Less than or equal to a 10% cumulative variation in the watertable, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:<br>(a) high priority groundwater dependent ecosystem; or<br>(b) high priority culturally significant site;<br>listed in the schedule of the relevant water sharing plan.<br>A maximum of a 2 m decline cumulatively at any water supply work.<br>2. If more than 10% cumulative variation in the watertable, allowing for typical climatic "post-water sharing plan" variations, 40 m away from any:<br>(a) high priority groundwater dependent ecosystem; or<br>(b) high priority culturally significant site;<br>listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site.<br>If more than 2 m decline cumulatively at any water supply work, then make good provisions should apply. | | A large number of potential GDE areas are also now listed as high priority GDEs in the WSP for the NSW GAB Groundwater Sources 2020, based on high potential areas identified in the GDE Water Atlas. However, predicted drawdowns at all such sites are less than 10% of the estimated cumulative variation in the water table or the water table is predicted to be sufficiently deep that they are considered unlikely to be dependent on regional groundwater resources.<br><br>There are no listed high priority culturally significant sites in the WSP for the NSW GAB Groundwater Sources 2020 in the vicinity of the Project.<br><br>Cumulative pressure head declines of greater than 2 m are predicted at some privately owned registered water supply works that extract from less productive formations within the porous rock groundwater sources. NCOPL has committed to 'make good' provisions for affected groundwater users.<br><br>**The Project meets the Level 2 minimal impact consideration classification.** |
| *Water Pressure*<br>1. (a) Less than 0.2 m cumulative variation in the groundwater pressure, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:<br>(i) high priority groundwater dependent ecosystem; or<br>(ii) high priority culturally significant site;<br>listed in the schedule of the relevant water sharing plan.<br>(b) A cumulative pressure level decline of not more than 15 m, allowing for typical climatic "post-water sharing plan" variations.<br>(c) The cumulative pressure level decline of no more than 10% of the 2008 pressure level above ground surface at the NSW State border, as agreed between NSW and Qld.<br>2. If the predicted pressure head decline is greater than requirement 1. (a). above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long term viability of dependent ecosystem or culturally significant site.<br>Pressure level decline should not:<br>(a) cause any flowing bore to cease to flow,<br>(b) be any more than 1 m, allowing for typical "post-water sharing plan" variations, at any flowing water supply work unless make good provisions apply, or<br>(c) be any more than 2 m, allowing for typical "post-water sharing plan" variations, at any non flowing water supply work unless make good provisions apply. | | As described above, cumulative pressure head declines of greater than 2 m are predicted at some privately owned registered water supply works that extract from less productive formations within the porous rock groundwater sources. NCOPL has committed to 'make good' provisions for affected groundwater users.<br><br>**The Project meets the Level 2 minimal impact consideration classification.** |
| *Water Quality*<br>1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.<br>2. If condition 1. is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works. | | There would be no change to beneficial use categories of the porous rock groundwater source as a result of the Project.<br><br>**The Project meets the Level 1 minimal impact consideration classification.** |

## Table 7.13 Minimal Impact Considerations – Gunnedah-Oxley Basin MDB Groundwater Source

| Aquifer | Gunnedah-Oxley Basin MDB Groundwater Source (WSP for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2020) |
|---|---|
| Type | Porous Rock Aquifer |
| Category | Less Productive |
| **Minimal Impact Consideration** | **Assessment** |
| *Watertable*<br>1. Less than or equal to a 10% cumulative variation in the watertable, allowing for typical climatic "post-water sharing plan" variations, 40 m from any:<br>(a) high priority groundwater dependent ecosystem; or<br>(b) high priority culturally significant site;<br>listed in the schedule of the relevant water sharing plan.<br>A maximum of a 2 m decline cumulatively at any water supply work.<br>2. If more than 10% cumulative variation in the watertable, allowing for typical climatic "post-water sharing plan" variations, 40 m away from any:<br>(a) high priority groundwater dependent ecosystem; or<br>(b) high priority culturally significant site;<br>listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site.<br>If more than 2 m decline cumulatively at any water supply work, then make good provisions should apply. | A large number of high priority GDE areas are listed in the recently updated WSP for the NSW Murray Darling Basin Porous Rock Groundwater Sources based on potential GDE sites identified in the GDE Water Atlas. Predicted maximum drawdown impacts at some of these potential GDE areas exceed 10% of estimated cumulative variation in water table.<br>There are no listed high priority culturally significant sites in the WSP for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2020 in the vicinity of the Project.<br>Cumulative pressure head declines of greater than 2 m are predicted at some privately owned registered water supply works that extract from the Gunnedah-Oxley Basin MDB Groundwater Source. NCOPL has committed to 'make good' provisions for affected groundwater users.<br>**The Project meets the Level 2 minimal impact consideration classification except for water table drawdown at potential GDE areas covering approximately 153.5 ha.** |
| *Water Pressure*<br>1. A cumulative pressure head decline of not more than a 2 m decline, at any water supply work.<br>2. If the predicted pressure head decline is greater than requirement 1. above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply. | As described above, pressure head declines of greater than 2 m are predicted at some privately owned registered water supply works that extract from the Gunnedah-Oxley Basin MDB Groundwater Source. NCOPL has committed to 'make good' provisions for affected groundwater users.<br>**The Project meets the Level 2 minimal impact consideration classification.** |
| *Water Quality*<br>1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.<br>2. If condition 1. is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works. | There would be no change to beneficial use categories of the porous rock groundwater source as a result of the Project.<br>**The Project meets the Level 1 minimal impact consideration classification.** |

## 7.12 EPBC Act Significant Impact of Water Resources Guidelines

In June 2013, the Federal Government enacted changes to the EPBC Act, to provide that 'water resources' are a MNES in relation to CSG and large coal mining development. This change is referred to as the 'water trigger'. In December 2013, the DoEE released guidelines for proponents of coal seam gas and large coal mining projects to assess the potential for significant impacts on water resources.

The Project was deemed a 'controlled action' on 30 September 2019 (including water resources) (EPBC 2019/8427). The elements of the Project which require EPBC Act approval (i.e. "the Action") exclude the Approved Mine, which was previously referred in 2009 and determined to be "a controlled action" (EPBC 2009/5003) (last varied on 19 March 2020). Notwithstanding this, the assessment described herein considers the potential impacts of the Action on water resources cumulatively with the Approved Mine, as well as other relevant operations (i.e. the Narrabri Gas Project).

### *7.12.1 Potential Impacts on Hydrological Characteristics*

The Significant Impact Guidelines for Water Resources (DotE, 2013) provides the following guidance on potential impacts of an action on hydrological characteristics:

*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)*

*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.*

Based on the results of the groundwater modelling, the Project would result in:

- minimal drawdown (less than 2 m) in the "highly productive" Namoi River alluvium and Pilliga Sandstone;
- negligible impact on access to water in known registered production bores in "highly productive" aquifers; and
- negligible changes to baseflow in the Namoi River.

A large number of high priority GDEs have been recently added to a number of the WSPs of relevance to the Project. These GDEs are understood to be based on 'high potential' GDE areas identified in The National Groundwater Dependent Ecosystem Atlas (GDE Atlas, BoM, 2018). As such the majority of the areas identified are potential GDE areas identified using satellite image analysis with limited ground truthing. Predicted water table drawdown at a relatively small number of these GDE areas is higher that the estimated AIP threshold and hence the project represents a risk to some GDE areas which have recently been assigned a high priority. It should be stressed, however, that few if any of these GDEs have been field verified and should be considered to be potential GDEs at this stage.

It is unlikely that the Project would result directly or indirectly in a substantial change in the hydrology of groundwater resources.

### 7.12.2 Potential Impacts on Water Quality

The Significant Impact Guidelines for Water Resources (DotE, 2013) provide the following guidance on potential impacts of an action on water quality:

*A significant impact on a water resource may occur where, as a result of the action:*

- *a) there is a risk that the ability to achieve relevant local or regional water quality objectives would be materially compromised, and as a result the action:*
  - *i. creates risks to human or animal health or to the condition of the natural environment as a result of the change in water quality*
  - *ii. substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality*
  - *iii. causes persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment*
  - *iv. seriously affects the habitat or lifecycle of a native species dependent on a water resource, or*
  - *v. causes the establishment of an invasive species (or the spread of an existing invasive species) that is harmful*
  - *vi. to the ecosystem function of the water resource, or*
- *b) there is a significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives), or*
- *c) high quality water is released into an ecosystem which is adapted to a lower quality of water.*

As described in Section 7.8, negligible impacts on groundwater quality in nearby aquifers are anticipated during operation and post-mining (including following the re-injection of brine towards the completion of mining). Therefore, the Project would not have a significant impact on groundwater quality.

### 7.12.3 Consideration of Cumulative Impacts

The Significant Impact Guidelines for Water Resources (DotE, 2013) require the action to be:

*considered with other developments, whether past, present or reasonably foreseeable developments.*

The assessment that the Project would not result in a substantial change in the hydrology or significantly impact the quality of groundwater resources (presented in Sections 7.12.1 and 7.12.3) considers the cumulative impacts of the Action with the Approved Mine as well as the Narrabri Gas Project.

The cumulative effects of the Narrabri Gas Project are largely limited to drawdown within the Hoskissons Coal Seam and restricted to the area west of the Project.

### 7.12.4 Consideration of Potential for Significant Impact

Based on the assessment presented above, the proposed action under the EPBC Act would not result in significant changes to the quantity or quality of water available to third party users or the environment. Accordingly, the Action would not have a significant impact on water resources.

## 7.13 Climate Change and Groundwater

Climate change is predicted to affect rainfall and other climatic variables, of which any predicted changes in rainfall are likely to have the most significant effect on groundwater by affecting recharge rates. Two sources of projected changes in rainfall have been reviewed:

- NSW/ACT Regional Climate Modelling (NARCliM) for the New England and North West Region (Office of Environment and Heritage, 2014); and
- Climate Change in Australia Technical Report (CCiA) produced by the CSIRO and BoM covering Australia's National Resource Management (NRM) regions, including the 'Eastern Australia' region (CSIRO and BoM, 2015).

Table 7.14 presents the median projection for change in rainfall from these sources for 2030 and longer-term projections for 2070 and 2090.

Rainfall projections are somewhat similar, at least on an annual basis, for 2030, but quite variable for the 2070-2090 forecast. NARCliM projections suggest a wetter climate, while CCiA projections suggest a drier climate.

**Table 7.14 Climate Change Projections – Percentage Change in Rainfall**

| Period | 2030 | | 2070 | 2090 | |
|---|---|---|---|---|---|
| | NARCliM New England and North West Region | CCiA RCP 4.5 | NARCliM New England and North West Region | CCiA RCP 4.5 | CCiA RCP 8.5 |
| Summer | -3.3 | -2.0 | +9.8 | -2.0 | 4.0 |
| Autumn | 14.9 | -4.0 | +16.8 | -7.0 | -8.0 |
| Winter | -7.6 | -3.0 | -0.7 | -10.0 | -16.0 |
| Spring | 2.6 | -2.0 | -0.7 | -10.0 | -16.0 |
| **Annual** | **+1.6** | **-1** | **+7.7** | **-7.0** | **-10.0** |

***Note:*** *RCP = Representative Concentration Pathways.*

The effect of the predicted climate change has not been specifically assessed for the Project groundwater inflow as the average change in inflow (due to climate change) over the remaining life of the Narrabri Mine is likely to be minor, given that there is only a small change in average rainfall by 2030 (the closest projection to the end of the mine life in 2044) based on the NARCliM and CCiA projections (Table 7.14). In the short-term, typical climate variability, rather than climate change, will govern whether rainfall is similar to the long-term average or not. Post-mining, NARCliM and CCiA differ in their prediction with respect to the likely changes in rainfall. If rainfall were to increase, this would result in quicker recovery, while conversely if rainfall were to decrease this would result in slower recovery. Notwithstanding, the predictive uncertainty analysis discussed in Section 7.9 and Appendix D considers a wide range of possible recharge rates (i.e. which could be influenced by future changes in rainfall due to climate change).

The Surface Water Assessment (WRM, 2020) has considered the implications of climate change on the potential surface water losses from the catchment.

# 8 Groundwater monitoring and management plan

## 8.1 Existing water management plan

The Narrabri Mine operates in accordance with a WMP (or its latest approved version) which is prepared in consultation with NSW government agencies. The WMP includes a standalone Groundwater Monitoring and Management Plan (GWMMP). The WMP describes the management of environmental and community aspects, impacts and performance relevant to the sites water management system.

As described in Section 5.2.1, the Narrabri Mine operates an extensive existing groundwater monitoring network. The monitoring network comprises standard 50 mm or 25 mm PVC monitoring bores installed within the alluvial aquifers and the deeper Permian strata including coal measures. The network also includes arrays of VWPs cemented into selected drill holes to monitor pressure in deeper strata. This includes monitoring sites installed immediately above longwall panels to monitor responses in overlying units and assist with determining the height of fracturing above mined areas. In the event that existing VWPS or other monitoring facilities fail (e.g. due to subsidence or other factors) NCOPL will determine appropriate replacement monitoring sites in liaison with DPIE-Water post approval when updating the WMP to account for the Project.

Currently, groundwater levels and field water quality (pH and EC) are measured in the monitoring bores on a monthly basis, in addition to daily water level readings recorded by the dataloggers in VWPs. Ongoing monitoring would enable natural groundwater level fluctuations, such as responses to rainfall, to be distinguished from potential groundwater level impacts due to depressurisation resulting from proposed mining activities. Ongoing monitoring of groundwater levels would also be used to assess the extent and rate of depressurisation against model predictions.

Yearly reporting of the water level results from the monitoring network is included in the Annual Review. The Annual Review also identifies if any additional monitoring sites are required, or if optimisation of the existing monitoring sites should be undertaken.

Water samples are also collected annually from all standpipe piezometers and submitted for laboratory testing for the following parameters:

- pH, EC (field measurements);
- major ions - Ca, Cl, K, Na, Mg, $SO_4$, $HCO_3$;
- alkalinity;
- nutrients - total P; and
- total metals- Arsenic, Cadmium, Chromium, Copper, Nickel, Lead, Zinc, Mercury, Vanadium and Manganese.

Groundwater quality analysis should continue in the existing bores (as well as any new bores recommended in Section 8.2) to detect changes in groundwater quality during mining.

Like the water level monitoring, yearly reporting of the water quality results from the monitoring network should be included in the annual review. The Surface Water and Groundwater Response Plan currently provides site-specific triggers for water quality parameters. Laboratory results for monitoring points included in the network are currently compared to National Environmental Protection Measures (NEPM) guidelines for livestock and to the 97.5$^{th}$ percentile of the available baseline data and any exceedances reported to relevant agencies. The comparison of water quality measurements to the site-specific trigger levels will continue. The trigger levels are periodically reviewed, in consultation with relevant agencies, as additional monitoring information becomes available. If required, the WMP would be updated to reflect any changes to site-specific trigger levels.

The WMP also includes a requirement to monitor groundwater inflows (flow and quality) to the mine and compare the results to the predicted inflows from groundwater modelling. Sustained inflows of more than 100% greater than predicted would also trigger additional investigations and reporting to relevant agencies.

The numerical model would be used as a management tool for the periodic review and validation of predicted groundwater impacts through the life of the Project. In the event that actual groundwater inflows are materially more, or less than, predicted inflows, the groundwater model may be re-calibrated using updated groundwater monitoring results.

## 8.2 Additional monitoring recommendations

Based on the predicted impacts of the Project and a review of the current monitoring and management plan, a number of additional monitoring measures are recommended as described below.

There is currently no monitoring of shallow groundwater and surface water levels in the vicinity of Pine, Kurrajong and Tulla Mullen creeks although standing pools of water were observed on the latter two creeks during the recent site visit. Additional monitoring is therefore recommended ideally at a minimum of two locations on each creek comprising:

- monitoring of surface water levels and field water quality parameters in any standing pools;
- installation and monitoring of groundwater levels and field water quality parameters in the shallow Quaternary alluvium and the underlying bedrock at the same location; and
- regular sampling and laboratory testing of surface water and groundwater samples taken from the above facilities.

Whilst monitoring of both the volume and quality of inflow to the mine is stipulated in the WMP, only very limited information appears to be available on the hydrochemistry of water reporting to the mine drainage systems. The presence or absence of temporal trends, or other patterns, in the chemistry of water drawn can provide important insights into the degree of connectivity between the mine and overlying aquifers and/or surface water systems. Continuous monitoring of TDS, PH and temperature at a number of gathering points as close as possible to the point of inflow underground is recommended. Water samples should also be routinely collected and sent for laboratory analysis. Such data can also provide an early warning of unexpected increases in inflow.

Further regular site visits to the Mayfield Spring, Hardys Spring and Eather Spring (Dams 1 and 2) sites are recommended to observe any changes to flow rates and surface conditions and to confirm whether these features are groundwater dependent. Depending on the results of these visits, further ongoing groundwater and surface water monitoring at these sites, similar to that described above for local creeks, may also be required to confirm predicted impacts. Site specific monitoring details (including monitoring frequency and duration) should be developed as part of the Water Management Plan.

# 9 Summary and conclusions

The Project involves an extension to the south of the approved underground mining area to gain access to additional coal reserves within MLAs 1 and 2, an extension of the mine life to FY 2044 and development of supporting surface infrastructure. ROM coal production would occur at a rate of up to 11 Mtpa, consistent with the currently approved limit.

This Groundwater Assessment has been guided by the SEARs, outcomes of the Gateway Process, AIP and IESC Information Guidelines.

The assessment makes use of data from a network of groundwater monitoring points. This data has supported development and calibration of a substantially revised numerical groundwater flow model. In total, data for some 262 groundwater level monitoring points have been used for the assessment comprising 115 Narrabri Mine monitoring points, 43 Narrabri Gas Project and 129 NSW State monitoring bores. Both the Project and the neighbouring Narrabri Gas Project target the Hoskissons Coal Seam and hence the cumulative impacts of both projects have been assessed.

The calibrated model was able to satisfactorily replicate observed groundwater levels and head differences in the Narrabri Mine area, the Narrabri Gas Project area and in the Namoi Alluvium. Observed baseflow gains in the Namoi River between Boggabri and Narrabri and estimated inflows to the existing underground mining area were also well matched on average. Accordingly, a review of the calibration output by the independent peer reviewer concluded that the model was suitable for use in predicting the impacts of the Project.

Two highly productive aquifers, the Pilliga Sandstone and the Namoi Alluvium, support substantial extraction in the region. The Pilliga Sandstone is present at outcrop towards the west of ML 1609 and MLAs 1 and 2. The Namoi Alluvium is present approximately 6 km to the east of the Project underground mining area. The remaining hydrostratigraphic units in the vicinity of the Project are identified in the AIP as “less productive” aquifers.

Drawdown of more than 2 m (i.e. the AIP threshold) is not predicted in any existing privately owned water supply bores thought to extract water from either the Pilliga Sandstone or Namoi Alluvium aquifers.

Predictions suggest that impacts would continue to develop in each of the “less productive” hydrostratigraphic units in which impacts have already been observed, namely the Digby Formation, Napperby Formation, Garrawilla Volcanics and Purlawaugh Formation. Drawdown of more than the AIP threshold of 2 m for these ‘aquifers’ are predicted some distance outside of ML 1609 and MLAs 1 and 2. Eight existing privately owned water supply bores are thought to extract from these units and are therefore predicted to experience more than 2 m of drawdown. However, predicted drawdowns at four of these bores represents less than 50% of the available ‘headroom’ (i.e. the distance between the observed standing water level in the bore and the uppermost water bearing horizon) and hence the yield of these bores may not be significantly impaired.

In accordance with the AIP, NCOPL would implement ‘make good’ provisions at any privately owned water supply bore experiencing more than 2 m of drawdown.

In most hydrostratigraphic units, maximum impacts are predicted to occur many years after completion of mining due the time taken for impacts to propagate vertically and laterally away from the point of extraction.

Groundwater extraction for the Project is expected to peak at 2,406 ML/year in 2040 towards the end of the mine life and additional licences from the Gunnedah-Oxley Basin MDB Groundwater Source would be required. Predicted maximum inflows are approximately 1,000 ML/year (or 75%) higher than previously predicted for the Approved Mine, consistent with the 75% larger footprint of the Project. Predictions also suggest minor net reductions in groundwater discharge to the Quaternary alluvium (108 ML/year), to the Namoi River itself (142 ML/year) and to other local watercourses (68 ML/year).

A large number of high priority GDEs have been recently added to a number of the WSPs of relevance to the Project. However, it should be noted that these areas are based on high potential areas identified in the GDE Atlas and have for the most part not been field verified. Comparison of predicted maximum water table drawdowns and estimated water table fluctuations, as required under the AIP, suggests that estimated minimal impact thresholds may be exceeded at a number of potential GDE areas totalling up to 153.5 ha in the Gunnedah-Oxley Basin MDB Groundwater Source and two areas totalling 7.4 ha in the Namoi Alluvial Groundwater Source – Upper Zone 5. However, only very minor drawdown (i.e. less than 5 cm) is predicted at three potential spring sites in the area; the Mayfield, Hardys and Eather Springs. The Hardy's and Eather Springs are identified as high priority springs in the WSP Southern Recharge Groundwater (Pilliga Sandstone) WSP.

Following completion of mining, groundwater levels in the Hoskissons Coal Seam would begin to recover. Predictions suggest groundwater levels in the Hoskissons Coal Seam close to the Narrabri Mine would take up to 400 years to recover to within 10% of current levels. Full recovery in other "less productive" units more distant from the Narrabri Mine would be delayed further. Following the completion of mining, re-injection of brine into the goaf is not anticipated to significantly affect either groundwater levels or groundwater quality outside of the Project underground mining area, predominantly since the total volume to be injected represents less than 2% of the total estimated void space underground.

In terms of impacts on groundwater receptors, in all cases the predicted cumulative impacts of development of the Project and Narrabri Gas Project are only marginally greater than the impacts of the Narrabri Mine Project on its own. This reflects the relative depth of the two projects and proximity to potential receptors.

Whilst an extensive monitoring network already exists, some additional monitoring of shallow groundwater and surface water levels and quality in the vicinity of Pine, Kurrajong and Tulla Mullen creeks and of underground mine water quality is recommended. Further regular site visits to the Mayfield Spring, Hardys Spring and Eather Spring (Dams 1 and 2) sites are recommended to observe any changes to flow rates and surface conditions and to confirm whether these features are groundwater dependent. Depending on the results of these visits, further ongoing groundwater and surface water monitoring at these sites, similar to that described above for local creeks, may also be required to confirm predicted impacts. Site specific monitoring details (including monitoring frequency and duration) should be developed as part of the Water Management Plan. Otherwise groundwater levels and quality should continue to be monitored in accordance with the approved WMP.

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# Appendix A **Groundwater monitoring network**

## Table A 1 Summary of groundwater monitoring site measurements (after HydroSimulations, 2019a)

| Monitoring Site | Parameter | Frequency |
|---|---|---|
| **All Standpipes**<br>P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11, P12, P13, P14, P15, P16, P17, P18, P19, P28, P29, P30, P31, P32, P33, P34, P39A, P39B, P43, P47, P51, P52, P53, WB2, WB3a, WB3b, WB4, WB5a, WB5b, WB6a, WB6b, and WB7 | Water level | Monthly |
| | EC | Monthly |
| | pH | Monthly |
| | TDS | Annual |
| | Metals | Annual |
| | Anions and | Annual |
| | Cations | Annual |
| **Vibrating Wire Piezometers**<br>P21, P22, P24, P25, P26, P27, P35, P36, P37 and P48 | Water Level | Daily (Data Logger) |
| **Multi-Level Vibrating Wire Piezometers**<br>P23, P24, P40, P42, P44, P45, P46, P54, P55, P56 and P57 | Water Level | Daily (Data Logger) |

***Notes:*** *EC = electrical conductivity*
*TDS = total dissolved solids*

## Table A 2 Summary of groundwater monitoring site types (after HydroSimulations, 2019a)

| Monitoring Site | Lithology | Start Date | Type |
|---|---|---|---|
| WB3A, WB3B, WB4, WB5A, WB5B, WB6A, WB6B and WB7 | Alluvium | All from September 2008 except WB7 from November 2008 | Standpipe |
| P6 and P7 | Piiliga Sandstone | From November 2007 | Standpipe |
| P8, P9, P11 and P17 | Purlawaugh Formation | All from March 2008.<br>P17 stopped on February 2009 | Standpipe |
| P1, P13, P15, P16, P47, WB1 and WB2 | Garrawilla Volcanics | P1 from November 2007<br>P15 from January 2009<br>P13, P16 from March 2008<br>P32 from June 2012<br>WB1 from August 2008 – December 2008<br>WB2 from August 2008 – October 2011<br>P47 from June 2012 | Standpipe |
| P2, P4, P10, P12, P14, P28, P29, P30, P31, P32, P33 and P34 | Napperby Formation | P2, P4 from November 2007<br>P10, P12 from March 2008<br>P14 from January 2009 – April 2012<br>P28, P29, P30, P31, P32, P33, P34 from June 2012 | Standpipe |
| P18, P21, P22, P25, P26 and P27 | Hoskissons Seam | P18 from March 2008 | Standpipe |
| | | P21, P22, P25, P26, P27 from June 2009 | Vibrating wire |
| P23, P24, P35, P36, P37, P38, P40, P44, P45, P46, P54, P55, P56 and P57 | Multi-Level | Variable time | Multi-level vibrating wire |
| P20 | Arkarula Formation | From March 2008 to June 2010 | Standpipe |
| P3, P5 and P19 | Pamboola Formation | P3, P5 from November 2007<br>P19 from March 2008 | Standpipe |

## Table A 3 Narrabri mine monitoring bore construction details

| Name | Type | Unit | RL | Bore depth | Monitoring interval |
|---|---|---|---|---|---|
| | | | mAHD | mBGL | mBGL |
| P01 | Standpipe | Garrawilla Volcanics | 316.06 | 50 | 44-50 |
| P02 | Standpipe | Napperby Formation | 275.92 | 50 | 44-50 |
| P03 | Standpipe | Pamboola Formation | 236.31 | 45 | 34-40 |
| P04 | Standpipe | Napperby Formation | 248.96 | 30 | 24-30 |
| P05 | Standpipe | Pamboola Formation | 233.41 | 30 | 24-30 |
| P06 | Standpipe | Pilliga Sandstone | 326.19 | 90 | 78-90 |
| P07 | Standpipe | Pilliga Sandstone | 289.69 | 90 | 78-90 |
| P08 | Standpipe | Purlawaugh Formation | 322.11 | 65 | 57-63 |
| P09 | Standpipe | Purlawaugh Formation | 287.60 | 30 | 24-30 |
| P10 | Standpipe | Napperby Formation | 302.53 | 130 | 118-130 |
| P11 | Standpipe | Purlawaugh Formation | 302.40 | 50 | 44-50 |
| P12 | Standpipe | Napperby Formation | 276.48 | 90 | 84-90 |
| P13 | Standpipe | Garrawilla Volcanics | 276.48 | 30 | 24-30 |
| P14 | Standpipe | Napperby Formation | 277.41 | 78 | 72-78 |
| P15 | Standpipe | Garrawilla Volcanics | 277.41 | 30 | 24-30 |
| P16 | Standpipe | Garrawilla Volcanics | 303.51 | 146 | 137-146 |
| P17 | Standpipe | Purlawaugh Formation | 303.24 | 56 | 47-56 |
| P18 | Standpipe | Hoskissons Coal Seam | 270.90 | 146 | 143-146 |
| P19 | Standpipe | Pamboola Formation | 275.09 | 187 | 184-187 |
| P21 | Vibrating Wire | Hoskissons Coal Seam | 275.00 | 200 | 160 |
| P22 | Vibrating Wire | Hoskissons Coal Seam | 274.12 | 180 | 165 |
| P23 | Vibrating Wire | Multiple | 286.04 | 199 | 45, 120, 169, 188 |
| P24 | Vibrating Wire | Multiple | 277.59 | 181 | 112, 148, 166, 180 |
| P25 | Vibrating Wire | Hoskissons Coal Seam | 270.00 | 200 | 165 |
| P26 | Vibrating Wire | Hoskissons Coal Seam | 275.41 | 200 | 176 |
| P27 | Vibrating Wire | Hoskissons Coal Seam | 275.36 | 180 | 176 |
| P28 | Standpipe | Napperby Formation | 262.46 | 25 | 19-25 |
| P29 | Standpipe | Napperby Formation | 256.84 | 25 | 19-25 |
| P30 | Standpipe | Napperby Formation | 254.95 | 15 | 9-15 |
| P31 | Standpipe | Napperby Formation | 264.39 | 15 | 9-15 |
| P32 | Standpipe | Napperby Formation | 252.49 | 15 | 9-14 |
| P33 | Standpipe | Napperby Formation | 253.56 | 15 | 9-14 |
| P34 | Standpipe | Napperby Formation | 255.96 | 15 | 9-14 |
| P35 | Vibrating Wire | Hoskissons Coal Seam | 278.71 | 183.1 | 173 |
| P36 | Vibrating Wire | Hoskissons Coal Seam | 281.50 | 190.1 | 176 |
| P37 | Vibrating Wire | Hoskissons Coal Seam | 277.38 | 186.3 | 177 |

| Name | Type | Unit | RL | Bore depth | Monitoring interval |
|---|---|---|---|---|---|
| | | | mAHD | mBGL | mBGL |
| P39A | Standpipe | Watermark Formation | 228.25 | 80 | 72-78 |
| P39B | Standpipe | Alluvium | 228.33 | 32 | 15-30 |
| P40 | Vibrating Wire | Multiple | 321.22 | 360 | 95, 135, 307, 322, 346, 357 |
| P42 | Vibrating Wire | Multiple | 335.92 | 427 | 90, 185, 345, 375, 395, 415 |
| P43 | Standpipe | Watermark Formation | 233.20 | 66 | 59-65 |
| P44 | Vibrating Wire | Multiple | 268.15 | 471 | 95, 134, 245, 330, 375, 445 |
| P45 | Vibrating Wire | Multiple | 247.27 | 291 | 42.5, 80, 150, 200, 240, 276 |
| P46 | Vibrating Wire | Multiple | 262.33 | 396 | 70, 87, 151, 250, 308, 343 |
| P47 | Standpipe | Garrawilla Volcanics | 288.78 | 30.5 | 8-30.5 |
| P48 | Vibrating Wire | Hoskissons Coal Seam | 276.00 | 210 | 195 |
| P51 | Standpipe | Garrawilla Volcanics | 267.15 | 17 | 9-12 |
| P52 | Standpipe | Napperby Formation | 268.85 | 24 | 18-21 |
| P53 | Standpipe | Garrawilla Volcanics | 270.98 | 24 | 18-21 |
| P54 | Vibrating Wire | Multiple | 344.89 | 348 | 28, 58. 98, 138, 178, 218, 258 298, 336 |
| P55 | Vibrating Wire | Multiple | 274.56 | 230 | 25, 44, 75, 98, 110, 135, 159, 195, 228 |
| P56 | Vibrating Wire | Multiple | 315.38 | 300 | 55, 85, 115, 145, 175, 205, 235, 265, 300 |
| P57 | Vibrating Wire | Multiple | 302.81 | 180 | 40, 60, 80, 100, 120, 140, 160, 180 |
| WB2 | Production Bore | Garrawilla Volcanics | 281.00 | - | 22-26 |
| WB3a | Production Bore | Alluvium | 226.00 | - | 8.2-8.5 |
| WB3b | Production Bore | Alluvium | 226.00 | - | 35.1-36.3 |
| WB4 | Production Bore | Alluvium | 224.00 | - | 11.3-15.9 |
| WB5a | Production Bore | Alluvium | 233.00 | - | 11-14.5 |
| WB5b | Production Bore | Alluvium | 233.00 | - | 26.5-28 |
| WB6a | Production Bore | Alluvium | 234.00 | - | 11.5-13 |
| WB6b | Production Bore | Alluvium | 234.00 | - | 76.7-78 |
| WB7 | Production Bore | Alluvium | 230.00 | - | - |
| Namoi Bore | Production Bore | Alluvium | 223.31 | 62 | 32-46 |

***Notes:*** *mAHD = elevation in metres with respect to the Australian Height Datum*

*mBGL = metres below ground level*

*" - " = no information*

# Appendix B Groundwater hydrographs

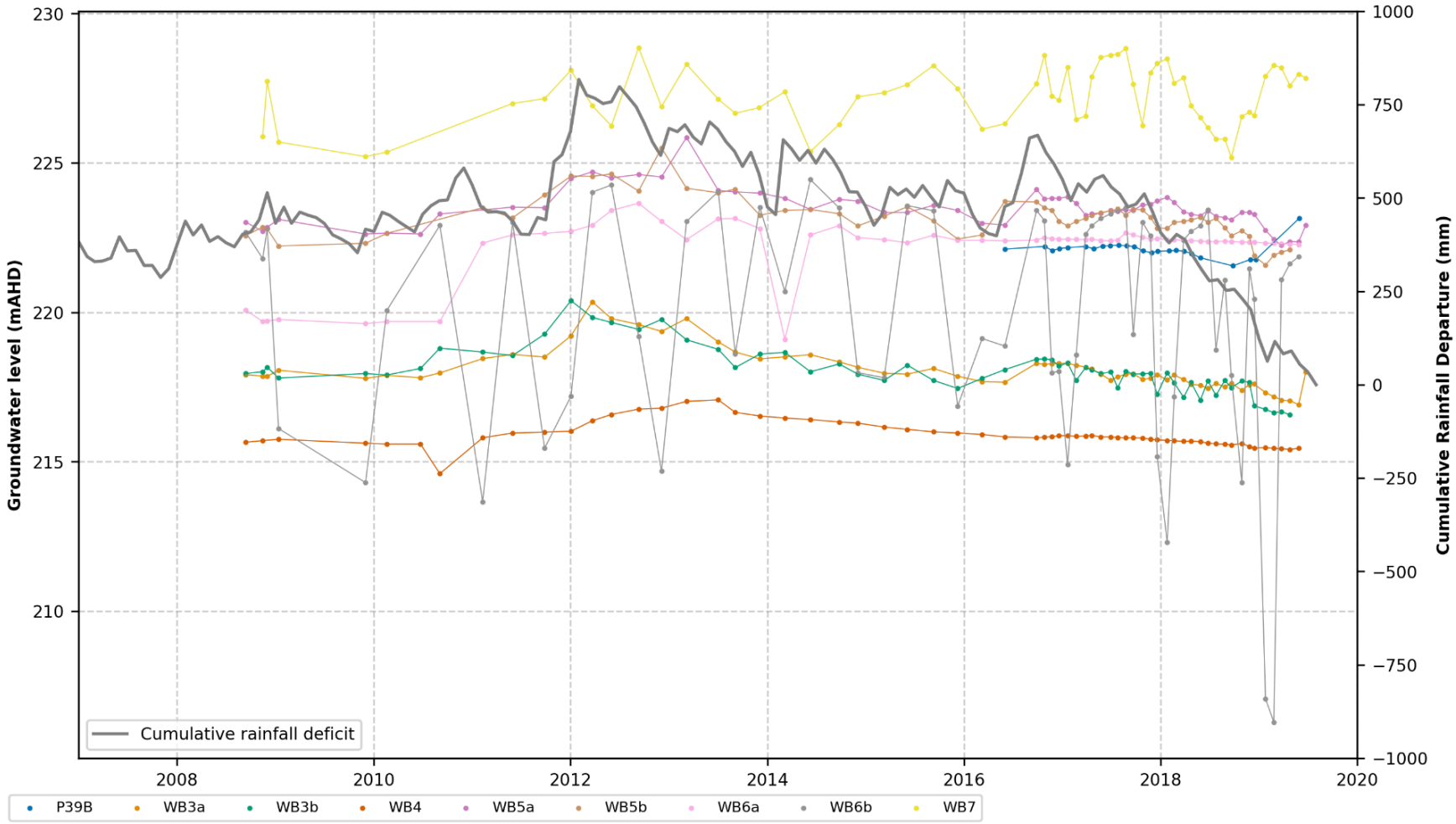



**Figure B 1 Alluvium water levels**

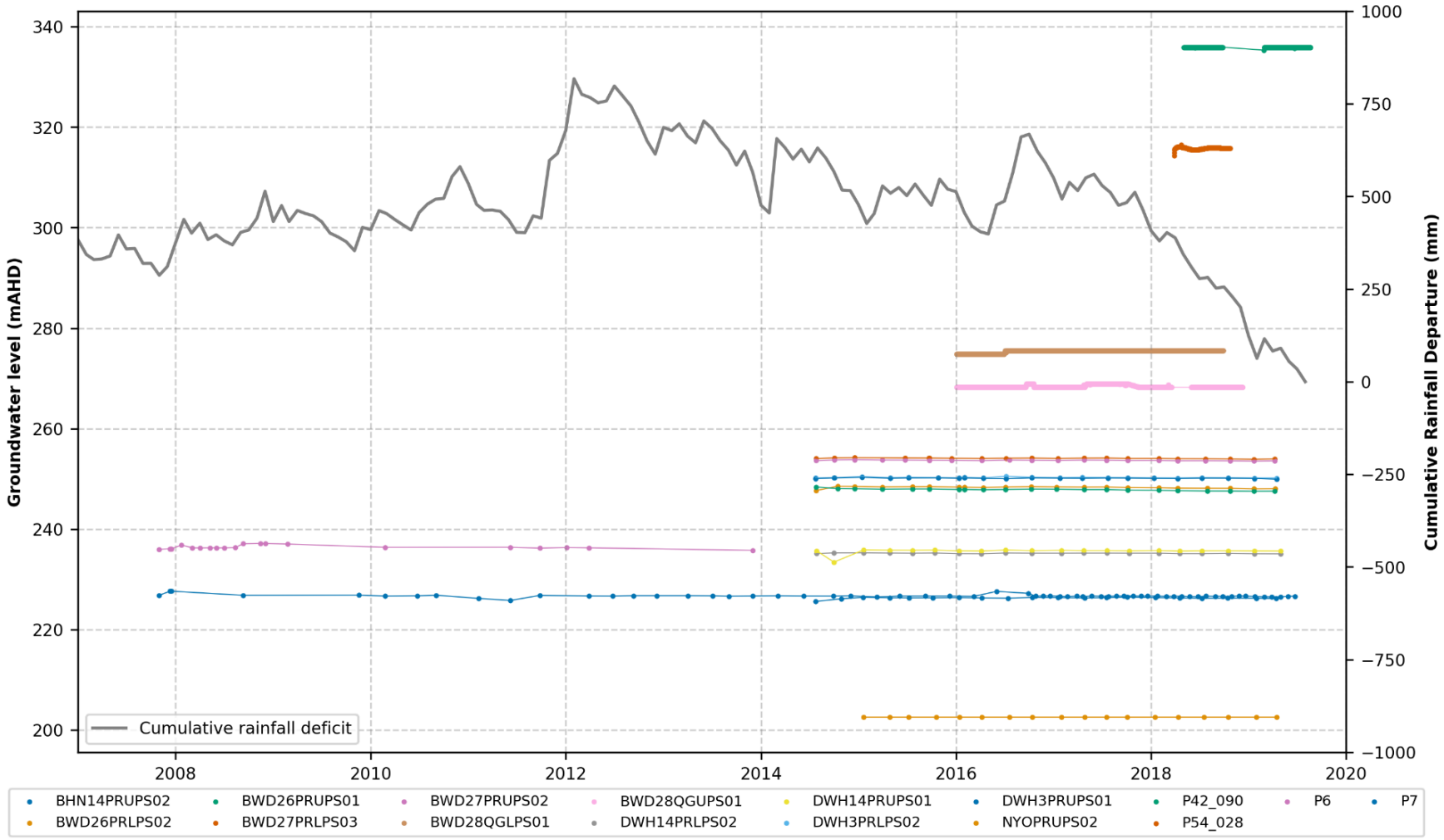



**Figure B 2 Pilliga Sandstone water levels**

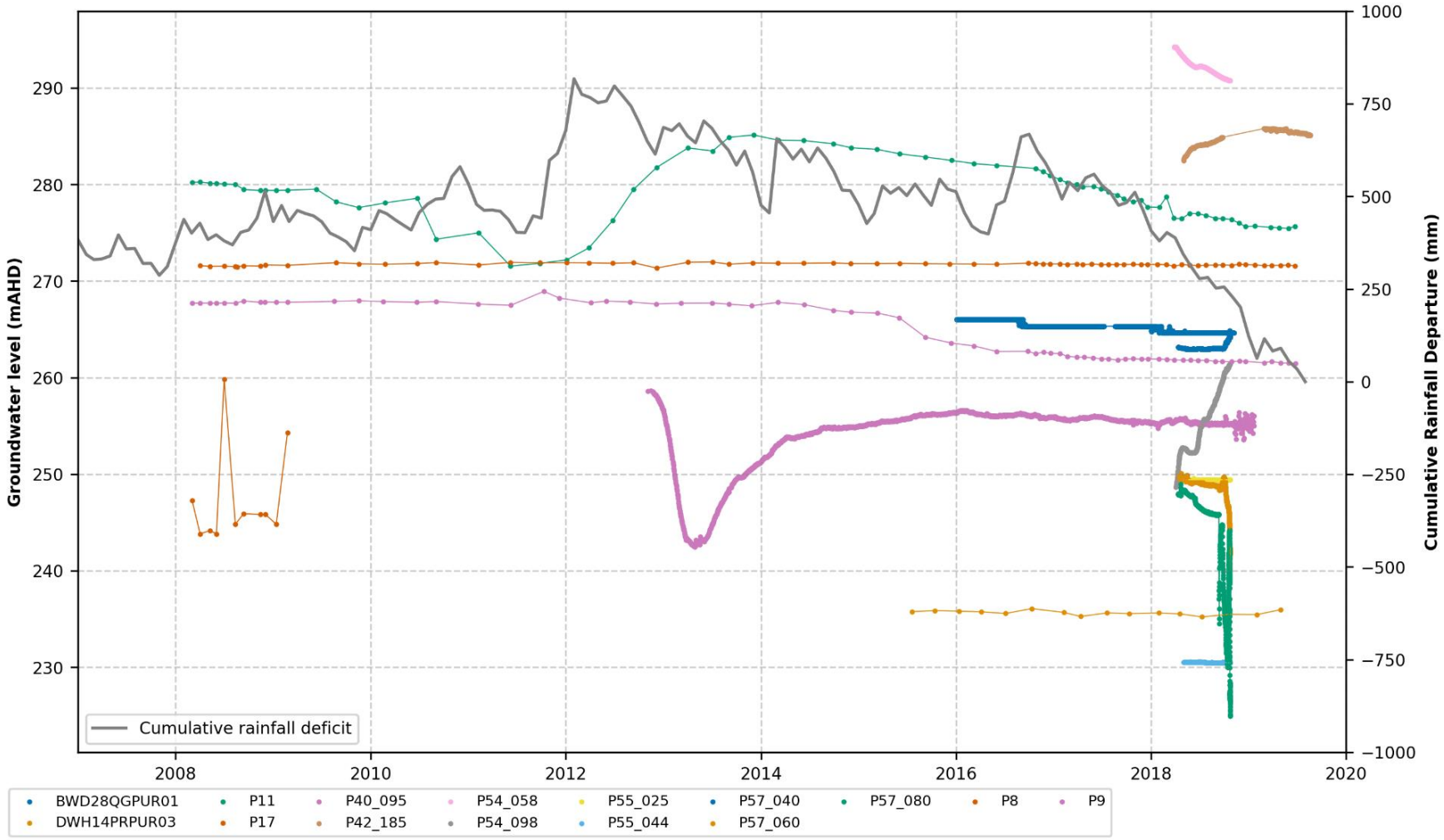



**Figure B 3 Purlawaugh Formation water levels**

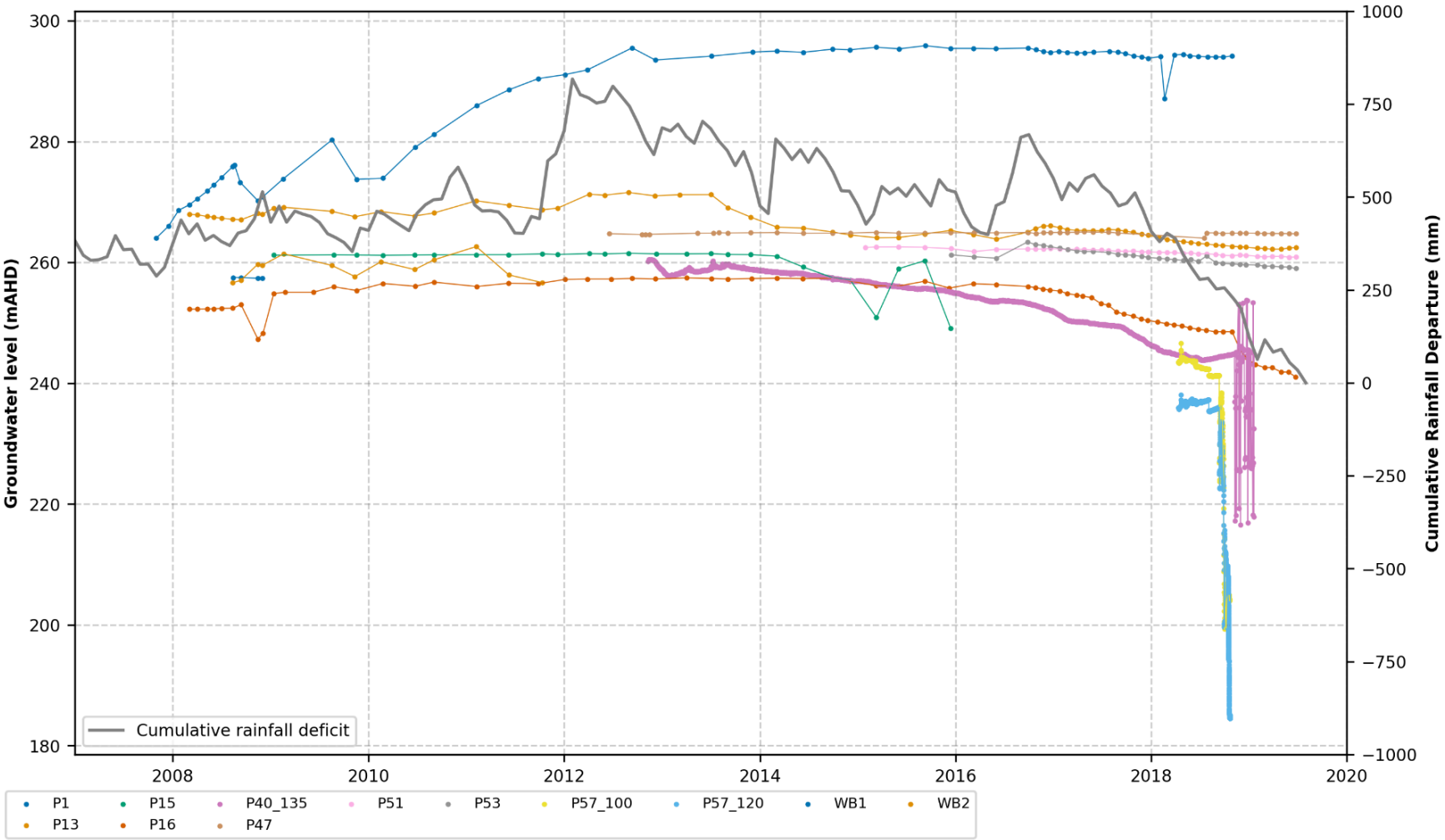



**Figure B 4 Garrawilla Volcanics water levels**

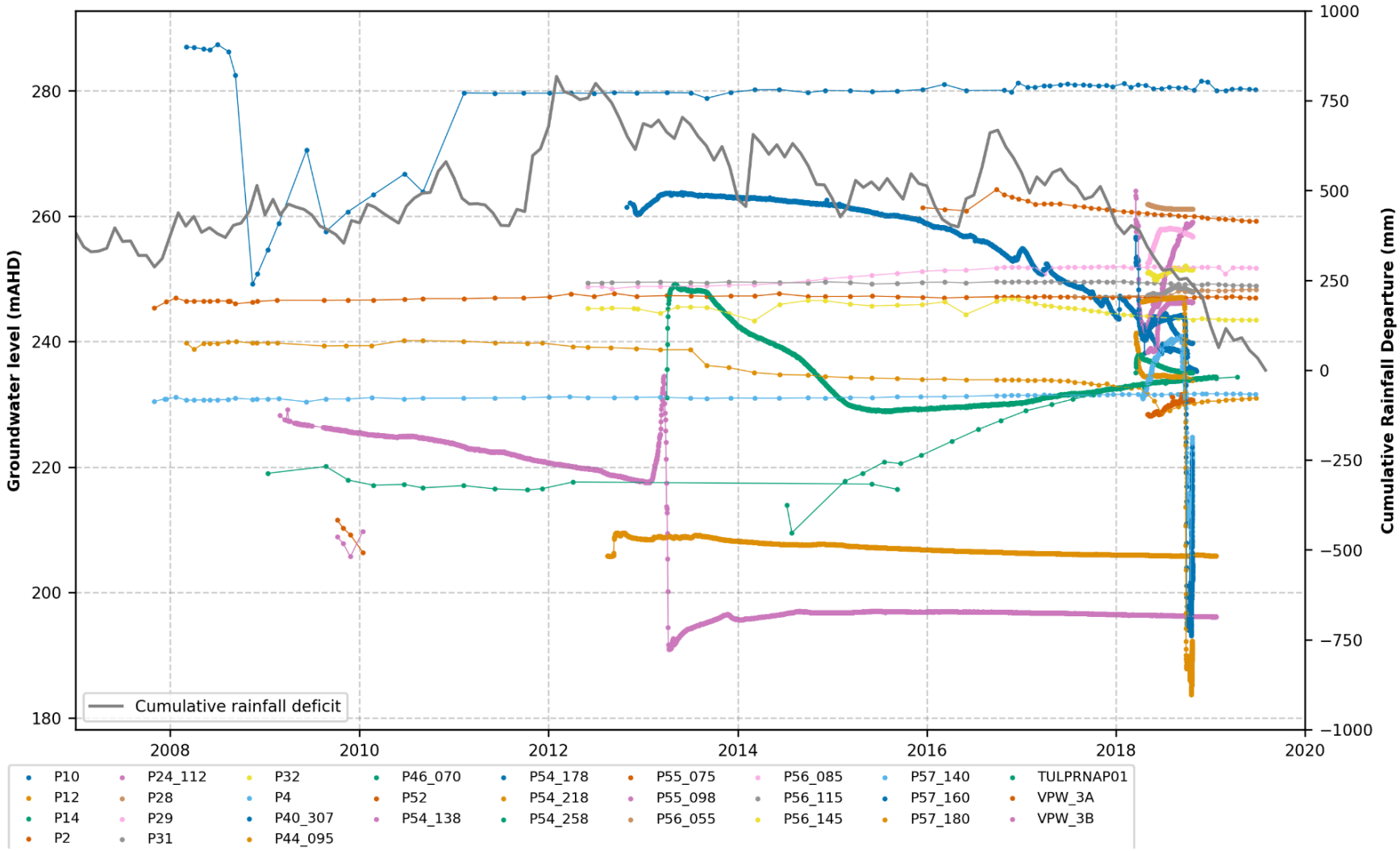



**Figure B 5 Napperby Formation water levels**

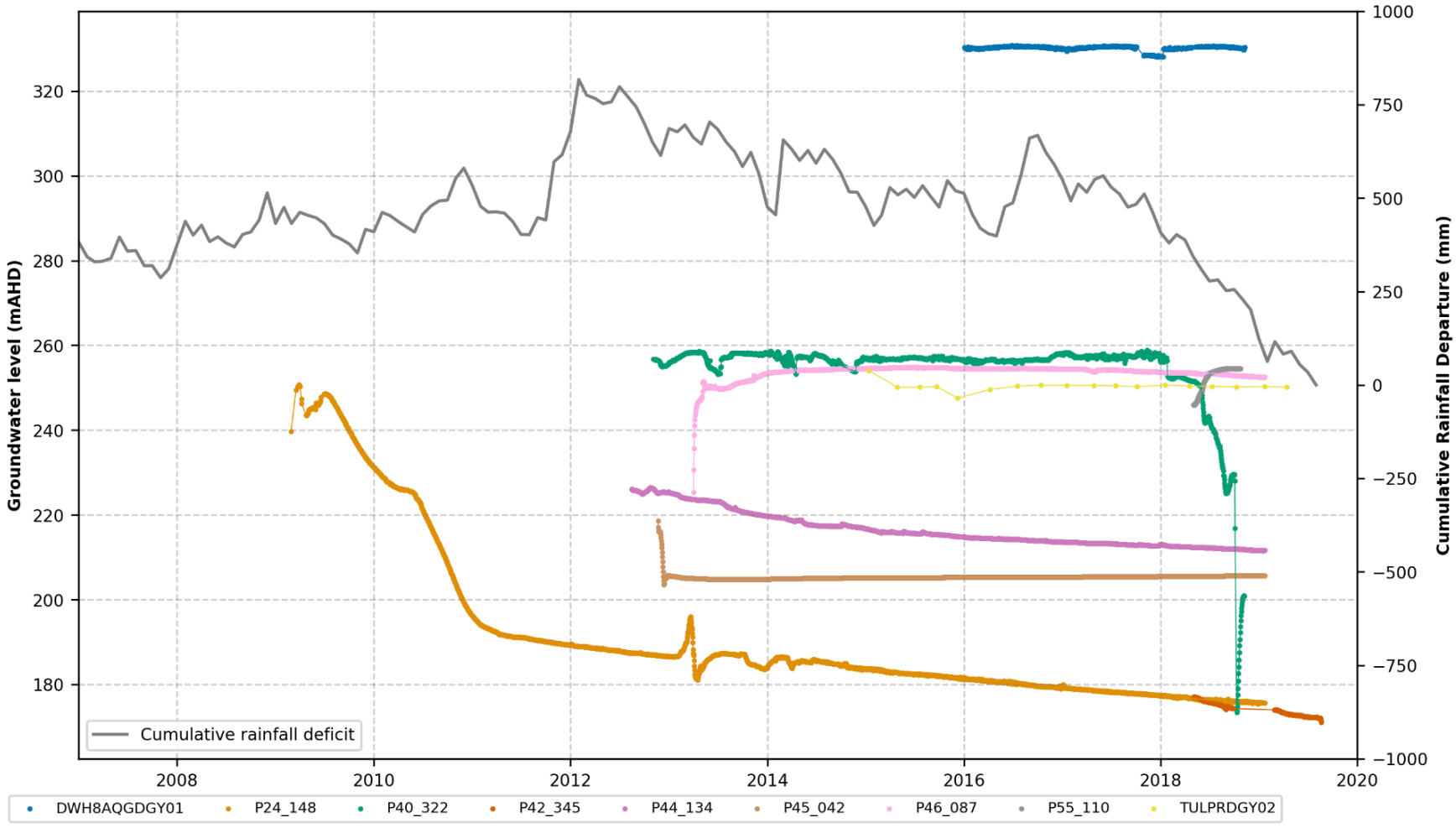



**Figure B 6 Digby Formation water levels**

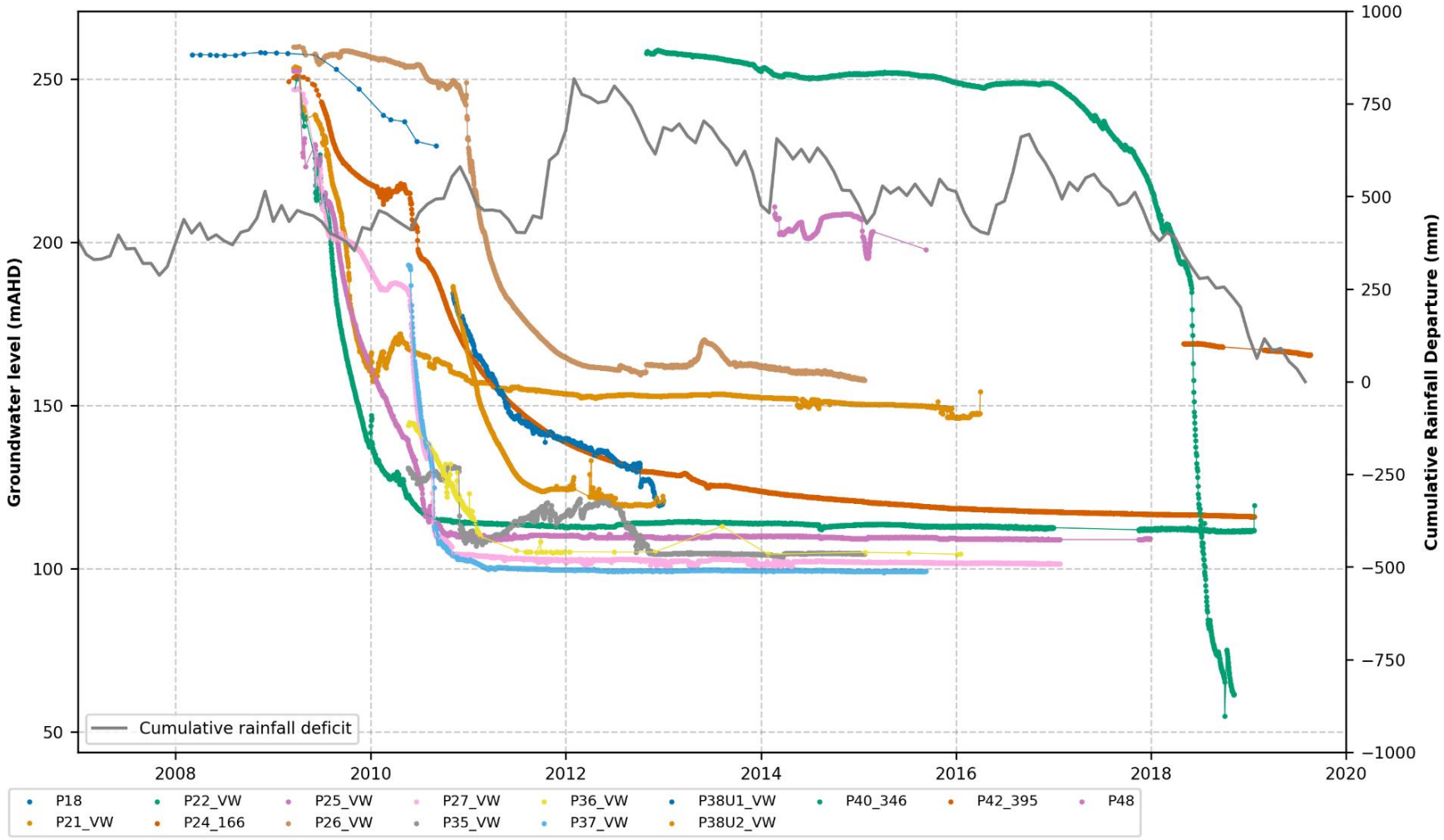



**Figure B 7 Hoskissons Coal Seam water levels**

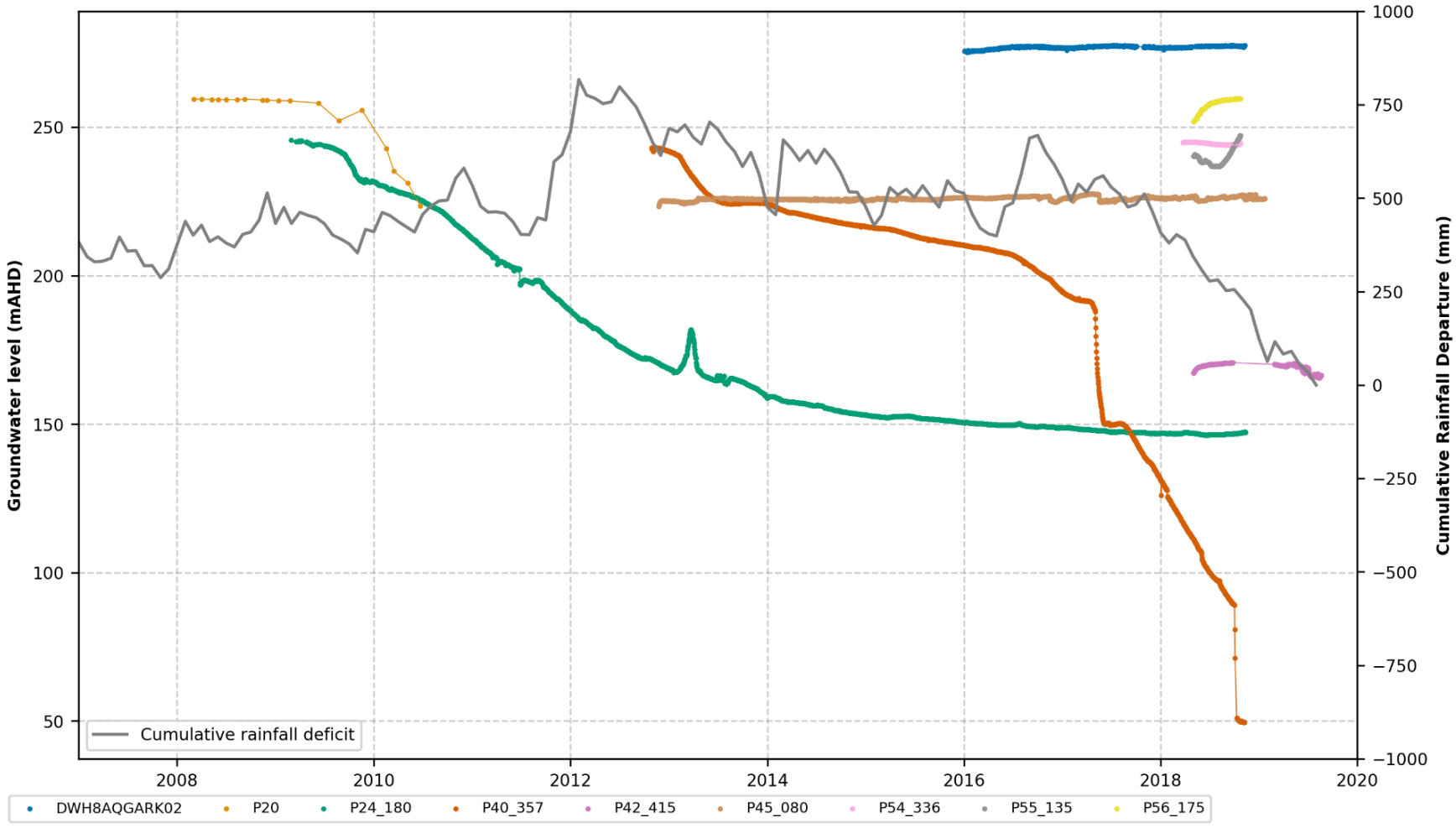



**Figure B 8 Arkarula Formation water levels**

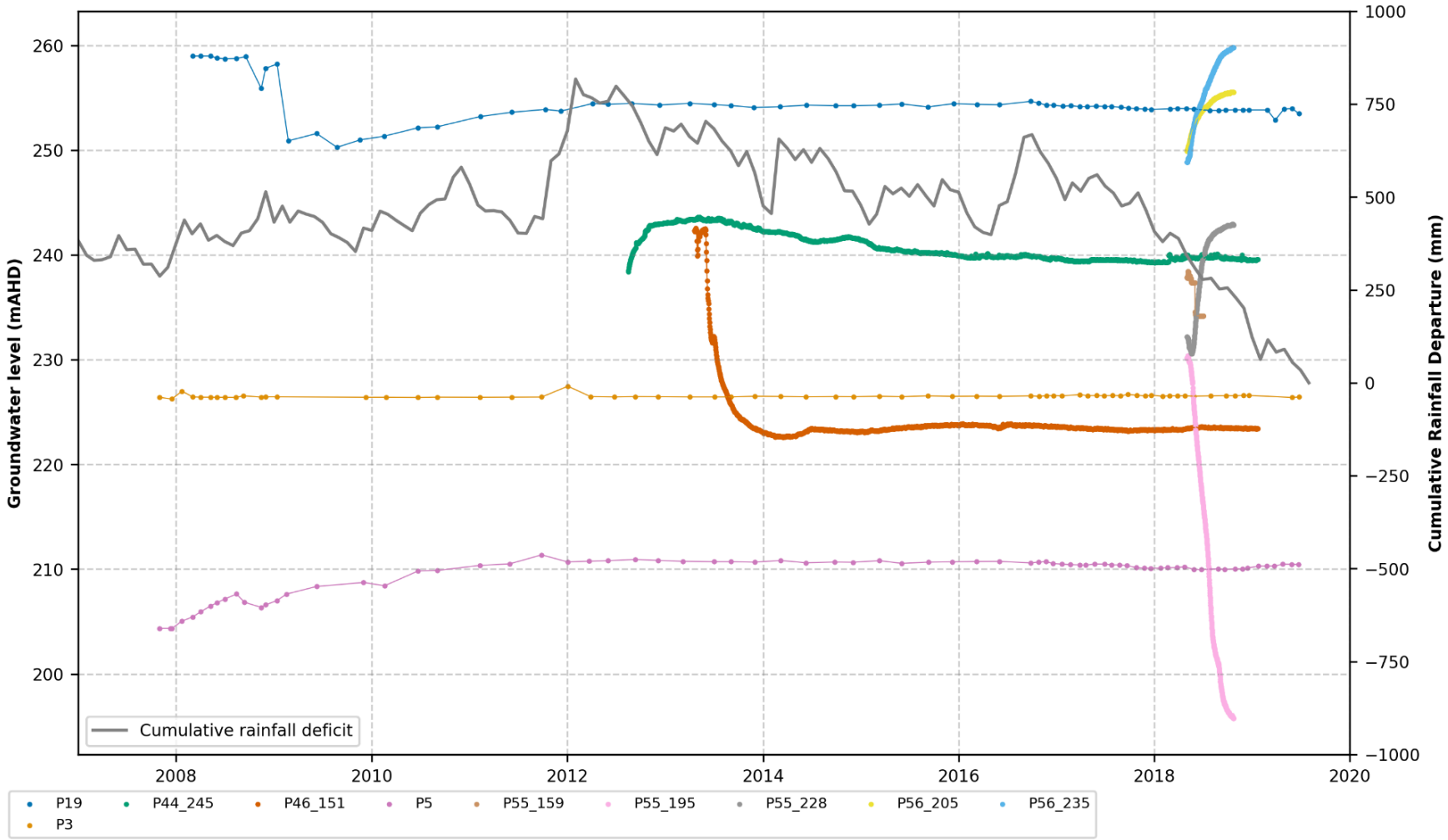



**Figure B 9 Pamboola Formation water levels**

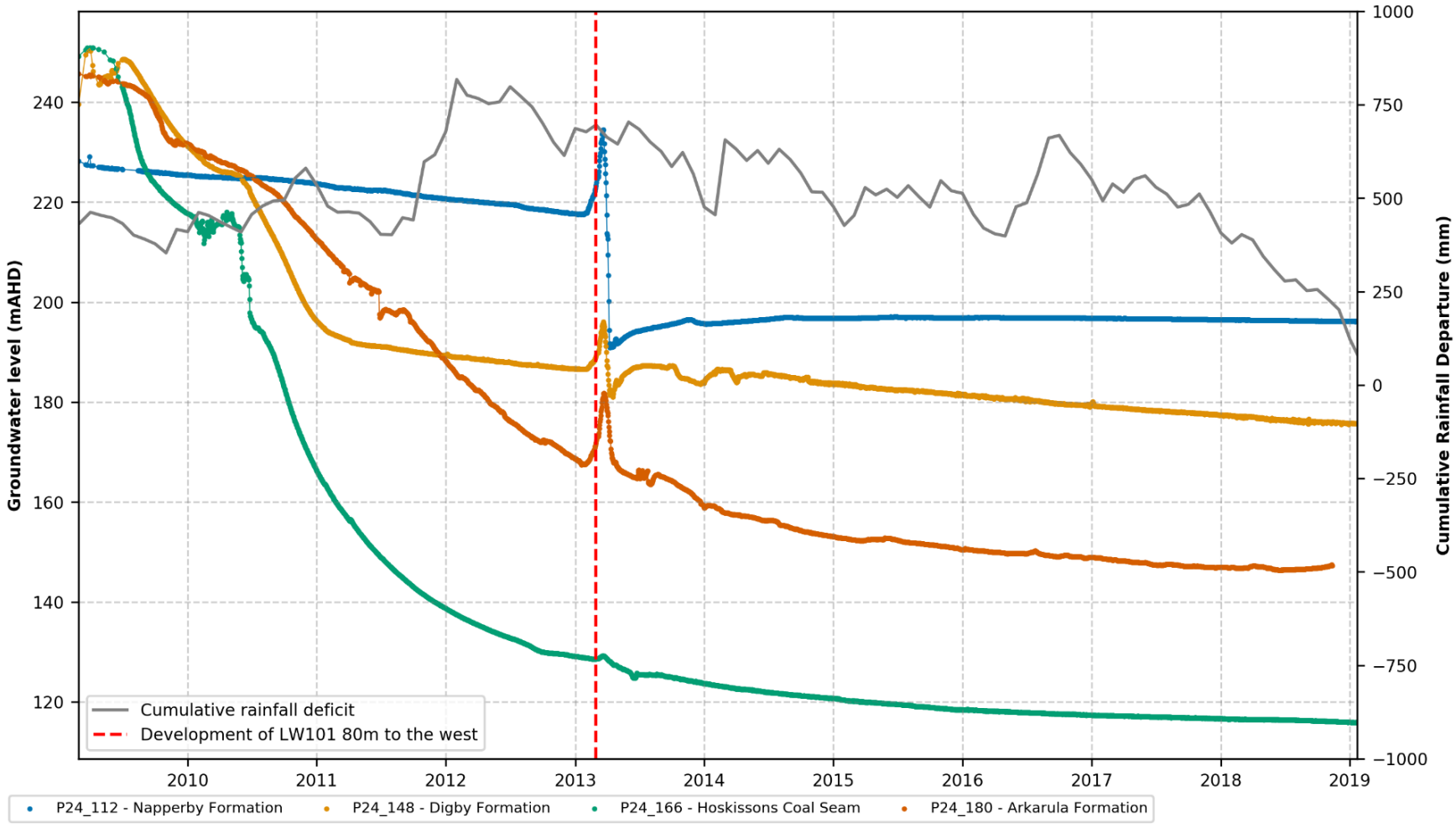



**Figure B 10 Water levels nested monitoring facility (P24)**

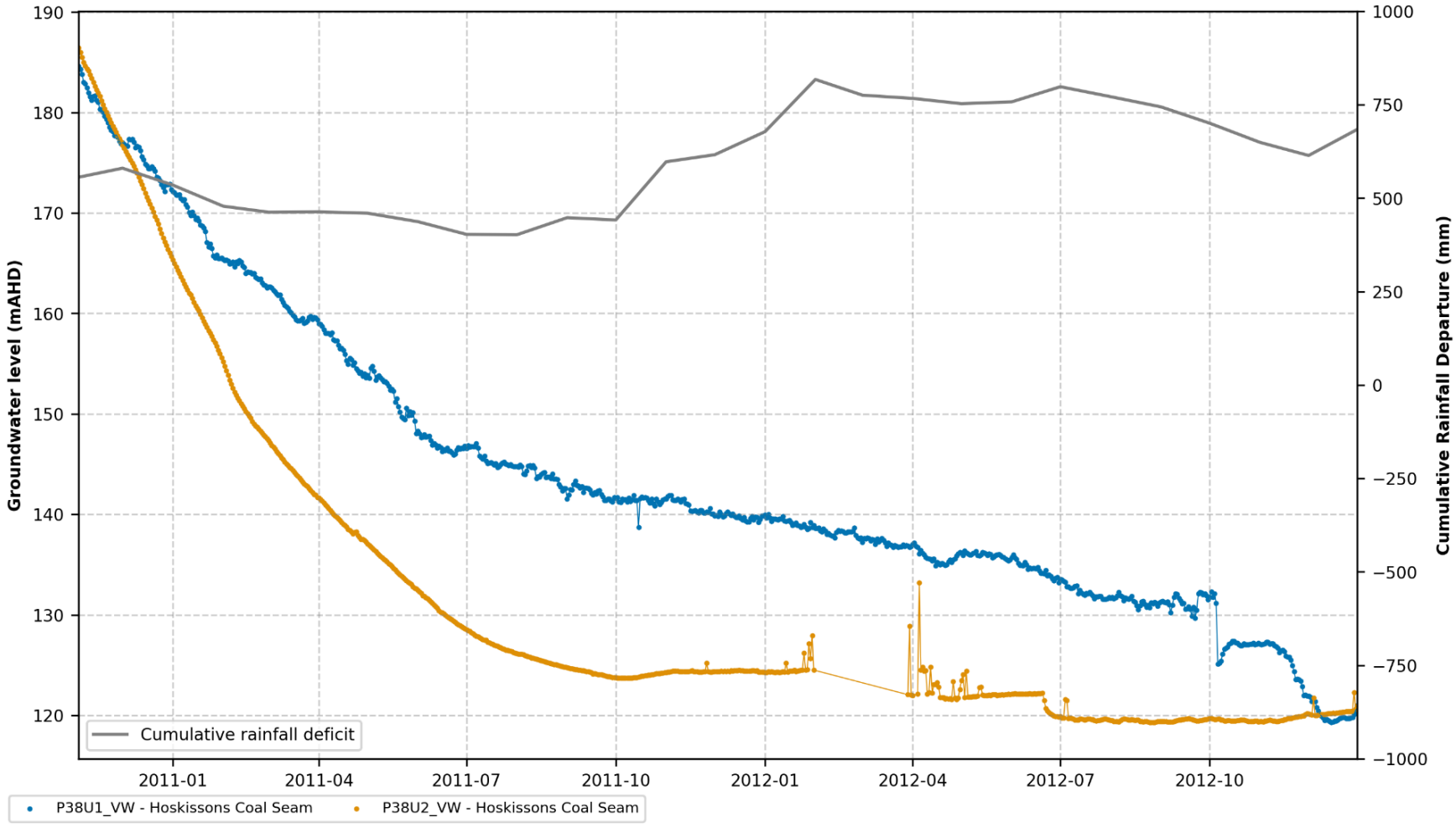



**Figure B 11 Water levels nested monitoring facility (P38)**

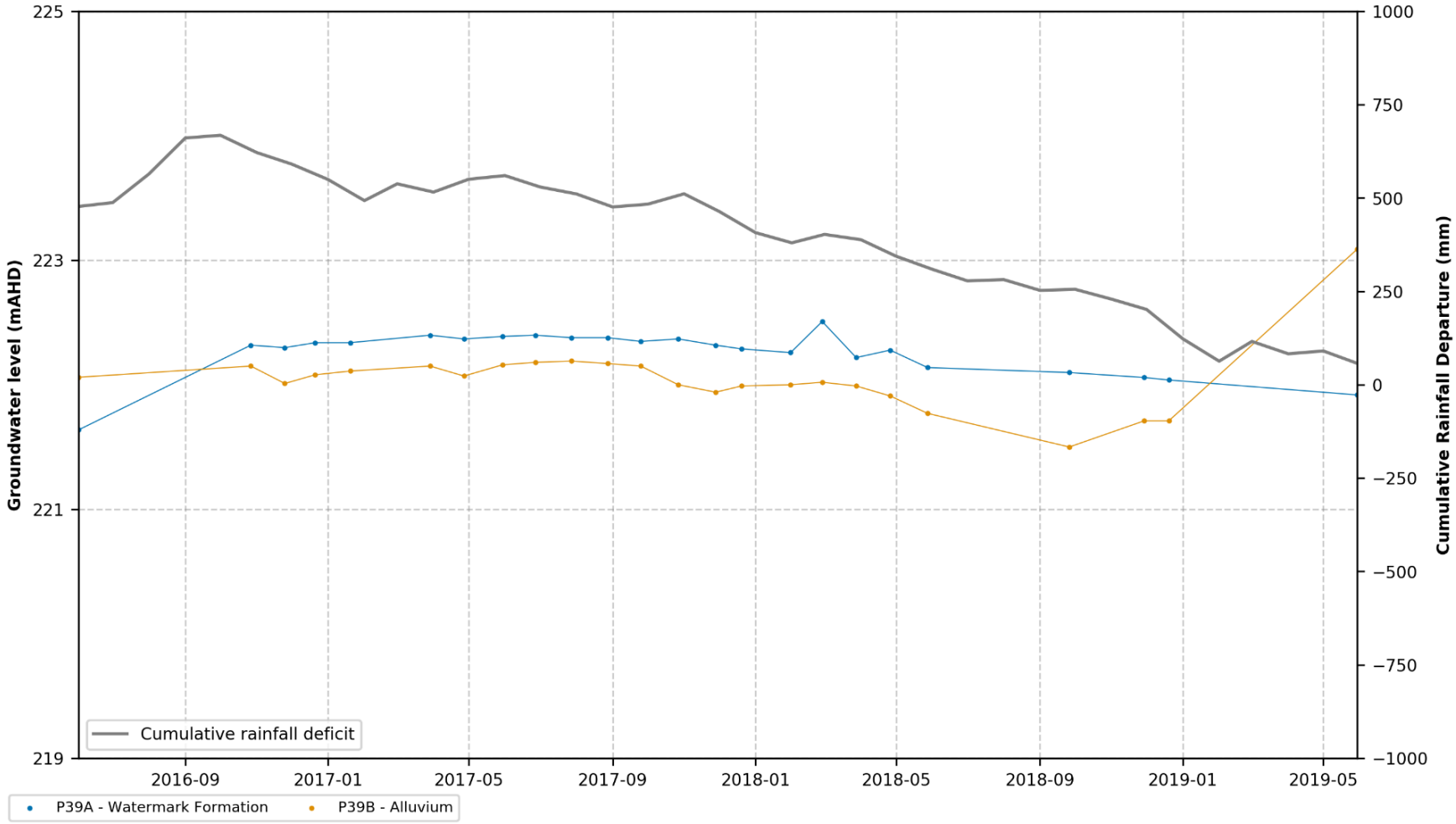



**Figure B 12 Water levels nested monitoring facility (P39)**

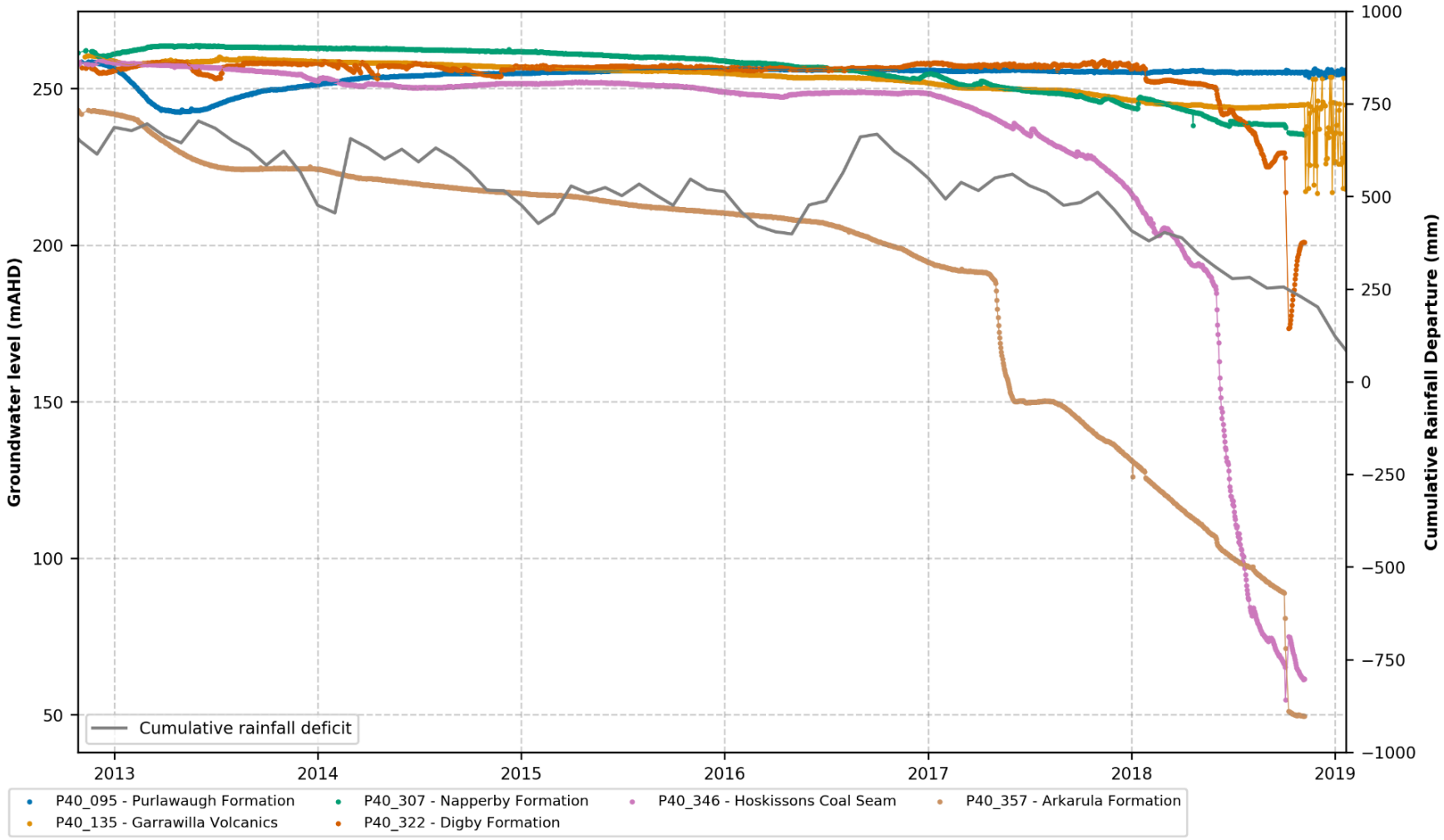



**Figure B 13 Water levels nested monitoring facility (P40)**

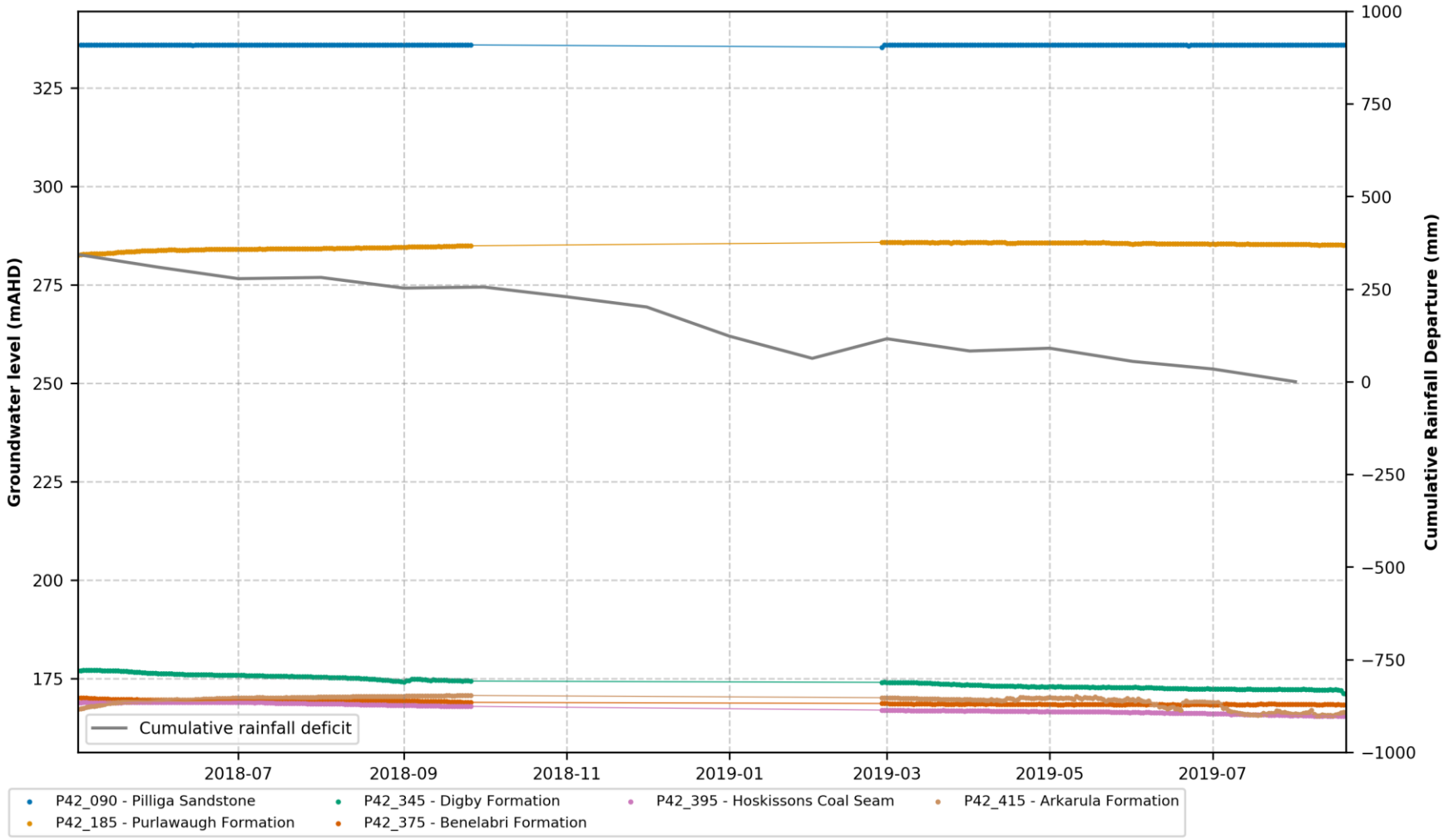



**Figure B 14 Water levels nested monitoring facility (P42)**

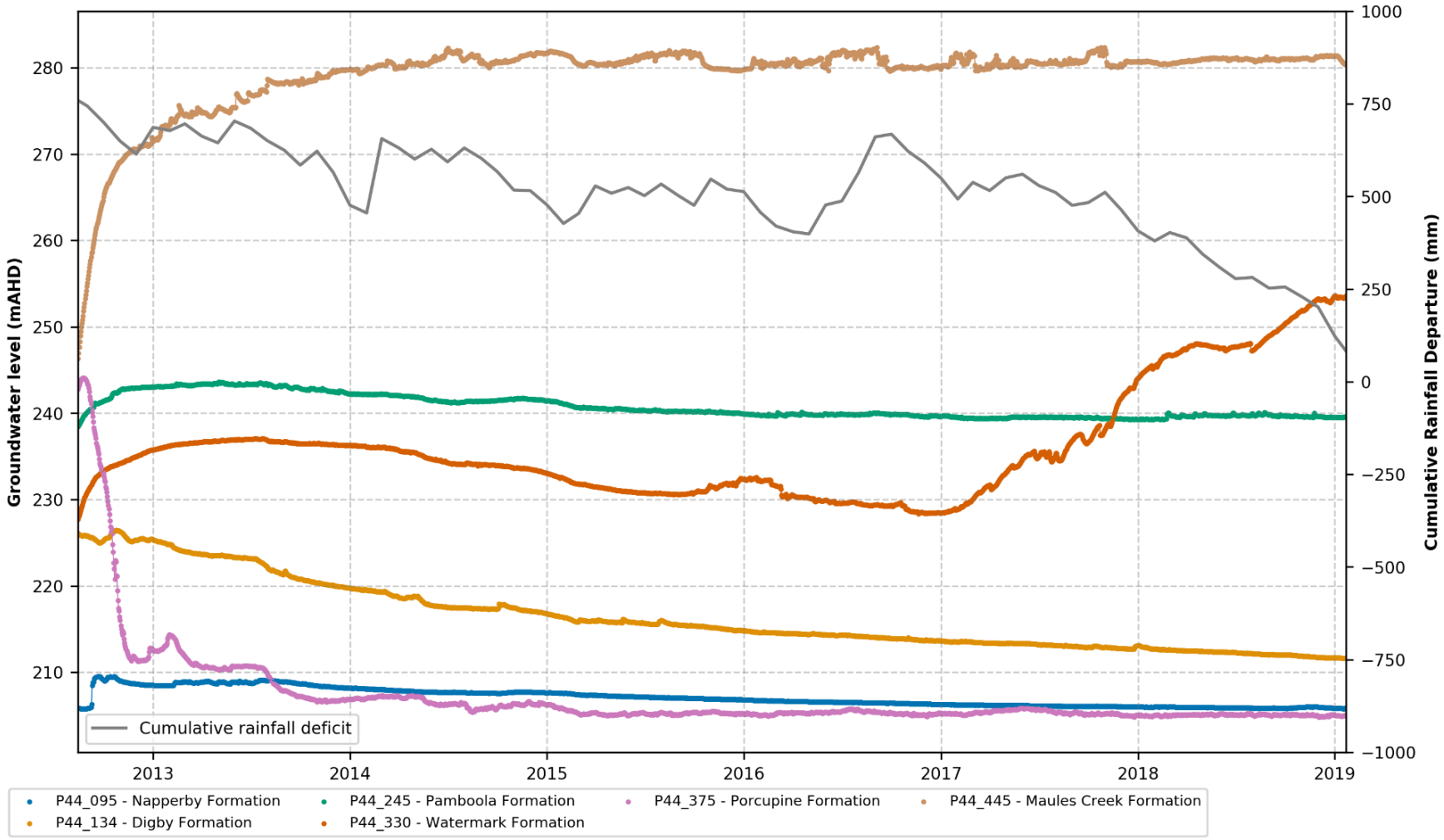



**Figure B 15 Water levels nested monitoring facility (P44)**

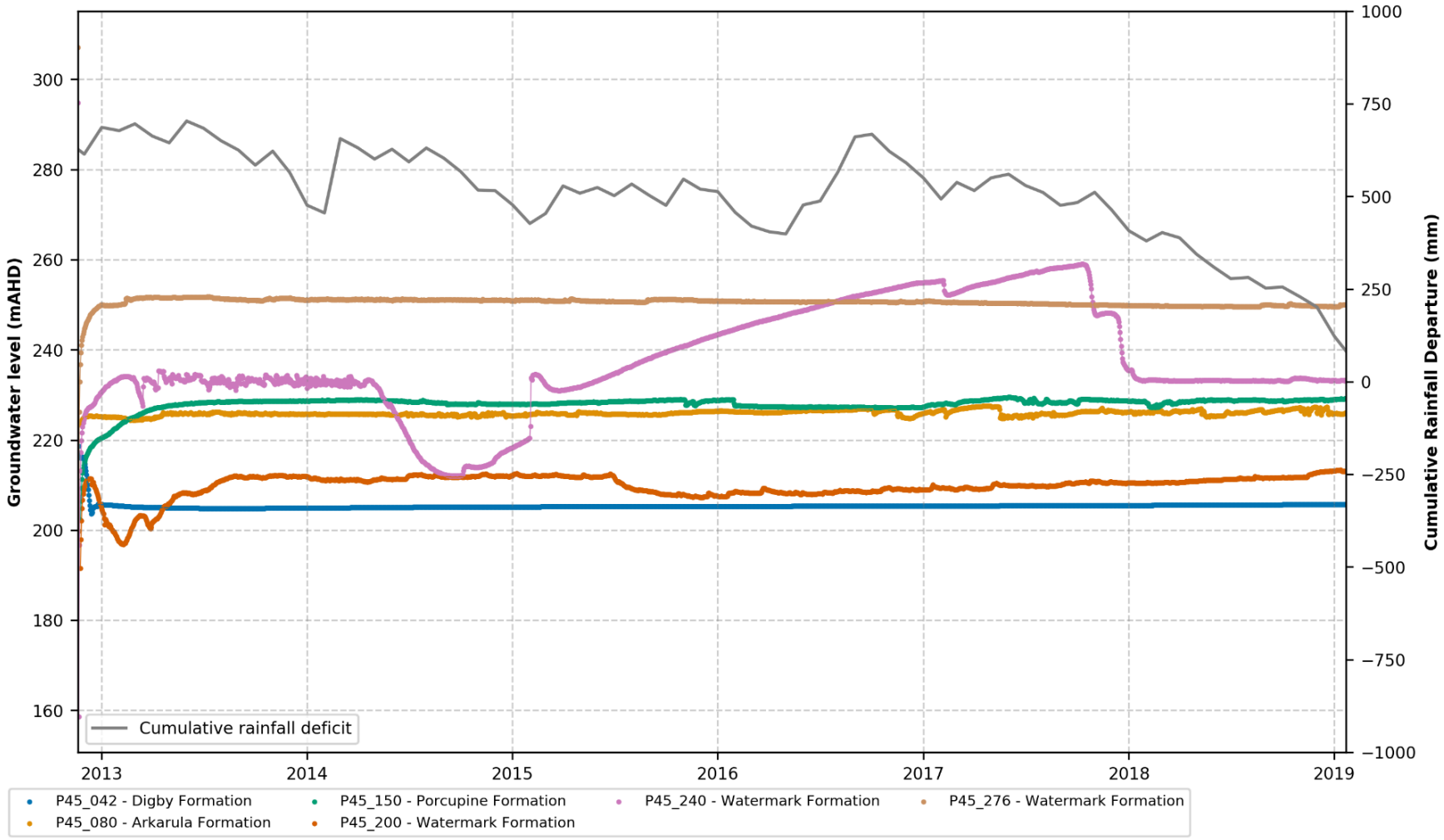



**Figure B 16 Water levels nested monitoring facility (P45)**

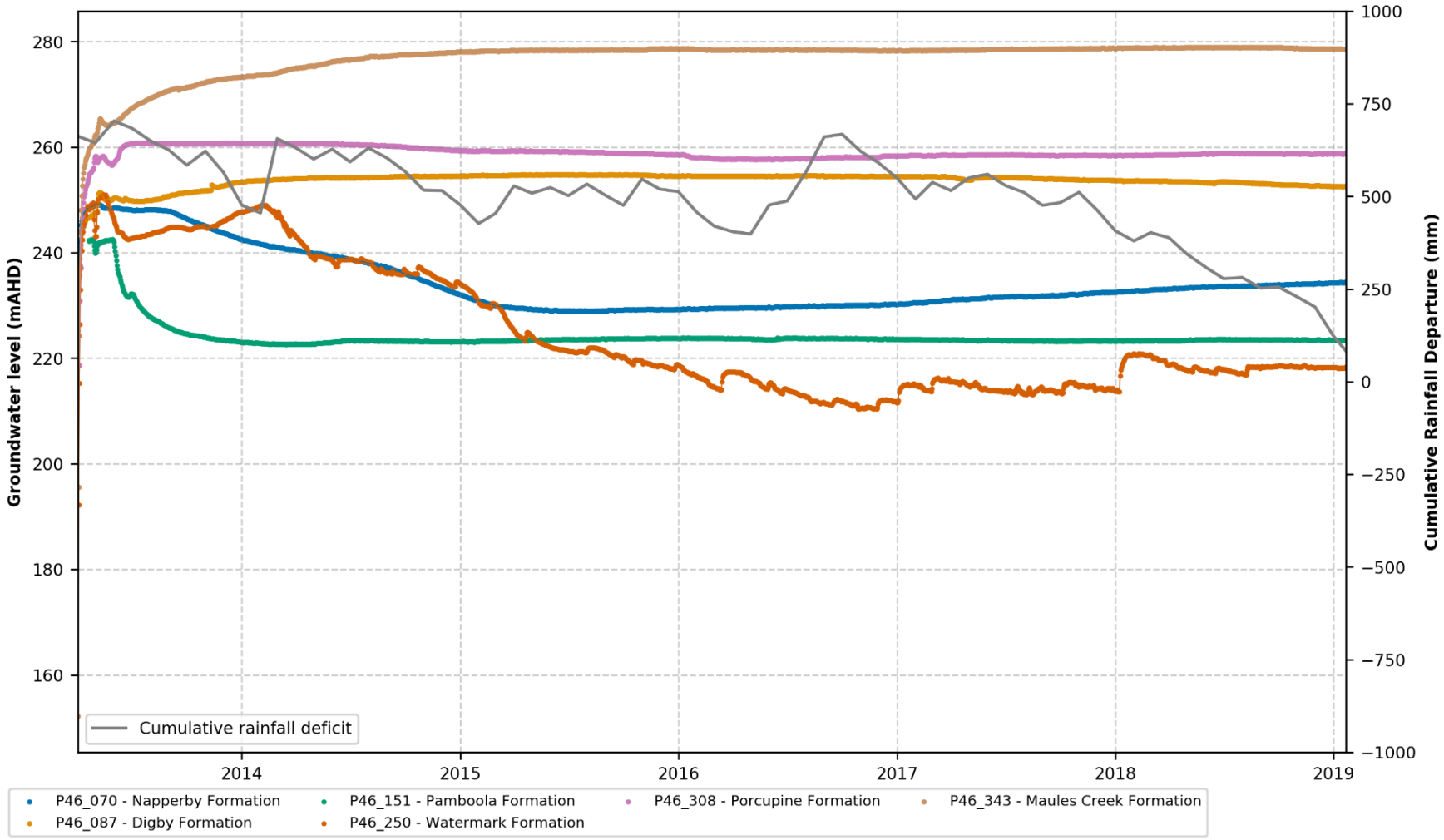



**Figure B 17 Water levels nested monitoring facility (P46)**

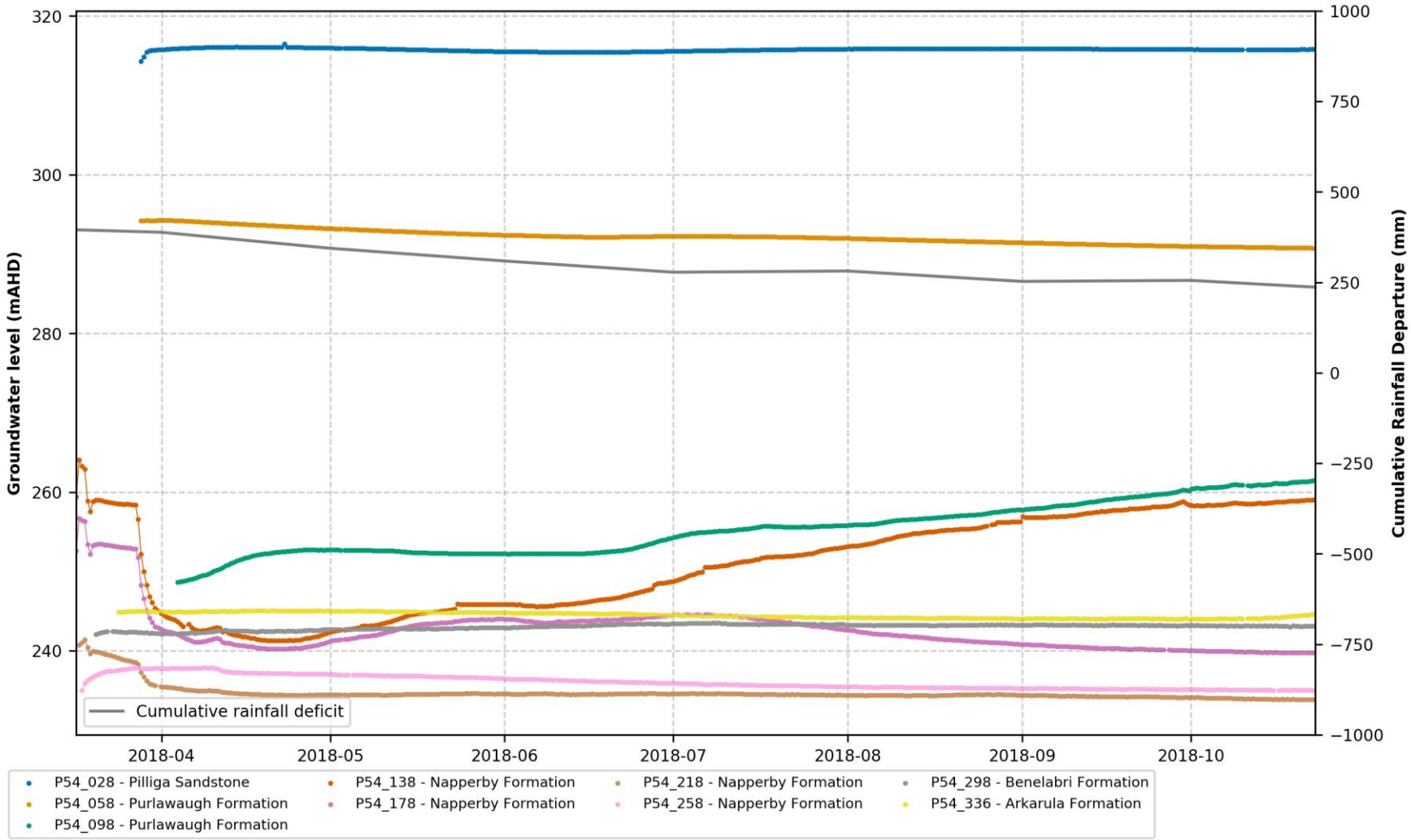



**Figure B 18 Water levels nested monitoring facility (P54)**

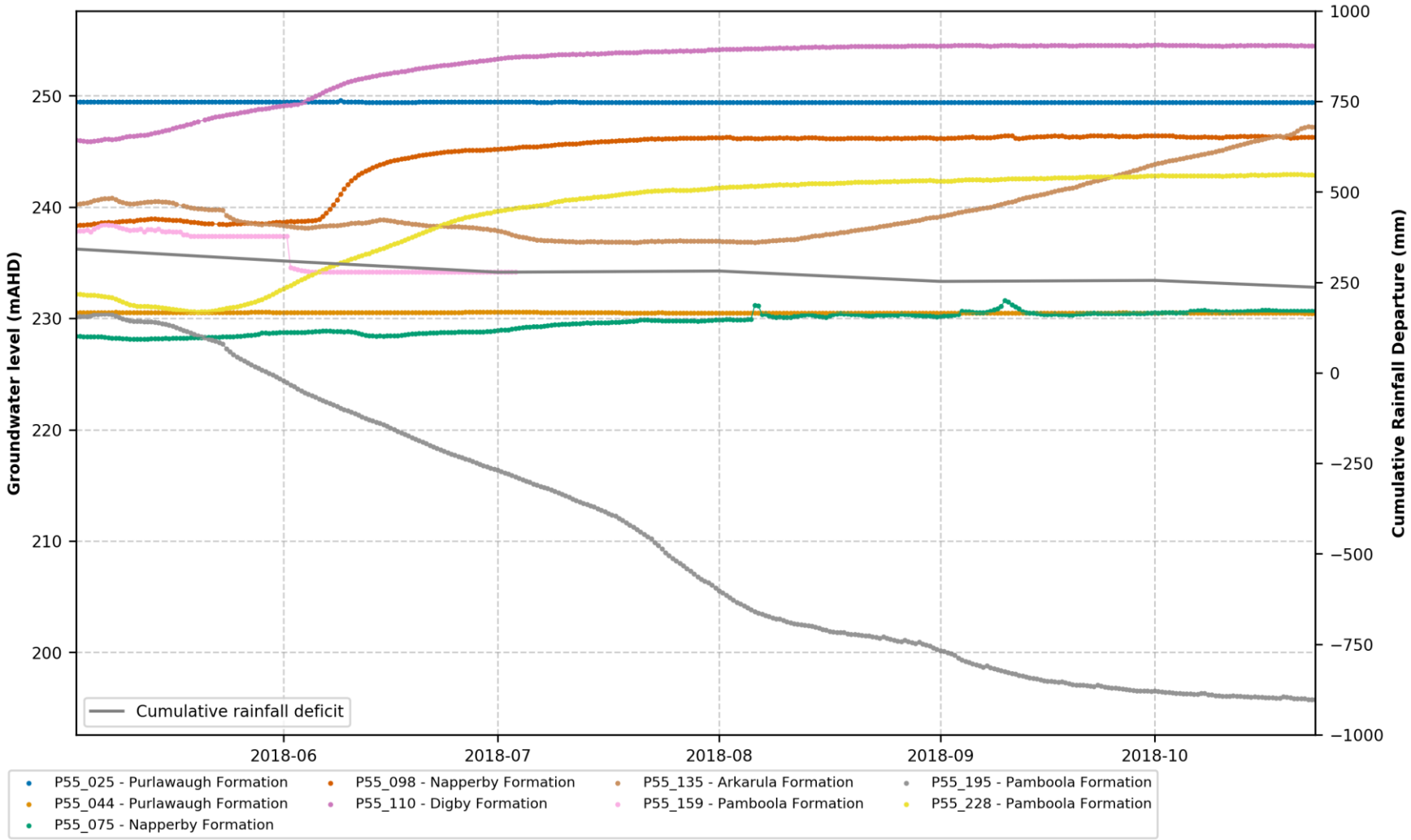



**Figure B 19 Water levels nested monitoring facility (P55)**

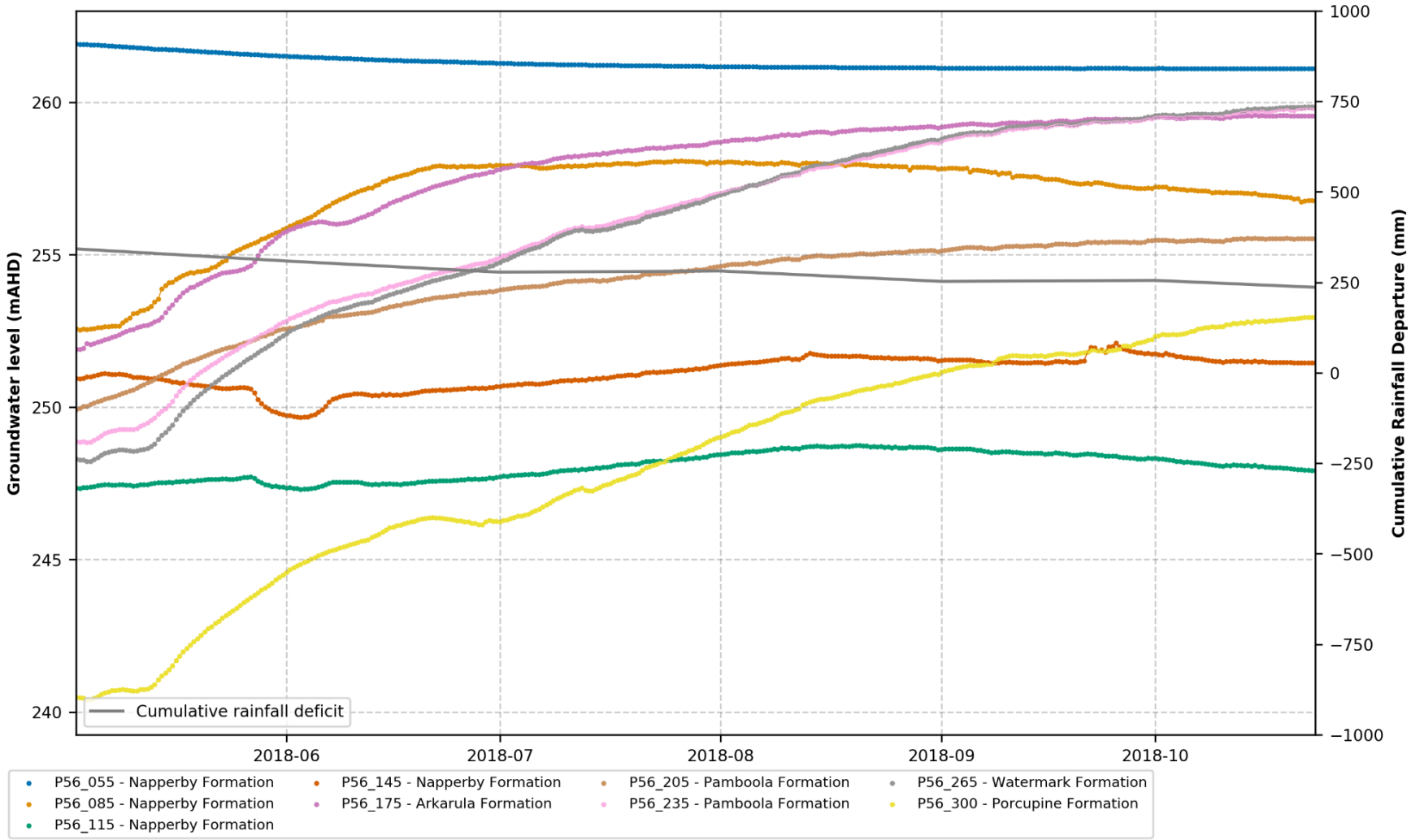



**Figure B 20 Water levels nested monitoring facility (P56)**

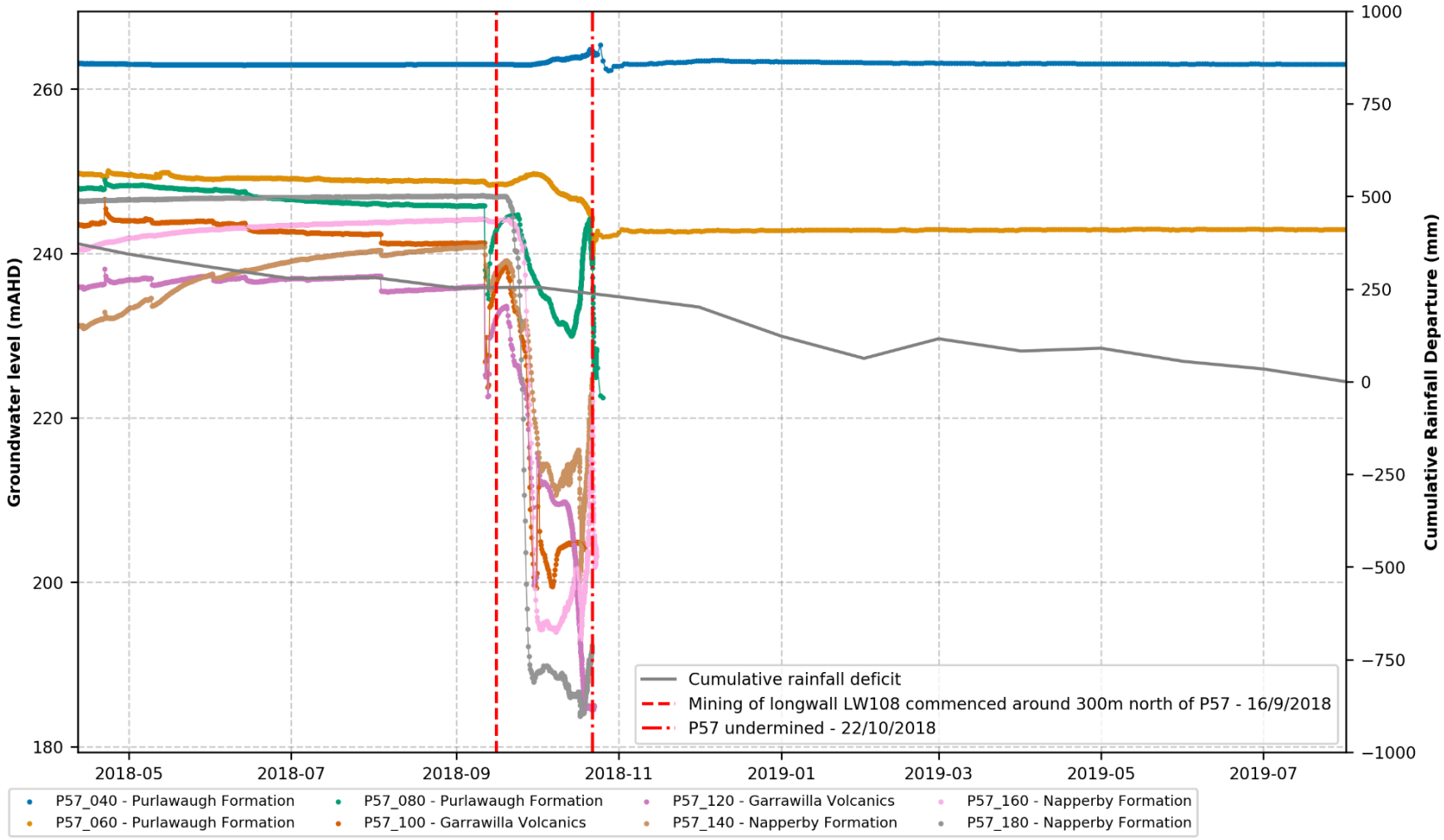



**Figure B 21 Water levels nested monitoring facility (P57)**

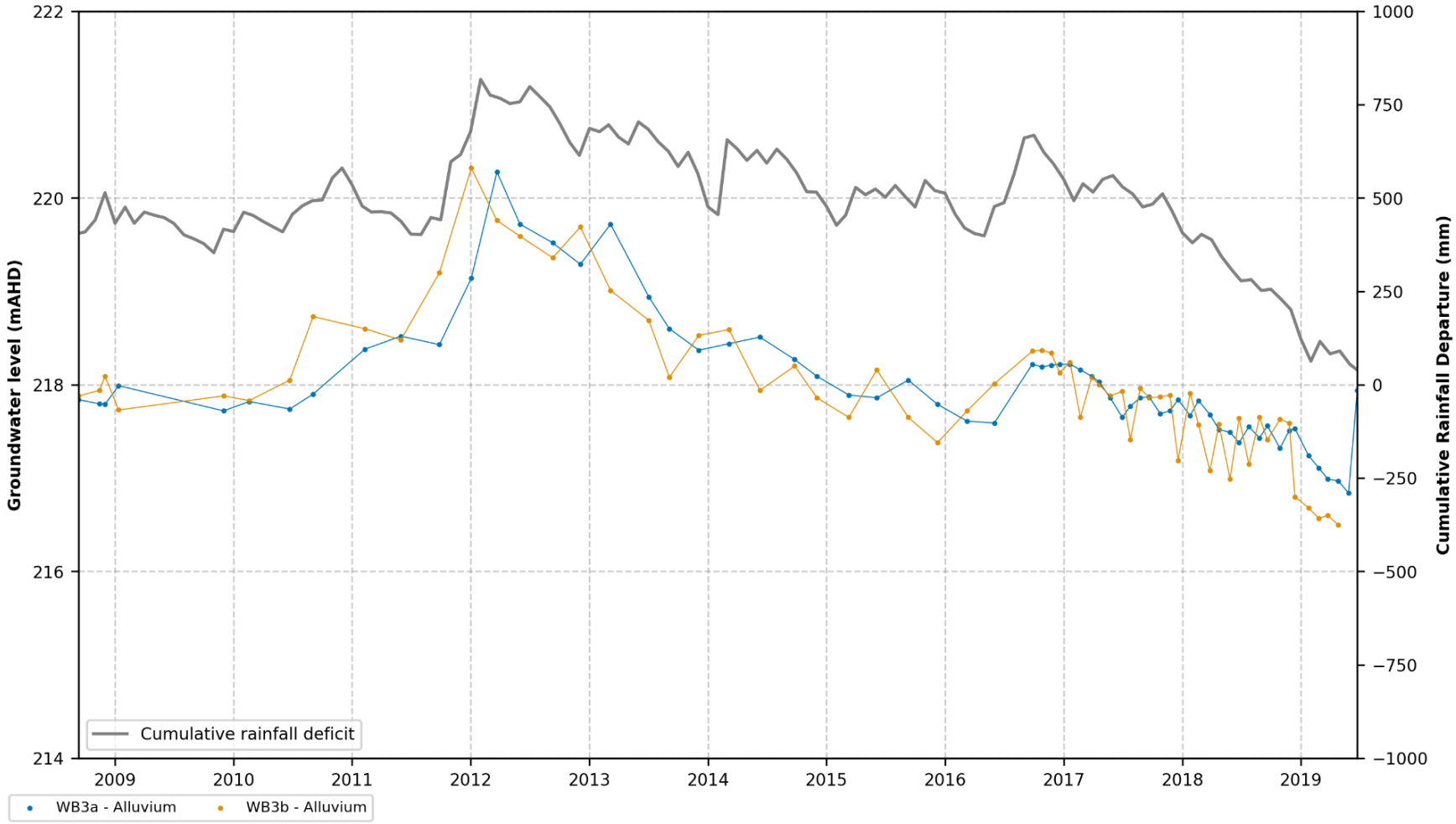



**Figure B 22 Water levels nested monitoring facility (WB3)**

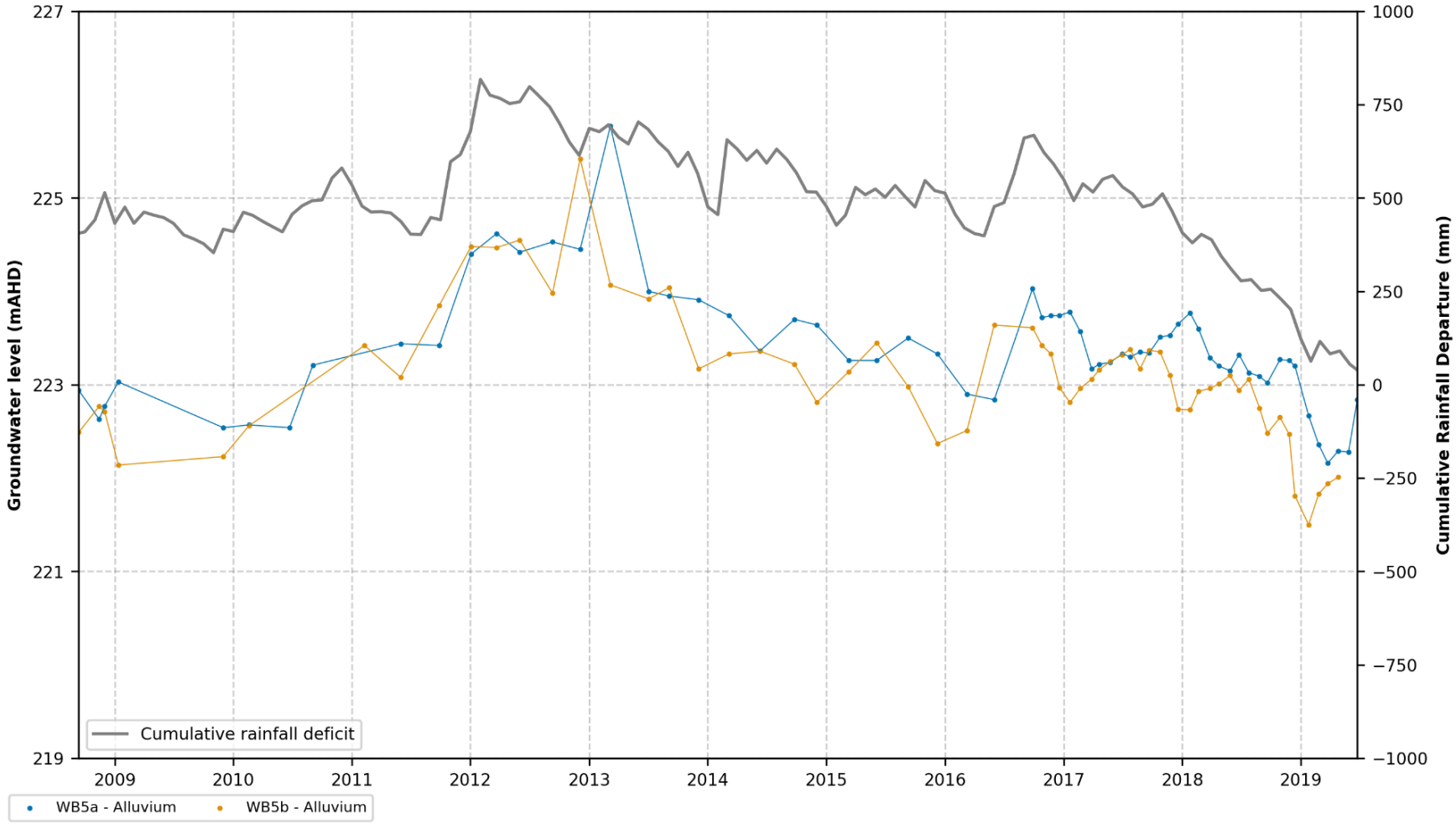



**Figure B 23 Water levels nested monitoring facility (WB5)**

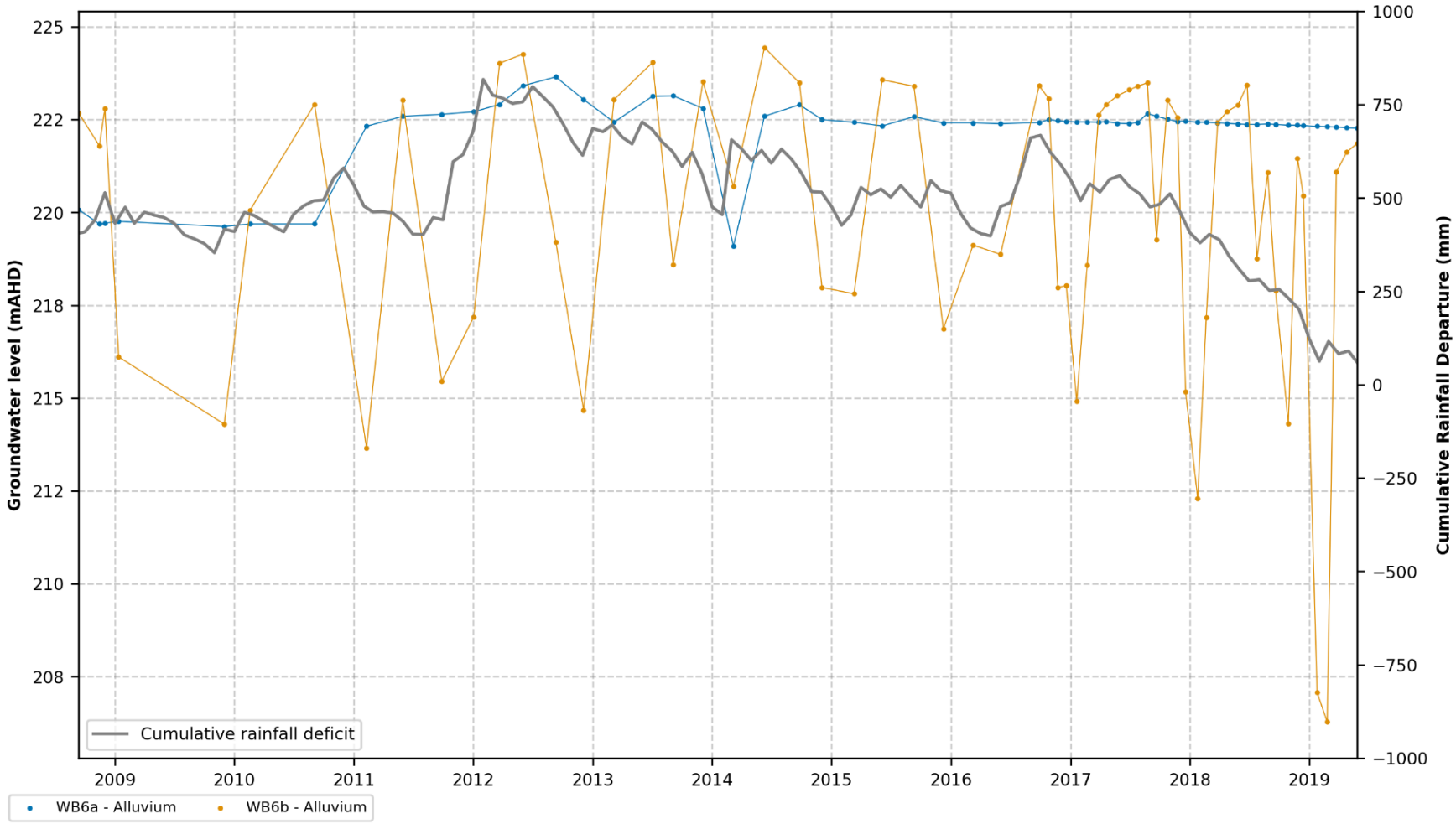



**Figure B 24 Water levels nested monitoring facility (WB6)**

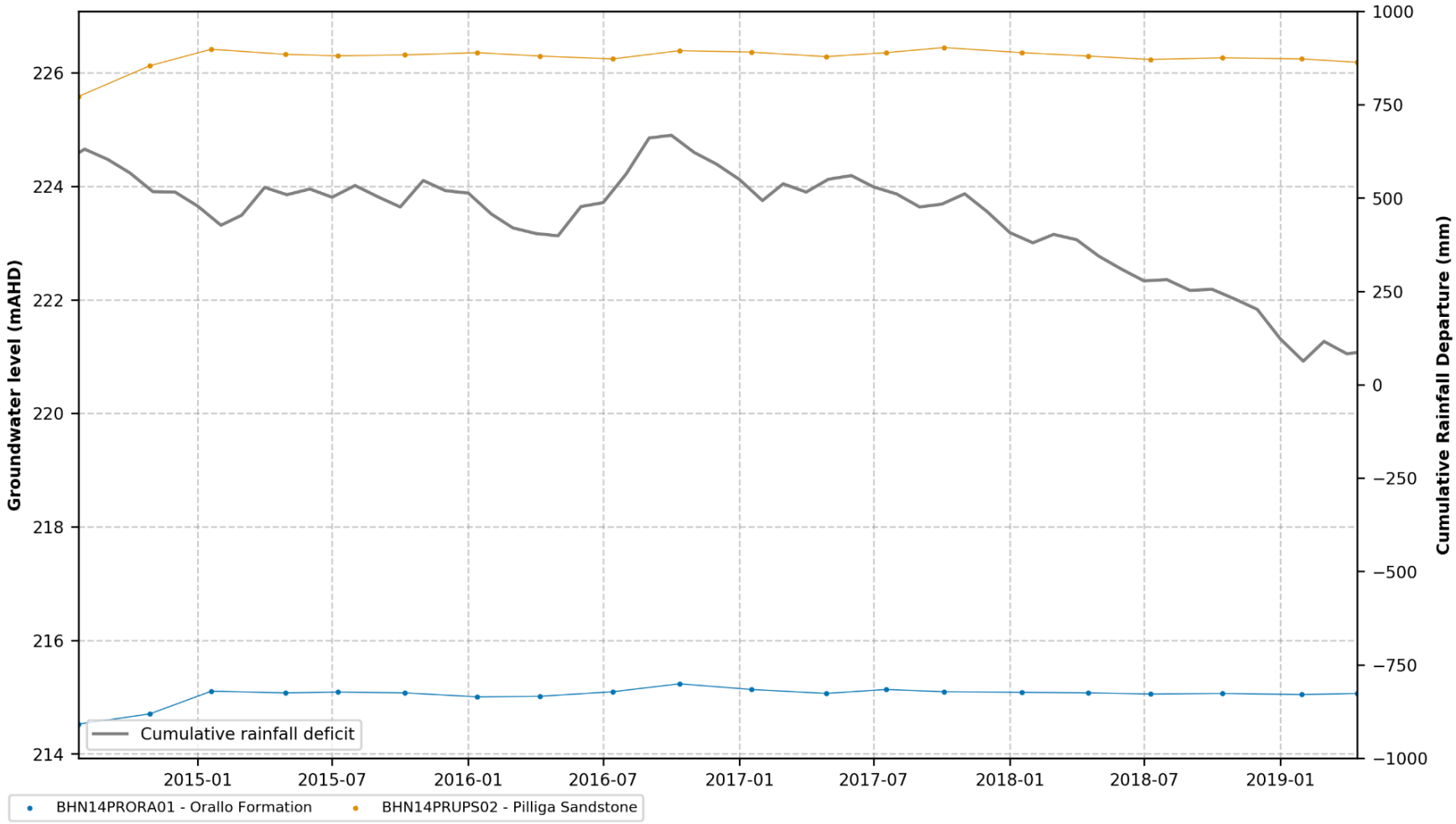



**Figure B 25 Water levels nested monitoring facility (BHN14PR)**

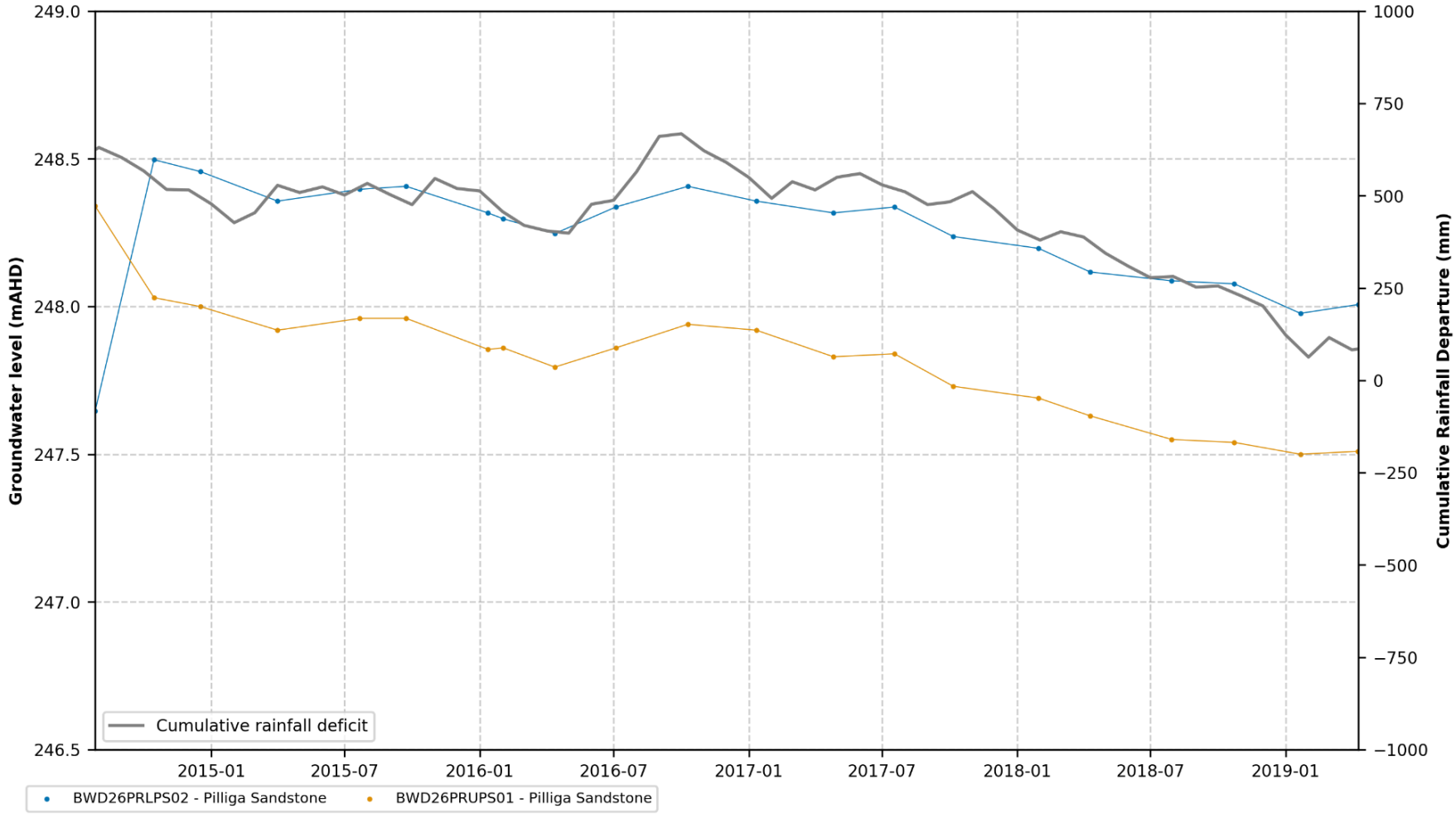



**Figure B 26 Water levels nested monitoring facility (BWD26PR)**

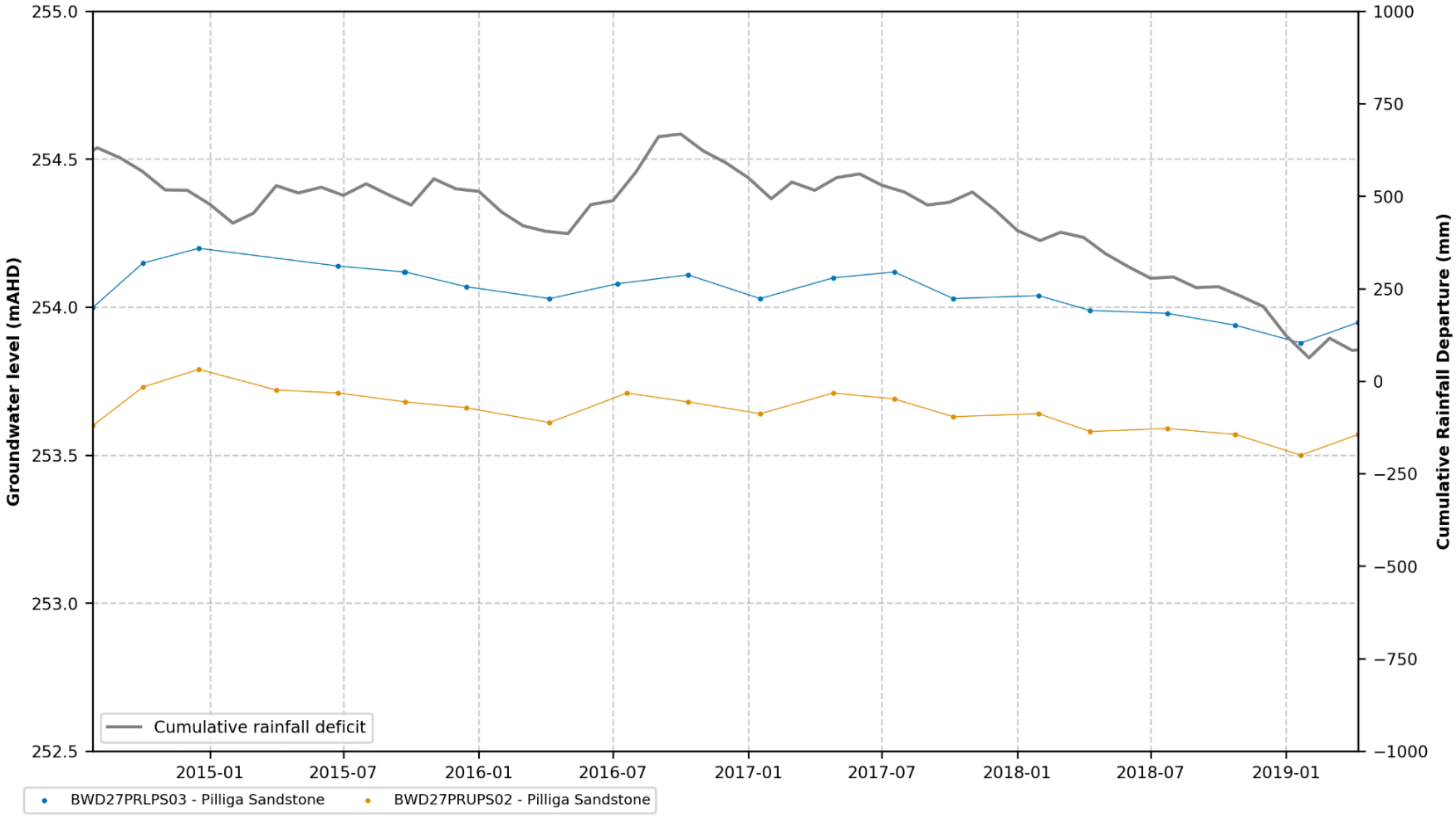



**Figure B 27 Water levels nested monitoring facility (BWD27PR)**

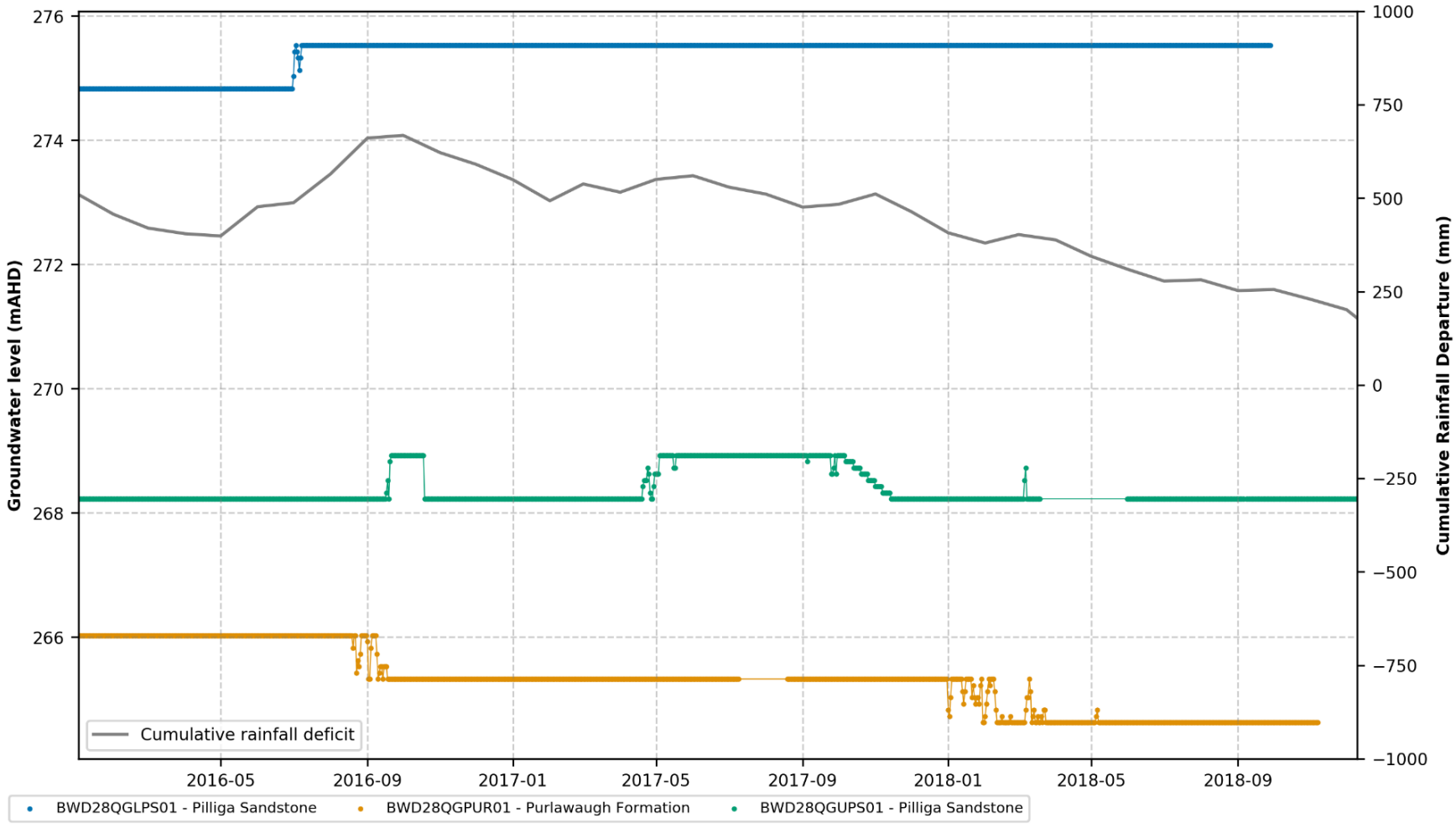



**Figure B 28 Water levels nested monitoring facility (BWD28QG)**

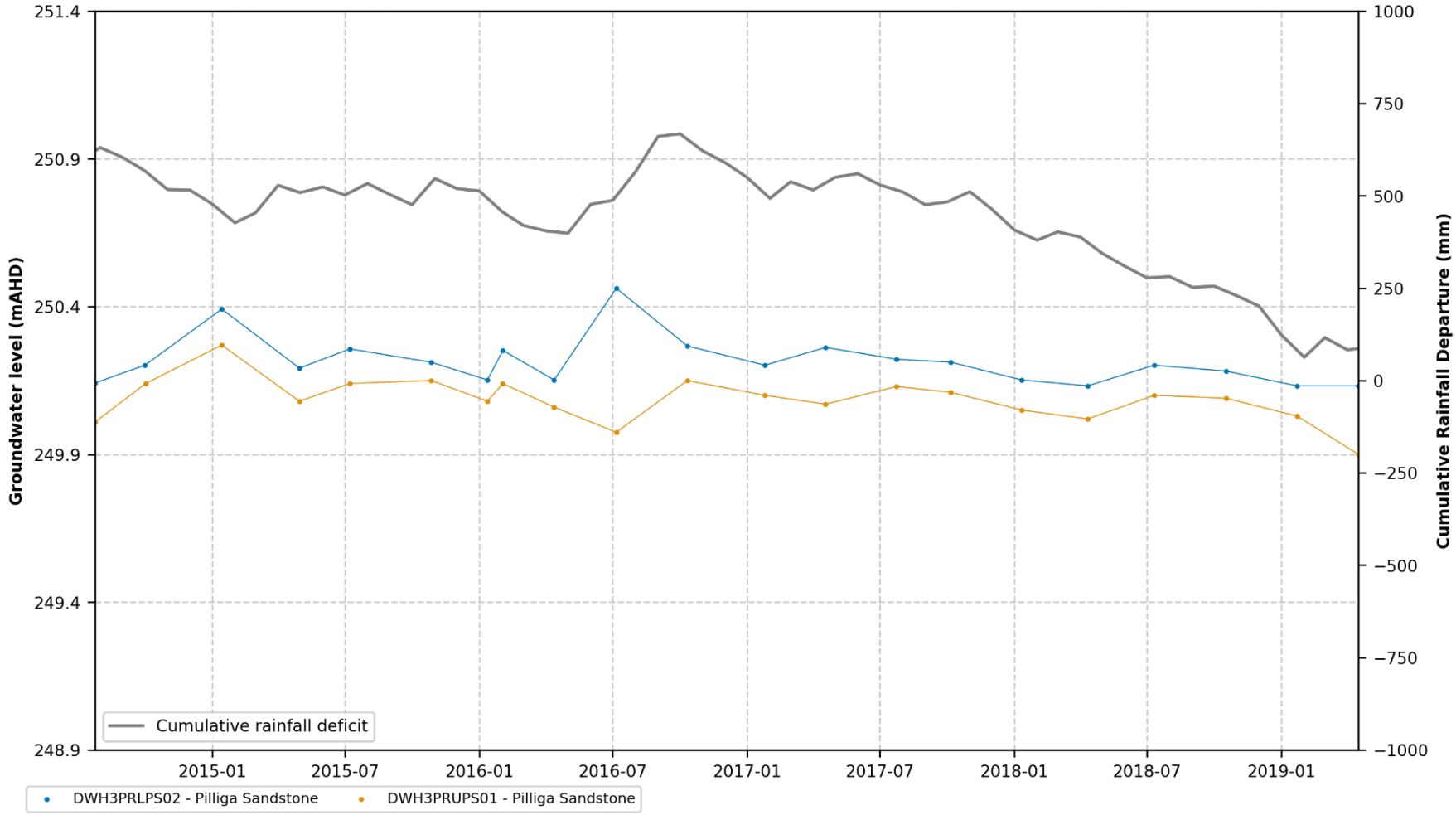



**Figure B 29 Water levels nested monitoring facility (DWH3PR)**

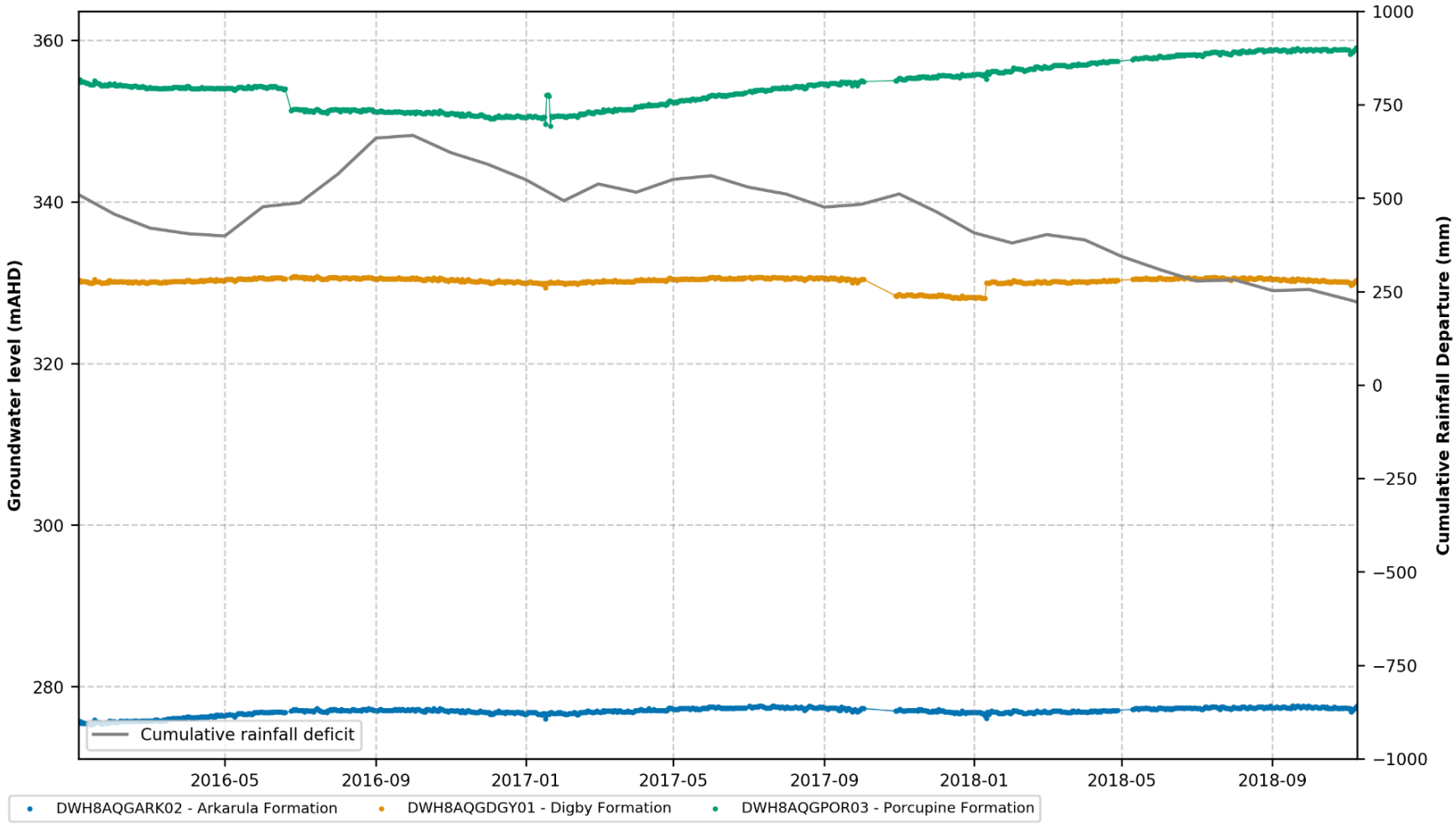



**Figure B 30 Water levels nested monitoring facility (DWH8AQG)**

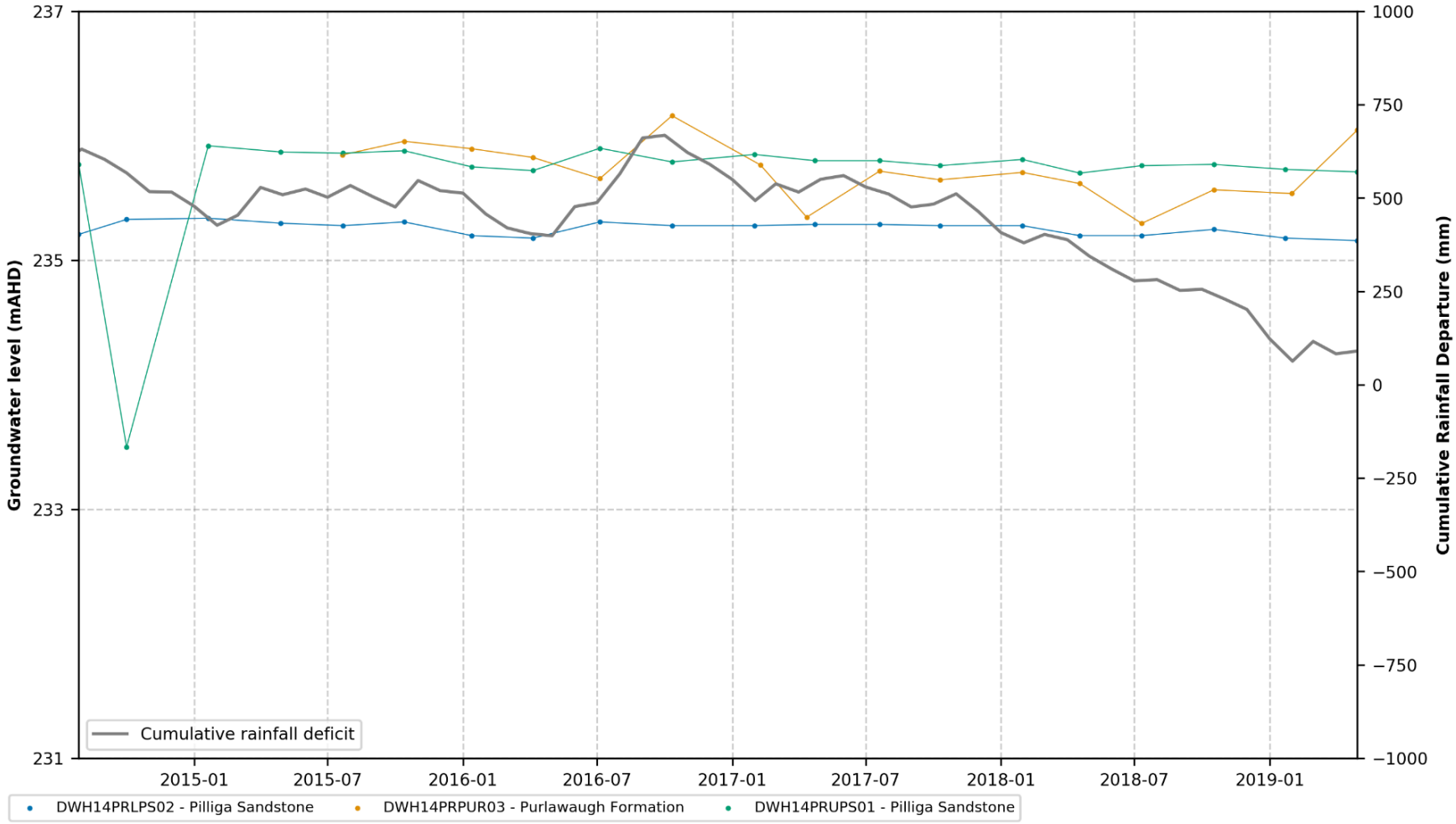



**Figure B 31 Water levels nested monitoring facility (DWH14PR)**

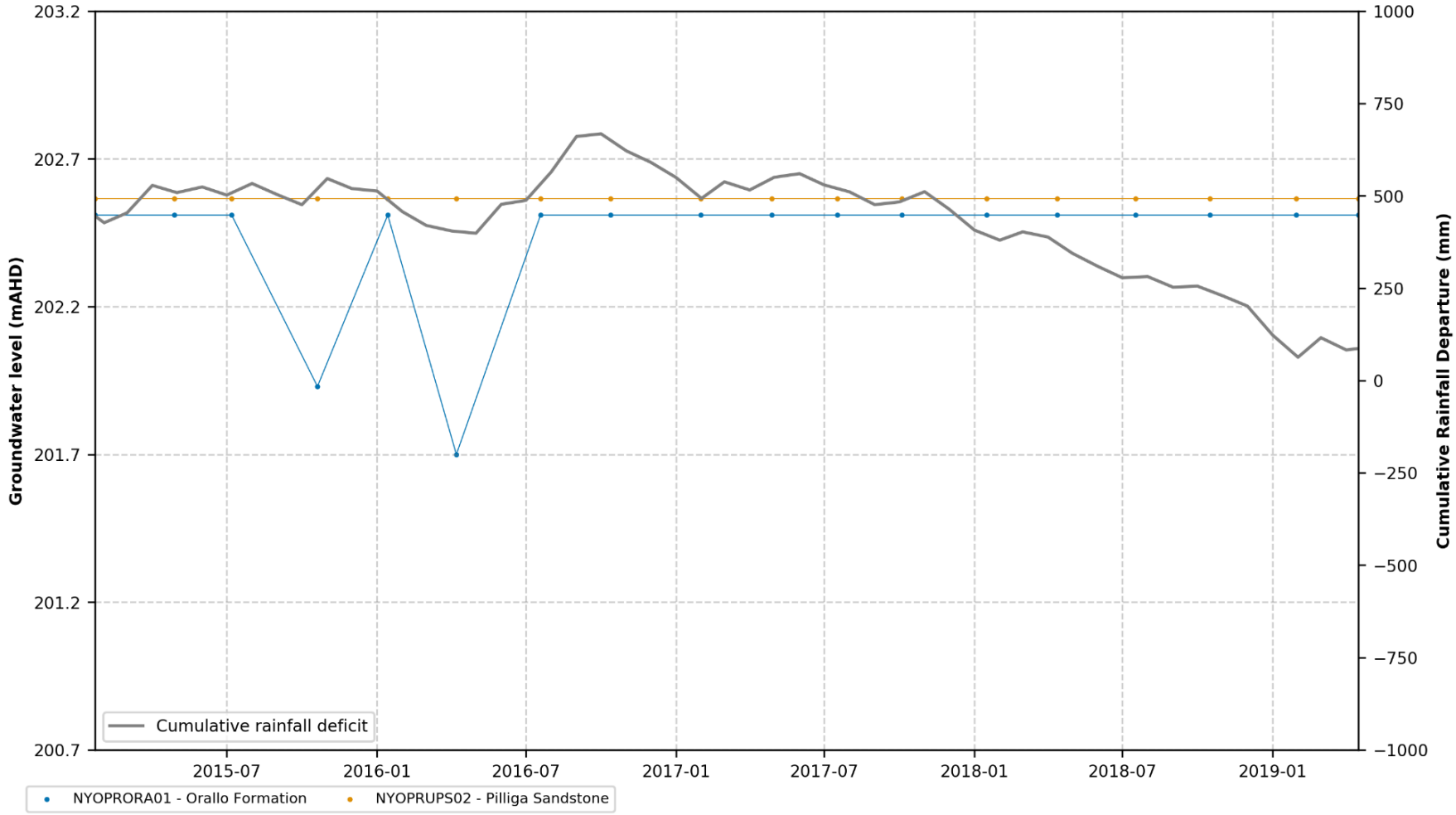



**Figure B 32 Water levels nested monitoring facility (NYOPR)**

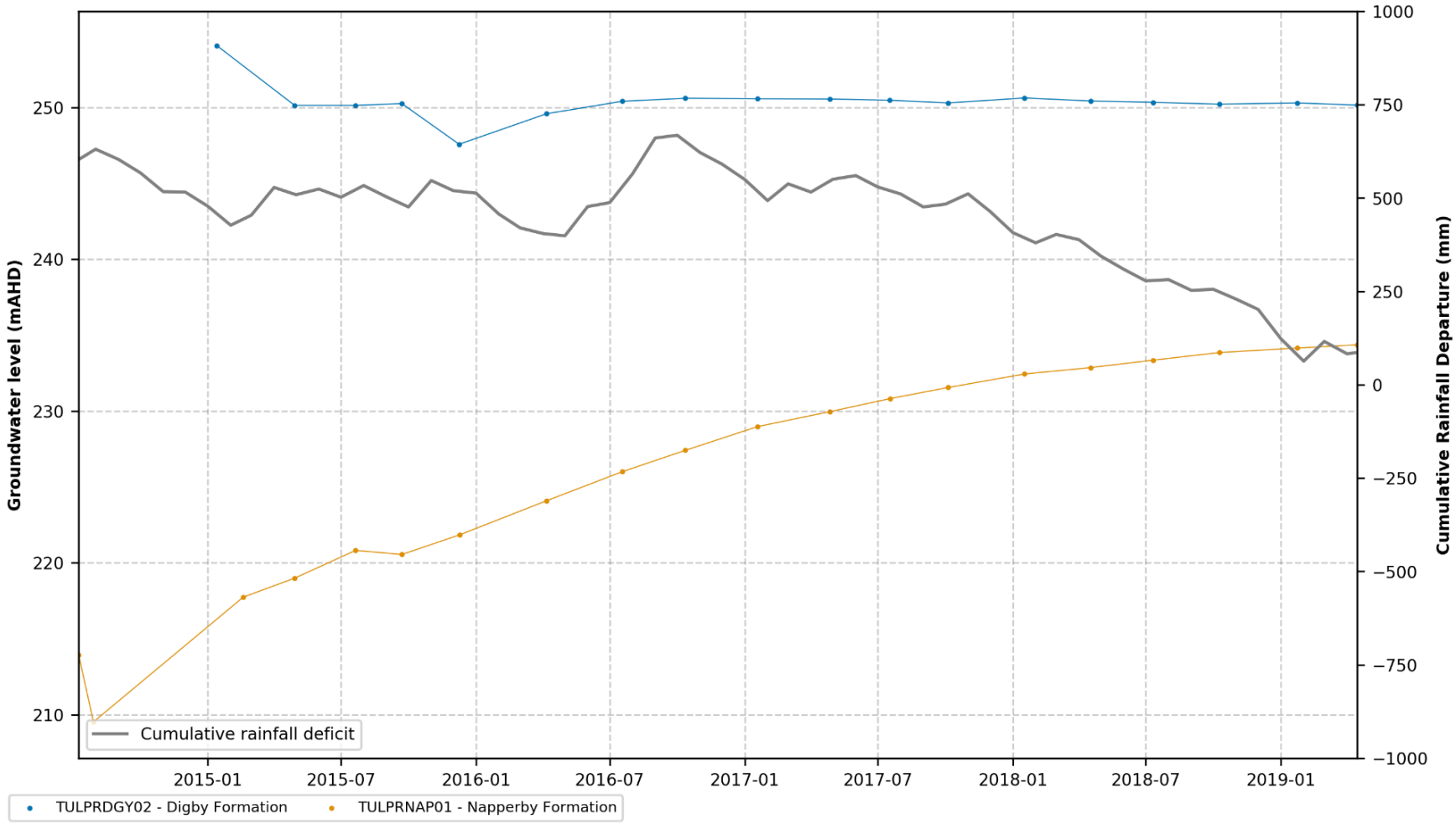
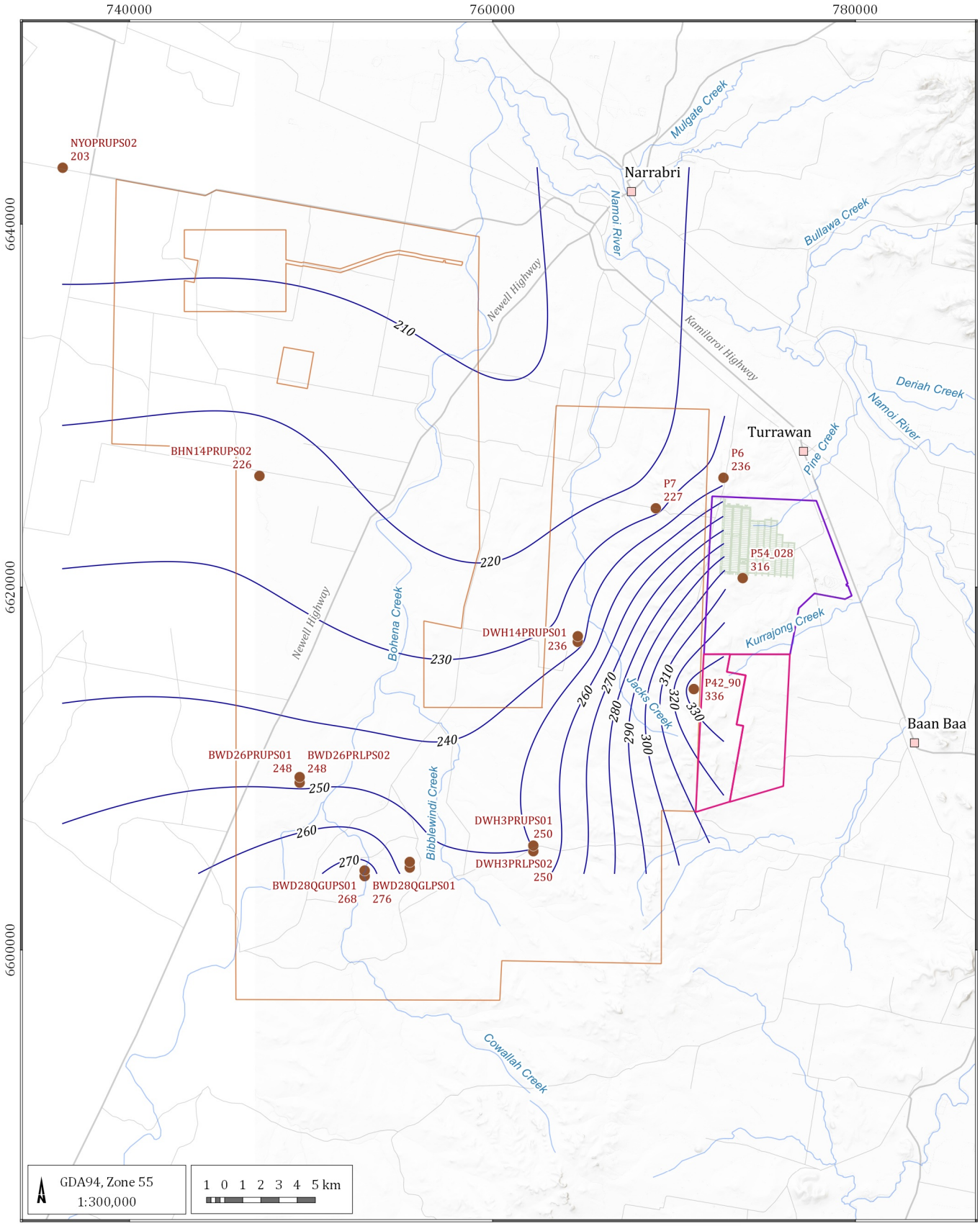



**Figure B 33 Water levels nested monitoring facility (TULPR)**




LEGEND

- Populated place
- Monitoring bore
- Interpolated groundwater level contour (mAHD)
- Drainage
- Road
- Existing longwall panel
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)

P7: BoreID
227 : Water level (mAHD)

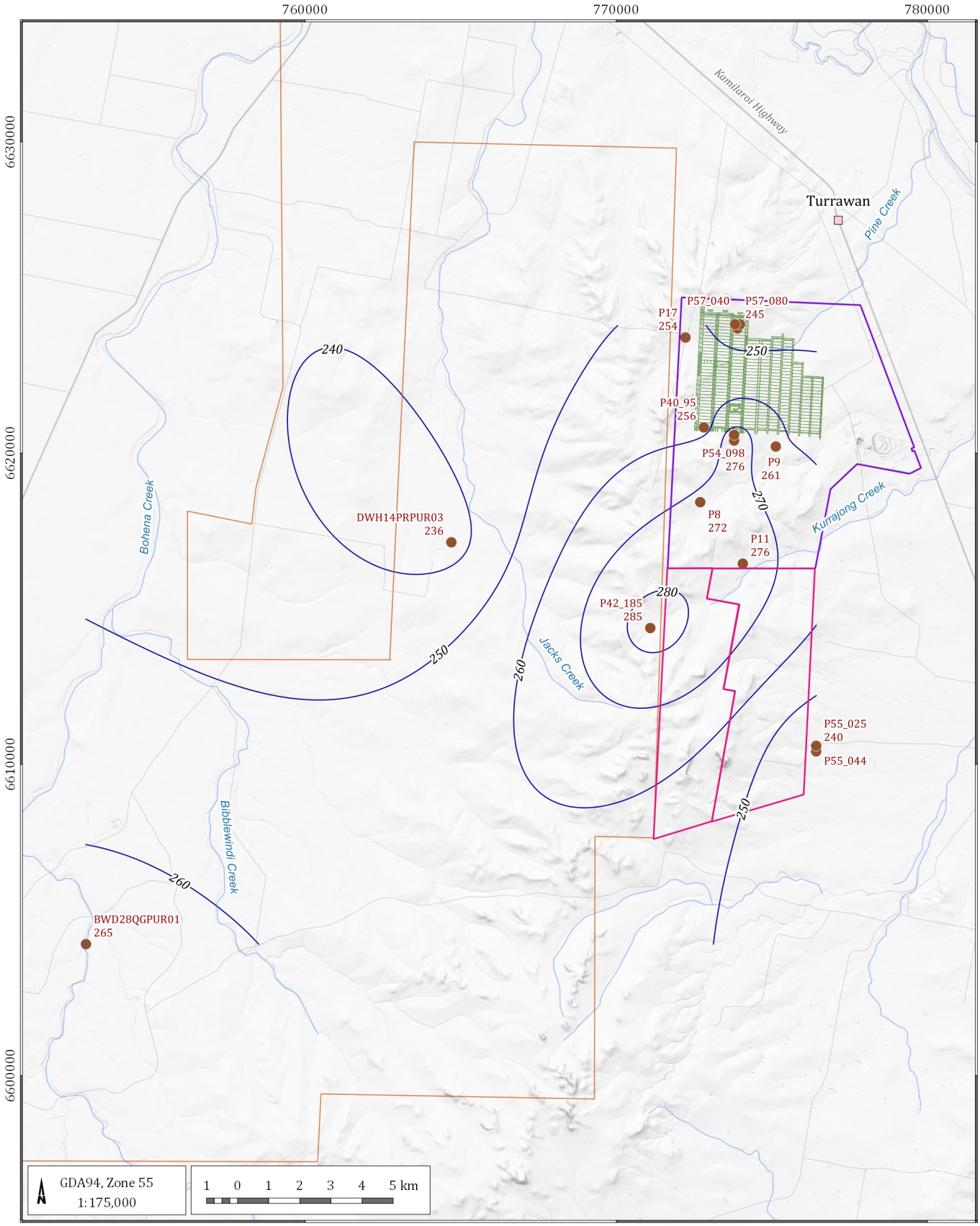
Narrrabri Stage 3 Extension GIA (G1972)

## Current groundwater levels - Pilliga Sandstone

DATE
06/02/2020

FIGURE No:
**B 34**

©2020 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\G1972.Narrrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\B 34 to B 41_G1972_Current groundwater levels.qgs




LEGEND

- Populated place
- Monitoring bore
- Interpolated groundwater level contour (mAHD)
- Drainage
- Road
- Existing longwall panel
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)

P17: BoreID
254 : Water level (mAHD)

Narrrabri Stage 3 Extension GIA (G1972)

**Current groundwater levels - Purlawaugh Formation**

DATE
06/02/2020

FIGURE No:
**B 35**

©2020 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.;
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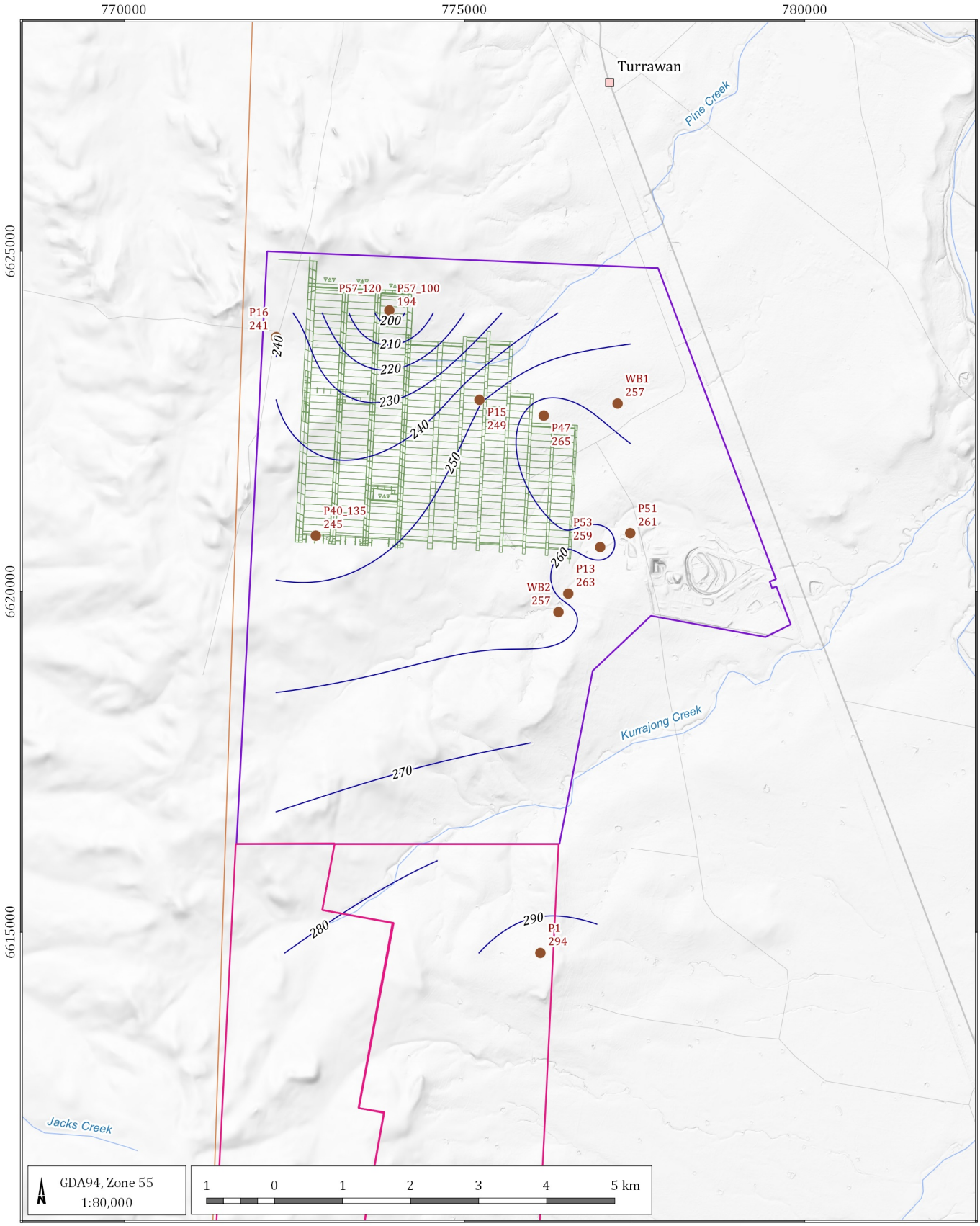


LEGEND

- Populated place
- Monitoring bore
- Interpolated groundwater level contour (mAHD)
- Drainage
- Road
- Existing longwall panel
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)

P1: BoreID
294 : Water level (mAHD)

Narrrabri Stage 3 Extension GIA (G1972)

## Current groundwater levels - Garrawilla Volcanics

DATE 06/02/2020

FIGURE No: **B 36**

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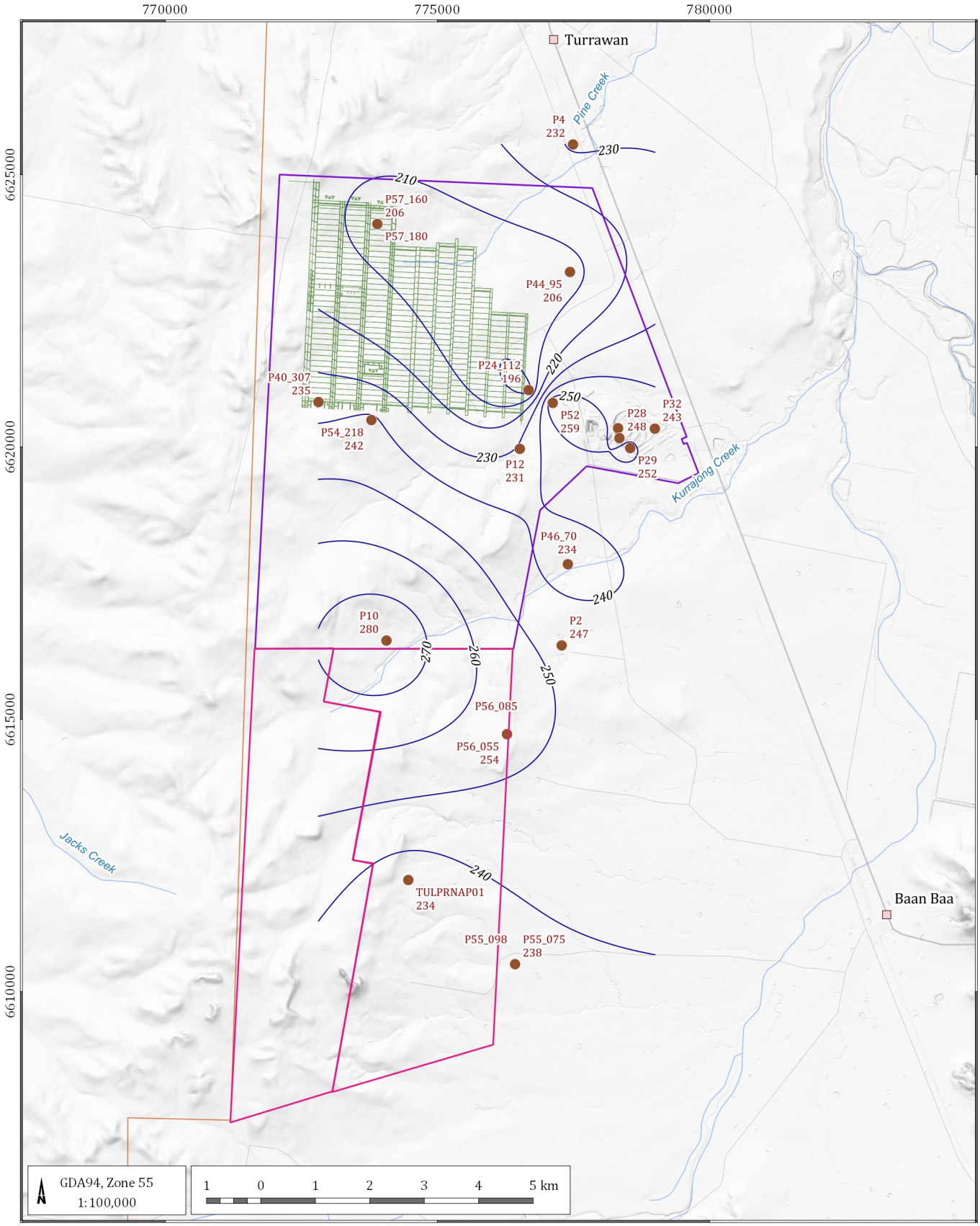
G:\Projects\G1972.Narrrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\B 34 to B 41_G1972_Current groundwater levels.qgs




LEGEND

- Populated place
- Monitoring bore
- Interpolated groundwater level contour (mAHD)
- Drainage
- Road
- Existing longwall panel
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)

P4: BoreID
232 : Water level (mAHD)

Narrrabri Stage 3 Extension GIA (G1972)

## Current groundwater levels - Napperby Formation

DATE
06/02/2020

FIGURE No:
**B 37**

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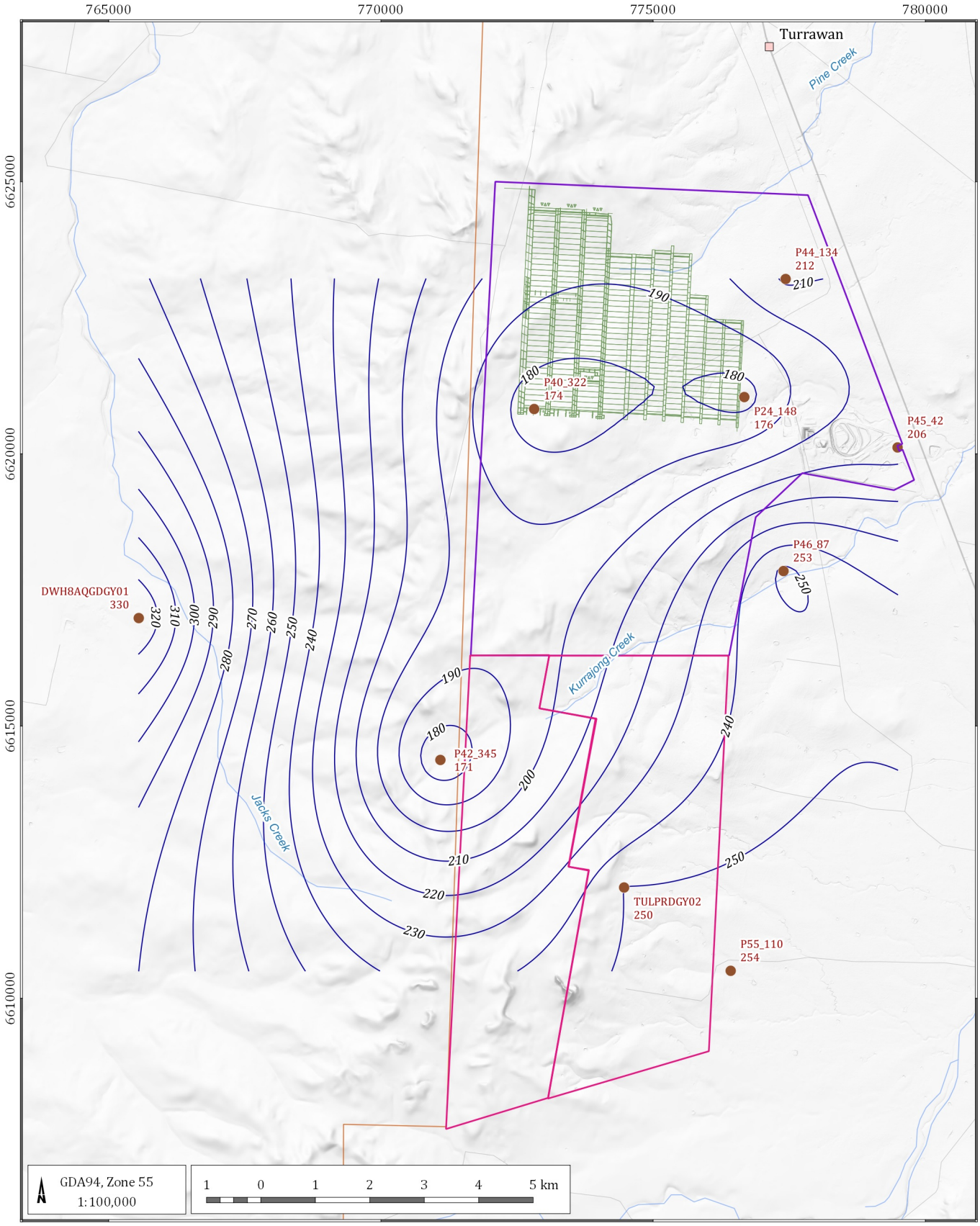
G:\Projects\G1972.Narrrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\B 34 to B 41_G1972_Current groundwater levels.qgs




LEGEND

- Populated place
- Monitoring bore
- Interpolated groundwater level contour (mAHD)
- Drainage
- Road
- Existing longwall panel
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)

P45_42: BoreID
206 : Water level (mAHD)

Narrrabri Stage 3 Extension GIA (G1972)

## Current groundwater levels - Digby Formation

DATE 06/02/2020

FIGURE No: **B 38**

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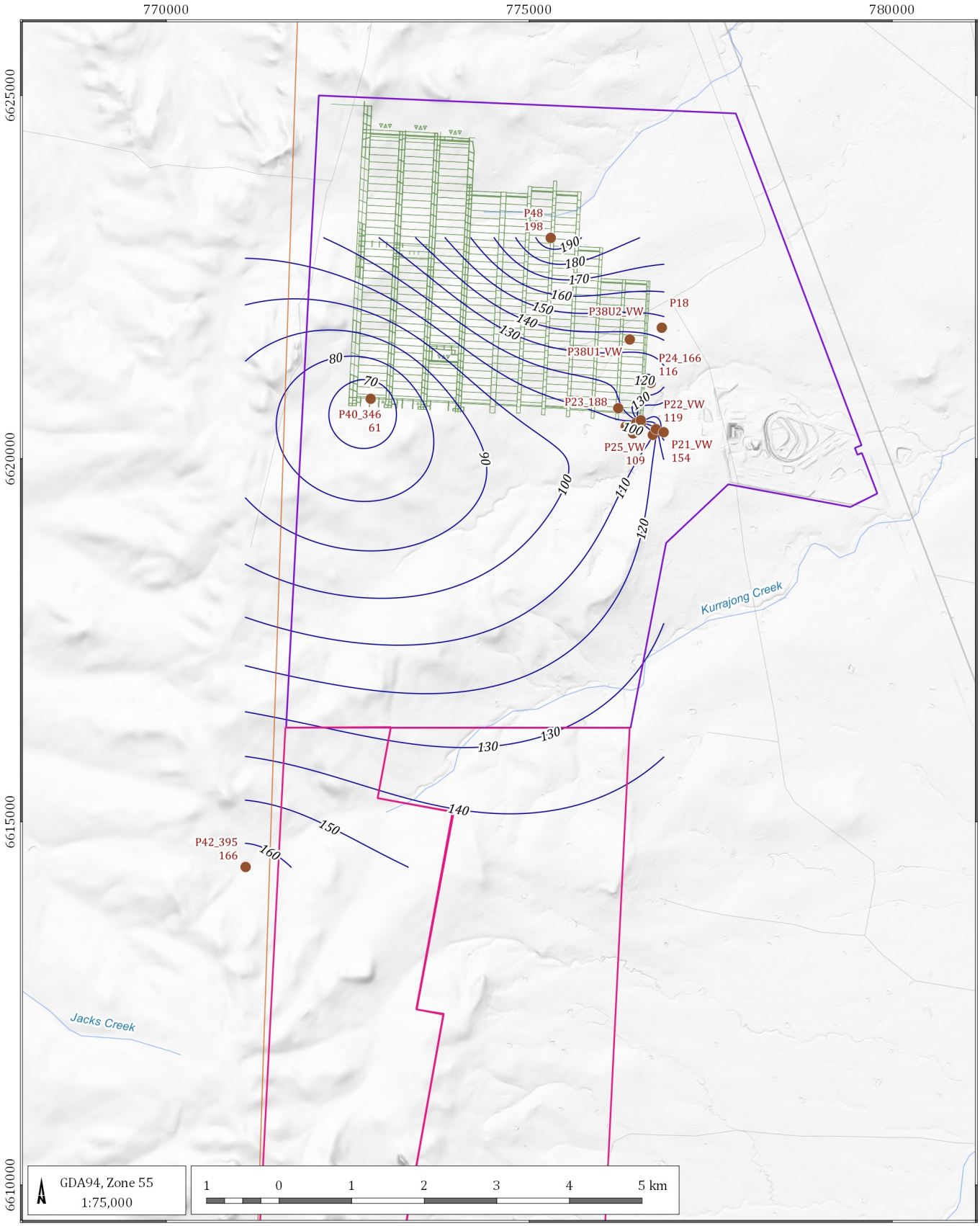
G:\Projects\G1972.Narrrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\B 34 to B 41_G1972_Current groundwater levels.qgs




LEGEND

- Populated place
- Monitoring bore
- Interpolated groundwater level contour (mAHD)
- Drainage
- Road
- Existing longwall panel
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)

P42_395: BoreID
166 : Water level (mAHD)

Narrrabri Stage 3 Extension GIA (G1972)

**Current groundwater levels - Hoskissons Coal Seam**

DATE 06/02/2020

FIGURE No: **B 39**

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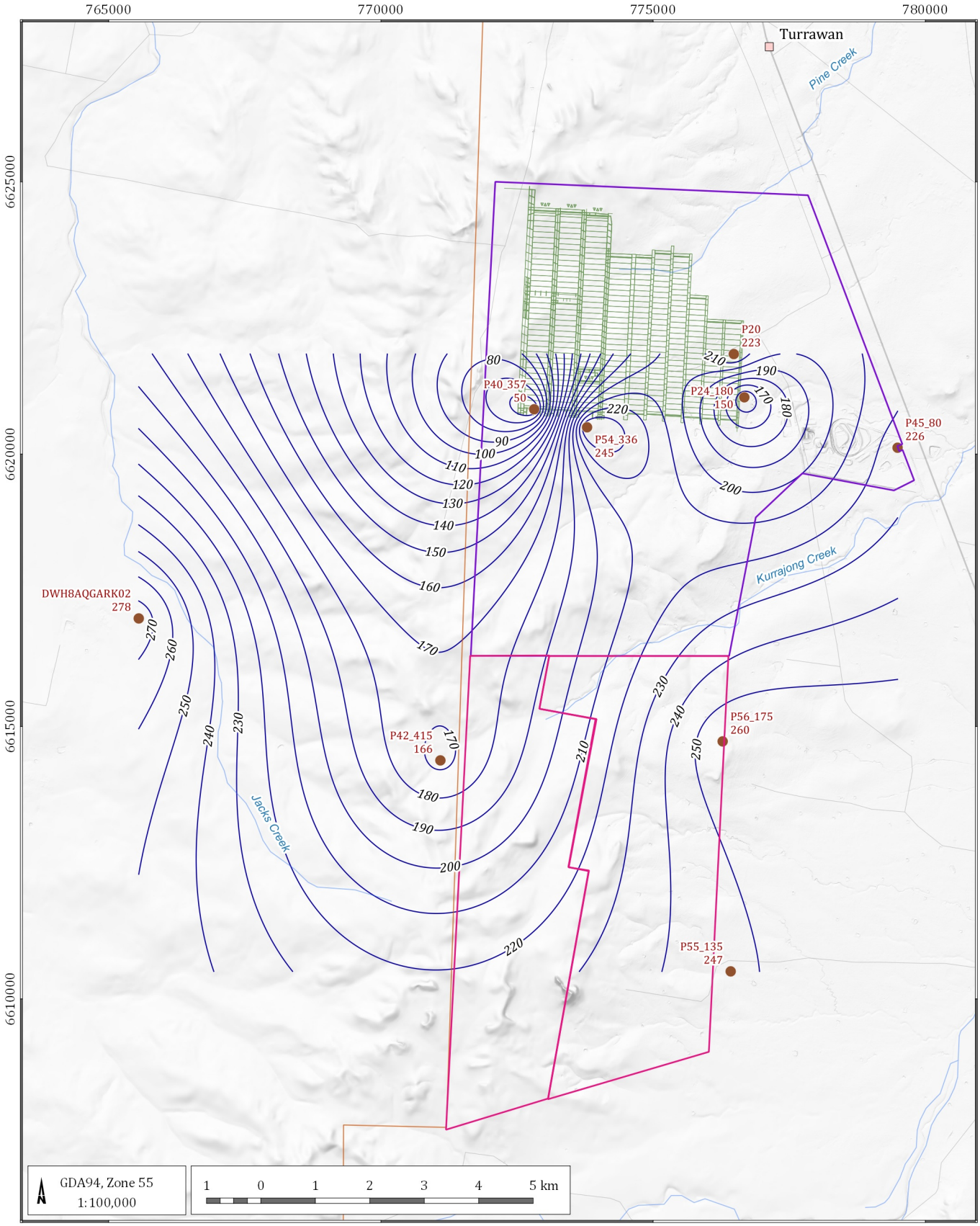
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1972.Narrrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\B 34 to B 41_G1972_Current groundwater levels.qgs




LEGEND

- Populated place
- Monitoring bore
- Interpolated groundwater level contour (mAHD)
- Drainage
- Road
- Existing longwall panel
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)

P20: BoreID
223 : Water level (mAHD)

Narrrabri Stage 3 Extension GIA (G1972)

## Current groundwater levels - Arkarula Formation

DATE
06/02/2020

FIGURE No:
**B 40**

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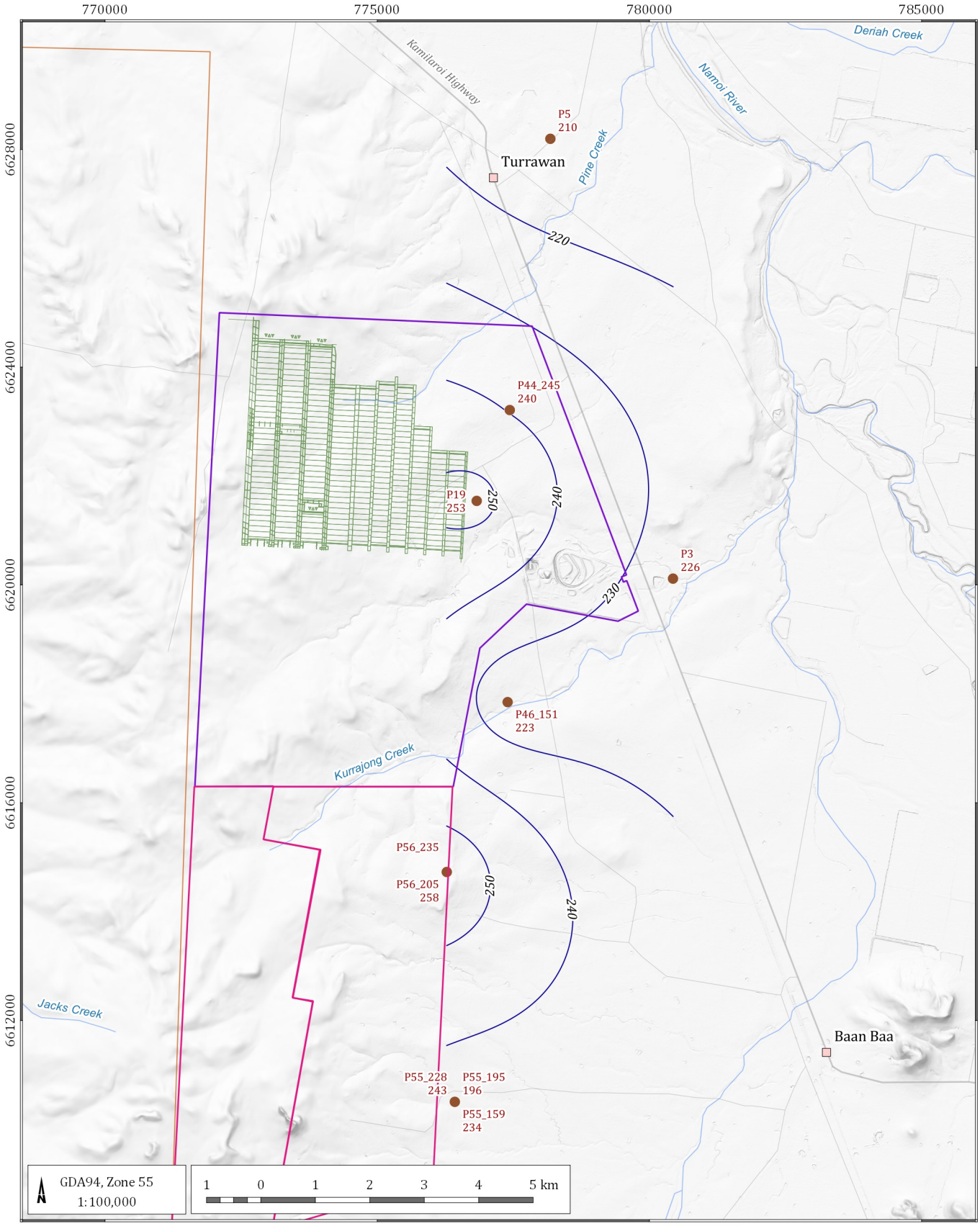
G:\Projects\G1972.Narrrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\B 34 to B 41_G1972_Current groundwater levels.qgs




LEGEND

- Populated place
- Monitoring bore
- Interpolated groundwater level contour (mAHD)
- Drainage
- Road
- Existing longwall panel
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)

P5: BoreID
210 : Water level (mAHD)

Narrrabri Stage 3 Extension GIA (G1972)

## Current groundwater levels - Pamboola Formation

DATE
06/02/2020

FIGURE No:
**B 41**

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G:\Projects\G1972.Narrrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\B 34 to B 41_G1972_Current groundwater levels.qgs

# Appendix C **Water quality**

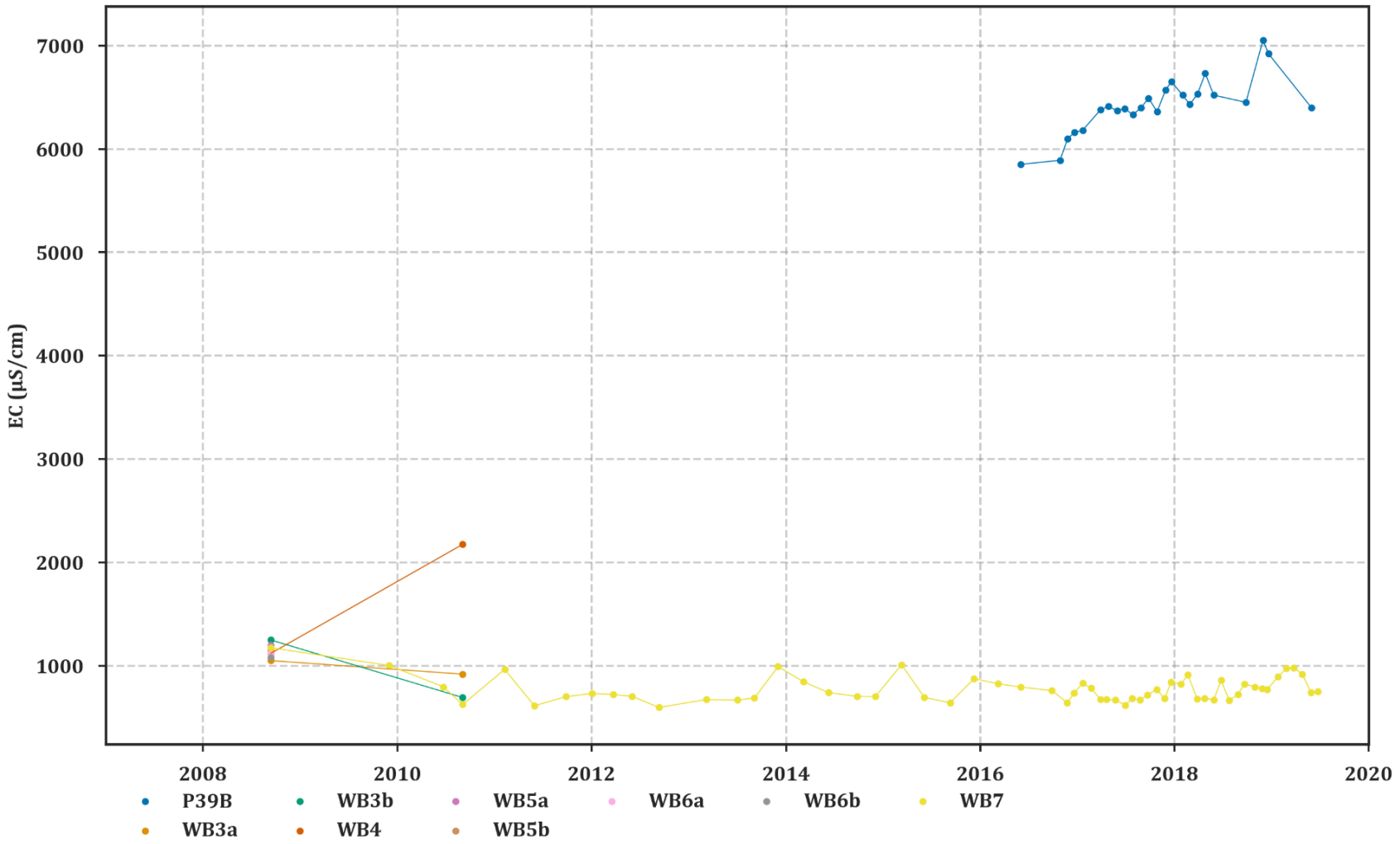



**Figure C 1 Alluvium field electrical conductivity**

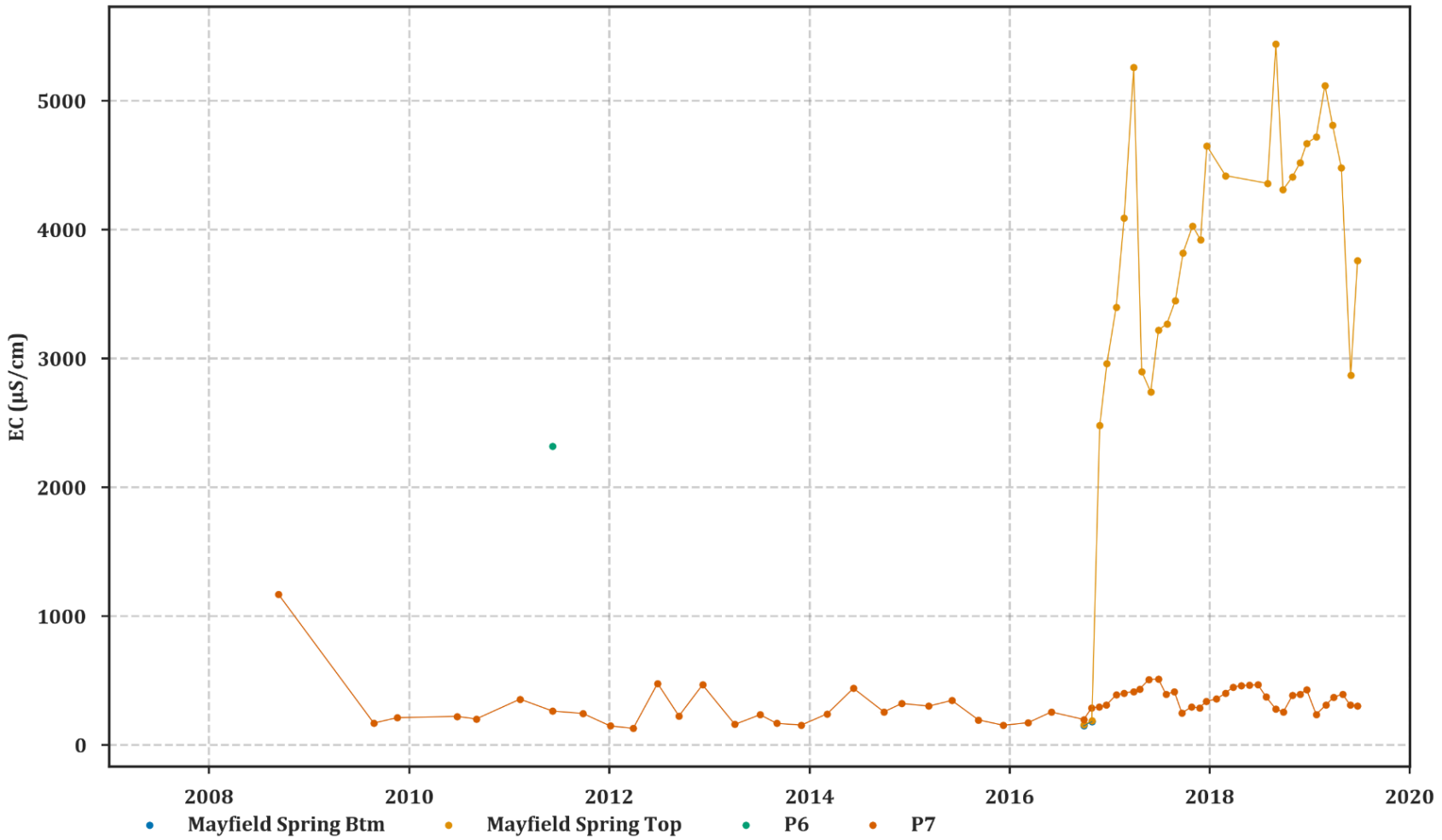



**Figure C 2 Pilliga Sandstone field electrical conductivity**

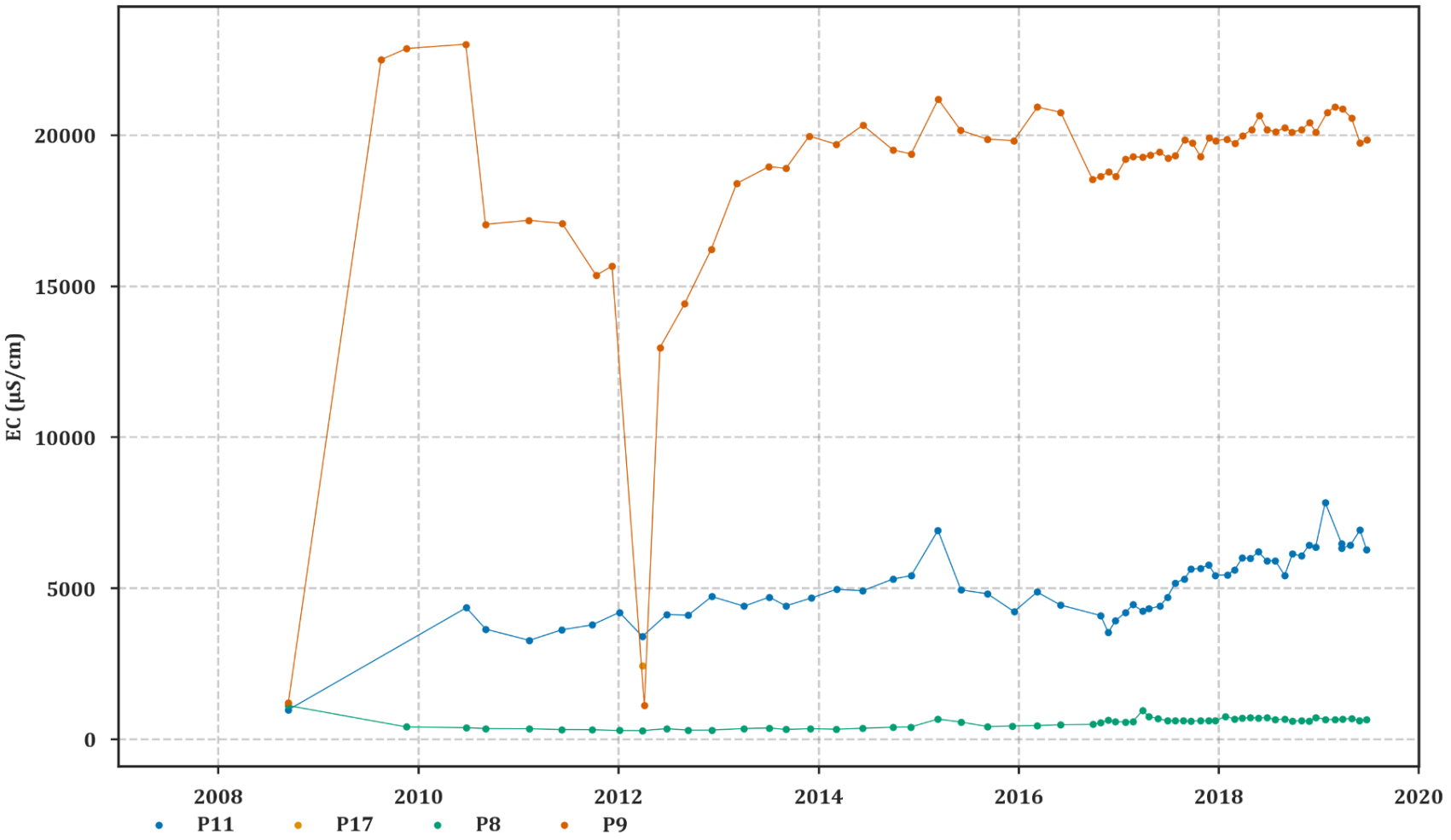



**Figure C 3 Purlawaugh Formation field electrical conductivity**

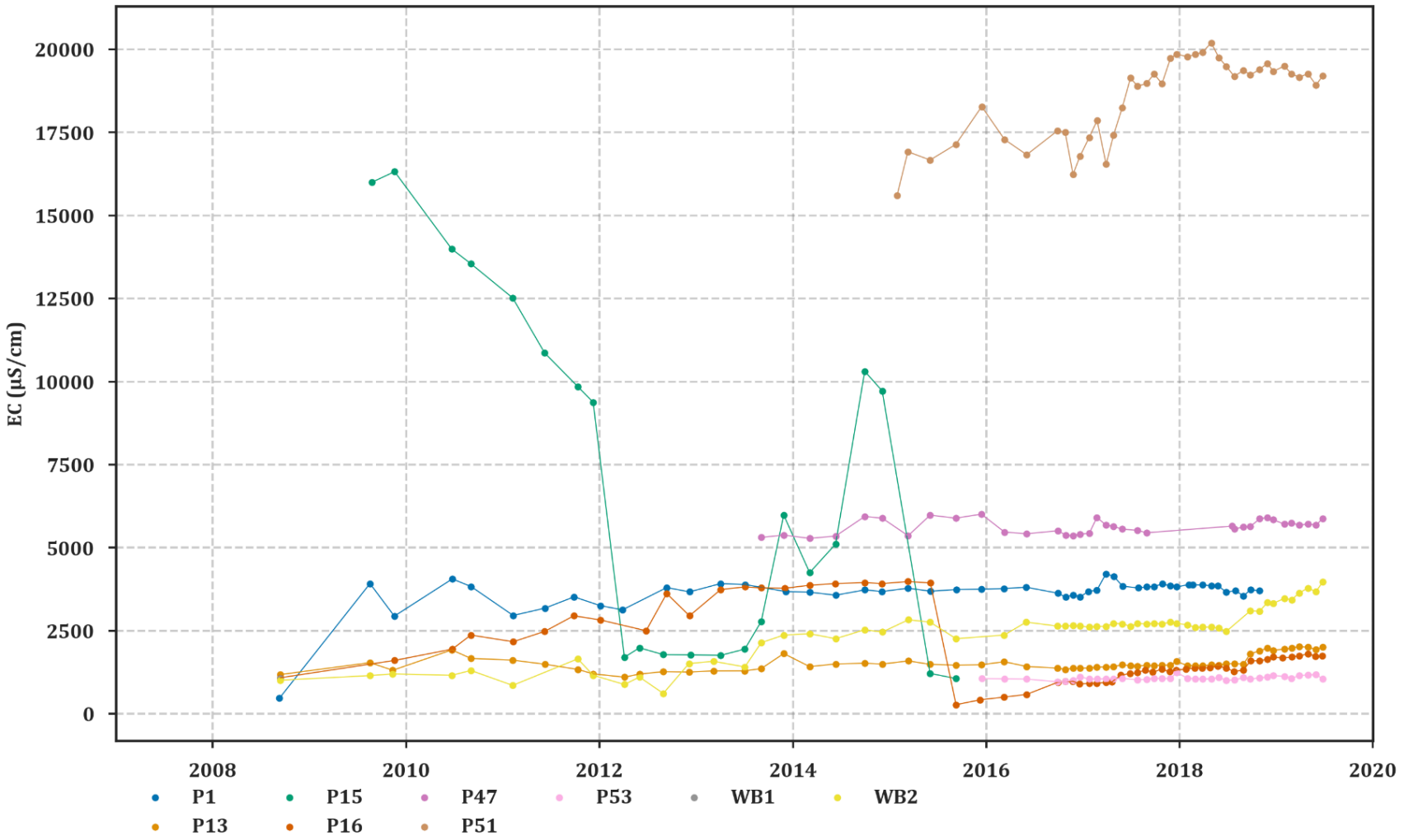



**Figure C 4 Garrawilla Volcanics field electrical conductivity**

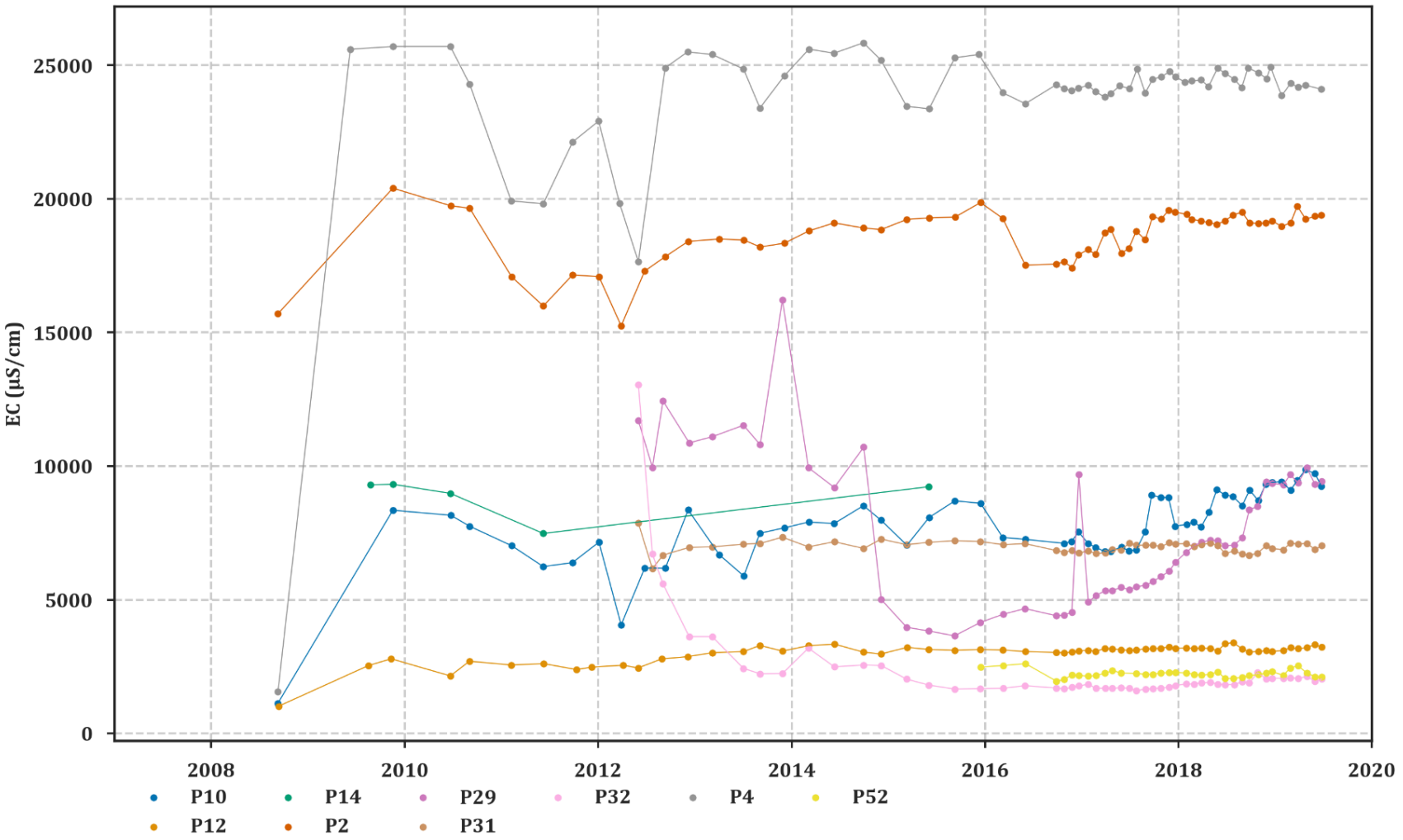



**Figure C 5 Napperby Formation field electrical conductivity**

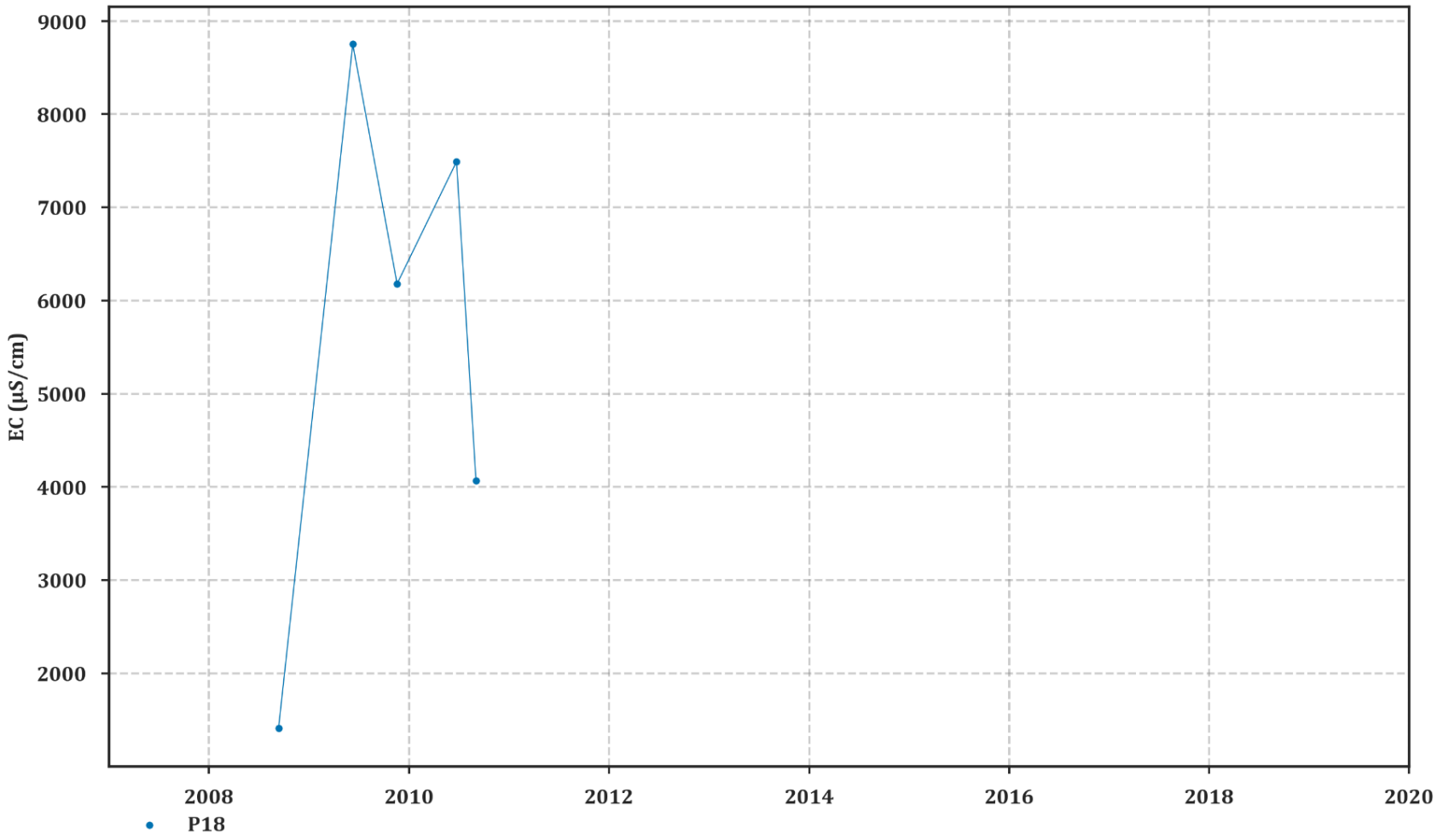



**Figure C 6 Hoskissons Coal Seam field electrical conductivity**

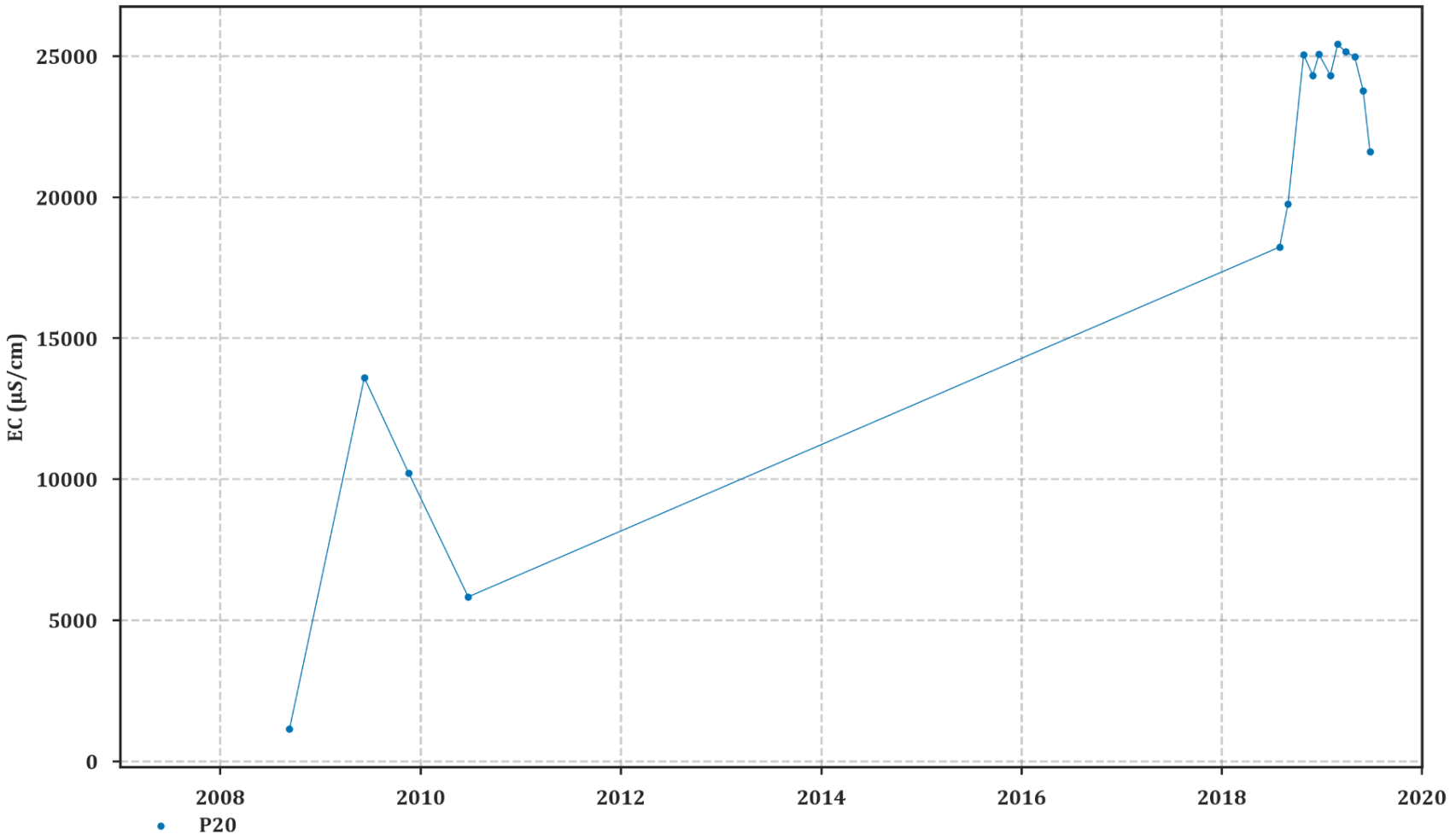



**Figure C 7 Arkarula Formation field electrical conductivity**

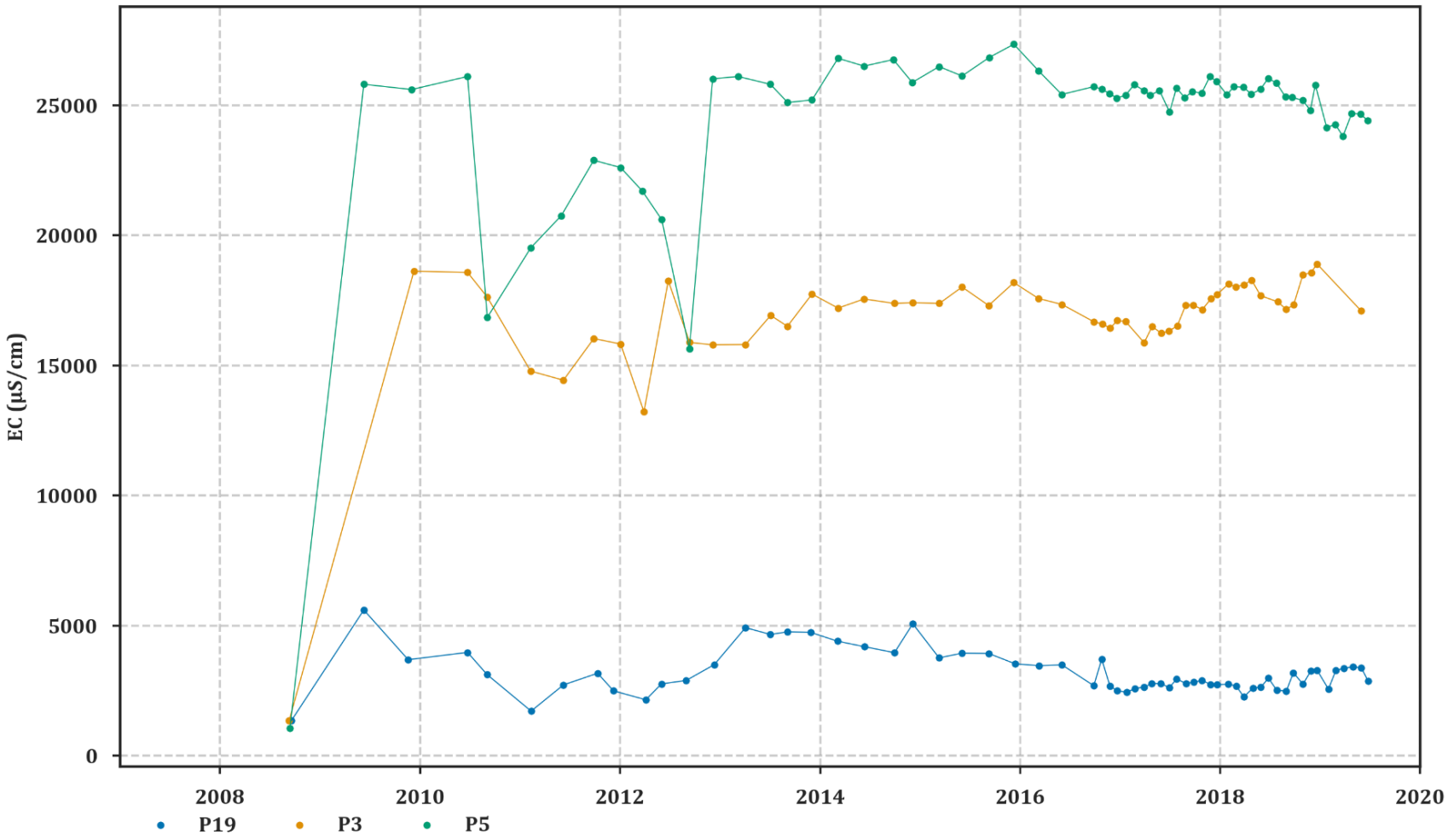



**Figure C 8 Pamboola Formation field electrical conductivity**

# Appendix D **Numerical Modelling Report**

# D 1 Objectives

Predictive numerical modelling was undertaken to assess the impact of the Project on the groundwater regime. The key objective being to assess risks to the groundwater regime using a groundwater model to systematically investigate the causal pathways for potential impacts on water resources and water-dependent assets. Whilst the model has been primarily developed to inform the Environmental Impact Statement for the Project, it will also be used for ongoing mine planning purposes, and as a management tool for the periodic review and validation of predicted groundwater impacts throughout the life of the Project. Whilst the model may well also be suitable for use for other purposes further model refinement may be required.

Outputs resulting from the modelling process described herein include the following:

- estimates of the volume and rate of groundwater directly intercepted by the mine workings as a function of mine position and timing;
- estimates of the volume of groundwater indirectly affected or intercepted from adjacent water sources outside the Project footprint;
- the amount water entitlements required to account for the water directly and indirectly intercepted by the Project;
- estimates of the extent and magnitude of drawdown in surrounding water sources and the potential for the Project to induce drawdown that exceeds the threshold levels of impact for receptors specified within in the NSW Aquifer Interference Policy (AIP);
- characterising the nature of changes to the groundwater regime post mining and the potential to exceed thresholds for water level and quality specified in the AIP for water sources and water dependent assets;
- identification of areas of potential risk where groundwater impact mitigation/control measures may be necessary; and
- an assessment of the influence of parameter uncertainty on the magnitude of predicted impacts and the need for any further management and mitigation measures to ensure preparedness for uncertainty.

The key to the modelling exercise is robust conceptualisation of the groundwater regime to be represented by the numerical model. The conceptual model is a demonstration of how the groundwater system operates given the available data and is an idealised and simplified representation of the natural system. The main report details the conceptual understanding of the hydrogeological regime at the project site. The purpose of this appendix is to describe the model setup, calibration, predictive scenarios and uncertainty analysis undertaken using the numerical model. The model predictions from the basecase model (the 'best' calibrated model) are summarised in the main report but not included here to ensure there is no duplication within the documents.

# D 2 Model construction and development

## D 2.1 Previous numerical models

A number of numerical models of the Narrabri Mine have been developed to support environmental approvals sought at different stages of the Project as follows:

- Initial project approval including boxcut operations, Stage 1 (GHD, 2007). An 11 layer model was developed using MODFLOW 2000.
- Development of longwall mining operation, Stage 2 (Aquaterra, 2009). This model adopted the same layering system but was developed using MODFLOW SURFACT v3.
- Longwall panel modification, Stage 2 MOD 5 (HydroSimulations, 2015 and 2016). A further development of the 2009 Stage 2 model developed using MODFLOW SURFACT v4 and incorporating revised layer geometries, fracture zone simulation and re-calibration.
- Stage 3 Gateway Application (HydroSimulations, 2019). Further re-calibration of the 2015 Stage 2 MOD 5 groundwater model was undertaken for this assessment.

The model described herein represents a further development of the 2019 HydroSimulations model. Outside of the existing and proposed mining lease area the model layers, model layer elevations and thicknesses are based directly on those simulated in HydroSimulations (2019). However, most other aspects of the model design have been revised and refined based on the revised conceptualisation described in the main body of the GIA report.

## D 2.2 Model uncertainty

Middlemis and Peeters (2018) indicate sources of uncertainty affecting numerical modelling simulations can be grouped as follows:

- structural/conceptual – geological structure and hydrogeological conceptualisation assumptions applied to derive a simplified view of a complex hydrogeological reality (any system aspect that cannot be changed in an automated way in a model);
- parameterisation – hydrogeological property values and assumptions applied to represent complex reality in space and time (any system aspect that can be changed in an automated way in a model via parameterisation);
- measurement error – combination of uncertainties associated with the measurement of complex system states (heads, discharges), parameters and variability (3D spatial and temporal) with those induced by upscaling or downscaling (site-specific data, climate data); and
- scenario uncertainties – guessing future stresses, dynamics and boundary condition changes (e.g. mining, climate variability, land and water use change).

Each of these sources of uncertainty are discussed within this document within relevant sections below. Attempts are also made to identify inherent bias and transparently communicate this as recommended by Middlemis and Peeters (2018).

## D 2.3 Model code

The model utilises the MODFLOW-USG code to simulate groundwater flow in the Project Area. This model code was selected as being most suitable for meeting the model objectives because it:

- allows use of an unstructured mesh where cells can be refined around localised features such as rivers, alluvial aquifers and mining, and larger cells used where refinement is not required;
- does not need layers to be continuous over the model domain, allowing layers to be removed where geological units pinch out or outcrop;
- the unstructured gridding functionality allows the number of model cells to be minimised thereby reducing the overall size of the model allowing faster model run times and enabling further analyses of uncertainty and data worth etc; and
- allows better representation of flow transfer processes between eroded contacts (e.g. between bedrock and overlying alluvium aquifers).

The input files for the MODFLOW-USG model were created using custom Fortran code and MODFLOW-USG specific versions of the Groundwater Data Utilities developed by Watermark Numerical Computing (2018) which form part of the PEST suite of software tools. The model mesh was generated using Algomesh (HydroAlgorithmics, 2014).

## D 2.4 Model design

### *D 2.4.1 Model extent and lateral boundaries*

The model extent and lateral boundaries (Figure D 2.1) are largely the same as those adopted for the 2019 Gateway Application model (HydroSimulations, 2019). The model therefore covers an area of approximately 3,970 km$^2$, 75 km from west to east (Eastings 747000-822000) and 52.9 km from south to north (Northings 6591000-6643900). This domain is sufficiently large that it covers all potentially sensitive receptors (including creeks, rivers, GDEs and other water users) that could be affected by mining activities.

As shown in Figure D 2.1 and as per previous versions of the model no flow boundary conditions are assumed to the east of the Namoi Alluvium. Groundwater discharge to the Namoi Alluvium from bedrock strata to the east (which are thought to be minor) are therefore ignored. Given the location of the Narrabri Mine to the west of the Namoi Alluvium the location of this no flow boundary is considered to be extremely unlikely to affect the models ability to predict the impacts of the proposed development.

The 2019 HydroSimulations model also assumed no flow within the Namoi alluvium into or out of the model domain creating flow towards the Namoi River at both of these boundaries. Whilst model predictions are considered unlikely to be sensitive to this assumption, as shown in Figure D 2.1, GHB boundary cells have been added within the Namoi Alluvium at both the southern and northern boundary of the model domain to simulate sub-surface flow into and out of the domain in this area. Surface water inflows to the model domain via the Namoi River and Cox's Creek at the southern model boundary have also been simulated as in input flow to the MODFLOW Stream package which is used to simulate these water courses (Section D 2.5.2).

As per the 2019 HydroSimulations model GHB boundary cells have also been used in the north-western corner of the model domain to simulate flow out of the model domain in this area which is thought to occur especially via the Pilliga Sandstone (see Section 5.2 in the main report). As shown in Figure D 2.1 additional GHB cells were also added into the Purlawaugh and Narrabri formations along the southern edge of the modelling domain to simulate inflow from the south and at the boundary with the overlying Namoi Alluvium close to the northern edge of the modelling domain to simulate outflow.

Prior to adding these GHB cells towards the north of the model the mapped boundary between the Purlawaugh and Narrabri formation and the northern boundary of the Quaternary Alluvium at this location was acting as a no flow boundary and no flow could enter or exit the model within these units. Given that both the Purlawaugh and Narrabri formation are present at or close to outcrop to the north of the modelling domain and the Namoi River this was not considered to be conceptually realistic and hence GHB cells were also added along this boundary.

Conductance values assigned to all GHB cells are assigned dynamically within the model calibration based on the modelled hydraulic conductivity in the relevant layers at the GHB cell location to ensure that in and outflows remain consistent with modelled hydraulic conductivity throughout the calibration. The sensitivity, or otherwise, of key model predictions to GHB conductance has also been assessed as part of the uncertainty analysis (Section D 5).

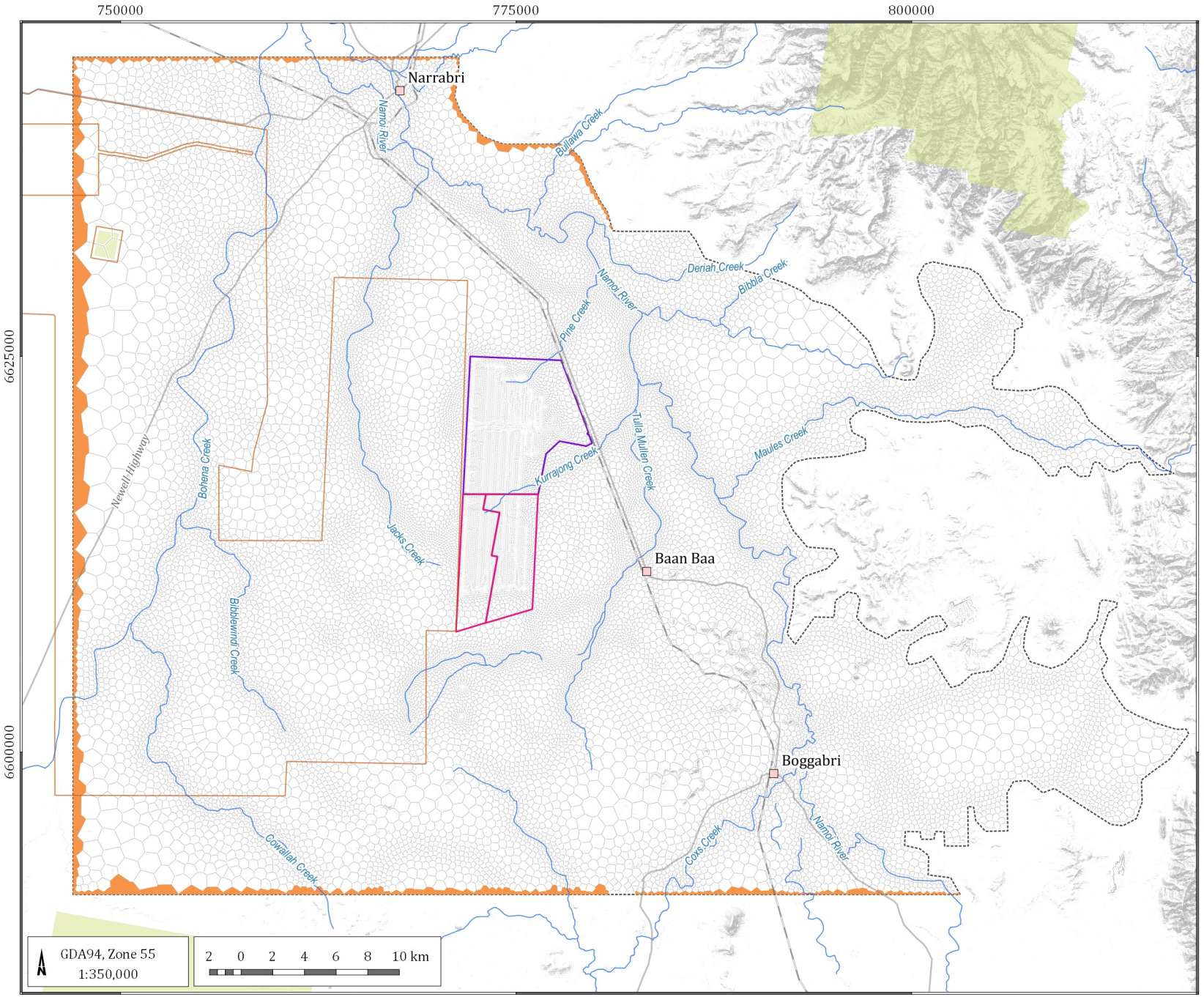
### *D 2.4.2 Grid*

The model domain was discretised and arranged into 11 layers comprising up to 31,149 cell nodes in each layer with the dimensions of the cells varying according to the features that required representation. The following cells dimensions where adopted:

- longwall mining areas – 35 m x 35 m to 100 x 130 cells using cell edges aligned to existing and proposed panel layouts;
- streams – 150 m x 150 m to 300 m x 300 m;
- alluvial flood plains – 150 m x 150 m to 300 m x 300 m; and
- potential GDEs and springs – 40 m x 40 m to 100 m x 100 m.
- Geological outcrops and faults – 200 m x 200 m to 400 m x 400 m.

Figure D 2.1 and Figure D 2.2 show final adopted model cells over the entire model domain and in the vicinity of the Narrabri mine itself respectively.

Overall, the model comprised 307, 321 cells across the 11 layers with significantly reduced model run times compared to previous versions.




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Approved mining lease
- Proposed mining lease
- Santos CSG project
- National Park
- Model boundary
- Model mesh
- General head boundary

Narrrabri Stage 3 Extension GIA (G1972)

**Model domain, grid and boundary conditions**

DATE
27/05/2020

FIGURE No:
**D 2.1**

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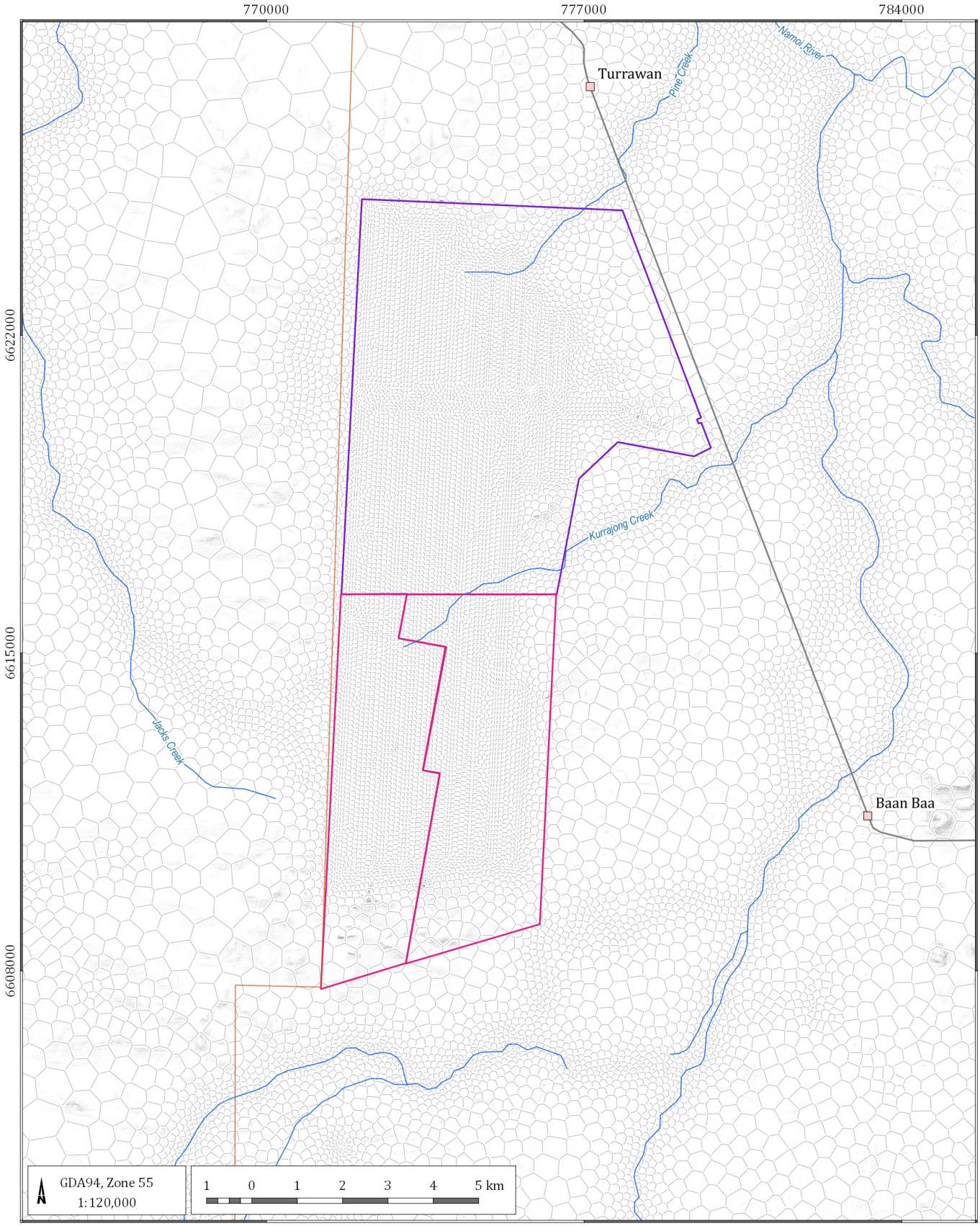
G:\Projects\G1972.Narrrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 02.01_G1972_Model domain grid and boundary conditions .qgs




LEGEND

- Populated place
- Drainage
- Road
- Rail
- Approved mining lease
- Proposed mining lease
- Santos CSG project
- Alluvium extent
- National Park
- Model boundary
- Model mesh

Narrrabri Stage 3 Extension GIA (G1972)

**Grid layout (Project Area)**

DATE 15/04/2020

FIGURE No: **D 2.2**

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Source: ELVIS LiDAR DEM © Spatial Services, a unit of Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1972.Narrrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 02.02_G1972_Grid layout (Project Area).qgs

### *D 2.4.3 Model Layers*

Outside of the existing and proposed mining lease areas the same 11 layer system adopted by all of the previous models of the Project Area has been retained. These layers are as follows (see Table D 2.1 for further details):

- Layer 1 – Alluvium, colluvium and regolith;
- Layer 2 – Pilliga Sandstone;
- Layer 3 – Purlawaugh Formation;
- Layer 4 - Garrawilla Volcanics;
- Layer 5 – Upper Napperby Formation (above Napperby Sill);
- Layer 6 – Napperby Sill;
- Layer 7 – Lower Napperby Formation (below Napperby Sill);
- Layer 8 – Digby Formation;
- Layer 9 – Hoskissons Coal Seam;
- Layer 10 – Arkarula Formation;
- Layer 11 – Pamboola Formation/other early Permian strata

Isopachs of model layer thicknesses are provided in Appendix D 3.

As outlined above a single layer has been used to simulate the Namoi Alluvium within the area. As discussed previously in Section 4.2.1 of the main report some previous studies divide this alluvium into two separate units, namely the Narrabri Formation at the surface and the underlying Gunnedah Formation. However, the boundary between these two units is not always obvious and previous modelling of the Namoi Alluvium undertaken by AGE (2012) and McNeilage (2006) have returned very similar hydraulic properties for the two units. Potential sub-division of the Namoi Aluvium has been further investigated for the current study by generating a series of east west cross sections through the Namoi Alluvium east of the Narrabri mine using the SGEMS geological modelling package and based on input lithological data extracted from the NSW PINEEA database. The results of this work are summarised in Appendix E and suggest no clear stratification of the alluvium. The Namoi Alluvium aquifer in this area appears to be highly heterogenous with highly variable thicknesses of sand and gravel and clay rich strata.

Inside of the existing and proposed mining lease areas, taking advantage of the unstructured gridding functionality in MODFLOW-USG, the Purlawaugh Formation and Napperby Formation layers (layers 3, 5 and 7) which are relatively thick have been split into four sub-layers each. This additional detail was added to allow better representation of the steep hydraulic gradients and fracturing which are likely to occur in these areas post mining and to make full use of the nested VWP data available in this area. The additional sub-layers in the Purlawaugh and Napperby Formation are numbered Layer 3a, 3b, 3c, 3d, and 5a, 5b, 5c and 5d and 7a, 7b, 7c and 7d respectively. Initial parameters in all four sub-layers were assumed to be the same but were then allowed to vary during calibration, where necessary to fit the available observation data, subject to the parameter constraints outlined in Section D 3.3. Similarly, the Pilliga Sandstone, Garawilla volcanics and Digby formation were split into two sub-layers each.

As per the Gateway Application model (HydroSimulations, 2019) depending on location within the model domain model layer 11 represents either the Pamboola Formation or other underlying early Permian strata. As shown schematically in Figure 5.16 of the main report the Pamboola Formation which forms part of the Brothers sub-group is typically not present east of the Namoi River. In these areas layer 11 therefore represents the upper 50m of the other underlying early Permian aged strata which are present beneath the Namoi Alluvium.

Figure D 2.3 and Figure D 2.4 show graphically the model layers in 3D oblique views. Figure D 2.3 shows the model viewed from the south looking to the north, with Figure D 2.4 providing a view into the model through a cut out into the Project area. Figure D 2.5 presents an east-west cross-section through the historic mine workings and the location of a nested vibrating wire piezometer (VWP) P57. This VWP monitoring facility is located close to the northern end of longwall panel LW108A provides key information on the observed response in a number of different units immediately overlying a longwall mining area (see Section 5.2.11 of the main report). Figure D 2.5 shows the discretisation of model layers compared to the P57 vibrating wire sensor locations, and the location of the anticipated height of fracturing, which discussed in more detail in Section D 2.5.6.

Middlemis and Peeters (2018) describe the model surfaces as a structural and conceptual source of uncertainty in the numerical model that cannot be changed in an automated way in a model. Within the existing and proposed mining lease areas layer elevations and thicknesses are based on a detailed geological model developed by NCOPL. This model is in turn based on data from over 1600 exploration bores. Within the lease areas therefore the thickness of each modelled unit is considered to be well defined. Outside of the lease areas the extent and elevations of each are based on modelled surfaces extracted from the Gateway Application model (HydroSimulations, 2019) and current published geological mapping. With regard to predicting the impacts of the proposed extension on groundwater resources the critical geological controls are considered to be the extent and elevation of the following three units:

- The Hoskissons Coal Seam, especially to the east of the Narrabri Mine;
- The Pilliga Sandstone; and
- The Namoi Alluvium.

The Namoi Alluvium and Pilliga Sandstone are the two main aquifers present in the project area. In this case the extent and elevation of all three of these units are considered to be known with a relatively high degree of accuracy. Extensive exploration drilling has confirmed that the Hoskissons Coal Seam pinches out within the mining lease areas and does not therefore subcrop beneath the Namoi Alluvium to the east. This is consistent with geological mapping which shows older strata associated with the Brothers Sub-Group (i.e. the Arkarula and/or the Pamboola Formation) at outcrop in the area between the Narrabri Mine and the Namoi River to the east (see Figure 4.5 in the main report). The extent and thickness of the Pilliga Sandstone in the area is also relatively well known since it occurs at outcrop within the lease area and has therefore been regionally mapped and intersected by some 616 NCOPL exploration bores. Similarly, the extent and thickness of the Namoi and other alluvial strata present within the area is also well known. The Namoi Alluvium is intersected by over 1,000 licensed water supply bores within the model domain and has been the subject of a number of modelling and other studies (including McNeilage, 2006; Aryal et al., 2018; CSIRO, 2007; SWS, 2012). In addition to mapping the extent of the Namoi Alluvium the current regional geological mapping of the area (Figure 4.5 in the main report) includes additional alluvial areas associated with the Tulla Mullen Creek to the south of the proposed lease area which were not shown on previous versions. It does not show any alluvium associated with the Kurrajong or Pine Creek. However, these are minor creeks with likely minor associated alluvium. This is consistent with NCOPL exploration drilling results which shows that only 25 bores were logged as intersecting alluvium to a maximum depth of 10m below ground level, 2 m thick on average.

## Table D 2.1 Model layers

| Geological age | Hydrostratigraphic unit | Description | Model layer |
|---|---|---|---|
| Quaternary | Alluvium | Mapped alluvial deposits (Q_m_c) underlying the Namoi River and tributary creeks | 1 |
| | Colluvium | Mapped colluvial valley flank deposits (Q_cr) | 1 |
| | Regolith | Unmapped in-situ weathered material typically found in areas where consolidated strata are mapped at outcrop. Thickness estimated from CSIRO quaternary cover mapping (Wilford et al, 2015) | 1 |
| Jurassic | Pilliga Sandstone | Jinp - An important regional aquifer dominated by well sorted, fine to coarse grained sandstones (86% sandstone). | 2a, 2b |
| | Purlawaugh Formation | J_p - Fine grained lithic to labile sandstone/siltstone, 64% fine material (siltstone, claystone, mudstone) | 3a, 3b, 3c, 3d |
| | Garrawilla Volcanics | J_g - Generally fresh (72%) basalt | 4a, 4b |
| Triassic | Deriah/Napperby Formation above sill | Tute/Tutn - The upper part of the Deriah/Napperby Formation overlying the basalt sill, 54% sandstone, 43% fine material (siltstone, claystone, mudstone) | 5a, 5b, 5c, 5d |
| | Basalt Sill | Tute/Tutn - A 10-30m thick basalt sill present within the mining area but not thought to be present elsewhere. 97% fresh basalt | 6 |
| | Deriah/Napperby Formation below sill | Tute/Tutn - The lower part of the Deriah/Napperby Formation underlying the basalt sill, 59% fine material (siltstone, claystone, mudstone), 38% sandstone | 7a, 7b, 7c, 7d |
| | Digby conglomerate | Tutd - Medium to high strength conglomerate, expected very low hydraulic conductivity and porosity outside of mining zone | 8a, 8b |
| Permian | Hoskissons Coal Seam | Part of Black Jack Group (Pbj) 7-10m thick seam. Relatively low permeability compared to other mining developments | 9 |
| | Arkarula Formation | Part of Brothers sub-group (Pbb). Typically, 10 m thick sandstone aquifer directly underlying longwall panels, 75% sandstone, 12% siltstone | 10 |
| | Pamboola Formation | Part of Brothers sub-group (Pbb). Dominated by lithic sandstone (63%) and siltstone (29%) | 11 |

***Note:*** Total MFUSG model layers total 18, i.e. 2b = 3, 3a = 4, etc.

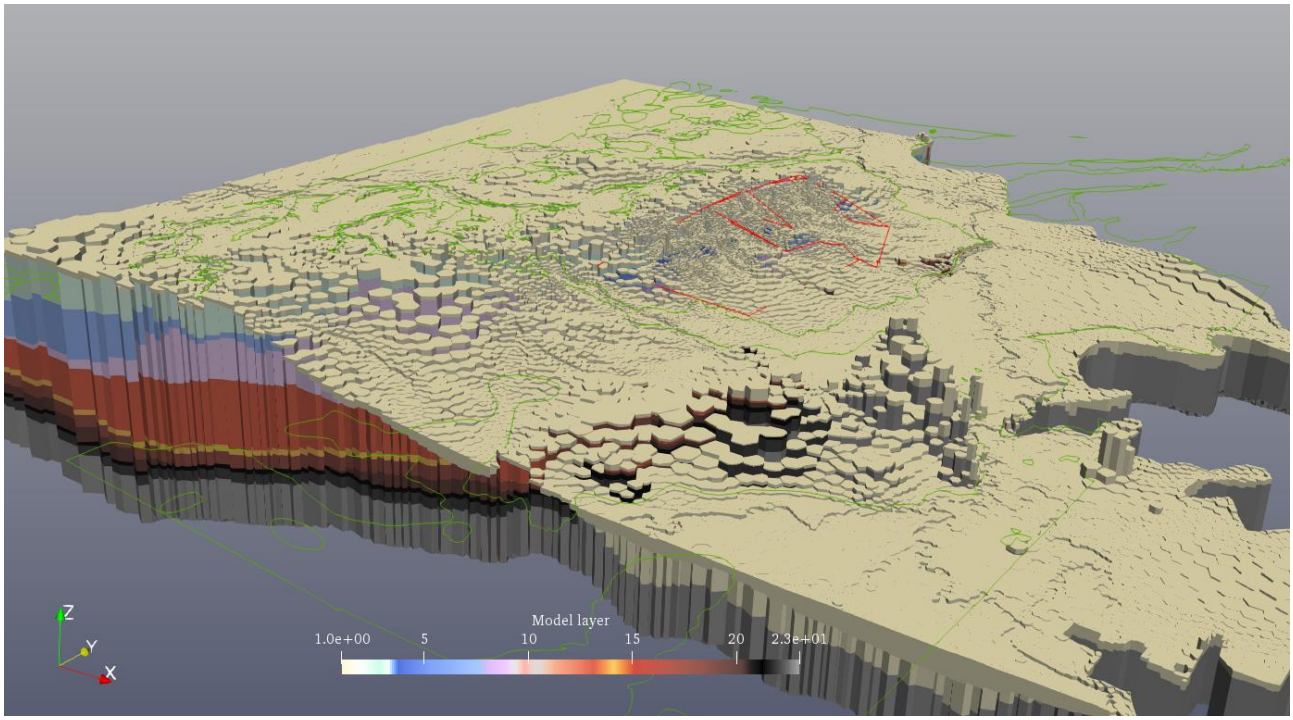



**Figure D 2.3 Oblique view of model layers looking from south to north**

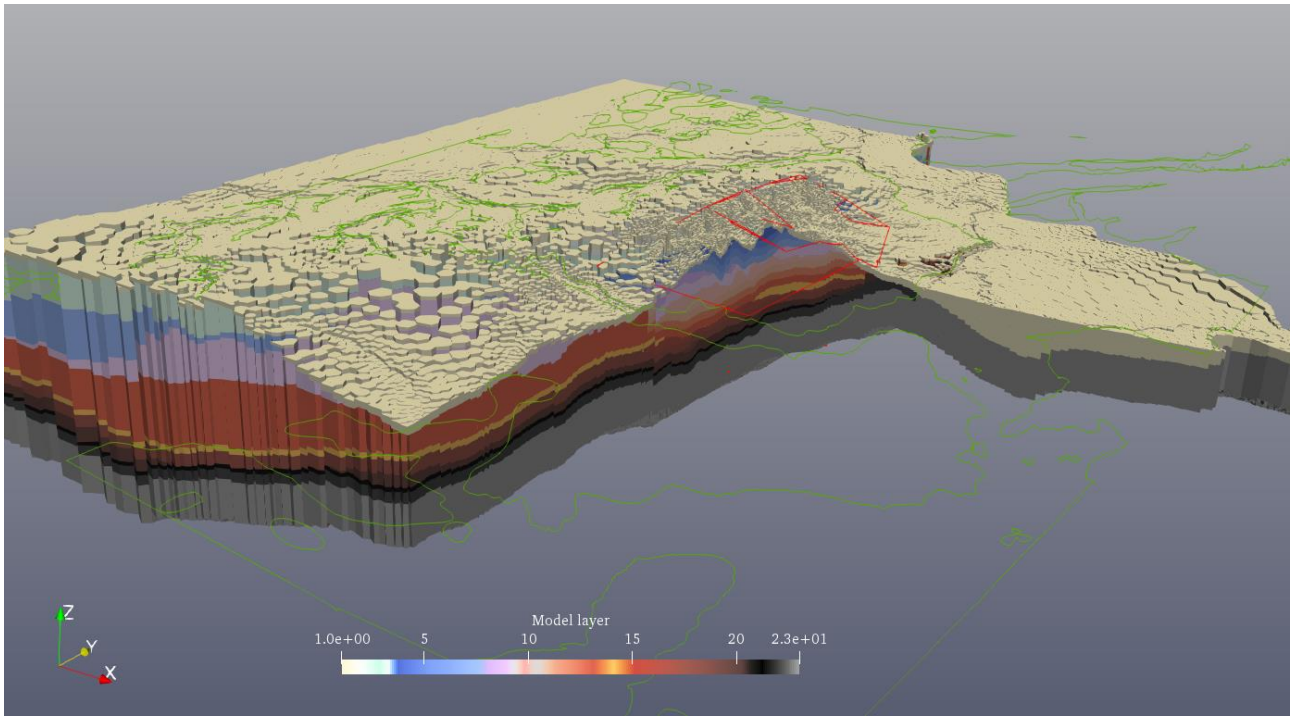



**Figure D 2.4 Oblique view of model layers – cut through the Project Area**

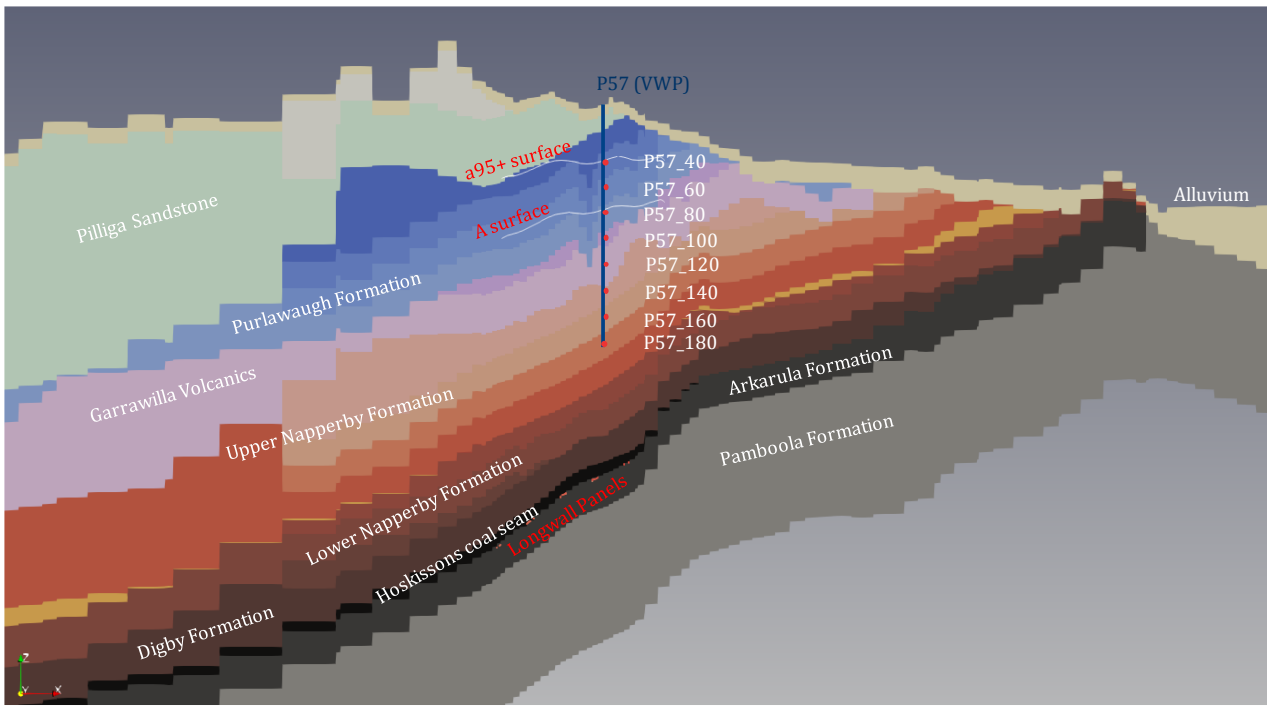



**Figure D 2.5 Cross section showing model layers vs monitoring points at VWP P57**

### *D 2.4.4 Geological structures*

The model domain includes a number of known geological structures including intrusions and faults the potential influence of which on the groundwater regime are discussed in the main report in Section 4. In the Project area the main geological structures are:

- The Boggabri Ridge which separates the Mullaley sub-basin in which the Project Area is located from the Maules Creek sub-basin to the east;
- a number of north west to south east and north east to south west trending faults which appear on regional geology maps (Pratt, 1998) two of which extend into the existing and proposed mining lease areas;
- a large number of small faults the largest of which are associated with displacements of around 5 m identified in exploration drillholes and/or during underground mining operations: and
- a basalt sill intrusion into the Napperby Formation.

These structures are shown in Figure 4.4 in the main report. Truncation of the various Permian aged model layers against the Boggabri Ridge has been represented via incorporating the mapped extents of the units beneath the Namoi Alluvium.

Each of the site mapped faults shown in blue in Figure 4.4 of the main report within the mining lease is represented in the NCOPL geological model and hence the displacements associated within these faults have been incorporated into the numerical groundwater model structure. Where appropriate non-neighbour connections and horizontal flow barrier (HFB) cells have also been added at the mapped location of each fault. Prior to calibration, however, each of these 'barrier' cells have been parameterised such that they do not act to limit groundwater flow.

The basalt sill intrusion into the Napperby Formation is represented within the NCOPL geological model of the mining area. As per previous simulations this sill has been represented using a dedicated layer in the current model with the Napperby Formation above and below the sill represented using between two and eight further layers or sub-layers depending on location within the model. This sill is not thought to be present outside of the mining area and hence is modelled as pinching out, based on the estimated extent of the unit in the NCOPL geological model.

### *D 2.4.5 Timing*

Largely as per the Gateway Application model (HydroSimulations, 2019) the model simulation comprises an initial steady state simulation intended to replicate pre-mining conditions, followed by a transient historic calibration and a predictive period. The transient model was set up as follows:

- last day of 2008 – steady state stress period, pre-mining initial conditions;
- 1 January 2009 to 30 June 2019 – 126 x monthly stress periods, historic transient calibration period; and
- 1 July 2019 to 31 December 2043 – 98 x quarterly stress periods, predictive simulation period.

Monthly stress periods were adopted during the historic transient calibration period so that some seasonal variability in recharge and stream flows could be represented where data was available for the calibration period. Quarterly stress periods were then used during the predictive period to allow accurate representation of the mine plan whilst minimising the number of stress periods. The drains representing future mining activities (Section D 2.5.6) were therefore advanced in quarterly intervals and remained active until the end of mining.

An additional version of the model was developed for simulating recovery post mining. Both models were combined into a single, continuous simulation with one finishing and the other starting immediately following completion of mining. The timing for the recovery model was set up as a 10 exponentially increasing transient stress periods.

All simulations were undertaken using the ATS (Adaptive Time Stepping) functionality supported by MODFLOW-USG and applying a 1.41 multiplier and 2.82 divisor, with an initial time-step length varying slightly, depending on the stress period length, to ensure each stress period comprises at least three time steps and that there are no short time steps at the end of any stress periods.

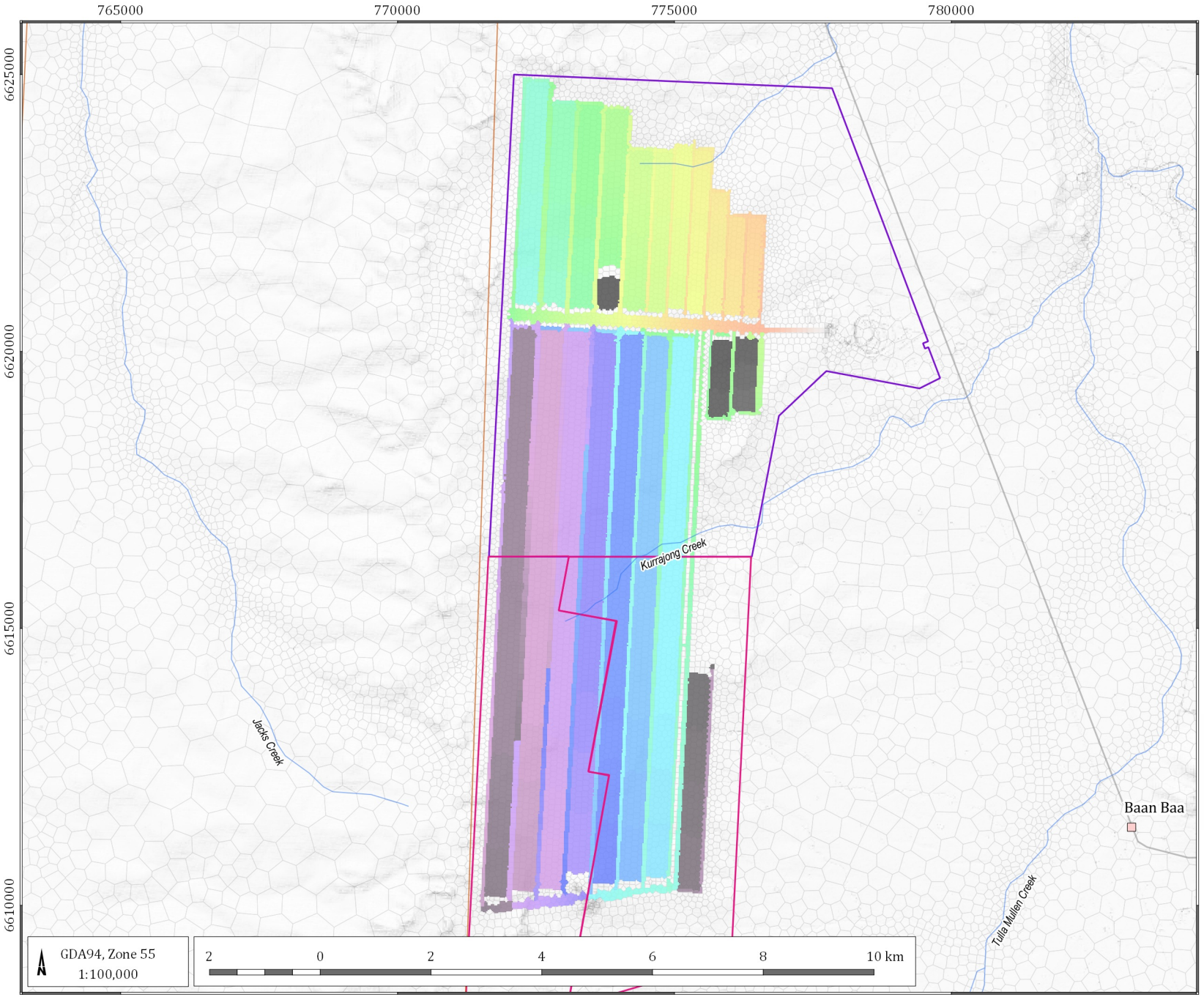
### *D 2.4.6 Mining progression*

Progression of the historic and proposed future mining activities has been simulated in the model based on detailed mine schedule information provided by NCOPL. It has been assumed that mining is limited to the Hoskissons Coal Seam the thickness and elevation of which has been taken from the NCOPL mine geology model. Initial dewatering via lateral underground in seam (UIS) wells and surface to seam (SIS) is assumed to take place 18 months prior to the proposed mining date of each longwall panel wells. Further details relating to the timing of the development of each longwall panel and other components of the underground mine during the historic calibration and predictive periods is summarised in Table D 2.2 and Figure D 2.6.

It is noted that the Project would involve the development of a number of ventilation shafts (shown in Figure 2.1 of the main report). Given the ventilation shafts would be steel or concrete lined (as per approved and existing ventilation shafts developed at the Narrabri Mine), it is considered unlikely the ventilation shafts would result in any perceptible take of groundwater (or result in any significant cross-contamination of groundwater). Other development activities, such as exploration boreholes and service boreholes, would similarly have a negligible groundwater take and not contribute to the predicted overall groundwater inflows for the Project.

## Table D 2.2 Model domain historic and proposed mine progression

| Mine Component | Heading start date | Panel start date | Heading/panel end date |
|---|---|---|---|
| Drift tunnels | 1/02/2009 | NA | 1/06/2010 |
| Main Heading | 1/06/2010 | NA | 1/12/2010 |
| LW101 | 1/11/2010 | 1/06/2012 | 28/06/2013 |
| LW102 | 1/04/2011 | 1/07/2013 | 28/01/2014 |
| LW103 | 1/01/2012 | 1/03/2014 | 28/10/2014 |
| LW104 | 1/08/2012 | 1/12/2014 | 28/07/2015 |
| LW105 | 1/03/2013 | 1/09/2015 | 28/05/2016 |
| LW106 | 1/01/2014 | 1/06/2016 | 15/03/2017 |
| LW107 | 1/08/2014 | 1/04/2017 | 28/06/2018 |
| LW108A | 1/05/2015 | 1/09/2018 | 14/11/2019 |
| LW109 | 1/05/2016 | 6/01/2020 | 13/04/2021 |
| LW110 | 1/07/2017 | 2/06/2021 | 15/09/2022 |
| LW111 | 1/11/2018 | 4/11/2022 | 21/03/2024 |
| LW203 | 1/08/2019 | 2/05/2024 | 4/08/2026 |
| LW204 | 1/10/2020 | 15/09/2026 | 17/12/2028 |
| LW205 | 1/05/2023 | 28/01/2029 | 18/05/2031 |
| LW206 | 1/03/2025 | 29/06/2031 | 30/09/2033 |
| LW207 | 1/04/2026 | 11/11/2033 | 17/03/2036 |
| LW208 | 1/06/2028 | 28/04/2036 | 15/09/2038 |
| LW209 | 1/02/2029 | 27/10/2038 | 27/05/2041 |
| LW210 | 1/01/2039 | 8/07/2041 | 29/06/2042 |
| LW201 | 1/03/2018 | 10/08/2042 | 31/12/2042 |
| LW202 | 1/03/2019 | 11/02/2043 | 27/06/2043 |
| LW108B | 1/01/2016 | 27/07/2043 | 18/10/2043 |




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Approved mining lease
- Proposed mining lease
- Santos CSG project
- National Park
- Model boundary
- Model mesh

Mine start year

- 2009
- 2010
- 2013
- 2015
- 2018
- 2020
- 2022
- 2025
- 2028
- 2031
- 2034
- 2037
- 2040
- 2042
- 2043

Narrrabri Stage 3 Extension GIA (G1972)

**Predictive mine progression for the Project – Hoskissons Coal Seam**

DATE
27/05/2020

FIGURE No:
**D 2.6**

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Source: ELVIS LiDAR DEM © Spatial Services, Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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The timing and location of mining represented within the numerical model contains an unavoidable element of uncertainty. Middlemis and Peeters (2018) categorise this as 'scenario uncertainty'. This is because records of historical mining can be difficult to obtain, and assumptions on the progress of mining operations, particularly older operations are therefore required. The exact advancement of future mining operations is also uncertain as all mining operations are subject to market conditions that can alter the economics of projects. The historical and future mining represented within the numerical model should therefore be considered to be a guide rather than being expected to be highly accurate. In this case, however, detailed mine plans are available for the historic period and the depth and distribution of the single seam targeted within the mine lease is well known. Accordingly, the location and elevation of both the historic and future mining activities is also well known and only the rate and possibly also the order of progression of the future activities is considered likely to change significantly in the future. Nevertheless, some uncertainty remains since the model cannot represent the full detail of the underground activities. This has the potential to influence the calibration of the model, particularly in areas where water level calibration points are in close proximity to mining activities. In areas more distant from mining activities the uncertainties in the historical progression of mining become less influential on the model predictions. The NSW and Commonwealth approval process allows for this inherent uncertainty in future mining schedules by typically requiring three or five yearly updates to numerical models during the operational period to allow any changes in schedules to be represented in the model and also allow for validation of predictions or further calibration utilising new monitoring and parameter datasets.

## D 2.5 System stresses

### *D 2.5.1 Recharge*

The MODFLOW USG recharge package (RCH) was used to represent diffuse rainfall recharge. The upstream weighting function with the CONSTANTCV option was selected and therefore flow through the vadose zone was not simulated in the model.

Recharge to groundwater systems in the area occurs predominantly through diffuse infiltration of rainfall through the soil profile and subsequent deep drainage to underlying groundwater systems. A simple SWAT model (Arnold, 2012) covering the model domain was developed to guide the groundwater recharge rates used in the model calibration process. Global FAO soil and static land use data were assumed, and weather was applied using interpolated SILO climate data. SWAT provided estimates of long term average recharge rates of around 81 mm/year for the Quaternary alluvium, and 4 mm/year elsewhere. As discussed in Section 5.4 of the main report these rates are comparable to Chloride Mass Balance (CMB) calculations undertaken by AGE for the current study and by CSIRO as part of the Bioregional Assessment for the Namoi sub-region (Aryal et al., 2016.), which suggested rates of up to 69 mm/year for the Quaternary Alluvium and 0 to 6 mm/year elsewhere. However, CMB calculations for the Pilliga Sandstone suggest somewhat higher rates of recharge of up to 16 mm/year consistent with the high permeability of this major aquifer system.

Groundwater recharge was represented in the numerical model using zones based on the mapped geology occurring at the land surface. Figure D 2.7 shows the recharge zones represented in the groundwater model. Long term average pre-calibration recharge rates for each zone are summarised in Table D 2.3. As summarised in Table D 2.3 a relatively simple initial parameterisation has been assumed pre-calibration with relatively high initial values assumed for the Alluvium (35 mm/year i.e. at the middle of the range estimated in the Namoi sub-region bioregional assessment) and the Pilliga Sandstone (16 mm/year based on CMB calculations). A long term average rate of 4 mm/year based on SWAT results has been assumed for all other zones.

As discussed in Section D 3.3 recharge is then scaled as necessary during calibration using a pilot point based multiplier field, subject to the minimum and maximum constraints shown in Table D 2.3. However, since the preferred value of the multiplier field has been set to unity then the recharge assigned at each pilot points will only deviate from the initial estimates where necessary to fit the available calibration data i.e. adding the minimum amount of variance necessary to fit the data.

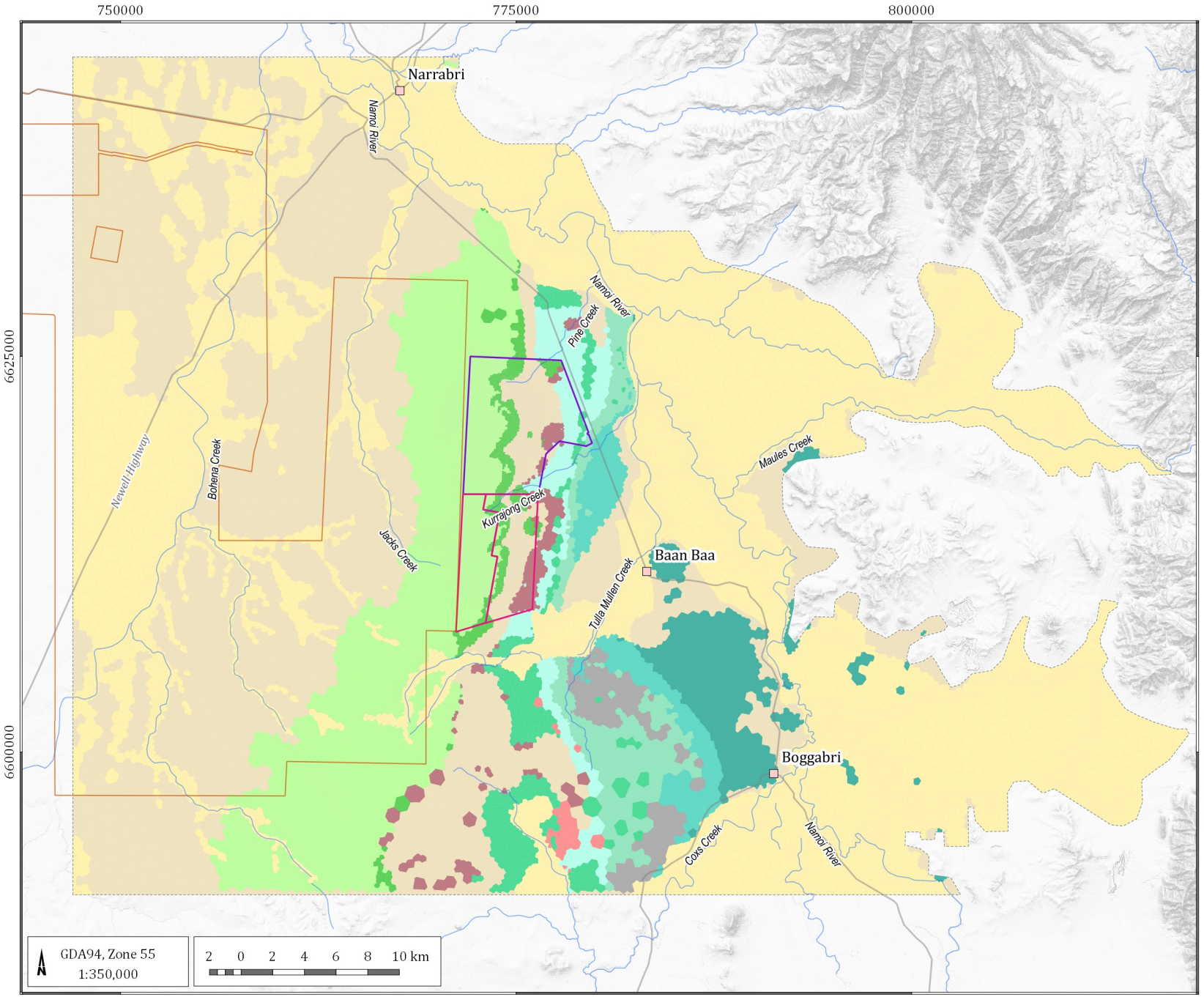
Timing of transient recharge during the calibration period was obtained from the SWAT soil moisture balance calculations scaled as necessary based on the calibrated multiplier field described above. Pre-calibration recharge volumes applied to modelled outcrop alluvium, Pilliga Sandstone and other layers are shown in Figure D 2.8.

The rate of rainfall recharge is an inherently uncertain parameter in the numerical model, as it cannot be directly measured, only inferred from changes in groundwater levels and/or chemistry within monitoring bores. Rainfall recharge also varies spatially depending on a large range of factors including soils, land-use, geology, topography and depth to water table. Whilst the numerical model represents some of these elements it cannot be expected to provide highly accurate values of rainfall recharge, and the rainfall recharge rates determined during the calibration process are considered to be one potential realisation. Given the uncertainty in this model parameter recharge has been varied as part of the uncertainty analysis to determine its influence on the model predictions (Section D 5)

### Table D 2.3 Estimated long term average recharge rates and possible ranges (pre-calibration)

| | Diffuse long term average recharge rate | | | |
|---|---|---|---|---|
| **Zone** | **Initial best estimate (mm/year)** | **% of annual rainfall** | **Minimum (mm/year)** | **Maximum mm/year)** |
| Alluvium | 35.0 | 6.5% | 11[a] | 80.0[d] |
| Colluvium | 4.0 | 0.65% | 0.2[c] | 16.0[f] |
| Pilliga Sandstone | 16.0 | 2.5% | 6.0[b] | 32.0[e] |
| Purlawaugh Formation | 4.0 | 0.65% | 0.2 [c] | 16.0 [f] |
| Garrawilla Volcanics | 4.0 | 0.65% | 0.2 [c] | 16.0 [f] |
| Napperby Upper | 4.0 | 0.65% | 0.2 [c] | 16.0 [f] |
| Napperby Sill | 4.0 | 0.65% | 0.2 [c] | 16.0 [f] |
| Napperby Lower | 4.0 | 0.65% | 0.2 [c] | 16.0 [f] |
| Digby Formation | 4.0 | 0.65% | 0.2 [c] | 16.0 [f] |
| Hoskissons Coal Seam | 4.0 | 0.65% | 0.2 [c] | 16.0 [f] |
| Arkarula Formation | 4.0 | 0.65% | 0.2 [c] | 16.0 [f] |
| Pamboola Formation | 4.0 | 0.65% | 0.2 [c] | 16.0 [f] |

***Notes:*** *[a] Minimum recharge estimate for the Alluvium from CMB calculations.*
*[b] Minimum recharge estimate for the Pilliga Sandstone from CMB calculations.*
*[c] Minimum recharge estimate for other strata from CMB calculations.*
*[d] Maximum long term average value for Alluvium based on CMB, SWAT and bioregional assessment results.*
*[e] Maximum long term average value for Pilliga Sandstone based on CMB, SWAT and bioregional assessment results.*
*[f] Maximum long term average value for other strata based on CMB, SWAT and bioregional assessment results.*




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Approved mining lease
- Proposed mining lease
- Santos CSG project
- Model boundary
- Model mesh

**Recharge Zones**

Model layer 1 (recharge mm/y)
- Qx - Quaternary Sediments (23.6)
- CZ_c - Colluvium (0.9)

Model layer 2 (recharge mm/y)
- Jps - Pillaga Sandstone (8.4)

Model layer 4 (recharge mm/y)
- Jgv - Garawilla Volcanics (0.6)

Model layer 5 (recharge mm/y)
- Rns - Napperby Formation (0.6)

Model layer 8 (recharge mm/y)
- Rdc - Digby Formaton (2.9)

Model layer 9 (recharge mm/y)
- Pnc - Black Jackgroup (3.7)

Model layer 10 (recharge mm/y)
- Pb - Pamboola Formation (2.8)

Model layer 11 (recharge mm/y)
- Jpx - Purlawaugh Formation (2.1)
- Rdh - Deriah Formation (0.6)
- Pwf - Watermark Formation (3.7)
- Pps - Porcupine Formation (3.7)
- Pmx - Maules Creek Formation (3.7)
- Pbr - Boggabri Volcanics (3.7)

Narrrabri Stage 3 Extension GIA (G1972)

## Recharge zones

DATE
27/05/2020

FIGURE No:
**D 2.7**

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Source: ELVIS LiDAR DEM © Spatial Services, Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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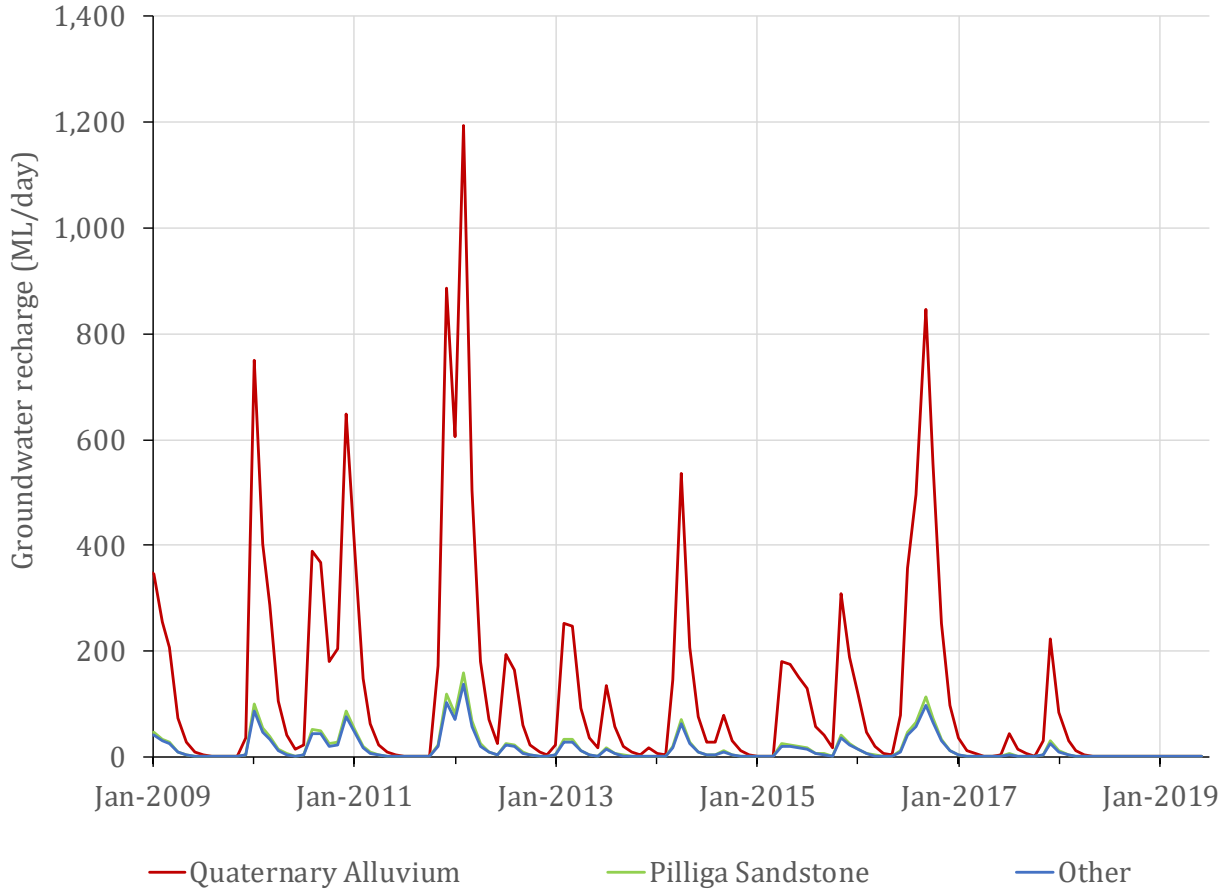


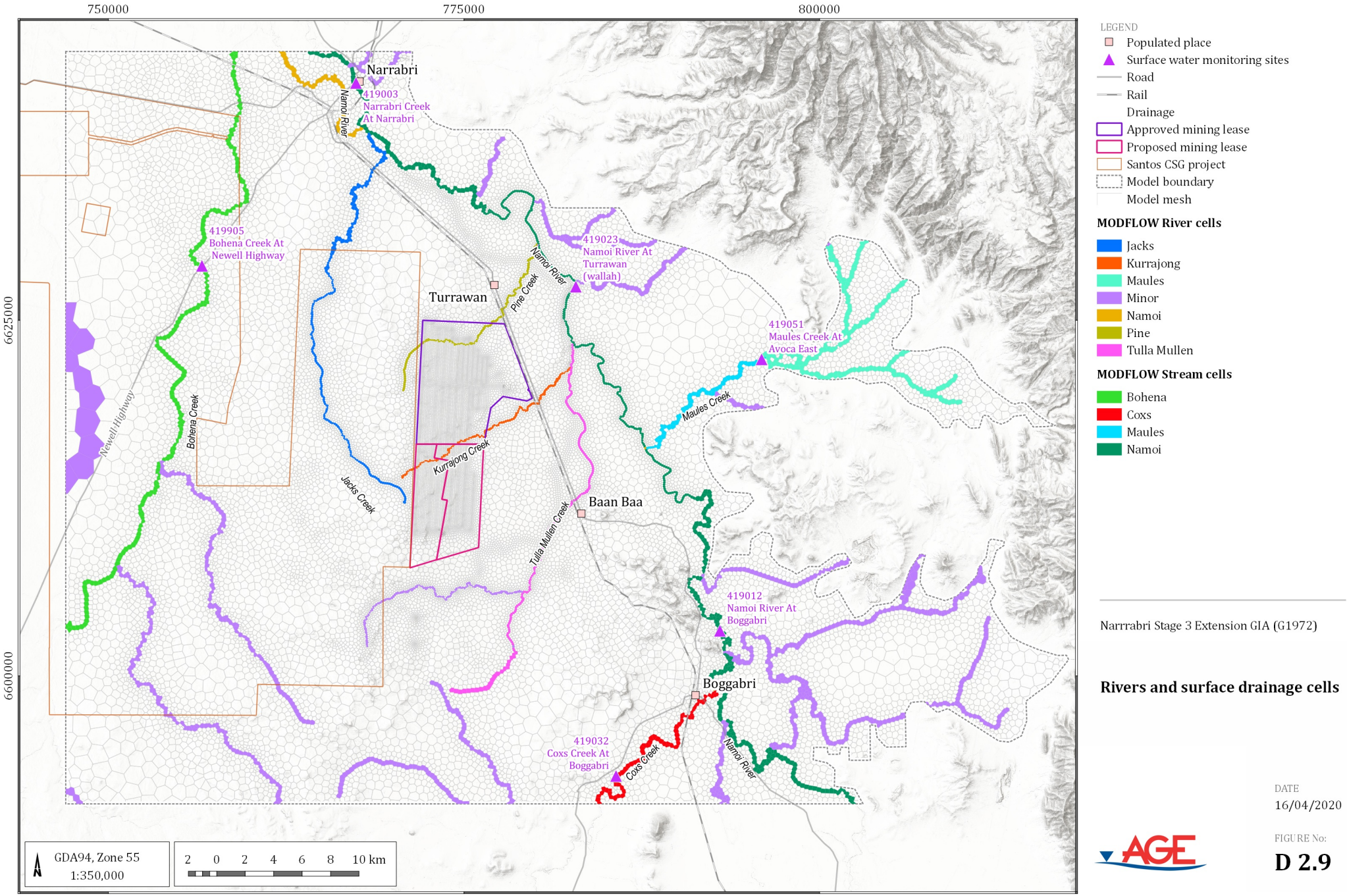

**Figure D 2.8 Pre-calibration recharge rates**

### *D 2.5.2 Surface drainage*

Groundwater interaction with surface drainage have been simulated using either the stream package (STR), or the river package (RIV) of MODFLOW. The cells assigned to these packages in the model were divided into zones or reaches to represent each of the drainage systems and are displayed on Figure D 2.9.

As shown in Figure D 2.9 the Namoi River and its major tributaries in the area Maules Creek, Cox's Creek and Bohena Creek have been simulated using the MODFLOW stream (STR) package. Flow in these water courses is less ephemeral than the other creeks in the area due to their relatively large catchments and in the Namoi due to discharges from upstream reservoirs. For these 'major' water courses the stream package has been used to ensure that the volume of modelled leakage cannot exceed the volume of flow gained upstream. Since a large part of the Maules Creek catchment is not included within the active model domain (Figure D 2.9) then MODFLOW STR cells have only been defined downstream of the location of the Avoca East flow gauge (419051).

Flow in all four of these major water courses is gauged within the model domain and data for these gauges has been used to parameterise the stream package and to generate suitable surface water flow targets for model calibration purposes, as described in Section D 3.2.4.




Narrrabri Stage 3 Extension GIA (G1972)

## Rivers and surface drainage cells

DATE
16/04/2020

FIGURE No:
**D 2.9**

©2020 Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) - www.ageconsultants.com.au
Source: ELVIS LiDAR DEM © Spatial Services, Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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The remaining mapped water courses in the area have been simulated using the MODFLOW river package but parameterised in a way that prevents any loss (i.e. they act like MODFLOW drains). This is achieved by setting the modelled river level to the same value as the bed level (i.e. assigning a water depth of zero). This representation is consistent with the highly ephemeral nature of these minor water courses. Flow is understood to occur in these channels only following heavy rainfall, suggesting limited interaction between groundwater and surface water in either direction. However, as discussed in Sections 5.7 and 5.8 of the main report groundwater discharge is thought to be occurring at a small number of locations in the Project Area including the Mayfield, Hardys and Eather springs, one site on a tributary of Kurrajong Creek and two sites on the Tulla Mullen Creek. Modelled groundwater discharge of greater than zero to the surface at each of these locations has therefore been included as a calibration target (Section D 3.2.5).

Initial parameterisation of each of the modelled stream and river segments are summarised in Table D 2.4 and Table D 2.5. Stream and river bed conductance were both adjusted as necessary during the calibration by varying vertical hydraulic conductivity over the range 0.001 to 10 m/d. Manning's coefficient values were based on the metric application of firm soil to gravel streambeds, which ranges from 0.025 to 0.035 (USGS, 1989). A value in the middle of this range was therefore selected for internal use by MODFLOW to calculate stage in stream cells based on the modelled streamflow and the bed slope (estimated at each location based on the modelled DTM). Stream and river cells were assigned to the highest active layer in the model at each cell location, which was generally layer 1 or layer 2.

### Table D 2.4 Modelled stream (STR) parameters

| Segment No. | Segment name | Initial vertical hydraulic conductivity Kz (m/day) | Width (m) | Bed thickness (m) | Incision Depth (m) | Slope | Manning's coefficient |
|---|---|---|---|---|---|---|---|
| 1 | Cox's Creek | 0.1 | 40.0 | 1 | 5 | 0.004 | 0.03 |
| 2 | Maules Creek | 0.1 | 40.0 | 1 | 5 | 0.004 | 0.03 |
| 3 | Bohena Creek | 0.1 | 40.0 | 1 | 5 | 0.004 | 0.03 |
| 3 | Namoi River upstream of the Cox's Creek confluence | 0.1 | 50.0 | 1 | 8 | 0.0005 | 0.03 |
| 4 | Namoi River upstream of the Maules Creek confluence | 0.1 | 50.0 | 1 | 8 | 0.0007 | 0.03 |
| 5 | Namoi River downstream of the Maules Creek confluence | 0.1 | 50.0 | 1 | 8 | 0.0015 | 0.03 |

## Table D 2.5 Modelled river (RIV) parameters

| Segment No. | Segment name | Initial vertical hydraulic conductivity Kz (m/day) | Width (m) | Bed thickness (m) | Incision depth (m) |
|---|---|---|---|---|---|
| 7 | Tulla Mullen Creek | 0.1 | 5.0 | 1 | 1-4 |
| 8 | Jacks Creek | 0.1 | 5.0 | 1 | 1-4 |
| 9 | Kurrajong Creek | 0.1 | 5.0 | 1 | 1-2 |
| 10 | Pine Creek | 0.1 | 5.0 | 1 | 1-2 |

Uncertainty in the representation of the rivers and creeks is introduced to the model through the adopted stream bed conductance and stream flow timing and rates in particular. As is usually the case no data on actual stream bed conductivity and/or conductance, which governs the degree of connectivity of surface water with groundwater, is available. This parameter has therefore been determined during the calibration process and was therefore also varied as part of the predictive uncertainty analysis, to confirm the degree to which predictions are affected by this unmeasured parameter. As discussed above, however, some flow data is available for all major water courses in the area and has been used to calibrate the model which should assist with reducing the predictive uncertainty deriving from these model parameters. Additional uncertainty can also arise from other model parameters listed in Table D 2.4 and Table D 2.5 which have adopted for use in the MODFLOW stream and river packages. However, since the vertical hydraulic conductivity of the stream/river bed can vary over several orders of magnitude, uncertainty in modelled interaction between groundwater and surface water resources tend to be dominated by vertical hydraulic conductivity, rather than channel width or bed thickness. Accordingly, the sensitivity of the model calibration and predictions have been assessed by considering a wide range of potential vertical hydraulic conductivity values such that varying this parameter also accounts for possible variations and discrepancies between modelled and actual channel width and other parameters.

### *D 2.5.3 Evapotranspiration*

Modelled evapotranspiration rates were guided by BOM areal actual evaporation rates averaging 630 mm/year. Evapotranspiration from the water table was represented in the numerical model using the MODFLOW evapotranspiration package (EVT). Evapotranspiration occurred from the upper most model cells across the model domain at a maximum rate of 630 mm/year, decreasing linearly to zero at the modelled extinction depth of 2 m below the surface.

Evapotranspiration, like recharge also varies spatially and is a function of similar factors including soil, land-use, geology, topography and depth to water table. Whilst there is inherent uncertainty in the volume of water removed by evapotranspiration from the water table, the process is only represented in the numerical model where the water table is within 2 m of the land surface. The water table is only close to the land surface in the numerical model in a thin riparian zone adjacent to the main rivers and creeks, and therefore only influences groundwater levels in these relatively narrow zones. In these zones depth of the river/creek bed and the nature of the stream (losing/gaining) also exerts significant control on the groundwater level, and in some areas may override the influence of the evapotranspiration on groundwater levels.

### *D 2.5.4 Abstraction*

Abstraction at estimated actual rates from all known licensed water supply bores in the Namoi Alluvium and other consolidated units have been included in the historic simulation. Known stock and domestic bores have also been included and assumed to operate at 20 ML/yr.

### *D 2.5.5 Lakes and dams*

There are no known large natural lakes or reservoirs within the model domain.

### *D 2.5.6 Mining*

Both historic and proposed future mining operations at the site have been simulated using the MODFLOW DRN (drain) package with the progression of mining over time based on the schedules provided by NCOPL. Goafing and fracturing above longwall panels in the underground mine was simulated using a methodology initially developed by AGE for use at the Integra mine (AGE, 2017) and subsequently applied to the simulation of underground coal mining operations at a number of other sites, including the Mount Owen Modification 2 (AGE, 2018), Glendell Continued Operations Project (AGE, 2019), and the Dendrobium groundwater model (HGEO, 2019).

For the most part the modelling approach outlined below in Sections D 2.5.6.1 to D 2.5.6.2 below is the same as that adopted for the Gateway Application modelling (HydroSimulations, 2019). The only significant deviation from the Gateway Application model is a slight refinement of the stacked drains approach, commonly used to represent underground coal mining operations, whereby the conductance of these cells is calculated empirically based on the expected intensity of fracturing at any given model cell, rather than being assumed. This key conductance parameter is then also subject to calibration, rather than being held constant, through comparison with actual data on pressure responses above existing longwall panels and estimated actual minewater inflows to the current mine (Section D 3.2).

#### *D 2.5.6.1 Fracture zone implementation*

Once the longwall mining has removed the coal seam and advanced, the roof strata subsides into the mined area creating a so called goaf zone within each longwall panel. This creates a zone of rubble within the goaf as the roof collapses which in turn also induces fracturing in the material above the spent coal seam. International and Australian research on longwall mining interaction with groundwater systems indicates that the overburden may be divided into four or five zones of surface and sub-surface fracturing with the degree of fracturing gradually decreasing with height above each longwall panel. Forster (1995) and ACARP (2007) define the following zones in descending order:

- Surface Zone (D-Zone).
- Elastic Zone (C-Zone).
- Discontinuous Fracture Zone (B-Zone).
- Continuous Fracture Zone (A-Zone).
- Caved Zone (included in the A-Zone).

Definition of the height of the continuous fracture zone (the A zone) above the mining zone represents a key component of the groundwater model developed to assess the project impacts. A detailed subsidence assessment was previously undertaken at the Gateway Application stage of the project based on observed subsidence and groundwater pressure responses above the workings at time (DGS, 2019). This assessment has now been updated based on the additional piezometer and extensometer data now available for longwall panel LW108A (DGS, 2020, see Section 5.2.11 in the main report) and concludes, based on the data available, that an A zone fracture height of 236 m should be adopted for this panel.

Predicted A zone fracture heights were then also calculated for all existing and proposed longwall panels based on the proposed depth of cover, panel width and mining height which are all known to affect the height of fracturing are summarised in Table D 2.6 and shown in Figure D 2.11. The predicted A zone fracture height represents a key input to the model as it governs the vertical extent of the strata affected by longwall mining.

Given the Narrabri Mine has been in operation since 2009 and data are available for a number of nested vibrating wire piezometers and extensometers installed above previously mine out longwall panels then predicted A zone heights are relatively well known for the Narrabri Mine, compared to say a greenfield site. Furthermore, as discussed in Section 7.2 of the main report the predicted A zone heights above most panels overlaps with the potential zone of subsidence induced surface cracking (Zone D). Accordingly seam to surface fracturing is simulated above most panels and hence in terms of the extent of the strata potentially affected by longwall mining the numerical model is considered to be close to a worst case. As discussed in Section 5.2.11 of the main report data for the nested vibrating wire piezometer monitoring site P57 above longwall panel LW180A also shows only minor groundwater level responses at 40 to 60 mbgl which suggests that seam to surface fracturing does not actually occur in practice. Consistent with this assessment the A zone fracture height has not been varied as part of the predictive uncertainty analysis (Section D 5). However, as summarised in Table D 5.7 a range of model parameters which affect the hydraulic conductivity and storage within the A zone have been assessed.

**Table D 2.6 Predicted sub-surface fracturing heights (A-Zone, DGS, 2020)**

| Longwall panel | Panel width, W(m) | Mining height, T (m) | Cover depth range (m) | Predicted A zone height range (m) | Depth to A zone range (m) | Depth to D zone (m) |
|---|---|---|---|---|---|---|
| 101 | 306 | 4.2 | 165-177 | 144-154 | 21-23 | 42 |
| 102 | 306 | 4.2 | 175-188 | 156-163 | 23-25 | 42 |
| 103 | 306 | 4.3 | 195-200 | 170-174 | 25-26 | 43 |
| 104 | 306 | 4.3 | 180-215 | 158-187 | 22-28 | 43 |
| 105 | 306 | 4.3 | 200-235 | 174-198 | 26-37 | 43 |
| 106 | 306 | 4.3 | 220-255 | 190-208 | 30-47 | 43 |
| 107 | 409 | 4.3 | 240-285 | 207-244 | 33-41 | 43 |
| 108a | 409 | 4.3 | 265-290 | 227-248 | 38-42 | 43 |
| 108b | 409 | 4.3 | 305 | 256 | 49 | 43 |
| 109 | 410 | 4.3 | 290-320 | 248-264 | 42-56 | 43 |
| 110 | 410 | 4.3 | 310-325 | 259-268 | 51-62 | 43 |
| 111 | 410 | 4.3 | 325-360 | 266-282 | 59-78 | 43 |
| 201 | 418 | 4.3 | 185 | 162 | 23 | 43 |
| 202 | 372 | 4.3 | 195 | 170 | 25 | 43 |
| 203 | 403 | 4.3 | 199-224 | 173-194 | 26-30 | 43 |
| 204 | 402 | 4.3 | 222-260 | 192-223 | 30-37 | 43 |
| 205 | 400 | 4.3 | 250-289 | 215-246 | 35-43 | 43 |
| 206 | 400 | 4.3 | 285-312 | 244-257 | 41-55 | 43 |
| 207 | 402 | 4.3 | 318-330 | 261-267 | 57-63 | 43 |
| 208 | 401 | 4.3 | 323-356 | 263-278 | 60-78 | 43 |
| 209 | 357 | 4.3 | 346-400 | 261-282 | 85-118 | 43 |
| 210 | 415 | 4.3 | 180-184 | 158-161 | 22-23 | 43 |

As shown in Table D 2.5 and Figure D 2.11 estimated A zone fracturing heights vary from 144 m above longwall panel LW101, towards the north east of the existing mineworkings where the coal is shallowest, to 282 m above longwall panels 111 and 209, at the western limit of the proposed mineworkings where the coal is at its deepest. There are no areas where the A zone is anticipated to reach the surface, although as discussed below (Section D 2.5.6.3) there are areas where the predicted A and D zones intersect and seam to surface fracturing is predicted to occur.

### *D 2.5.6.2 Drain conductance*

In addition to estimating the height of the A zone, representation of the impacts of longwall mining also require that the related increase in hydraulic conductivity (lateral and vertical) be quantified within each strata where fracturing is induced. As discussed above the degree of fracturing and hence the relative change in hydraulic conductivity typically reduces with height above the longwall panel. Accordingly, an estimate of the relative increase in hydraulic conductivity is required at the top and bottom of the A zone and also the rate at which the hydraulic conductivity increase declines with height. This is implemented in MODFLOW-USG by adjusting the conductance applied to drain cells emplaced into the A zone. Rather than assume an initial value for the drain conductance the parameter has instead been estimated based on the anticipated density of fracturing (Ap, expressed as the total aperture of fractures present within a 1 $m^3$ volume of aquifer material). Importantly this is a parameter which can be measured in the field, predicted using geomechanical modelling packages and which also represents the primary causal mechanism which increases the hydraulic conductivity in the first place. Unfortunately, no field measurements of Ap above existing longwall panels are available for the Narrabri Mine. However, previous projects informed by geomechanical modelling and/or groundwater model calibration suggest total fracture aperture (Ap) values ranging from 30 mm to 120 $mm/m^3$ immediately above longwall panels to 0.1 mm to 0.3 $mm/m^3$ at the top of the A zone. Accordingly, as shown in Table D 2.7 values at the centre of these range were adopted as initial values during model calibration.

**Table D 2.7 Range in fracture network aperture within A zone**

| Height above coal seam (% within A zone) | Number of studies | Fracture aperture (*Ap*) ($mm/m^2$) – initial value | Fracture aperture (*Ap*) ($mm/m^2$) – calibration range |
|---|---|---|---|
| 0% (e.g. above Hoskissons Coal Seam) | 5 | 75 | 30 to 120 |
| 100% (e.g ~170 to 270 m) | 5 | 1.55 | 0.1 to 3 |

Drain conductance, or 'fracture conductance' ($\alpha_{fn}$), was then calculated using a modified form of the Thiem equation which is also used in the MODFLOW-USG connected linear network package (CLN, Panday et al., 2013), as follows:

$$\alpha_{fn} = \left[ \frac{\ln\left(\frac{r_{oz}}{r_n}\right) + S_f}{2\pi l K_v \sqrt{1/\Re_{rz}}} \right]$$

where,

$r_{oz}$ = effective external radius of MODFLOW cell to fractured network

$r_n$ = effective radius of the fracture network ($A_p$)

$S_f$ = skin factor

$l$ = effective thickness of fracturing within the model cell

$K_v$ = host vertical hydraulic conductivity

$\Re_{rz}$ = x:y anisotropy ratio ($K_{xx}/K_{yy}$)

Importantly this equation also deals with the partial penetration of fractures within model layers, via the inclusion of the effective thickness of fracturing term ($l$) as well as the cell radius ($r_{oz}$) term. Hence there is no need for the model geometry to be adjusted to ensure that the estimated height of the A zone coincides with the top or bottom of a model layer.

Previous studies (including Guo, 2007) suggest that delamination of strata within the A zone causes the horizontal hydraulic conductivity to enhance to a much higher rate than the effective vertical hydraulic conductivity. To simulate this phenomenon, the drain cells applied to represent longwall fracturing remained active for the entirety of the predictive model simulation; effectively replicating the transmissive flow network established once longwall mining advances. To ensure complete drainage of the goaf, a conductance value of 100 $m^2$/day was also applied to the mined coal seam. Drain conductance applied to the remaining cells within the A zone above the coal seam calculated using the equation above ranged from approximately $1x10^{-4}$ to 0.06 $m^2$/day, which was highly dependent on the host permeability of the fractured strata and the thickness and penetration of the model cell. Drain conductance was dynamically calculated during model calibration and as part of the uncertainty analysis.

A separate model run was undertaken to simulate recovery of the groundwater system once all longwall mining is complete. For this simulation the drain cells were removed, and the hydraulic conductivity enhanced to represent the residual fracture network. The hydraulic conductivity of the residual fracture network was back-calculated from drain conductance values ($\alpha_{fn}$) derived using the Thiem approach described above.

The vertical hydraulic conductivity ($Kv_{frac}$) of model cells falling within the modelled A zone was calculated for the recovery simulation using the following equation:

$$Kv_{frac} = \frac{\alpha_{fn} w}{lw}$$

where,

$\alpha_{fn}$ = fracture conductance ($m^2$/day)

$w$ = cell width (m)

$l$ = cell thickness (m)

Based on the work of Guo (2007) an equation was derived, to estimate post mining horizontal hydraulic conductivity within the A zone ($Kh_{frac}$) from $Kv_{frac}$ and depending on the proximity the cell to the top of the modelling coal seam, as follows:

$$Khc_{frac} = \left(\frac{2(Kv_{frac} - Kv)}{\log(c)}\right)^5$$

$$Kh_{frac} = Kh * Khc_{frac}$$

where,

$Kv$ = Host vertical hydraulic conductivity (m/day)

$Khc_{frac}$ = horizontal hydraulic conductivity change factor

$c$ = height above top of coal seam (m)

Horizontal and vertical hydraulic conductivity values calculated using the equations shown above were applied to the recovery model once mining was complete. Specific yield and specific storage parameters representing highly fractured goaf zones were also applied to the Hoskissons Coal Seam layer only (i.e. layer 9). Table D 2.8 and Figure D 2.10 presents the actual values of $Khc_{frac}$ applied to the recovery model stress periods compared to the same simulated factors presented in Guo (2007). The results show good agreement between the Guo simulations.

**Table D 2.8 Recovery model underground parameters**

| Recovery model zone | Horizontal hydraulic conductivity Kh (m/day) | Vertical hydraulic conductivity Kv (m/day) | Specific storage (m-1) | Specific yield (%) |
|---|---|---|---|---|
| Mined coal seam fracture zone and goaf | $Kh_{frac}$ | $Kv_{frac}$ | 1 x $10^{-6}$ | 0.1 |
| Main/access roads | 100 | 100 | 1 x $10^{-5}$ | 1.0 |

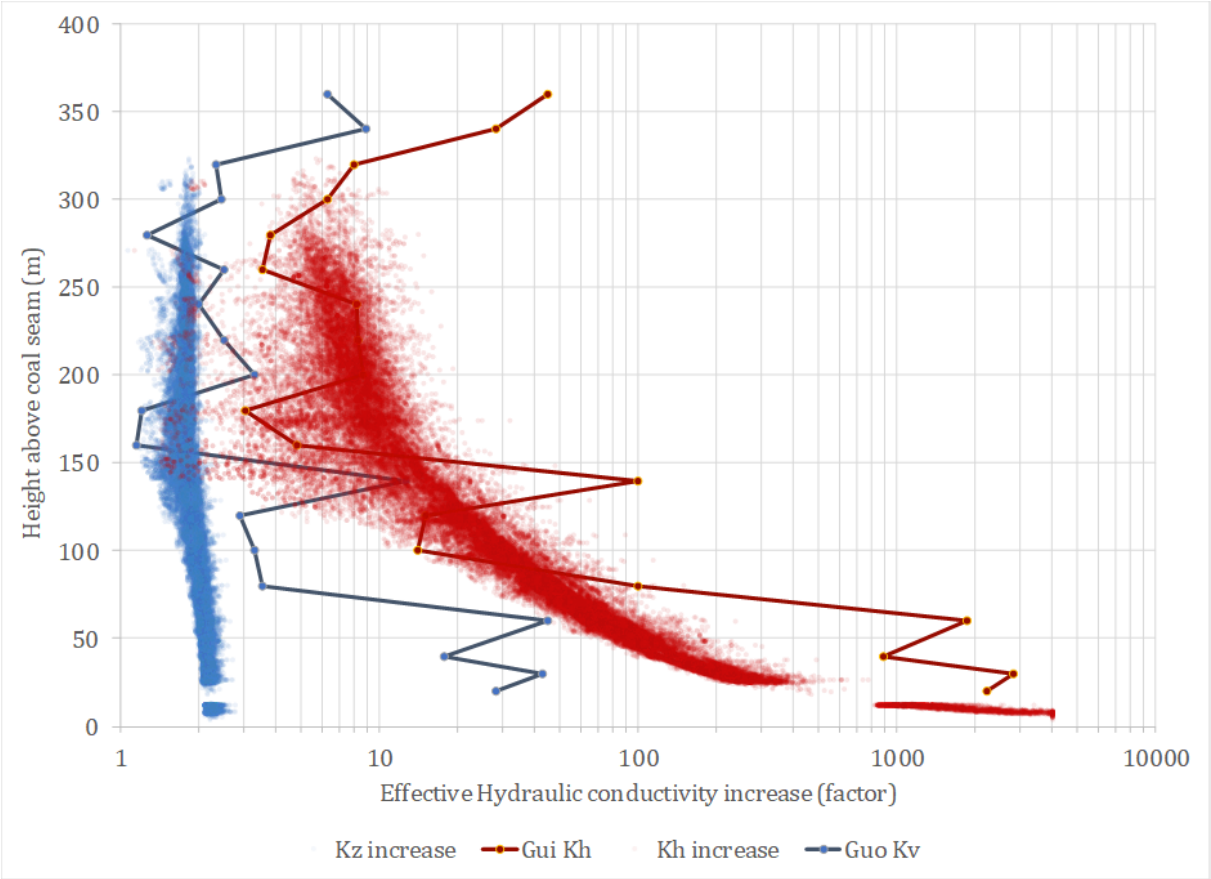



**Figure D 2.10 Hydraulic conductivity increase during recovery vs. Guo et Al (2007)**

Main/access roads were simulated using drain cells with a drain conductance of 100 $m^2$/day. Post-mining, main road cells were converted to replicate void properties with high hydraulic conductivity and storage.

### *D 2.5.6.3 Surface cracking zone implementation*

As discussed above (Section D 2.5.6.1) ACARP (2007) also define a separate surface zone subject to subsidence induce cracking (Zone D) which can lead to temporary increases in hydraulic conductivity and storage in strata affected. Longer term the values of these hydraulic parameters tend to revert to background, since the induced near surface fractures are readily filled with fine material.

Anecdotal descriptions of farm dams within the existing Narrabri mine footprint draining as they were under-mined and then re-filling later are thought to be a reflection of this process. Previous estimates of the depth of surface cracking include:

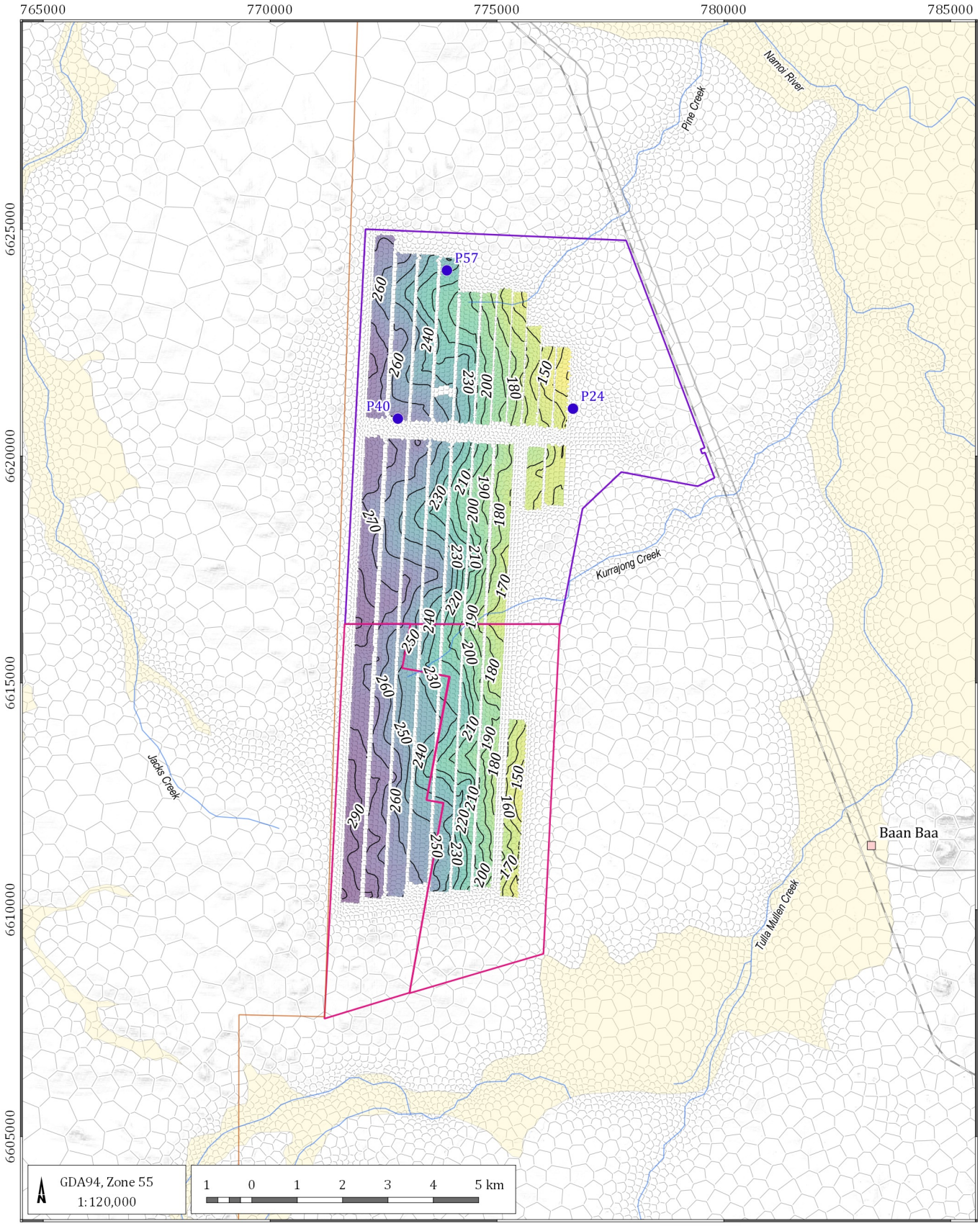
- 20 to 30 m at Springvale, 7 to 10 times the mining height (Guo et al, 2007);
- up to 15 m Kendorski (2006); and
- 10 to 15 m (Ditton and Merrick, 2014).

As shown in Table D 2.6 based on the upper bound estimated by Guo et al (2007) a value of 10 times the mining height (T), i.e. 43 m has been conservatively assumed for this assessment. Model cells falling into this zone within 43 m of the surface were subject to the parameter enhancements shown in Table D 2.9 during the period of mining only. Post mining then these parameters revert to pre-mining values. Values were also allowed to vary during calibration within the ranges shown in Table D 2.9.

### Table D 2.9 Surface cracking zone, modelled hydraulic parameter enhancements

| Parameter | Initial multiplier | Calibration range |
|---|---|---|
| Horizontal hydraulic conductivity (Kh) | 3 | 1-10 |
| Vertical hydraulic conductivity (Kv) | 2 | 1-5 |
| Specific yield | 2 | 1-3 |
| Specific storage | 2 | 1-3 |

As shown in Table D 2.6 predicted A zone fracture heights above panels 101 to 109 inclusive, 201 to 206 inclusive and 210 extend to within 43 m of the ground surface and therefore intersect with the base of the modelled surface cracking (D zone). Through modelling of hydraulic conductivity and storage increases in both the A zone and D zone then fracturing from the top of the Hoskissons Coal Seam to the ground surface is simulated above these panels.




LEGEND

- Nested monitoring bores
- Populated place
- Road
- Rail
- Drainage
- Quaternary alluvium
- Approved mining lease
- Proposed mining lease
- Santos CSG project
- Model mesh

**Fracture height (mAHD)**

- 100
- 150
- 200
- 250
- 300
- Contour line

Narrrabri Stage 3 Extension GIA (G1972)

## Modelled A Zone fracture height (DGS, 2020)

DATE 27/05/2020

FIGURE No: **D 2.11**

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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\G1972.Narrrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 02.11_G1972_Modelled A Zone fracture height (DGS, 2020).qgs

# D 3 Model calibration

## D 3.1 Calibration method

The groundwater model was calibrated through reference to a pre-mining steady state run and a transient run (January 2009 to June 2019) predominantly using available groundwater level data, estimated actual mine inflows and estimated baseflows in major local water courses. Calibration was achieved by adjusting a number of modelled parameters and stresses to produce the best possible statistical match between modelled outputs and observed targets (or observations). Manual testing and automated parameterisation software (PEST_HP, Doherty 2018) were used to determine optimal hydraulic parameters and recharge rates to achieve the best history match to the available observations.

As with all models the resulting calibration is non-unique, that is an alternative set of parameters could produce an equally valid calibration, especially where simulations are sensitive to parameter combinations that lie within the calibration null space. The calibration null space refers to the model parameters and parameter combinations that are not informed by the available observations. A model calibrated in this way is classified as conditionally calibrated (verified) in that it has not yet been falsified by tests against observational data (Middlemis & Peeters, 2018).

## D 3.2 Calibration targets

### *D 3.2.1 Groundwater levels*

The steady state and transient model simulated water levels in all available monitoring bores within the bedrock and alluvial aquifers. A total of 262 monitoring points were used to calibrate the model, comprising:

- 129 NSW State groundwater monitoring points, predominantly completed into the Namoi Alluvium;
- 115 monitoring points which form part of the Narrabri Coal Mine monitoring network including a number of nested Vibrating Wire Piezometer (VWP) facilities; and
- 18 monitoring points installed in the area to the west of the existing Narrabri coal mine as part of the Narrabri Gas Project EIS.

A summary of the available calibration data by formation and model layer is shown in Table D 3.1 below.

As shown on Table D 3.1 and Figure D 3.1, whilst data are available for a relatively large number of monitoring points and in all model layers the spatial coverage is variable. Notable gaps in the monitoring network include the Quaternary Alluvium associated with the Tulla Mullen Creek to south and south-east of the proposed mining area. There are also relatively few monitoring bores in the underlying units in this area. Conversely the data coverage at multiple levels within the existing mine area is considered to be very good.

### Table D 3.1 Groundwater monitoring locations by model layer and data source

| Formation (model layer) | Narrabri Coal Mine | Narrabri Gas Project, Santos | NSW State Monitoring Bore | Total |
|---|---|---|---|---|
| Alluvium (layer 1) | 9 | - | 91 | 101 |
| Pilliga Sandstone (layer 2) | 4 | 12 | 4 | 21 |
| Purlawaugh Formation (layer 3) | 13 | 2 | 2 | 10 |
| Garrawilla Volcanics (layer 4) | 11 | - | 3 | 14 |
| Napperby Formation (layer 5) | 27 | 1 | 4 | 23 |
| Digby Formation (layers 6 to 8) | 7 | 2 | 5 | 14 |
| Hoskissons Coal Seam (layer 9) | 13 | - | 1 | 15 |
| Arkarula Formation (layer 10) | 7 | 1 | 18 | 23 |
| Pamboola Formation (layer 11) | 10 | - | - | 5 |
| Older units (NA) | 14 | - | 1 | 3 |
| **Total** | **115** | **18** | **129** | **229** |

Middlemis & Peeters (2018) suggest groundwater assessments consider the uncertainty around measurements used during the modelling process. The groundwater levels within the monitoring networks are typically either measured manually with electronic water level dippers or using pressure transducers and the water level converted to an elevation based on surveyed levels at measurement point which is usually the top of bore casing. Modern electronic water level dippers and pressure transducers are expected to be accurate to within ±1 cm, and with the measurement point elevation also ±1 m to 10 cm depending on the method of surveying. The measurement of water levels within the monitoring network is therefore considered unlikely to have introduced any significant uncertainty to the model predictions. Vibrating wire piezometers in contrast measure pore pressure which is converted to a potentiometric surface based on the elevation of the VWP sensor. The VWPs are sealed with cement grout within the boreholes and therefore cannot be validated, or the data loggers checked for instrument drift. Therefore, the measurement error for the VWPs is considered likely to be higher than monitoring bores and possibly in the range of ±5 m to 10 m. Despite the potential for a larger measurement error in the VWP data, when used with caution it is still considered a useful additional dataset to understand the groundwater regime and guide the calibration of the numerical model where the observed pressure changes are considered conceptually sound.

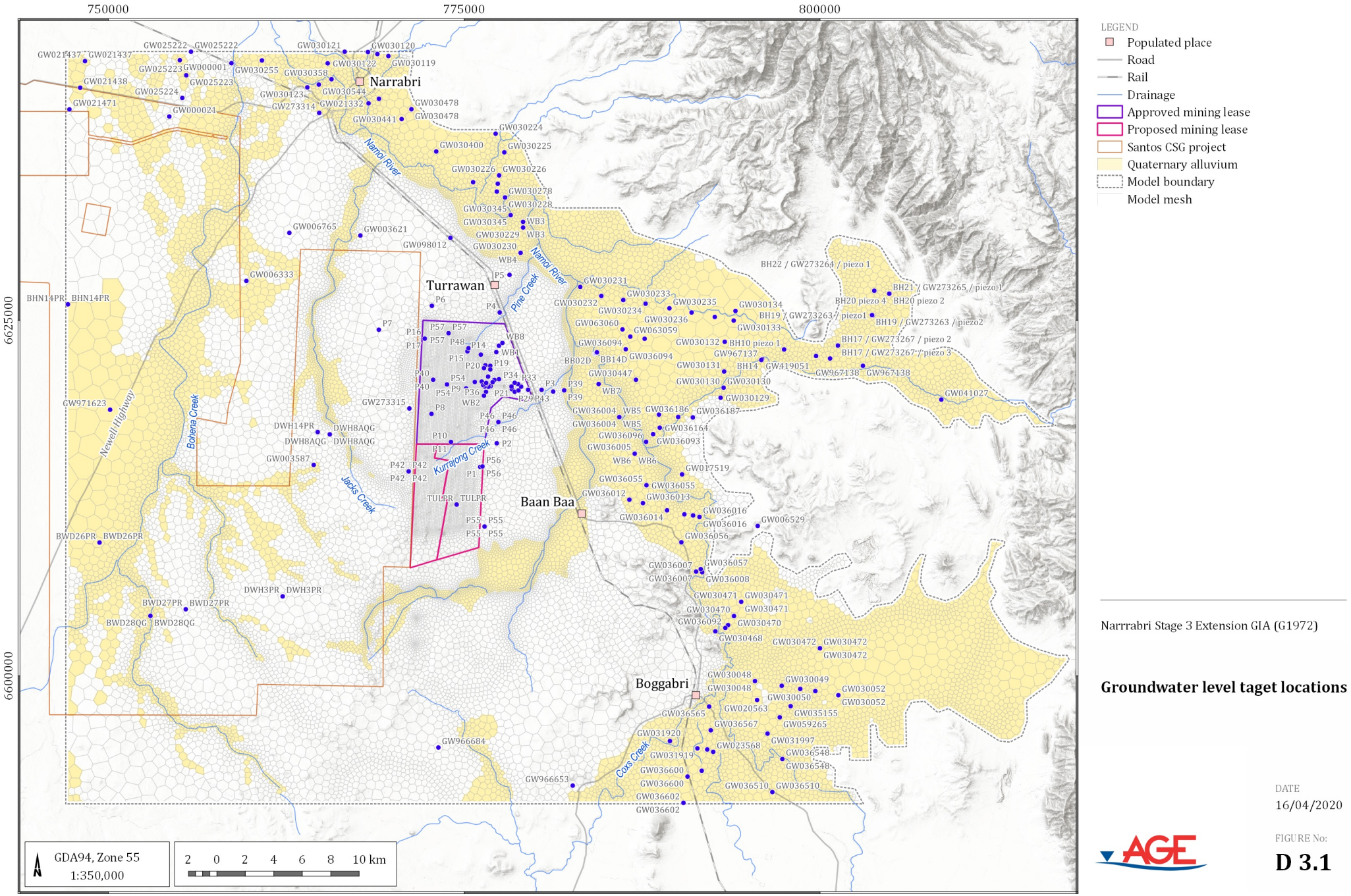
Figure D 3.1 shows the location of observation bores that were used in the calibration process. For model calibration purposes the observation bore water level records were weighted as follows:

- obviously anomalous results were removed;
- datalogger data was reduced to a monthly frequency; and
- datapoints for each location were weighted according to the formula:

$$\text{weight of datapoint} = 1/\sqrt{(\text{number of points for that site})}.$$

Using this method bores with longer records have a lower weighting per datapoint, but a higher overall weighting in the combined dataset.

The model was calibrated to the observed water level datasets, with the 'best calibrated' model returning the lowest objective function (phi) value i.e., the lowest statistical difference between the observed and modelled values across the chosen dataset.




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Approved mining lease
- Proposed mining lease
- Santos CSG project
- Quaternary alluvium
- Model boundary
- Model mesh

Narrrabri Stage 3 Extension GIA (G1972)

**Groundwater level taget locations**

DATE
16/04/2020

FIGURE No:
**D 3.1**

©2020 Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) - www.ageconsultants.com.au
Source: ELVIS LiDAR DEM © Spatial Services, Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1972.Narrrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 03.01_G1972_Groundwater level taget locations.qgs

### *D 3.2.2 Groundwater level head differences*

Data for nested monitoring locations form key data for model calibration since they directly inform modelled vertical hydraulic conductivity, a parameter for which there is typically little or no actual data, particularly at the same scale as the model layers. As discussed in Section 5.2.11 of the main report data are available for ten nested VWP facilities located in and around the existing Narrabri Mine area. In addition to including time series of observed groundwater levels at each of these monitoring points a second set of transient head difference observations has also been included in the calibration. These observations have been created by calculating the observed head differences between pairs of monitoring points in adjacent layers. A summary of the layers monitored and the number of pairs of monitoring point used for model calibration at each location is presented in Table D 3.2.

**Table D 3.2 Vertical head difference target summary**

| Nested VWP Monitoring Point ID | Depth range (mbgl) | Formation range | Number of monitoring points | Number of monitoring point pairs |
|---|---|---|---|---|
| P24 | 112-180 | Napperby to Arkarula (layer 7 to 10) | 4 | 3 |
| P40 | 95 – 357 | Purlawaugh to Arkarula (layer 3 to 10) | 6 | 5 |
| P42 | 90 – 415 | Pilliga Sandstone to Arkarula (layer 2 to 10) | 6 | 5 |
| P44 | 95 – 245 | Napperby to Pamboola (layer 7to 11) | 3 | 2 |
| P45 | 42-80 | Digby to Arkarula (layer 8 to 10) | 2 | 1 |
| P46 | 70-151 | Digby to Pamboola (layer 8 to 11) | 3 | 2 |
| P54 | 28-336 | Pilliga to Arkarula (layer 2 to 10) | 9 | 8 |
| P55 | 18-221 | Purlwaugh to Pamboola (layer 3 to 11) | 9 | 8 |
| P56 | 55-300 | Napperby to Pamboola (layer 7 to 11) | 7 | 6 |
| P57 | 40-180 | Purlwaugh to Napperby (layer 3 to 7) | 8 | 7 |
| | | **Total** | **57** | **47** |

### *D 3.2.3 Mine Inflows*

Estimated actual inflows to the current mineworking (see Figure D 3.2), as calculated using a separate mine water balance model (WRM ,2019), have also been used as a target during the transient calibration. As shown in Figure D 3.2 estimated actual inflow has risen gradually since 2010 to around 1.5 ML/d in late 2018.

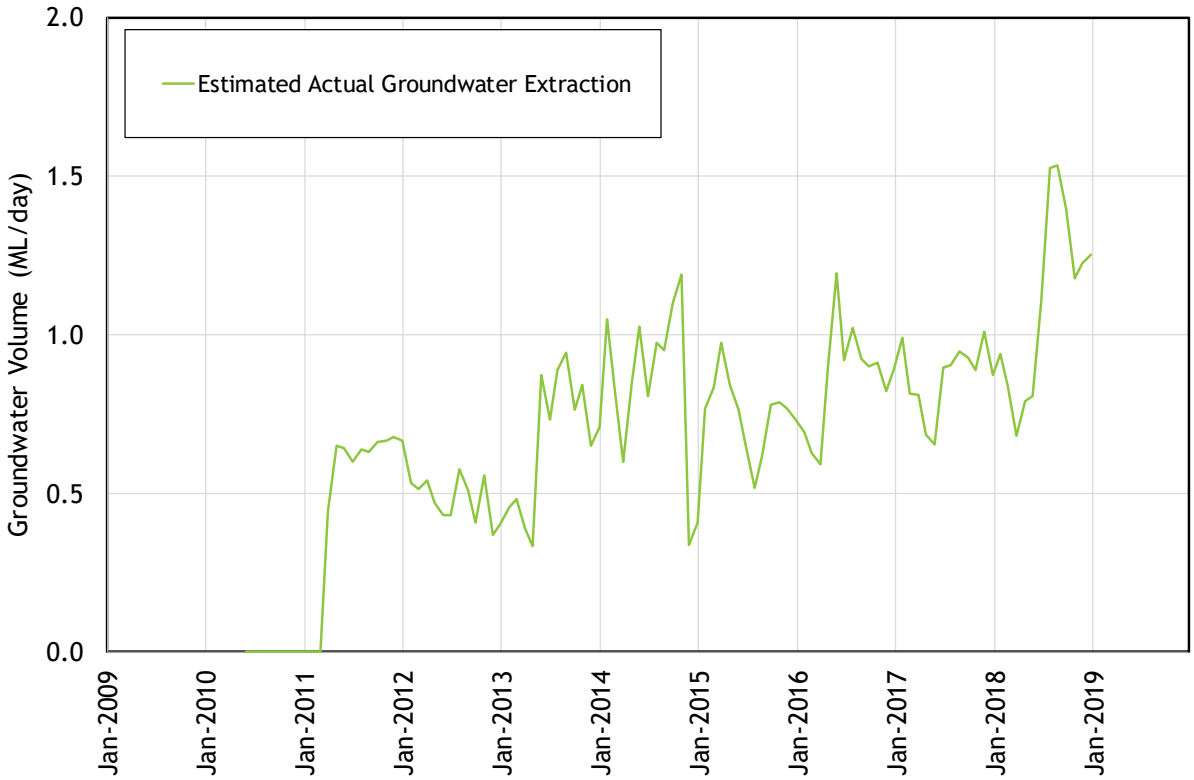



**Figure D 3.2 Calibration targets – estimated mine inflow (WRM, 2019)**

### *D 3.2.4 Estimated baseflow*

As discussed previously in Section D 2.5.2 surface water flow data are available for each of the main creeks represented using the MODFLOW stream package. Flow in the Namoi River/Narrabri Creek are gauged at three locations within the model domain at Boggabri (419012), Turrawan (419023) and Narrabri (419003) and data are also available for the gauge at Gunnedah (419001) upstream. Data are also available for the Bohena Creek at the Newell Highway (419905), the Maules Creek at Avoca East (419051) and Cox's Creek at Boggabri (419032).

Since the numerical model does not simulate surface water runoff then it was first necessary to estimate groundwater baseflow from the observed total surface water flow. This was undertaken using the relatively simple approach developed by the UK Institute of Hydrology (IoH) which is based on the identification and interpolation of turning points within an input flow data time series (Institute of Hydrology, 1980). The results of this baseflow separation exercise are summarised in Table D 3.3 below. As a check on this method the filtering method developed by Lynne and Hollick (1979) was also applied to the data for the Narrabri gauging station and returned a baseflow index within 1% of the IoH 15 day turning point estimate for the same gauge adopting an alpha parameter of 0.93.

Monthly average baseflow time series used directly for model calibration over the model calibration period January 2009 to June 2019 are shown in Figure D 3.3. No data are available for the Bohena Creek gauge during the transient calibration period, however, the estimated long term average baseflow for this gauge (Table D 3.3) has been incorporated as a steady state target. As shown in Figure D 2.9 the start of the modelled stream reaches occurs at or close to the Cox's Creek and Maules Creek gauges. Accordingly estimated baseflow data for these gauges (Figure D 3.4) has been used as an input to the MODFLOW stream package rather than calibration targets.

Similarly, baseflow in the Namoi River at the upstream boundary of the model domain has been estimated based on the catchment area of the Namoi at the upstream model boundary (18,022 km$^2$) and scaling estimated baseflows at the nearest upstream gauge (Gunnedah, 419001).

As discussed above modelled streamflows entering the model domain at the upstream boundary are based on estimated baseflows rather than total flow. This approach was adopted due to the size of the upstream catchment area and the magnitude of surface water flows reporting to the upstream boundary of the model during high flow periods. The MODFLOW stream package is often used in preference to the MODFLOW river package in models where induced losses could theoretically exceed the volume of flow in the river. Unlike the river package flows are routed between modelled stream cells and hence the losses to groundwater cannot exceed total modelled flow in the river. In this case, however, given the size of the upstream catchment then such a situation was considered unlikely to occur. Current mine inflows (up to 1.5 ML/d) represent only around 0.1% of long term average observed total flow at Gunnedah upstream of the modelled domain and only around 0.3% of estimated long term average baseflow at the same point (Table D 3.3). Hence it was considered extremely unlikely that modelled flow in the river during wet periods would have any material impact on predicted impacts. With this lack of sensitivity in mind estimated baseflow, rather than total flow, was applied at the upstream boundary since the calibration period includes several large events including a peak flow of almost 70,000 ML/d in February 2012. In practice such events would likely result in significant out of bank flow and are therefore difficult to simulate realistically using the MODFLOW stream package which relies on single width, slope and roughness parameters and assumes a rectangular channel to estimate the stream stage. Without complicated external calculations it can be difficult to prevent MODFLOW calculating unrealistically high stages during high flow events resulting in model instability and/or and calibration errors. It is recognised therefore that the modelled flow in the Namoi River is likely to be somewhat lower than actual during high flow periods. However, accurate modelling of such events is typically not possible using MODFLOW or required to assess impacts on baseflow. Conversely losses could theoretically be limited by flow in the river during low flow periods. However, total flow and baseflow will be the same during such periods and hence the exclusion of runoff from streamflows entering the model domain are not expected to have any material impact on predictions.

Estimated baseflow losses over the entire river reach from Boggabri to Narrabri (rather than from Boggabri to Turrawan and Turrwan to Narrabri, Figure D 3.5) has been adopted as the model calibration target. As shown in Figure D 3.5 this data set suggests minor baseflow gains of, typically around 10 ML/d, during low flows periods (e.g. mid 2014) interspersed with large gains or losses which typically occur during high flow periods. The former low flow periods have been given more weight in the calibration since the baseflow separation is more likely to be accurate during such periods. Conversely, baseflow separation is particularly difficult during periods when flows are increasing rapidly and apparent gains and losses can also be caused by the passage of flood peaks down the river.

**Table D 3.3 Baseflow separation results**

| Location | Catchment Area (km²) | Average total flow (Ml/d) | Average baseflow (ML/d) | Baseflow ML/d/km² | Baseflow Index (%) | Turning point period length (days) | Data Period |
|---|---|---|---|---|---|---|---|
| **Namoi River / Narrabri Creek** | | | | | | | |
| Gunnedah (419001) | 17,100 | 1481 | 567 | 0.033 | 38 | 15 | May 1976 to Oct 2019 |
| Boggabri (419012) | 22,600 | 1531 | 522 | 0.068 | 34 | 15 | Dec 1979 to Oct 2019 |
| Turrawan (419023) | 24,500 | 1280 | 375 | 0.052 | 29 | 15 | May 1995 to Dec 2000 and Mar 2001 to Oct 2019 |
| Narrabri (419003) | 25,400 | 1351 | 464 | 0.018 | 34 | 15 | Jul 1993 to Oct 2019 |

| Location | Catchment Area (km²) | Average total flow (Ml/d) | Average baseflow (ML/d) | Baseflow ML/d/km² | Baseflow Index (%) | Turning point period length (days) | Data Period |
|---|---|---|---|---|---|---|---|
| **Other creeks** | | | | | | | |
| Maules Creek at Avoca East (419051) | 739 | 51 | 14 | 0.019 | 27 | 10 | Aug 1984 to Oct 2019 |
| Cox's Creek at Boggabri (419032) | 4,040 | 206 | 9 | 0.002 | 4 | 10 | Feb 1979 to Oct 2019 |
| Bohena Creek at Newell Highway (419905) | 2,180 | 121 | 52 | 0.024 | 43 | 10 | Sep 1995 to Jun 2005 |

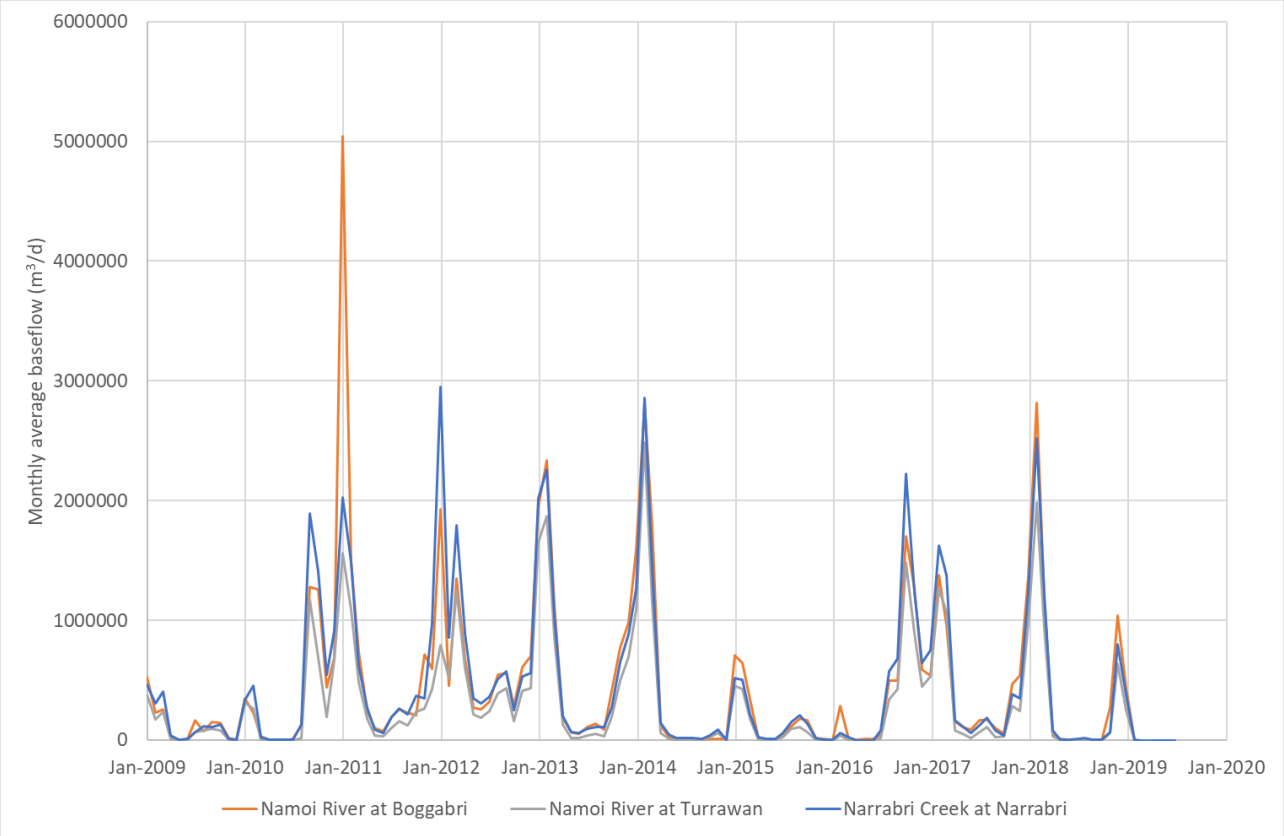



**Figure D 3.3 Estimated baseflow, Namoi River**

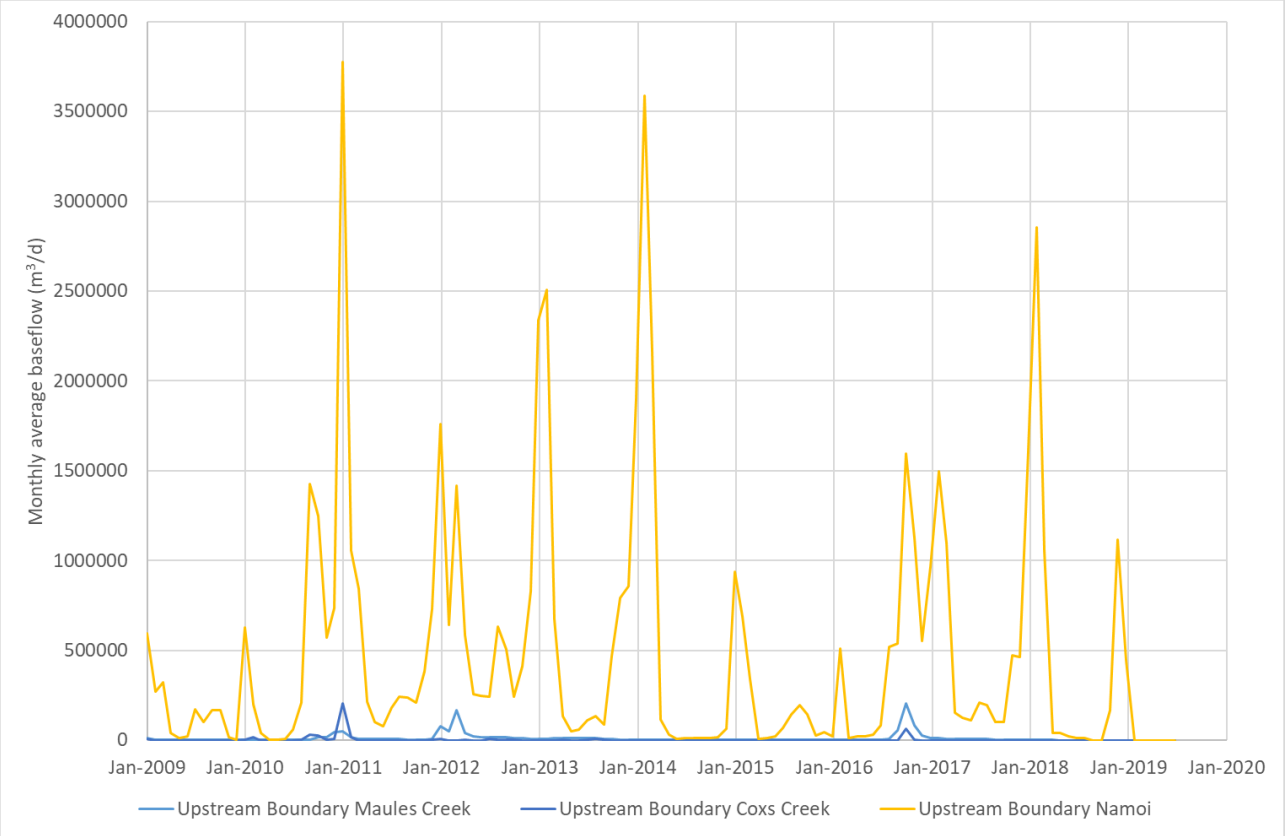



**Figure D 3.4 Estimated baseflow at upstream stream boundary**

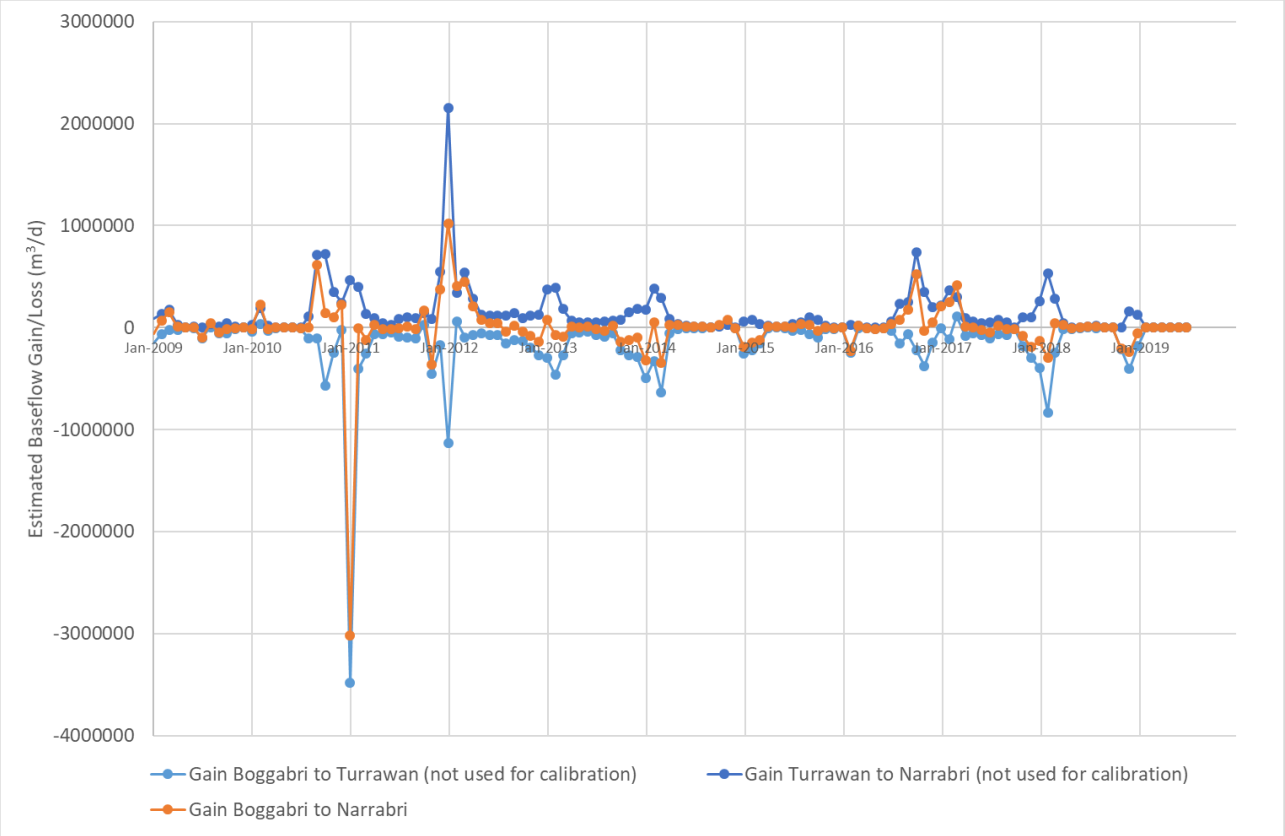



**Figure D 3.5 Calibration targets – baseflow gain, Namoi River**

### *D 3.2.5 Springs and other groundwater expressions*

As discussed in Sections 5.7 and 5.8 of the main report, potential groundwater discharge, or near surface groundwater, has previously been reported to be occurring at a number of other locations in and around the existing and proposed mining area including via three springs (Mayfield, Hardys and Eather Springs) to the south of the existing mine workings, at two locations on the Tulla Mullen Creek and one on a tributary of the Kurrajong Creek. No monitoring of flows and/or groundwater levels is currently undertaken at these locations and recent field investigations suggest that groundwater discharge may no longer be occurring at the Hardy's and Eather Spring sites and that there is no observable flow at the Mayfield Spring. However, they are all sites where groundwater has been observed at the ground surface at some point in the past. Accordingly, a calibration target that modelled head should be at the modelled ground surface at each of these locations has been incorporated into the observation data set. However, as there is no observable flow at any of these sites they were not considered suitable locations for calibration flow targets.

## D 3.3 Pilot points

The model domain contains a significant network of monitoring bores and water level datasets. The water level responses recorded in the monitoring points (as discussed in the main report Section 5.2) vary depending on a range of factors including geology, location, climatic conditions and mining activities. Water levels recorded in the monitoring points indicate heterogeneous hydraulic properties and recharge rates. To represent heterogeneity within the model domain and provide a degree of flexibility during the calibration, a series of pilot points were added to each model layer. The locations of the pilot points in each model layer are shown in Figure D 3.6, hydraulic parameter values and recharge at each pilot shown were adjusted during the calibration.

Parameter values at each pilot point were interpolated across the model domain in each layer of the model using ordinary automatic Kriging implemented via the PLPROC utility which forms part of the PEST suite of software (Watermark Numerical Computing, 2015). Horizontal (Kh) and vertical conductivity (Kv) were then adjusted where necessary from their initial values using a multiplier field subject to the constraints shown in Table D 3.4. The initial hydraulic conductivity values and ranges used for calibration shown in Table D 3.4 were derived primarily based on the available hydraulic testing results available for the Narrabri area (as described in Section 5.3 of the main report).

Initial values and calibration ranges for the alluvium (model layer 1) were based on previous detailed modelling of the Namoi Alluvium (McNeilage, 2006). In the absence of any local testing colluvium and regolith strata which also form part of layer 1 were assumed be an order of magnitude and two orders of magnitude respectively lower than the alluvium. Where necessary ranges to be used for calibration were increased to ensure that the adopted range encompassed values resulting from previous calibration of the Gateway Application model (HydroSimulations, 2019).

Anisotropy values and ranges for calibration were defined through reference to the thickness, degree of consolidation and average lithological composition of each model layer (see Figure 4.2 in the main report) as well as previous model calibrations. Hence relatively thin and/or homogenous consolidated layers including the Pilliga Sandstone, Garrawilla Volcanics, Napperby Sill, Digby Conglomerate, Hoskissons Coal Seam and Arkarula Formation were assigned initial anisotropy ratios of 100 and a range of 10 to 1000 used for calibration. The same initial value and range was adopted for the Quaternary alluvium, colluvium and regolith in model layer 1. A higher initial anisotropy of 1000 was assigned to the remaining consolidated layers (the Purlawaugh, Napperby and Pamboola formations) on the basis that these units are relatively thick and/or more lithologically heterogenous. These relatively large initial values and ranges are supported by the available field data and also previous model calibration results (HydroSimulations, 2019).

All pilot points in each layer/zone were assigned a single value initially, apart from pilot points used to represent the Hoskissons Coal Seam (model layer 9), the hydraulic conductivity of which was assumed to reduce with depth. The same equation used to parameterise the coal in the BTM complex model has been adopted albeit with a slightly lower intercept value of 0.1 m/d (i.e. theoretical coal hydraulic conductivity at the surface). The following equation has therefore been used:

$$\text{Coal Kh (m/d)} = 0.1\ EXP^{-0.026d}$$

Where: d = depth to coal

In the absence of local test results for the most part specific storage values are constrained by literature ranges (Rau et al, 2018 in particular), derived from regional studies of similar strata, using the relationship between bulk modulus, Poisson's ratio, and effective porosity, to calculate a physically possible value. As per hydraulic conductivity initial values and calibration ranges for specific yield in the alluvium are based on previous detailed modelling results (McNeilage, 2006).

Adopted initial specific yield and specific storage and calibration ranges are summarised in Table D 3.5.

To calibrate the model, the pilot point multipliers for Kx were allowed to vary ±1 orders of magnitude from the starting point. Figure D 3.6 presents the locations of the pilot point multipliers applied to the model layers. The density of the pilot points applied to layer 2 and below was higher around the Narrabri mine corresponding with the spatial resolution of the observation data. The number of pilot points in the Narrabri Project area applied to specific yield and specific storages was reduced to optimise the calibration process. The starting point for all multipliers was assumed to be 1.

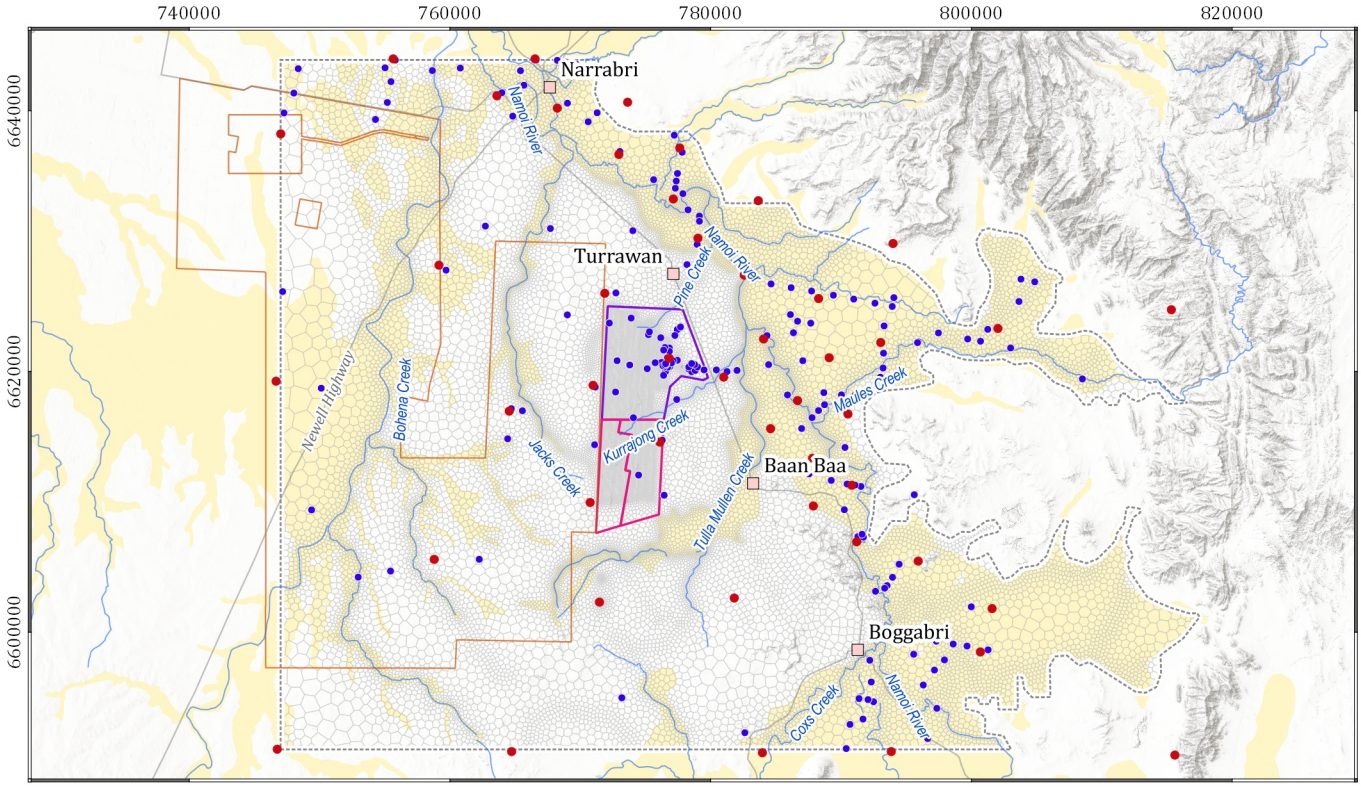
## Table D 3.4 Hydraulic conductivity parameter constraints

| Hydrostratigraphic Unit | Model Layer | Kh, Initial (m/d) | Kh, Range (m/d) | Kv, Initial (m/d) | Kv Range (m/d) | Initial Anisotropy (Kh:Kv) | Anisotropy Range (Kh:Kz) |
|---|---|---|---|---|---|---|---|
| Alluvium | 1 | 7 | 0.3 - 30 | 0.07 | $3x10^{-4}$ – 3 | 100 | 10-1000 |
| Colluvium | 1 | 0.7 | $3x10^{-2}$ – 3 | $7x10^{-3}$ | $3x10^{-5}$ – 0.3 | 100 | 10-1000 |
| Regolith | 1 | $7x10^{-2}$ | $3x10^{-3}$ - 0.3 | $7x10^{-4}$ | $3x10^{-6}$ – $3x10^{-2}$ | 100 | 10-1000 |
| Pilliga Sandstone | 2 | 1 | 0.1 – 1 | $1x10^{-2}$ | $1x10^{-4}$ – 1 | 100 | 10-1000 |
| Purlawaugh Formation | 3 | $1x10^{-2}$ | $1x10^{-3}$ – $1x10^{-1}$ | $1x10^{-5}$ | $1x10^{-7}$ – $1x10^{-3}$ | 1,000 | 100-10,000 |
| Garrawilla Volcanics | 4 | $5x10^{-2}$ | $5x10^{-3}$ – $5x10^{-1}$ | $5x10^{-4}$ | $5x10^{-6}$ – $5x10^{-2}$ | 100 | 10-1000 |
| Napperby Formation Upper | 5 | $5x10^{-2}$ | $1x10^{-3}$ – $5x10^{-1}$ | $5x10^{-5}$ | $1x10^{-7}$ – $5x10^{-3}$ | 1,000 | 100-10,000 |
| Napperby Sill | 6 | $1x10^{-3}$ | $1x10^{-4}$ – $5x10^{-1}$ | $1x10^{-5}$ | $1x10^{-7}$ – $5x10^{-2}$ | 100 | 10–1000 |
| Napperby Formation Lower | 7 | $5x10^{-3}$ | $5x10^{-4}$ – $5x10^{-2}$ | $5x10^{-6}$ | $5x10^{-8}$ – $5x10^{-4}$ | 1,000 | 100-10,000 |
| Digby Conglomerate | 8 | $1x10^{-4}$ | $1x\ 10^{-5}$ – $5x10^{-3}$ | $1x10^{-6}$ | $1x\ 10^{-8}$ – $5x10^{-4}$ | 100 | 10–1000 |
| Hoskissons Coal Seam | 9 | Variable ($0.1\ exp^{-0.026\ d}$) | $1x\ 10^{-7}$ – $1x10^{-1}$ | Variable (Kh/100) | $1x\ 10^{-10}$ – $1x10^{-2}$ | 100 | 10-1000 |
| Arkarula Formation | 10 | 0.1 | $1x10^{-3}$ – 1 | $1x10^{-3}$ | $1x10^{-6}$ – 0.1 | 100 | 10-1000 |
| Pamboola Formation | 11 | $1x10^{-2}$ | $1x10^{-3}$ – $1x10^{-1}$ | $1x10^{-5}$ | $1x10^{-7}$ – $1x10^{-3}$ | 1,000 | 100-10,000 |

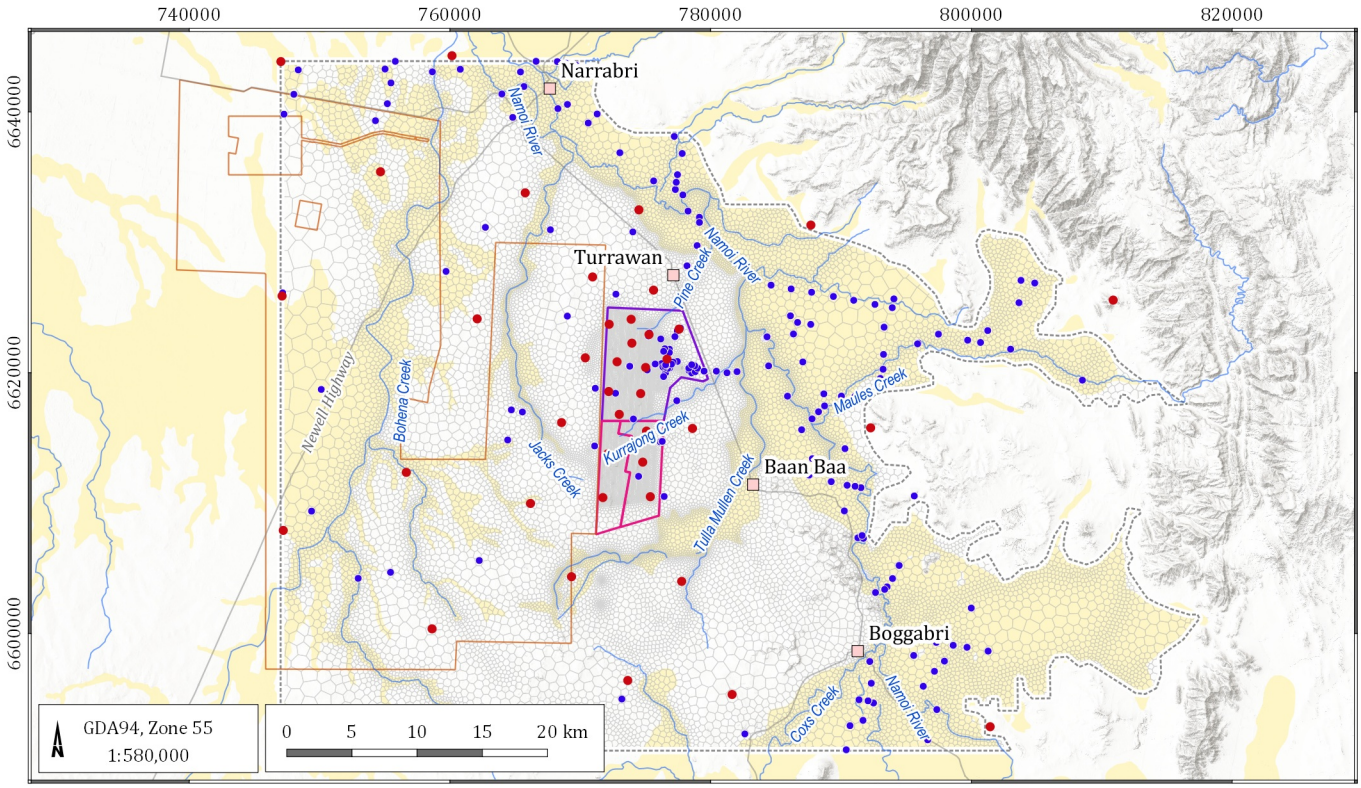
## Table D 3.5 Storage parameter constraints

| Hydrostratigraphic Unit | Model Layer | Sy, Initial | Sy, Range | Ss, Initial ($m^{-1}$) | Ss Range ($m^{-1}$) |
|---|---|---|---|---|---|
| Alluvium | 1 | 0.044 | 0.01 – 0.1 | NA | NA |
| Colluvium | 1 | 0.02 | 0.01 – 0.1 | NA | NA |
| Regolith | 1 | 0.02 | 0.01 – 0.1 | NA | NA |
| Pilliga Sandstone | 2 | 0.01 | 0.005 – 0.05 | $1.3x10^{-6}$ | $2.3x10^{-7}$ – $1.3x10^{-5}$ |
| Purlawaugh Formation | 3 | 0.01 | 0.005 – 0.05 | $1.3x10^{-6}$ | $2.3x10^{-7}$ – $1.3x10^{-5}$ |
| Garrawilla Volcanics | 4 | 0.01 | 0.005 – 0.05 | $1.3x10^{-6}$ | $2.3x10^{-7}$ – $1.3x10^{-5}$ |
| Napperby Formation Upper | 5 | 0.01 | 0.005 – 0.05 | $1.3x10^{-6}$ | $2.3x10^{-7}$ – $1.3x10^{-5}$ |
| Napperby Sill | 6 | 0.01 | 0.005 – 0.05 | $1.3x10^{-6}$ | $2.3x10^{-7}$ – $1.3x10^{-5}$ |
| Napperby Formation Lower | 7 | 0.01 | 0.005 – 0.05 | $1.3x10^{-6}$ | $2.3x10^{-7}$ – $1.3x10^{-5}$ |
| Digby Conglomerate | 8 | 0.01 | 0.005 – 0.05 | $1.3x10^{-6}$ | $2.3x10^{-7}$ – $1.3x10^{-5}$ |
| Hoskissons Coal Seam | 9 | 0.01 | 0.005 – 0.05 | $1.3x10^{-6}$ | $2.3x10^{-7}$ – $1.3x10^{-5}$ |
| Arkarula Formation | 10 | 0.01 | 0.005 – 0.05 | $1.3x10^{-6}$ | $2.3x10^{-7}$ – $1.3x10^{-5}$ |
| Pamboola Formation | 11 | 0.01 | 0.005 – 0.05 | $1.3x10^{-6}$ | $2.3x10^{-7}$ – $1.3x10^{-5}$ |

**Layer 1**




**Layer 2+ (high priority)**




LEGEND

- Populated place
- Road
- Drainage
- Approved mining lease
- Proposed mining lease
- Santos CSG project
- Model boundary
- Model mesh
- Alluvium
- Pilot point multiplier
- Observation monitoring location

Narrrabri Stage 3 Extension GIA (G1972)

**Location of pilot points**

DATE 02/04/2020

FIGURE No: **D 3.6**

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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.;
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## D 3.4 Surrogate calibration approach

The groundwater model contains 306,369 cells and runs over 128 stress periods to simulate historic mining. The complexity of the model and stresses occurring within the groundwater system during the simulation significantly slows down the model run time.

Standard gradient based calibration techniques require deriving of the Jacobian matrix at each step in the optimisation process. To do this, each adjustable parameter and pilot point in the model requires its own model simulation. The Narrabri groundwater model contains thousands of adjustable parameters, meaning the Jacobian matrix alone requires thousands of hours of CPU processing time to prepare.

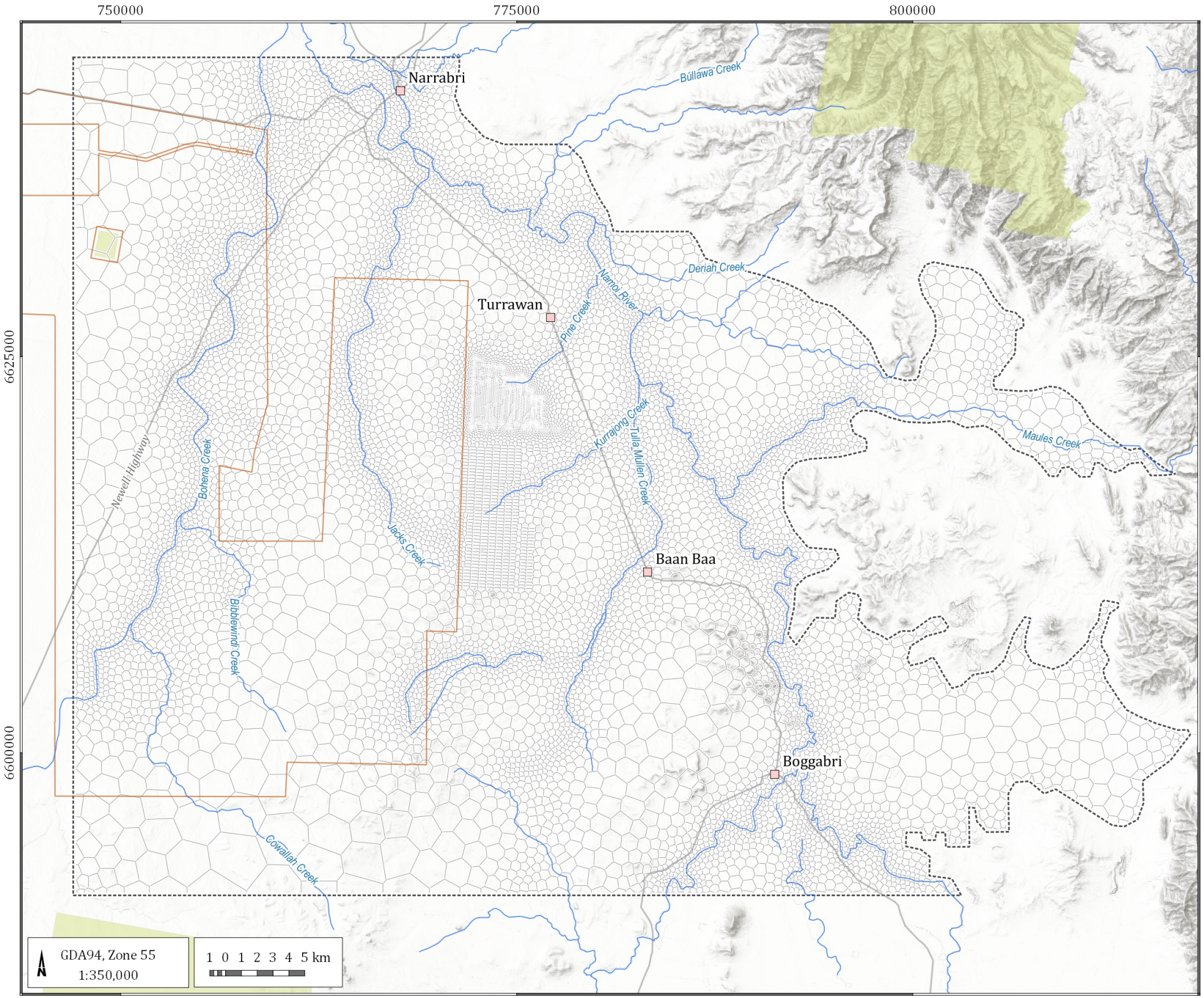
To combat the common issue with slow model runtimes and a high number of parameters, a lower resolution 'surrogate' model was developed. The surrogate model was identical to the 'parent' model in every way, the only difference being the resolution of the model cells.

The 'surrogate' model domain also contained 11 layers but was discretised into about 10,000 cell nodes in each layer with the dimensions of the cells varying according to the features that required representation. The surrogate model grid is presented in Figure D 3.7. The following cells dimensions were adopted:

- longwall mining areas – 35 m x 35 m to 100 x 130 cells using cell edges aligned to 2019 dxf panel dimensions;
- streams – 300 m x 300 m;
- alluvial flood plains – 300 m x 300 m; and

Overall, the surrogate model comprises of 133,457 cells across the 11 layers, consequently model runtimes were around 10 minutes, compared to over 45 minutes for the parent model.

To maintain the integrity of the model calibration and predictions, the calibration process firstly used the surrogate model to derive parameter sensitivities to groundwater level observations (Jacobian matrix) at the start of each optimisation step. The information from the surrogate Jacobian matrix was then used to optimise the parent model. This optimising step required far less CPU resources and enabled rapid calibration with little compromise. The surrogate model produced near identical calibration statistics to the parent model. This allowed the use of the surrogate model calibration results within the more refined parent model which was more refined around environmental and mining features.




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Approved mining lease
- Proposed mining lease
- Santos CSG project
- National Park
- Model boundary
- Surrogate model mesh

Narrrabri Stage 3 Extension GIA (G1972)

**Surrogate Model Grid**

DATE
02/04/2020

FIGURE No:
**D 3.7**

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Source: ELVIS LiDAR DEM © Spatial Services, a unit of Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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## D 3.5 Calibration results

### *D 3.5.1 Calibrated heads*

Figure D 3.8, Figure D 3.9 and Figure D 3.10 presents observed and simulated groundwater levels determined from the calibration in a series of scattergrams.

Figure D 3.8 shows data from groundwater level monitoring points completed into the Namoi Alluvium and shows a relatively high level of agreement between observed and modelled levels as evidenced by a root mean square (RMS) residual error of 5.7 m and a scaled RMS (SRMS) error of 3.3%.

Figure D 3.9 shows data from groundwater levels monitoring points which form part of the Narrabri Coal Mine monitoring network. Again, a relatively high degree of fit is achieved as evidenced by the scaled RMS error of 7.7%, although as is normally the case it is not possible to closely match all of the observed data.

Data for other state government monitoring points outside of the Namoi Alluvium and for monitoring in and around the Narrabri Gas Project area are shown in Figure D 3.10. Again, a relatively good match is achieved although the SRMS error is slightly higher than for the other two groups of bores. However, this is largely due to two Santos observation points DWH8AQGDGY and DWH8AQGPOR, screened in the Digby Conglomerate and Porcupine Formation. Observed data for both of these monitoring points show unusually high groundwater levels of around 350 mAHD which cannot be replicated in the groundwater model and may be erroneous.

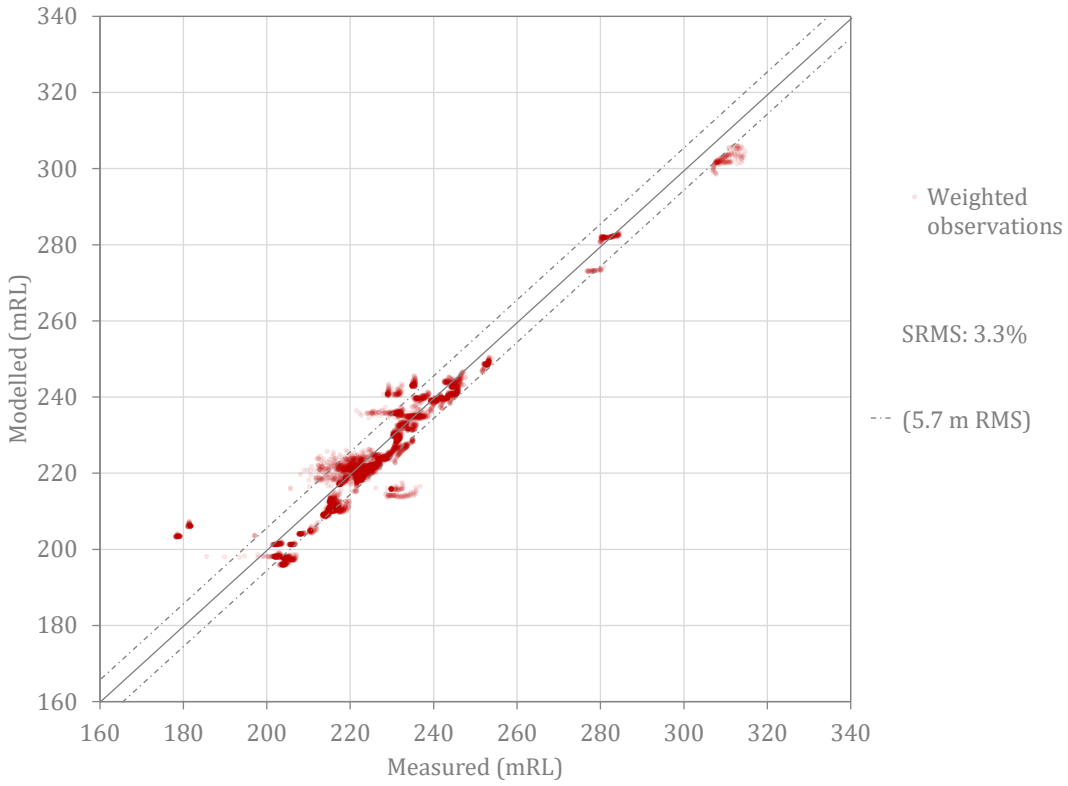



**Figure D 3.8 Transient calibration – modelled vs observed groundwater levels, Namoi Alluvium**

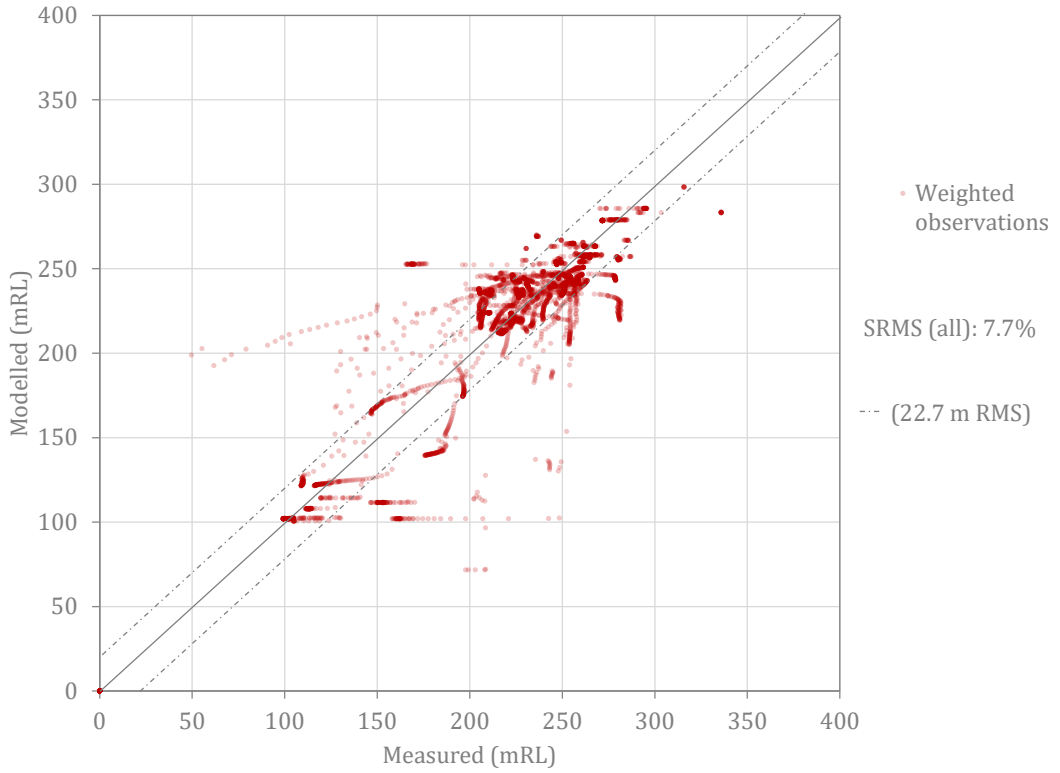



**Figure D 3.9 Transient calibration – modelled vs observed groundwater levels, NCOPL monitoring bores**

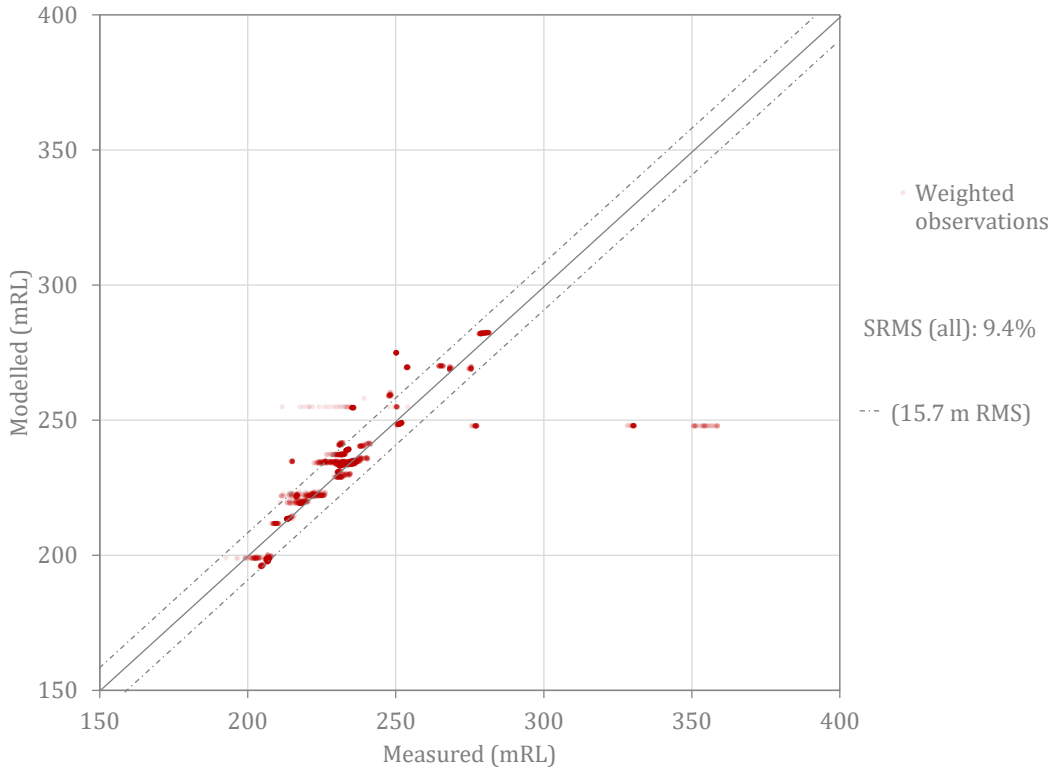



**Figure D 3.10 Transient calibration – modelled vs observed groundwater levels, other bores**

Table D 3.6 presents a further breakdown of unweighted RMS and SRMS statistics for the transient calibration model by model layer. As shown in Table D 3.6 the overall RMS error and SRMS errors are 15.4 m and 5.0% respectively, the latter being well within the 10% target typically applied.

Larger errors are however evident in individual layers, especially deeper model layers closer to the Hoskissons Coal Seam. This is a reflection of the high magnitude of drawdown observed in these units in and around the mineworkings. As discussed above it is not possible to match all of these observations with a high degree of accuracy since like all such models the groundwater flow model is a relatively simple representation of a much more complex geological reality. Even small errors in say the timing of modelled drawdown, which can occur due to say incomplete knowledge of UIS drilling operations, can result in large residuals and elevated SRMS errors in units which experience large drawdowns.

Conversely RMS and SRMS errors are typically less than 10m and less than 10% respectively in shallower units which include the Namoi Alluvium (model layer 1) and Pilliga Sandstone (model layer 2) suggesting the model is better able to match observed groundwater levels in these key aquifers closer to the surface.

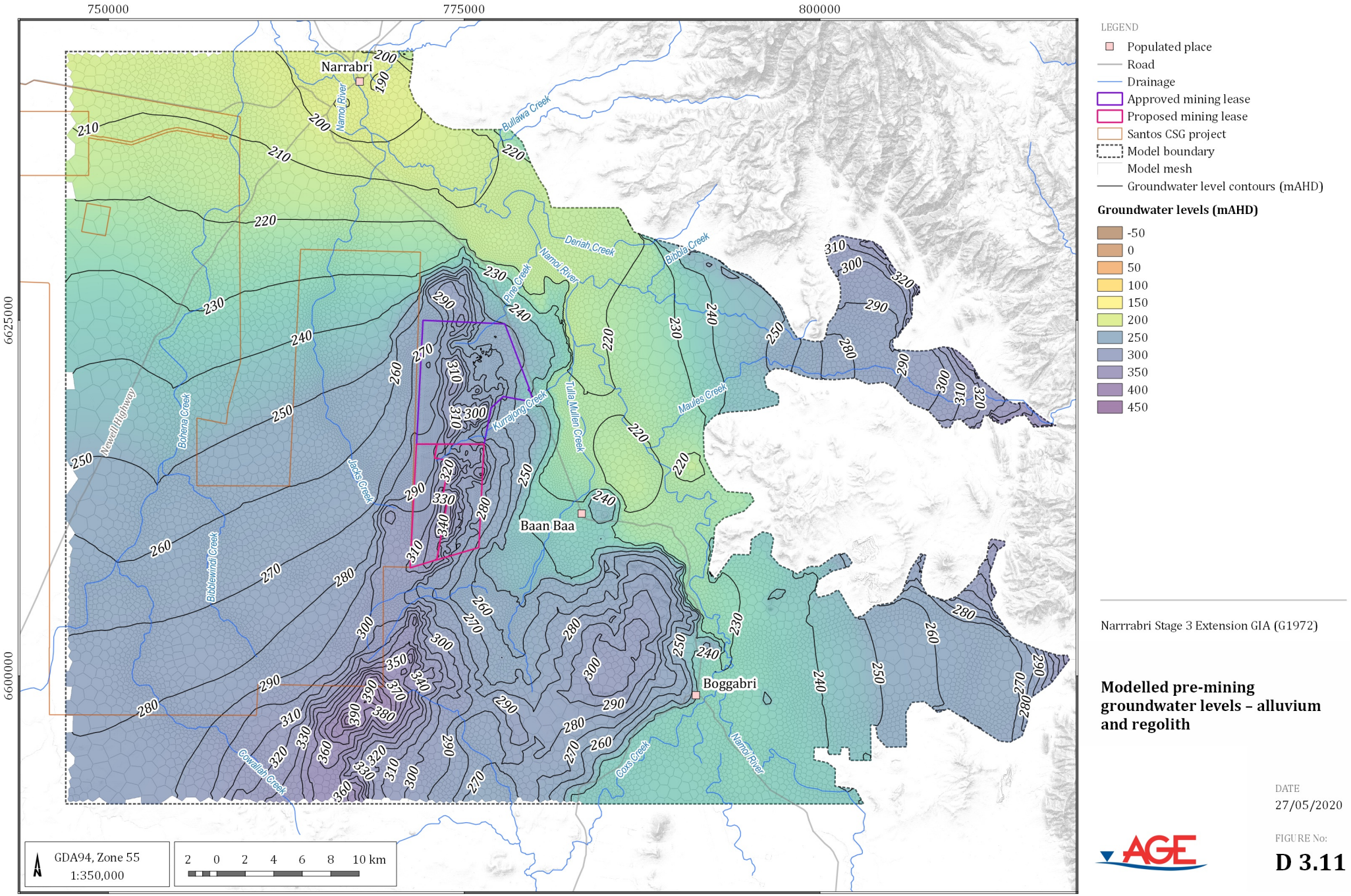
### Table D 3.6 Transient root mean square (RMS) errors by model layer

| Model layer | Count of measurements | RMS (m) | Scaled RMS (%) |
|---|---|---|---|
| 1 – Alluvium, colluvium, regolith | 8482 | 5.7 | 3.3 |
| 2 – Pilliga Sandstone | 873 | 13.8 | 9.6 |
| 3 – Purlawaugh Fm | 397 | 8.1 | 11.7 |
| 4 – Garrawilla Volcanics | 474 | 8.1 | 8.3 |
| 5 – Napperby upper | 677 | 12.2 | 12.2 |
| 6 – Napperby sill | No data | No data | No data |
| 7 – Napperby lower | 442 | 16.8 | 23.6 |
| 8 – Digby Conglomerate | 526 | 38.1 | 23.5 |
| 9 – Hoskissons Coal Seam | 894 | 32.0 | 16.5 |
| 10 – Arkarula Fm | 352 | 33.6 | 14.7 |
| 11 – Pamboola Fm | 3402 | 17.7 | 10.9 |
| **Total** | **16519** | **15.4** | **5.0** |

Appendix D 1 presents the historic calibration hydrographs, showing the fit between modelled and observed groundwater levels from January 2009 to June 2019 at each bore. The appendix also presents a table with the location and the modelled residuals for each bore used during the calibration.

Calibrated heads from the pre-development steady state model for the unconsolidated sediments (alluvium, colluvium and regolith) are presented in Figure D 3.11. Steady state heads in the Hoskissons Coal Seam are presented in Figure D 3.12.

Calibrated heads at the end of the transient model period in June 2019 within the unconsolidated sediments (alluvium and regolith) are shown in Figure D 3.13. Current heads in the Hoskissons Coal Seam are shown in Figure D 3.14.




LEGEND

- Populated place
- Road
- Drainage
- Approved mining lease
- Proposed mining lease
- Santos CSG project
- Model boundary
- Model mesh
- Groundwater level contours (mAHD)

**Groundwater levels (mAHD)**

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

Narrrabri Stage 3 Extension GIA (G1972)

## Modelled pre-mining groundwater levels – alluvium and regolith

DATE
27/05/2020

FIGURE No:
**D 3.11**

©2020 Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) - www.ageconsultants.com.au
Source: ELVIS LiDAR DEM © Spatial Services, Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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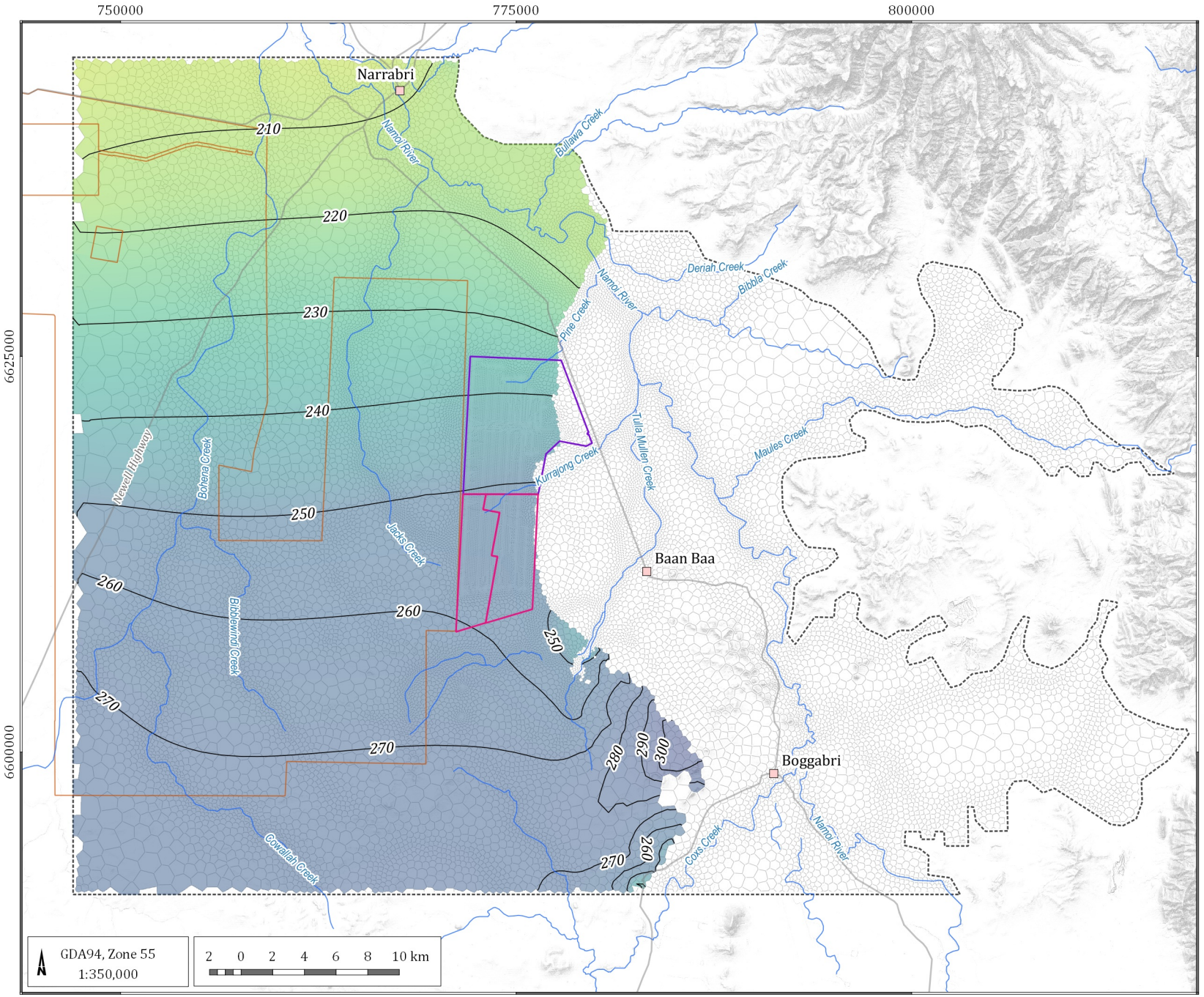


LEGEND

- Populated place
- Road
- Drainage
- Approved mining lease
- Proposed mining lease
- Santos CSG project
- Model boundary
- Model mesh
- Groundwater level contours (mAHD)

**Groundwater levels (mAHD)**

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

Narrrabri Stage 3 Extension GIA (G1972)

## Modelled pre-mining groundwater levels – Hoskissons Coal Seam

DATE
27/05/2020

FIGURE No:
**D 3.12**

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Source: ELVIS LiDAR DEM © Spatial Services, Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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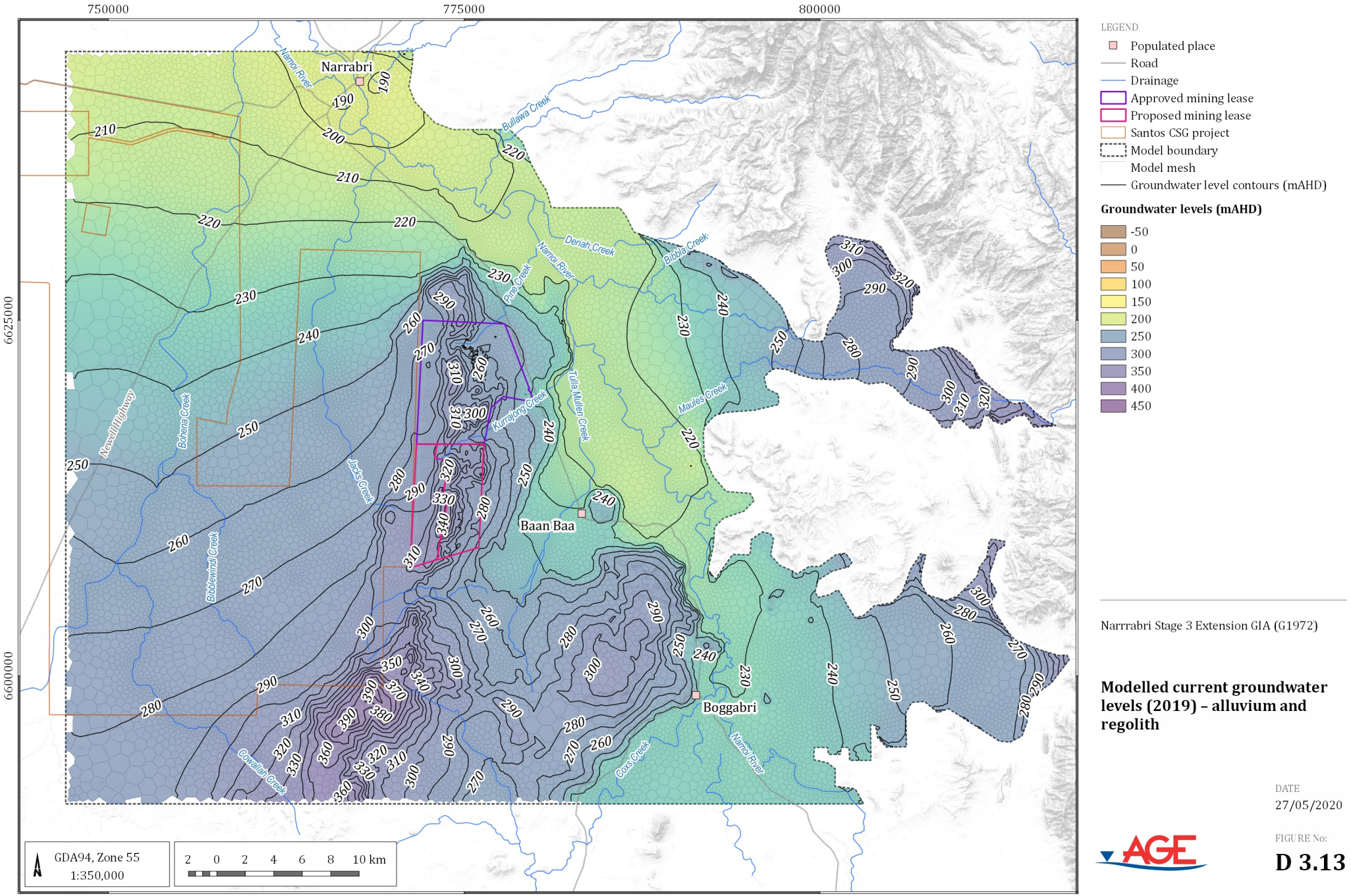


LEGEND

- Populated place
- Road
- Drainage
- Approved mining lease
- Proposed mining lease
- Santos CSG project
- Model boundary
- Model mesh
- Groundwater level contours (mAHD)

**Groundwater levels (mAHD)**

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

Narrrabri Stage 3 Extension GIA (G1972)

## Modelled current groundwater levels (2019) – alluvium and regolith

DATE
27/05/2020

FIGURE No:
**D 3.13**

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Source: ELVIS LiDAR DEM © Spatial Services, Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
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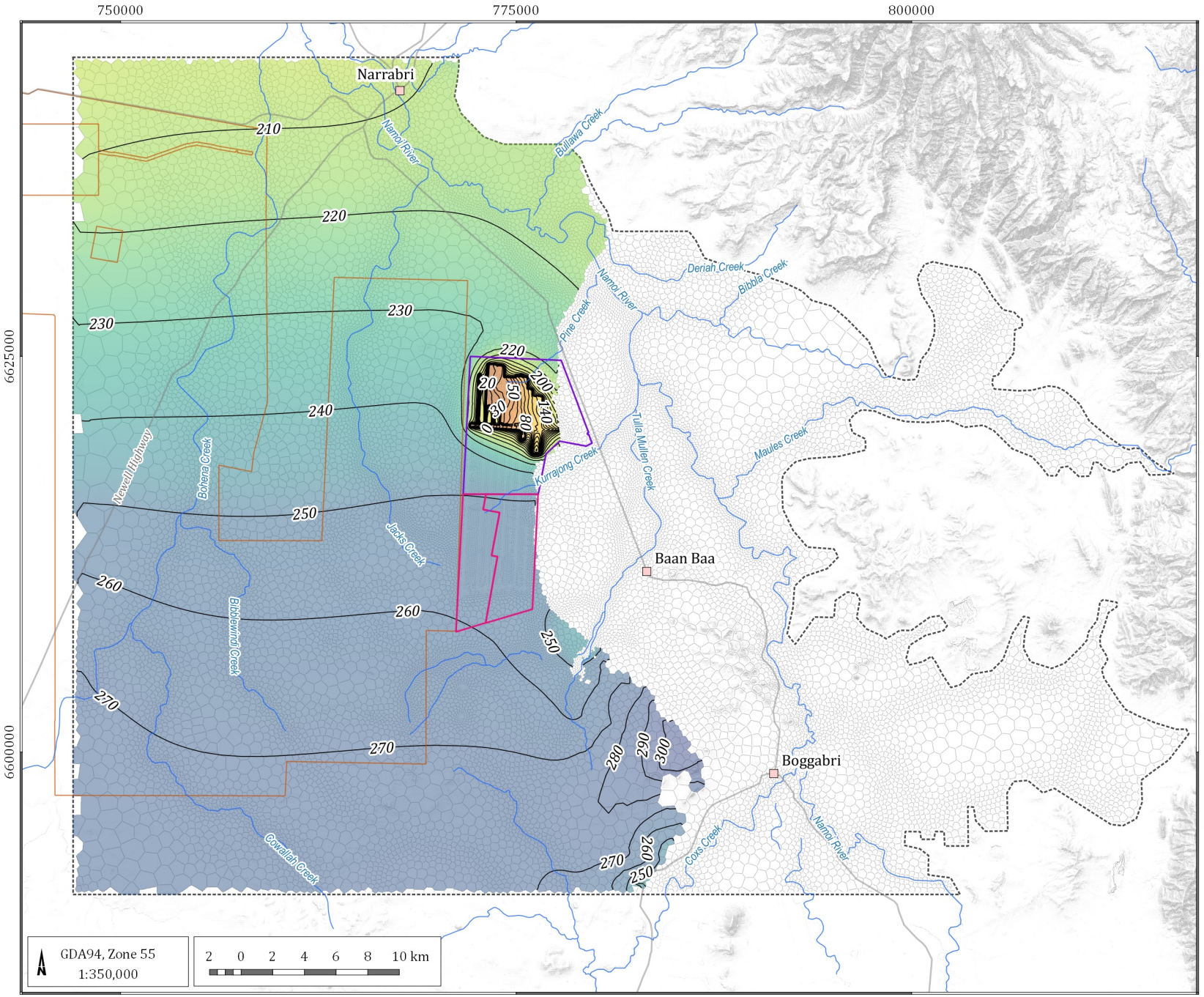


LEGEND

- Populated place
- Road
- Drainage
- Approved mining lease
- Proposed mining lease
- Santos CSG project
- Model boundary
- Model mesh
- Groundwater level contours (mAHD)

**Groundwater levels (mAHD)**

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

Narrrabri Stage 3 Extension GIA (G1972)

## Modelled current groundwater levels (2019) - Hoskissons Coal Seam

DATE
27/05/2020

FIGURE No:
**D 3.14**

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Source: ELVIS LiDAR DEM © Spatial Services, Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 03.11_G1972_Modelled groundwater levels.qgs

### *D 3.5.2 Calibrated head differences*

An analysis of average simulated versus measured vertical head differences in available key VWPs in the vicinity of the existing Narrabri Mine was also carried out to assess the ability of the model to simulate vertical gradients. The result is displayed on Figure D 3.15. As shown in Figure D 3.15 the majority of the measured data show downward gradients in response to de-pressurisation of the underlying Hoskissons Coal Seam. In all cases where the observed gradient is downwards the model is able to replicate the direction of the gradient, although the fit to the measured value is somewhat variable. Measured data for a much smaller number of monitoring points show upward gradients often between the Arkarula and/or Pamboola Formation (model layers 10 and 11) and the overlying Hoskissons Coal Seam (model layer 9). As shown in Figure D 3.15 the model is often unable to match this measured direction, as evidenced by the number of points which plot in the upper left hand quadrant on the chart. However, data for one bore (P24_166 to P24_188) which shows a particularly large 40 m upward gradient and is therefore highly visible during the calibration is relatively well matched by the model.

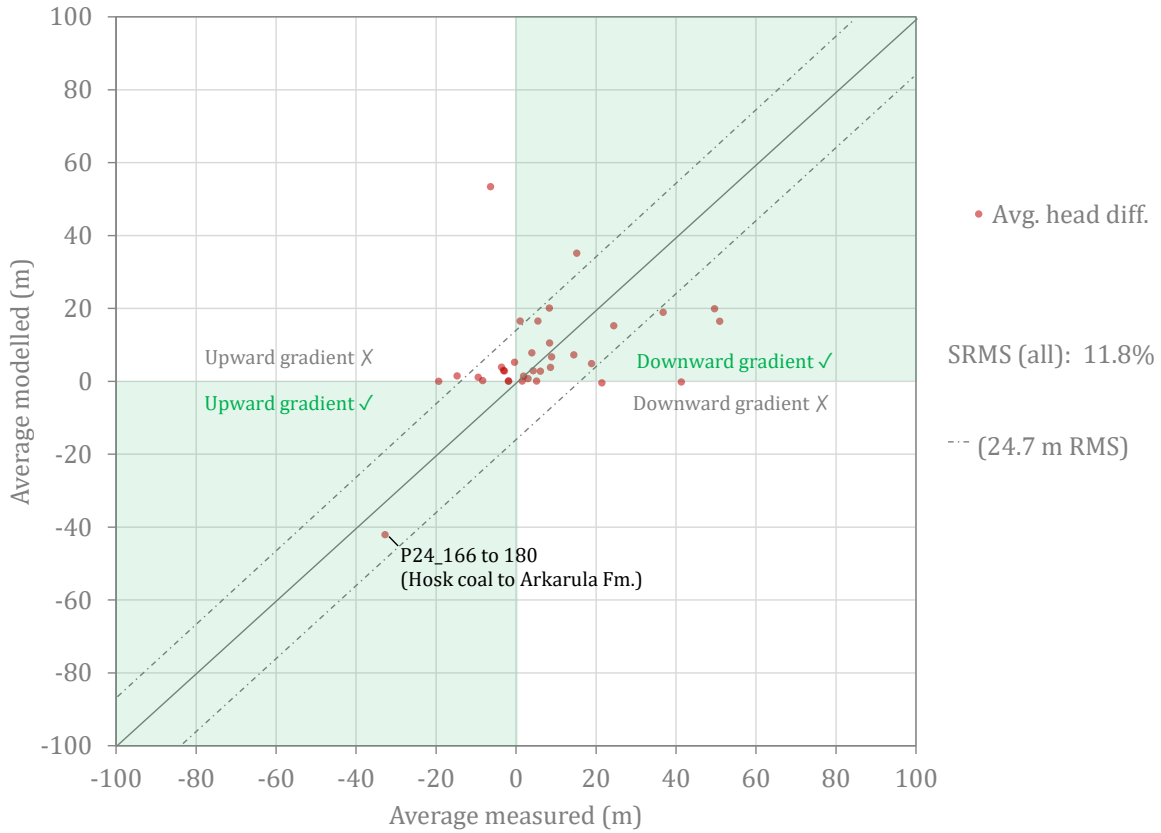



**Figure D 3.15 Modelled versus observed average vertical head differences at nested VWP locations**

### *D 3.5.3 Hydraulic parameters*

Table D 3.7 summarises the calibrated average horizontal (Kh), vertical hydraulic conductivity (Kv) and Kh:Kv ratios for each of the hydrostratigraphic units within the model domain.

## Table D 3.7 Calibrated hydraulic conductivity values

| Model layer | Hydrostratigraphic Unit | Average horizontal hydraulic conductivity Kh (m/day) | Average vertical hydraulic conductivity Kv (m/day) | Average vertical hydraulic conductivity factor (Kh/Kv) |
|---|---|---|---|---|
| 1 | Alluvium (Qa) | 9.4 | $4.9 \times 10^{-1}$ | 19 |
| 1 | Colluvium/regolith | 1.6 | $1.4 \times 10^{-1}$ | 12 |
| 2 | Pilliga Sandstone | 1 | $5.4 \times 10^{-2}$ | 18 |
| 3 | Purlawaugh Formation | 0.006 | $7.4 \times 10^{-7}$ | 7,412 |
| 4 | Garrawilla Volcanics | 0.03 | $2.4 \times 10^{-6}$ | 10,421 |
| 5 | Napperby upper | 0.01 | $4.9 \times 10^{-6}$ | 2,055 |
| 6 | Napperby Sill | 0.0009 | $7.1 \times 10^{-6}$ | 120 |
| 7 | Napperby lower | 0.006 | $7.7 \times 10^{-5}$ | 75 |
| 8 | Digby Conglomerate | 0.0003 | $3.0 \times 10^{-5}$ | 10 |
| 9 | Hoskissons Coal Seam | 0.009 | $2.8 \times 10^{-4}$ | 33 |
| 10 | Arkarula Formation | 0.01 | $9.8 \times 10^{-5}$ | 102 |
| 11 | Pamboola Formation | 0.009 | $8.5 \times 10^{-5}$ | 100 |

As discussed previously (Section D 3.3) the hydraulic conductivity of the Hoskissons Coal Seam (model layer 9) decreases with depth. Calibration of the hydraulic conductivity of this layer was undertaken through the use of multipliers assigned at pilot points. Figure D 3.16 shows the resulting calibrated relationship between depth and hydraulic conductivity for the Hoskissons Coal Seam in red. Also shown are the upper and lower bounds adopted for calibration (shown as dotted lines and grey shading) and actual measurements of hydraulic conductivity available for the mine site (shown as grey/black points). As shown in Figure D 3.16 the calibrated values are towards the centre of the calibration range and close to the majority of the observed hydraulic conductivity data.

Figure D 3.17 provides cumulative exceedance plots for the calibrated hydraulic conductivity within the model layers. The plots use data from a regularised 1500 m grid covering the model domain rather than model cell centres. This approach has been used to remove the effect of different cell sizes, which could bias the outputs. The results illustrate the influence of the pilot point multipliers during the calibration process.

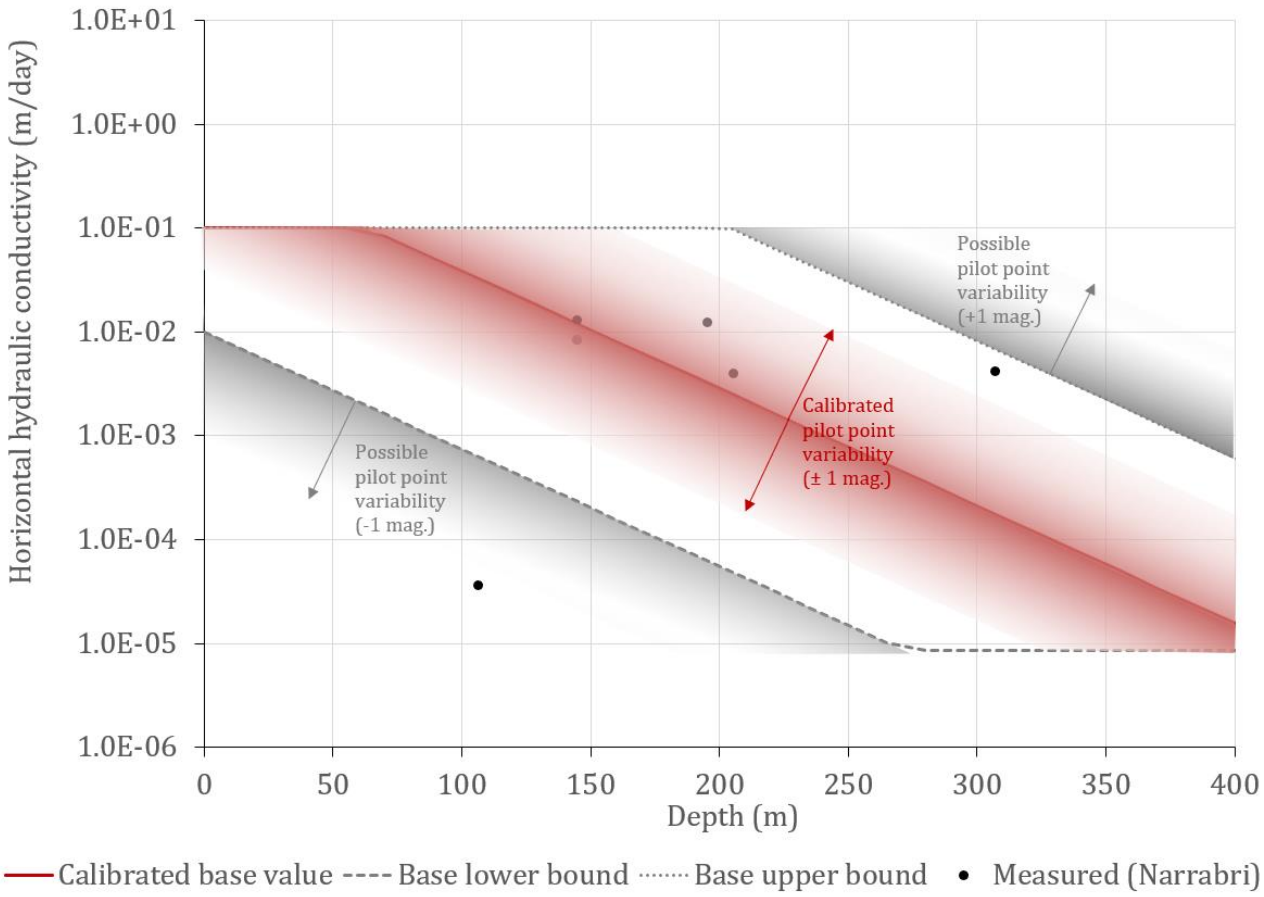



**Figure D 3.16 Coal horizontal hydraulic conductivity distribution graph**

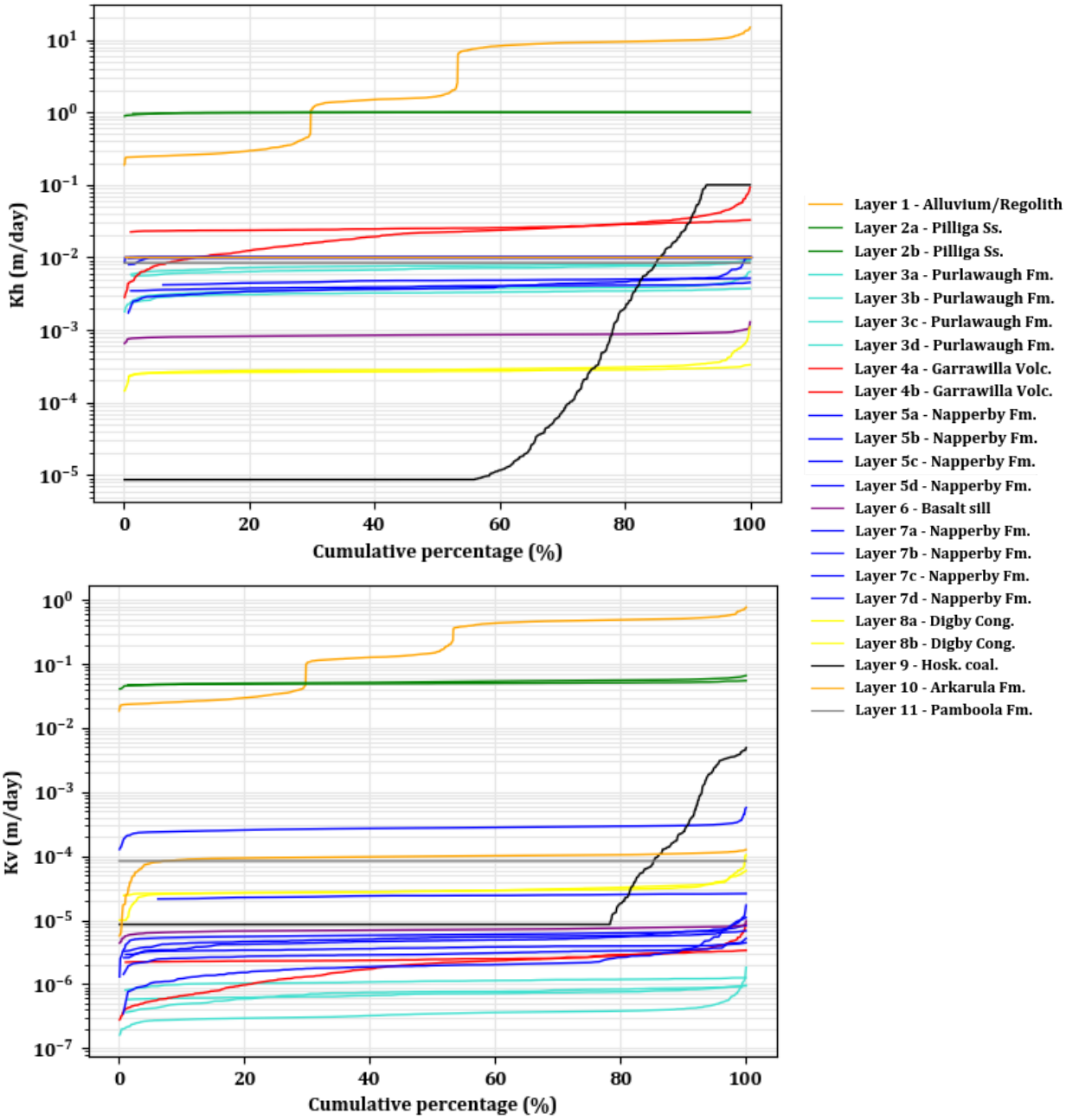



**Figure D 3.17 Hydraulic conductivity cumulative exceedance plots**

### *D 3.5.4 Storage properties*

Table D 3.8 summarises calibrated values for specific storage, specific yield and recharge.

## Table D 3.8 Calibrated recharge and storage values

| Model layer | Hydrostratigraphic Unit | Specific yield – Sy (%) | Specific storage - Ss ($m^{-1}$) | Long term average recharge (mm/year) |
|---|---|---|---|---|
| 1 | Alluvium (Qa) | 1.6 | $1.0 \times 10^{-5}$ | 23.6 |
| 1 | Colluvium / Regolith | 1.1 | $1.0 \times 10^{-5}$ | 0.9 |
| 2 | Pilliga Sandstone | 1.7 | $2.0 \times 10^{-6}$ | 8.4 |
| 3 | Purlawaugh Formation | 0.9 | $9.9 \times 10^{-7}$ | 2.1 |
| 4 | Garrawilla Volcanics | 1 | $1.0 \times 10^{-6}$ | 0.6 |
| 5 | Napperby Formation | 1.1 | $1.4 \times 10^{-6}$ | 0.6 |
| 6 | Sill | 1 | $1.3 \times 10^{-6}$ | 3.9 |
| 7 | Napperby Formation | 1.1 | $2.4 \times 10^{-6}$ | 0.6 |
| 8 | Digby Conglomerate | 1 | $1.0 \times 10^{-6}$ | 2.9 |
| 9 | Hoskissons Coal Seam | 0.5 | $1.1 \times 10^{-6}$ | 3.1 |
| 10 | Arkarula Formation | 1 | $7.0 \times 10^{-7}$ | 2.8 |
| 11 | Pamboola Formation | 0.9 | $1.4 \times 10^{-5}$ | 3.7 |

Upper and lower bound specific storage values for calibration purposes were derived from Rau et al (2018) who suggest that specific storage is restricted to the range of $2.3 \times 10^{-7}$ $m^{-1}$ and $1.3 \times 10^{-5}$ $m^{-1}$. As shown in Table D 3.8 calibrated values for most layers were around $1 \times 10^{-6}$ i.e. towards the centre of this range. Values towards the upper end of the range were calibrated for the alluvium and the Pamboola Formation.

Calibrated specific yield values were typically around 1% with slightly higher values calibrated for the alluvium and Pilliga Sandstone, consistent with the major aquifer status of these units. It should be stressed that the outcrop area of most of the deeper units is somewhat limited and hence the model calibration is relatively insensitive to the specific yield of these layers. Accordingly, calibrated values in most layers are close to the initial values. The specific yield of the Hoskissons Coal Seam has however reduced during the calibration in order to improve the level of fit between estimated actual and modelled mine inflow rates (Section D 3.5.9).

Figure D 3.18 provides cumulative exceedance plots for the calibrated storage within each model layers. The results indicate that the specific yield pilot point multipliers were most influential to the alluvium/regolith, Pilliga Sandstone, and Hoskissions coal seam layers. Pilot point multipliers more readily adjusted the specific storage in the Napperby Formation and the Hoskissons Coal Seam.

Long term average calibrated recharge values are also summarised in Table D 3.8 and are largely as would be expected with relatively high recharge modelled to the main aquifers (24 mm/yr to the alluvium and 8 mm/yr to the Pilliga Sandstone) and relatively low rates (less than 3mm /yr) modelled to other units. Calibrated values are typically lower than the initial estimates.

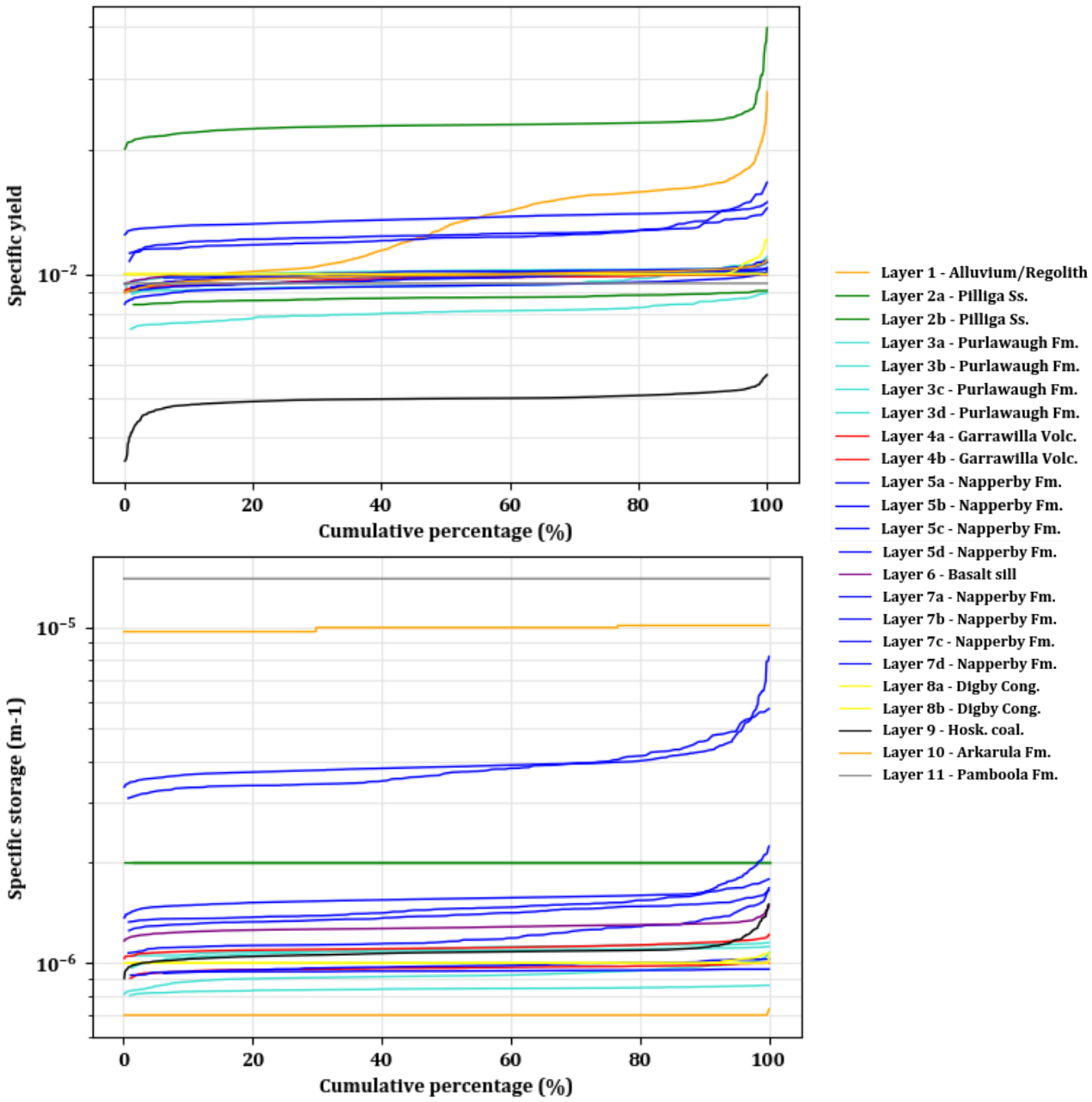



**Figure D 3.18 Storage cumulative exceedance plots**

### *D 3.5.5 Other parameters*

Calibrated values for other model parameters are summarised in Table D 3.9, many of which are largely unchanged from pre-calibration values. In particular the fracture aperture values which govern the degree of fracturing immediately above the Hoskissons Coal Seam and at the top of the A Zone (Section D 2.5.6) have not changed significantly during calibration. This suggests that the estimated A Zone height incorporated into the model, which was derived from a separate subsidence, analysis is consistent with the available observations above the existing mineworkings.

Similarly, the horizontal flow barrier conductance values which simulate cross fault permeability in the model remained unchanged during the calibration. This suggests that the numerous minor faults which have been mapped in the mining area have no significant effect on groundwater levels in the area.

**Table D 3.9 Calibrated values – other parameters**

| Group | Parameter | Value | Unit |
|---|---|---|---|
| Mine | Skin factor | 0.14 | - |
| Mine | Ap (top of +a95 zone) | 2.5 | mm |
| Mine | Ap (above coal) | 49.7 | mm |
| Mine | Surface cracking factor (Kh) | 2.7 | multiplier |
| Mine | Surface cracking factor (Kv) | 2.7 | multiplier |
| Mine | Surface cracking factor (Sy) | 1.9 | multiplier |
| Mine | Surface cracking factor (Ss) | 2.1 | multiplier |
| GHB | General head conductance factor | 1.3 | multiplier |
| HFB | Horizontal flow barrier conductance (zone 1) | 1 | multiplier |
| HFB | Horizontal flow barrier conductance (zone 2) | 1 | multiplier |
| HFB | Horizontal flow barrier conductance (zone 3) | 1 | multiplier |
| HFB | Horizontal flow barrier conductance (zone 4) | 1 | multiplier |
| RIV | Riverbed Kv (zone 1 to 7) | 0.1 | m/day |
| STR | Stream bed Kv (zone 1 – Bohena Creek) | 0.014 | m/day |
| STR | Stream bed Kv (zone 2 – Maules Creek) | 0.007 | m/day |
| STR | Stream bed Kv (zone 3 – Coxs Creek) | 0.01 | m/day |
| STR | Stream bed Kv (zone 4 – Namoi River upstream) | 0.008 | m/day |
| STR | Stream bed Kv (zone 5 – Namoi River mid) | 0.009 | m/day |
| STR | Stream bed Kv (zone 6 – Namoi River downstream) | 0.003 | m/day |

### *D 3.5.6 Parameter sensitivity and identifiability*

Identifiability is a term used to describe the capability of a model calibration to constrain parameters used by a model and ultimately reduce the uncertainty in predictions made by the model. An identifiability value of one means that the range in the model parameter can be constrained through the calibration process and hence the parameter is highly estimable. In contrast, an identifiability value of zero indicates that the parameter range cannot be constrained by the calibration and hence its uncertainty is not reduced through the calibration process.

To further investigate this issue the PEST utility GENLINPRED was used to provide an estimate of parameter identifiability. GENLINPRED provides an identifiability value for each model parameter. Table D 3.10 shows the identifiability of groundwater model parameter zones for Kx, Kz, Sy and Ss in respect to the groundwater level observation dataset. Figure D 3.19 presents a visual representation of the most sensitive parameter set, horizontal hydraulic conductivity. Table D 3.11 presents a summary of the identifiability of other model parameters.

Of particular note is the relatively low identifiability of Kv in model layer 1 (Alluvium and Colluvium/regolith). Key model predictions, including impacts on the Namoi Alluvium and Namoi River itself are likely to be sensitive to these parameters which are not readily identifiable in the calibration. This has been addressed, however, by the inclusion of these parameters in the predictive uncertainty analysis (Section D 5).

## Table D 3.10 Average parameter identifiability – Kh, Kv, Ss and Sy and recharge

| Model layer | Lithology | Horizontal hydraulic conductivity (Kh) | Vertical hydraulic conductivity (Kv) | Specific yield - Sy | Specific storage - Ss | Recharge |
|---|---|---|---|---|---|---|
| 1 | Alluvium (Qa) | 0.97 | 0.05 | 0.94 | 0.006 | 1.00 |
| 1 | Colluvium | 0.85 | 0.009 | 0.89 | 0.022 | 1.00 |
| 2 | Pilliga sandstone | 0.08 | 0.08 | 0.45 | <0.001 | 1.00 |
| 3 | Purlawaugh Fm | 0.45 | 0.45 | 0.07 | 0.12 | 0.97 |
| 4 | Garrawilla Volcanics | 0.76 | 0.68 | <0.001 | 0.05 | 0.89 |
| 5 | Napperby Fm | 0.57 | 0.45 | 0.29 | 0.26 | 0.93 |
| 6 | Basalt Sill | 0.62 | 0.39 | <0.001 | 0.15 | 0.011 |
| 7 | Napperby Fm | 0.49 | 0.49 | 0.02 | 0.23 | 0.26 |
| 8 | Digby Conglomerate | 0.89 | 0.08 | 0.03 | 0.51 | 0.03 |
| 9 | Hoskissons Coal | 0.93 | 0.58 | 0.699 | 0.19 | 0.324 |
| 10 | Arkarula Fm | 0.59 | 0.66 | 0.05 | 0.69 | 0.223 |
| 11 | Pamboola Fm | 0.60 | 0.63 | 0.01 | 0.99 | 0.767 |

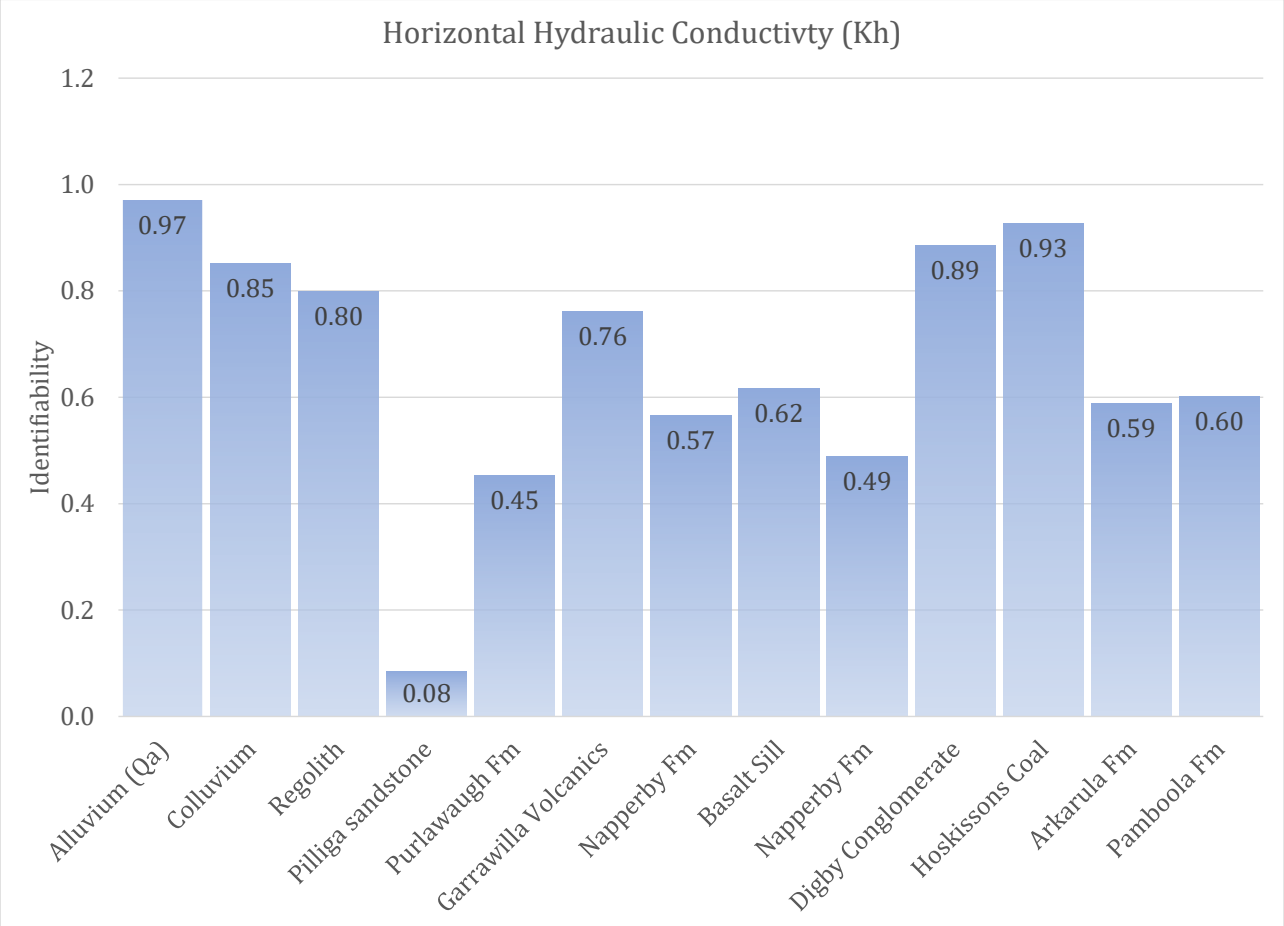



**Figure D 3.19 Parameter identifiability – Horizontal hydraulic conductivity (Kh)**

### *D 3.5.7 Water budget*

The mass balance error, that is, the difference between calculated model inflows and outflows at the completion of the steady state calibration was 0.00%. The maximum percent discrepancy at any time step in the transient simulation was also 0.00%. This value indicates that the model is stable and achieves an accurate numerical solution.

Table D 3.11 shows individual water budget components for the steady state (pre-mining) model and the averages from the transient model for the period January 2009 to June 2019 inclusive.

**Table D 3.11 Modelled water balance (ML/day)**

| Water balance component | Steady state model | | | Transient model average | | |
|---|---|---|---|---|---|---|
| | in | out | in - out | in | out | in - out |
| Storage | - | - | - | 57.8 | 49.9 | 7.9 |
| Rainfall recharge | 90.2 | 0.0 | 90.2 | 90.9 | 0.0 | 90.9 |
| River (minor watercourses) | 0.0 | 4.5 | -4.5 | 0.0 | 6.1 | -6.1 |
| Stream (major watercourses) | 10.8 | 44.8 | -34.0 | 10.3 | 47.7 | -37.4 |
| Evapotranspiration | 0 | 2.6 | -2.6 | 0.0 | 3.2 | -3.2 |
| General head boundary | 23.1 | 12.7 | 10.4 | 24.0 | 13.8 | 10.2 |
| Wells | 0 | 59.5 | -59.5 | 0.0 | 61.3 | -61.3 |
| Drains (mine inflows) | 0 | 0 | 0.0 | 0.0 | 1.0 | -1.0 |
| **Total** | **124.2** | **124.2** | **0.0** | **183.0** | **183.0** | **0.0** |

The steady state water budget indicates that recharge to the groundwater system within the model averages 90.2 ML/day, with approximately 38.5 ML/day being discharged via surface drainage, and 2.6 ML/day lost to evapotranspiration in areas where the water table is within 2 m of the land surface. Regional through flow from the general head boundary contributes 19% (23.1 ML/d) of the total input to the groundwater model, whereas around 48% (59.5 ML/d) of total inflow is extracted via landholder pumping wells.

The transient model water budget departs from steady state conditions due to the effects of existing mining operations and transient climate conditions in the model domain. Modelled water balance results suggest the existing mine workings intercepts 1 ML/day on average during the transient period.

### *D 3.5.8 Baseflow verification*

Figure D 3.20 and Table D 3.12 show a comparison of modelled and observed net baseflow gain between the Boggabri and Narrabri gauges on the Namoi River.

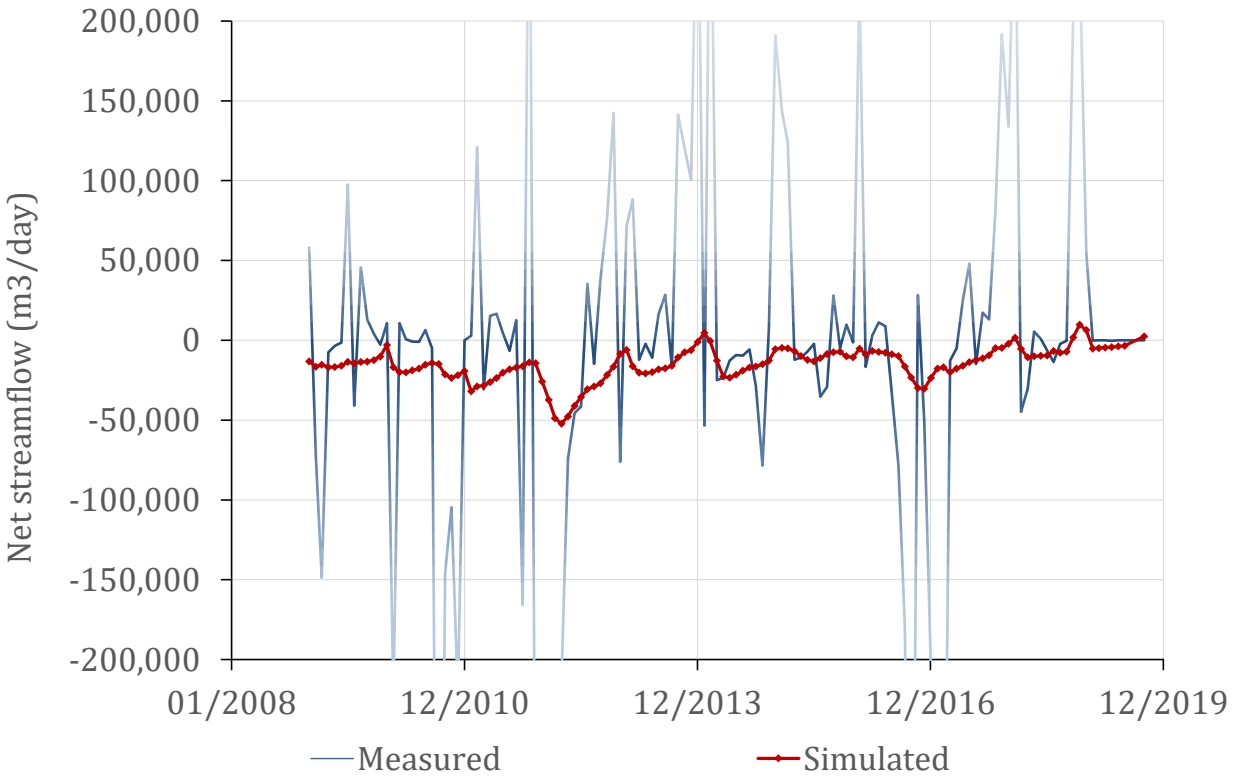



**Figure D 3.20** **Modelled versus estimated baseflow gain Namoi River (Boggabri to Narrabri)**

**Table D 3.12** **Modelled versus estimate baseflow gain Namoi River**

| Year | Average estimated net baseflow gain (ML/day) | Average modelled net baseflow gain (ML/day) |
|---|---|---|
| 2008 | 58.0 | -13.2 |
| 2009 | -8.9 | -13.5 |
| 2010 | -108.7 | -18.7 |
| 2011 | -88.8 | -22.1 |
| 2012 | -85.0 | -33.0 |
| 2013 | 70.7 | -13.4 |
| 2014 | 24.6 | -13.6 |
| 2015 | 16.8 | -9.0 |
| 2016 | -67.4 | -14.9 |
| 2017 | -15.2 | -12.3 |
| 2018 | 58.7 | -4.0 |
| 2019 | -0.1 | -3.4 |
| **Average** | **-19.2** | **-14.3** |

As shown the model is able replicate the much smaller gains which occur during drier periods better than the high baseflow events. As described in Section D 3.2.4 this reflects the greater weight given to low values of estimated baseflow which occur during dry periods, since these observations are likely to be more reliable. Baseflow separation during periods of rapidly increasing or decreasing flow is particularly prone to error. Hence the modelled long term average net baseflow to the Namoi River of 14.3 ML/day is similar to the calculated measured target of 19.2 ML/day and a particularly good match is achieved to the recent very dry period when net baseflows to the river of close to zero have been estimated from the flow data.

### *D 3.5.9 Mine inflow verification*

Figure D 3.21 and Table D 3.13 present a comparison of modelled and estimated actual inflow to the existing mineworkings. A good match to the average estimated actual inflows is achieved by the model although the variability evident in the actual data is not replicated. This 'noise' in the estimated actual data is thought to be related to UIS drilling and other underground activities and events which are not represented in the groundwater flow model.

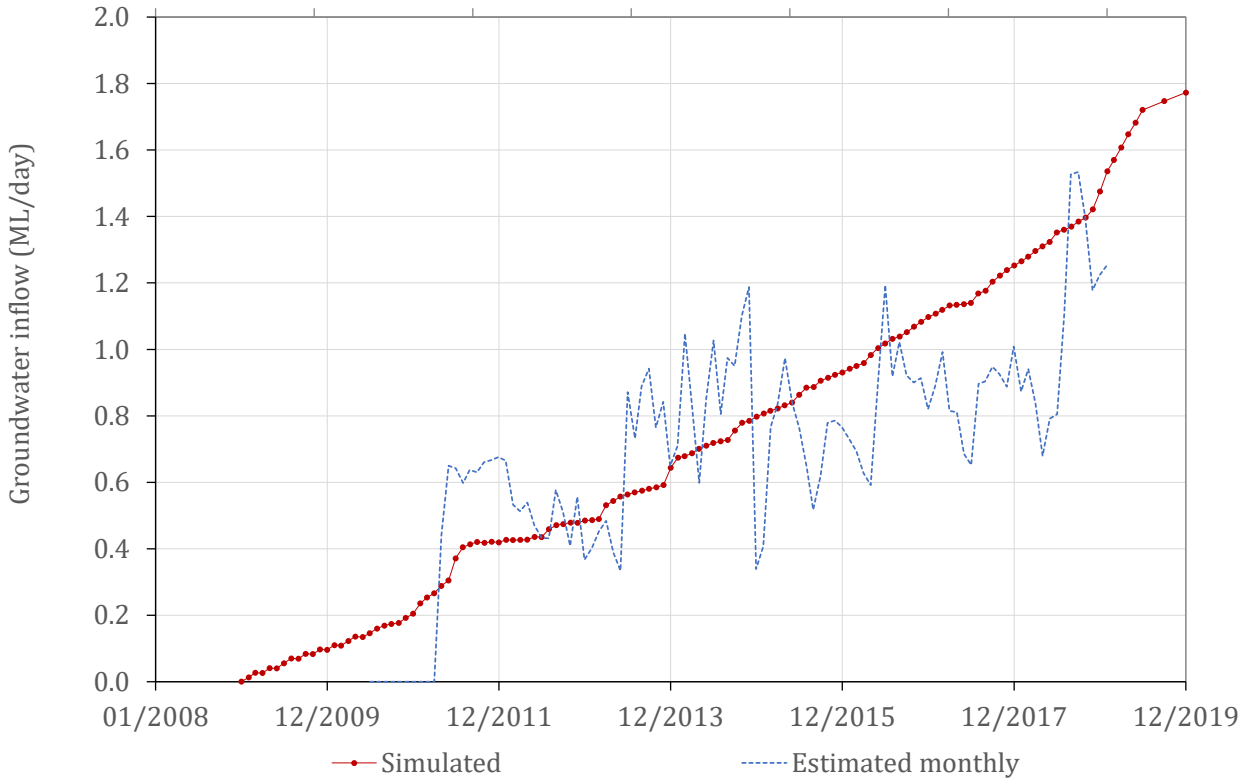



**Figure D 3.21 Modelled versus observed Narrabri mine inflow**

**Table D 3.13 Modelled versus observed Narrabri mine inflow**

| Year | Average measured (ML/year) | Average modelled (ML/year) |
|---|---|---|
| 2011 | 170 | 128 |
| 2012 | 183 | 165 |
| 2013 | 236 | 204 |
| 2014 | 317 | 266 |
| 2015 | 265 | 317 |
| 2016 | 311 | 372 |
| 2017 | 317 | 427 |
| 2018 | 393 | 479 |
| **Average** | **274** | **295** |

### *D 3.5.10 Model confidence level classification*

Barnett *et al*., (2012) developed a system to classify the confidence-level for groundwater models. Models are classified as either Class 1, Class 2, or Class 3 in order of increasing confidence. Several factors are considered in determining the model confidence-level:

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

A Class 3 model is often referred to as an aquifer simulator, in that it encapsulates a very detailed and well understood conceptualisation. Despite the use of all available data for the model inputs, it is difficult to obtain all of the Class 3 descriptors, and an appropriate and achievable level is commonly somewhere between an aquifer simulator and an impact model. Barnett *et al*., (2012) suggest "*it is not expected that any individual model will have all the defining characteristics of Class 1, 2 or 3 models*".

An assessment of the confidence level applicable to the current model in presented in Table D 3.14 and suggests that the Project groundwater model can classified as a Class 2/3 model. That is, the model classification identifies:

- 0 out 18 (0%) performance indicators align with a Class 1 model;
- 8 out 20 (40%) performance indicators align with a Class 2 model; and
- 15 out 22 (68%) performance indicators align with a Class 3 model.

## Table D 3.14 Model confidence level classification

| Class | Data | | Calibration | | Prediction | | Quantitative Indicators | |
|---|---|---|---|---|---|---|---|---|
| **2 (Impact Assessment)** | × | Some | × | Partial performance | × | Timeframe > Calibration | × | Time frame = 3-10x |
| | × | Ok coverage | × | Some long term trends wrong. | × | Long stress periods | ✓ | Stresses = 2-5x |
| | ✓ | Some usage data/ low volumes | × | Short term record. | ✓ | Ok validation | × | Mass balance <1% |
| | ✓ | Baseflow estimates.<br>Some K & S measurements | × | Weak seasonal match. | ✓ | Transient calibration and prediction | ✓ | Some properties < > field values.<br>Review by Hydrogeologist |
| | ✓ | Some high resolution topographic DEM &/or some aquifer geometry | × | No use of targets compatible with model purpose (heads & fluxes) | ✓ | New stresses not in calibration | × | Some coarse discretisation in key areas of grid or at key times |
| | ✓ | Lots, with good coverage. | ✓ | Good performance stats | ✓ | Timeframe ~ calibration | ✓ | Timeframe < 3x |
| | × | Good metered usage info. | ✓ | Most long term trends matched | ✓ | Similar stress periods | × | Stresses < 2x |
| **3 (Complex Simulator)** | ✓ | Local climate data | ✓ | Most seasonal matches ok. | × | Good validation | ✓ | Mass balance < 0.5% |
| | × | Kx, Kz & Sy measurements from range of tests | ✓ | Present day data targets | ✓ | Calibration & prediction consistent (transient or steady state). | × | Properties ~field measurements |
| | × | High resolution DEM all areas. | ✓ | Head & Flux targets used to constrain calibration | × | Similar stresses to those in calibration. | ✓ | No coarse discretisation in key areas (grid or time) |
| | ✓ | Good aquifer geometry. | | | | | ✓ | Review by experienced Modeller |

# D 4 Predictive simulations

Having achieved a satisfactory calibration to the observed historic data the modelling period was extended from June 2019 over a 2,000 year period to include the proposed Project mining period and track recovery of groundwater levels post-mining. Potential impacts predicted using the model are described in Section 7 of the main report.

## D 4.1 Project mining period

As mentioned previously in Section D 2.4.5 the mine operational period extending from the end of the current historical model run (June 2019) to the end of mining has been simulated using quarterly stress periods. Model drain elevations used to represent the longwall panels and mine roads etc vary during this period as described in Section D 2.4.6. Recharge reverts to a time invariant long term average condition during this period as do levels used in the MODFLOW River, Stream and GHB boundary packages.

## D 4.2 Recovery period

Additional stress periods were also added to the groundwater model to simulate recovery of the groundwater system once underground mining is complete. Post-mining, any remaining drain cells were removed, and the model was adjusted to simulate post-mining conditions. This included increases to the modelled hydraulic conductivity and storage properties of the strata above the mining areas to represent long term longwall fracturing induced enhancement.

Model cells above and including the mined coal seam were assigned a higher horizontal conductivity as described in Section D 2.5.6.2. Appropriate specific yield increases were calculated by considering the bulk change in storage from the removal of coal, minus average subsidence levels from surface, and the ratio of the model layer thickness versus the actual extraction height. The total increase in storage in the model within the mining area is approximately 133 GL. Calculated increases to storage from the subsidence assessment and planned extraction heights are calculated at 138 GL, assuming an average bulk subsidence of 2.0 m and the haul/access roads remain fully open post-mining.

Post-mining, all groundwater boundary conditions (recharge, streamflow, etc) were set to the steady state values to allow the groundwater system to fully recover close to pre-mining conditions.

## D 4.3 Predicted groundwater level and flow impacts

### *D 4.3.1 Scenarios*

As described in Section 6.2 of the main report groundwater impacts have been assessed by comparing predicted groundwater levels and flows under the following three scenarios:

- a 'baseline' or no development scenario which excludes both the approved Narrabri Mine and the Narrabri Gas Project;
- a 'cumulative' scenario incorporating development of both the Project (including the approved Narrabri Mine) and the Narrabri Gas Project; and
- a 'Narrabri Gas Project only' scenario which excludes the Project (including the approved Narrabri Mine) from the cumulative scenario was also undertaken.

Predicted cumulative and Project only impacts are then calculated by comparing head and flow outputs from two pairs of scenarios as follows:

- Cumulative impacts = baseline scenario minus cumulative scenario; and
- Project only impacts = Narrabri Gas Project only scenario minus cumulative scenario.

### *D 4.3.2 Narrabri Gas Project*

As shown in Figure D 2.1 the area immediately to the west of the Narrabri Mine lease area forms part of the Narrabri Gas Project area. Both the Narrabri Gas and Narrabri Mine projects are expected to be in operation concurrently. Accordingly, the cumulative scenario described above includes operation of both developments.

The Narrabri Gas Project includes extraction from both the Hoskissons Coal Seam and the deeper Melville Coal Seams which are not represented in the Project groundwater model. Separate extraction rates for the Hoskissons and Melville seams were not available from Santos and hence cumulative impacts have been assessed by assigning predicted extraction from Narrabri Gas Project to the Hoskissions Coal Seam. This is considered to be a conservative assumption which will tend to over-estimate cumulative drawdown impacts since a proportion of the extraction will actually take place from the underlying Melvilles Coal Seams. However, it is also considered likely that inflows to the shallower Hoskissions Coal Seam will be significantly higher since as discussed previously in Section 3.3 the permeability of coal seams typically reduces relatively rapidly with depth and since the shallower seams are also closer to surficial recharge sources.

The impacts of the Narrabri Gas Project have been simulated using 'basecase' extraction rates provided by Santos (Figure D 4.1). These rates were then input to the model as extraction from the Hoskissons Coal Seam (model layer 9) via the MODFLOW well package although extraction rates were distributed as necessary to account for the different grid resolution adopted for the Project groundwater model within the Narrabri Gas Project area, compared to the Narrabri Gas Project model (CDM Smith, 2016). The MODFLOW well package was also used to simulate CSG extraction in the Narrabri Gas Project model. Predicted groundwater levels in the Narrabri Gas Project area generated by the two models were also compared, to confirm that the Project groundwater model was able to reasonably accurately replicate the reported impacts of the Narrabri Gas Project (CDM Smith, 2016). This was considered to be an important check, since whilst the same MODFLOW well based approach was used in the AGE model and well rates were provided by Santos, the model cell resolution and parameterisation of the two models are somewhat different. Furthermore, as discussed above all of the extraction was assumed to be occurring from the Hoskissons Coal Seam, rather than the Hoskissons and Melville seams

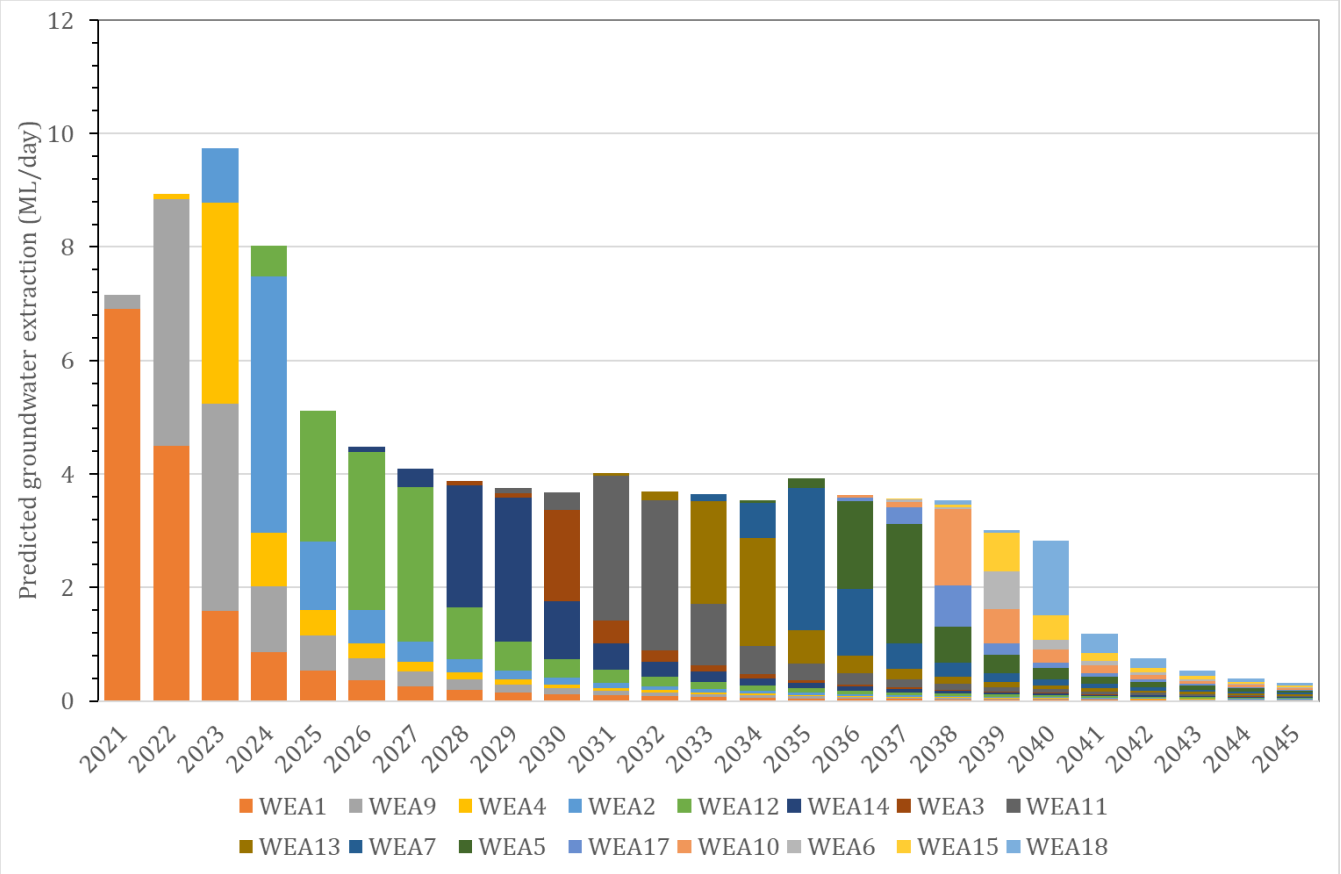



**Figure D 4.1 Base case estimated water extraction by Water Extraction Area (WEA) – Narrabri Gas Project**

### *D 4.3.3 Predicted impacts*

Predicted maximum all time drawdown in each model layer are presented in Appendix D 4.

Figure D 4.2, Table D 4.1 and Table D4.2 show predicted Project only impacts on individual modelled water budget components and suggest that during the mining period the additional demand created by extraction from the Project is largely met by groundwater being released from storage. The relatively minor impacts on other modelled water budget components including modelled surface water courses, evaporation and flow across the modelled boundaries predominantly occur post-mining.

Other Project only and cumulative impacts for key hydrostratigraphic units are described in Section 7 of the main report.

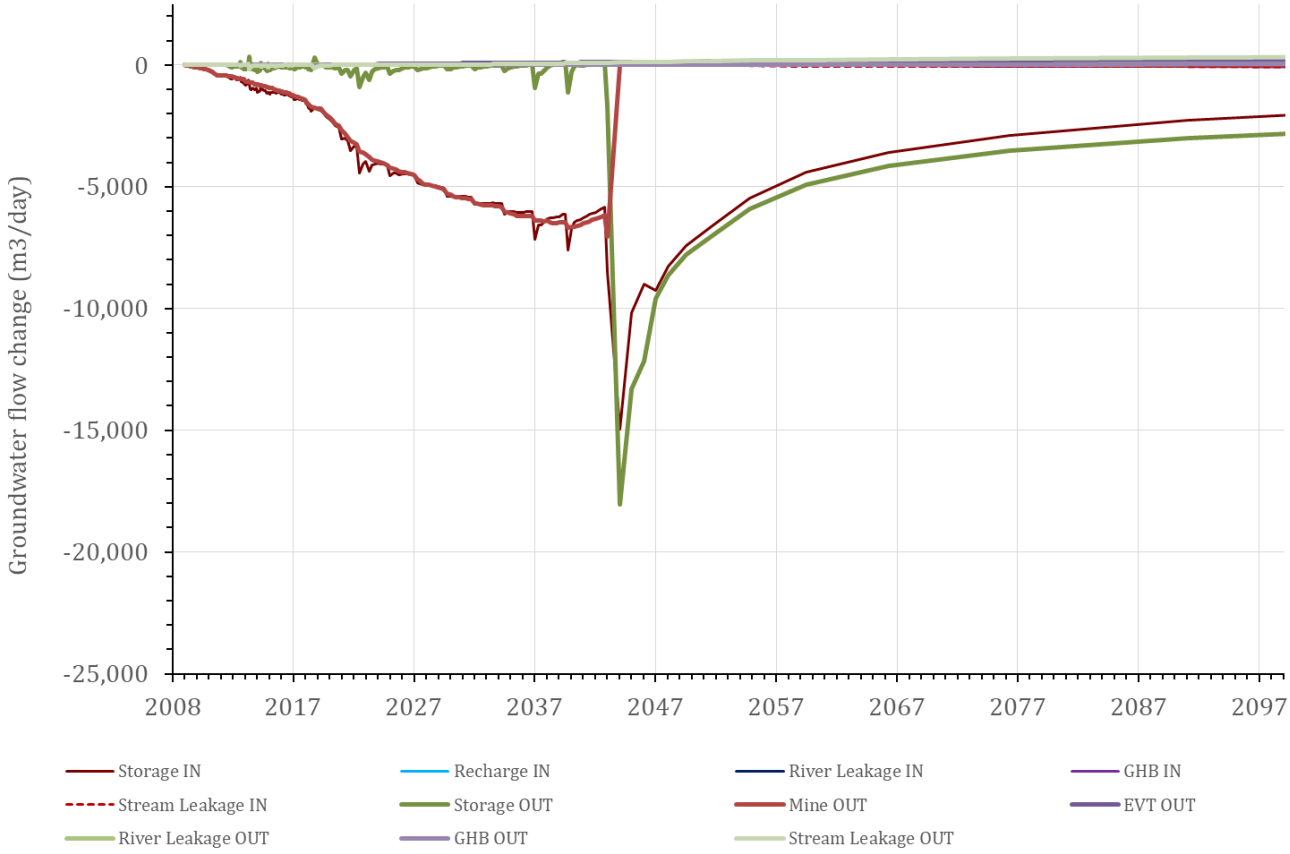



**Figure D 4.2 Timing of predicted impacts on modelled water budget components (Project Only)**

## Table D 4.1 Summary of predicted impacts on modelled water budget components – Project only, operational period (m3/d)

| Water balance component | Narrabri Gas Project Only Scenario | | | Cumulative scenario | | | Predicted Impact – Project Only | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Average | Max | Min | Average | Max | Min | Average | Max |
| **Inflows** | | | | | | | | | |
| Storage | 1 | 32490 | 134047 | 175 | 35155 | 134473 | -13 | -2665 | -8482 |
| Recharge | 0 | 90232 | 857826 | 0 | 90232 | 857826 | 0 | 0 | 0 |
| GHBs | 11076 | 24120 | 32834 | 11076 | 24119 | 32834 | 66 | 1 | -22 |
| SW leakage | 4025 | 10345 | 22047 | 4025 | 10344 | 22048 | 109 | 0 | -21 |
| **Total IN** | **94146** | **157187** | **873280** | **96051** | **159850** | **873692** | **-13** | **-2664** | **-8511** |
| **Outflows** | | | | | | | | | |
| Storage | 14 | 27789 | 636905 | 33 | 27888 | 636898 | 352 | -99 | -1705 |
| Wells | 45042 | 62241 | 91081 | 45042 | 62241 | 91081 | 0 | 0 | 0 |
| Mine | 0 | 0 | 0 | 13 | 2606 | 7049 | -13 | -2606 | -7049 |
| Evaporation | 952 | 2851 | 16586 | 940 | 2820 | 16580 | 116 | 31 | -52 |
| GHBs | 8028 | 13250 | 35171 | 8028 | 13250 | 35171 | 9 | 0 | -57 |
| SW discharge | 24213 | 51052 | 136049 | 24209 | 51041 | 136047 | 118 | 11 | -235 |
| **Total OUT** | **94146** | **157183** | **873244** | **96051** | **159846** | **873656** | **-13** | **-2664** | **-8511** |

## Table D 4.2 Summary of predicted impacts on modelled water budget components – Project only, recovery period (m3/d)

| Water balance component | Narrabri Gas Project Only Scenario | | | Cumulative scenario | | | Predicted Impact – Project Only | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Average | Max | Min | Average | Max | Min | Average | Max |
| **Inflows** | | | | | | | | | |
| Storage | 0 | 219 | 820 | 0 | 4224 | 15761 | 0 | -3995 | -14941 |
| Recharge | 90245 | 90245 | 90245 | 90245 | 90245 | 90245 | 0 | 0 | 0 |
| GHBs | 23532 | 23810 | 24167 | 23533 | 23875 | 24181 | -1 | -52 | -170 |
| SW leakage | 10135 | 10141 | 10148 | 10135 | 10183 | 10240 | 0 | -41 | -100 |
| **Total IN** | **123913** | **124415** | **125380** | **123913** | **128912** | **143185** | **0** | **-4474** | **-17805** |
| **Outflows** | | | | | | | | | |
| Storage | 0 | 588 | 1430 | 6 | 5473 | 19339 | -6 | -4858 | -18062 |
| Wells | 59515 | 59546 | 59915 | 59515 | 59548 | 59915 | 0 | 0 | 0 |
| Mine | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Evaporation | 2554 | 2569 | 2584 | 2326 | 2422 | 2554 | 235 | 148 | 29 |
| GHBs | 12618 | 12639 | 12683 | 12572 | 12612 | 12683 | 73 | 25 | -8 |
| SW discharge | 49002 | 49069 | 49156 | 48631 | 48854 | 49150 | 458 | 212 | -16 |
| **Total OUT** | **123909** | **124412** | **125376** | **123909** | **128908** | **143181** | **0** | **-4474** | **-17805** |

# D 5 Uncertainty analysis

A number of potential sources of uncertainty have been highlighted in the preceding sections including uncertainties in model inputs and simplifications which are inherent in any numerical model of complex natural systems. The following sections describe the methodology and results of an uncertainty analysis completed for the Project which was undertaken to assess the sensitivity of key model predictions to inevitable uncertainties in model parameters.

## D 5.1 Methodology

Middlemis and Peeters (2018) outline three general approaches to analysing parameter uncertainty in increasing order of complexity and of the level of resources required, they are:

1. deterministic scenario analysis with subjective probability assessment;
2. deterministic modelling with linear probability quantification; and
3. stochastic modelling with Bayesian probability quantification.

A Null-space Monte Carlo (NSMC) uncertainty analysis was undertaken (option 3), implemented using the PEST suite of software, to quantify the magnitude of uncertainty in the future impacts predicted by the model. This type of analysis produces probability distributions for predictive impacts by assessing a composite likelihood of an impact occurring through assessing and ranking the predictions from hundreds of alternative model 'realisations'. Each model realisation is informed by the observation dataset by using the relationship between the observation's statistics to perturbations of each parameter in the groundwater model.

This uncertainty analysis was essentially a three-part process. Firstly, a valid range for each parameters (i.e. pre-calibration range) was determined, and then 240 alternative model realisations were created, each having differing values of model parameters. Outputs from each realisation were then tested and any models that failed to converge or produced outputs that were inconsistent with the available calibration data set were rejected, leaving output from 100 successful models for subsequent statistical analysis. Models were considered to be at least reasonably consistent with the calibration data set if the value of the objective function was within 30% of that achieved by the fully calibrated model and modelled mine inflows were within 30% of observed inflow.

Outputs from the uncertainty modelling were processed in accordance with the risk-based calibrated language proposed in Middlemis & Peeters (2018). The ranges adopted are shown in Table D 5.1.

**Table D 5.1 Calibrated uncertainty modelling language**

| Narrative descriptor | Probability class | Description | Colour code |
|---|---|---|---|
| Very likely | 90 – 100 % | Likely to occur even in extreme conditions | |
| Likely | 67 – 90 % | Expected to occur in normal conditions | |
| About as likely as not | 33 – 67 % | About an equal change of occurring as not | |
| Unlikely | 10 – 33 % | Not expected to occur in normal conditions | |
| Very unlikely | 0 – 10 % | Not likely to occur even in extreme conditions | |

## D 5.2 Parameter generation

### *D 5.2.1 Prior ranges*

To undertake this type of analysis it is necessary to firstly assess the response of the calibration statistics to changes in the parameters in the groundwater model using a 'prior' or pre-calibration range. Table D 5.2 to Table D 5.7 shows the 'prior' range explored during the uncertainty analysis simulations which was at least as wide as the range used during calibration of the model (Table D 3.4 and Table D 3.5). In cases where the calibrated parameter value was at either the lower or upper bound used for calibration then the adopted prior range was either increased or decreased as appropriate within realistic physical bounds to prevent bias in the analysis. All parameters were assumed to possess a log-normal distribution centred around a mean value, or most probable value, which represents the parameter derived from the calibration process.

As mentioned previously a total of 240 models were generated using a random parameter generator to produce 'realisations' to assess predictive impacts.

**Table D 5.2 Prior range – horizontal hydraulic conductivity**

| Model layer | Lithology | Horizontal hydraulic conductivity (m/day) | | |
|---|---|---|---|---|
| | | lower | mean | upper |
| 1 | Alluvium (Qa) | 0.3 | 9.4 | 30 |
| 1 | Colluvium/regolith | 0.003 | 1.6 | 3 |
| 2 | Pilliga Sandstone | 0.1 | 1 | 1 |
| 3 | Purlawaugh Formation | 0.001 | 0.006 | 0.1 |
| 4 | Garrawilla Volcanics | 0.005 | 0.03 | 0.5 |
| 5 | Napperby upper | 0.001 | 0.01 | 0.5 |
| 6 | Napperby Sill | 0.0001 | 0.0009 | 0.5 |
| 7 | Napperby lower | 0.001 | 0.006 | 0.5 |
| 8 | Digby Conglomerate | 0.00001 | 0.0003 | 0.005 |
| 9 | Hoskissons Coal Seam | 0.01 | 0.009 | 0.1 |
| 10 | Arkarula Formation | 0.001 | 0.01 | 1 |
| 11 | Pamboola Formation | 0.001 | 0.009 | 0.1 |

## Table D 5.3 Prior range – vertical hydraulic conductivity factor

| Model layer | Lithology | Vertical hydraulic conductivity factor (Kz/Kx) | | |
|---|---|---|---|---|
| | | Lower | Mean | Upper |
| 1 | Alluvium (Qa) | 0.001 | 0.05 | 0.3 |
| 1 | Colluvium/regolith | 0.001 | 0.1 | 0.2 |
| 2 | Pilliga Sandstone | 0.001 | 0.05 | 0.1 |
| 3 | Purlawaugh Formation | 0.00001 | 0.0001 | 0.01 |
| 4 | Garrawilla Volcanics | 0.00001 | 0.0001 | 0.1 |
| 5 | Napperby upper | 0.0001 | 0.0005 | 0.01 |
| 6 | Napperby Sill | 0.001 | 0.00863 | 0.1 |
| 7 | Napperby lower | 0.0001 | 0.01 | 0.03 |
| 8 | Digby Conglomerate | 0.001 | 0.1 | 0.5 |
| 9 | Hoskissons Coal Seam | 0.001 | 0.01 | 0.5 |
| 10 | Arkarula Formation | 0.0001 | 0.001 | 0.1 |
| 11 | Pamboola Formation | 0.0001 | 0.01 | 0.1 |

## Table D 5.4 Prior range – Specific yield

| Model layer | Lithology | Specific yield – Sy | | |
|---|---|---|---|---|
| | | Lower | Mean | Upper |
| 1 | Alluvium (Qa) | 1 | 1.6 | 10 |
| 1 | Colluvium/regolith | 1 | 1.1 | 10 |
| 2 | Pilliga Sandstone | 0.5 | 1.7 | 5 |
| 3 | Purlawaugh Formation | 0.5 | 0.9 | 5 |
| 4 | Garrawilla Volcanics | 0.5 | 1 | 5 |
| 5 | Napperby upper | 0.5 | 1.1 | 5 |
| 6 | Napperby Sill | 0.5 | 1 | 5 |
| 7 | Napperby lower | 0.5 | 1.1 | 5 |
| 8 | Digby Conglomerate | 0.5 | 1 | 5 |
| 9 | Hoskissons Coal Seam | 0.5 | 0.5 | 5 |
| 10 | Arkarula Formation | 0.5 | 1 | 5 |
| 11 | Pamboola Formation | 0.5 | 0.9 | 5 |

## Table D 5.5 Prior range – specific storage

| Model layer | Lithology | Specific storage $m^{-1}$ | | |
|---|---|---|---|---|
| | | Lower | Mean | Upper |
| 1 | Alluvium (Qa) | $2.3 \times 10^{-7}$ | $1.0 \times 10^{-5}$ | $2.0 \times 10^{-5}$ |
| 1 | Colluvium/regolith | $2.3 \times 10^{-7}$ | $1.0 \times 10^{-5}$ | $2.0 \times 10^{-5}$ |
| 2 | Pilliga Sandstone | $2.3 \times 10^{-7}$ | $2.0 \times 10^{-6}$ | $2.0 \times 10^{-5}$ |
| 3 | Purlawaugh Formation | $2.3 \times 10^{-7}$ | $9.9 \times 10^{-7}$ | $2.0 \times 10^{-5}$ |
| 4 | Garrawilla Volcanics | $2.3 \times 10^{-7}$ | $1.0 \times 10^{-6}$ | $2.0 \times 10^{-5}$ |
| 5 | Napperby upper | $2.3 \times 10^{-7}$ | $1.4 \times 10^{-6}$ | $2.0 \times 10^{-5}$ |
| 6 | Napperby Sill | $2.3 \times 10^{-7}$ | $1.3 \times 10^{-6}$ | $2.0 \times 10^{-5}$ |
| 7 | Napperby lower | $2.3 \times 10^{-7}$ | $2.4 \times 10^{-6}$ | $2.0 \times 10^{-5}$ |
| 8 | Digby Conglomerate | $2.3 \times 10^{-7}$ | $1.0 \times 10^{-6}$ | $2.0 \times 10^{-5}$ |
| 9 | Hoskissons Coal Seam | $2.3 \times 10^{-7}$ | $1.1 \times 10^{-6}$ | $2.0 \times 10^{-5}$ |
| 10 | Arkarula Formation | $2.3 \times 10^{-7}$ | $7.0 \times 10^{-7}$ | $2.0 \times 10^{-5}$ |
| 11 | Pamboola Formation | $2.3 \times 10^{-7}$ | $1.4 \times 10^{-5}$ | $2.0 \times 10^{-5}$ |

## Table D 5.6 Prior range – recharge

| Model layer | Lithology | Recharge | | |
|---|---|---|---|---|
| | | Lower | Mean | Upper |
| 1 | Alluvium (Qa) | 0.25 | 0.25 | 0.85 |
| 1 | Colluvium/regolith | 9.19E-03 | 0.002 | 0.17 |
| 2 | Pilliga Sandstone | 4.00E-02 | 0.002 | 0.17 |
| 3 | Purlawaugh Formation | 8.95E-02 | 0.06 | 0.34 |
| 4 | Garrawilla Volcanics | 2.19E-02 | 0.002 | 0.17 |
| 5 | Napperby upper | 6.06E-03 | 0.002 | 0.17 |
| 6 | Napperby Sill | 5.99E-03 | 0.002 | 0.17 |
| 7 | Napperby lower | 4.09E-02 | 0.002 | 0.17 |
| 8 | Digby Conglomerate | 3.05E-02 | 0.002 | 0.17 |
| 9 | Hoskissons Coal Seam | 3.32E-02 | 0.002 | 0.17 |
| 10 | Arkarula Formation | 2.93E-02 | 0.002 | 0.17 |
| 11 | Pamboola Formation | 3.93E-02 | 0.002 | 0.17 |

## Table D 5.7 Prior range – Other parameters

| Group | Parameter | Value | | | Unit |
|---|---|---|---|---|---|
| | | Lower | Mean | Upper | |
| Mine | Skin factor | 0.01 | 0.14 | 1 | - |
| Mine | Ap (top of +a95 zone) | 0.1 | 2.5 | 50 | mm |
| Mine | Ap (above coal) | 30 | 49.7 | 100 | mm |
| Mine | Surface cracking factor (Kh) | 1 | 2.7 | 10 | multiplier |
| Mine | Surface cracking factor (Kv) | 1 | 2.7 | 5 | multiplier |
| Mine | Surface cracking factor (Sy) | 1 | 1.9 | 3 | multiplier |
| Mine | Surface cracking factor (Ss) | 1 | 2.1 | 3 | multiplier |
| GHB | General head conductance factor | 0.000001 | 1.3 | 10 | multiplier |
| HFB | Horizontal flow barrier conductance (zone 1) | 0.000001 | 1 | 1 | multiplier |
| HFB | Horizontal flow barrier conductance (zone 2) | 0.000001 | 1 | 1 | multiplier |
| HFB | Horizontal flow barrier conductance (zone 3) | 0.000001 | 1 | 1 | multiplier |
| HFB | Horizontal flow barrier conductance (zone 4) | 0.000001 | 1 | 1 | multiplier |
| RIV | Riverbed Kv (zone 1 to 7) | 0.01 | 0.1 | 1 | m/day |
| STR | Stream bed Kv (zone 1 – Bohena Creek) | 0.001 | 0.014 | 1 | m/day |
| STR | Stream bed Kv (zone 2 – Maules Creek) | 0.001 | 0.007 | 1 | m/day |
| STR | Stream bed Kv (zone 3 – Coxs Creek) | 0.001 | 0.01 | 1 | m/day |
| STR | Stream bed Kv (zone 4 – Namoi River upstream) | 0.001 | 0.008 | 1 | m/day |
| STR | Stream bed Kv (zone 5 – Namoi River mid) | 0.001 | 0.009 | 1 | m/day |
| STR | Stream bed Kv (zone 6 – Namoi River downstream) | 0.001 | 0.003 | 1 | m/day |
| EVT | Evapotranspiration factor (zone1-3) | 0.7 | 1 | 1.5 | multiplier |

### *D 5.2.2 Posterior ranges*

Through reference to a Jacobian matrix and the prior probability distributions for each parameter, as described above, PEST then generates a suite of posterior parameter probability distributions which are randomly sampled to produce alternative realisations.

As pilot points are present in each layer, review of the calibrated prior and posterior ranges is not sufficient to show the full distribution in parameters for each layer. Instead the posterior distribution of parameters was analysed using regularised (200 m) cumulative distribution function (CDF) plots with uncertainty ranges added. Example plots are provided as Figure D 5.1, Figure D 5.2 and Figure D 5.3 for Kx in layer 1 (Quaternary Alluvium/Regolith/Colluvium), Kx in layer 3 (Pilliga Sandstone), and Kx in layer 21 (Hoskissons seam).

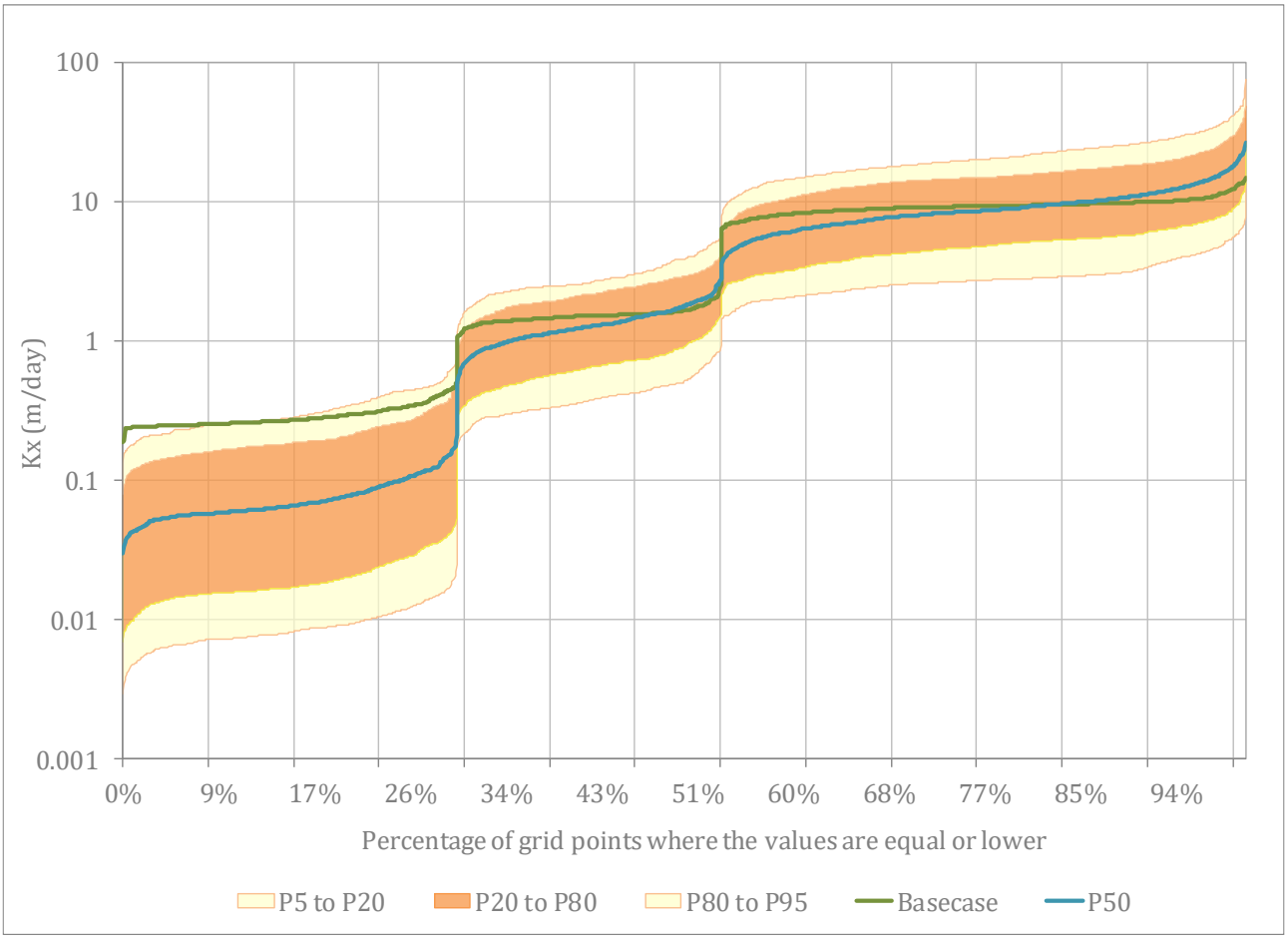



**Figure D 5.1 Cumulative distribution function plot for Kx layer 1 – Quaternary alluvium/Regolith/Colluvium**

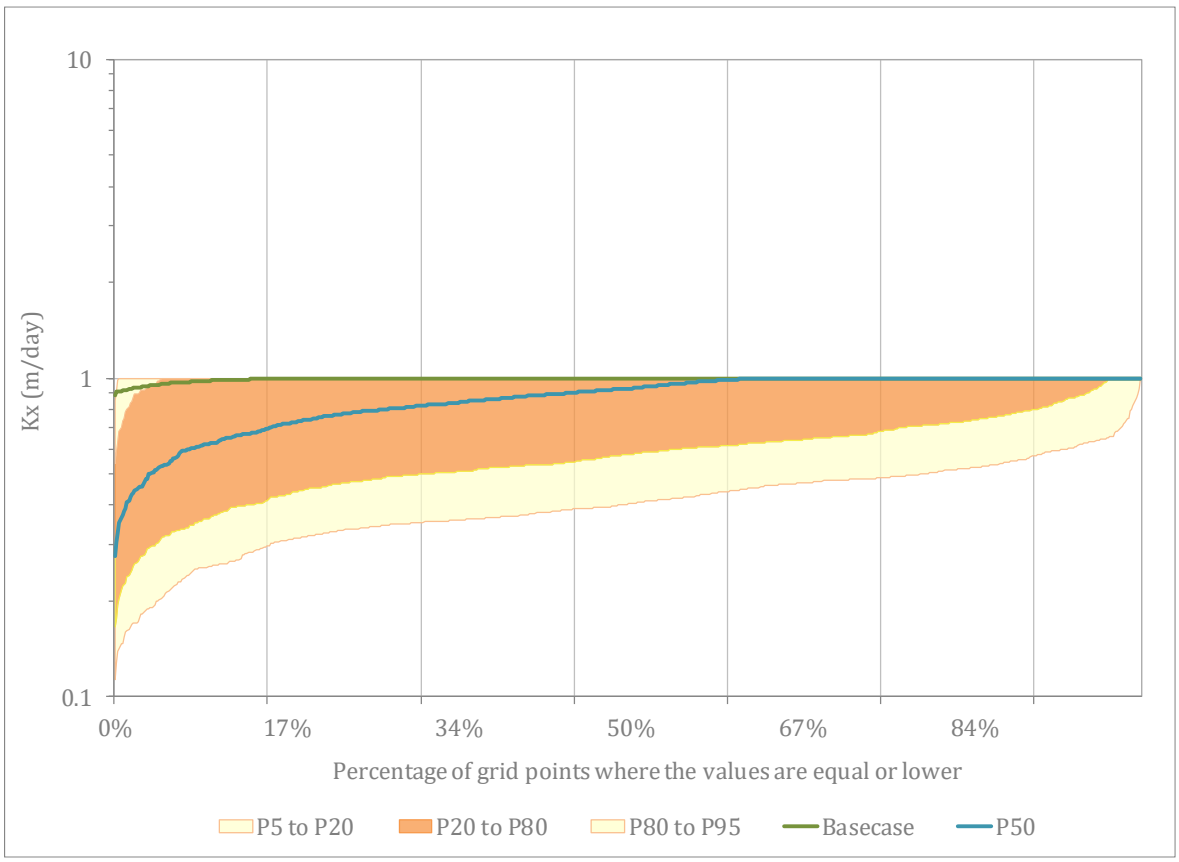



**Figure D 5.2 Cumulative distribution function plot for Kx layer 3 – Pilliga Sandstone**

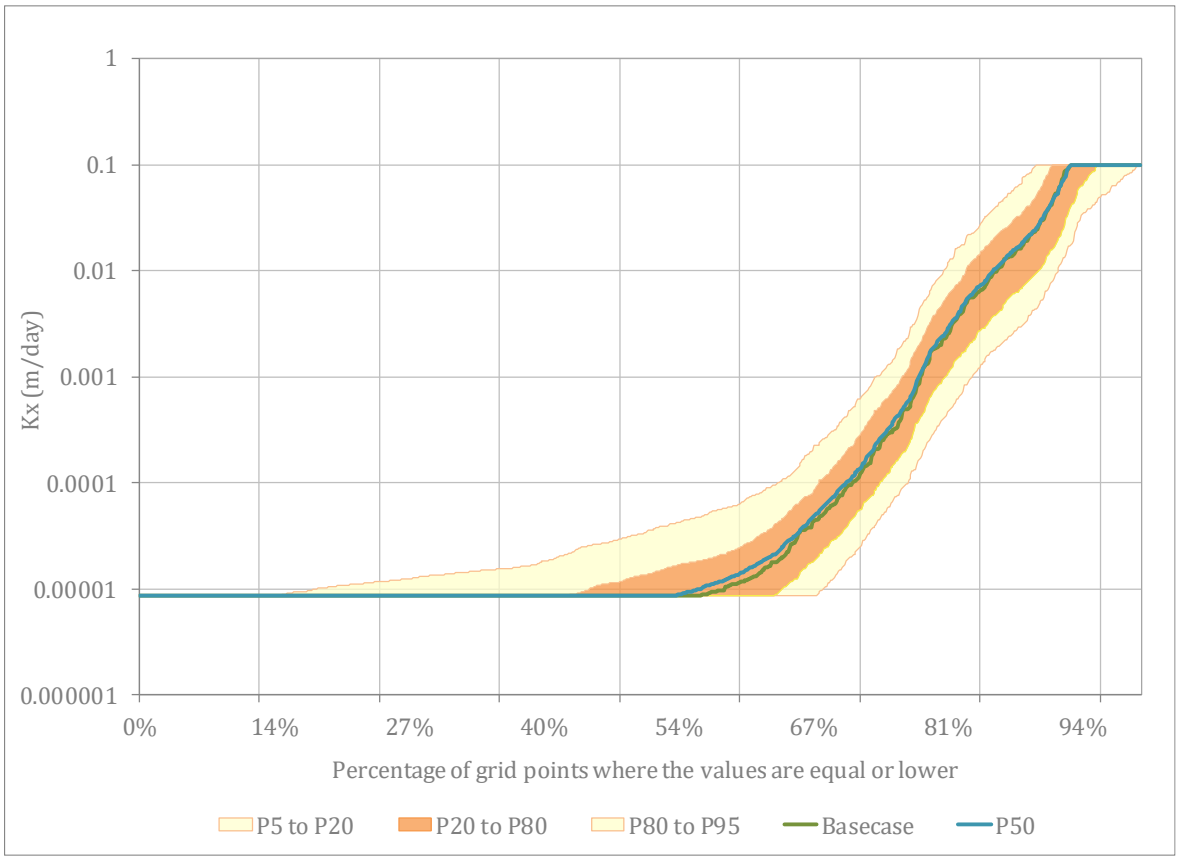



**Figure D 5.3 Cumulative distribution function plot for Kx layer 21 – Hoskissons Seam**

In most cases these plots show that the 50th percentile (P50) parameter values adopted for the uncertainty analysis are similar to the basecase or fully calibrated model, although in some cases the final calibrated parameter value is towards the upper bound of the range that is considered physically realistic. For instance, in layer 3 the highest Kx values in the fully calibrated model reached the upper limit prescribed for Sandstone (1 m/day) at more than 90% of grid points. However, around 50% of the uncertainty models were generally below this limit on average. If this cap were not present the pilot point multipliers would have increased hydraulic conductivity values to a physically unrealistic value.

The uncertainty bands for each layer show that the average Kx varied by approximately 0.5 to 1 order of magnitude across the 100 realisations, while the pilot points varied by as much as 0.1-10x the average Kx from the prescribed base parameter (see Table D 5.2). This represents the variation in the average transmissivity of the entire unit in the model commensurate with the field testing data ranges. This is considered to be a suitable range in conditions to properly simulate uncertainty, but could be expanded if the calibration criteria were allowed to vary by more than 30% of the basecase model phi.

## D 5.3 Results

### *D 5.3.1 Number of model runs*

As noted previously, statistical analysis was undertaken on predictions generated using some 100 alternative realisations which are at least reasonably consistent with expert knowledge and the historic calibration data set (i.e. they are calibration constrained).

As the number of models contributing to the uncertainty analysis increases, statistics generated using the outputs tend to stabilise, until the addition of further models has little influence on the results. Figure D 5.4 shows the number of model simulations contributing to the uncertainty analysis and the statistics of two key predictions, in this case, the maximum water table drawdown above the longwall workings and discharge to the Quaternary alluvium. As shown in Figure D 5.4 the P10, P50 and P90 values stabilise after results from around 80 realisations are included in the statistical analysis, which tends to confirm that the 100 realisations generated are sufficient to fully explore parameter uncertainty in this case.

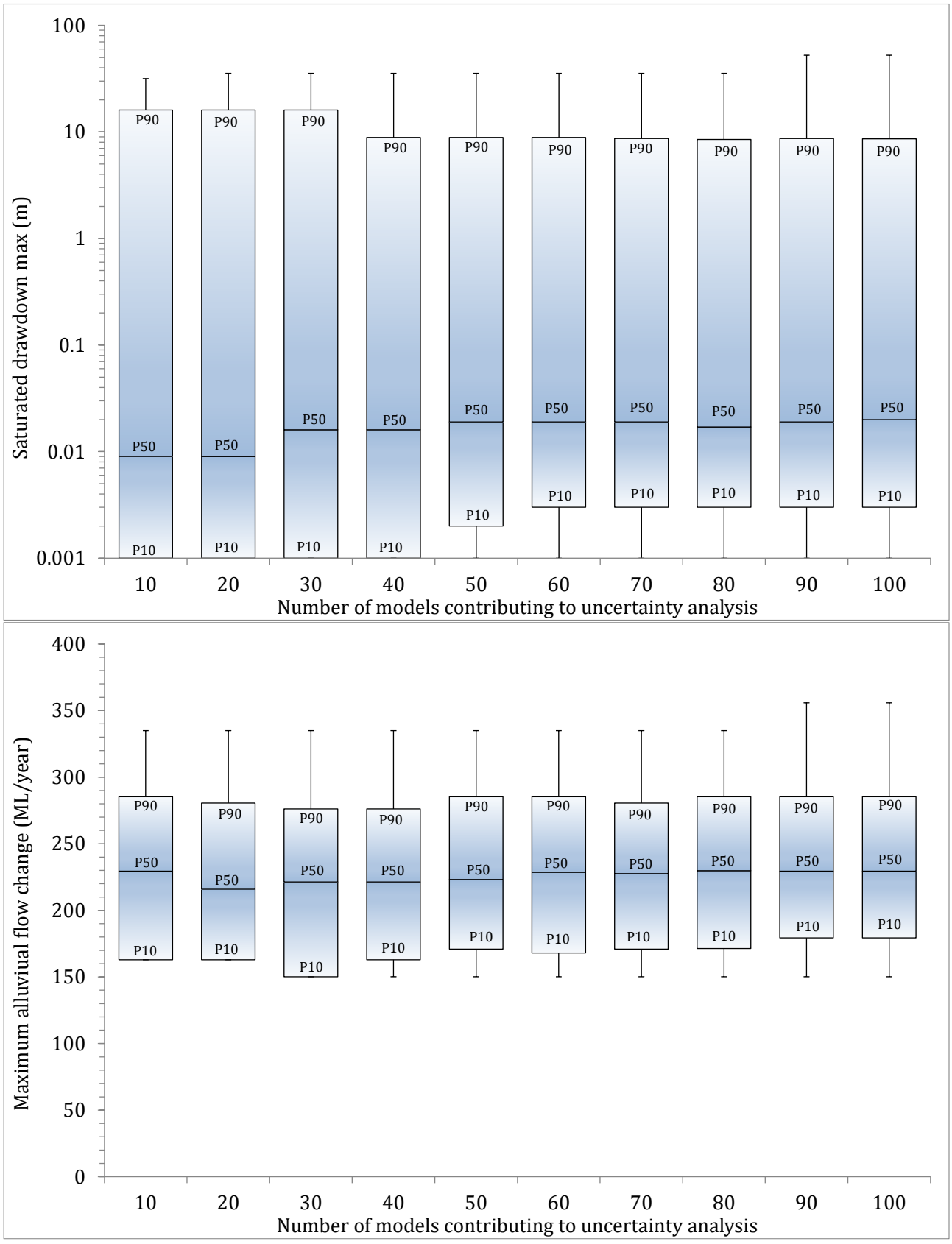



**Figure D 5.4 Model convergence check points (Box and whisker)**

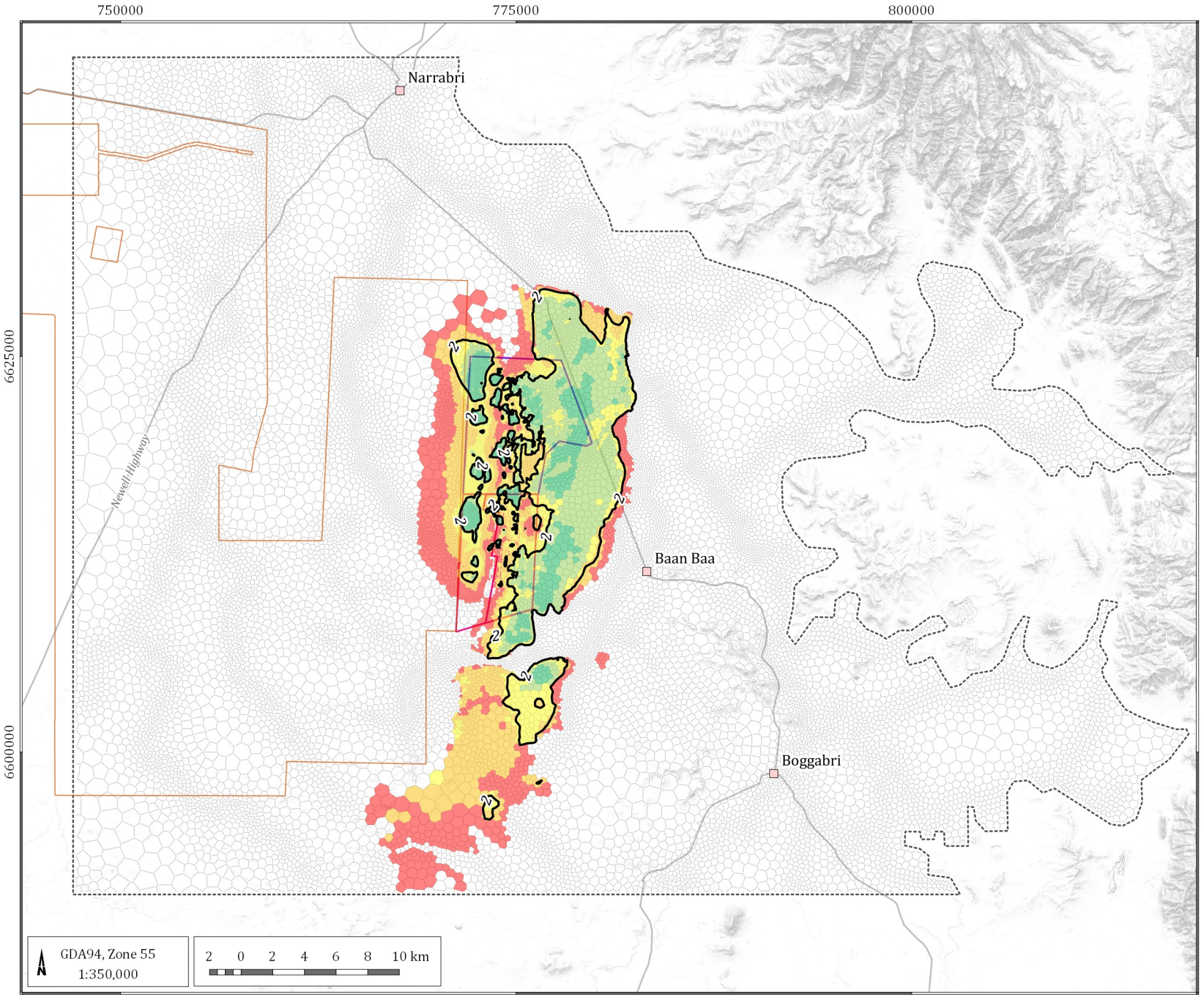
A summary of the calibration performance and predictive response to mining is provided in Appendix D 2 The hydrographs show the composite distribution of the heads across all 100 realisations and indicate that the majority of the models are acceptably calibrated.

### *D 5.3.2 Uncertainty in drawdown*

Drawdown predicted by the fully calibrated model is provided within the main report predominantly for the water table, Pilliga Sandstone (Layer 3), and Hoskissons Seam (Layer 9). Figure D 5.5 to Figure D 5.7 show the likelihood of the maximum drawdown at any time during mining exceeding the AIP threshold of 2 m. The figures uses the calibrated language to describe uncertainty as detailed in Section D 5.1.

As shown in Figure D 5.5 uncertainty analysis results suggest that there are no areas within the Namoi Alluvium where drawdown is 'likely' or 'very likely' to exceed 2 m at any time in the future. This is because the indirect loss of groundwater from the base of the alluvium to the depressurised underlying Permian aquitards is less than the recharge rate to the alluvial groundwater system for the majority of the model realisations. Hence water table impacts of more than 2 m are unlikely to occur in Namoi Alluvium and as shown in Figure D 5.5 to the east of the Project the fully calibrated or 'best estimate' prediction of the extent of the 2 m drawdown contour is similar to the 90$^{th}$ percentile (shown in red). Conversely to the south and west of the project, in areas where high storage alluvial strata is not present, results for some predictions show more substantial increases in the area impacted.

Uncertainty analysis results for the Pilliga Sandstone (Figure D 5.6) suggest that it is unlikely that impacts of more than 2 m will occur at distances of more 3 km from the western boundary of the mining lease. Conversely in the deeper model layers including the Hoskissons Coal Seam (Figure D 5.7) the spatial extents of drawdown are greater and, as expected, radiate out in decreasing likelihood from the active mining area. Predictions in these layers also appear to be subject to a relatively high degree of uncertainty. In particular as shown in Figure D 5.7 the area which is statistically 'about as likely as not' to be impacted by more than 2 m in the Hoskissons Coal Seam extends some distance beyond the full calibrated or best estimate prediction. It is, however, considered extremely unlikely that actual impacts in the Hoskissons Coal Seam could extend over such long distances. The numerical model conservatively assumes that the seam is continuous to the western boundary of the model. Whilst the Hoskissons is known to be present within the Narrabri Gas Project it is unlikely that the seam is continuous given the seam is typically 7 to 10 m thick and known to affected by minor faulting. Any faults which are characterised by more than 7 to 10 m are therefore likely to significantly affect the continuity of flow within the seam and even smaller faults are likely to act as baffles, effectively reducing the transmissivity of the unit and limiting lateral propagation of impacts.




LEGEND

- Populated place
- Road
- Drainage
- Fully calibrated model, 2m drawdown prediction
- Quaternary alluvium boundary
- Mining Lease Boundary (ML1609)
- Proposed Mining Lease
- Proposed Narrabri Gas Project (Santos)
- Model boundary
- Model mesh
- Quaternary alluvium
- 0-10% (Very unlikely)
- 10-33% (Unlikely)
- 33-67% (About as likely as not)
- 67-90% (Likely)
- 90-100% (Very likely)

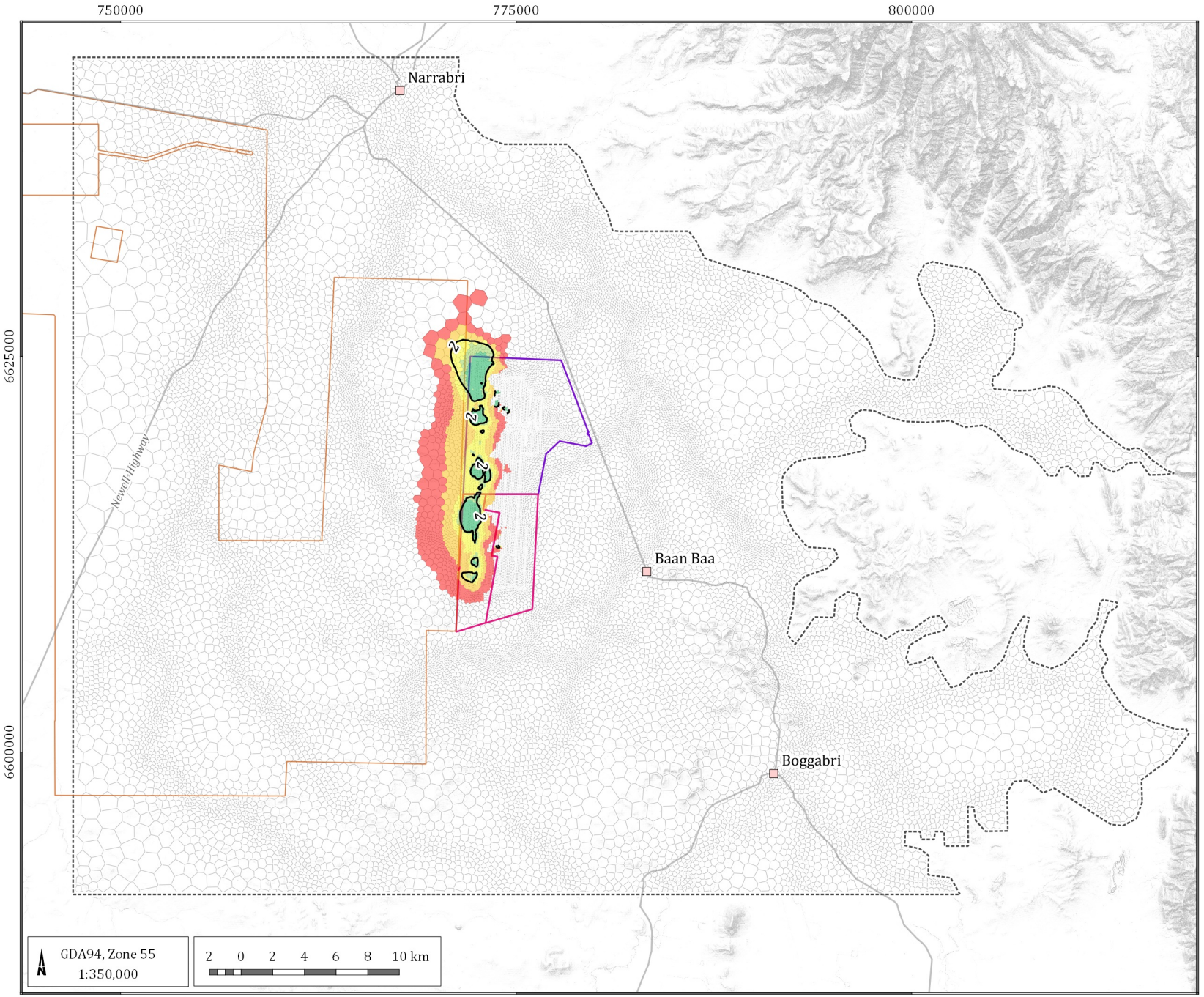
Narrrabri Stage 3 Extension GIA (G1972)

**Likelihood of 2m drawdown due to the Project - water table**

DATE
31/05/2020

FIGURE No:
**D 5.5**

©2020 Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) - www.ageconsultants.com.au
Source: ELVIS LiDAR DEM © Spatial Services, Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 05.05_G1972_Likelihood of 2m drawdown due to proposed extension - water table.qgs




LEGEND

- Populated place
- Road
- Drainage
- Fully calibrated model, 2m drawdown prediction
- Mining Lease Boundary (ML1609)
- Proposed Mining Lease
- Proposed Narrabri Gas Project (Santos)
- Model boundary
- Model mesh
- 0-10% (Very unlikely)
- 10-33% (Unlikely)
- 33-67% (About as likely as not)
- 67-90% (Likely)
- 90-100% (Very likely)

Narrrabri Stage 3 Extension GIA (G1972)

**Likelihood of 2m drawdown due to the Project - Pilliga Sandstone**

DATE
31/05/2020

FIGURE No:
**D 5.6**

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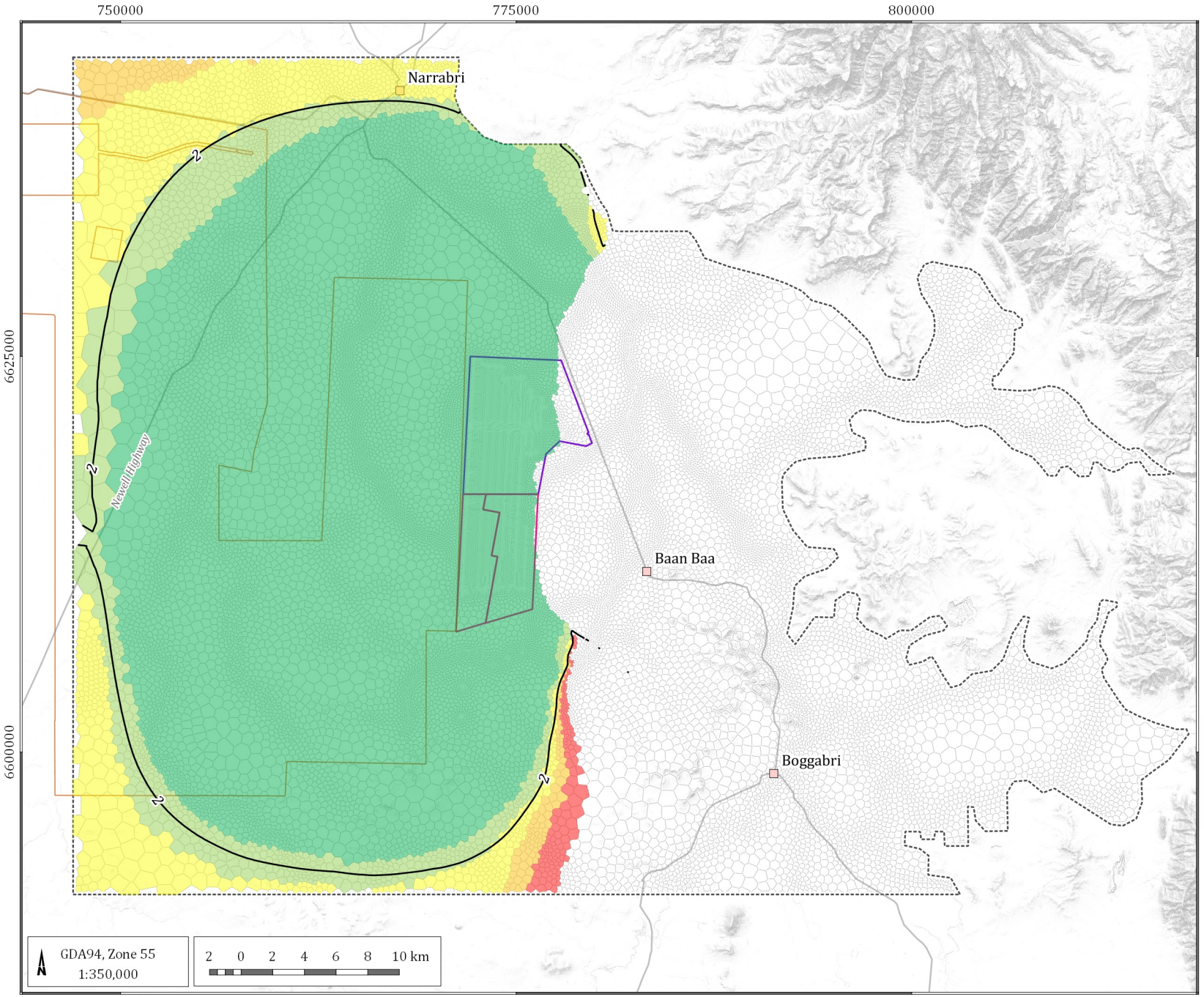
Source: ELVIS LiDAR DEM © Spatial Services, Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 05.05_G1972_Likelihood of 2m drawdown due to proposed extension - water table.qgs




Narrrabri Stage 3 Extension GIA (G1972)

**Likelihood of 2m drawdown due to the Project - Hoskissons Coal Seam**

DATE
31/05/2020

FIGURE No:
**D 5.7**

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Source: ELVIS LiDAR DEM © Spatial Services, Department Finance, Services and Innovation (DFSI) 2016, Accessed September 2019 (https://elevation.fsdf.org.au/); GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 05.05_G1972_Likelihood of 2m drawdown due to proposed extension - water table.qgs

### *D 5.3.3 Uncertainty in dewatering rate*

Figure D 5.8 presents the uncertainty of groundwater seepage into the Narrabri underground workings during operation.

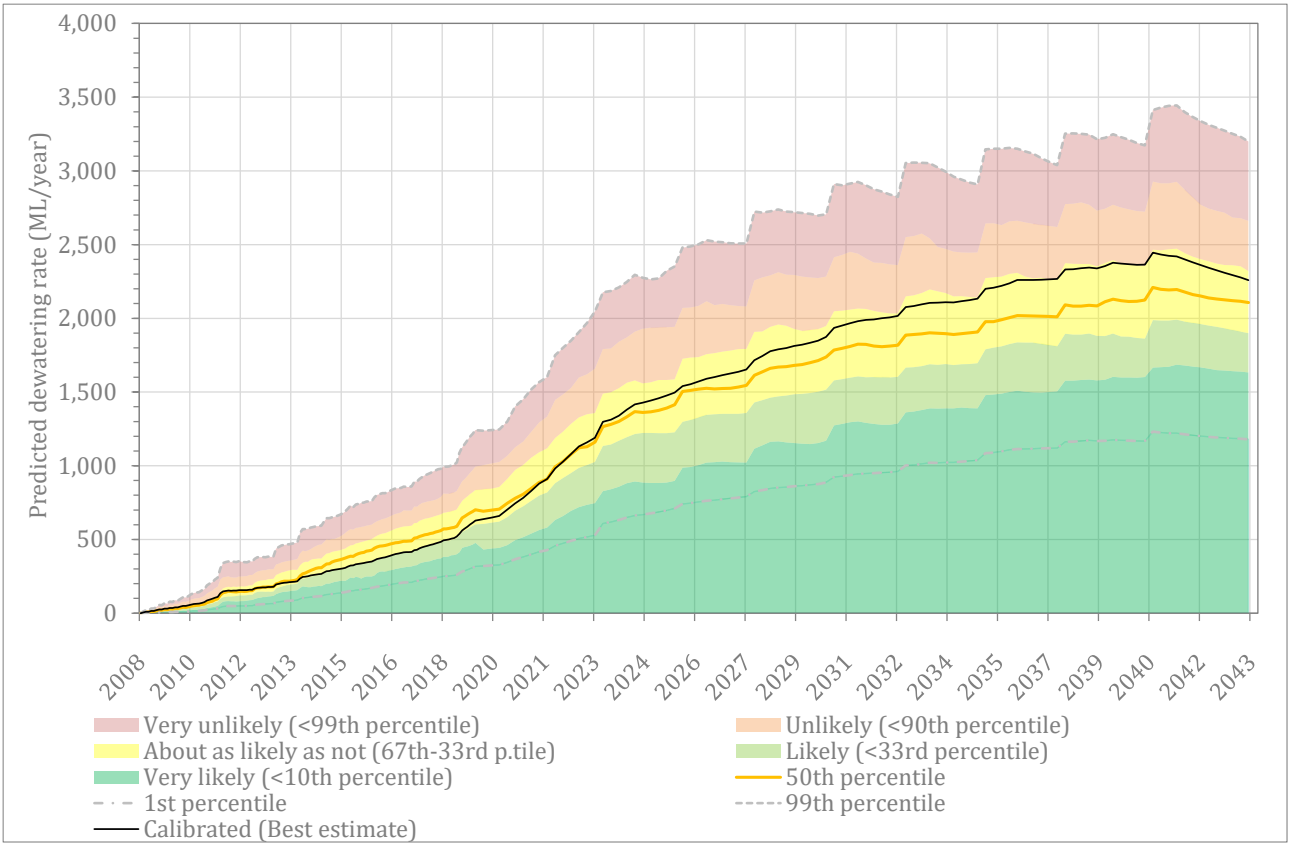


**Figure D 5.8 Uncertainty in dewatering rate**

The uncertainty analysis indicated future inflows of up to 3,444 ML/year in year 2041. The results suggest the calibrated case represents a higher estimate of potential inflow to the mine, and potentially the most likely inflow estimate is closer to the 50$^{th}$ percentile result. As shown in Figure D 5.8 the fully calibrated or 'best estimate' prediction sits close to the P67 result, i.e. around 67% of the simulations undertaken resulted in the less mine inflow. As discussed in Section 5.6.2 of the main report previous predictions made using previous iterations of the project numerical model (Aquaterra, 2009; and HydroSimulations 2015) have tended to over-estimate actual inflows which may be related to assumptions about the continuity of the Hoskissons Coal Seam (Section D 5.3.2) which are inherent in all of the simulations including the current model. Past behaviour therefore suggests that actual inflows may be less than that predicted by the fully calibrated model. Inflows to the current mine are currently sitting between 1 and 1.5 ML/d (equivalent to 365 – 550 ML/yr) suggesting that actual inflows are unlikely to be less than the 10$^{th}$ percentile shown in Figure D 5.8 and which predicts around 400 ML/yr in 2020.

### *D 5.3.4 Uncertainty in alluvial groundwater and surface water flow change*

Figure D 5.9 and Figure D 5.10 present the change in flux to the alluvial systems from the Narrabri Coal Project and surrounding CSG production (i.e. the cumulative scenario). As introduced previously in Section D 3.5.6 these predictions include consideration of parameters relating to the vertical hydraulic conductivity (Kv) of layer 1 which were not readily identifiable in the calibration. As shown in Figure D 5.9 predicted maximum impacts on the Namoi Alluvium range from around 150 ML to 420 ML/year, compared to the best estimate of around 260 ML/year.

Similarly predicted baseflow impacts on the Namoi River itself range from less than 50 ML/year to around 220 ML/year compared to a best estimate of around 140 ML/year.

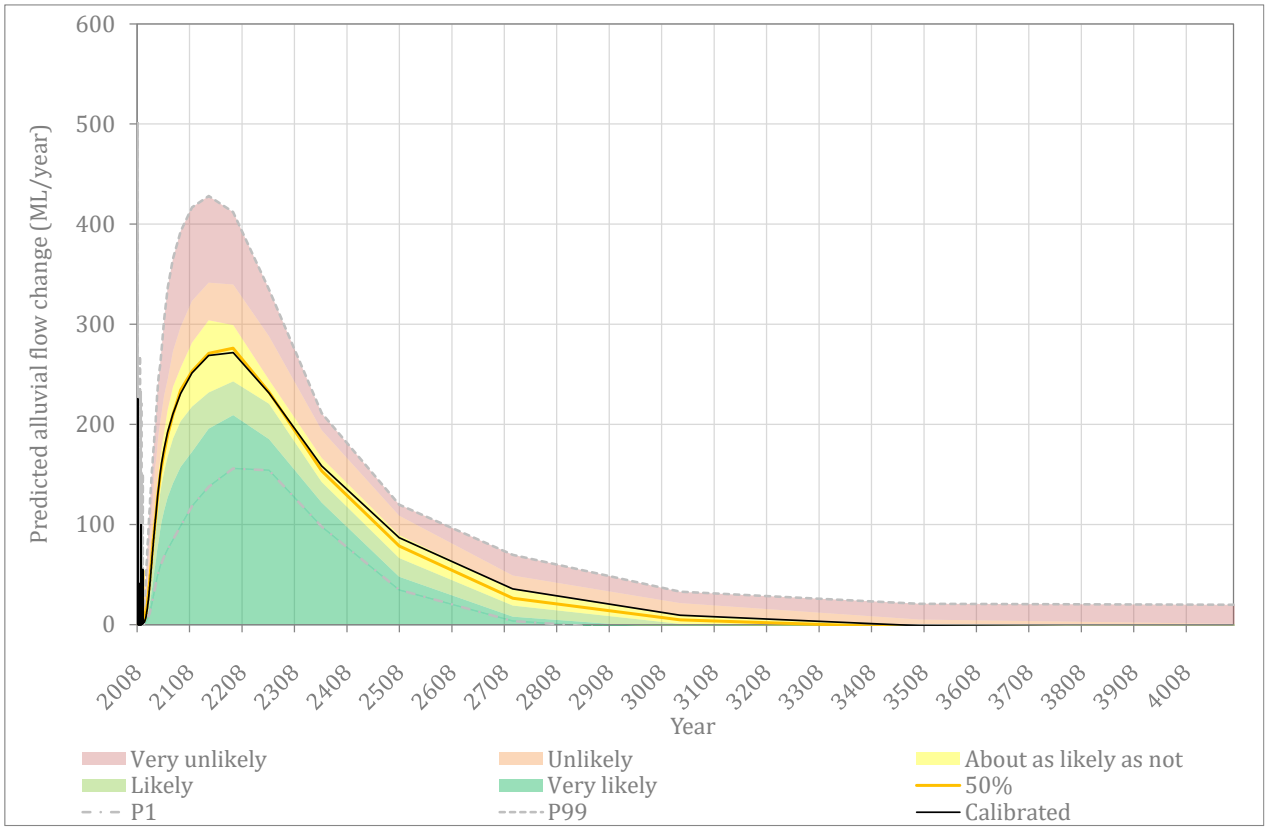


**Figure D 5.9 Uncertainty in alluvial flow change**

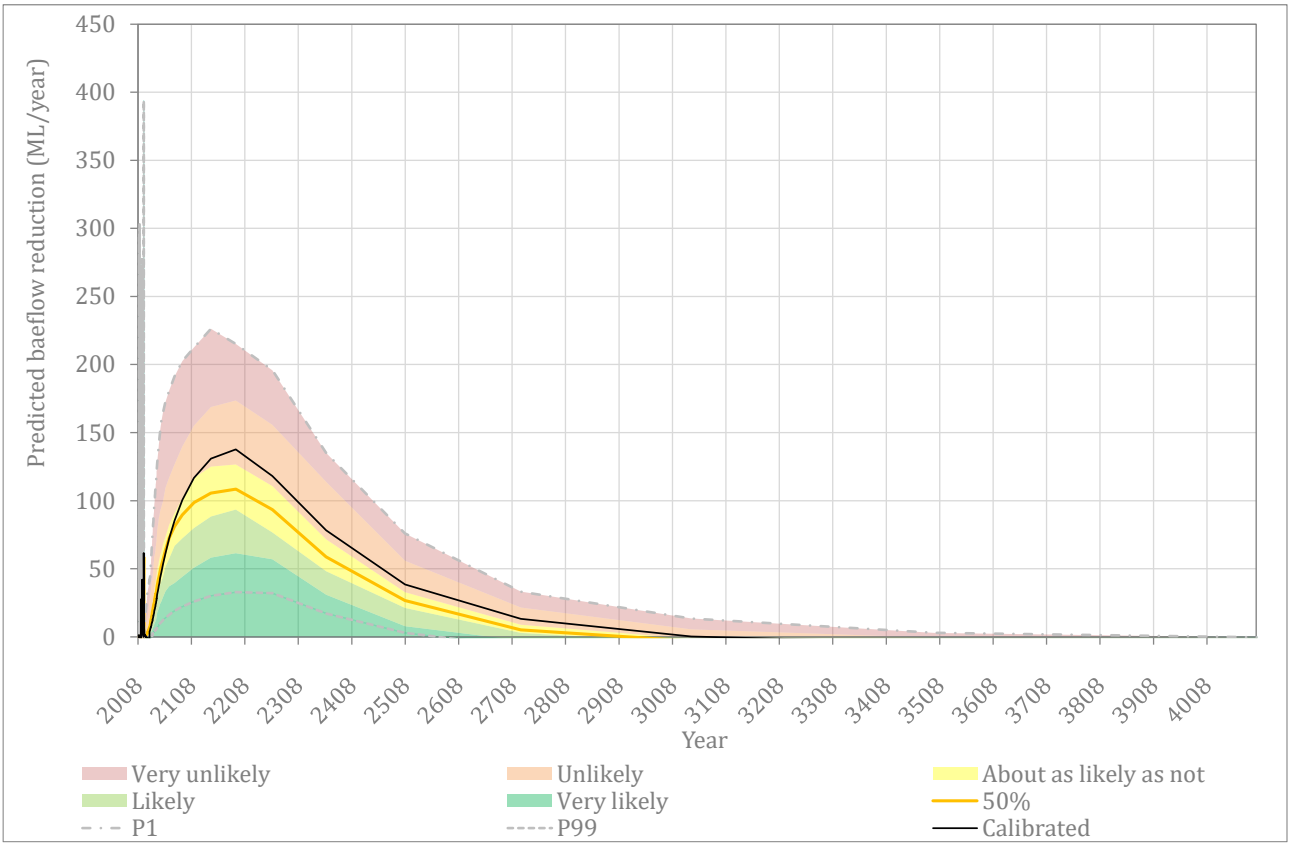


**Figure D 5.10 Uncertainty in baseflow change (Namoi River)**

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# *Appendix D 1* Calibration details and hydrographs

# Narrabri Mine monitoring locations

| Bore | Easting (GDA94 Z56) | Northing (GDA94 Z56) | Layer | Average residual | Range in residuals | |
|---|---|---|---|---|---|---|
| | | | | | Minimum | Maximum |
| P1 | 776116 | 6614694 | 4b | 2.16 | -21.56 | 10.27 |
| P10 | 774063 | 6616444 | 5b | 21.76 | -7.89 | 30.33 |
| P11 | 774066 | 6616447 | 3c | 0.12 | -7.35 | 6.22 |
| P12 | 776513 | 6619964 | 5d | 8.57 | -9.47 | 18.57 |
| P13 | 776526 | 6619972 | 4b | 7.93 | 4.31 | 13.41 |
| P14 | 775221 | 6622816 | 5b | -28.75 | -30.73 | -22.91 |
| P15 | 775221 | 6622818 | 4b | 9.92 | 0.70 | 12.61 |
| P16 | 772233 | 6623740 | 4b | 11.26 | 2.13 | 14.96 |
| P17 | 772222 | 6623712 | 3a | -15.88 | -19.37 | -3.37 |
| P18 | 776826 | 6621802 | 9 | 11.61 | -2.49 | 17.02 |
| P19 | 776827 | 6621543 | 11 | 32.86 | 9.38 | 48.76 |
| P2 | 777282 | 6616355 | 7c | -6.29 | -8.64 | -5.24 |
| P20 | 776482 | 6621837 | 10 | 12.79 | -12.71 | 18.29 |
| P21_VW | 776851 | 6620363 | 9 | 34.71 | -35.93 | 58.61 |
| P22_VW | 776745 | 6620406 | 9 | 0.17 | -68.77 | 14.87 |
| P24_112 | 776675 | 6621043 | 7c | 9.75 | -17.43 | 32.34 |
| P24_148 | 776675 | 6621043 | 8b | 29.63 | -11.49 | 43.50 |
| P24_166 | 776675 | 6621043 | 9 | -0.35 | -26.53 | 26.35 |
| P24_180 | 776675 | 6621043 | 10 | -9.37 | -19.15 | 11.49 |
| P25_VW | 776703 | 6620327 | 9 | -16.23 | -50.86 | 11.04 |
| P26_VW | 776537 | 6620528 | 9 | 62.56 | 17.17 | 140.64 |
| P27_VW | 776540 | 6620485 | 9 | -3.40 | -33.24 | 7.16 |
| P28 | 778343 | 6620162 | 5c | 3.71 | 2.53 | 4.12 |
| P29 | 778541 | 6619978 | 5c | 4.91 | 1.10 | 6.41 |
| P3 | 780433 | 6620115 | 11 | -7.21 | -8.11 | -6.11 |
| P31 | 778318 | 6620343 | 5b | -4.26 | -4.64 | -3.99 |
| P32 | 778993 | 6620335 | 5d | 5.32 | 3.21 | 7.36 |
| P35_VW | 776430 | 6620348 | 9 | 3.38 | -70.79 | 27.92 |
| P36_VW | 776329 | 6620442 | 9 | -5.19 | -65.45 | 18.16 |
| P37_VW | 776474 | 6620492 | 9 | -2.60 | -22.69 | 6.44 |
| P38U1_VW | 776385 | 6621640 | 9 | -1.35 | -50.11 | 25.49 |
| P38U2_VW | 776385 | 6621640 | 9 | -14.86 | -60.81 | 10.44 |
| P39A | 782024 | 6620076 | 11 | -1.13 | -1.83 | -0.87 |
| P39B | 782018 | 6620077 | 1 | 1.92 | 0.94 | 4.42 |
| P4 | 777490 | 6625553 | 5b | -9.01 | -10.53 | -7.56 |
| P40_095 | 772815 | 6620823 | 3b | -10.72 | -22.11 | -6.33 |
| P40_135 | 772815 | 6620823 | 4b | 4.74 | -11.69 | 9.88 |

| Bore | Easting (GDA94 Z56) | Northing (GDA94 Z56) | Layer | Average residual | Range in residuals | |
|---|---|---|---|---|---|---|
| | | | | | Minimum | Maximum |
| P40_307 | 772815 | 6620823 | 7d | 22.11 | 17.30 | 31.19 |
| P40_322 | 772815 | 6620823 | 8b | 21.66 | 3.51 | 41.92 |
| P40_346 | 772815 | 6620823 | 9 | -0.06 | -130.82 | 16.15 |
| P40_357 | 772815 | 6620823 | 10 | -41.65 | -149.70 | 0.37 |
| P42_090 | 771092 | 6614376 | 2b | 52.57 | 52.35 | 52.78 |
| P42_185 | 771092 | 6614376 | 3d | 18.15 | 16.39 | 19.03 |
| P42_345 | 771092 | 6614376 | 8a | -78.67 | -80.64 | -75.90 |
| P42_375 | 771092 | 6614376 | 8b | -83.76 | -84.23 | -82.90 |
| P42_395 | 771092 | 6614376 | 9 | -85.26 | -87.04 | -83.61 |
| P42_415 | 771092 | 6614376 | 10 | -83.31 | -86.49 | -81.93 |
| P43 | 781248 | 6619992 | 11 | -7.48 | -17.11 | -3.55 |
| P44_095 | 777434 | 6623212 | 7c | -15.32 | -27.10 | -8.96 |
| P44_134 | 777434 | 6623212 | 8b | -4.80 | -7.32 | -1.97 |
| P44_245 | 777434 | 6623212 | 11 | 13.36 | 4.00 | 20.15 |
| P44_330 | 777434 | 6623212 | 11 | 8.66 | -5.97 | 34.06 |
| P44_375 | 777434 | 6623212 | 11 | -19.91 | -25.83 | 8.40 |
| P44_445 | 777434 | 6623212 | 11 | 51.66 | 15.40 | 61.79 |
| P45_042 | 779491 | 6620117 | 8b | -31.24 | -33.16 | -21.95 |
| P45_080 | 779491 | 6620117 | 10 | -10.14 | -13.46 | -7.69 |
| P45_150 | 779491 | 6620117 | 11 | -8.24 | -27.92 | -4.86 |
| P45_200 | 779491 | 6620117 | 11 | -26.22 | -39.28 | -20.76 |
| P45_240 | 779491 | 6620117 | 11 | 1.60 | -24.75 | 23.63 |
| P45_276 | 779491 | 6620117 | 11 | 14.60 | 10.14 | 15.87 |
| P46_070 | 777395 | 6617847 | 7d | -9.84 | -15.65 | 2.31 |
| P46_087 | 777395 | 6617847 | 8b | 9.47 | -1.91 | 11.08 |
| P46_151 | 777395 | 6617847 | 11 | -20.68 | -23.65 | -4.74 |
| P46_250 | 777395 | 6617847 | 11 | -20.09 | -33.90 | 2.13 |
| P46_308 | 777395 | 6617847 | 11 | 13.95 | 3.16 | 15.80 |
| P46_343 | 777395 | 6617847 | 11 | 31.76 | 4.57 | 35.70 |
| P47 | 776166 | 6622586 | 4b | 8.10 | 7.59 | 8.39 |
| P48 | 775296 | 6623039 | 9 | 103.93 | 70.75 | 136.46 |
| P5 | 778180 | 6628195 | 11 | -14.30 | -19.54 | -12.53 |
| P51 | 777437 | 6620859 | 5a | 4.55 | 3.82 | 5.21 |
| P52 | 777118 | 6620808 | 5a | 6.82 | 5.21 | 10.07 |
| P53 | 776995 | 6620655 | 4b | 2.95 | 1.22 | 5.39 |
| P54_028 | 773786 | 6620493 | 2b | 19.60 | 17.11 | 34.80 |
| P54_058 | 773786 | 6620493 | 3a | 10.37 | 7.71 | 20.36 |

| Bore | Easting (GDA94 Z56) | Northing (GDA94 Z56) | Layer | Average residual | Range in residuals | |
|---|---|---|---|---|---|---|
| | | | | | Minimum | Maximum |
| P54_098 | 773786 | 6620493 | 3c | -7.46 | -13.07 | 1.82 |
| P54_138 | 773786 | 6620493 | 4b | 3.56 | -6.93 | 11.20 |
| P54_178 | 773786 | 6620493 | 5b | 5.66 | 1.80 | 13.07 |
| P54_218 | 773786 | 6620493 | 5d | 17.40 | 15.74 | 19.14 |
| P54_258 | 773786 | 6620493 | 7c | 48.23 | 44.62 | 52.17 |
| P54_298 | 773786 | 6620493 | 8b | 107.97 | 98.46 | 112.25 |
| P54_336 | 773786 | 6620493 | 10 | 57.17 | 55.20 | 59.10 |
| P55_025 | 776425 | 6610503 | 5b | -17.33 | -17.33 | -17.33 |
| P55_044 | 776425 | 6610503 | 5c | -31.41 | -31.43 | -31.39 |
| P55_075 | 776425 | 6610503 | 7c | -25.22 | -26.55 | -24.24 |
| P55_098 | 776425 | 6610503 | 7d | -9.04 | -14.77 | -7.07 |
| P55_110 | 776425 | 6610503 | 8b | -0.54 | -5.94 | 1.29 |
| P55_135 | 776425 | 6610503 | 10 | -13.00 | -15.92 | -7.46 |
| P55_159 | 776425 | 6610503 | 11 | -16.82 | -18.04 | -14.52 |
| P55_195 | 776425 | 6610503 | 11 | -42.76 | -56.12 | -23.78 |
| P55_228 | 776425 | 6610503 | 11 | -12.85 | -20.91 | -9.37 |
| P56_055 | 776277 | 6614725 | 5a | -4.22 | -4.38 | -3.79 |
| P56_085 | 776277 | 6614725 | 5b | -5.64 | -8.56 | -4.63 |
| P56_115 | 776277 | 6614725 | 5d | -7.87 | -8.42 | -7.27 |
| P56_145 | 776277 | 6614725 | 7d | -1.86 | -2.66 | -1.37 |
| P56_175 | 776277 | 6614725 | 10 | 5.44 | 1.23 | 7.25 |
| P56_205 | 776277 | 6614725 | 11 | 2.19 | -0.64 | 3.62 |
| P56_235 | 776277 | 6614725 | 11 | 4.31 | -1.34 | 7.77 |
| P56_265 | 776277 | 6614725 | 11 | 4.17 | -1.99 | 7.82 |
| P56_300 | 776277 | 6614725 | 11 | -3.57 | -9.87 | 0.81 |
| P57_040 | 773896 | 6624092 | 3b | 0.63 | 0.45 | 1.47 |
| P57_060 | 773896 | 6624092 | 3c | -6.60 | -9.28 | -5.69 |
| P57_080 | 773896 | 6624092 | 3d | -2.79 | -12.90 | 0.49 |
| P57_100 | 773896 | 6624092 | 4a | -7.64 | -39.11 | 0.10 |
| P57_120 | 773896 | 6624092 | 4b | -11.02 | -43.03 | -3.97 |
| P57_140 | 773896 | 6624092 | 5a | -3.57 | -23.66 | 3.20 |
| P57_160 | 773896 | 6624092 | 5b | 2.17 | -33.10 | 9.76 |
| P57_180 | 773896 | 6624092 | 5c | 7.76 | -41.30 | 18.10 |
| P6 | 772726 | 6626021 | 2b | -32.82 | -34.07 | -31.94 |
| P7 | 768998 | 6624338 | 2b | -15.95 | -16.71 | -14.56 |
| P8 | 772697 | 6618421 | 3a | -6.76 | -7.16 | -6.53 |
| P9 | 775127 | 6620209 | 3d | 1.51 | -1.76 | 5.67 |

| Bore | Easting (GDA94 Z56) | Northing (GDA94 Z56) | Layer | Average residual | Range in residuals | |
|---|---|---|---|---|---|---|
| | | | | | Minimum | Maximum |
| VPW_3A | 776580 | 6620616 | 5d | -36.83 | -38.78 | -35.14 |
| VPW_3B | 776553 | 6620593 | 5d | -37.79 | -40.12 | -35.49 |
| VPW_4A | 776539 | 6620593 | 5d | -41.07 | -41.07 | -41.07 |
| WB1 | 777251 | 6622763 | 5a | -1.87 | -1.93 | -1.81 |
| WB2 | 776382 | 6619701 | 4b | 0.76 | -1.70 | 4.30 |
| WB3a | 779133 | 6631524 | 1 | 5.53 | 4.72 | 6.65 |
| WB3b | 779133 | 6631524 | 1 | 5.47 | 4.49 | 6.95 |
| WB4 | 778957 | 6629746 | 1 | 2.67 | 1.11 | 3.51 |
| WB5a | 785892 | 6618196 | 1 | 3.89 | 2.52 | 5.56 |
| WB5b | 785892 | 6618196 | 1 | 3.51 | 2.20 | 5.01 |
| WB6a | 786976 | 6615621 | 1 | 3.98 | 0.78 | 6.97 |
| WB6b | 786976 | 6615621 | 1 | 1.74 | -9.62 | 6.56 |
| WB7 | 784440 | 6620521 | 1 | 7.75 | 4.83 | 10.19 |

## Alluvial monitoring locations

| Bore | Easting (GDA94 Z56) | Northing (GDA94 Z56) | Layer | Average residual | Range in residuals | |
|---|---|---|---|---|---|---|
| | | | | | Minimum | Maximum |
| GW 021437.1.1 | 748351 | 6643226 | 1 | -4.44 | -4.58 | -4.31 |
| GW 021437.2.2 | 748351 | 6643226 | 1 | -22.71 | -23.61 | -22.12 |
| GW 025224.1.1 | 755188 | 6640633 | 1 | -23.71 | -24.82 | -23.15 |
| GW 030048.1.1 | 795424 | 6599634 | 1 | -0.07 | -1.54 | 2.09 |
| GW 030048.1.2 | 795424 | 6599634 | 1 | -0.43 | -1.88 | 1.66 |
| GW 030049.1.1 | 797306 | 6599305 | 1 | -4.16 | -5.43 | -2.99 |
| GW 030049.1.2 | 797306 | 6599305 | 1 | -4.57 | -8.50 | -3.10 |
| GW 030049.1.3 | 797306 | 6599305 | 1 | -7.82 | -14.90 | -3.15 |
| GW 030052.1.1 | 801283 | 6598639 | 1 | -8.20 | -10.15 | -7.24 |
| GW 030052.1.2 | 801283 | 6598639 | 1 | -8.19 | -10.14 | -7.24 |
| GW 030119.1.1 | 769755 | 6643656 | 1 | -0.75 | -1.31 | -0.02 |
| GW 030122.1.1 | 765404 | 6643071 | 1 | 6.74 | 6.36 | 7.27 |
| GW 030122.1.2 | 765404 | 6643071 | 1 | 6.63 | 6.02 | 7.76 |
| GW 030122.1.3 | 765404 | 6643071 | 1 | 6.84 | 5.87 | 8.05 |
| GW 030129.1.1 | 793012 | 6619558 | 1 | 1.31 | 0.10 | 3.26 |
| GW 030130.1.1 | 793223 | 6620263 | 1 | 3.15 | 2.02 | 5.25 |
| GW 030130.1.2 | 793223 | 6620263 | 1 | -2.74 | -4.76 | -0.72 |
| GW 030131.1.1 | 793259 | 6621400 | 1 | 4.18 | 2.90 | 5.70 |
| GW 030132.1.1 | 793301 | 6623491 | 1 | 2.06 | 1.09 | 4.07 |
| GW 030132.1.2 | 793301 | 6623491 | 1 | 2.31 | 1.39 | 4.04 |
| GW 030133.1.1 | 793929 | 6624984 | 1 | 0.19 | -1.25 | 1.53 |
| GW 030134.1.1 | 794054 | 6625659 | 1 | -0.06 | -1.72 | 1.73 |

| Bore | Easting (GDA94 Z56) | Northing (GDA94 Z56) | Layer | Average residual | Range in residuals | |
|---|---|---|---|---|---|---|
| | | | | | Minimum | Maximum |
| GW 030224.1.1 | 777014 | 6638006 | 1 | 17.73 | 14.00 | 21.21 |
| GW 030225.1.1 | 777812 | 6636813 | 1 | 14.63 | 10.05 | 16.63 |
| GW 030226.1.1 | 777450 | 6635189 | 1 | 7.38 | 5.91 | 9.02 |
| GW 030226.1.2 | 777450 | 6635189 | 1 | 6.63 | 5.18 | 8.27 |
| GW 030226.1.3 | 777450 | 6635189 | 1 | 6.63 | 5.18 | 8.27 |
| GW 030227.1.1 | 777287 | 6634053 | 1 | 4.87 | 4.01 | 6.14 |
| GW 030227.1.2 | 777287 | 6634053 | 1 | 4.83 | 3.85 | 6.12 |
| GW 030228.1.1 | 777864 | 6633637 | 1 | 4.78 | 3.75 | 6.09 |
| GW 030228.1.2 | 777864 | 6633637 | 1 | 4.50 | 3.35 | 5.97 |
| GW 030229.1.1 | 779133 | 6631524 | 1 | 2.79 | 2.23 | 3.33 |
| GW 030229.1.2 | 779133 | 6631524 | 1 | 2.85 | 1.97 | 3.51 |
| GW 030230.1.1 | 778957 | 6629746 | 1 | 2.11 | 0.64 | 2.90 |
| GW 030231.1.1 | 783149 | 6627348 | 1 | 0.40 | -0.48 | 1.07 |
| GW 030231.1.2 | 783149 | 6627348 | 1 | 0.39 | -0.50 | 1.04 |
| GW 030233.1.1 | 786171 | 6626425 | 1 | -0.40 | -2.13 | 1.16 |
| GW 030233.1.2 | 786171 | 6626425 | 1 | -3.71 | -11.10 | 0.15 |
| GW 030233.1.3 | 786171 | 6626425 | 1 | -3.99 | -11.89 | -0.90 |
| GW 030234.1.1 | 787739 | 6626168 | 1 | -1.74 | -7.09 | 1.04 |
| GW 030242.1.1 | 768755 | 6643546 | 1 | 2.12 | 1.01 | 2.98 |
| GW 030242.2.2 | 768755 | 6643546 | 1 | 2.14 | 0.91 | 3.01 |
| GW 030242.3.3 | 768755 | 6643546 | 1 | 0.83 | -14.66 | 3.39 |
| GW 030255.1.1 | 758640 | 6643079 | 1 | 4.54 | 4.02 | 5.31 |
| GW 030259.1.1 | 760784 | 6643274 | 1 | 1.36 | 0.46 | 2.12 |
| GW 030259.2.2 | 760784 | 6643274 | 1 | 5.18 | 4.38 | 5.98 |
| GW 030278.1.1 | 777864 | 6633637 | 1 | 4.45 | 3.35 | 5.92 |
| GW 030308.1.1 | 777355 | 6634606 | 1 | 5.35 | 4.34 | 6.75 |
| GW 030308.2.2 | 777355 | 6634606 | 1 | 5.28 | 4.22 | 6.67 |
| GW 030308.3.3 | 777355 | 6634606 | 1 | 4.92 | 3.38 | 6.22 |
| GW 030358.2.2 | 765671 | 6641955 | 1 | 7.73 | 6.42 | 8.34 |
| GW 030358.3.3 | 765671 | 6641955 | 1 | 7.86 | 6.93 | 9.17 |
| GW 030399.1.1 | 775620 | 6634711 | 1 | 4.90 | 4.20 | 5.92 |
| GW 030399.1.2 | 775620 | 6634711 | 1 | 4.93 | 4.22 | 5.98 |
| GW 030399.1.3 | 775620 | 6634711 | 1 | 4.97 | 4.24 | 6.02 |
| GW 030400.1.1 | 773030 | 6636873 | 1 | 5.77 | 4.72 | 6.91 |
| GW 030446.1.1 | 787674 | 6623703 | 1 | 3.55 | 1.66 | 6.04 |
| GW 030446.1.2 | 787674 | 6623703 | 1 | -4.63 | -11.78 | -0.38 |
| GW 030447.1.1 | 787063 | 6620822 | 1 | -1.78 | -5.73 | 1.52 |
| GW 030469.1.1 | 793533 | 6603570 | 1 | 2.25 | 1.24 | 2.90 |
| GW 030470.1.1 | 793950 | 6604206 | 1 | 1.73 | 0.16 | 2.42 |
| GW 030470.2.2 | 793950 | 6604206 | 1 | 1.72 | 0.19 | 2.42 |
| GW 030471.1.1 | 794457 | 6605210 | 1 | 0.27 | -1.22 | 1.06 |
| GW 030471.2.2 | 794457 | 6605210 | 1 | 0.29 | -1.21 | 1.07 |

| Bore | Easting (GDA94 Z56) | Northing (GDA94 Z56) | Layer | Average residual | Range in residuals | |
|---|---|---|---|---|---|---|
| | | | | | Minimum | Maximum |
| GW 030472.1.1 | 799990 | 6601943 | 1 | -12.05 | -14.26 | -11.16 |
| GW 030472.2.2 | 799990 | 6601943 | 1 | -9.68 | -12.16 | -8.35 |
| GW 030535.1.1 | 797306 | 6599305 | 1 | -5.32 | -11.01 | -3.04 |
| GW 030544.1.2 | 764780 | 6641576 | 1 | 8.75 | 7.82 | 9.53 |
| GW 036004.1.1 | 785892 | 6618196 | 1 | 1.63 | 0.80 | 3.08 |
| GW 036004.1.2 | 785892 | 6618196 | 1 | 1.40 | 0.49 | 2.52 |
| GW 036005.1.1 | 786979 | 6615646 | 1 | 2.57 | -0.49 | 6.23 |
| GW 036005.1.2 | 786979 | 6615646 | 1 | 0.99 | -10.46 | 5.89 |
| GW 036007.1.1 | 791290 | 6607331 | 1 | 4.09 | 3.59 | 4.72 |
| GW 036007.2.2 | 791290 | 6607331 | 1 | 4.28 | 3.83 | 4.93 |
| GW 036007.3.3 | 791290 | 6607331 | 1 | 4.45 | 3.98 | 5.17 |
| GW 036008.1.1 | 791715 | 6607288 | 1 | 3.87 | 3.41 | 4.75 |
| GW 036012.1.1 | 786600 | 6612388 | 1 | 4.16 | 2.03 | 4.91 |
| GW 036013.1.1 | 787553 | 6612147 | 1 | 3.60 | 1.50 | 4.31 |
| GW 036014.1.1 | 789246 | 6611640 | 1 | 3.74 | 2.18 | 4.76 |
| GW 036014.2.2 | 789246 | 6611640 | 1 | 3.47 | 1.98 | 4.66 |
| GW 036015.1.1 | 790465 | 6611360 | 1 | 3.65 | 2.35 | 4.99 |
| GW 036015.2.2 | 790465 | 6611360 | 1 | 3.01 | -1.43 | 5.09 |
| GW 036016.1.1 | 791527 | 6611177 | 1 | 3.90 | 3.10 | 5.07 |
| GW 036016.2.2 | 791527 | 6611177 | 1 | 2.76 | 0.28 | 4.53 |
| GW 036016.3.3 | 791527 | 6611177 | 1 | 2.38 | -0.55 | 4.45 |
| GW 036055.1.1 | 787800 | 6613404 | 1 | 3.71 | 2.17 | 4.75 |
| GW 036055.2.2 | 787800 | 6613404 | 1 | 1.68 | -8.02 | 4.66 |
| GW 036055.3.3 | 787800 | 6613404 | 1 | 1.54 | -7.16 | 4.62 |
| GW 036056.1.1 | 790253 | 6609393 | 1 | 4.33 | 2.69 | 5.76 |
| GW 036057.1.1 | 791615 | 6607507 | 1 | 4.40 | 3.89 | 5.12 |
| GW 036057.2.2 | 791615 | 6607507 | 1 | 4.58 | 3.95 | 5.36 |
| GW 036092.1.1 | 793343 | 6603371 | 1 | 2.66 | 1.80 | 3.42 |
| GW 036093.1.1 | 788269 | 6616998 | 1 | 3.44 | 1.57 | 5.53 |
| GW 036093.2.1 | 788269 | 6616998 | 1 | 4.74 | 4.63 | 4.89 |
| GW 036093.2.2 | 788269 | 6616998 | 1 | 2.27 | -1.25 | 4.63 |
| GW 036093.3.3 | 788269 | 6616998 | 1 | 1.90 | -1.97 | 4.51 |
| GW 036094.1.1 | 786346 | 6622968 | 1 | -1.79 | -4.99 | 0.87 |
| GW 036094.2.2 | 786346 | 6622968 | 1 | -3.17 | -9.91 | 0.66 |
| GW 036096.1.1 | 787775 | 6616457 | 1 | 4.37 | 2.94 | 6.04 |
| GW 036096.2.2 | 787775 | 6616457 | 1 | 2.92 | -1.45 | 5.27 |
| GW 036186.1.1 | 790029 | 6618203 | 1 | 3.55 | 0.40 | 5.52 |
| GW 036187.1.1 | 791060 | 6618171 | 1 | 5.84 | 3.67 | 8.12 |
| GW 036510.1.1 | 796646 | 6591832 | 1 | 0.14 | -1.24 | 2.54 |
| GW 036510.2.2 | 796646 | 6591832 | 1 | -0.17 | -2.73 | 2.52 |
| GW 036548.1.1 | 797350 | 6594155 | 1 | 2.31 | 1.08 | 3.89 |
| GW 036548.1.2 | 797350 | 6594155 | 1 | 0.78 | -0.60 | 2.64 |

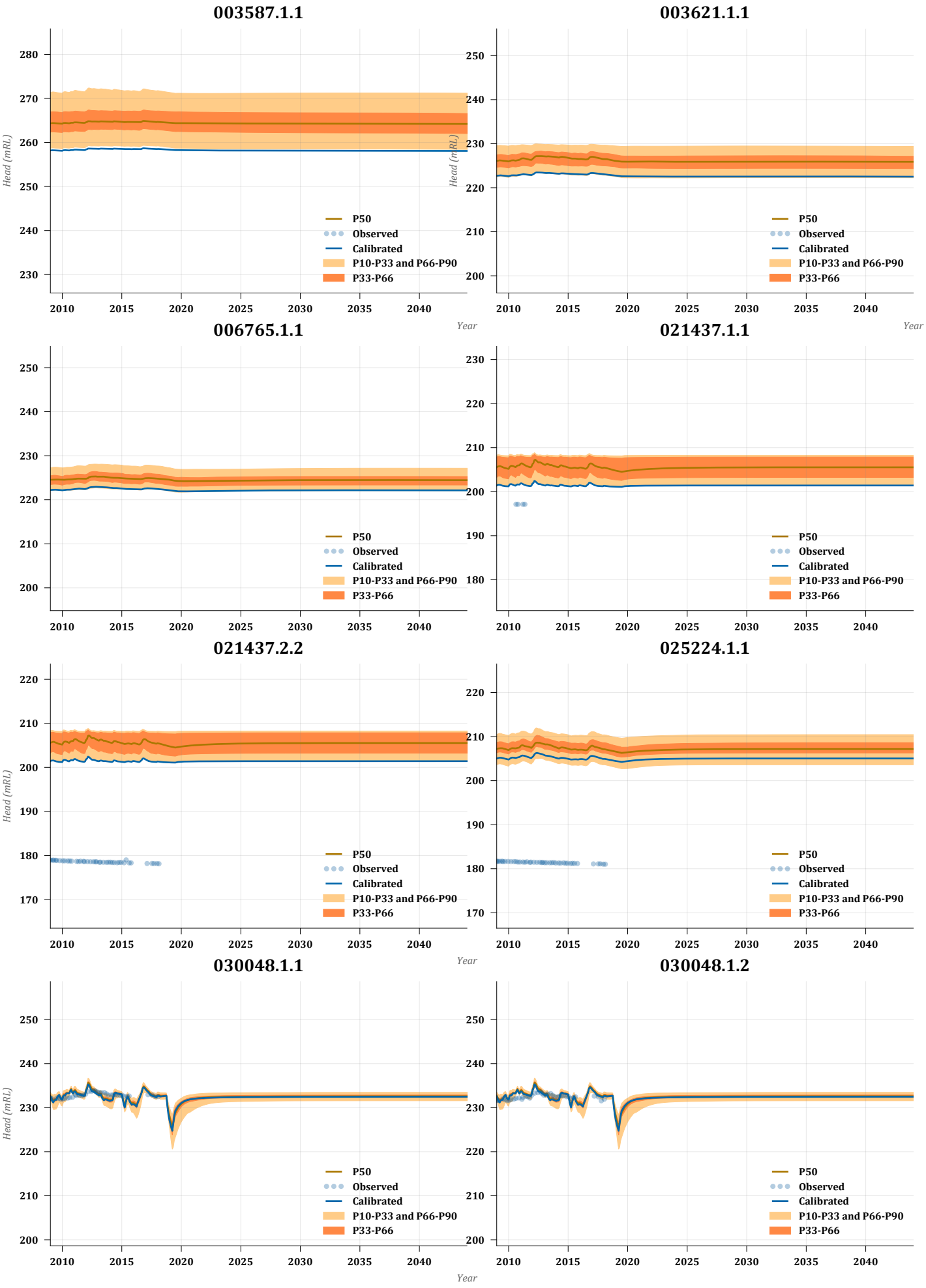
| Bore | Easting (GDA94 Z56) | Northing (GDA94 Z56) | Layer | Average residual | Range in residuals | |
|---|---|---|---|---|---|---|
| | | | | | Minimum | Maximum |
| GW 036548.1.3 | 797350 | 6594155 | 1 | -1.26 | -3.78 | 1.76 |
| GW 036565.1.1 | 792205 | 6597842 | 1 | 2.90 | 1.94 | 3.99 |
| GW 036567.1.1 | 792319 | 6596174 | 1 | 1.44 | 0.11 | 3.15 |
| GW 041027.1.1 | 808518 | 6619425 | 1 | 7.55 | 5.28 | 12.23 |
| GW 967137.1.1 | 795864 | 6622188 | 1 | 4.11 | 2.88 | 5.30 |
| GW 967138.1.1 | 803010 | 6621802 | 1 | -0.12 | -1.93 | 2.29 |
| GW 968531.1.1 | 800701 | 6622317 | 1 | 5.31 | 3.70 | 6.85 |

## Other monitoring locations

| Bore | Easting (GDA94 Z56) | Northing (GDA94 Z56) | Layer | Average residual | Range in residuals | |
|---|---|---|---|---|---|---|
| | | | | | Minimum | Maximum |
| GW 003587.1.1 | 764421 | 6614834 | 2b | -18.94 | -18.94 | -18.94 |
| GW 003621.1.1 | 767700 | 6630964 | 2b | 2.73 | 2.73 | 2.73 |
| GW 006765.1.1 | 762710 | 6631148 | 2b | -0.67 | -0.67 | -0.67 |
| GW 030050.1.1 | 798605 | 6599084 | 11 | -5.84 | -10.51 | -4.37 |
| GW 030050.1.2 | 798605 | 6599084 | 11 | -5.93 | -10.13 | -4.53 |
| GW 030050.1.3 | 798605 | 6599084 | 11 | -5.96 | -10.78 | -4.45 |
| GW 030051.1.1 | 799569 | 6598930 | 11 | -5.38 | -5.68 | -4.96 |
| GW 030051.1.2 | 799569 | 6598930 | 11 | -5.24 | -5.53 | -4.78 |
| GW 030123.1.1 | 763973 | 6641379 | 2b | 8.17 | 7.26 | 8.86 |
| GW 030123.1.2 | 763973 | 6641379 | 2b | 8.21 | 7.21 | 8.91 |
| GW 030232.1.1 | 784629 | 6626712 | 11 | -1.48 | -3.34 | 0.25 |
| GW 030232.1.2 | 784629 | 6626712 | 11 | -1.88 | -6.11 | 0.35 |
| 030232.1.3 | 784629 | 6626712 | 11 | -2.01 | -8.66 | 0.80 |
| 030235.1.1 | 789413 | 6625846 | 11 | 3.15 | 1.83 | 5.04 |
| 030235.1.2 | 789413 | 6625846 | 11 | 1.84 | 0.15 | 3.81 |
| 030236.1.1 | 790973 | 6625551 | 11 | 2.87 | 1.46 | 5.25 |
| 030236.1.2 | 790973 | 6625551 | 11 | 1.09 | -0.28 | 3.02 |
| 030237.1.1 | 792601 | 6625236 | 11 | -1.44 | -2.77 | 0.59 |
| 030242.4.1 | 768755 | 6643546 | 2b | 1.54 | 1.05 | 1.87 |
| 030242.4.4 | 768755 | 6643546 | 2b | 0.66 | -8.64 | 2.90 |
| 030345.1.1 | 778260 | 6632394 | 5d | 0.08 | -0.41 | 1.41 |
| 030345.1.2 | 778260 | 6632394 | 5d | 0.17 | -0.35 | 1.63 |
| 030358.1.1 | 765671 | 6641955 | 2b | 8.44 | 7.69 | 8.96 |
| 030468.1.1 | 792642 | 6603132 | 11 | -1.85 | -2.40 | 0.48 |
| 030471.3.3 | 794457 | 6605210 | 11 | -0.29 | -0.68 | 0.24 |
| 030472.3.3 | 799990 | 6601943 | 11 | -9.78 | -10.65 | -9.27 |
| 030478.1.1 | 771286 | 6639844 | 2b | 8.60 | 6.38 | 9.63 |
| 030478.1.2 | 771286 | 6639844 | 2b | 8.60 | 6.41 | 9.58 |
| 030478.1.3 | 771286 | 6639844 | 2b | 8.62 | 6.45 | 9.59 |
| 036003.1.1 | 788680 | 6618375 | 11 | -1.46 | -8.89 | 3.15 |
| 036094.3.3 | 786346 | 6622968 | 11 | -3.27 | -10.72 | 1.61 |
| 036164.1.1 | 788735 | 6617448 | 11 | -0.61 | -7.24 | 3.79 |
| 036185.1.1 | 791077 | 6611282 | 11 | 1.93 | -7.72 | 3.76 |
| 036568.1.1 | 792070 | 6594824 | 11 | 0.18 | -1.74 | 2.14 |
| 036568.1.2 | 792070 | 6594824 | 11 | -0.40 | -3.14 | 2.36 |
| 036568.1.3 | 792070 | 6594824 | 11 | -0.88 | -4.25 | 2.44 |
| 036598.1.1 | 791683 | 6593328 | 11 | -1.59 | -5.04 | 2.13 |
| 036598.1.2 | 791683 | 6593328 | 11 | -3.86 | -10.50 | 2.19 |
| 036598.1.3 | 791683 | 6593328 | 11 | -4.46 | -12.16 | 2.14 |
| 036600.1.1 | 790687 | 6592920 | 11 | -0.16 | -3.27 | 2.07 |
| 036600.1.2 | 790687 | 6592920 | 11 | -4.31 | -11.55 | 1.86 |

| Bore | Easting (GDA94 Z56) | Northing (GDA94 Z56) | Layer | Average residual | Range in residuals | |
|---|---|---|---|---|---|---|
| | | | | | Minimum | Maximum |
| 036600.1.3 | 790687 | 6592920 | 11 | -3.21 | -11.08 | 1.73 |
| 098012.1.1 | 774025 | 6630797 | 2b | -5.39 | -5.79 | -4.83 |
| 273314.1.1 | 764809 | 6639583 | 4b | -1.44 | -2.85 | -0.24 |
| 967137.2.2 | 795864 | 6622188 | 11 | 2.73 | 2.19 | 3.38 |
| 967138.2.2 | 803010 | 6621802 | 11 | -2.44 | -3.80 | -0.71 |
| BHN14PRORA | 747158 | 6626109 | 2b | -17.77 | -18.39 | -17.49 |
| BHN14PRUPS | 747153 | 6626124 | 2b | -6.54 | -7.33 | -6.32 |
| BWD26PRLPS | 749364 | 6609363 | 2b | -13.14 | -13.98 | -12.78 |
| BWD26PRUPS | 749373 | 6609377 | 2b | -13.56 | -14.45 | -13.22 |
| BWD27PRLPS | 755436 | 6604699 | 2b | -15.86 | -16.07 | -15.67 |
| BWD27PRUPS | 755433 | 6604685 | 2b | -16.26 | -16.47 | -16.05 |
| BWD28QGLPS | 752950 | 6604220 | 2b | 5.65 | 5.06 | 6.23 |
| BWD28QGPUR | 752950 | 6604220 | 3d | -5.14 | -5.81 | -4.40 |
| BWD28QGUPS | 752950 | 6604220 | 2b | -1.35 | -2.24 | -0.80 |
| DWH14PRLPS | 764689 | 6617119 | 2b | -19.55 | -19.68 | -19.44 |
| DWH14PRPUR | 764696 | 6617132 | 3d | -18.91 | -19.34 | -18.47 |
| DWH14PRUPS | 764703 | 6617145 | 2b | -19.13 | -21.37 | -18.85 |
| DWH3PRLPS0 | 762251 | 6605599 | 2b | -24.77 | -24.94 | -24.46 |
| DWH3PRUPS0 | 762240 | 6605589 | 2b | -24.90 | -25.07 | -24.78 |
| DWH8AQGARK | 765551 | 6616983 | 10 | 29.12 | 27.70 | 29.65 |
| DWH8AQGDGY | 765551 | 6616983 | 8b | 82.29 | 80.39 | 82.75 |
| DWH8AQGPOR | 765551 | 6616983 | 11 | 106.63 | 102.67 | 110.99 |
| TULPRDGY02 | 774466 | 6612033 | 8b | -4.45 | -7.25 | -0.75 |
| TULPRNAP01 | 774464 | 6612048 | 8b | -27.90 | -43.10 | -20.45 |

# *Appendix D 2* Predictive uncertainty hydrographs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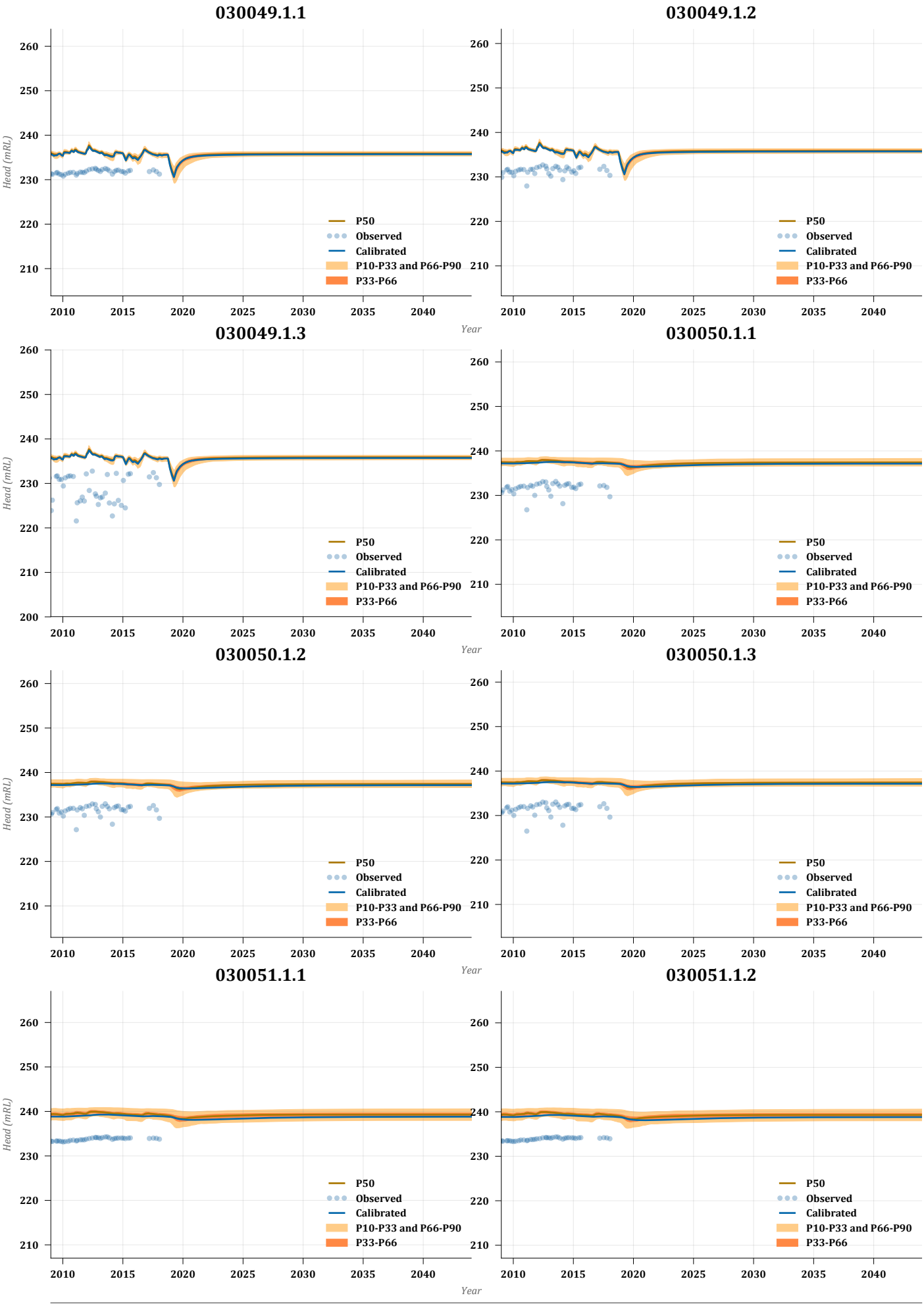
003621.1.1
006765.1.1
021437.1.1
021437.2.2
025224.1.1
030048.1.1
030048.1.2
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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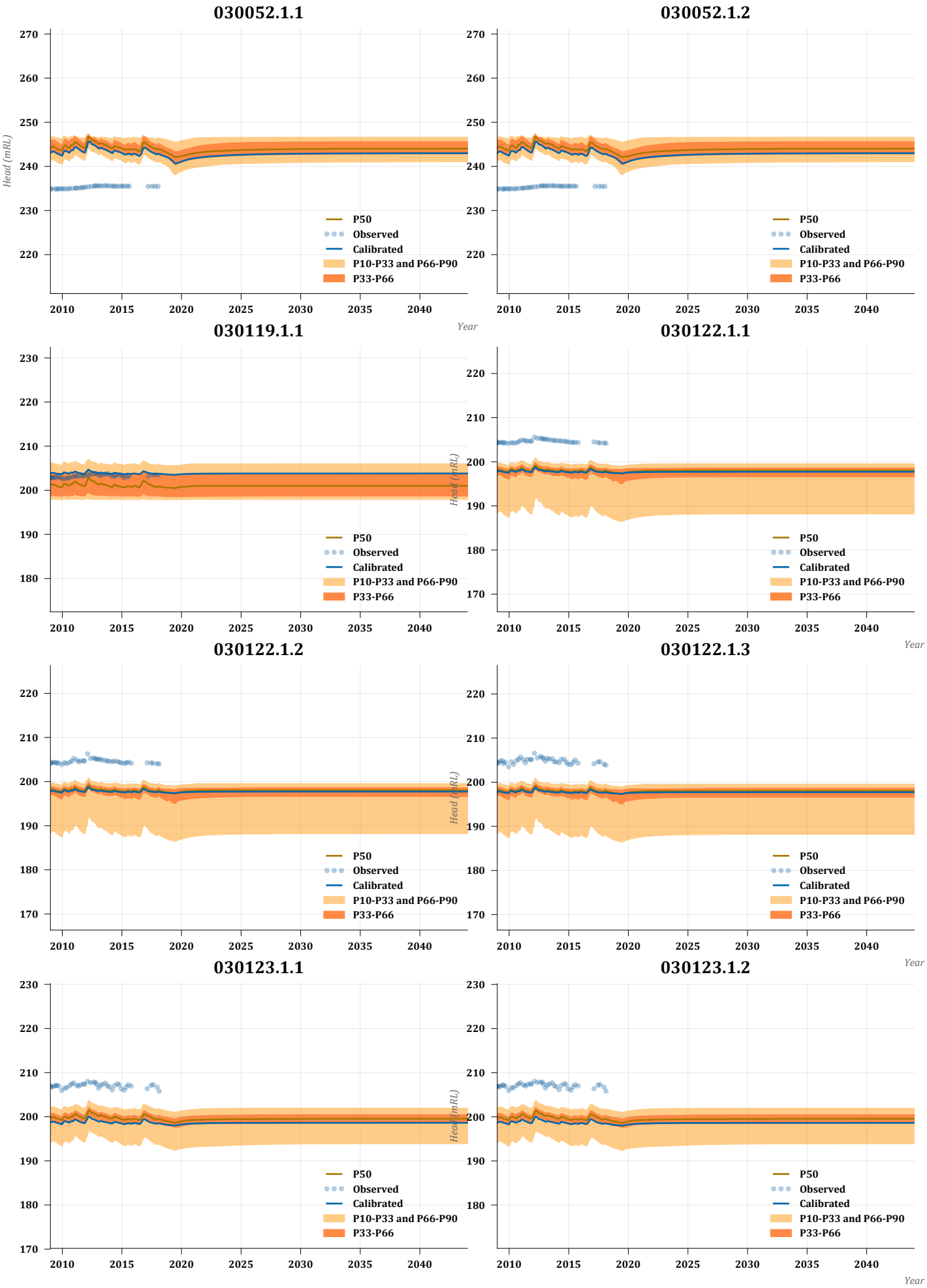
030049.1.2
030049.1.3
030050.1.1
030050.1.2
030050.1.3
030051.1.1
030051.1.2
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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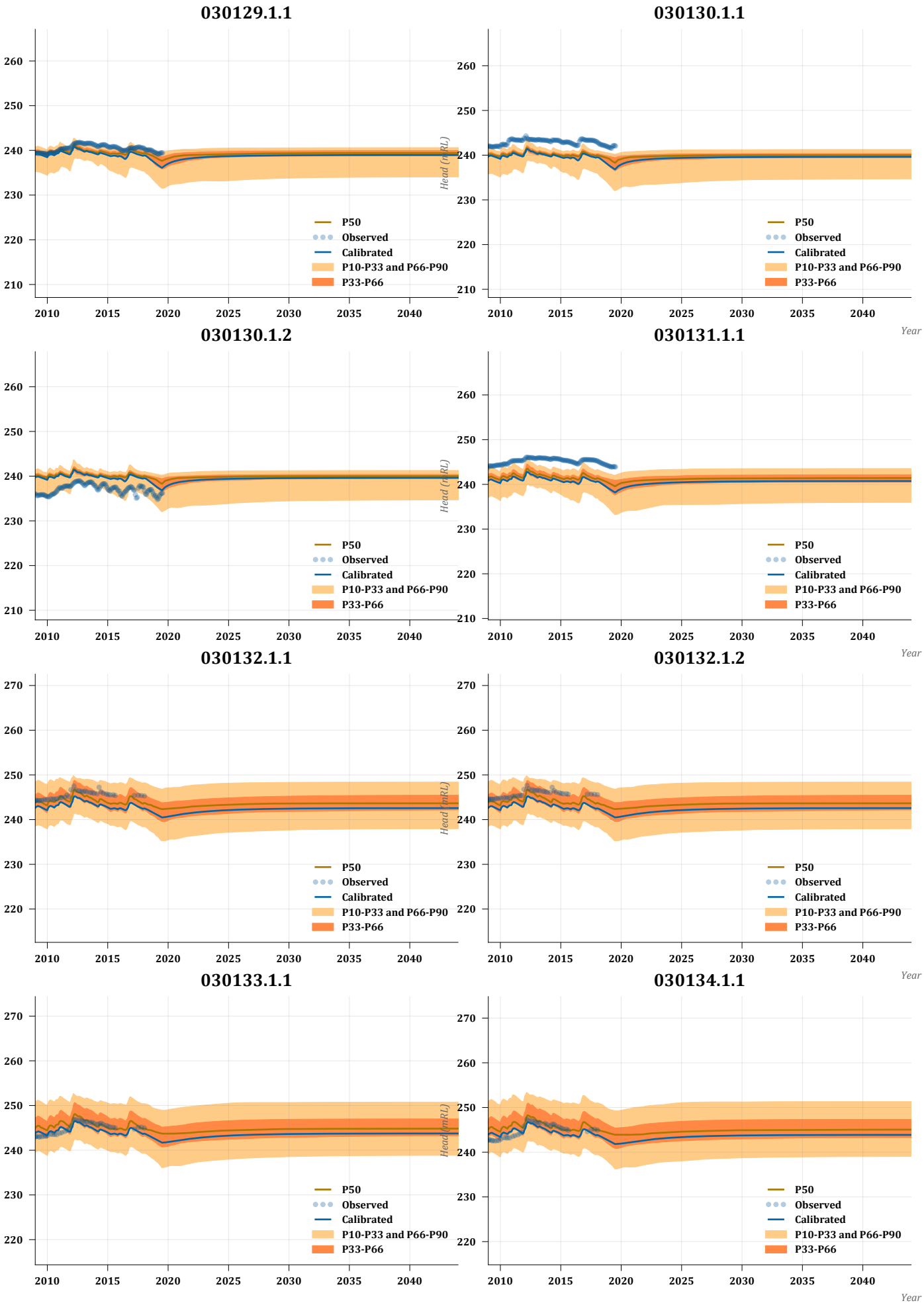
030052.1.2
030119.1.1
030122.1.1
030122.1.2
030122.1.3
030123.1.1
030123.1.2
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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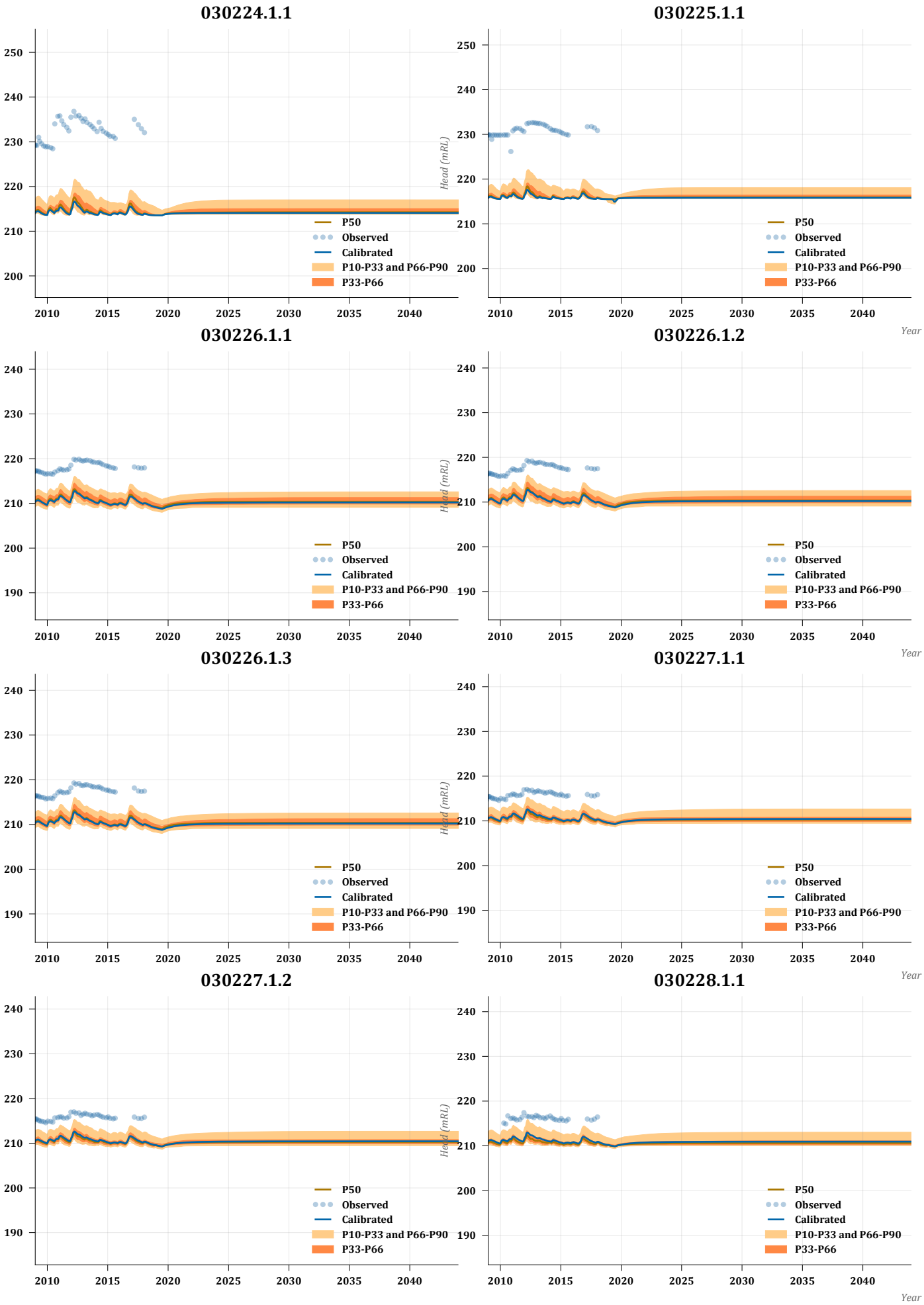
030130.1.2
030131.1.1
030132.1.1
030132.1.2
030133.1.1
030134.1.1
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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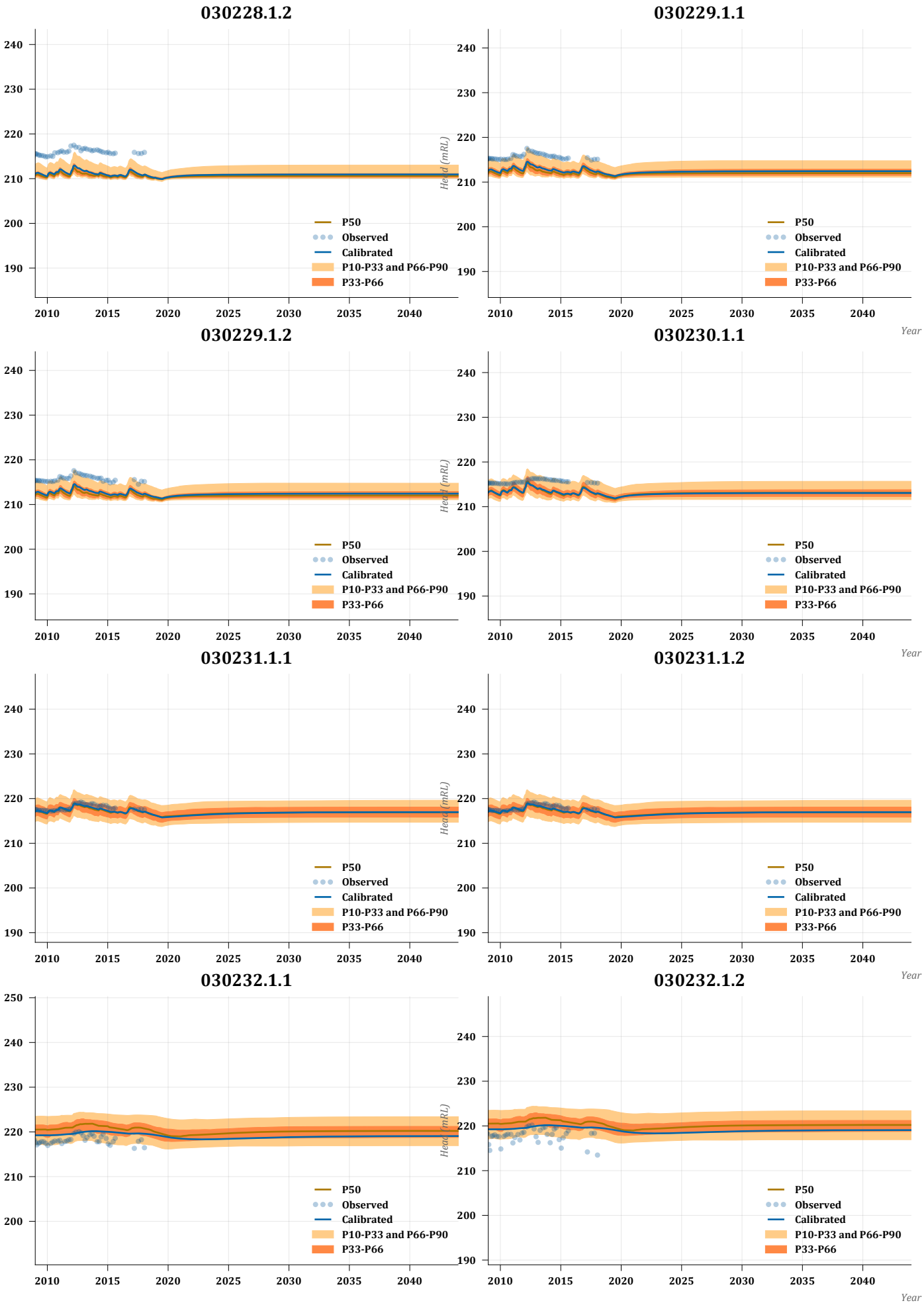
030226.1.1
030226.1.2
030226.1.3
030227.1.1
030227.1.2
030228.1.1
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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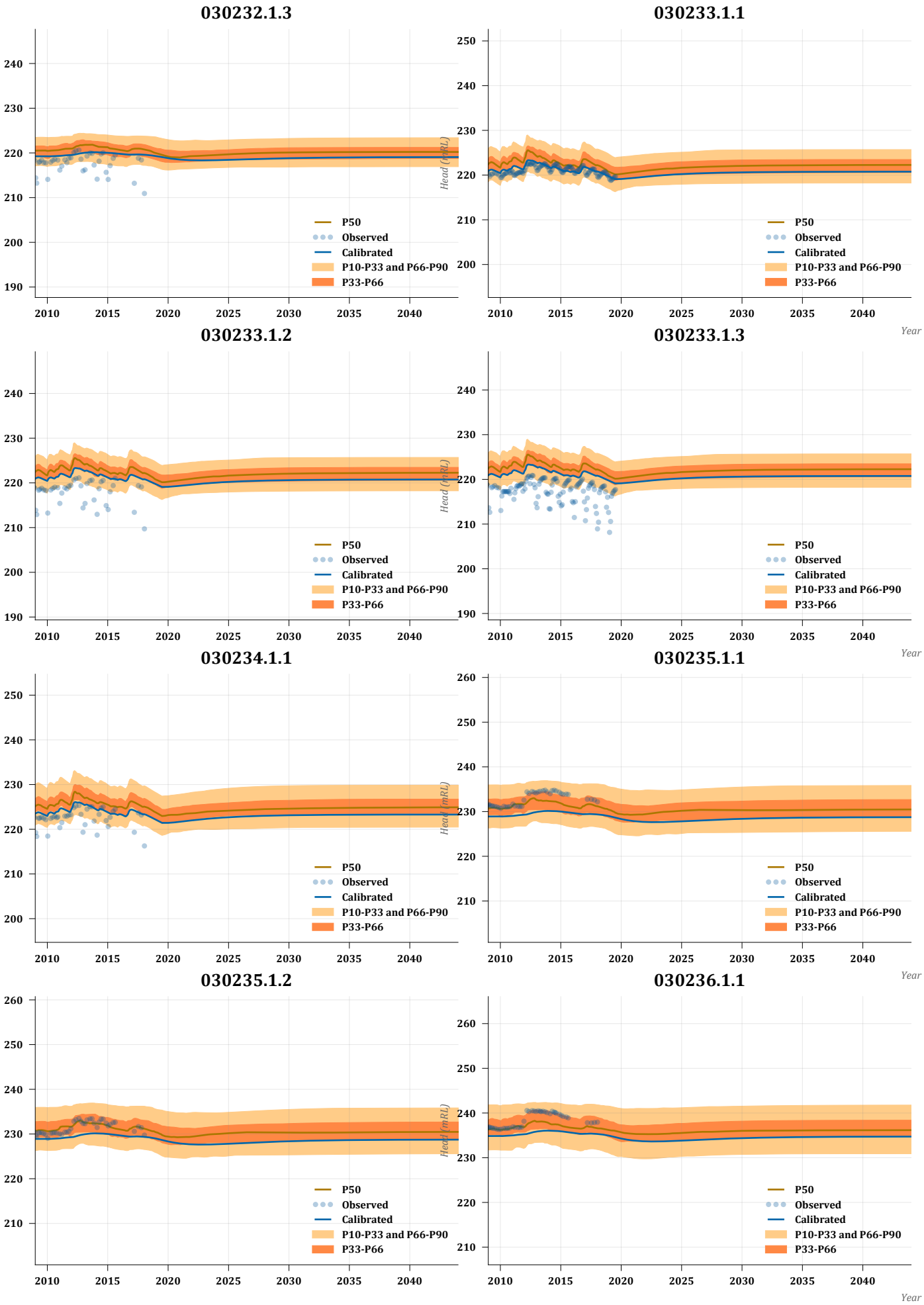
030229.1.2
030230.1.1
030231.1.1
030231.1.2
030232.1.1
030232.1.2
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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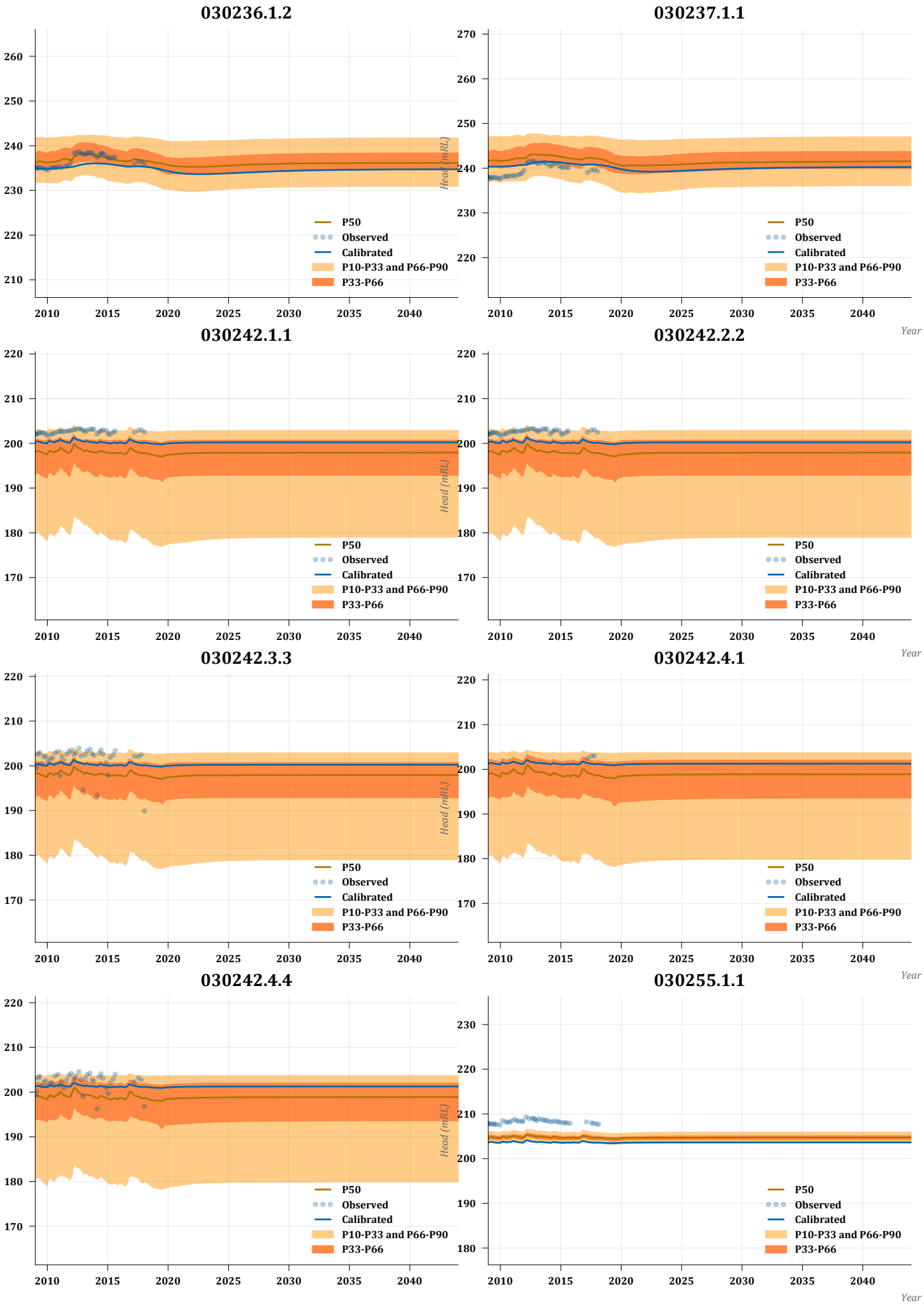
030233.1.1
030233.1.2
030233.1.3
030234.1.1
030235.1.1
030235.1.2
030236.1.1
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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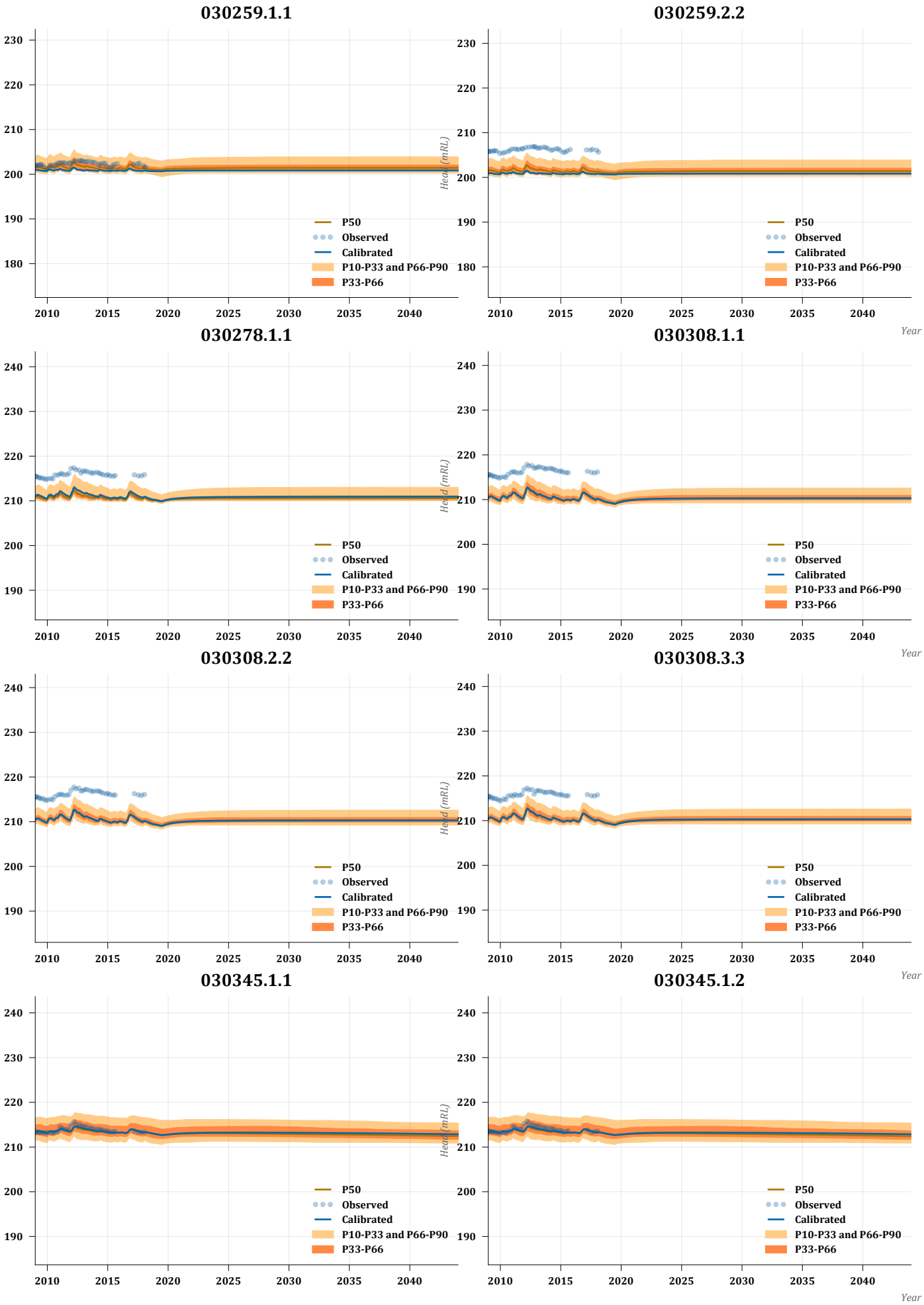
030237.1.1
030242.1.1
030242.2.2
030242.3.3
030242.4.1
030242.4.4
030255.1.1
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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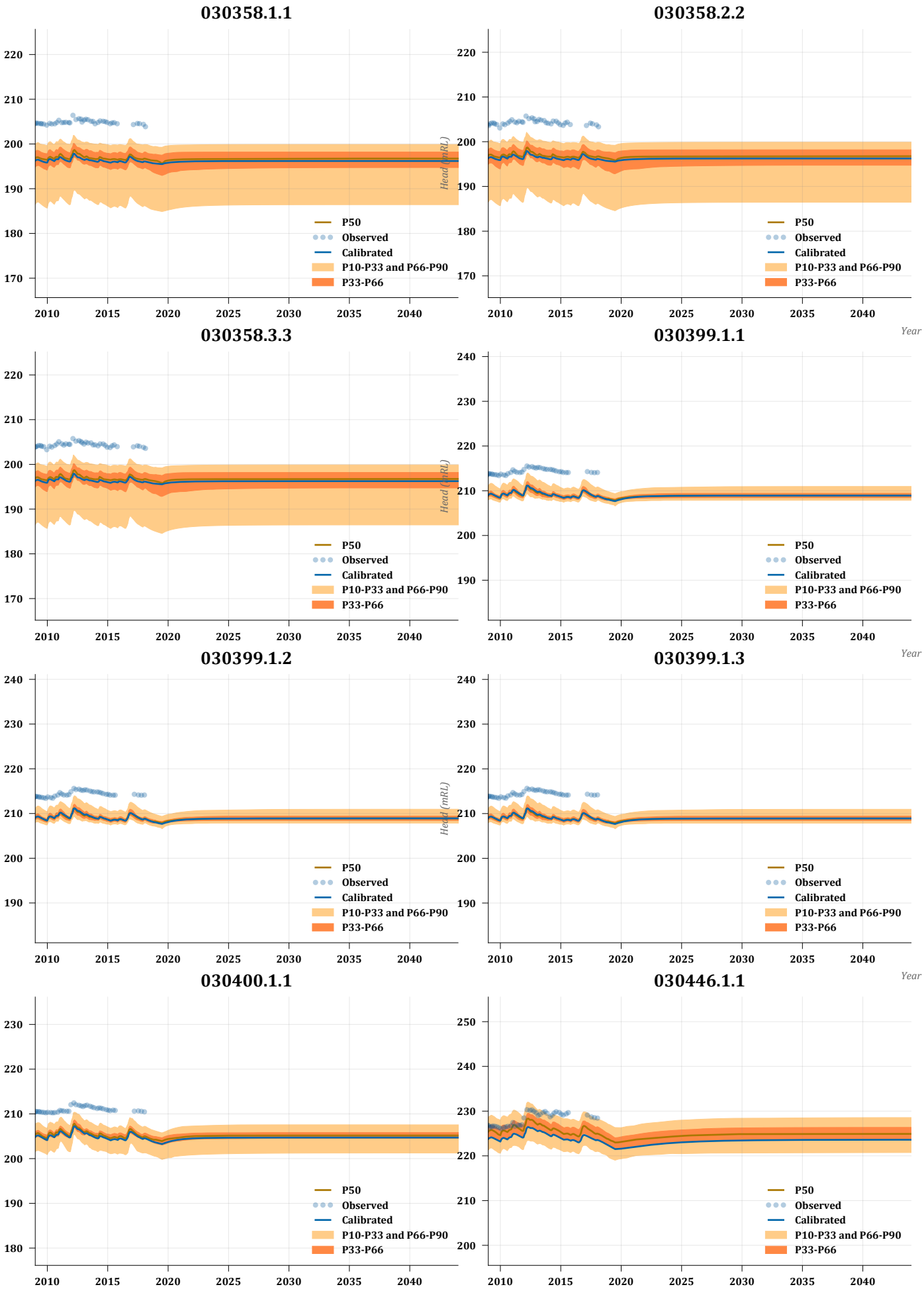
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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030358.3.3
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030399.1.2
030399.1.3
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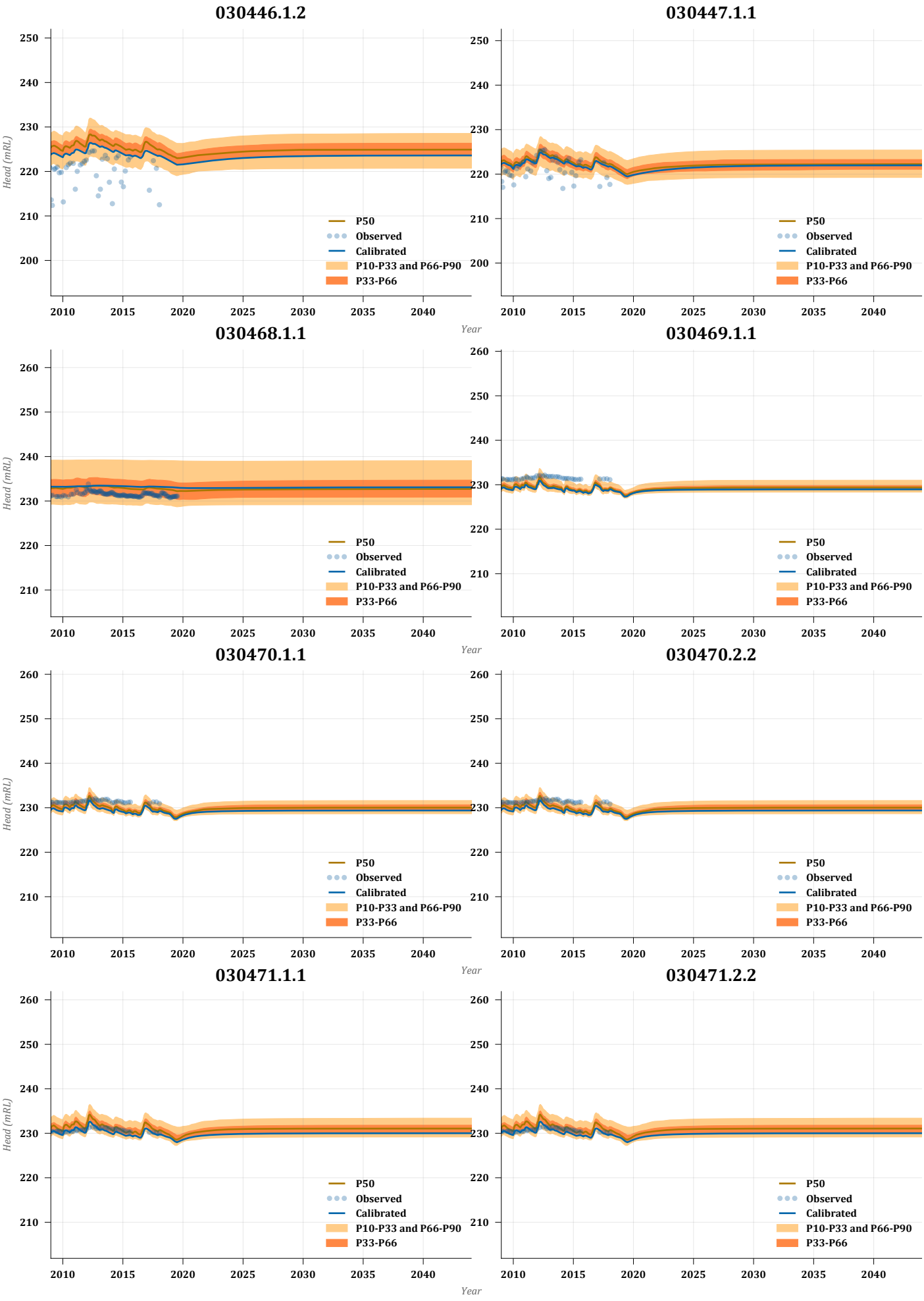
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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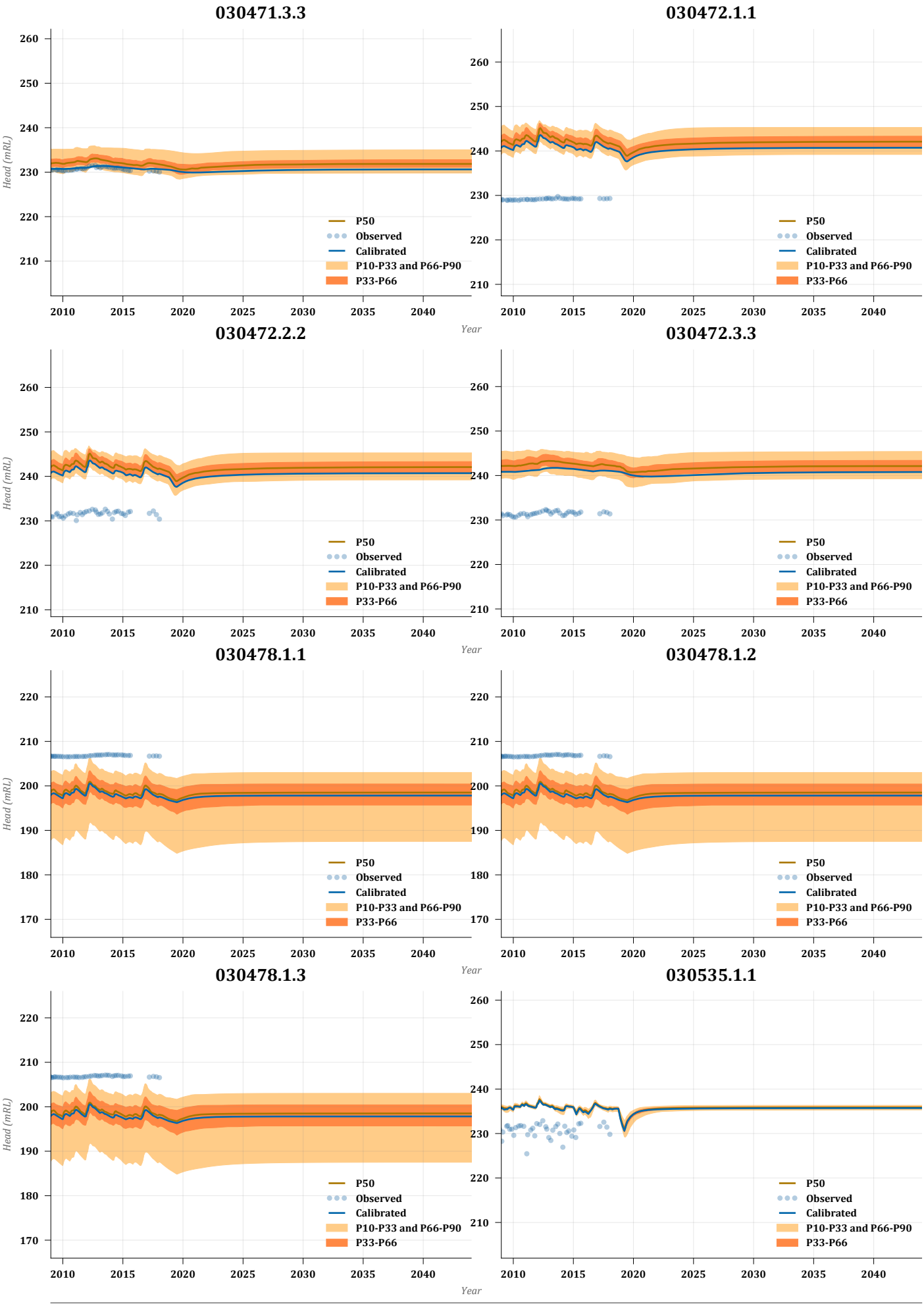
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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030478.1.2
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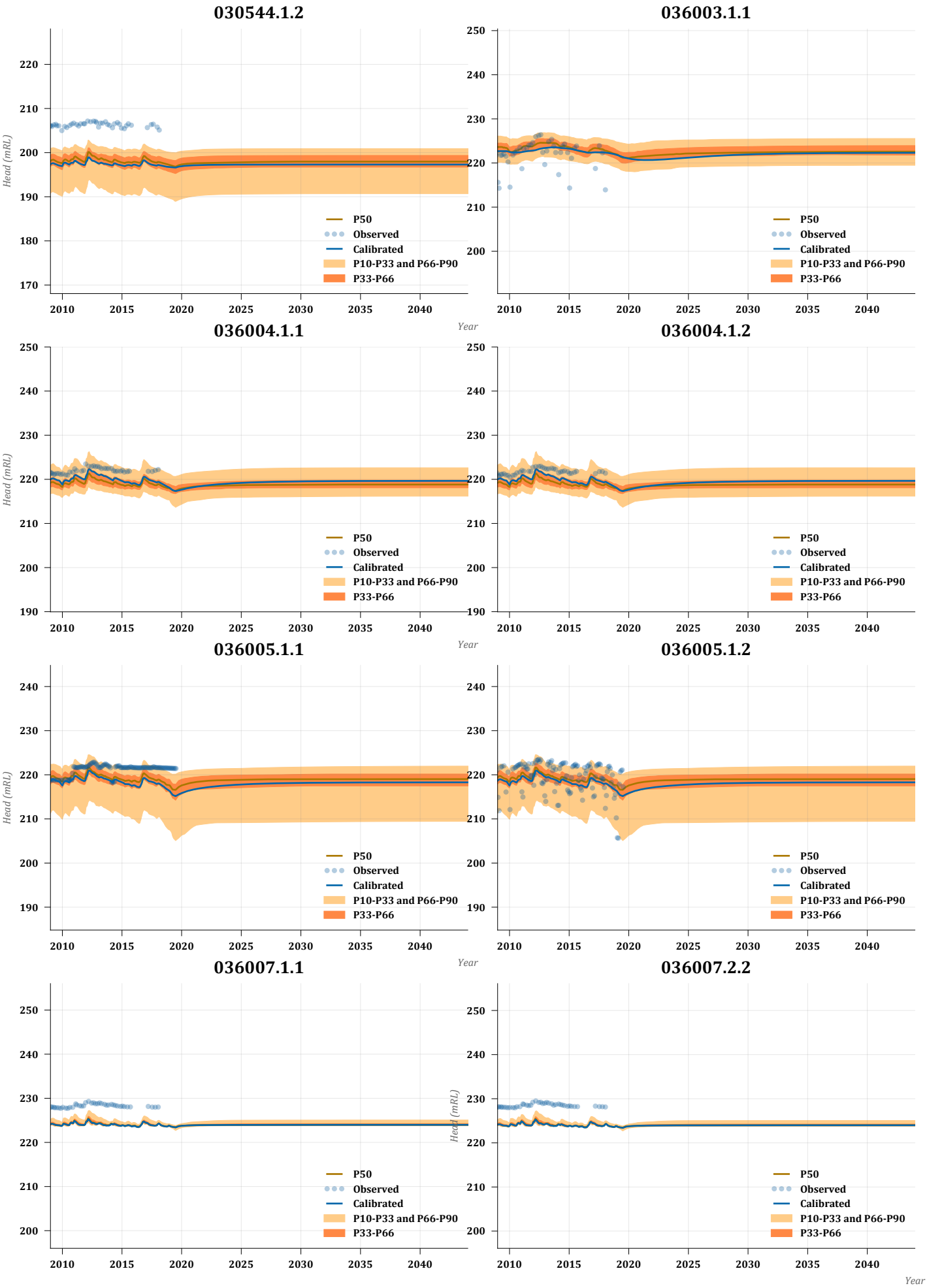
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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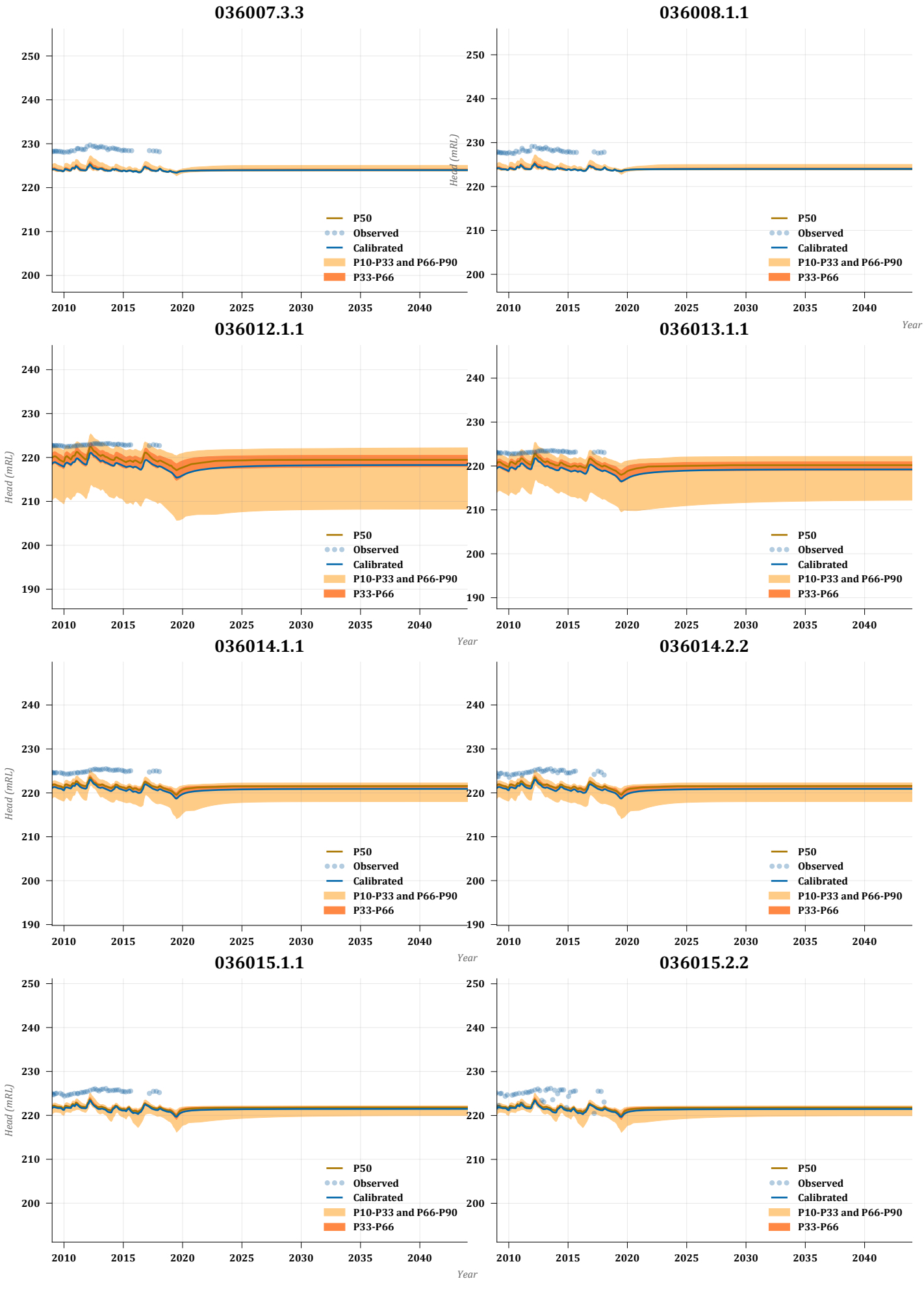
036004.1.1
036004.1.2
036005.1.1
036005.1.2
036007.1.1
036007.2.2
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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036008.1.1
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036013.1.1
036014.1.1
036014.2.2
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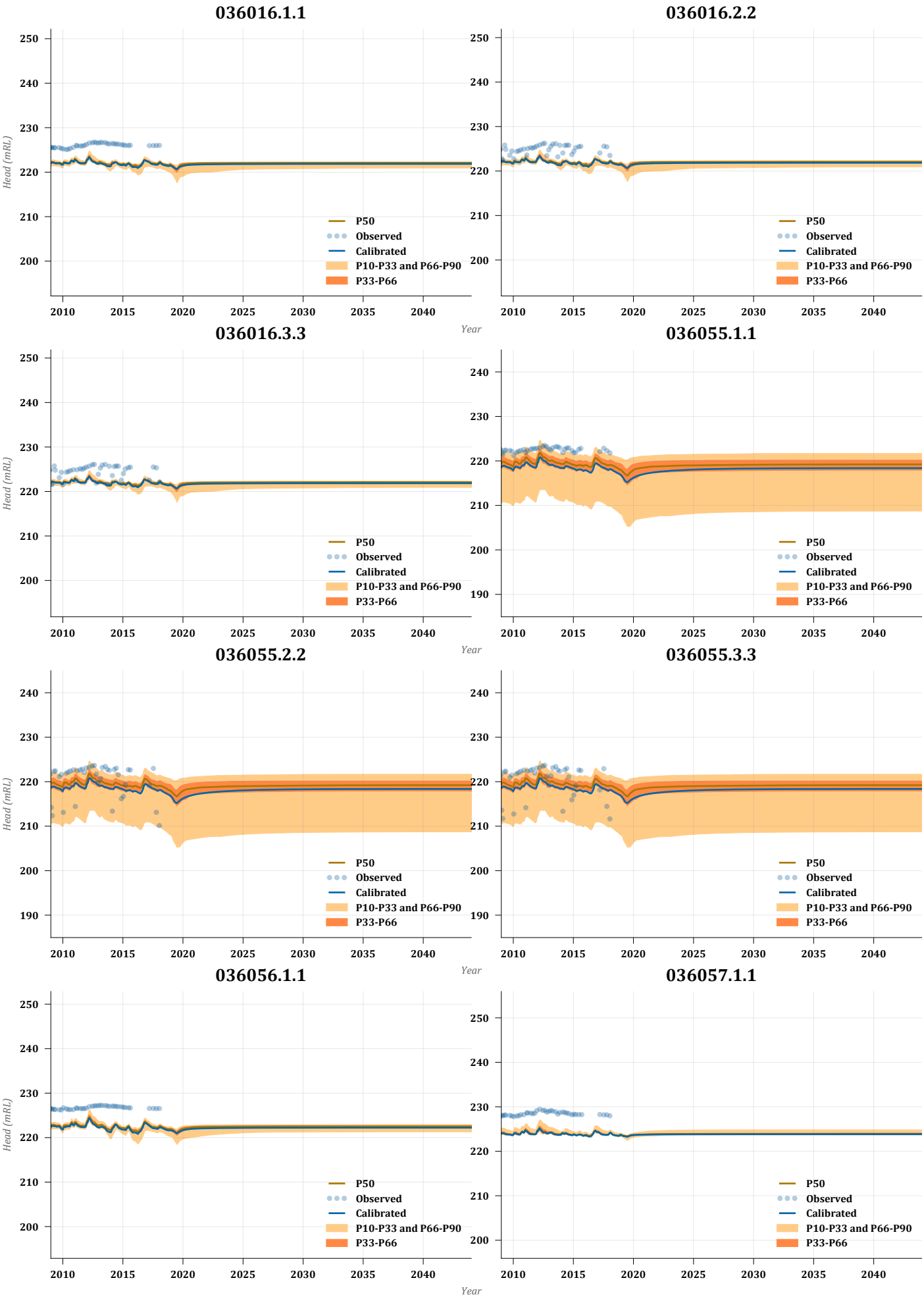
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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Head (mRL)
Year
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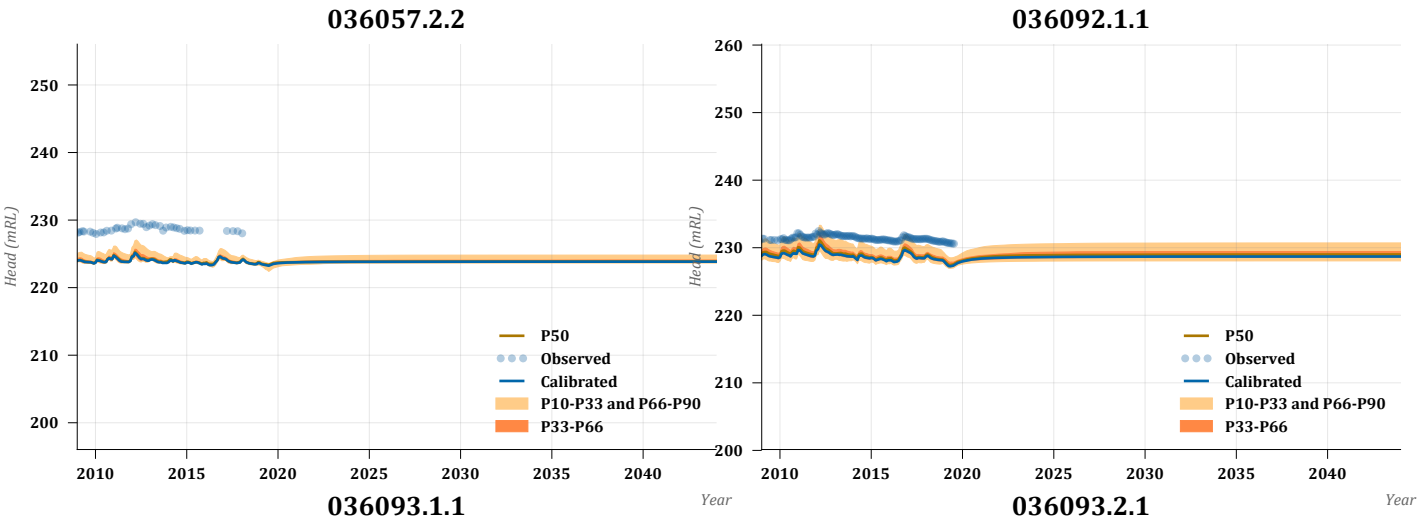
P10-P33 and P66-P90
P33-P66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Head (mRL)
Year
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Observed
Calibrated
P10-P33 and P66-P90
P33-P66


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Year
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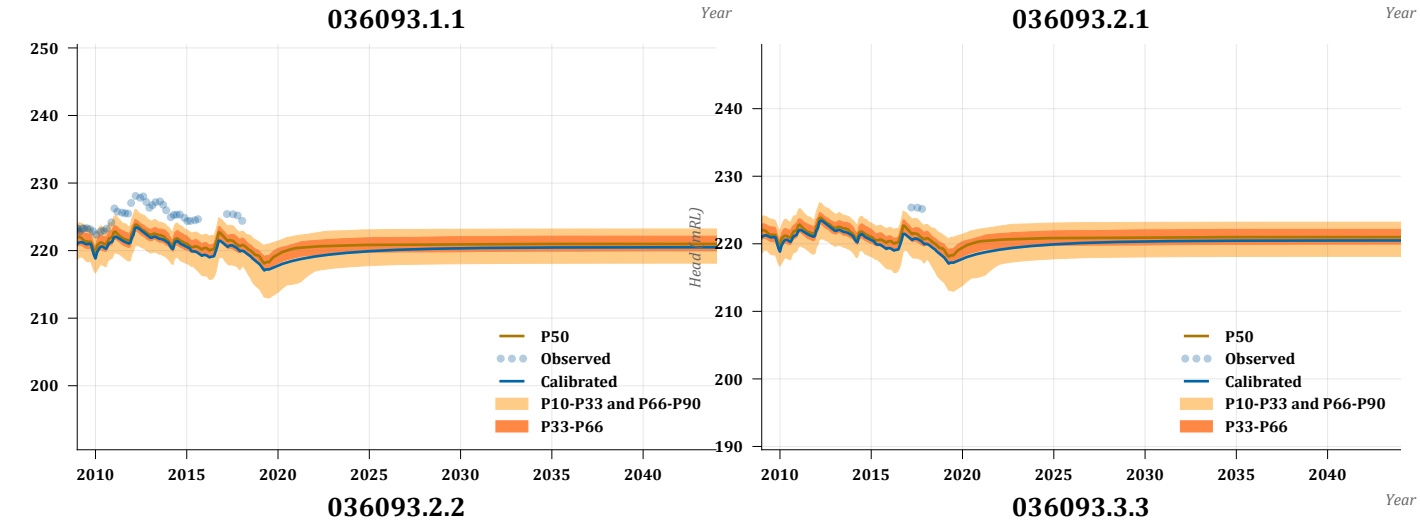
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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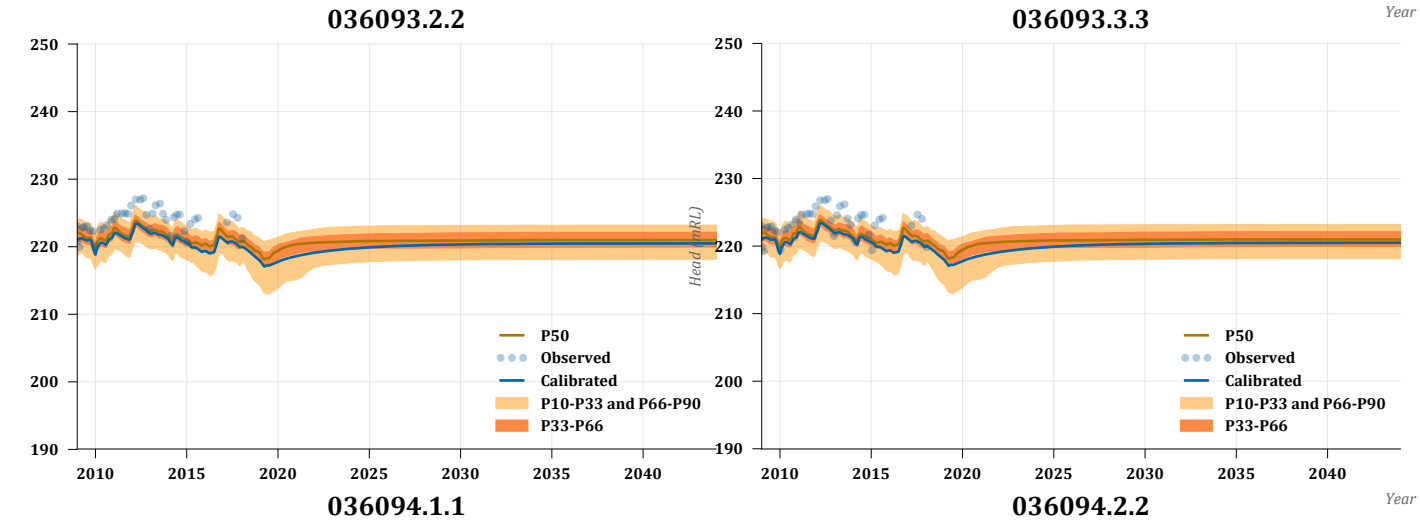
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66


036093.2.1
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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Head (mRL)
Year
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Observed
Calibrated
P10-P33 and P66-P90
P33-P66


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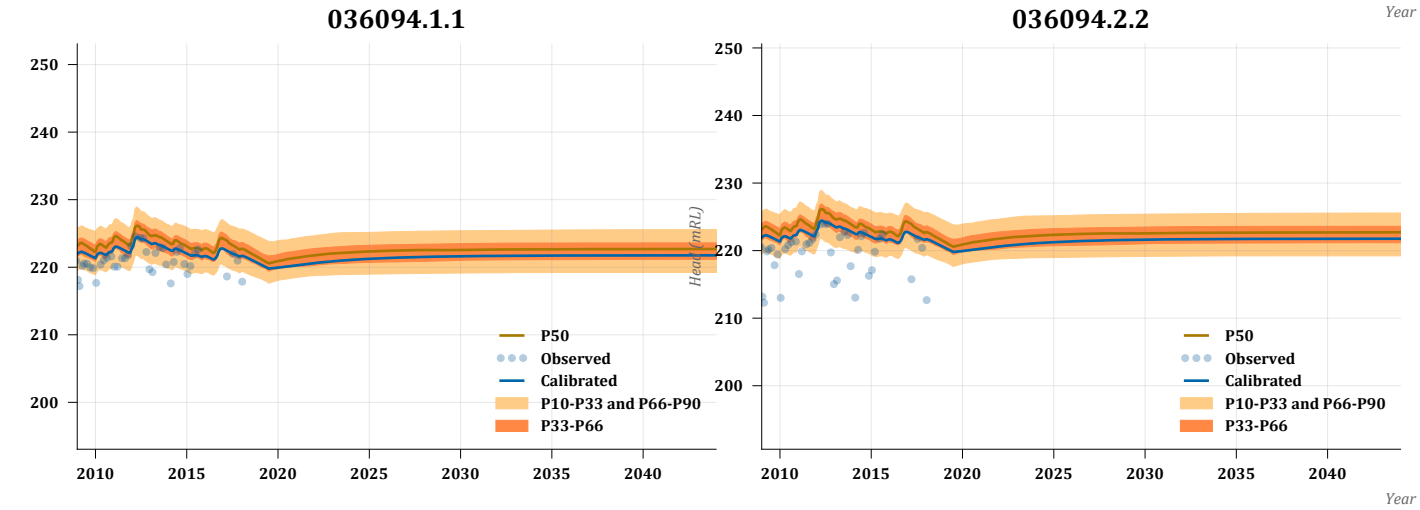
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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Head (mRL)
Year
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Observed
Calibrated
P10-P33 and P66-P90
P33-P66


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Head (mRL)
Year
P50
Observed
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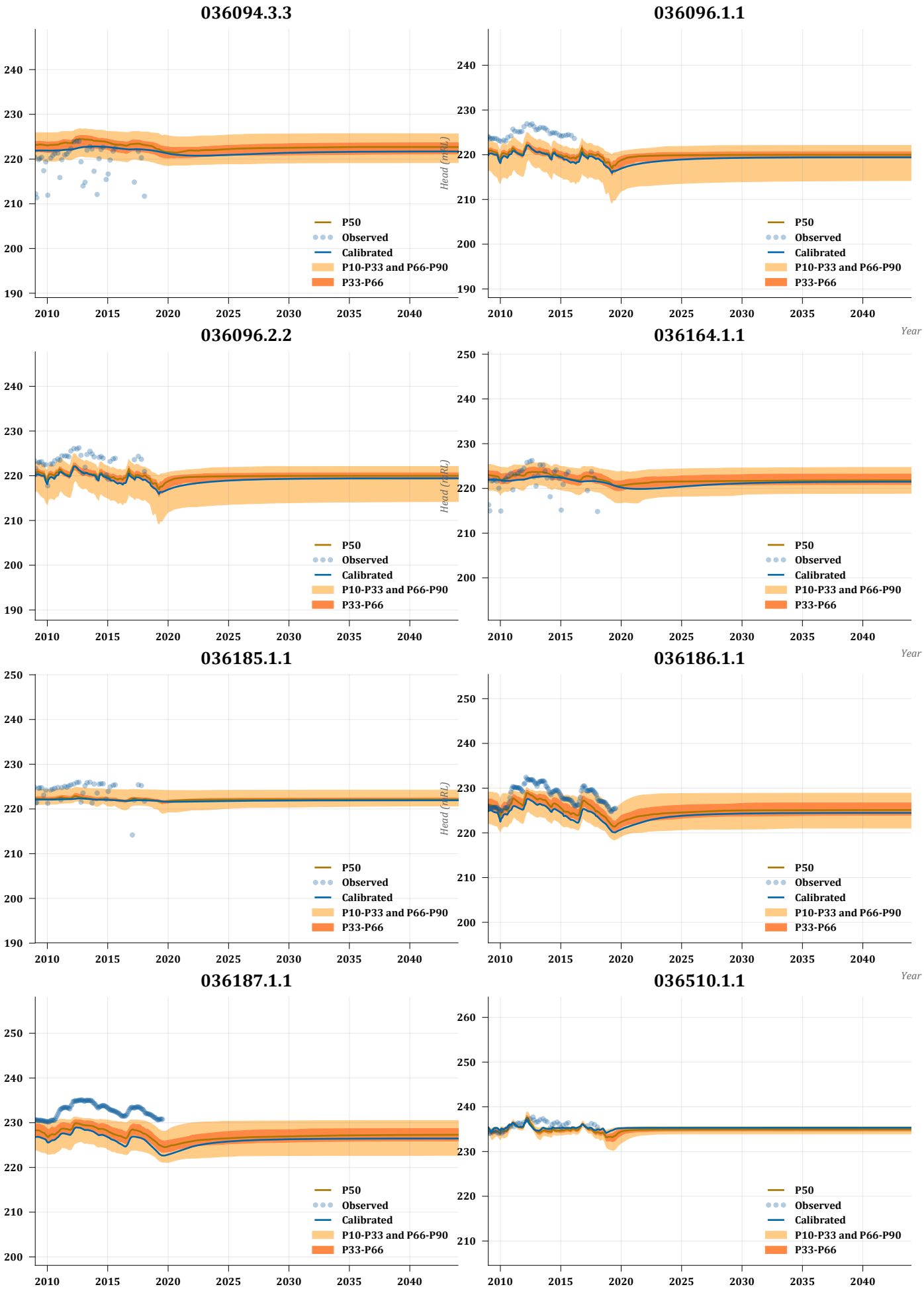
P10-P33 and P66-P90
P33-P66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036185.1.1
036186.1.1
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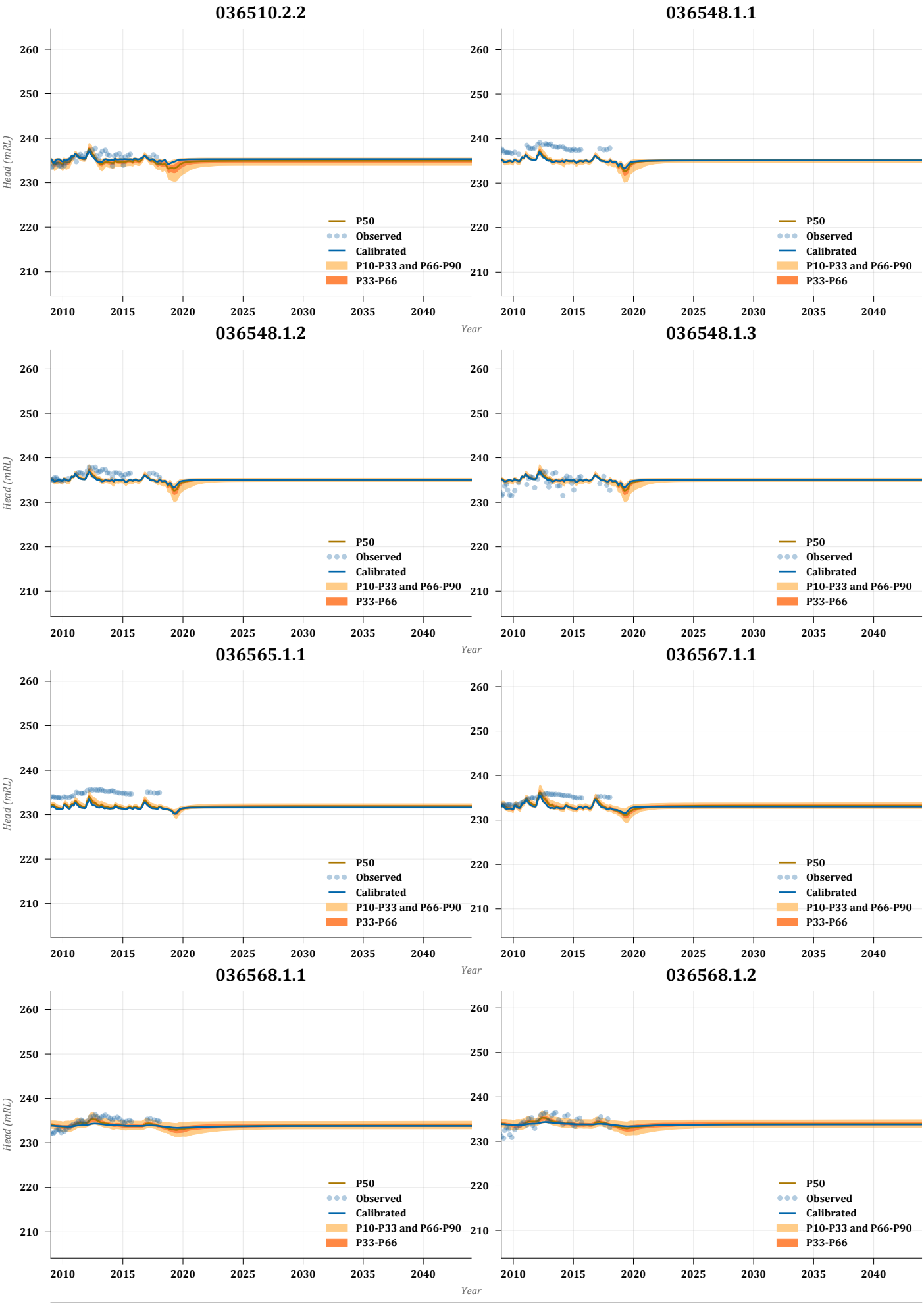
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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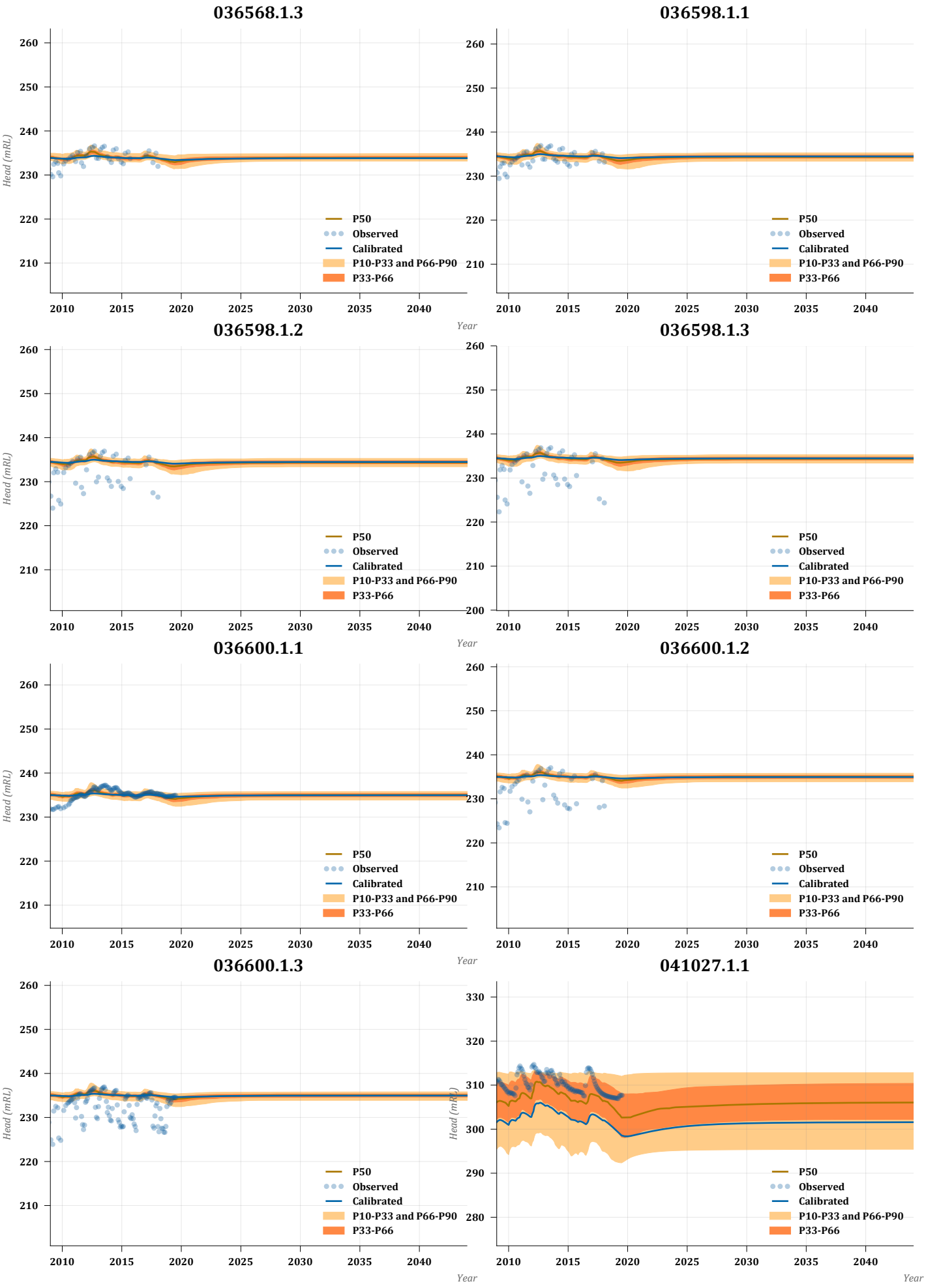
036548.1.1
036548.1.2
036548.1.3
036565.1.1
036567.1.1
036568.1.1
036568.1.2
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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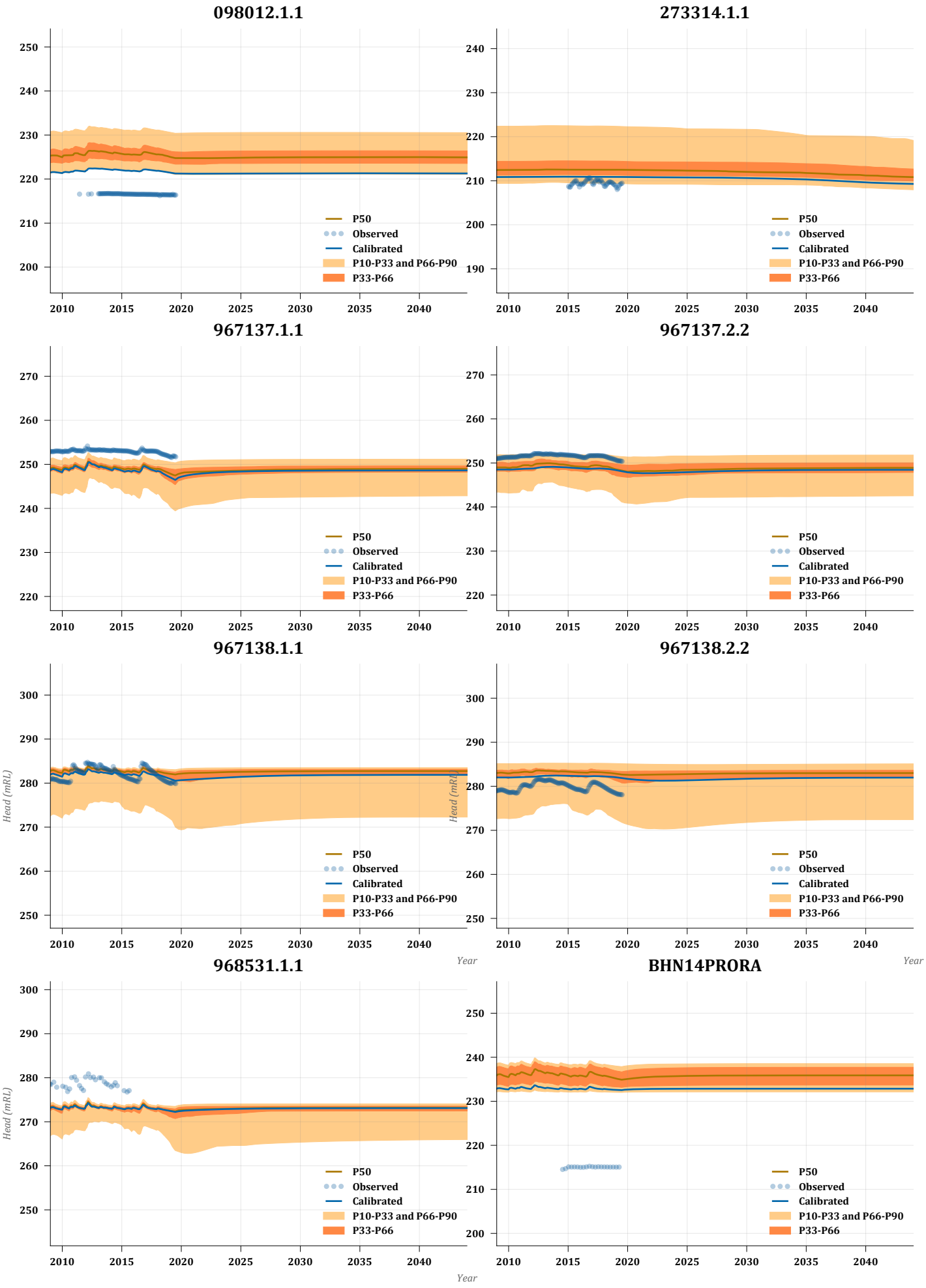
036598.1.3
036600.1.1
036600.1.2
036600.1.3
041027.1.1
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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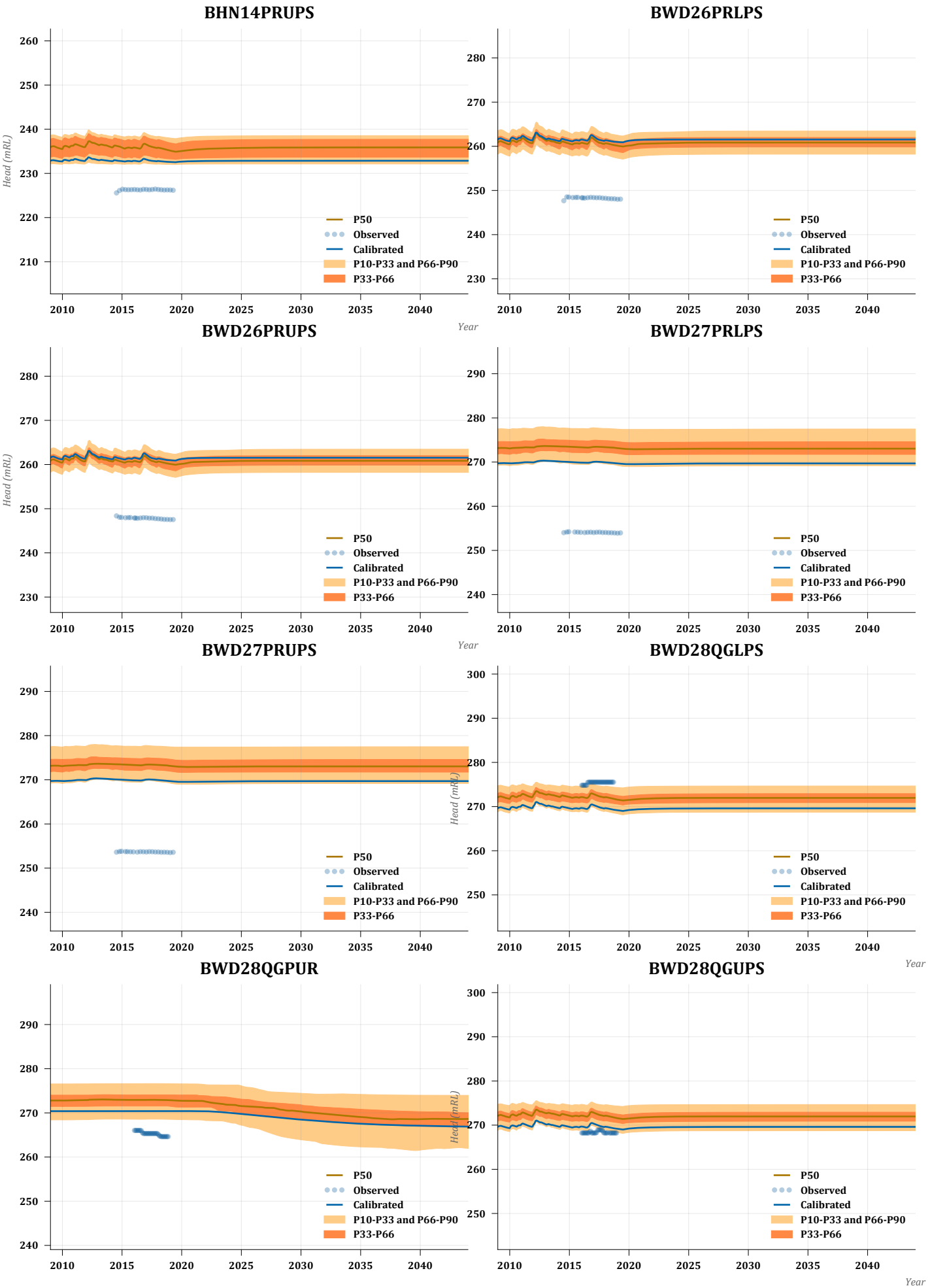
273314.1.1
967137.1.1
967137.2.2
967138.1.1
967138.2.2
968531.1.1
BHN14PRORA
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66
Head (mRL)
Year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BWD26PRLPS
BWD26PRUPS
BWD27PRLPS
BWD27PRUPS
BWD28QGLPS
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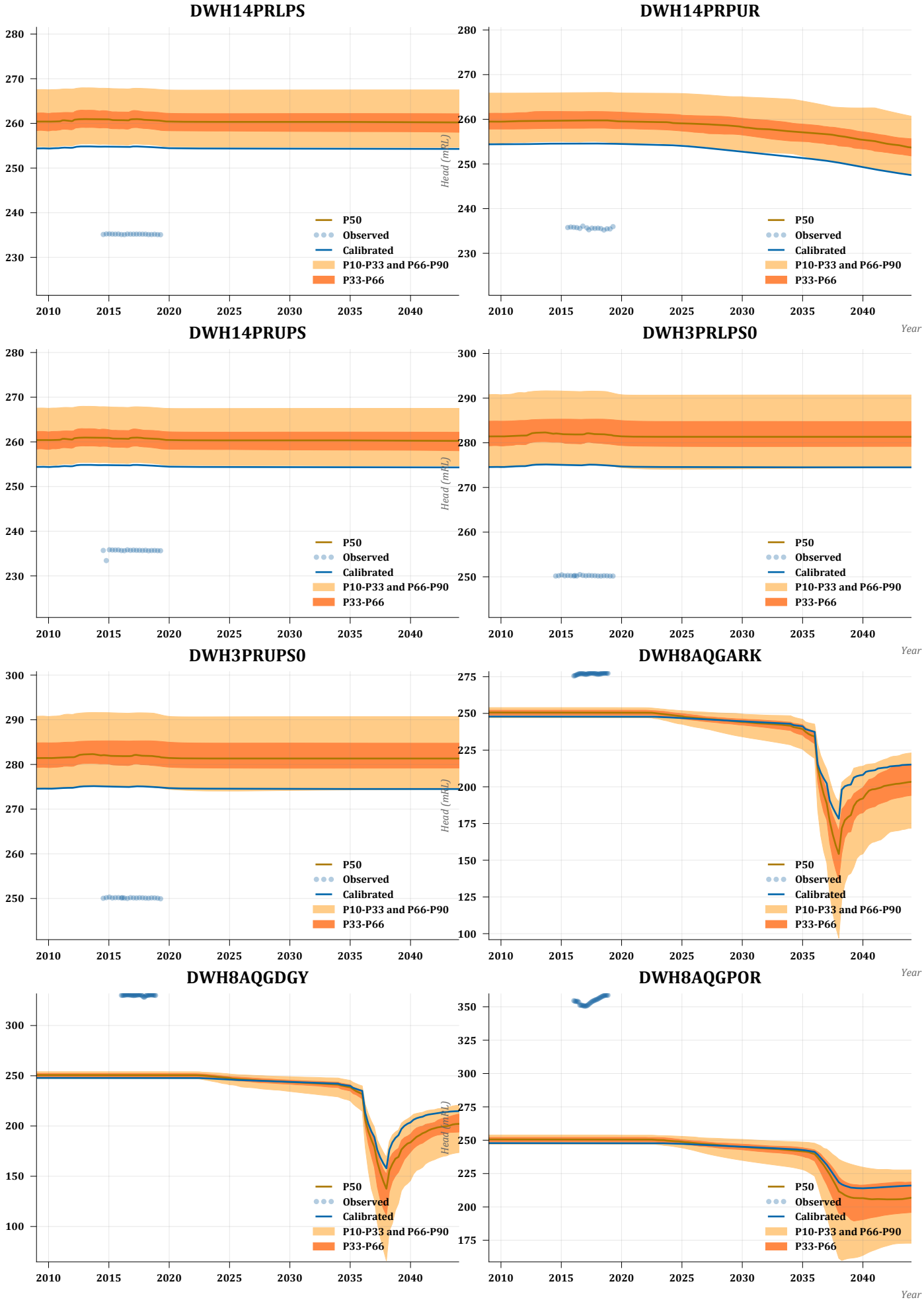
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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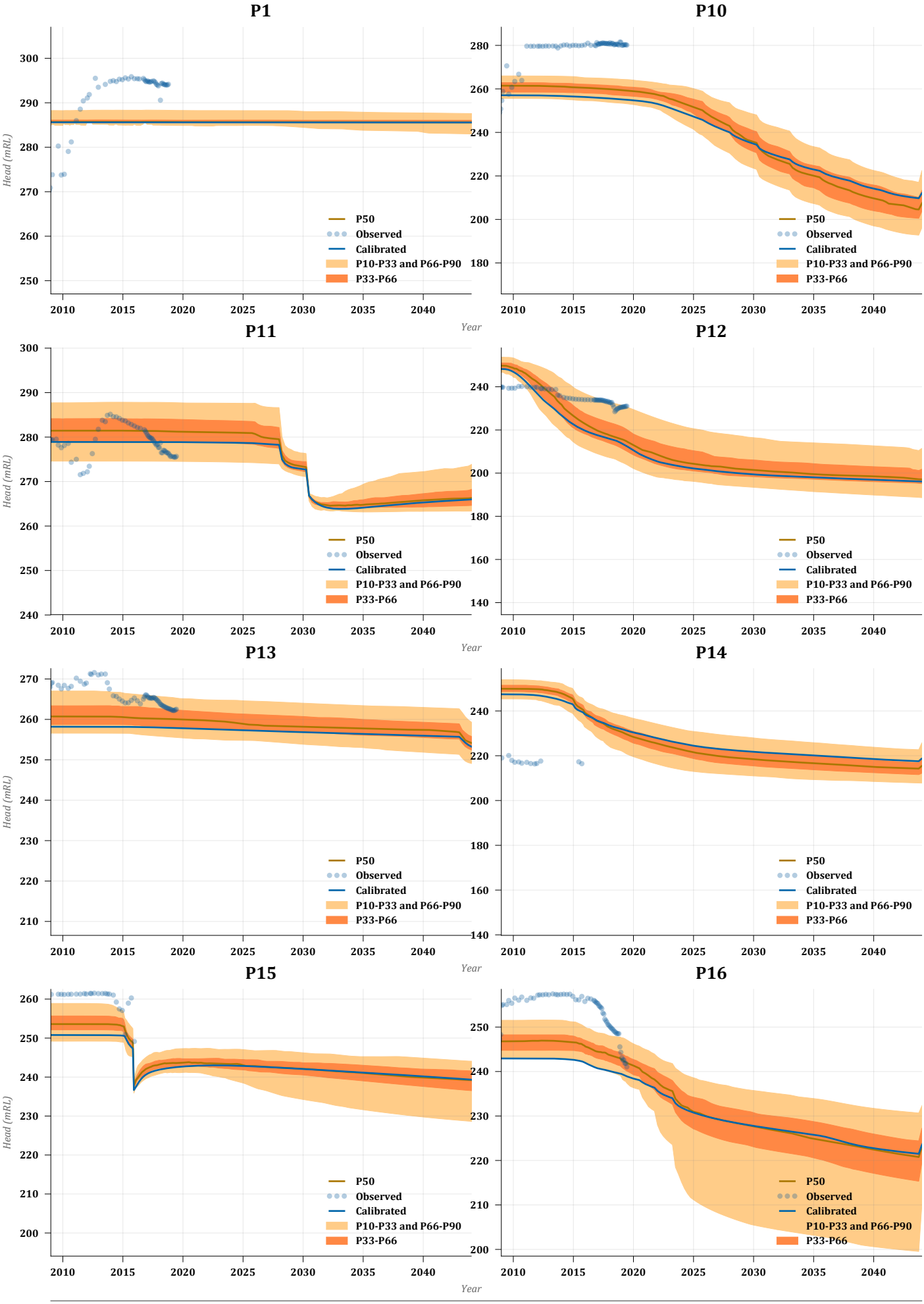
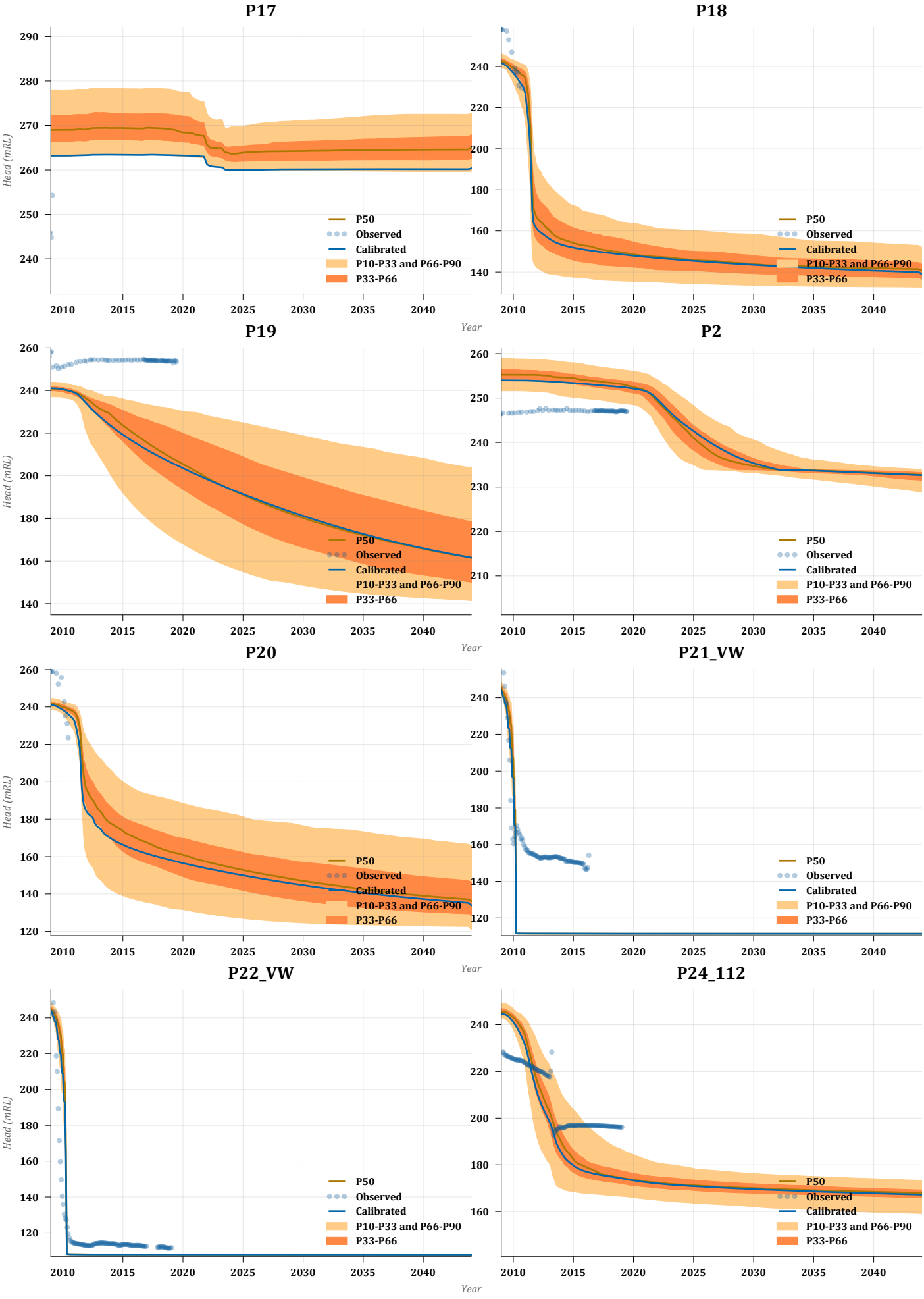
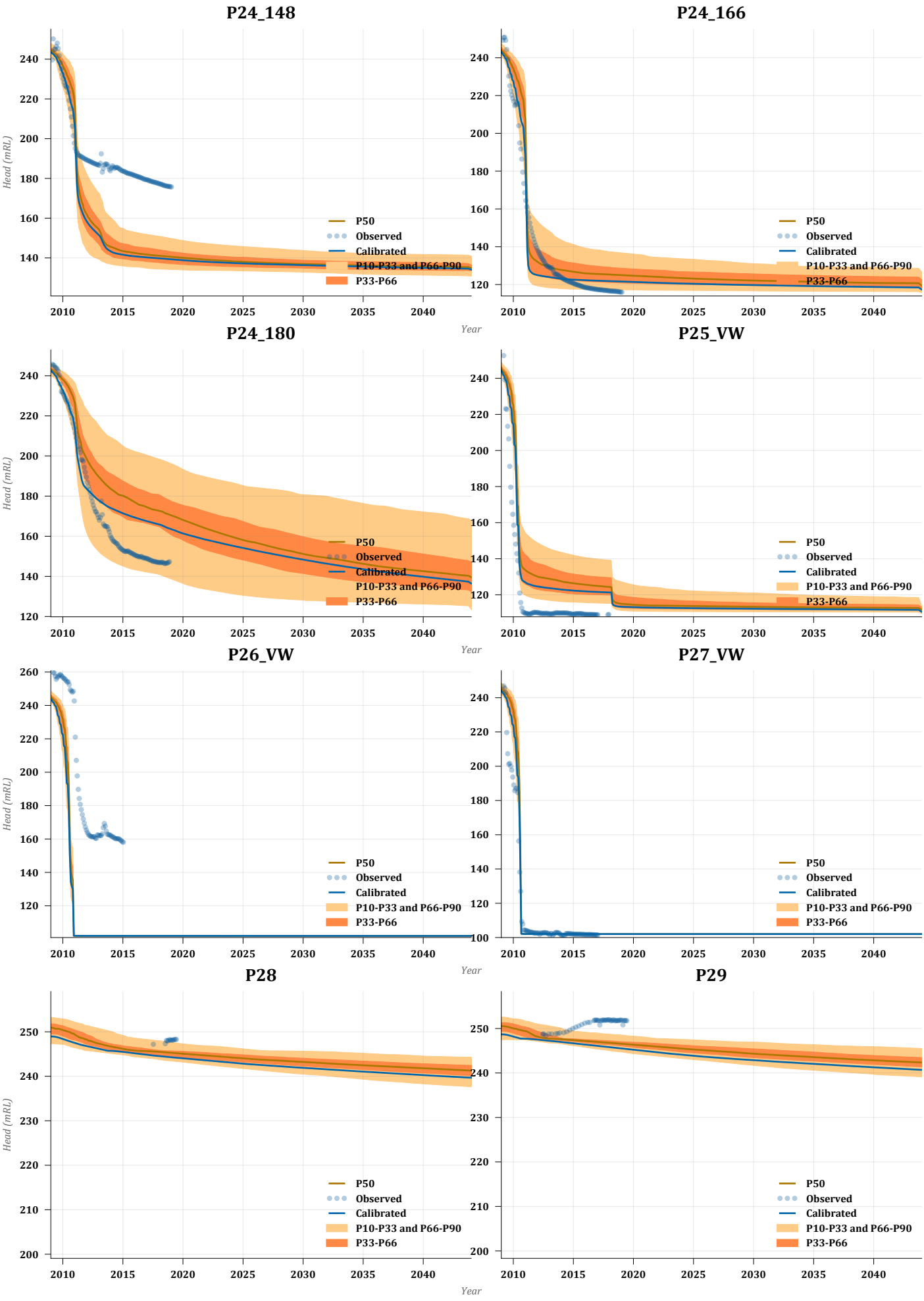
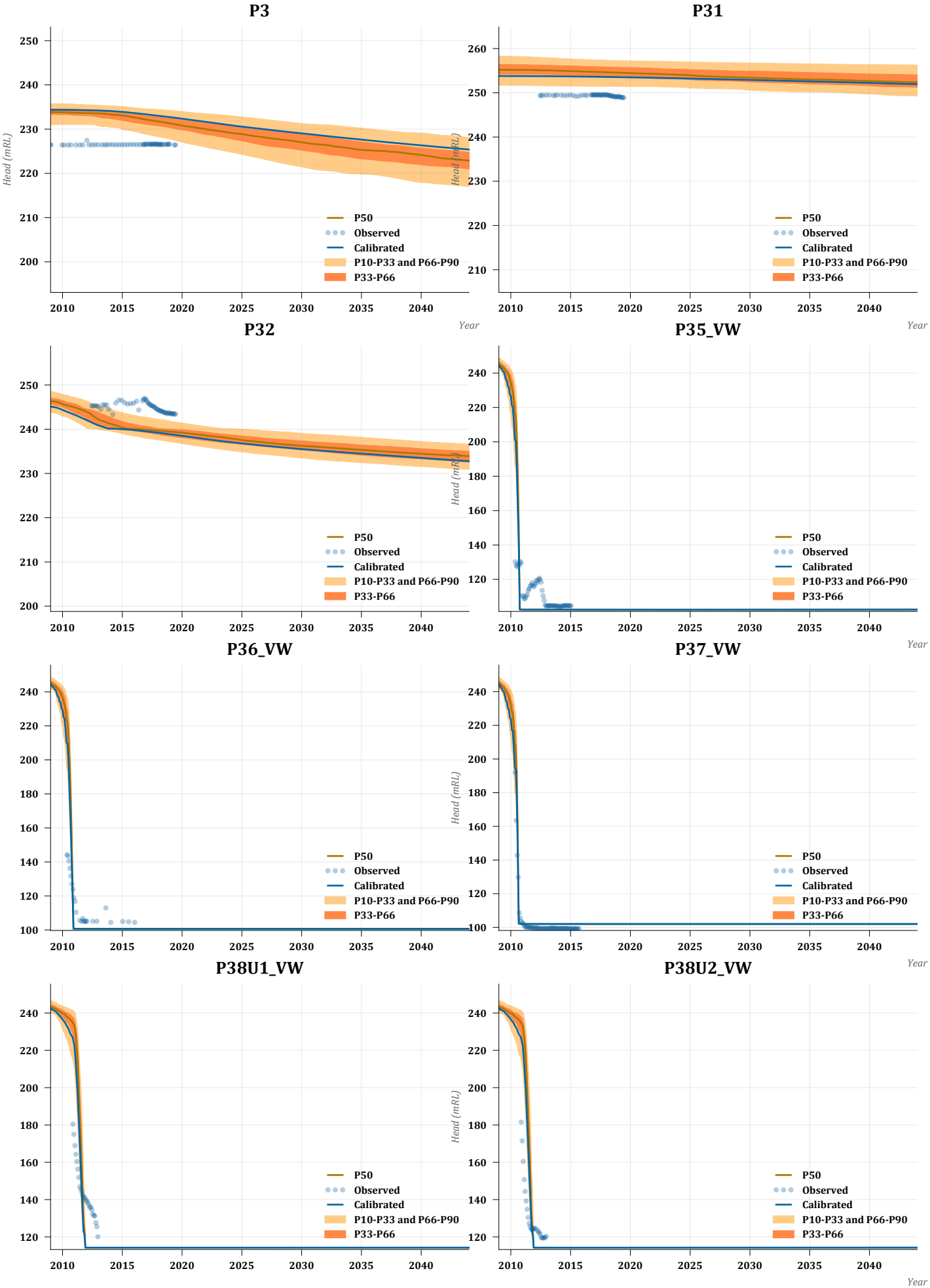
DWH14PRPUR
DWH14PRUPS
DWH3PRLPS0
DWH3PRUPS0
DWH8AQGARK
DWH8AQGDGY
DWH8AQGPOR
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66


P1
P10
P11
P12
P13
P14
P15
P16
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66


P17
P18
P19
P2
P20
P21_VW
P22_VW
P24_112
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66


P24_148
P24_166
P24_180
P25_VW
P26_VW
P27_VW
P28
P29
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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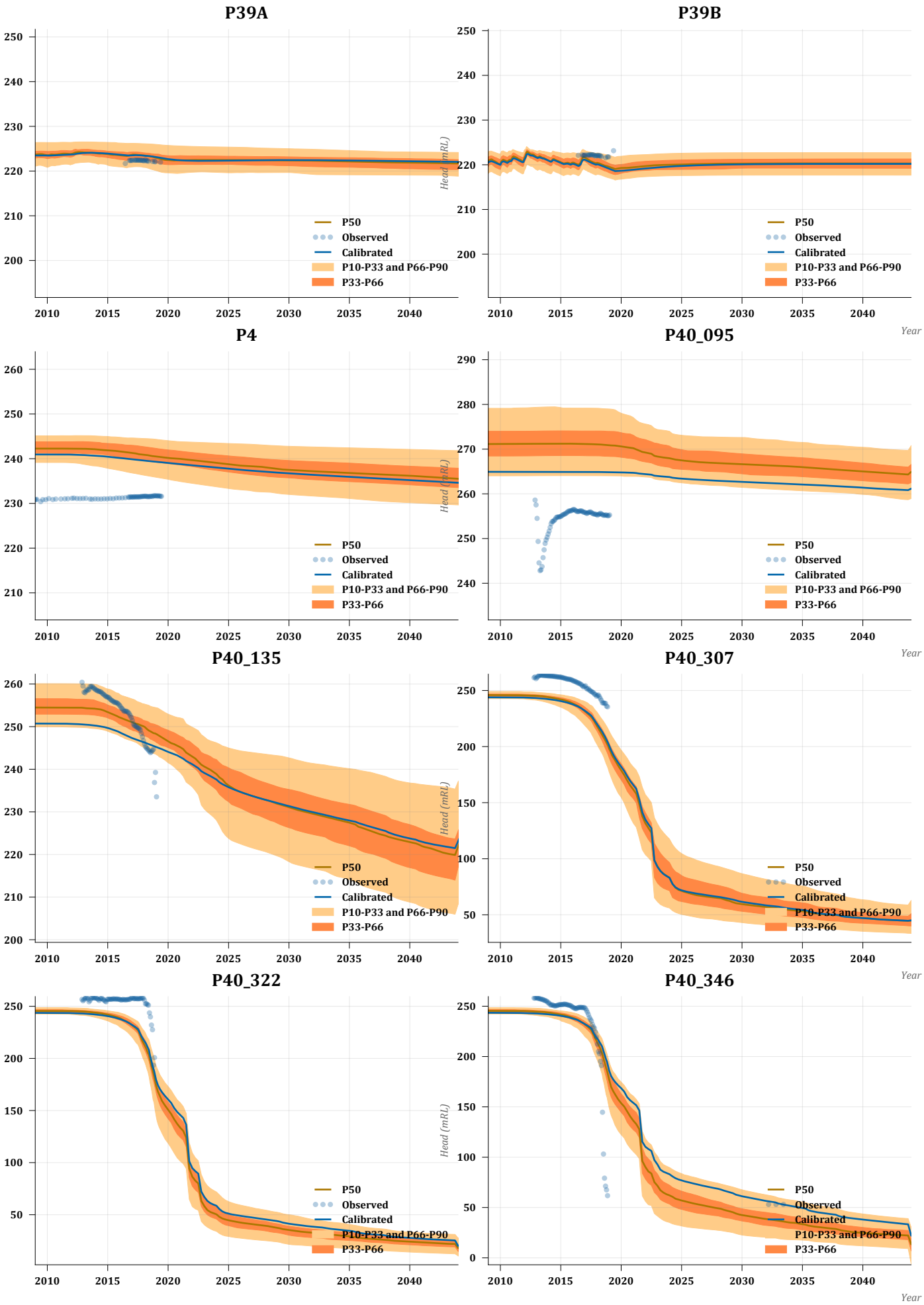
P31
P32
P35_VW
P36_VW
P37_VW
P38U1_VW
P38U2_VW
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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P39B
P4
P40_095
P40_135
P40_307
P40_322
P40_346
Head (mRL)
Year
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Observed
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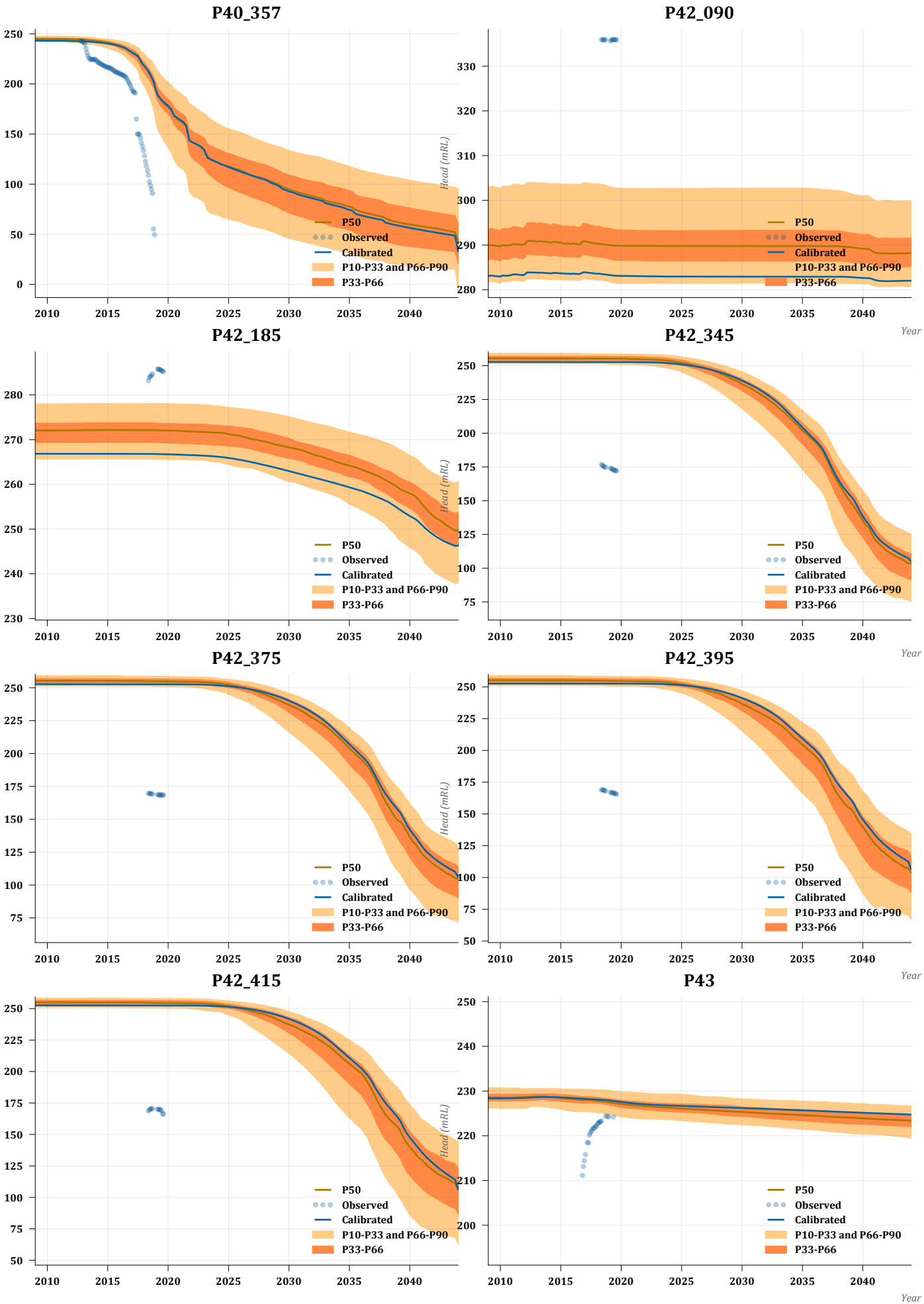
P10-P33 and P66-P90
P33-P66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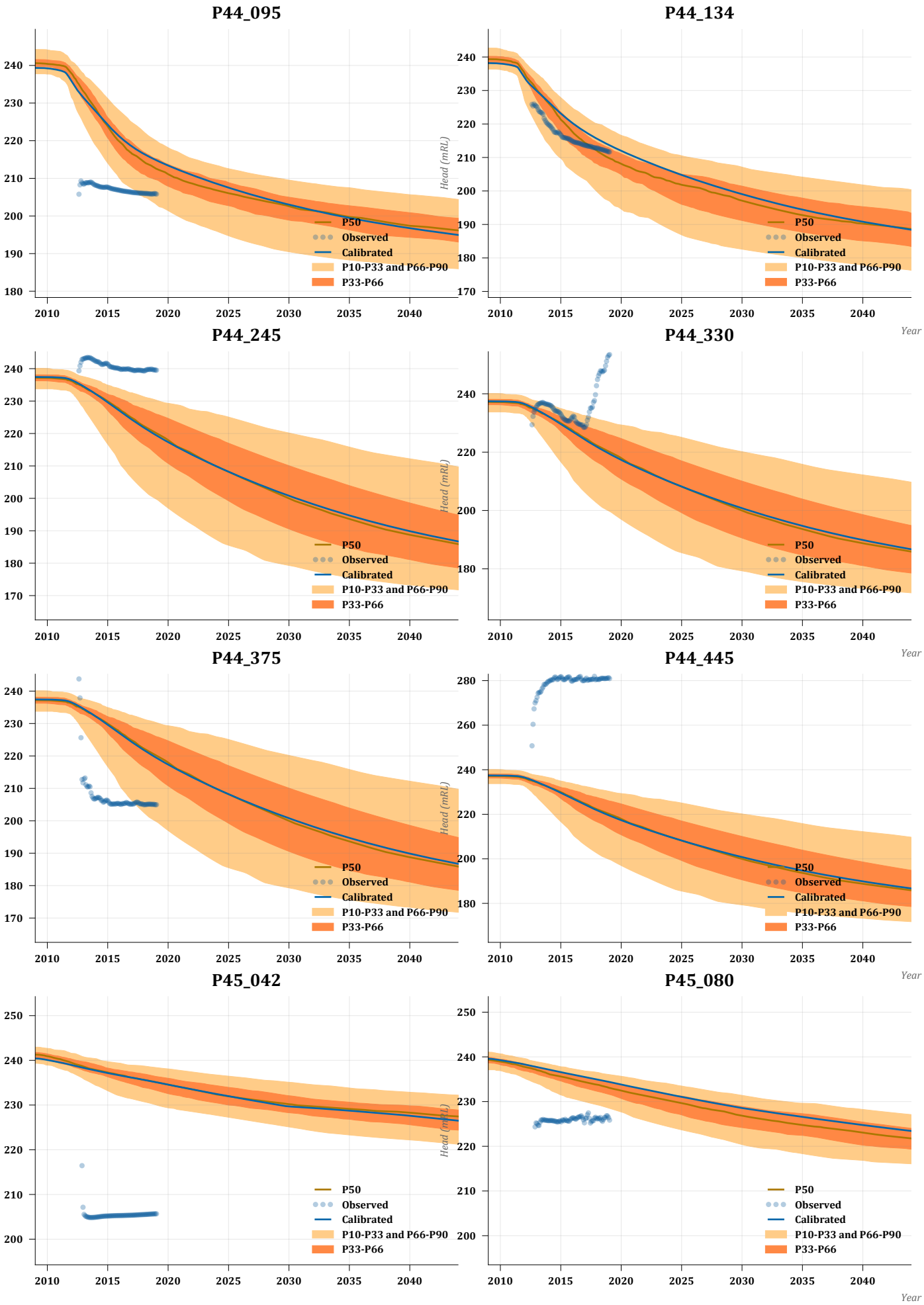
P42_090
P42_185
P42_345
P42_375
P42_395
P42_415
P43
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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P44_245
P44_330
P44_375
P44_445
P45_042
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Head (mRL)
Year
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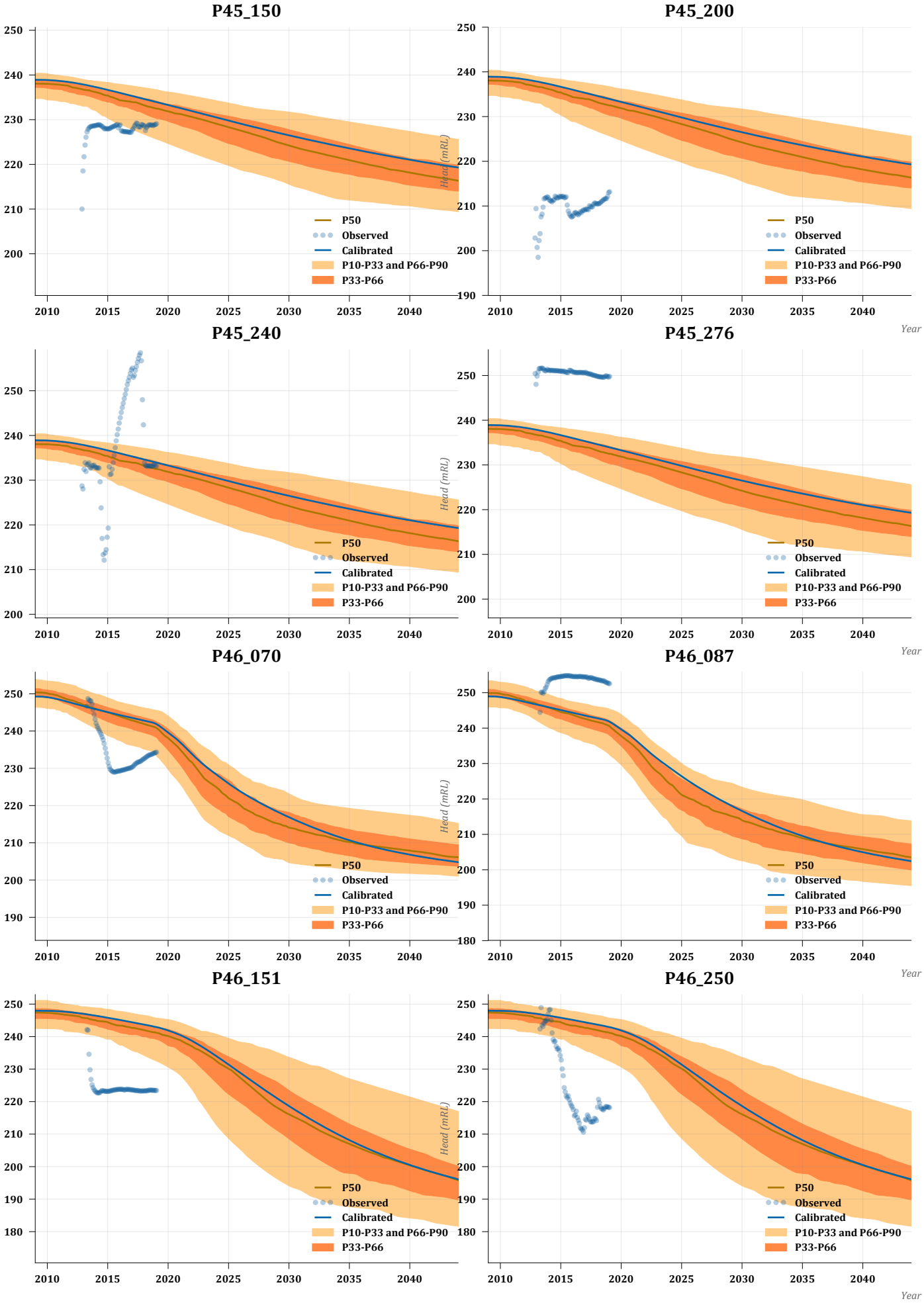
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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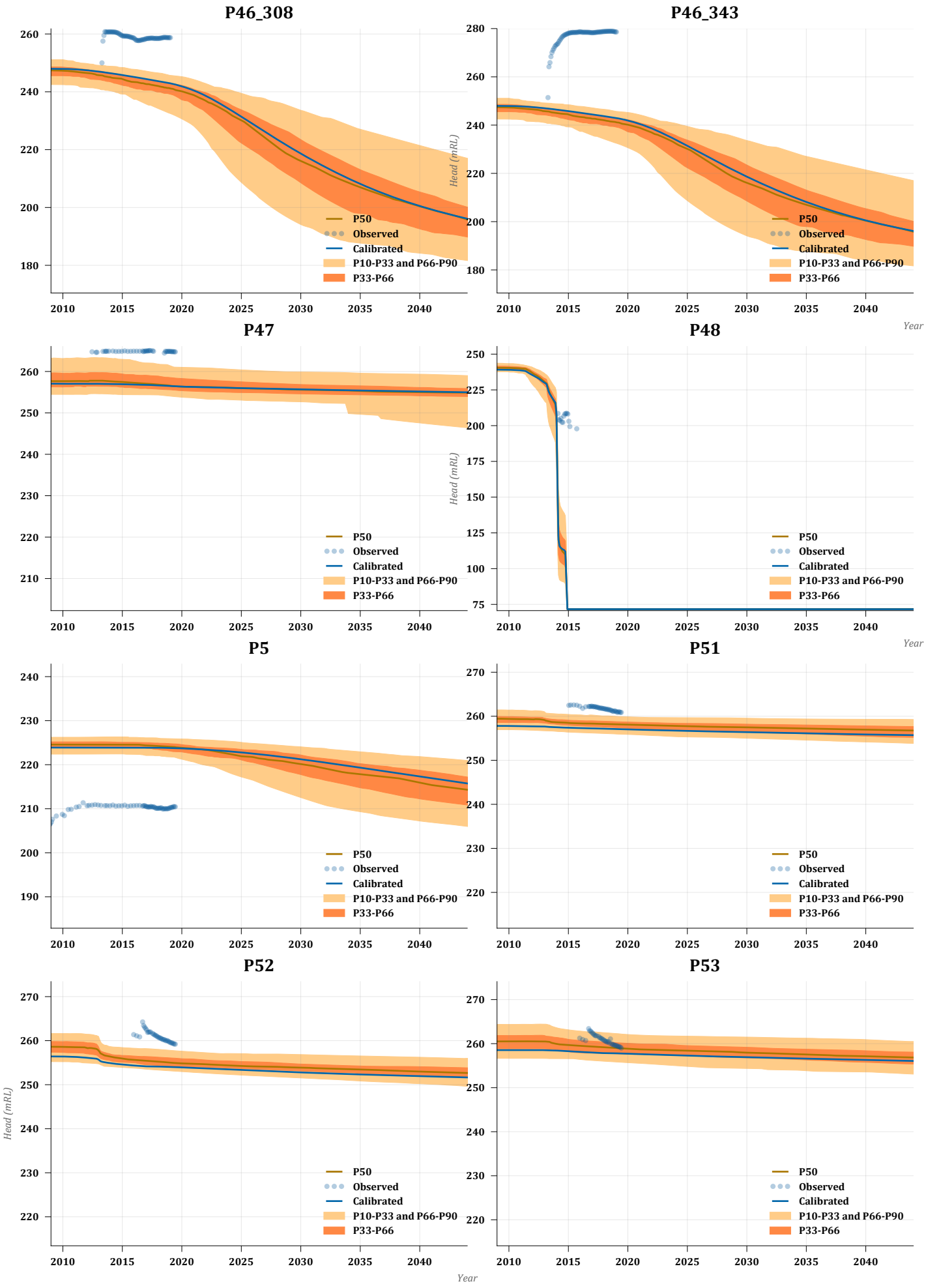
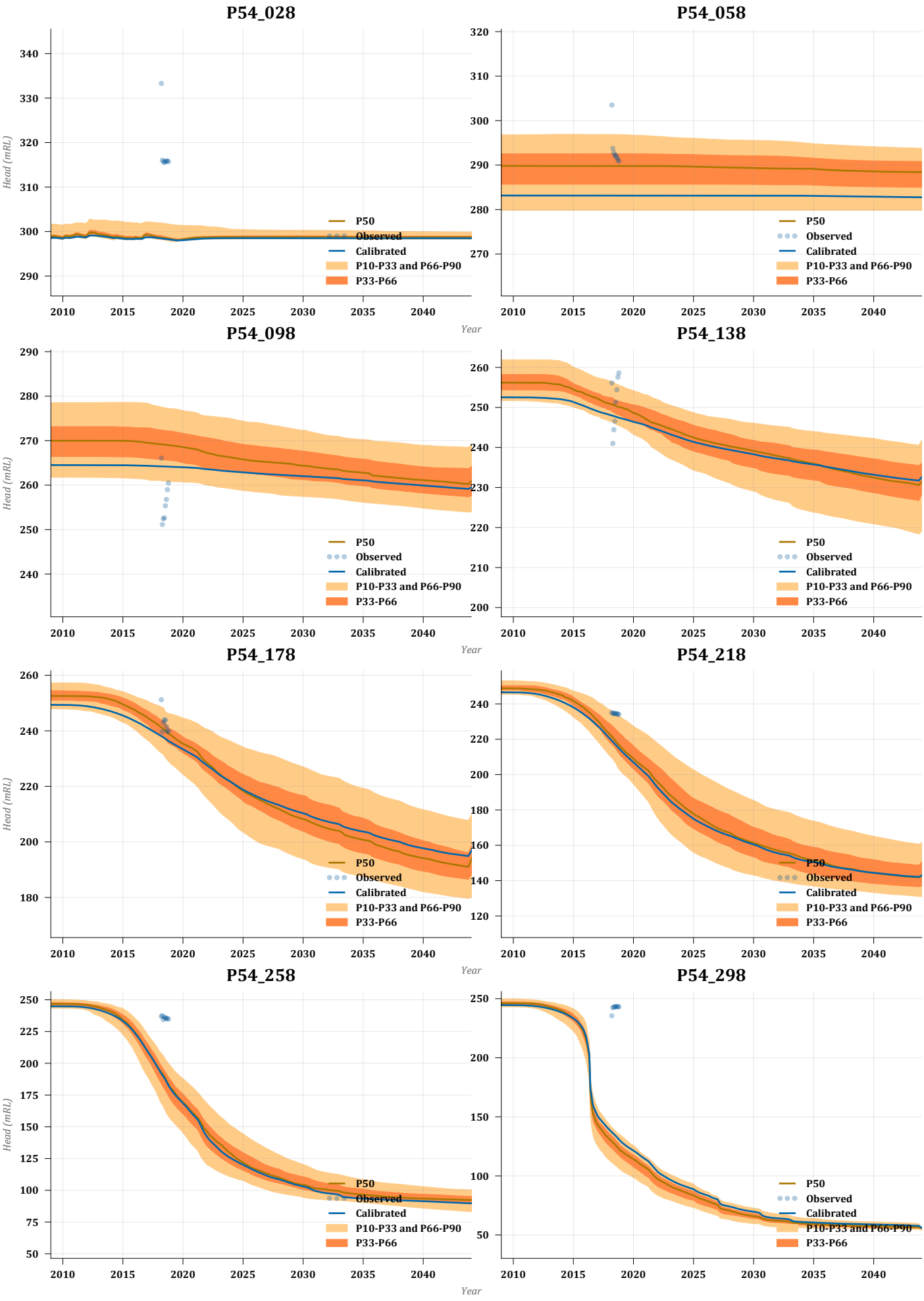
P45_200
P45_240
P45_276
P46_070
P46_087
P46_151
P46_250
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66


P46_308
P46_343
P47
P48
P5
P51
P52
P53
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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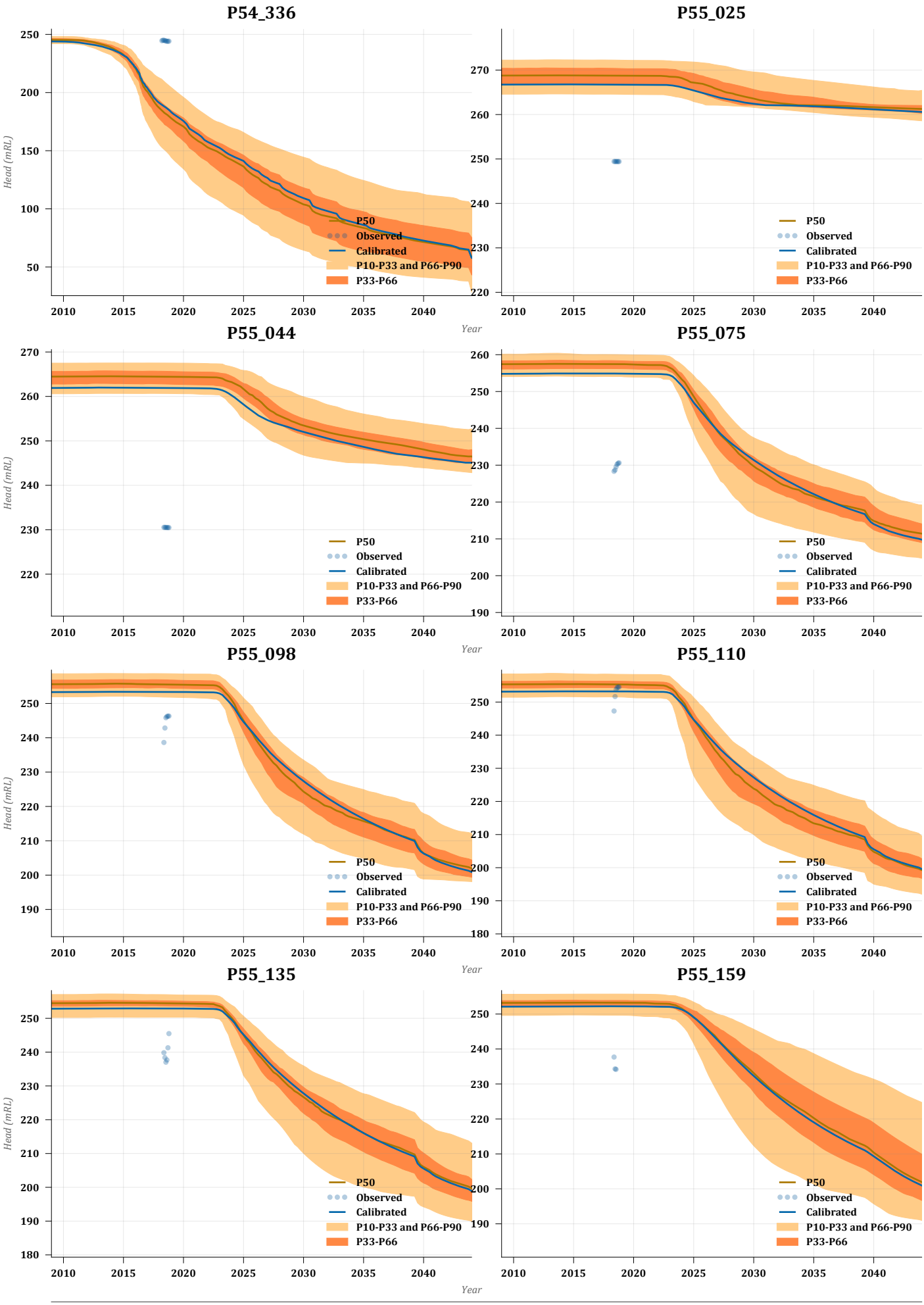
P54_058
P54_098
P54_138
P54_178
P54_218
P54_258
P54_298
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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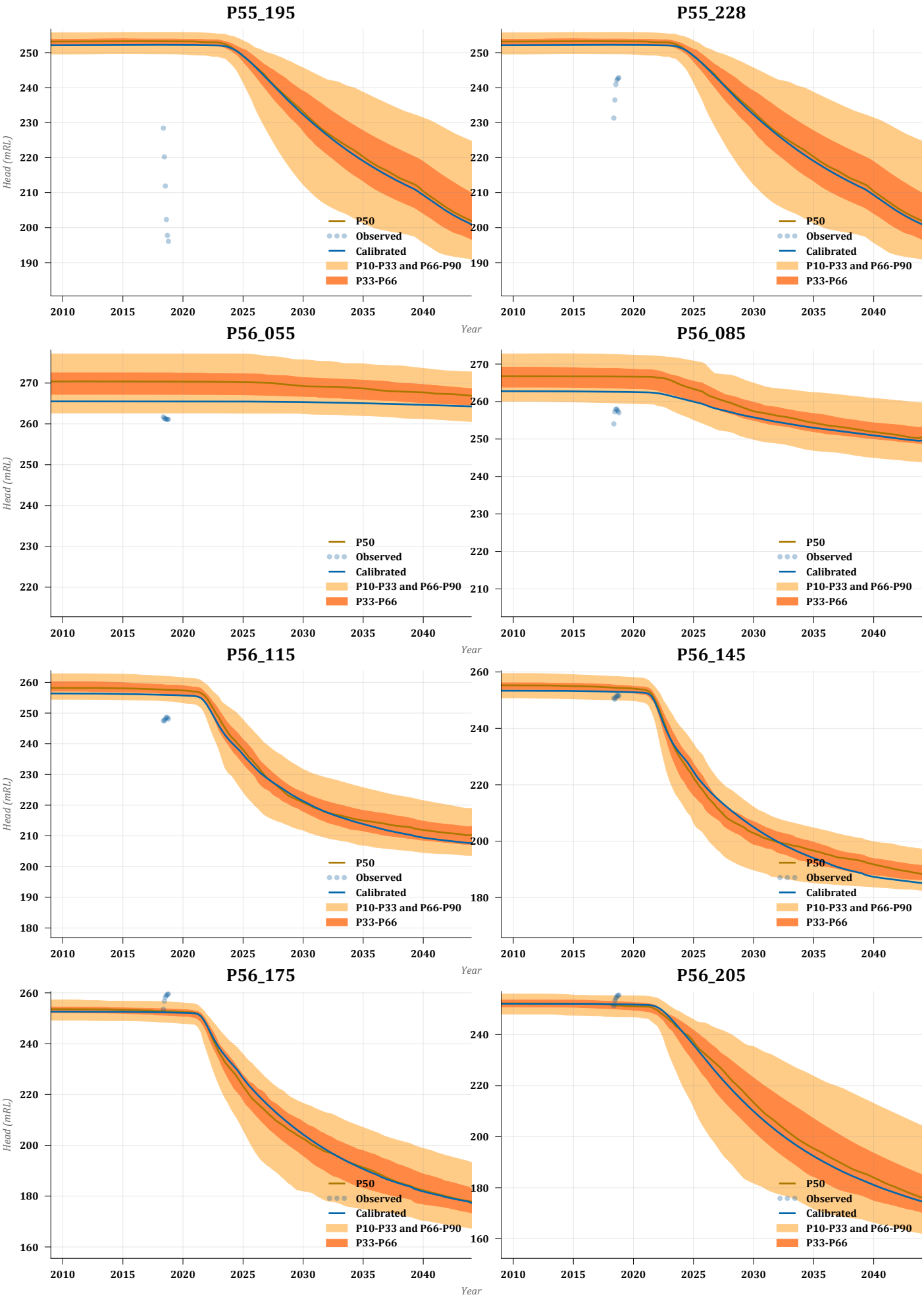
P55_025
P55_044
P55_075
P55_098
P55_110
P55_135
P55_159
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66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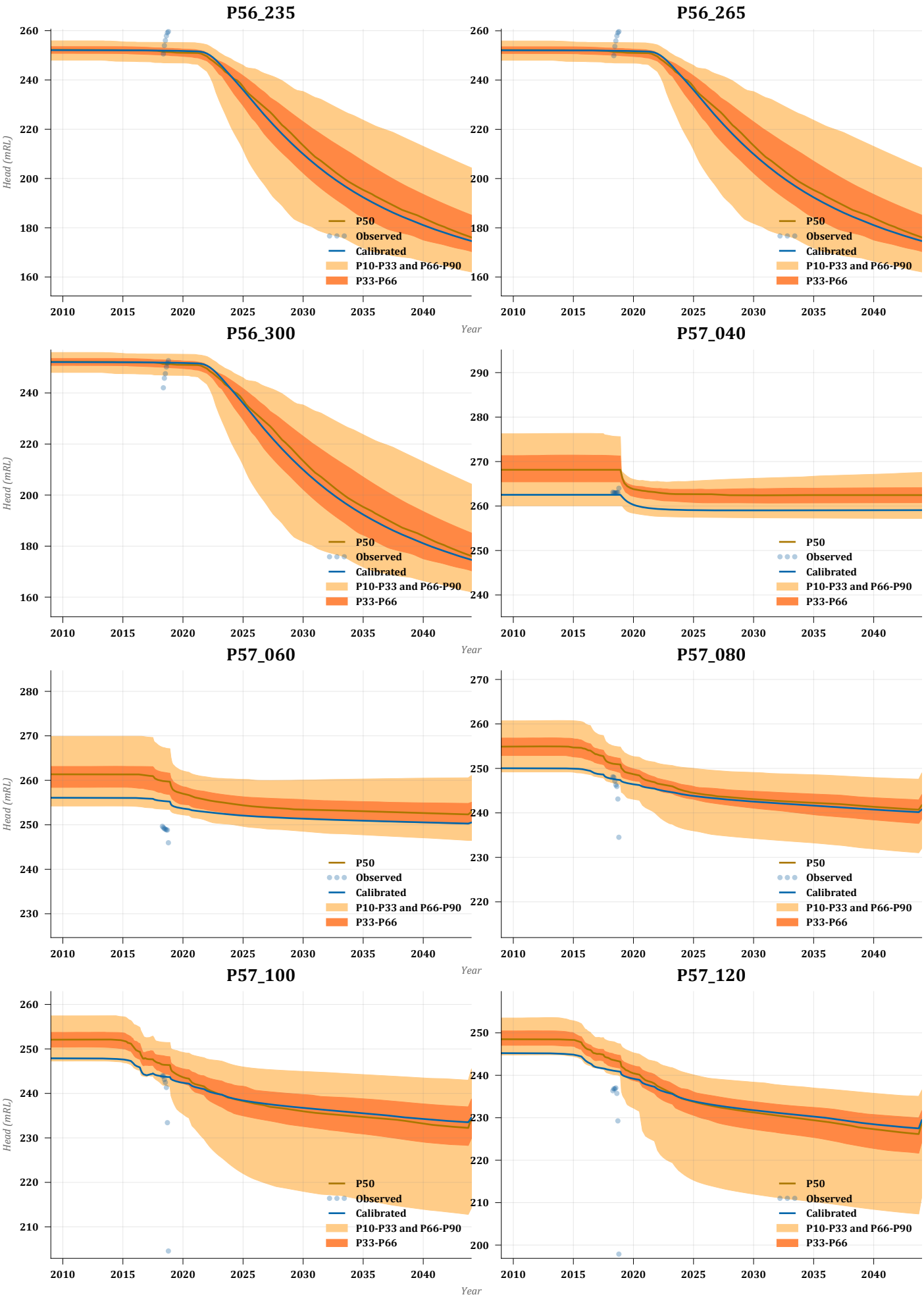
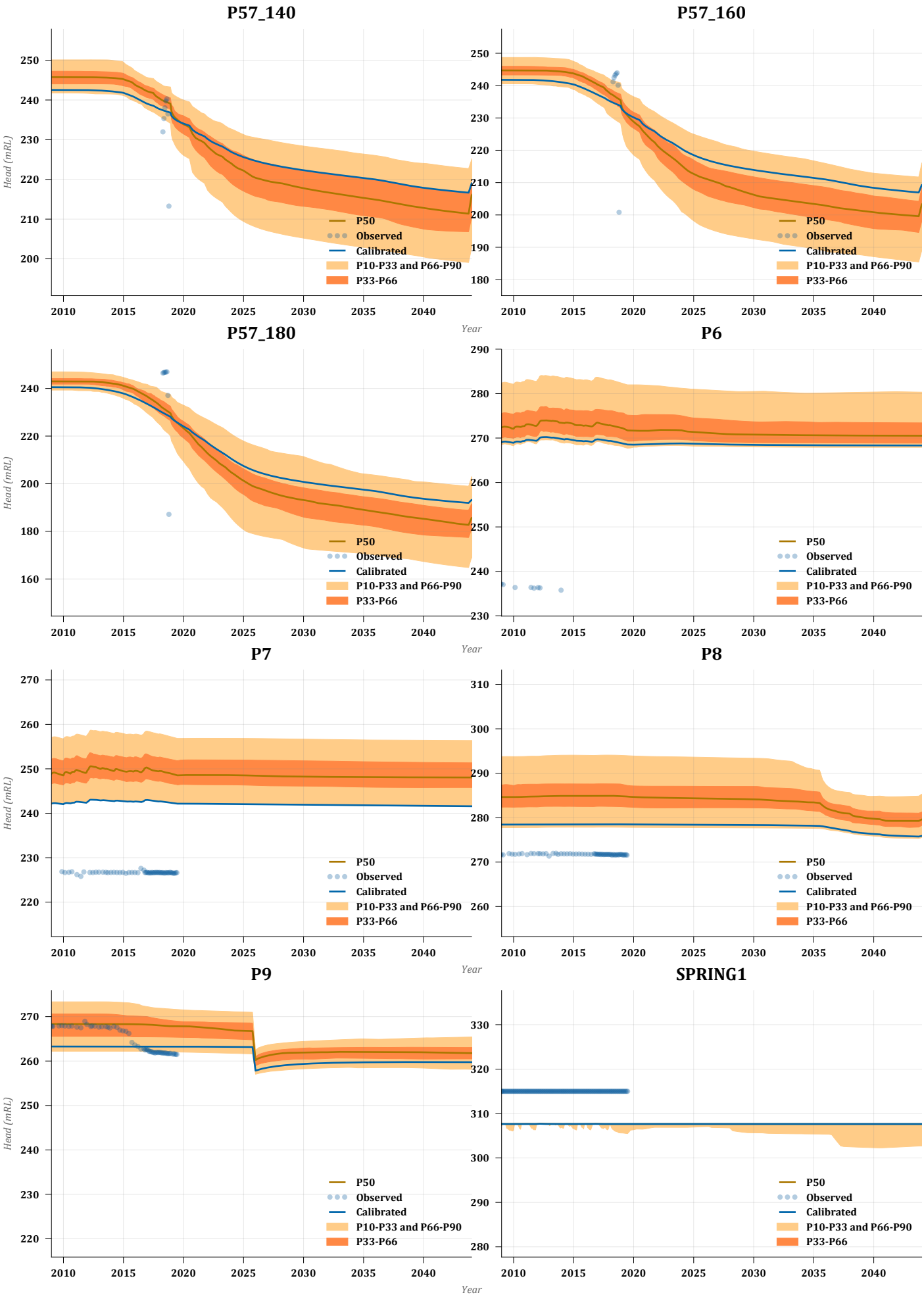
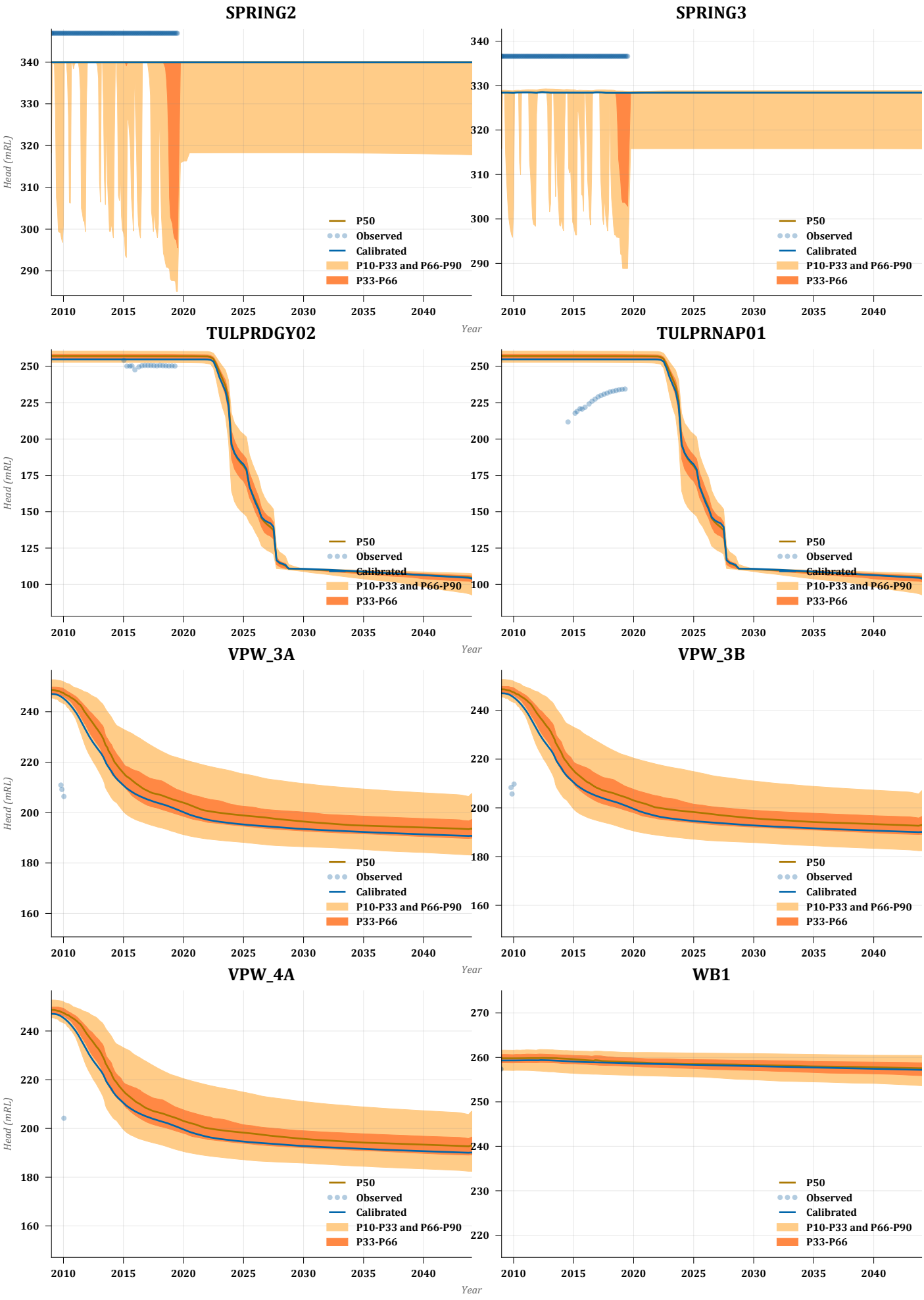
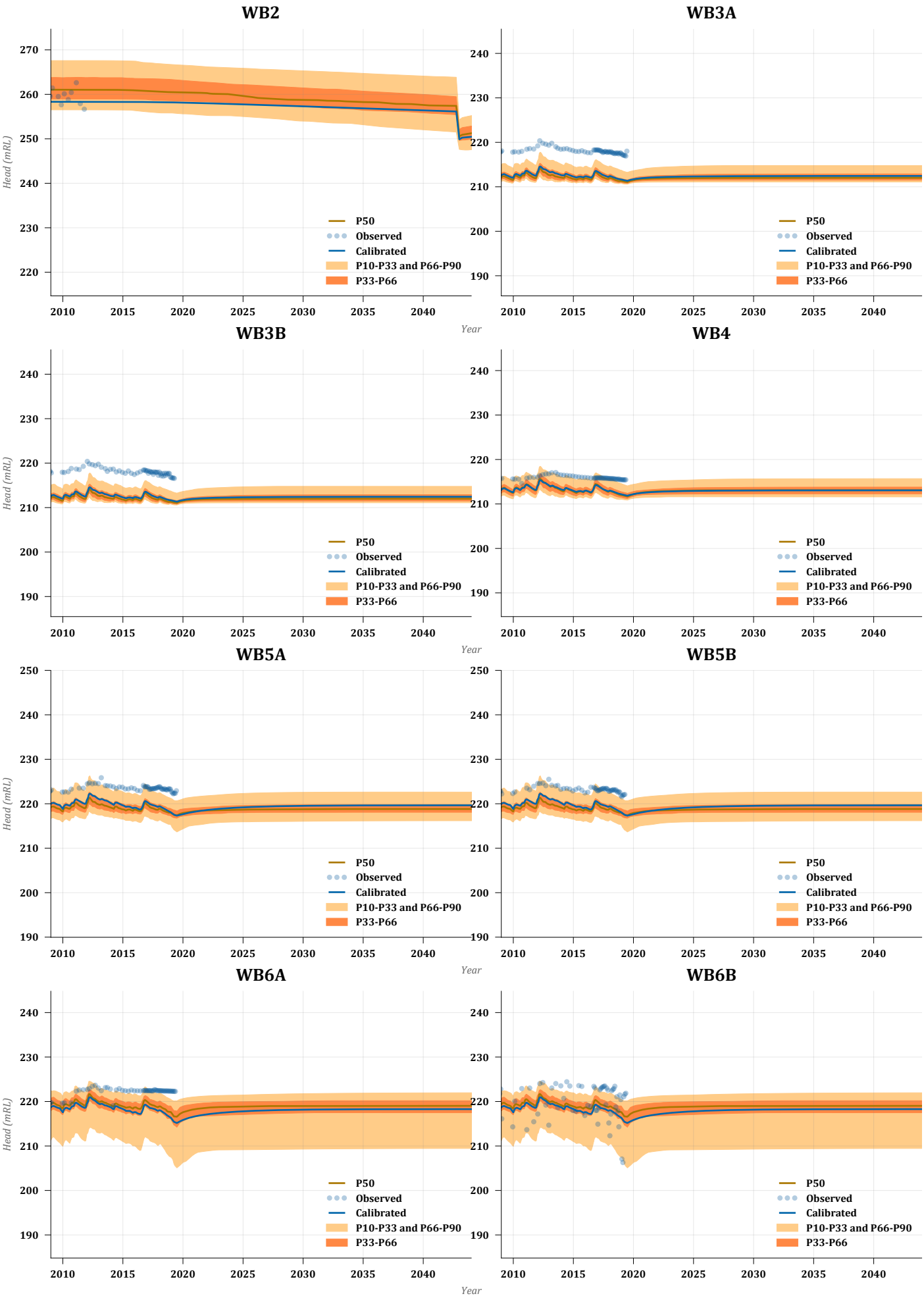
P55_228
P56_055
P56_085
P56_115
P56_145
P56_175
P56_205
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66

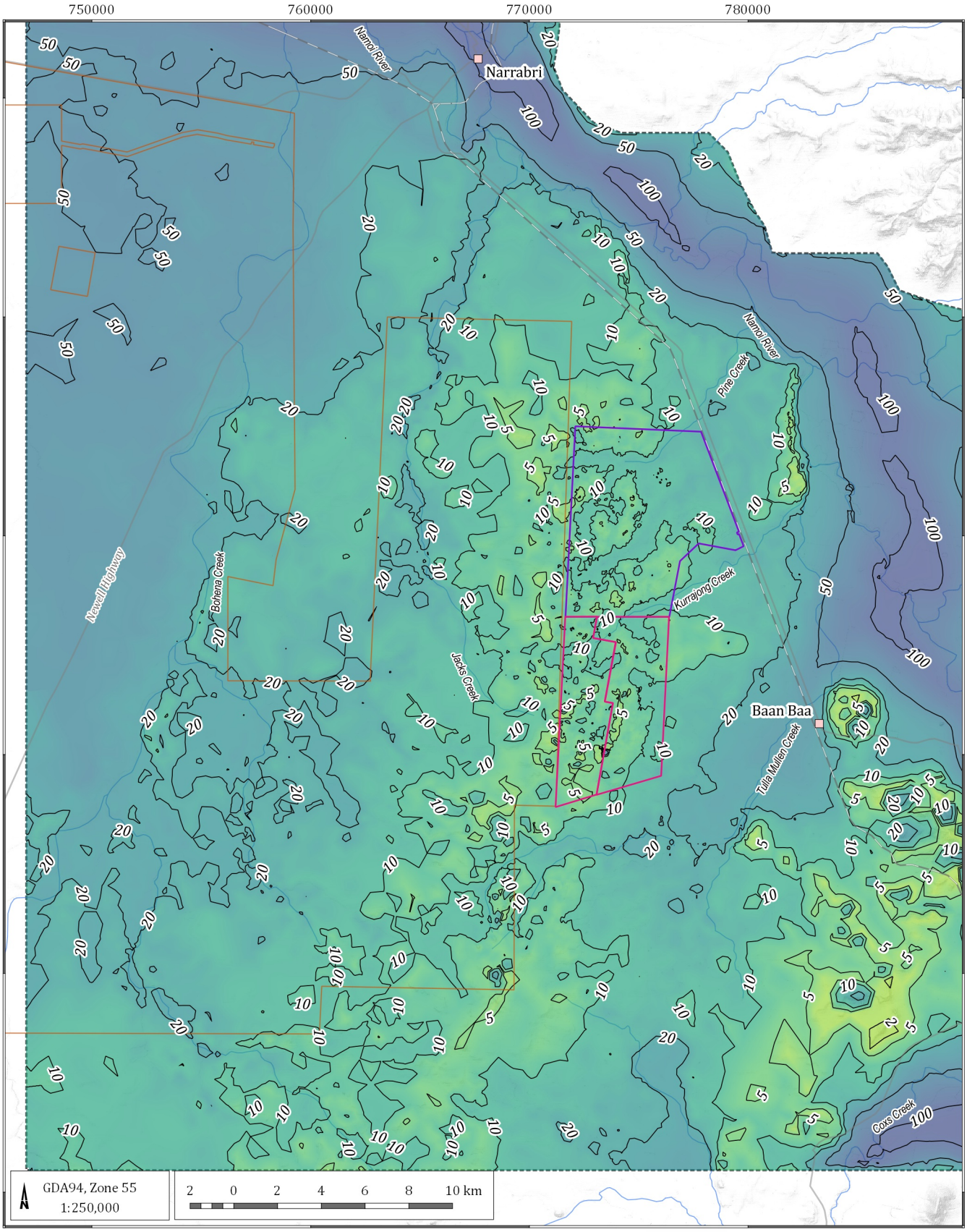

P56_235
P56_265
P56_300
P57_040
P57_060
P57_080
P57_100
P57_120
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66


P57_140
P57_160
P57_180
P6
P7
P8
P9
SPRING1
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66


SPRING2
SPRING3
TULPRDGY02
TULPRNAP01
VPW_3A
VPW_3B
VPW_4A
WB1
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66


WB2
WB3A
WB3B
WB4
WB5A
WB5B
WB6A
WB6B
Head (mRL)
Year
P50
Observed
Calibrated
P10-P33 and P66-P90
P33-P66

# *Appendix D 3* Model layer thickness isopachs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Thickness contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Thickness(m)**

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Narrabri Stage 3 Extension GIA (G1972)

**Alluvium/regolith**

DATE 12/08/2020

FIGURE No: **D 3.1**

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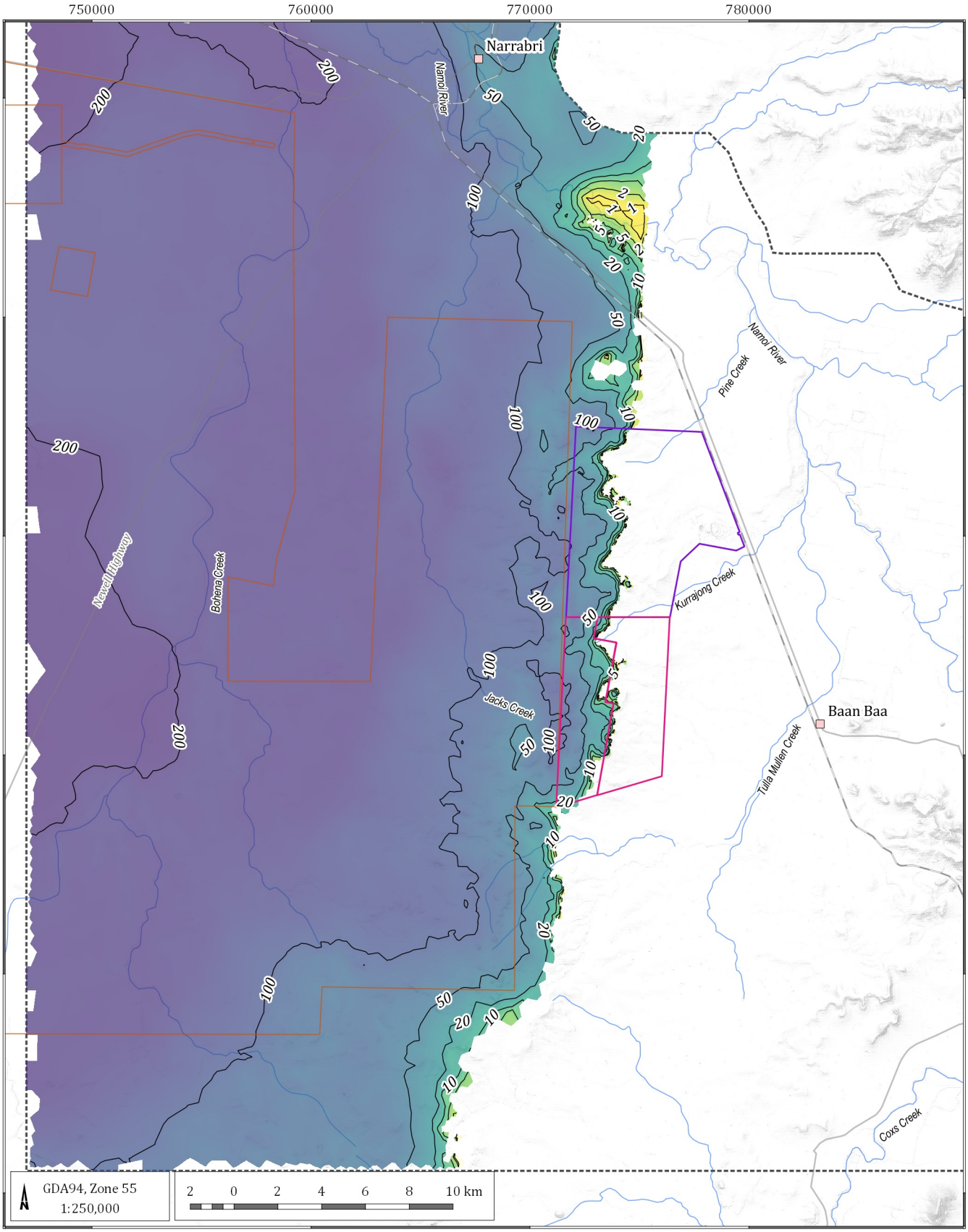
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 03.01 to D 03.11_G1972_Thickness.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Thickness contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Thickness (m)**

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Narrabri Stage 3 Extension GIA (G1972)

**Pilliga Sandstone**

DATE 12/08/2020

FIGURE No: **D 3.2**

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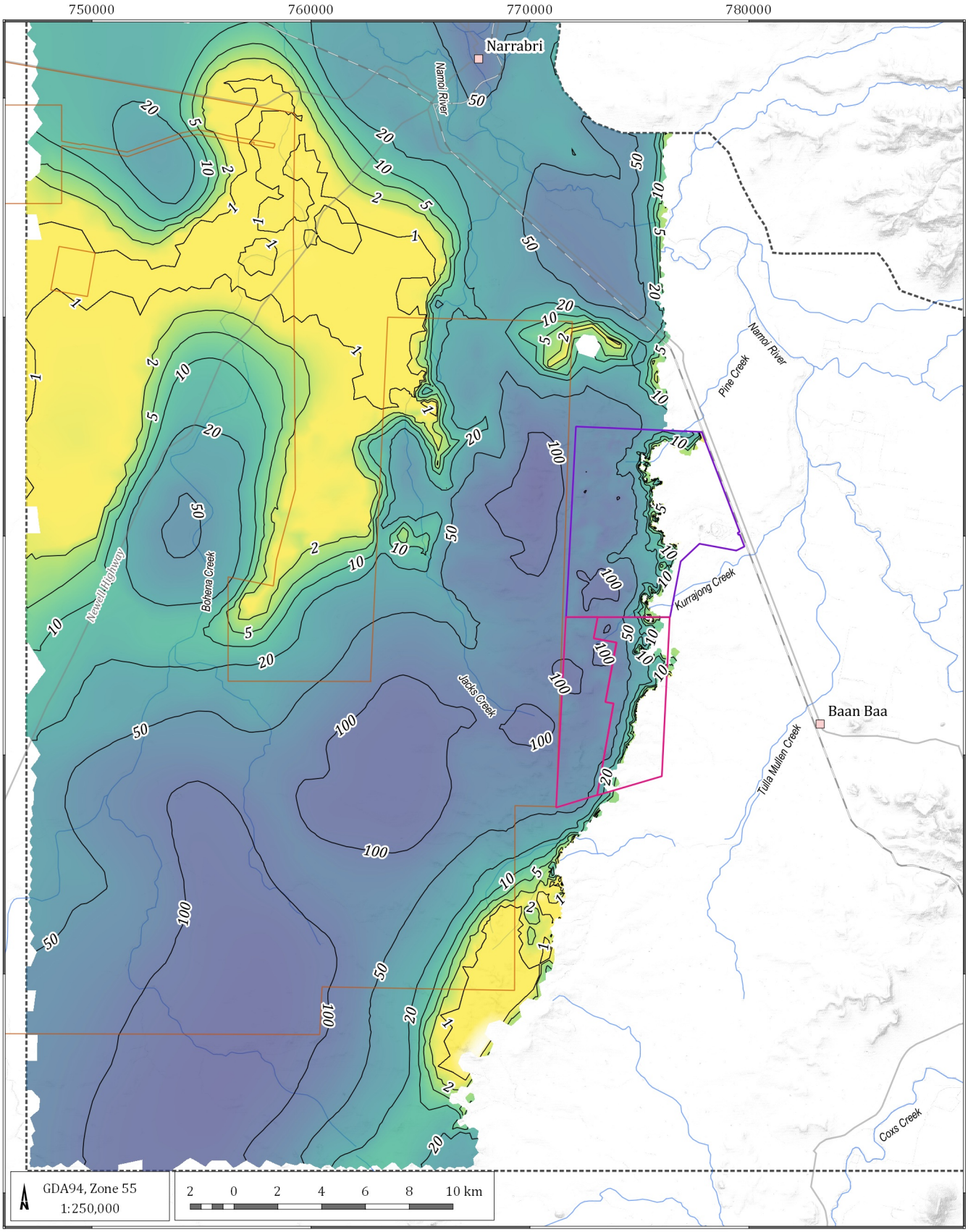


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Thickness contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Thickness (m)**

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Narrabri Stage 3 Extension GIA (G1972)

**Purlawaugh Formation**

DATE 12/08/2020

FIGURE No: **D 3.3**

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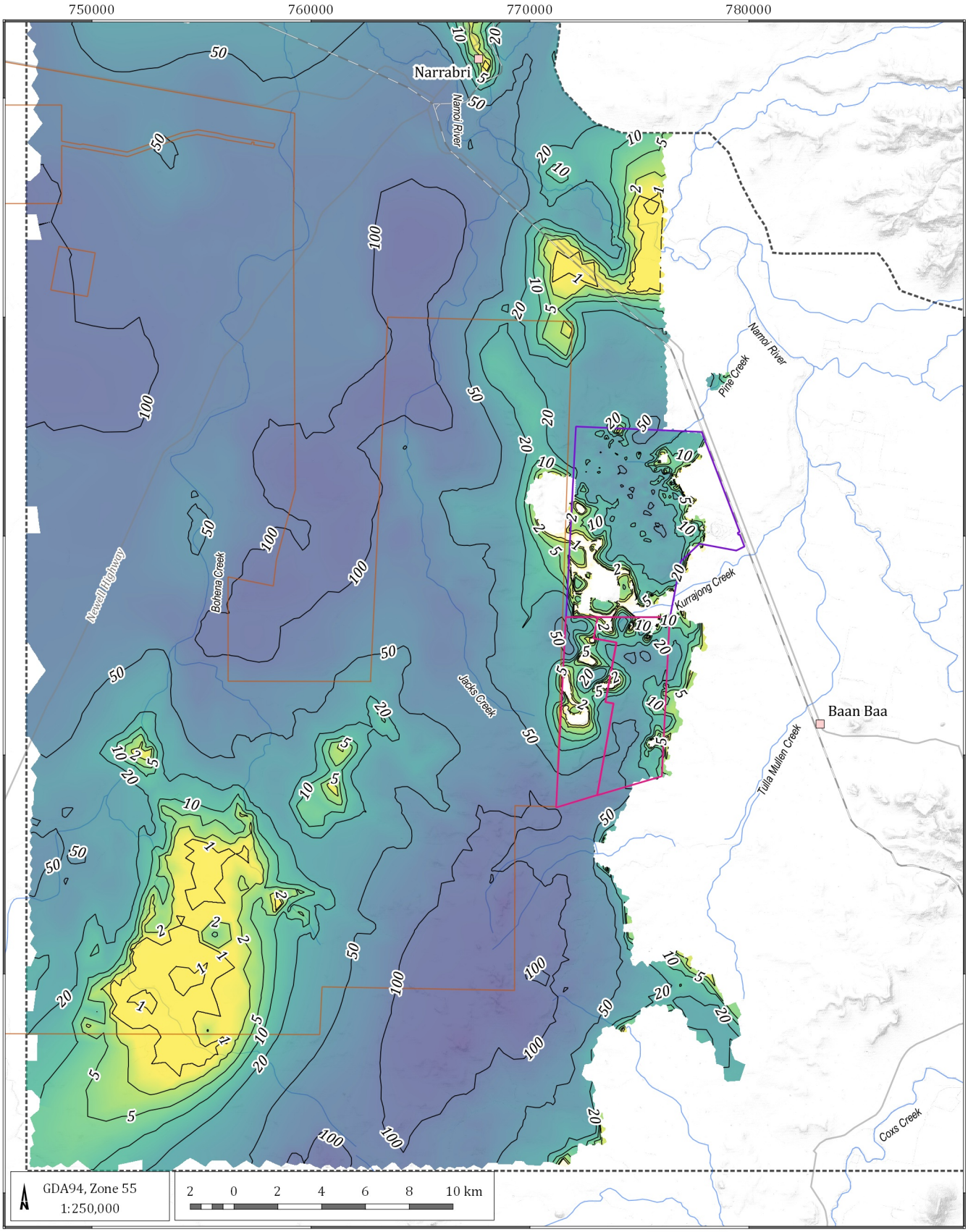


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Thickness contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Thickness (m)**

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Narrabri Stage 3 Extension GIA (G1972)

**Garrawilla Volcanics**

DATE 12/08/2020

FIGURE No: **D 3.4**

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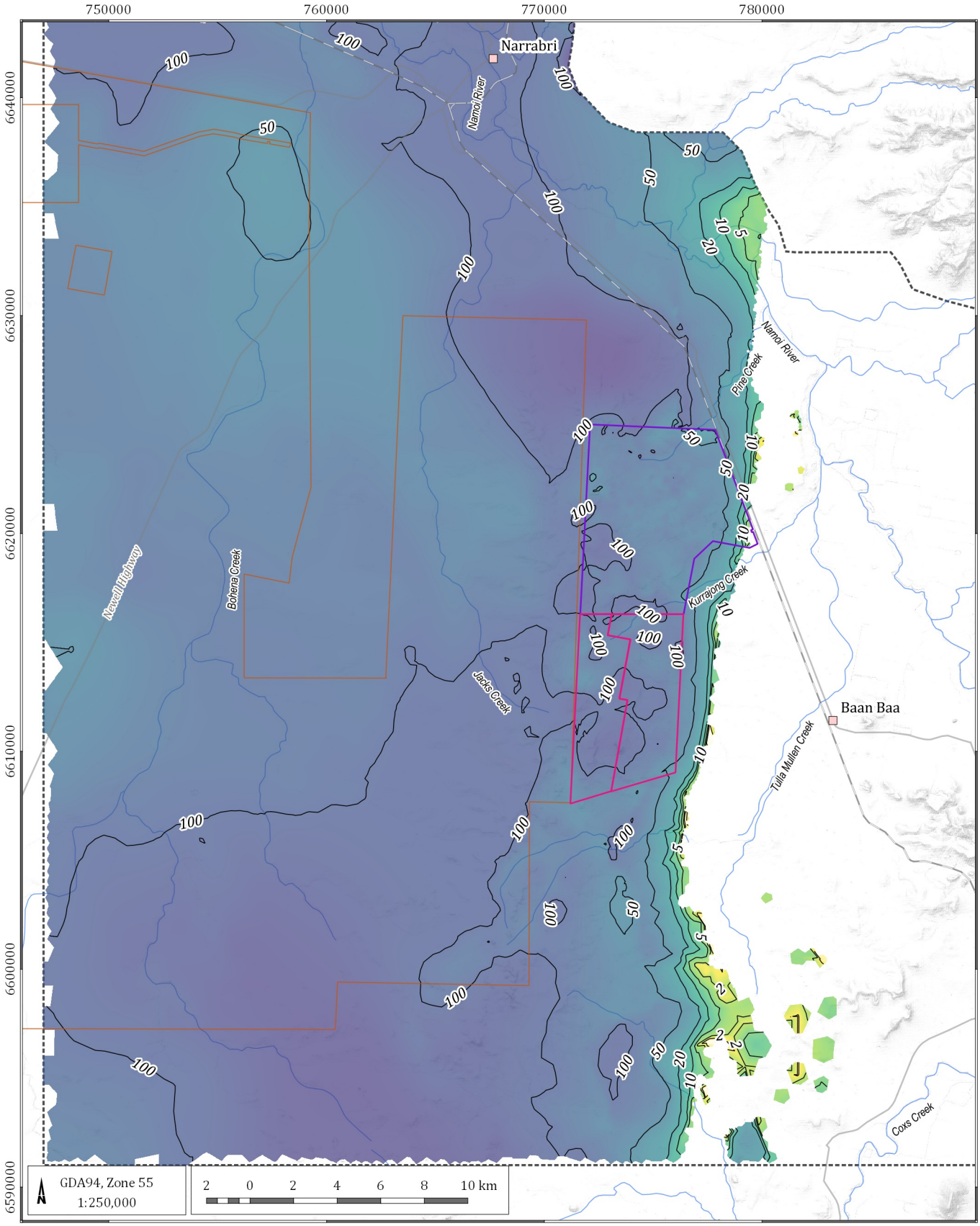


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Thickness contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Thickness (m)**

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Narrabri Stage 3 Extension GIA (G1972)

**Napperby Formation**

DATE 12/08/2020

FIGURE No: **D 3.5**

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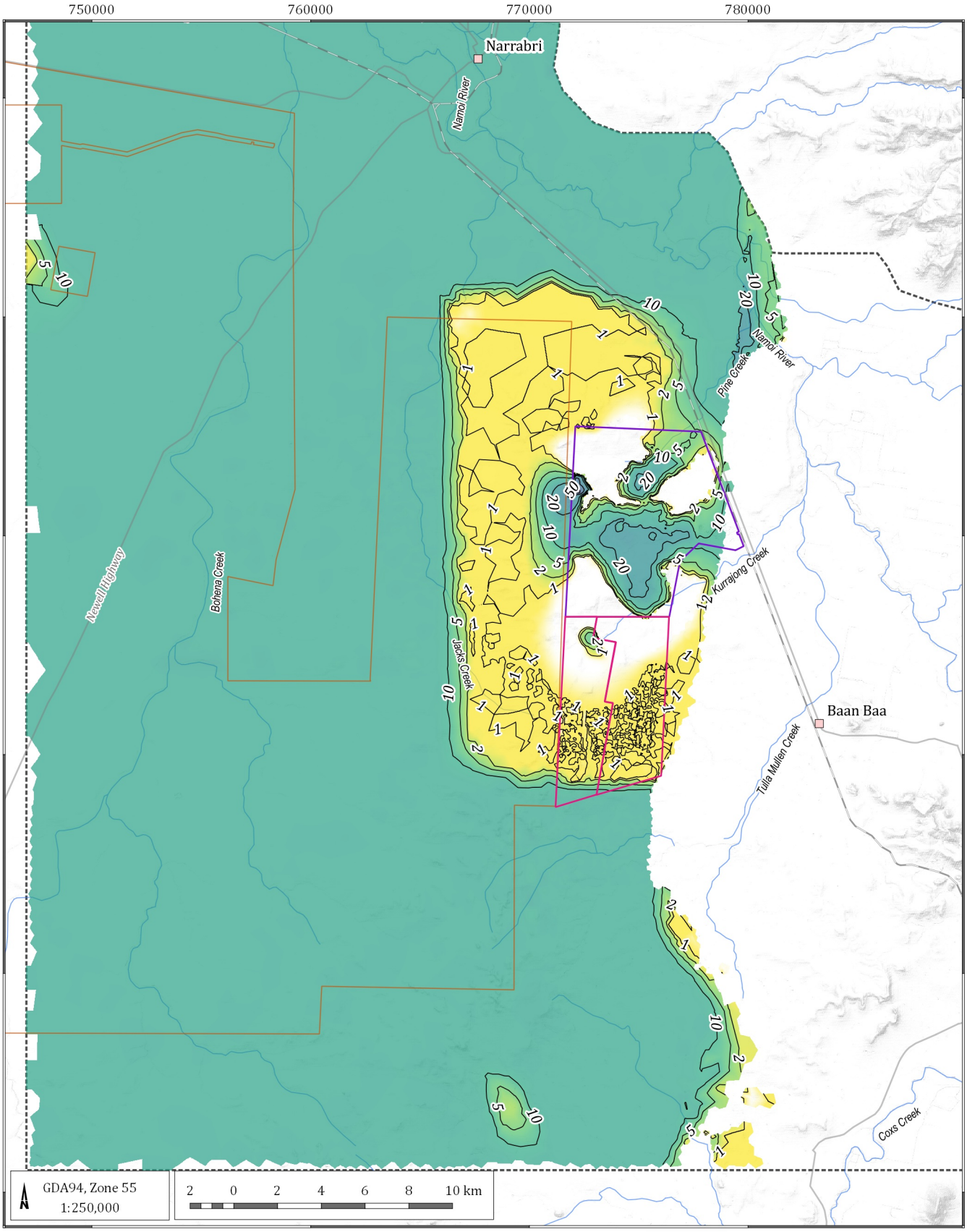


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Thickness contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Thickness (m)**

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Narrabri Stage 3 Extension GIA (G1972)

**Basalt sill**

DATE 12/08/2020

FIGURE No: **D 3.6**

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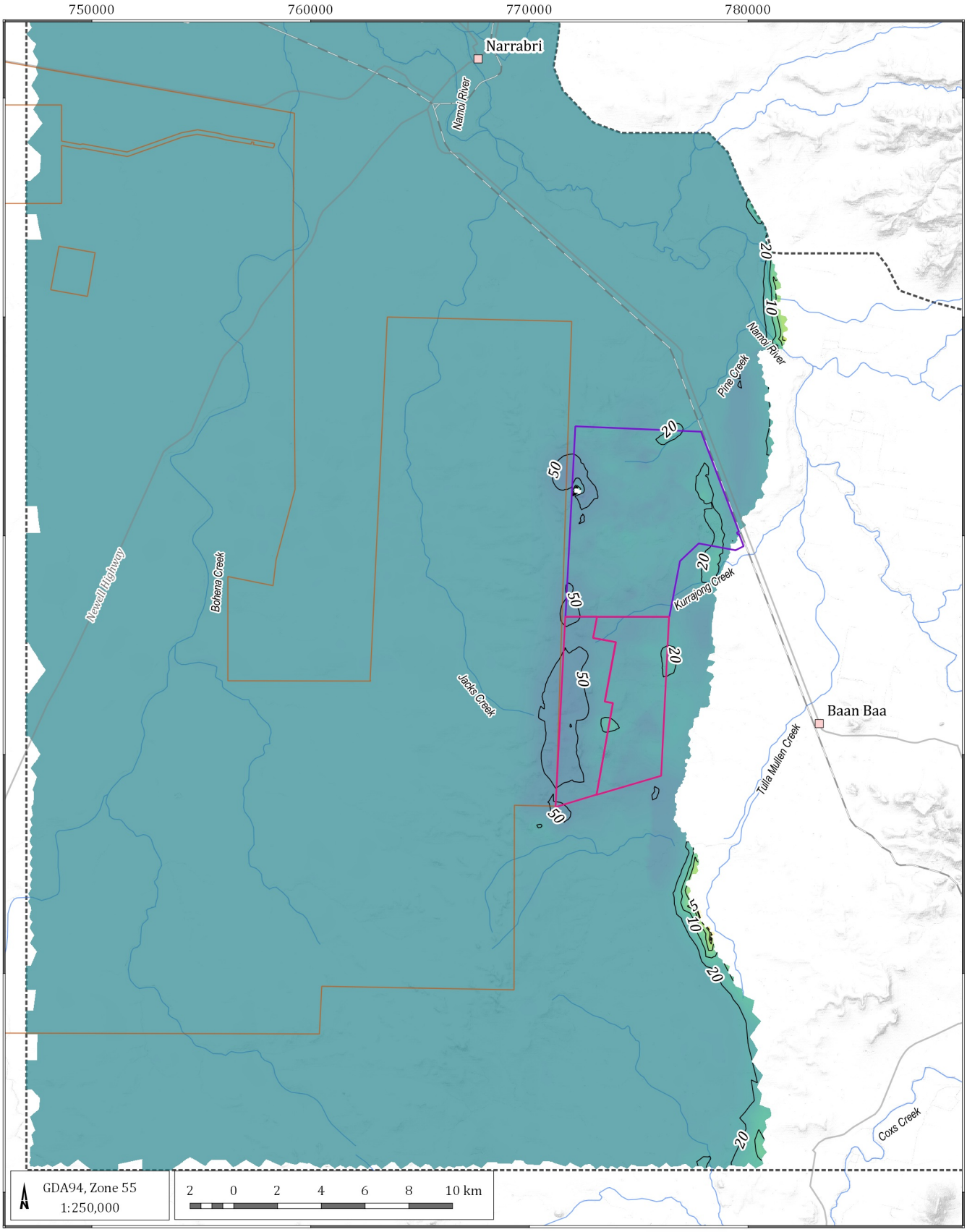
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 03.01 to D 03.11_G1972_Thickness.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Thickness contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Thickness (m)**

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Narrabri Stage 3 Extension GIA (G1972)

**Napperby Formation**

DATE 12/08/2020

FIGURE No: **D 3.7**

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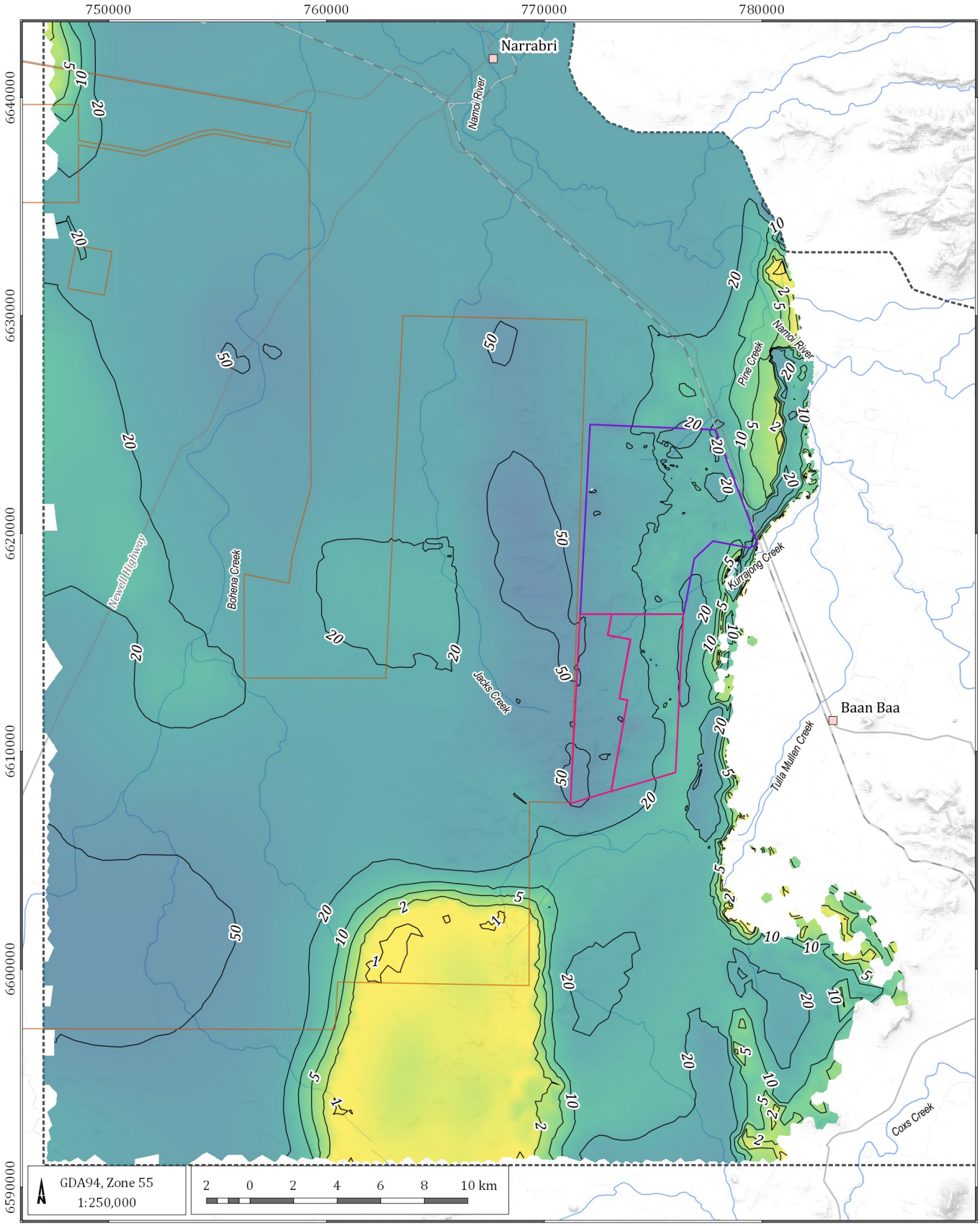


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Thickness contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Thickness (m)**

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Narrabri Stage 3 Extension GIA (G1972)

## Digby Conglomerate

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FIGURE No: **D 3.8**

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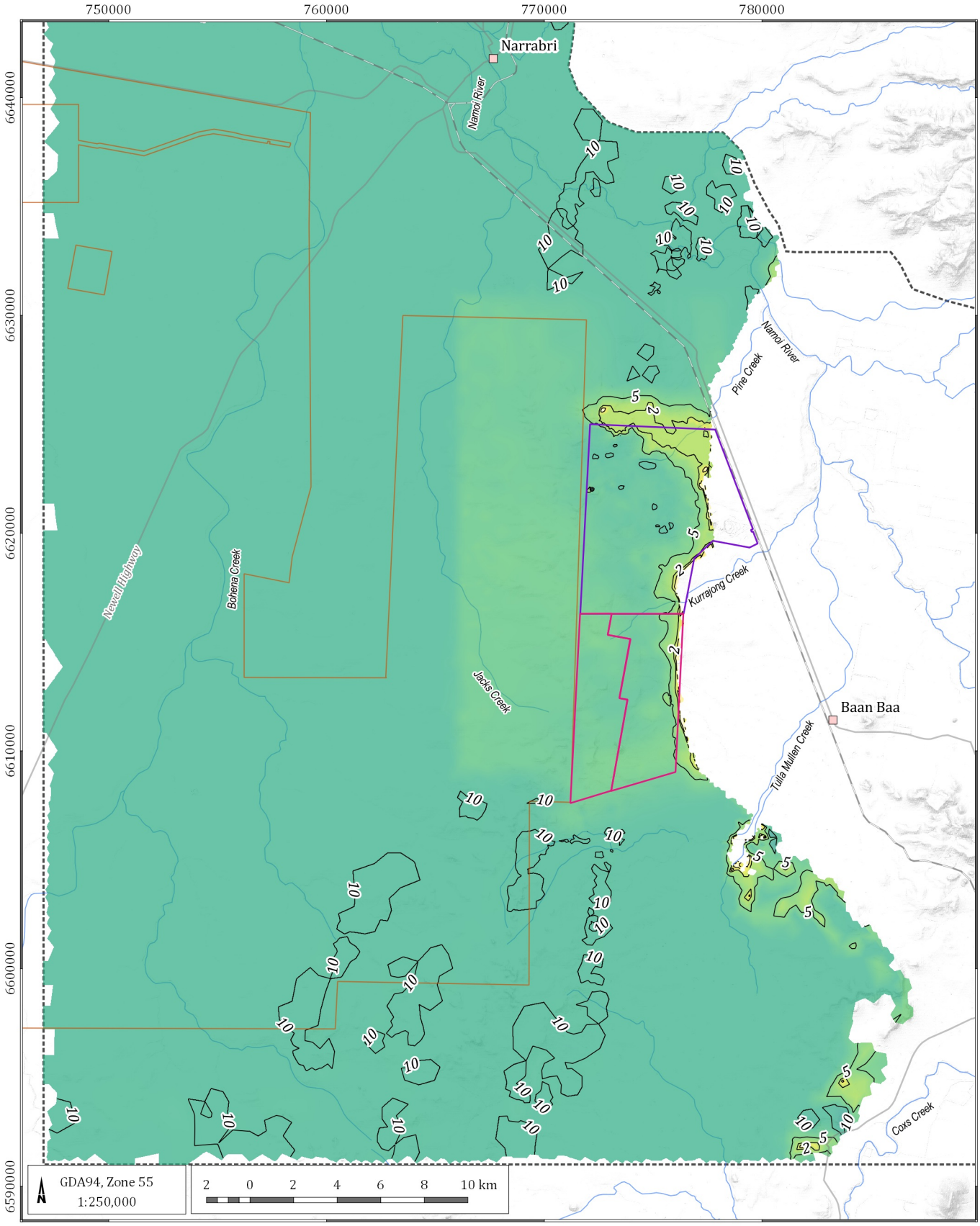
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 03.01 to D 03.11_G1972_Thickness.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Thickness contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Thickness (m)**

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Narrabri Stage 3 Extension GIA (G1972)

**Hoskissons Coal**

DATE 12/08/2020

FIGURE No: **D 3.9**

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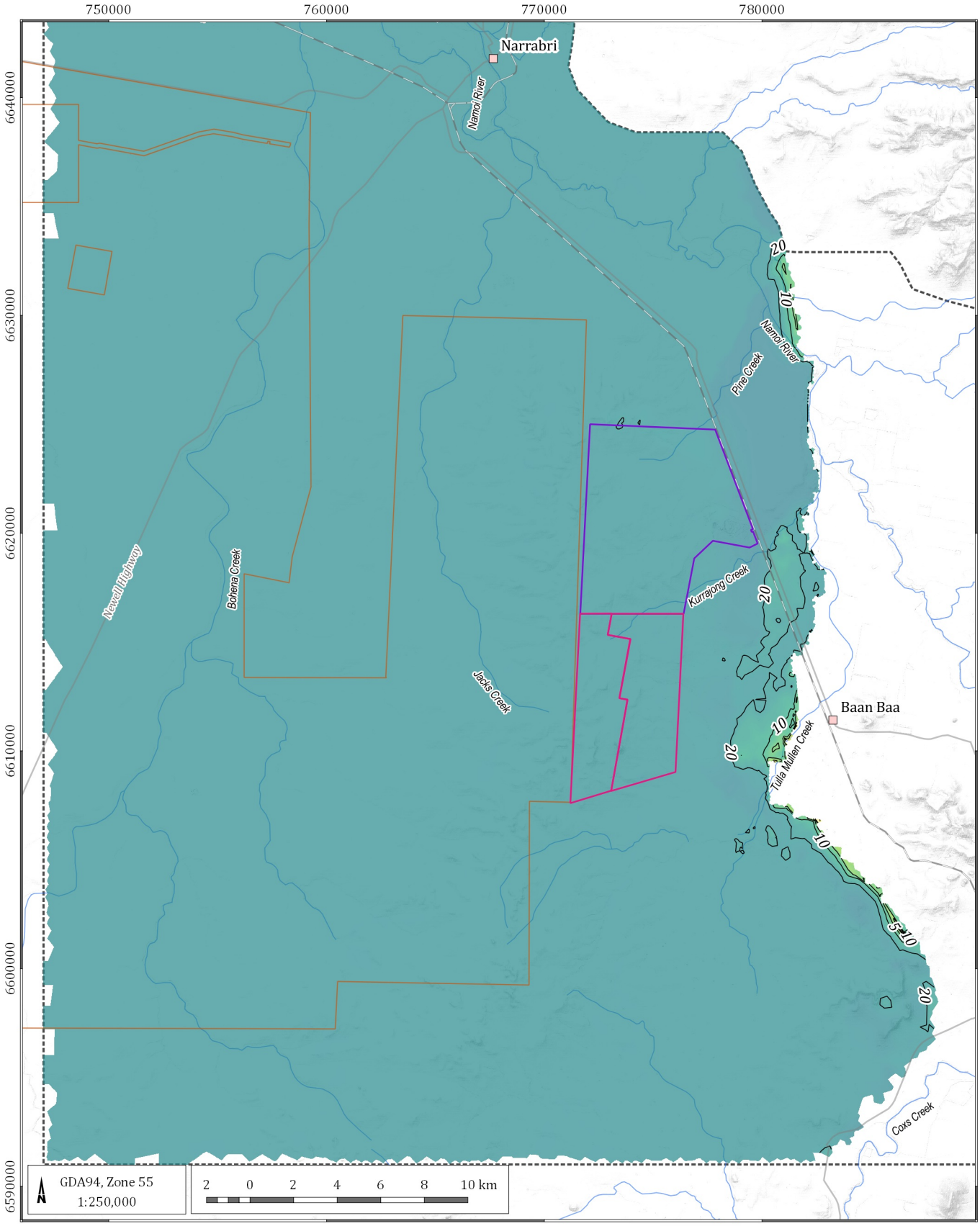
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 03.01 to D 03.11_G1972_Thickness.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Thickness contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Thickness (m)**

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Narrabri Stage 3 Extension GIA (G1972)

## Arkarula Formation

DATE 12/08/2020

FIGURE No: **D 3.10**

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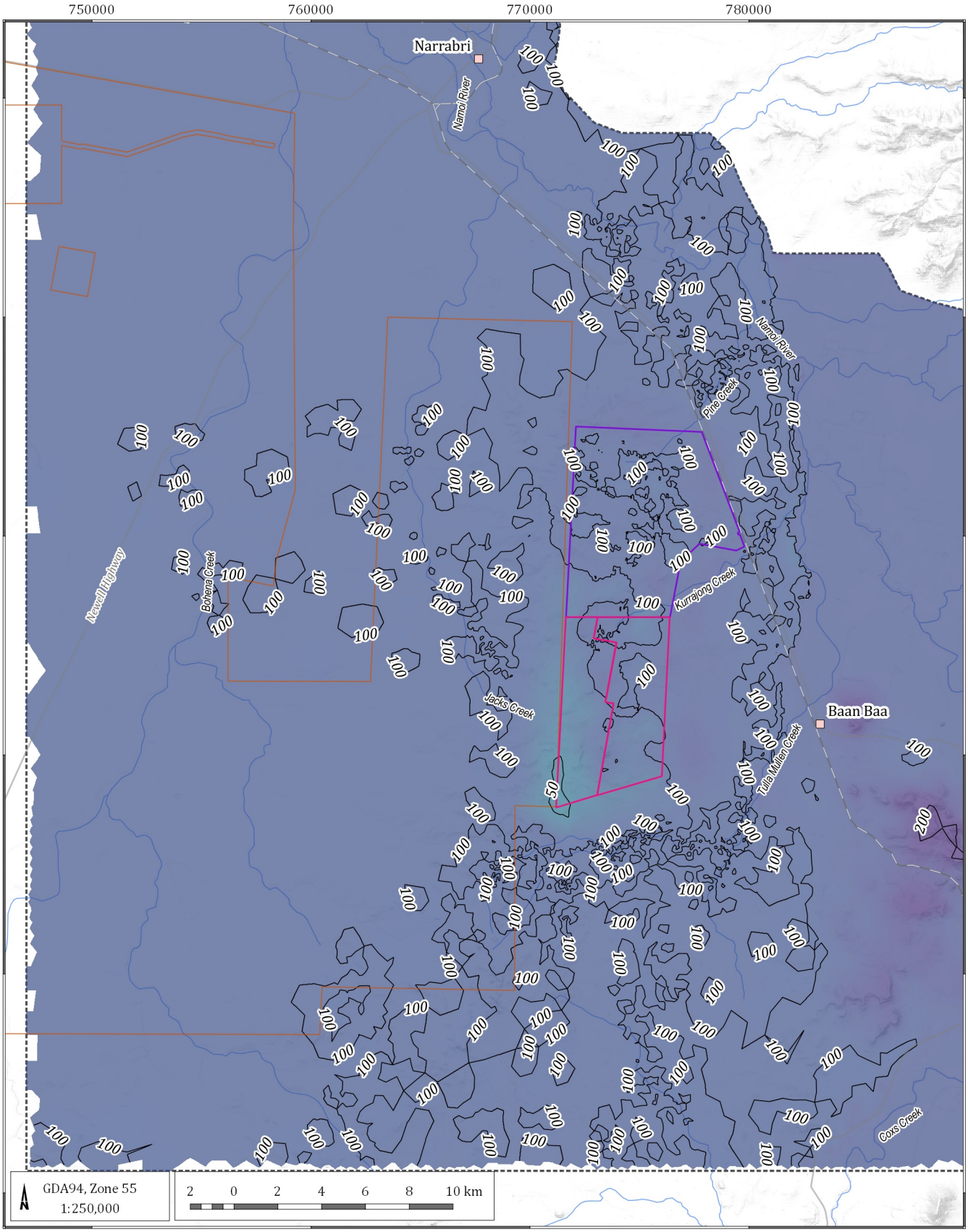
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 03.01 to D 03.11_G1972_Thickness.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Thicknes contour line (m)
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Thickness (m)**

- 0
- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200
- 500

Narrabri Stage 3 Extension GIA (G1972)

## Pamboola Formation

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FIGURE No: **D 3.11**

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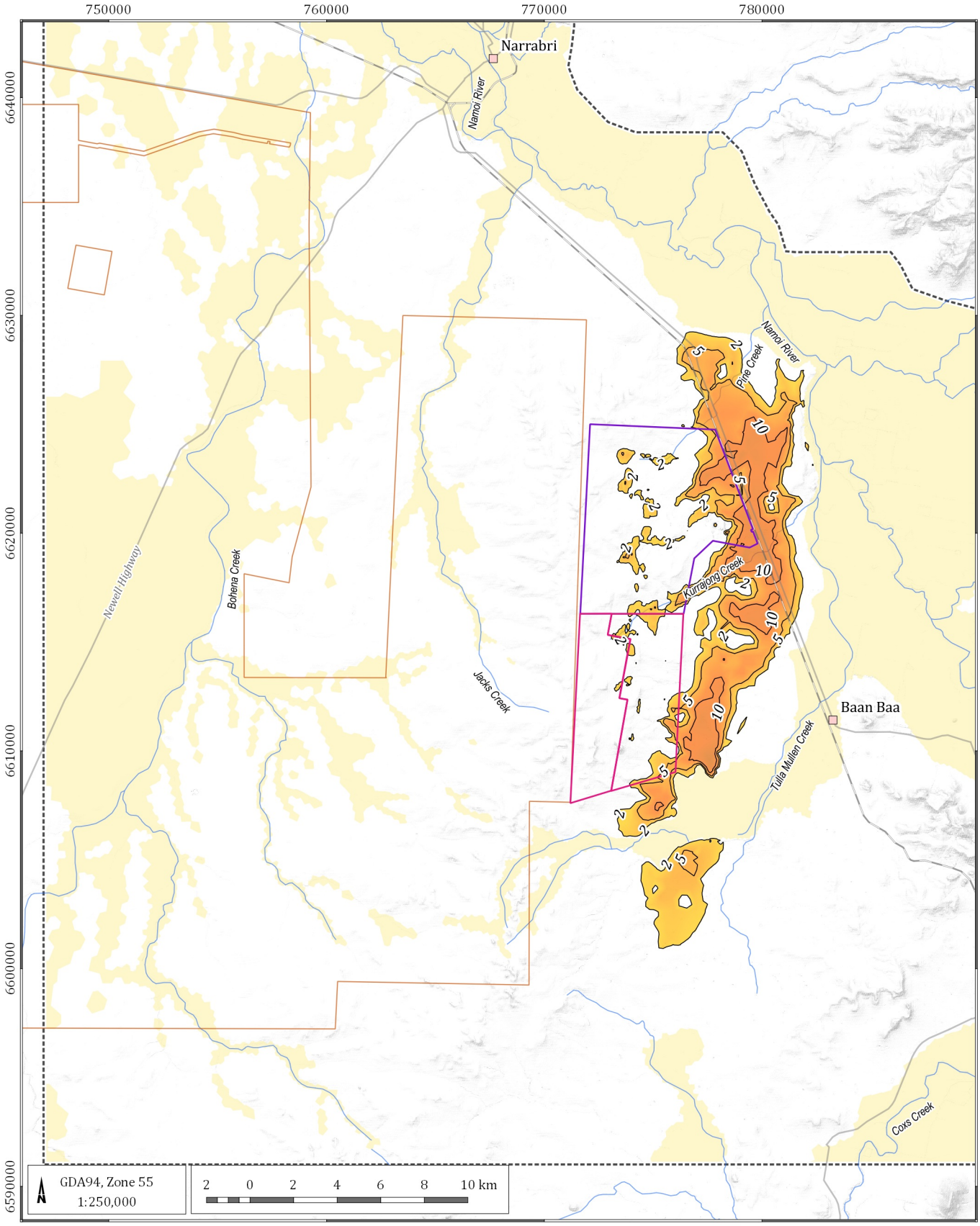
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 03.01 to D 03.11_G1972_Thickness.qgs

# *Appendix D 4* Predicted maximum drawdown contours




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown(m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum drawdown Project only - Alluvium/regolith (model layer 1)**

DATE 24/06/2020

FIGURE No: **D 4.1**

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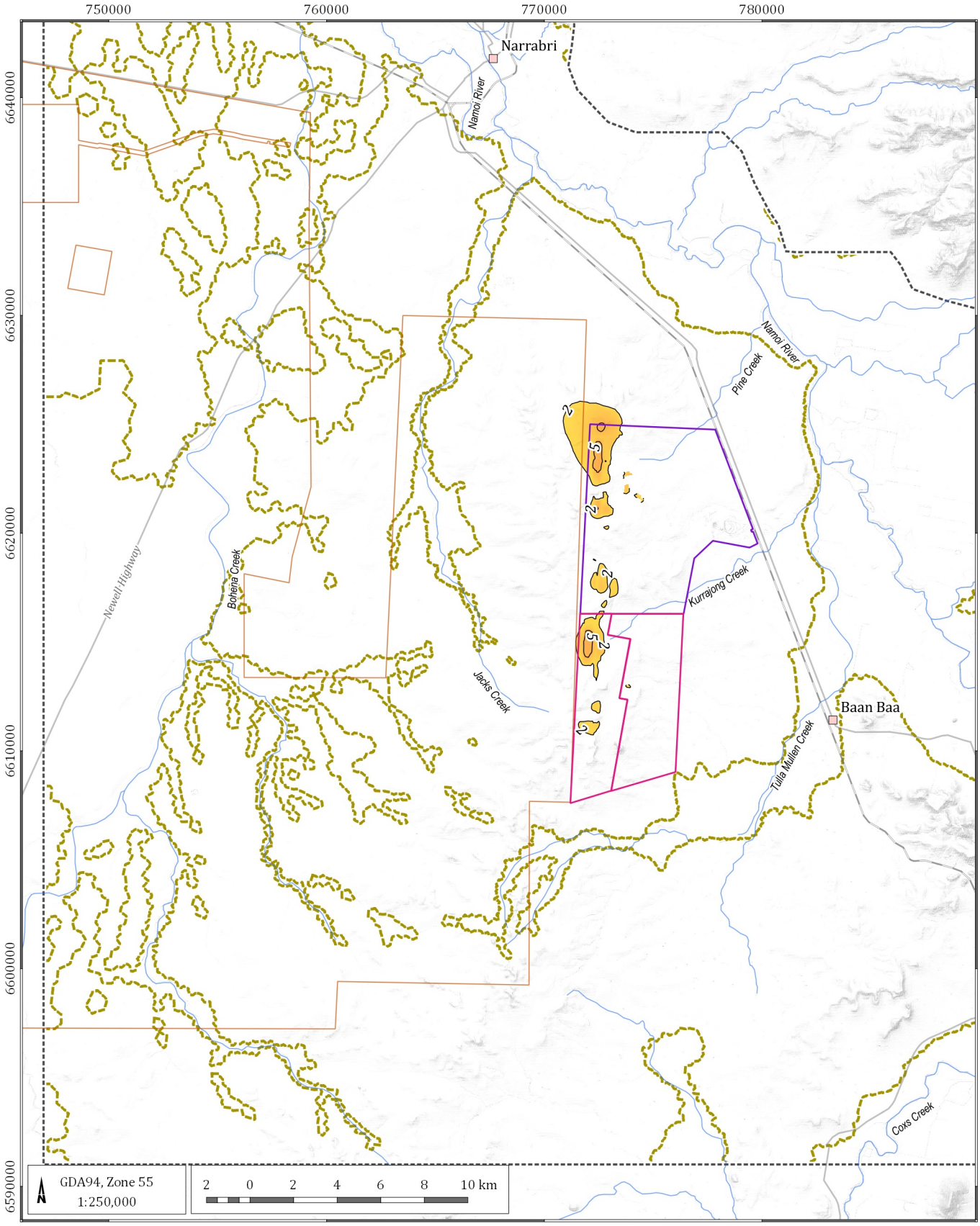
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 04.01 to D 04.11_G1972_Predicted maximum drawdown Project only.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown(m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum drawdown Project only - Pilliga Sandstone (model layer 2)**

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FIGURE No: **D 4.2**

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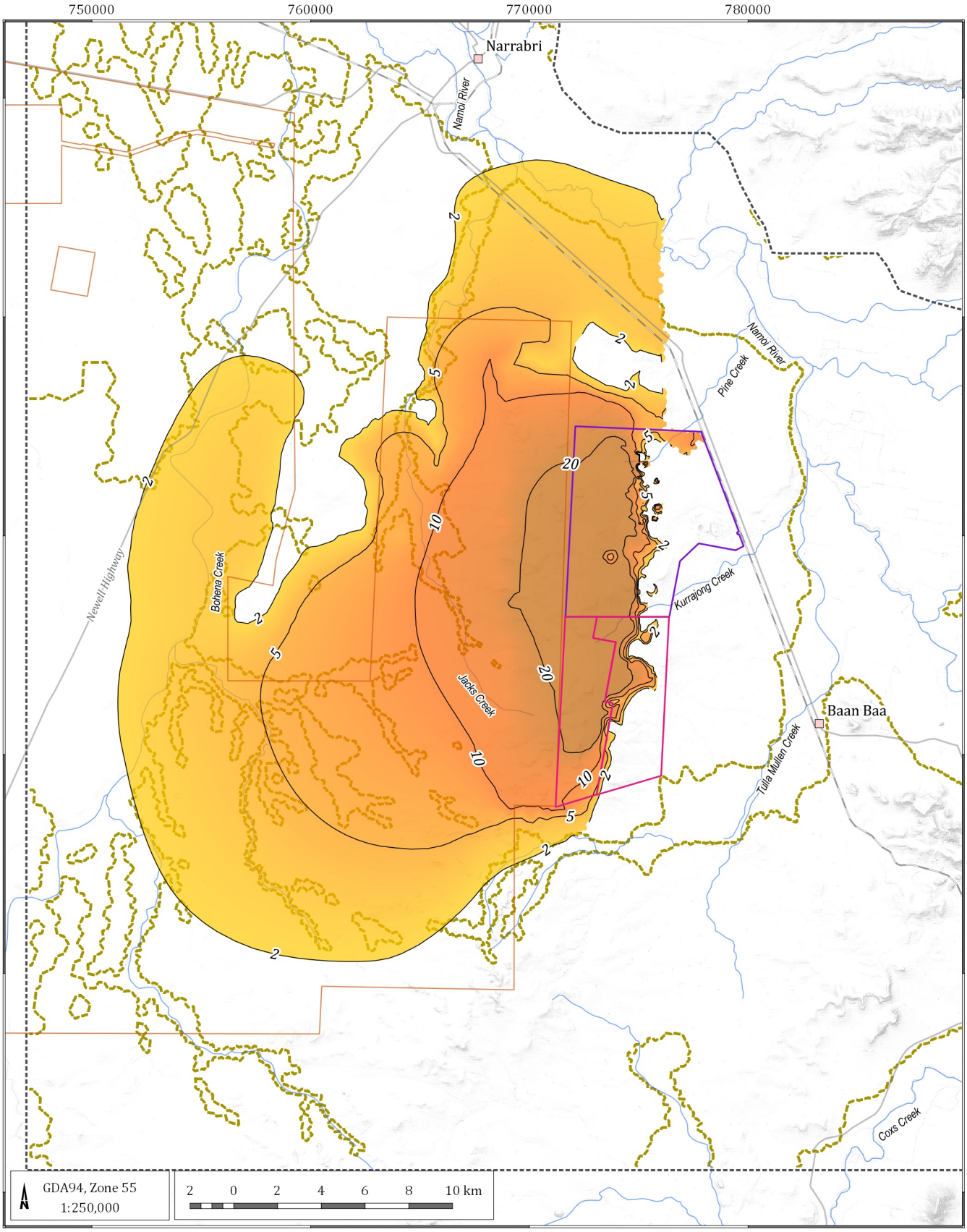
G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 04.01 to D 04.11_G1972_Predicted maximum drawdown Project only.qgs




LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown(m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

## Predicted maximum drawdown Project only - Purlawaugh Formation (model layer 3)

DATE 24/06/2020

FIGURE No: **D 4.3**

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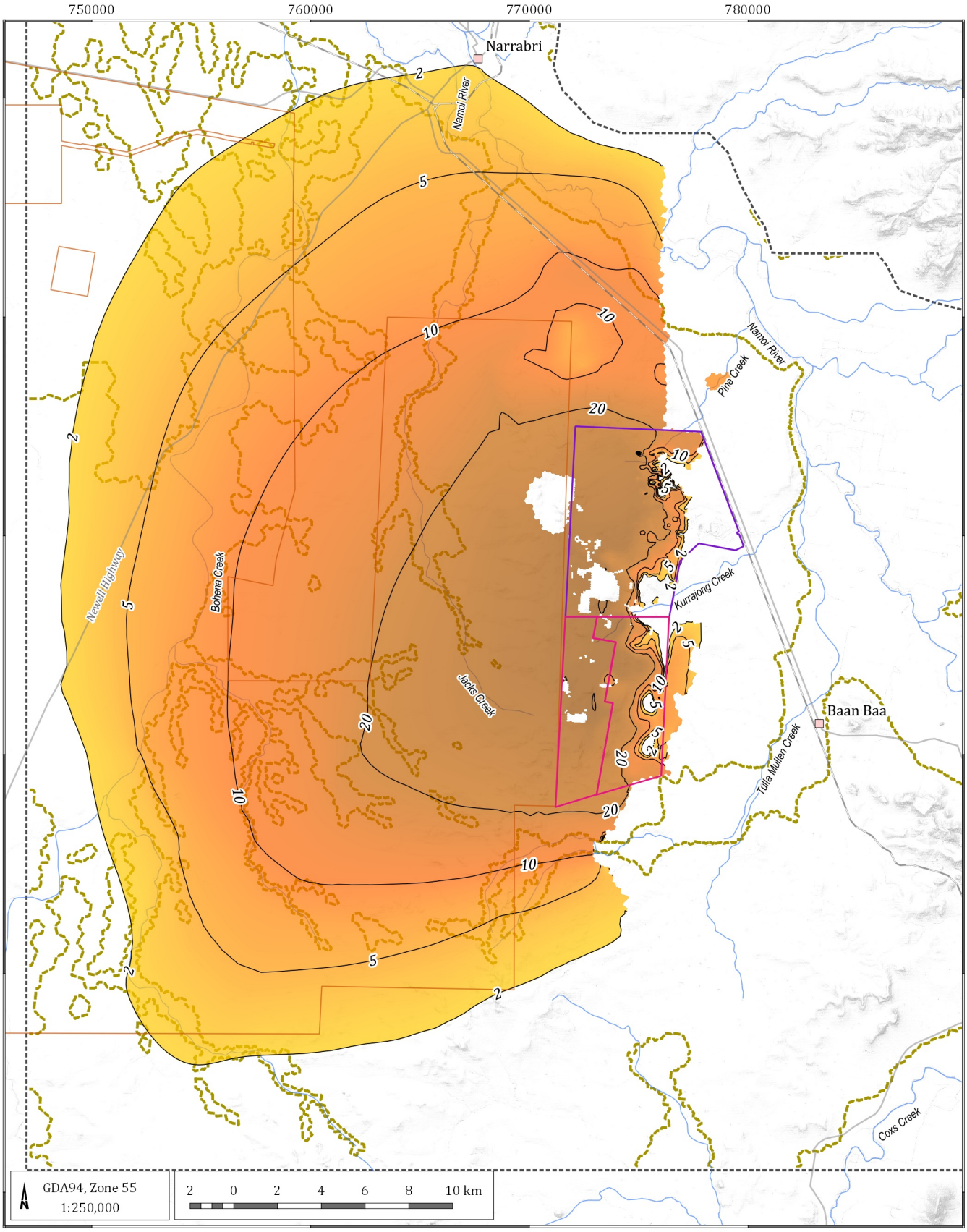


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown(m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum drawdown Project only - Garrawilla Volcanics (model layer 4)**

DATE 24/06/2020

FIGURE No: **D 4.4**

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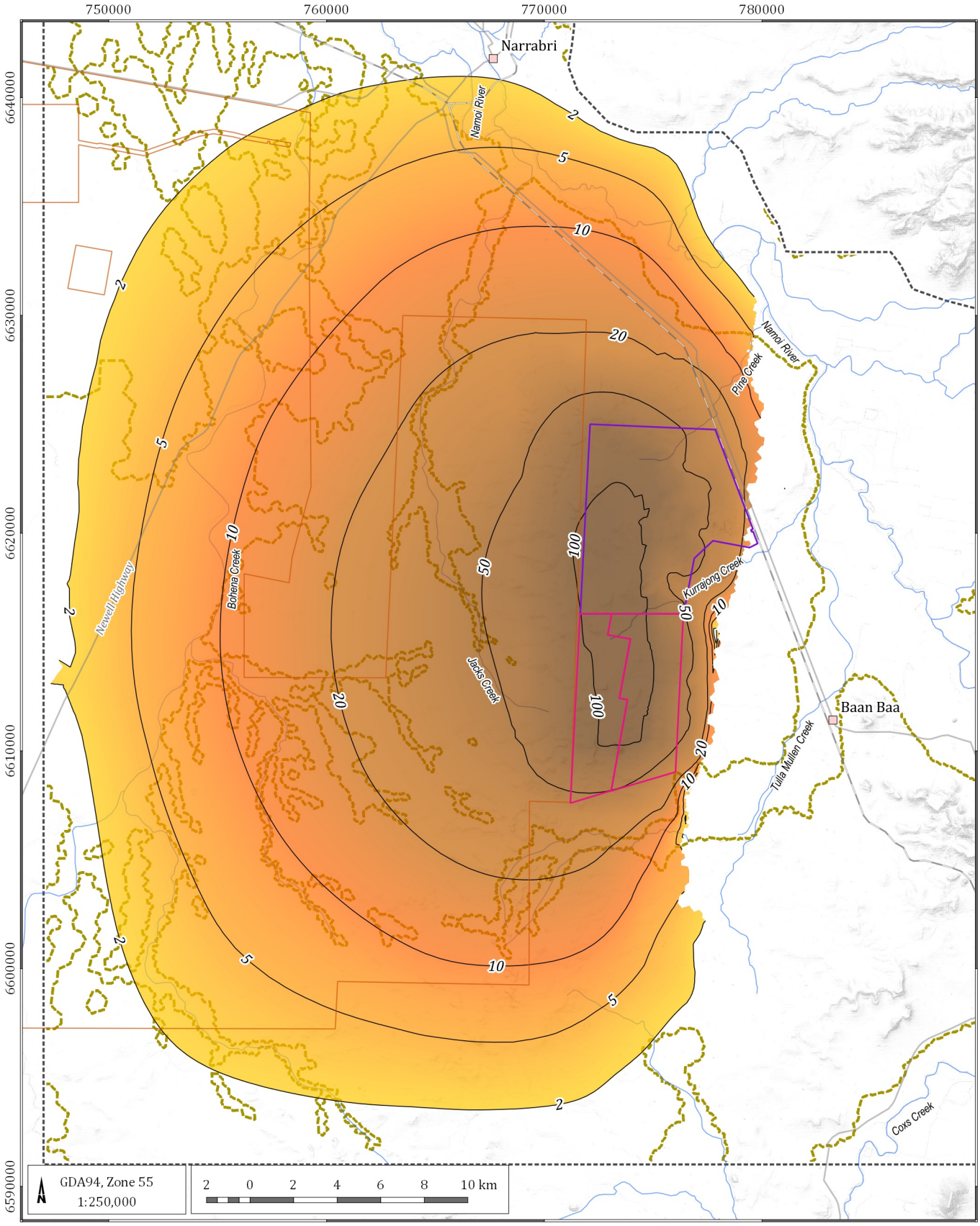


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown(m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum drawdown Project only - Napperby Formation (above sill, model layer 5)**

DATE 24/06/2020

FIGURE No: **D 4.5**

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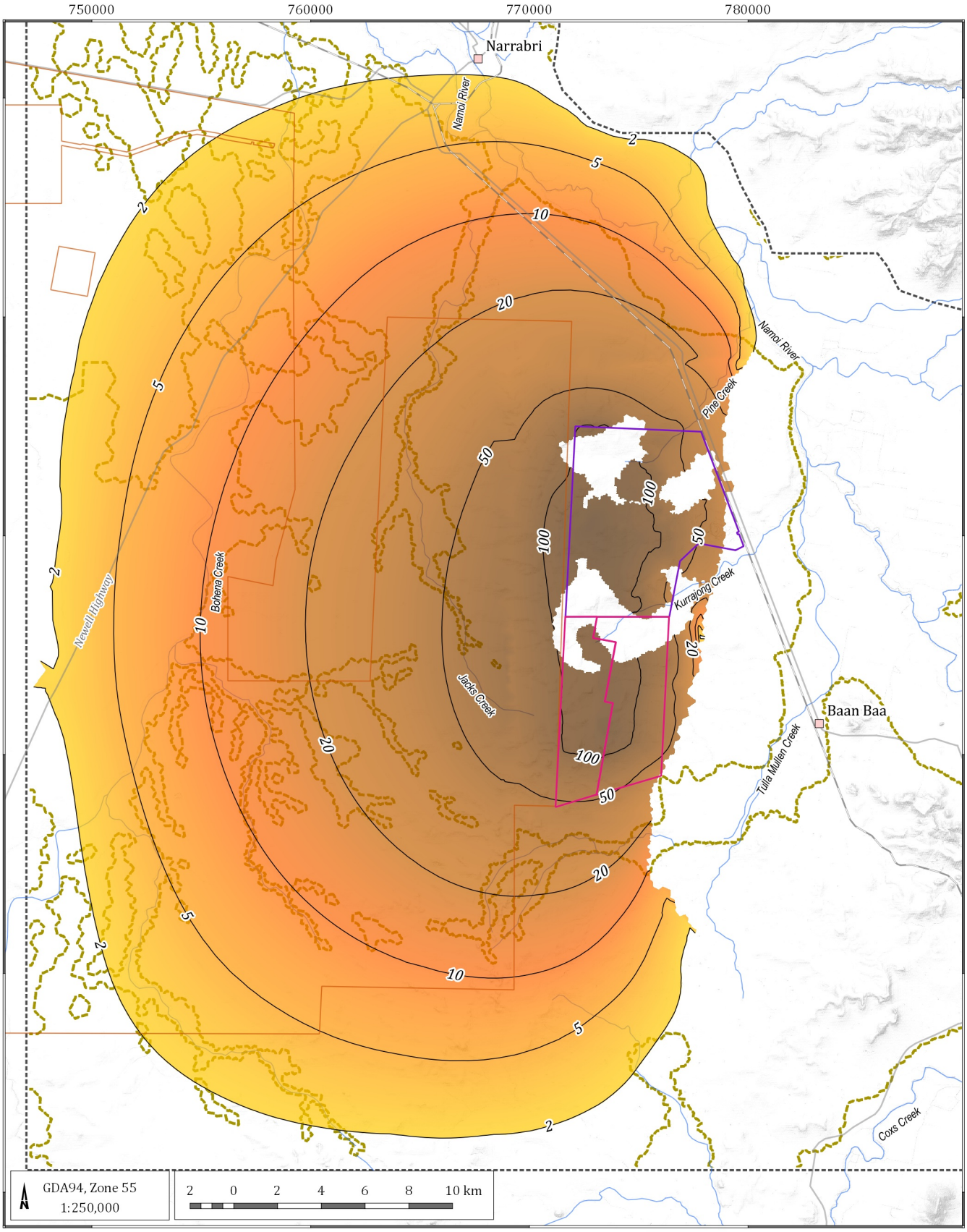


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown(m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Basalt sill**

DATE 24/06/2020

FIGURE No: D 4.6

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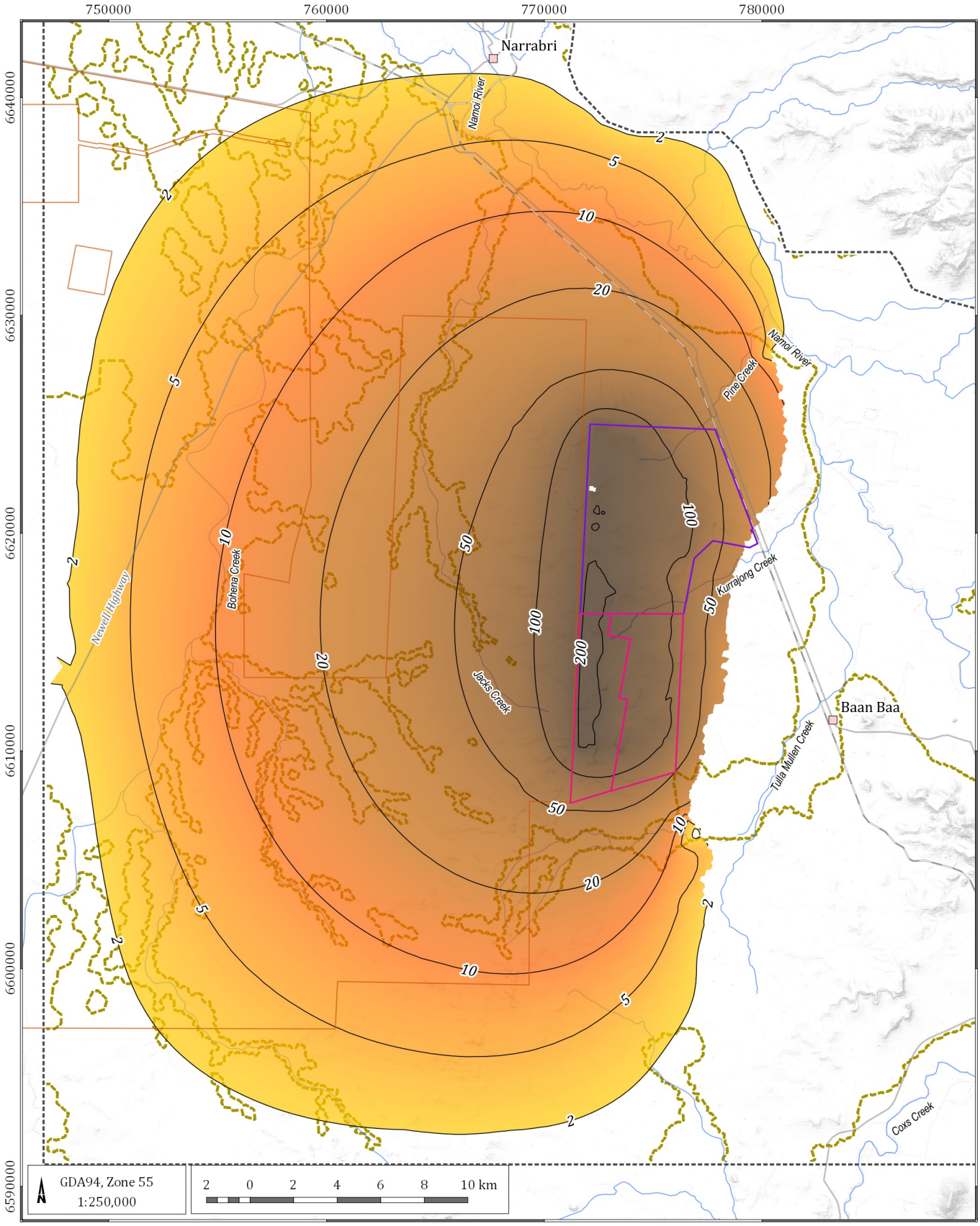


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown(m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum drawdown Project only - Napperby Formation (below sill, model layer 7)**

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FIGURE No: **D 4.7**

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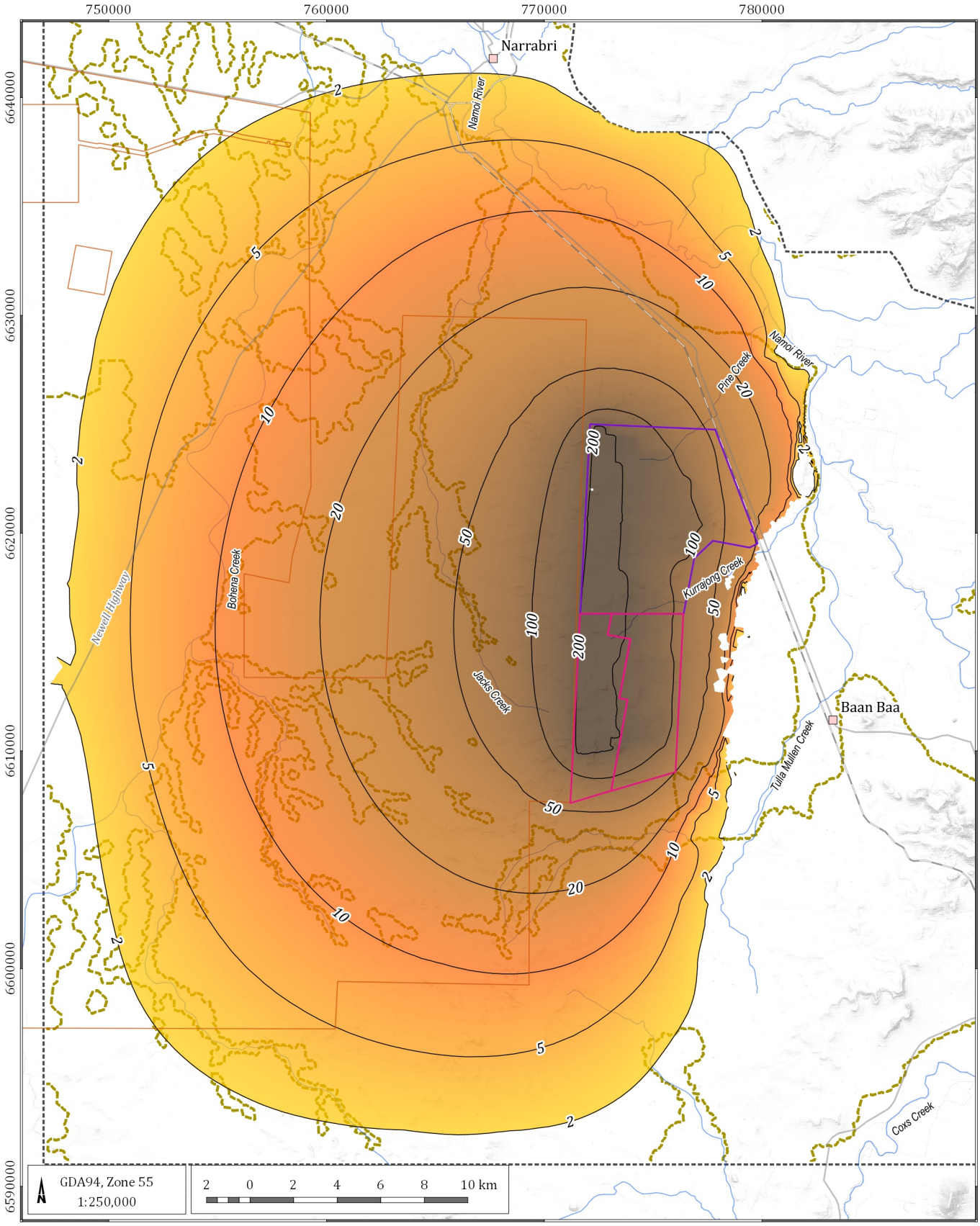


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown(m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

## Predicted maximum drawdown Project only - Digby Conglomerate (model layer 8)

DATE 24/06/2020

FIGURE No: **D 4.8**

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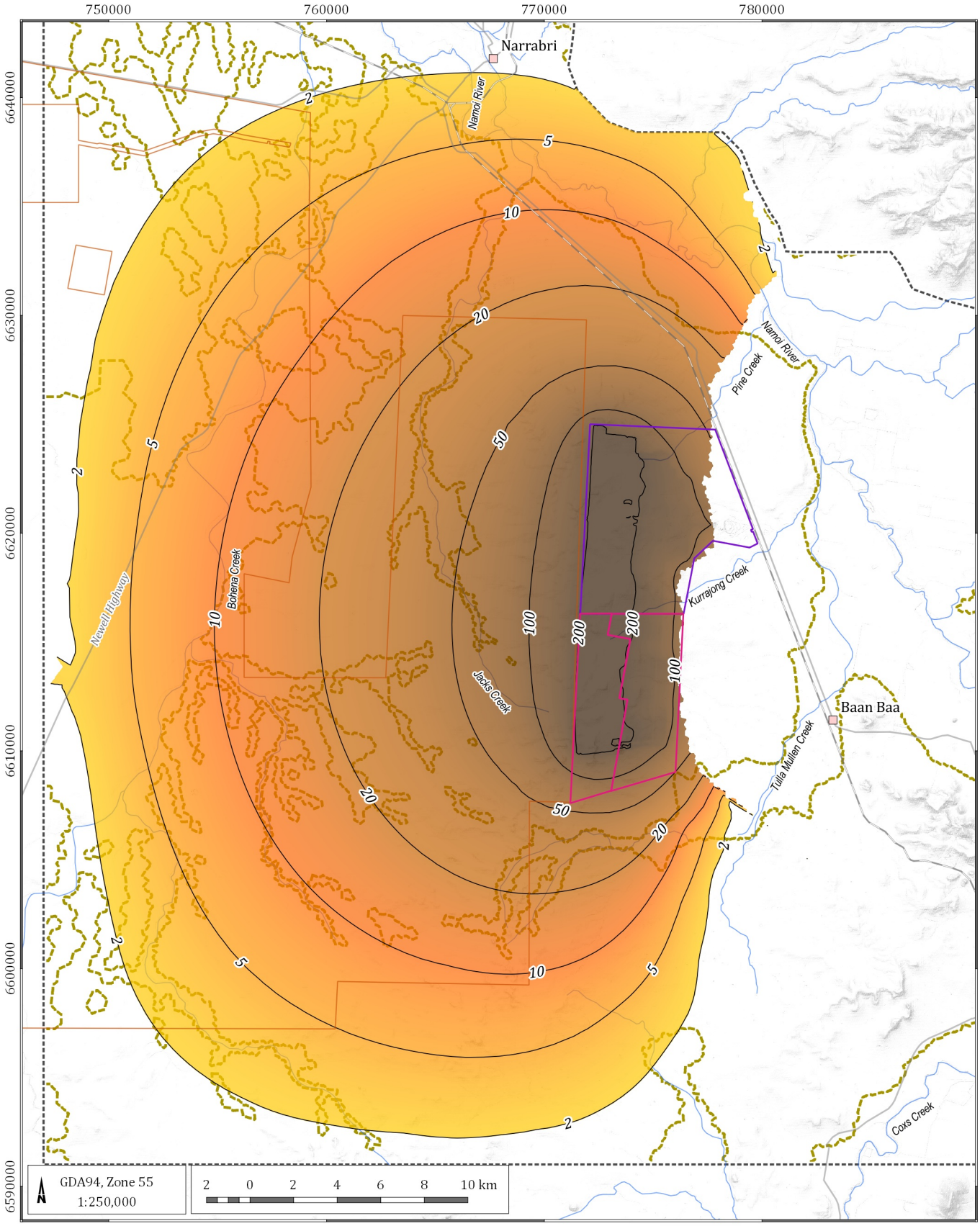


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown(m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum drawdown Project only - Hoskissons Coal Seam (model layer 9)**

DATE 24/06/2020

FIGURE No: **D 4.9**

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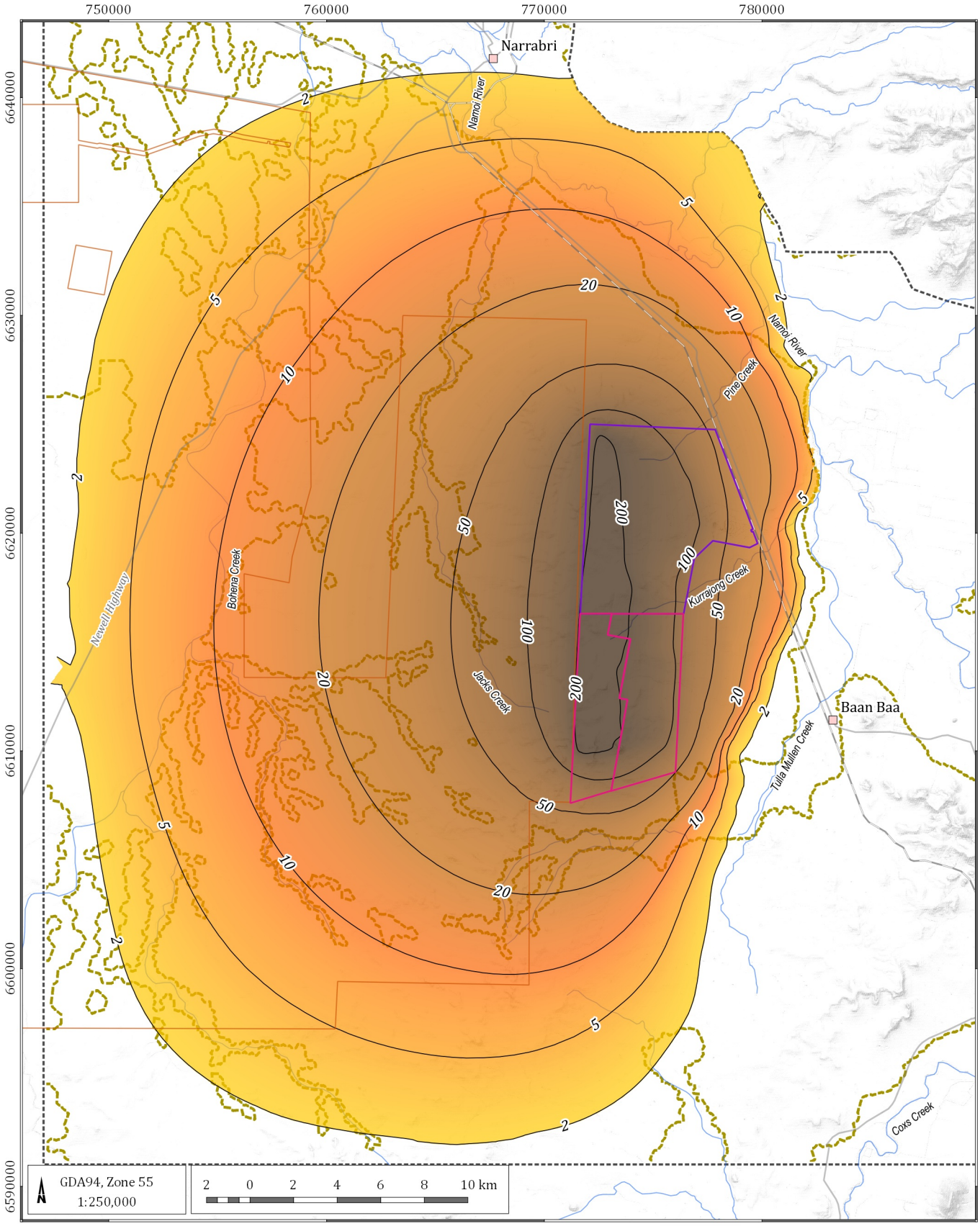


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown(m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum drawdown Project only - Arkarula Formation (model layer 10)**

DATE 24/06/2020

FIGURE No: **D 4.10**

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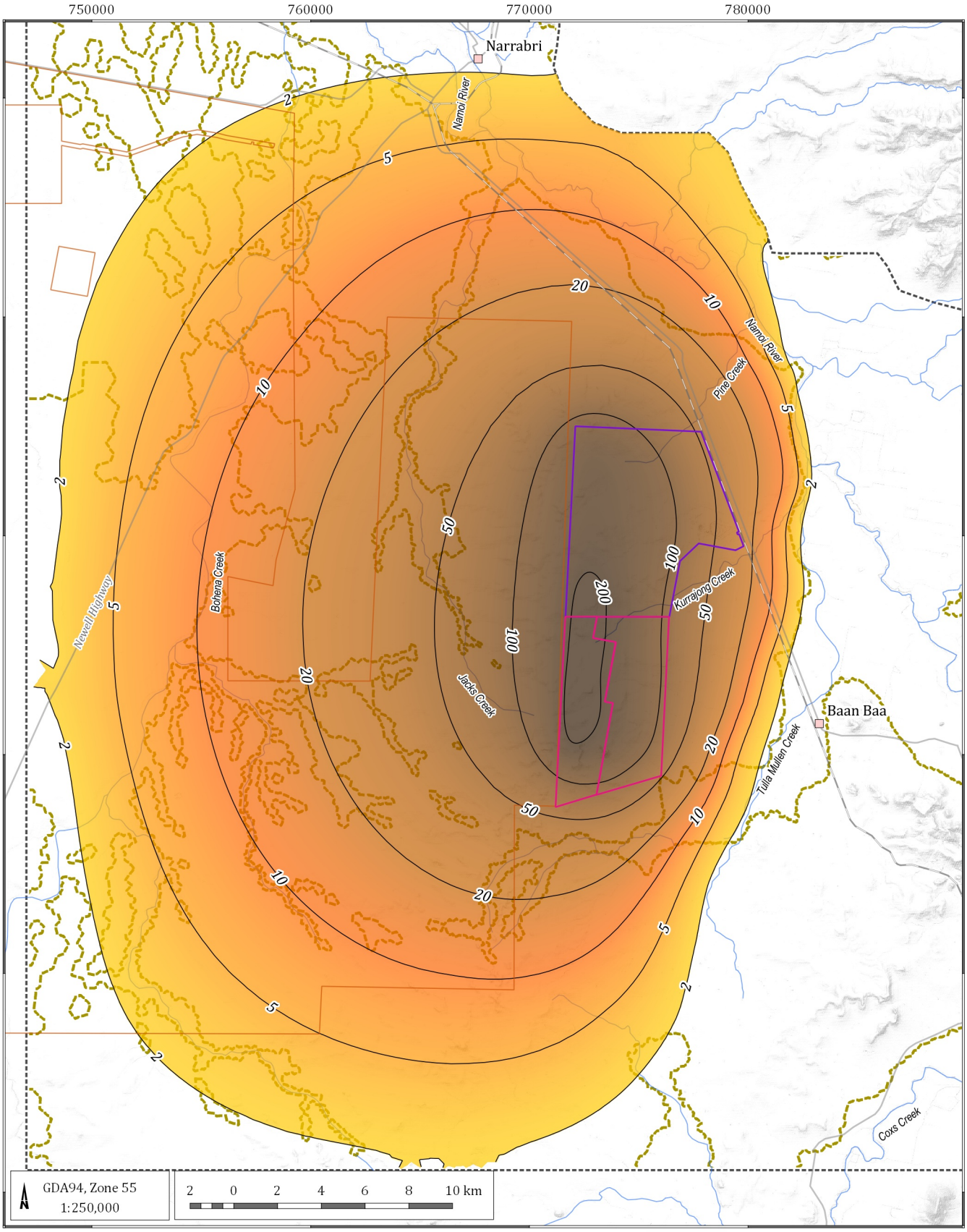


LEGEND

- Populated place
- Road
- Rail
- Drainage
- Drawdown contour line (m)
- Quaternary alluvium
- Mining Lease Boundary (ML1609)
- Provisional Mining Lease Application Area
- Proposed Narrabri Gas Project (Santos)
- Model boundary

**Drawdown(m)**

- 2
- 5
- 10
- 20
- 50
- 100
- 200

Narrabri Stage 3 Extension GIA (G1972)

**Predicted maximum drawdown Project only - Pamboola Formation and older Permian units (model layer 11)**

DATE 24/06/2020

FIGURE No: **D 4.11**

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G:\Projects\G1972.Narrabri Stage 3 Extension GIA\3_GIS\Workspaces\001_Deliverable1\D 04.01 to D 04.11_G1972_Predicted maximum drawdown Project only.qgs

# Appendix E Lithological modelling Namoi Alluvium

# Narrabri SGEMs Cross sections

22 October 2019

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE)
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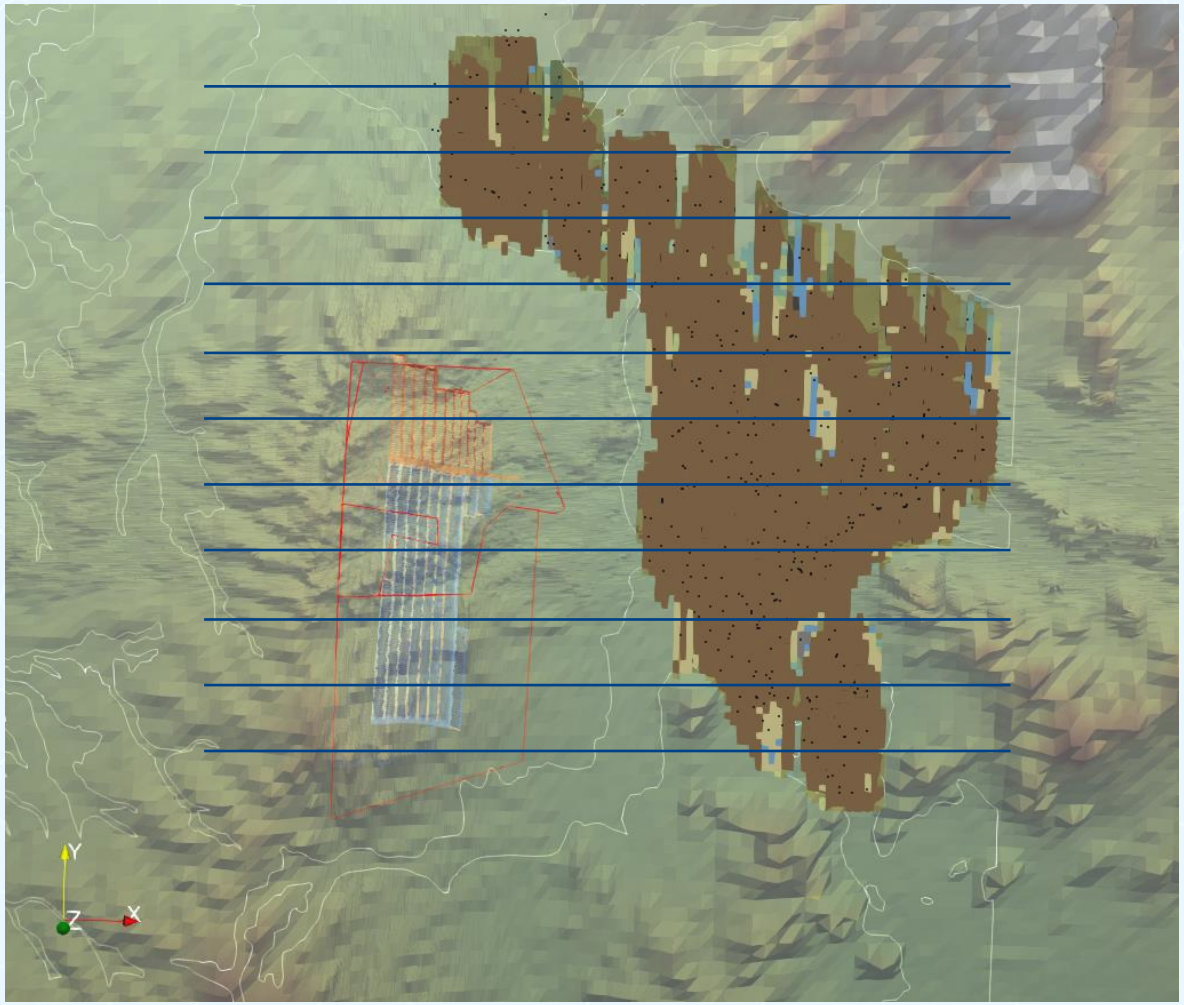
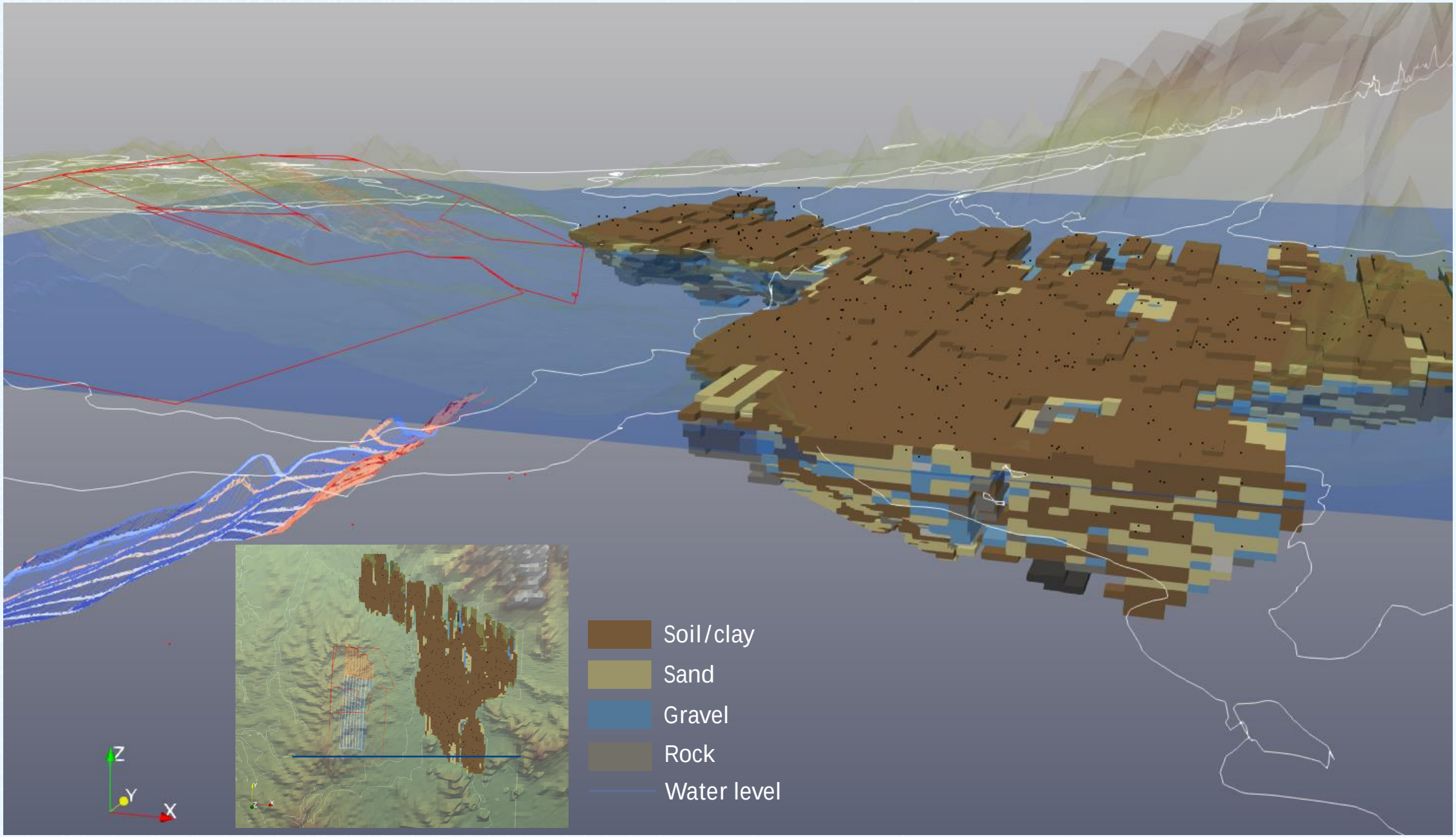
# Overview

- SGEMs geostatistical realization created from PINEENA lithological data (black dots)

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Rock
Water level
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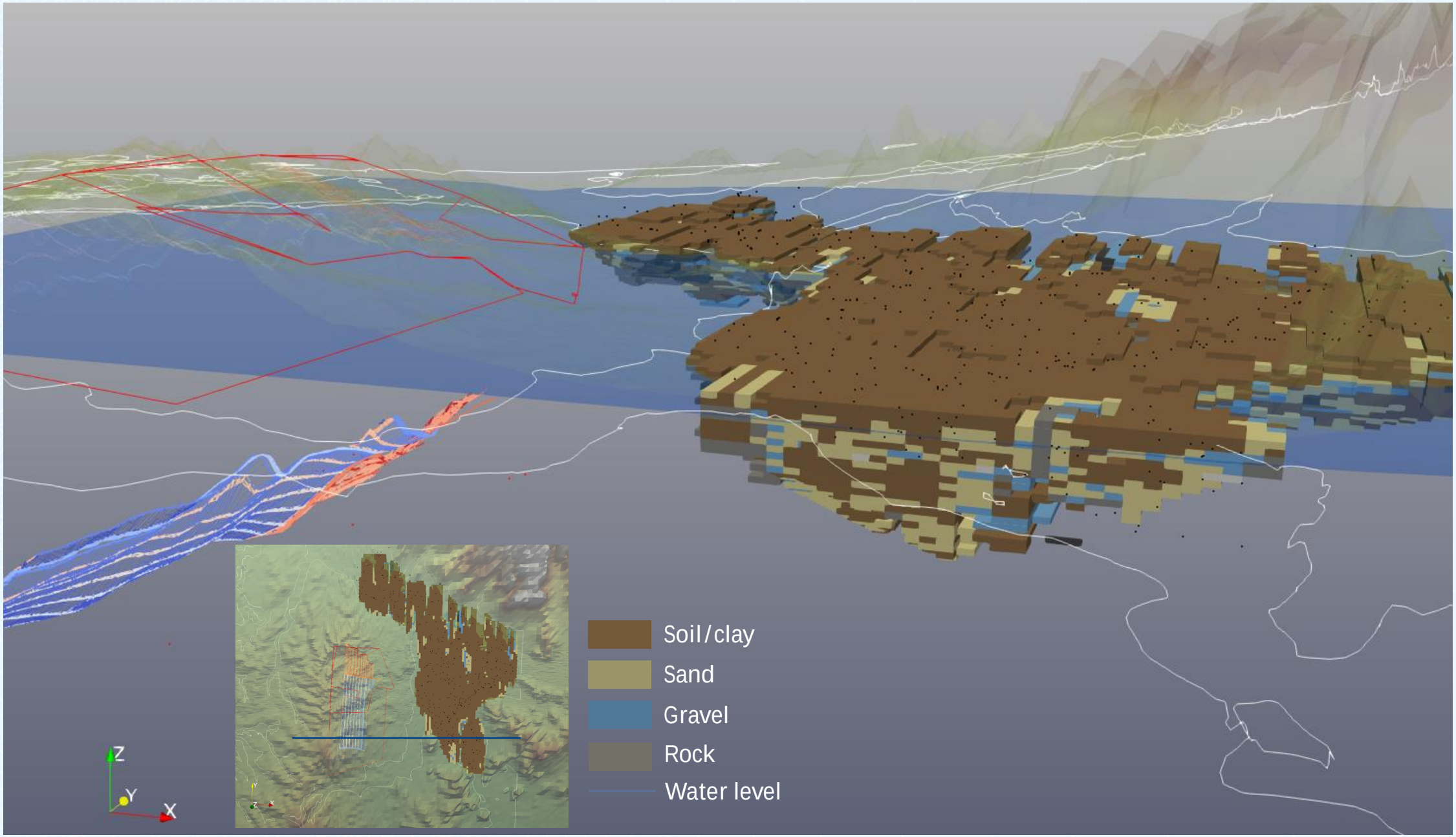
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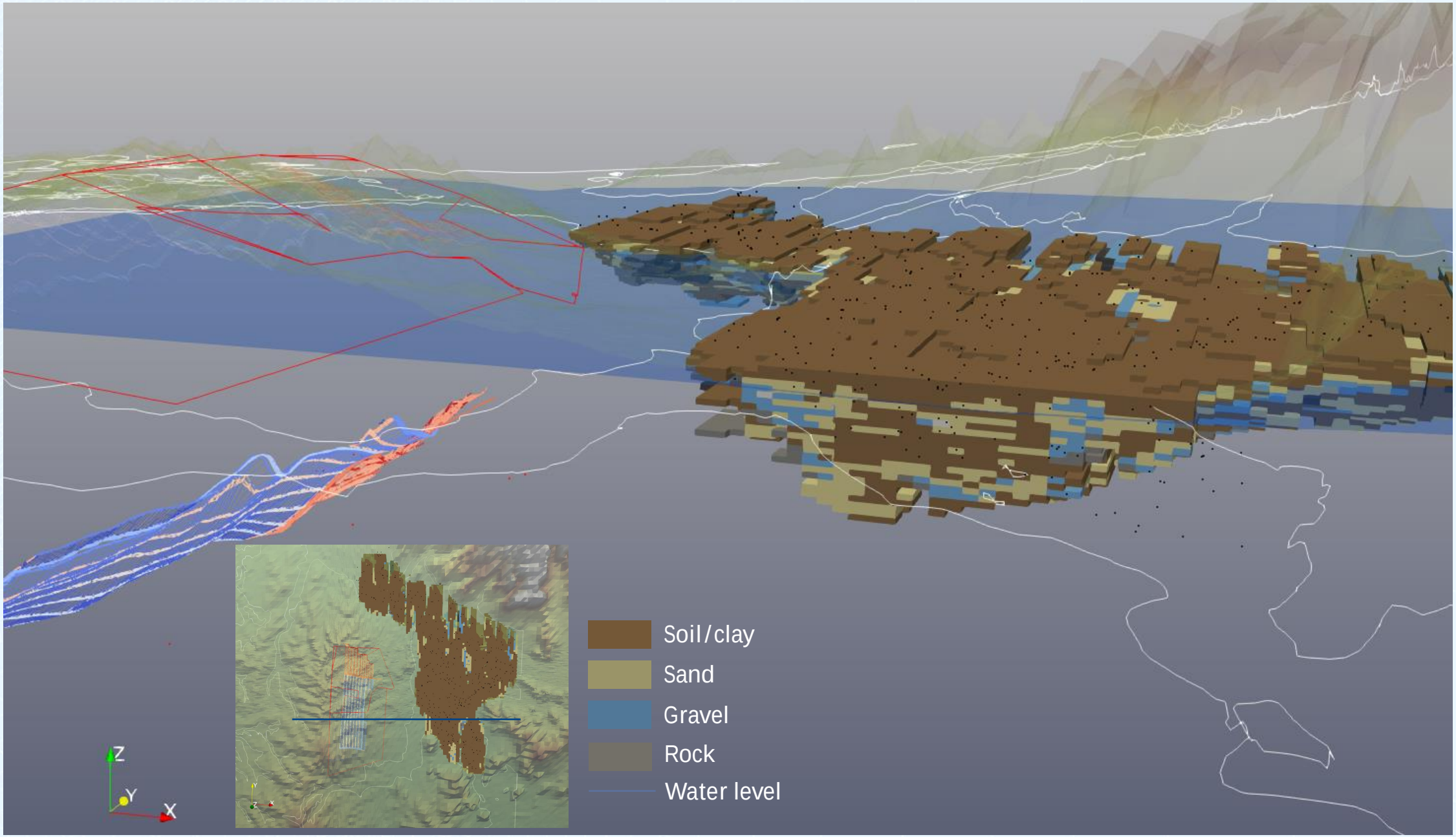
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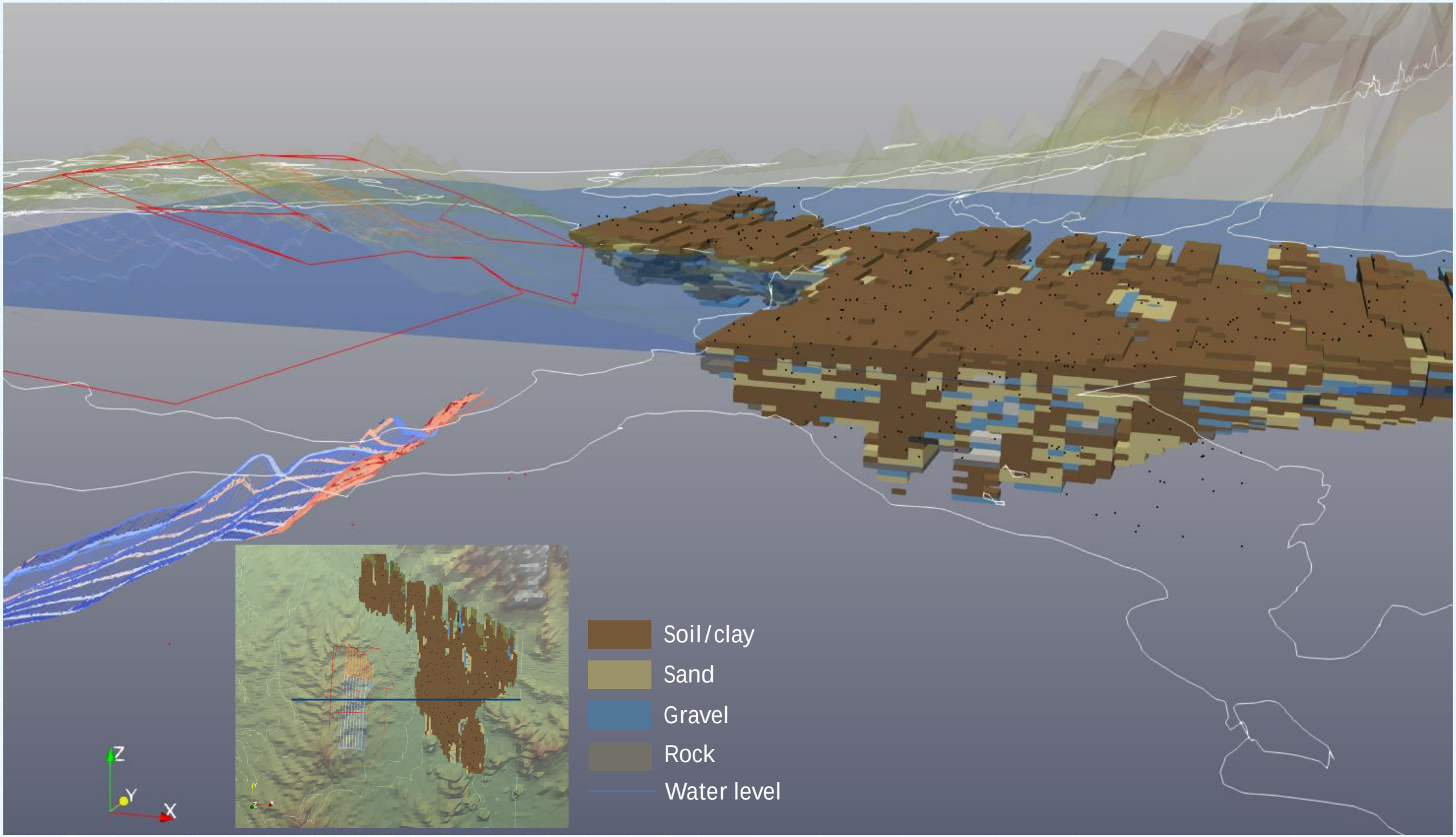
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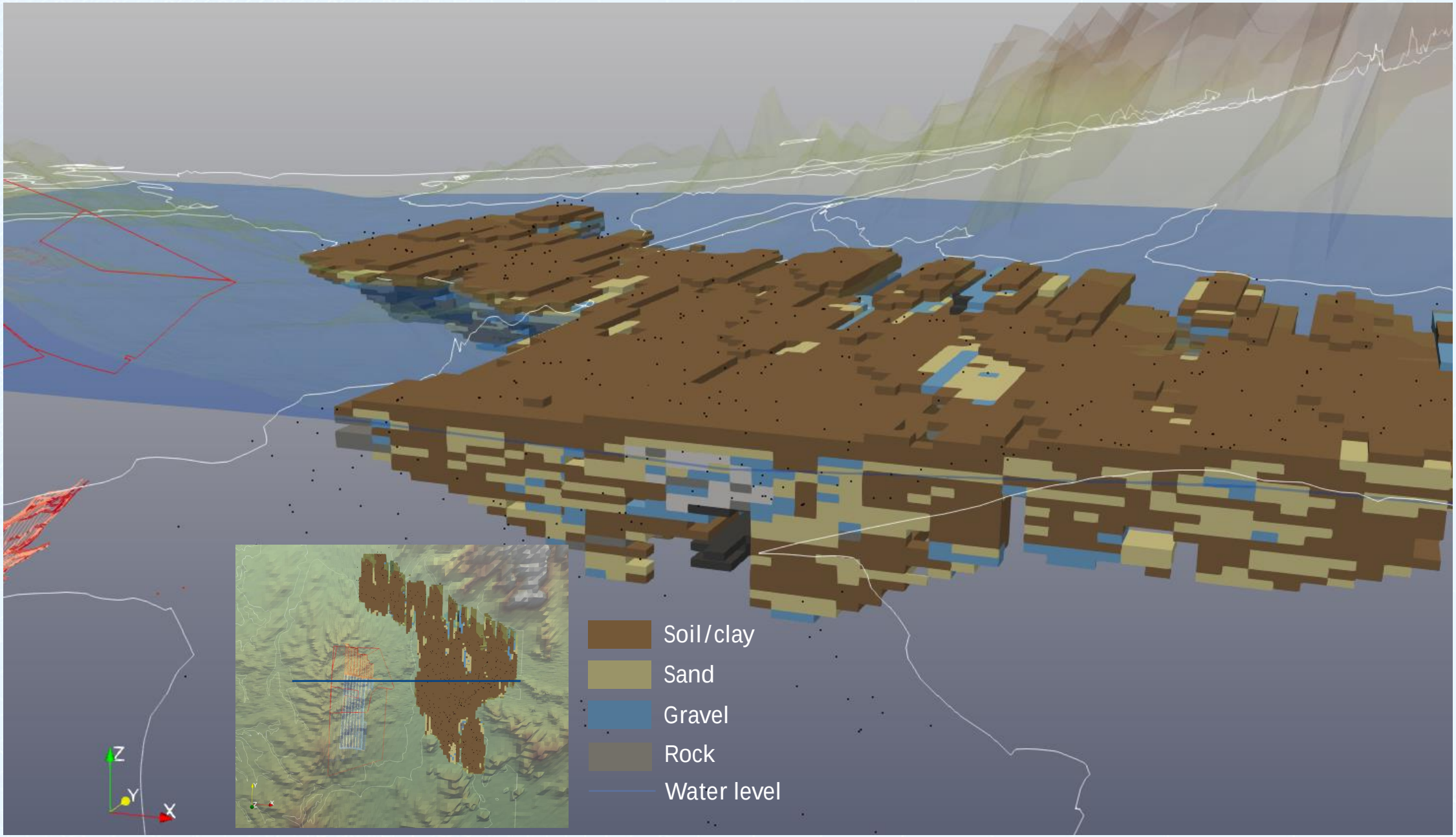
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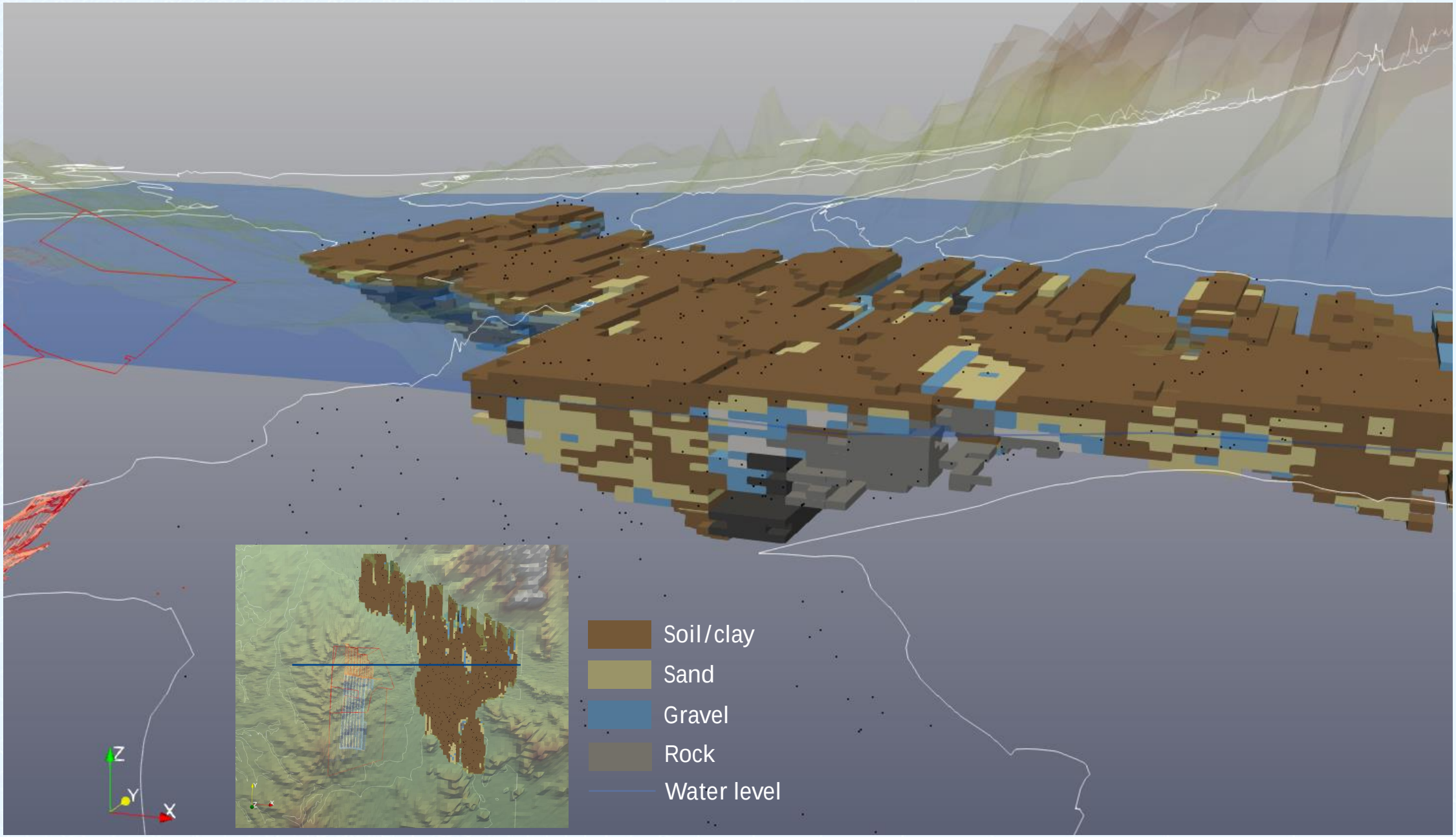
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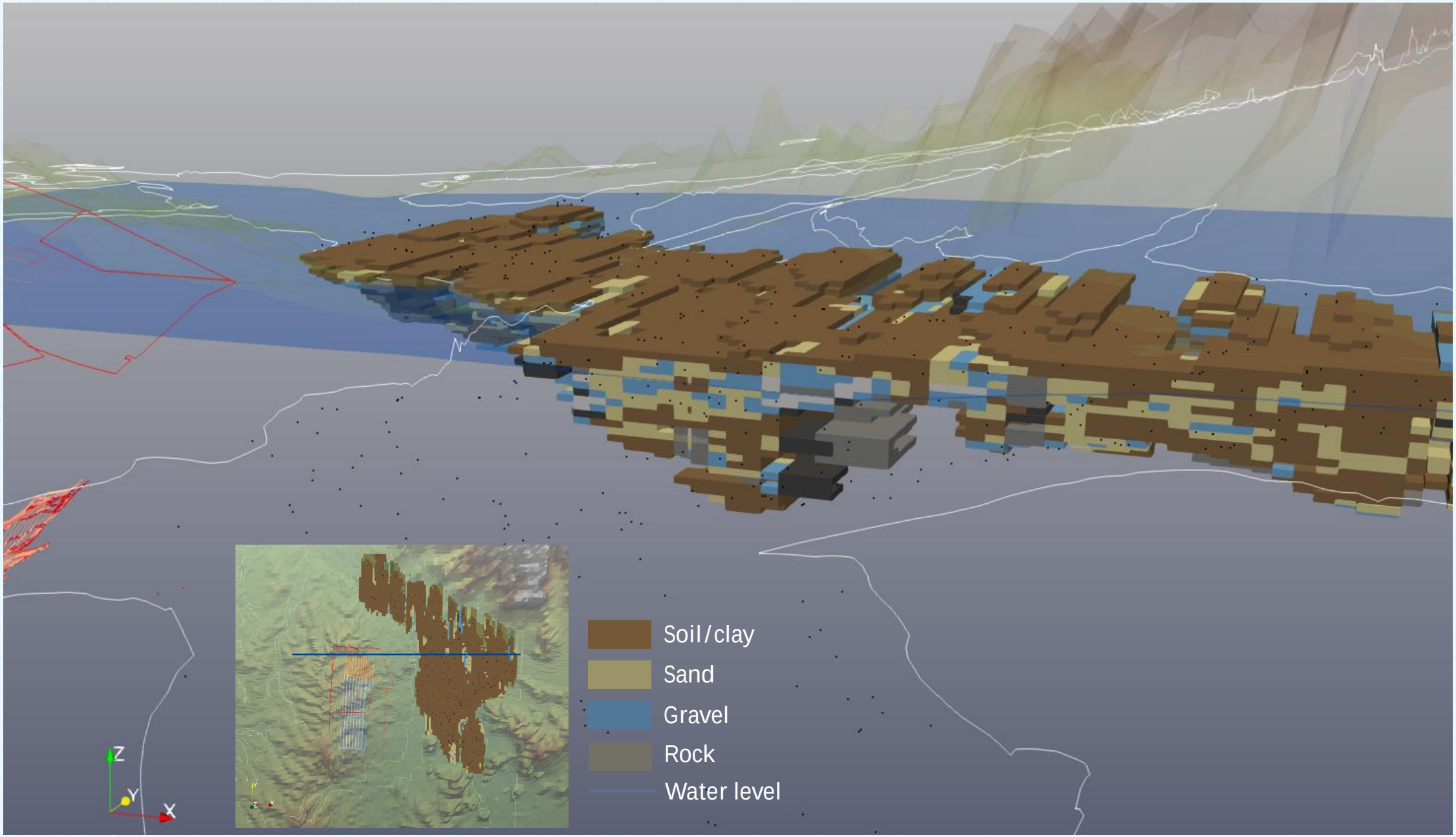
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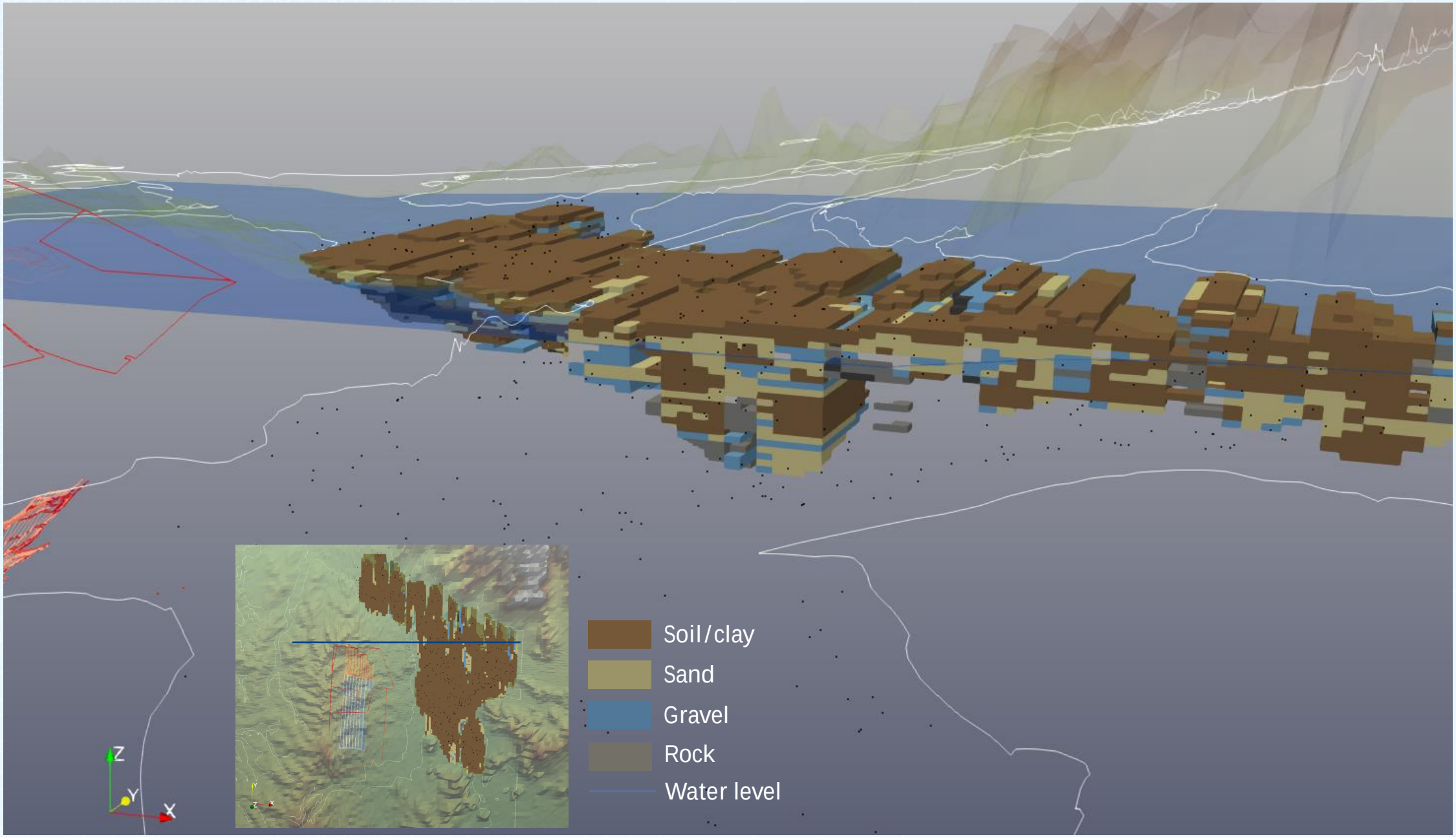
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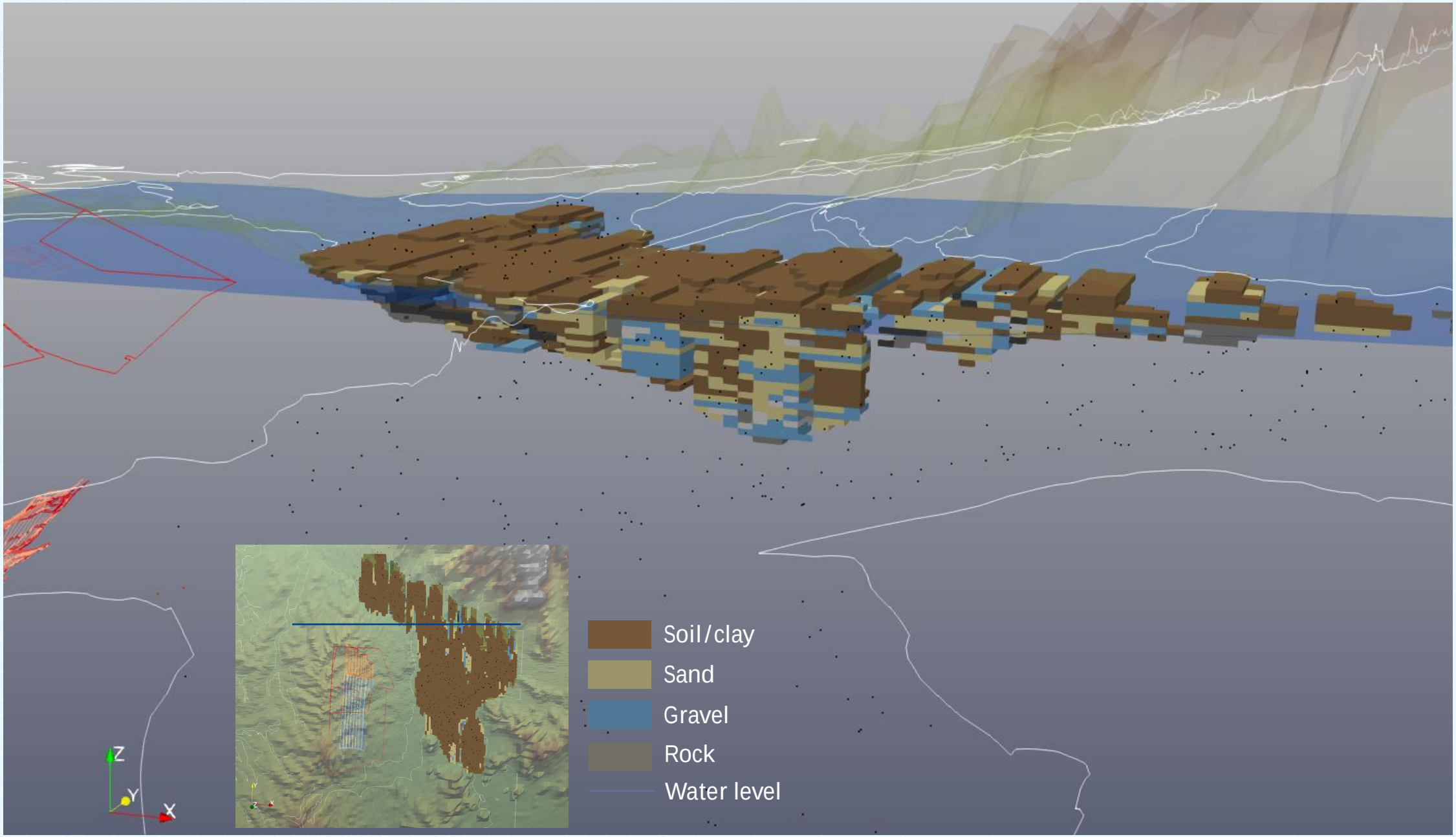
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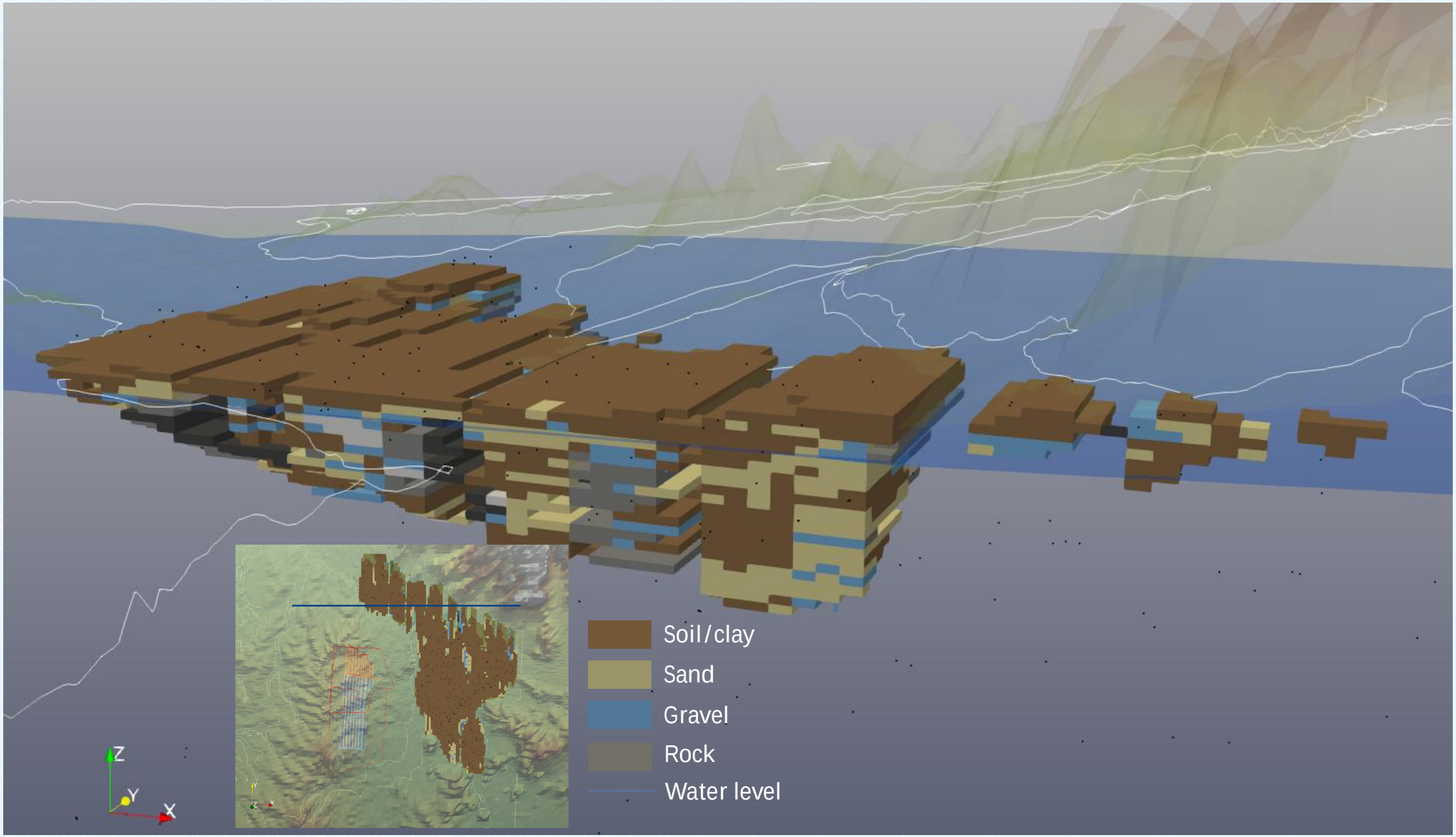
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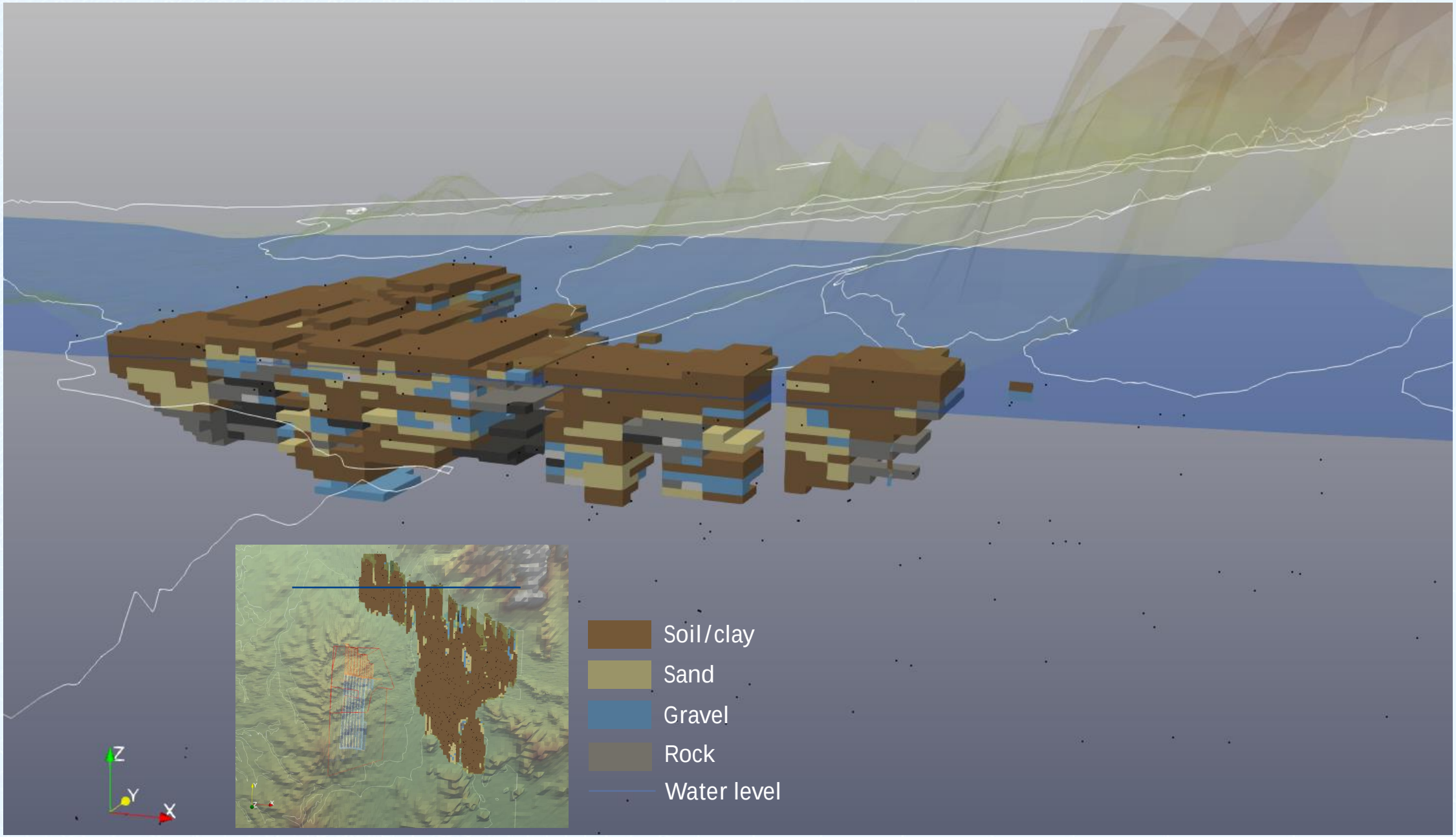
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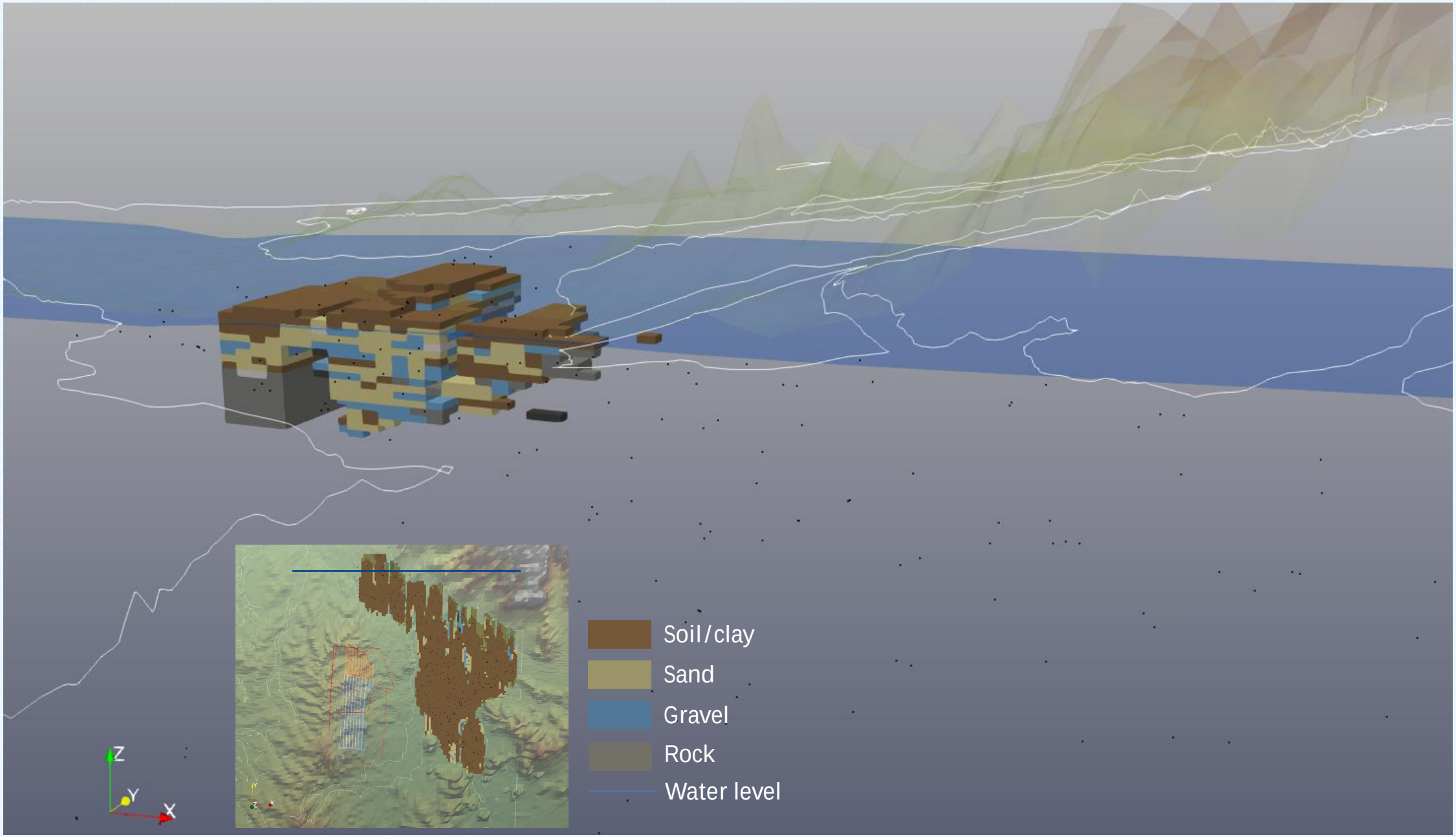
Water level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Sand
Gravel
Rock
Water level

# Appendix F Predicted drawdown at registered water supply bores

**Table F1 - Bores excluded based on detailed bore review results**

| BoreID | Drilled Date | Bore status | Bore purpose | Screen from (mbgl) | Screen to (mbgl) | Bore depth (m) | Unit impacted | Bore census completed? | Reason for exclusion |
|---|---|---|---|---|---|---|---|---|---|
| 244_New Bore | - | Not In Use | Stock | - | - | 50.2 | 03_Purlawaugh Formation | Yes | Unregistered bore from bore census. Saline and never used |
| 246_Unknown 1 | - | Not In Use | Monitoring | - | - | - | ?? | Yes | Unregistered bore from bore census. Fully grouted vibrating wire piezometer |
| 248_Darjeerling Well | - | Not In Use | Stock | - | - | 2.2 | 05_Napperby Formation | Yes | Unregistered bore from bore census. Collapsed and blocked |
| 249_Old Bore | - | Not In Use | Unknown | - | - | 14.5 | 05_Napperby Formation | Yes | Unregistered bore from bore census. Saline and never used |
| 256_Unknown 2 | - | Not In Use | Exploration | - | - | 154 | 05_Napperby Formation | Yes | Unregistered bore from bore census. Small diameter PVC exploration bore. Not in use for water supply |
| 260_Cement Tank | - | Not In Use | Stock | - | - | 28.4 | 01_Other Alluvium | Yes | Unregistered bore from bore census. 28.4 m deep which is within modelled Alluvium thickness. Within alluvium extent and good water quality (685 us/cm) tends to confirm alluvial source. Predicted maximum impact < 2m |
| 261_WB9 | - | Not In Use | Unknown | - | - | 31.15 | 04_Garrawilla Volcanics | Yes | Unregistered bore from bore census. Not in use. Bore partially collapsed and windmill not functional |
| Richardson's | - | Not In Use | Stock | - | - | 63 | 05_Napperby Formation | Yes | Landholder confirmed bore not used since 1980s |
| GW000013 | 1/07/1914 | Not In Use | Water Supply | 0 | 124.6 | 128.3 | 08_Arkarula Formation | Yes | Narrabri owned |
| GW000014 | 1/01/1915 | Not In Use | Water Supply | 0 | 115.1 | 122.4 | 05_Napperby Formation | Yes | Works summary report indicates casing withdrawn |
| GW000016 | 1/01/1915 | Not In Use | Water Supply | 0 | 112 | 152.4 | 05_Napperby Formation | Yes | Works summary report indicates casing withdrawn |
| GW000018 | 1/03/1915 | Not In Use | Unknown | 0 | 134.2 | 135.9 | 09_Pamboola Formation or older | Yes | Narrabri owned |
| GW001302 | 1/02/1924 | Not In Use | Stock and Domestic | - | - | 183.7 | 08_Arkarula Formation | No | Works summary report indicates casing withdrawn |
| GW002683 | 1/08/1929 | Unknown | Stock and Domestic | 0 | 90.5 | 90.5 | 05_Napperby Formation | Yes | Landholder confirmed no bore during bore census |
| GW003623 | 1/11/1938 | Not In Use | Stock and Domestic | 0 | 78.3 | 88 - 91.34 | 03_Purlawaugh Formation | Yes | Bore census suggests partially collapsed and dry for 20 years |
| GW003741 | 1/11/1941 | Not In Use | Water Supply | 0 | 247.5 | 267.6 | 09_Pamboola Formation or older | Yes | Landholder confirmed no bore during bore census |
| GW004846 | 1/05/1912 | Not In Use | Water Supply | - | - | 91.4 | 09_Pamboola Formation or older | Yes | Landholder confirmed no bore during bore census |
| GW005023 | 1/08/1912 | Not In Use | Water Supply | - | - | 39.6 | 04_Garrawilla Volcanics | Yes | Landholder confirmed no bore during bore census |
| GW005094 | 1/02/1913 | Not In Use | Unknown | 0 | 67 | 67 | 08_Arkarula Formation | Yes | Narrabri owned |
| GW005892 | 1/05/1935 | Not In Use | Stock and Domestic | 0 | 19.3 | 37.1 | 04_Garrawilla Volcanics | Yes | Landholder confirmed no bore during bore census |
| GW016336 | 1/07/1959 | Unknown | Stock and Domestic | 0 | 10.2 | 106.6 | 05_Napperby Formation | Yes | Landholder confirmed no bore during bore census |
| GW017215 | 1/01/1915 | Not In Use | Stock and Domestic | - | - | 58.4-167.6 | 09_Pamboola Formation or older | No | Narrabri owned |
| GW022595 | 1/07/1965 | Not In Use | Water Supply | 0 | 16.3 | 30.4 | 03_Purlawaugh Formation | Yes | Narrabri owned |
| GW022596 | 1/06/1965 | Not In Use | Water Supply | 0 | 35.9 | 1.25 - 268.2 | 09_Pamboola Formation or older | Yes | Narrabri owned |
| GW022956 | 1/07/1965 | Not In Use | Stock and Domestic | 0 | 6 | 179.8 | 06_Digby Conglomerate | No | Works summary suggests open hole below surface casing, penetrates multiple strata. Revised maximum impacts < 2m |
| GW028468 | 1/07/1968 | Unknown | Stock and Domestic | 0 | 125.8 | 125.8 | 05_Napperby Formation (Sill) | Yes | Bore census suggests borehead sealed |
| GW029261 | - | Not In Use | Stock and Domestic | - | - | 30.4 | 03_Purlawaugh Formation | Yes | Located in an area where the Pilliga Sandstone are mapped as being present at outcrop. Other nearby bores all target the Pilliga. Hence likely to be at least partially sourced from this aquifer, rather than underlying units. Revised maximum impacts <2m |
| GW029262 | - | In Use | Domestic | - | - | 33.5 | 03_Purlawaugh Formation | Yes | Located in an area where the Pilliga Sandstone are mapped as being present at outcrop. Other nearby bores all target the Pilliga. Hence likely to be at least partially sourced from this aquifer, rather than underlying units. Revised maximum impacts <2m |
| GW043315 | 1/12/1974 | Not In Use | Water Supply | 27.4 | 30.1 | 30.1 | 05_Napperby Formation | Yes | Landholder confirmed no bore during bore census |
| GW043721 | 1/01/1908 | In use | Water Supply | - | - | 38.1 | 04_Garrawilla Volcanics | Yes | Landholder confirmed no bore during bore census |
| GW051128 | 1/07/1980 | Unknown | Water Supply | 20 | 24 | 33.0 | 03_Purlawaugh Formation | No | Located in an area where the Pilliga Sandstone are mapped as being present at outcrop. Other nearby bores all target the Pilliga. Hence likely to be at least partially sourced from this aquifer, rather than underlying units. Revised maximum impacts <2m |
| GW060609 | 1/10/1984 | Not In Use | Water Supply | 21.5 | 30.2 | 32.2 | 03_Purlawaugh Formation | No | Works summary suggests screened across multiple strata from 21 to 30 mbgl. Revised maximum impacts < 2m |
| GW060976 | 1/05/1985 | Not In Use | Water Supply | 14.5 | 26.5 | 26.5 - 28.35 | 05_Napperby Formation | Yes | Narrabri owned |
| GW065023 | 26/08/1989 | Not In Use | Water Supply | 86 | 116 | 116 | 03_Purlawaugh Formation | No | Works summary suggest annulus backfilled with gravel and so screened across mutiple strata from 0 to 116 mbgl. Revised maximum impacts < 2m |
| GW067919 | 27/02/1989 | Not In Use | Water Supply | 5.2 | 12.2 | 39.6 | 03_Purlawaugh Formation | Yes | Works summary suggests open hole below surface casing, penetrates multiple strata. Revised impacts < 2m |
| GW071993 | 17/04/1994 | Not In Use | Water Supply | - | - | 48.0 | 03_Purlawaugh Formation | Yes | Landholder confirmed no bore during bore census |
| GW901289 | 16/10/1994 | Not In Use | Water Supply | 23 | 34.42 | 35.9 | 03_Purlawaugh Formation | Yes | Works summary suggest annulus backfilled with crushed aggregate and so screened across mutiple strata from 0 to 34 mbgl. Revised maximum impacts < 2m |
| GW902351 | 25/01/1995 | Unknown | Water Supply | 24 | 60 | 60.0 | 05_Napperby Formation | Yes | Landholder confirmed no bore during bore census |
| GW902531 | - | Not In Use | Unknown | - | - | 60 | 05_Napperby Formation | Yes | Narrabri owned |
| GW902742 | 19/09/1994 | Not In Use | Water Supply | 0 | 78 | 78 | 05_Napperby Formation | No | Works summary report indicates abandoned at time of drilling |
| GW966836 | 23/09/1994 | Not In Use | Stock and Domestic | 12 | 30 | 30.0 | 04_Garrawilla Volcanics | Yes | Narrabri owned |
| GW966837 | 3/09/1994 | Not In Use | Water Supply | 21.3 | 35 | 35.3 | 03_Purlawaugh Formation | No | Works summary suggest annulus backfilled with gravel and so screened across mutiple strata from 0 to 35 mbgl. Revised maximum impacts < 2m |
| GW967500 | 20/03/2006 | Not In Use | Water Supply | 0 | 190 | 190 | 04_Garrawilla Volcanics | No | Marked as being GAB bore and located in an areas where the Pilliga Sandstone is estimated to be more than 100m thick. Likely to be at least partially sourced from this major overlying aquifer. Revised maximum impacts < 2m |
| GW971254 | 20/10/2014 | Not In Use | Water Supply | 56 | 68 | 68 | 04_Garrawilla Volcanics | Yes | Works summary suggest annulus backfilled with gravel and so screened across mutiple strata from 39 to 55 mbgl. Revised maximum impacts < 2m |

**Table F2 - Existing water supply bores where maximum all time predicted drawdown exceeds 2m**

| BoreID | Drilled Date | Bore status | Bore purpose | Screen top and bottom (mbgl) | Bore depth (mbgl) | Standing water level[1] (mbgl) | Water bearing zone top and bottom (mbgl) | Unit impacted | Bore census completed? | Predicted maximum impact (m) - Narrabri Coal Mine Only | Year in which impact exceeds 2m - Narrabri Coal Mine Only | Predicted maximum impact (m) - Narrabri Mine and Gas Projects | Year in which impact exceeds 2m - Narrabri Mine and Gas Projects | Drawdown expressed as a percentage of headroom[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| House Bore | - | In Use | Stock and Domestic | - | - | 22.8 | - | 04_Garrawilla Volcanics | Yes | 2.34 | 2508 | 2.72 | 2360 | Depth unknown |
| 257_Bore | - | In Use | Stock | - | - | 57.2 | - | 08_Arkarula Formation | Yes | 12.59 | 2043 | 12.61 | 2043 | Depth unknown |
| GW008634 | 1/04/1950 | Not In Use | Stock and Domestic | 25.9 - 78.2 | 78.3 | 7.9 | 28.6 - 74.3 | 05_Napperby Formation | Yes | 2.65 | 2191 | 3.35 | 2113 | 4 - 16% |
| GW013851 | 1/01/1958 | Not In Use | Stock and Domestic | 12.1- 54.8 | 54.8 | 24.3 | 48.7 - 54.7 | 04_Garrawilla Volcanics | Yes | 5.02 | 2260 | 5.70 | 2191 | 21 - 23% |
| GW013858 | 1/01/1958 | In use | Stock and Domestic | 24.3- 30.3 | 33.5 | 18.2 | 30.4 - 33.4 | 05_Napperby Formation | Yes | 9.26 | 2067 | 10.93 | 2055 | 76 - 90% |
| GW026121 | - | Not In Use | Stock and Domestic | - | 20.1 | - | - | 04_Garrawilla Volcanics | Yes | 3.98 | 2260 | 4.57 | 2191 | 40 - 45% |
| GW054227 | 1/12/1981 | In use | Stock and Domestic | - | 38.1 | 13.7 | 32.9 - 33.5 | 03_Purlawaugh Formation | No | 3.79 | 2113 | 3.97 | 2113 | 20 - 21% |
| Windmill bore | 3/12/1999 | Unknown | Stock | - | 20.0 | 10.0 | - | 05_Napperby Formation | Yes | 4.44 | 2050 | 4.61 | 2050 | >100% - Bore may dry |

Notes

[1] Standing or rest water level observed in the bore, taken from bore census results where available or from works summary reports where not.

[2] In this case 'headroom' is defined as the distance between the observed standing water level and the top of the uppermost water bearing zone. For bores where only the bore depth is known then the top of water bearing zone has been assumed to be 50% of the total bore depth.

# Appendix G **Bore census report**



# GROUNDWATER BORE CENSUS

NARRABRI UNDERGROUND MINE STAGE 3
EXTENSION PROJECT
NARRABRI SHIRE LOCAL GOVERNMENT AREA, NSW

| | |
|---|---|
| Prepared for: | **Narrabri Coal Operations Pty Ltd** |
| Project Number: | **ENRS1049** |
| Date: | **22 July 2020** |

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|  <br>Matt Lemcke<br>*Hydrogeologist & Environmental Consultant* |  <br>Rohan Last<br>*Hydrogeologist & Environmental Scientist* |

## Record of Distribution

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| 1 x PDF | ENRS1049_NCOPL_Stage 3 Bore Census | Rev 01 | 13th Jan. 2020 | NCOPL |
| 1 x PDF | ENRS1049_NCOPL_Stage 3 Bore Census | Rev 02 | 14th Feb. 2020 | NCOPL |
| 1 x PDF | ENRS1049_NCOPL_Stage 3 Bore Census | Rev 03 | 28th Feb. 2020 | NCOPL |
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| 1x PDF | ENRS1049_NCOPL_Stage 3 Bore Census | Rev 06 | 22nd July 2020 | NCOPL |

# EXECUTIVE SUMMARY

Environment & Natural Resource Solutions (ENRS) was commissioned as a groundwater consultant by Narrabri Coal Operations Pty Limited (NCOPL) to complete a Bore Census for the Narrabri Underground Mine Stage 3 Extension Project (the Project) and surrounding area situated within the Narrabri Local Government Area, New South Wales (NSW).

In summary, the scope of work for the Bore Census comprised the following tasks:

- conduct a desktop review of registered groundwater bore records and potential groundwater features of interest;
- prepare landholder property maps to support site inspections (summary of available contact details, boundaries, access routes, and potential groundwater bore sites);
- conduct site inspections to meet with landholders and inspect relevant features;
- compile Bore Census results and prepare database; and
- document the Bore Census methodology and results, and prepare the Groundwater Bore Census Report.

The Bore Census site inspections were completed over two rounds (between 15 August to 11 October 2019, and between 18 May and 20 May 2020). Site inspections were conducted across 33 private properties, and NCOPL owned land.

Based on the findings made during the scope of works, the following outcomes and recommendations are provided:

- when contacted by NCOPL as part of the Bore Census, 11 landholders confirmed no groundwater bores were present on their property and, as such, were not inspected during the Bore Census;
- the Bore Census has culminated in a database with ground-truthed records for:
  - 73 present groundwater bores;
  - three potential groundwater features;
  - nine features of interest which had no identifiable interaction with groundwater at the time of inspection;
  - three sampling sites on Tulla Mullen Creek and a tributary of Kurrajong Creek tributary;
- Bore Census database records were provided to landholders with feedback incorporated into the final Bore Census report where relevant; and
- it is recommended that the results of the Bore Census be provided to the Environmental Impact Statement groundwater modelling team to support assessment of any potential impacts on existing bores and relevant features of interest.

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# 1 INTRODUCTION

Environment & Natural Resource Solutions (ENRS) was commissioned as a groundwater consultant by Narrabri Coal Operations Pty Limited (NCOPL) to complete a Bore Census for the Narrabri Underground Mine Stage 3 Extension Project (the Project) and surrounding area situated within the Narrabri Local Government Area (LGA), New South Wales (NSW). This Bore Census report documents the results of a desktop data review supported by site inspections and meetings with landholders. In the absence of a NSW guideline, this report has been prepared with general consideration of the Department of Environment and Science (DES) *Minimum requirements for undertaking a baseline assessment on a water bore* (DES, 2018).

## 1.1 OBJECTIVES

The aim of the census was to:

- identify potential groundwater features (including groundwater bores) and groundwater users in the vicinity of the Project;
- where possible, conduct site inspections to meet with landholders to verify borehole conditions and how groundwater is used; and
- to compile the Bore Census results and prepare a database to support the groundwater assessment process.

## 1.2 SCOPE OF WORK

The scope of work for the Bore Census comprised the following tasks:

- conduct a desktop review of registered groundwater bore records and potential groundwater features of interest (Section 2);
- prepare landholder property maps to support site inspections (summary of available contact details, boundaries, access routes, and potential groundwater bore sites) (Section 3.3);
- conduct landholder notification involving an NCOPL representative to schedule site inspections (letters, emails, meetings or phone calls, as practical) (Sections 3.2 and 3.4);
- conduct site inspections to meet with landholders and inspect relevant features (if any) (Sections 3.5 to 3.9):
    - meet with landholder, review property maps and identify any existing or historical bores;
    - record location of any existing bores (easting and northing);
    - photograph bore sites;
    - gauge base of borehole and depth to groundwater (where access allows);
    - conduct field measurement of water quality (potential Hydrogen [pH], Temperature and Electrical Conductivity [EC]);

- collect representative water samples (where practical) and submit to a National Association of Testing Authorities (NATA) accredited laboratory for testing; and
- document bore construction, equipment, purpose and pumping regime;

➢ compile Bore Census results and prepare a database of records; and

➢ document the Bore Census methodology and results, and prepare the Groundwater Bore Census Report.

## 1.3 PERSONNEL QUALIFICATIONS

The Bore Census was undertaken by experienced personnel with tertiary qualifications in hydrogeology, supported by professional technical staff (Table 1). As specified by the *Minimum requirements for undertaking a baseline assessment* (DES, 2018), the supervising hydrogeologist has attained more than two years' experience in groundwater level monitoring and sampling, including monitoring of water levels in bores equipped with pumping infrastructure, and has practical knowledge of water bore construction infrastructure.

**Table 1: Bore Census Personnel**

| Position | Name | Qualification/Experience |
|---|---|---|
| Supervising Hydrogeologist | Rohan Last | BSc (2000), MSc Hydrogeology (2004)<br>>17 years drilling, sampling and monitoring experience. |
| Field Hydrogeologist | Matt Lemcke | BSc (2013) Geology, currently undertaking postgraduate studies in Hydrogeology.<br>>7 years drilling, sampling and monitoring experience. |

Considerable assistance was also received from NCOPL personnel and landholders who provided property information and their time to locate and inspect groundwater bores.

# 2 DESKTOP DATA REVIEW

Preparation of the Bore Census database included the review and collation of information from various data sources outlined below (Sections 2.1 to 2.4).

The extent of the desktop data review was determined following a review of the *Narrabri Underground Mine Stage 3 Extension Project Gateway Application Preliminary Groundwater Assessment* (HydroSimulations, 2019) and generally comprised a 5 kilometre (km) buffer around the land pertaining to Mining Lease (ML) 1609 and the areas identified for the proposed Mining Lease Applications (MLAs) 1 and 2.

In addition, the extent of the desktop data review was expanded following the provision of initial groundwater modelling results prepared by Australasian Groundwater and Environmental Consultants (AGE) to support the Environmental Impact Statement (EIS) Groundwater Assessment (AGE, 2020).

## 2.1 REGISTERED BORE DATABASE

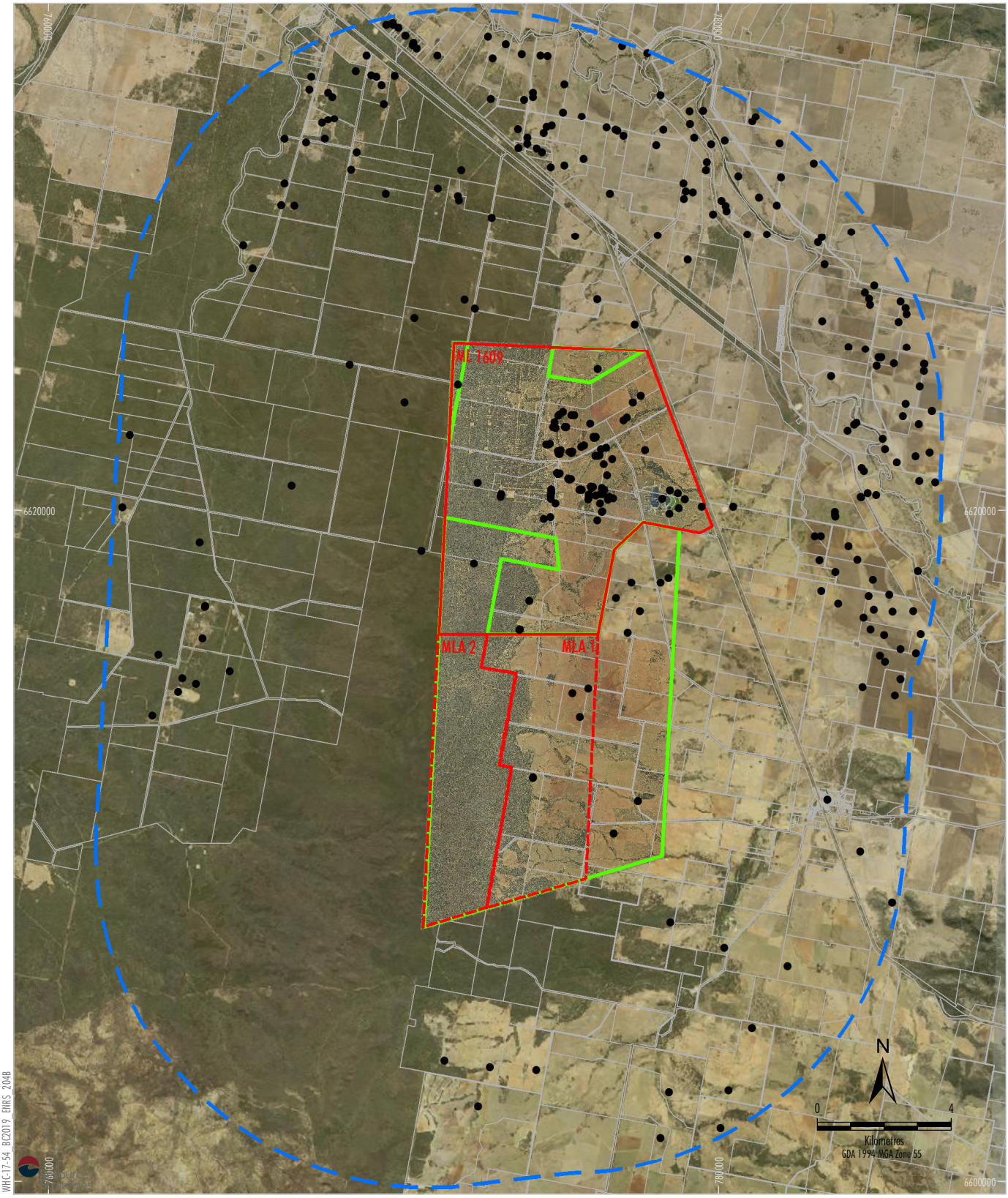
An initial search of the WaterNSW Registered Groundwater Bore Database (WaterNSW, 2019) was conducted to identify registered groundwater bores within the broader area (i.e. within approximately 10 km of ML 1609 and MLAs 1 and 2) (Figure 1). Where available, Groundwater Bore Summary reports, which include records such as bore location, construction, geology, and aquifer details derived from driller's logs, were collected and relevant information recorded in the Bore Census Database (Appendix A). The search extent of the groundwater bore database was expanded as required following the provision of initial groundwater modelling results prepared by AGE.

## 2.2 AERIAL IMAGERY

A search of online imagery from sources including NSW Spatial Information Exchange (SIX) maps (Spatial Services, 2019) and Google Earth (Google Earth, 2019) was conducted over the desktop data review extent to assist with the preparation of property maps. Imagery was inspected to validate the presence and location of potential features of interest, groundwater bores, infrastructure, access routes and boundaries.

## 2.3 TOPOGRAPHIC MAPS

The locations of windmills, potential springs, pumps and groundwater bores/wells are often marked with symbols on published topographic map sheets. A review of the current series 1:50 000 topographic maps sheets BAAN BAA (8836-N) and NARRABRI (8837-S) was undertaken during the desktop data review. This review identified a potential location for the Hardys Spring (in addition to the potential location identified through review of Santos [2017]) (Section 4.4.1).




WHC17-54 BC2019 ENRS 204B

LEGEND

Mining Lease Boundary (ML 1609)
Exploration Licence (EL 6243)
Provisional Mining Lease Application Area
Initial WaterNSW Groundwater Register Search Extent (10 km)

WaterNSW Groundwater Register Search Results

- Registered Groundwater Bore

*Source: NSW Spatial Services (2017, 2018, 2019); NCOPL (2019); ENRS (2019).*

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NARRABRI STAGE 3 PROJECT

**WaterNSW Registered Groundwater Bore Database Search**

**Figure 1**

## 2.4 ADDITIONAL SOURCES

ENRS, with input from AGE, conducted a desktop review of publicly available information to identify additional groundwater bores and features of interest, including:

- the preliminary groundwater assessment for the Narrabri Underground Mine Stage 3 Extension Project Gateway Application (HydroSimulations, 2019);
- the Narrabri Gas Project EIS (Santos, 2017);
- the Narrabri Coal Mine Water Management Plan (WMP) (NCOPL, 2013);
- the Narrabri Coal Mine Stage 2 Environmental Assessment (EA) (Aquaterra, 2009); and
- the Bioregional Assessments – Water-dependant asset register (Bioregional Assessment Programme, 2016).

# 3 CENSUS METHODOLOGY

## 3.1 INITIAL LANDHOLDER CONSULTATION

Initial contact with landholders was conducted by an NCOPL representative between August and September 2019 to invite them to participate in the Bore Census. Through this consultation, the landholders of 37 properties participated in the Bore Census. Of these, 26 landholders agreed to participate in a site inspection component, and 11 stated that no groundwater bores existed on their property (these properties were not inspected as part of the Bore Census).

Further initial contact with landholders was conducted in May 2020 following the provision of initial groundwater modelling results from AGE. Through this consultation, an additional seven landholders agreed to participate in a site inspection component for the Bore Census.

In total, 44 landholders participated in the Bore Census, and 33 private properties were inspected.

## 3.2 LAND ACCESS

Prior to Bore Census inspections, participating landholders were notified by an NCOPL or ENRS representative of the time of the inspection.

## 3.3 PROPERTY MAPS

Prior to Bore Census inspections, individual property maps were prepared using existing data sources to map potential groundwater bore sites (Section 2). The maps provided a valuable tool to direct site inspections and confirm which groundwater bores or other features were actually present on the ground.

## 3.4 LANDHOLDER MEETINGS

Upon arrival at each property the Bore Census team met with the landholders to provide an overview of the process and document any information provided by the landholders. The property map was annotated with the assistance of the landholders to confirm which groundwater bores were present or did not exist. Groundwater bores were then visited to ground-truth their location and survey the bore construction details and water quality. Landholders were also asked to identify the presence of any groundwater discharge sites such as springs or seeps, as these sites are often not identifiable due to dry conditions at the time of inspection. Feedback obtained from the landholders was incorporated into the Bore Census database where relevant.

During the landholder consultation, ENRS was made aware of some private unregistered groundwater bores (Section 4.3). In addition, landholder consultation identified the location of the Mayfield Spring, as well as a feature of interest which was referred to as the Merulana Feature (Section 4.4).

## 3.5 BORE LOCATION SURVEY

The location of each groundwater bore inspected was surveyed using a hand-held Global Positioning System (GPS) to record the coordinates (GDA 94, MGA 55). In general, a hand-held unit is expected to be accurate to within 5 metres (m) where supported by sufficient satellite coverage. Records were saved digitally within the GPS unit and recorded manually on designated field sheets.

## 3.6 BORE HEAD PHOTOGRAPH

Digital photos were taken at each groundwater bore site with the GPS location embedded within the file. Multiple photos were taken to record the bore head and surrounding infrastructure, if any. Where the groundwater bore was equipped, the photo frame was set to include the complete infrastructure.

## 3.7 BORE CONSTRUCTION LOG

A key aim of the Bore Census was to document the bore construction at each groundwater bore. Where available, a copy of the driller's log was provided by the landholders. Where a driller's log was not available, the existing bore details, namely: location, depth, age and construction, were applied to correlate this site data with a registered groundwater bore (Groundwater Works Number). Where the available information confirmed the correlation with a registered bore, the Groundwater Works Summary report was utilised to provide additional details of groundwater bore construction.

## 3.8 DEPTH MEASUREMENTS

Where the groundwater bore condition and equipment provided down-hole access, the depth of the groundwater bore was gauged using a groundwater dipper. The dipper comprised a metre tape reel with a weighted probe. Two probes were used during the Bore Census in7ections which were approximately 12 millimetres (mm) and 4 mm in diameter depending on the size of the opening available on groundwater bore to conduct the inspection. However, in the majority of situations where a bore is equipped with a pump it is not possible to insert the dipper into the bore as either:

1) the bore head is sealed;
2) there is insufficient access; or
3) there is a high risk that the dipper will become entangled between the pump column and electrical cables, which may require removing the entire pump column to recover the dipper.

Field notes were made where access was restricted, or the depth of the bore and groundwater level could not be gauged.

The depth to groundwater (DTW) was gauged and recorded in designated field sheets. The stick-up height of the bore casing above ground level was measured and recorded to facilitate an accurate calculation of the groundwater depth relative to ground level.

## 3.9 WATER QUALITY

### 3.9.1 Field Testing

Groundwater quality was tested in the field where a water sample could be obtained.

Sampling was conducted by the preferred methods in the following order:

- the existing pump was operated to purge the groundwater bore by removing at least three to five bore volumes (i.e. the total volume of water between the standing water level and the bottom of the bore) prior to collection of samples;
- the existing pump was operated to purge the groundwater bore for as long as practical prior to collecting sample (where it was not possible to remove three bore volumes, or the bore volume could not be calculated);
- a bailer was lowered manually in unequipped groundwater bores to collect grab sample (where it was not possible to purge the groundwater bore); or
- a sample was obtained from tap or junction in a pipeline connected to the groundwater bore.

Where a groundwater bore was already operating (i.e. by the landholder) or was operated to purge water, test samples were taken at two minute intervals until field parameters (i.e pH, temp, EC) stabilised. In some instances, samples could not be stabilised (e.g. for samples obtained from a bailer or storage tank).

Once field parameters had stabilised, a multi-probe water quality meter was used to measure the following parameters and the results recorded:

- temperature;
- EC (a measure of salinity); and
- pH (a measure of acidity/alkalinity).

In addition to field testing, several water samples were sent to a NATA laboratory for analysis (Section 3.9.4).

### 3.9.2 Electrical Conductivity

The EC provides a measure of the total concentration of ion species and is widely used to assess the levels of dissolved salts in water (salinity). Drinking water is generally less than 895 microSiemens per centimetre (µS/cm) (600 milligrams per litre [mg/L]) whilst sea water is generally 50,000 to 60,000 µS/cm.

### 3.9.3 Potential Hydrogen

The pH provides a test of water acidity (low pH) or alkalinity (high pH). Most natural freshwaters have a relatively neutral pH, in the range 6.5 to 8.0 (ANZECC and ARMCANZ, 2000), although groundwater can vary significantly due to bore construction and the host geology. Generally acidic groundwater has a low pH of less than 6.5 and alkaline groundwater has a high pH of greater than 8.0.

### 3.9.4 Laboratory Analysis

Representative groundwater quality samples were collected from groundwater bores where samples could be obtained (Section 3.9.1) and sent to a NATA laboratory for analysis. Groundwater samples for dissolved metal analysis were field filtered, using a disposable 0.45 µm membrane filter, prior to collection in acid preserved containers. Samples were sealed in laboratory-prepared sampling containers appropriate for the analysis and clearly labelled with the sample identification. All samples were stored on ice as soon as practicable after their collection and transported to the NATA laboratory under Chain of Custody (COC) documentation in accordance with Australian and New Zealand Standard AS/NZS 5667.11:1998 (R2016) Water Quality – Sampling Guidance on sampling groundwaters. ALS, a NATA registered laboratory, was contracted to undertake the laboratory analyses in accordance with the NATA approved methods.

### 3.9.5 Landholder Review

Following a review of the details obtained during the site inspection as well as any sampling results from the laboratory, landholders were provided a letter summarising the information relevant to their property. All relevant feedback obtained from landholders was incorporated into the Bore Census database.

### 3.9.6 Groundwater Assessment Criteria

The relevant groundwater assessment criteria provided for comparison for this Bore Census are:

- ANZG (2018) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* with reference to the Default Trigger Values for protection of 95% of species in freshwater;
- ANZECC and ARMCANZ (2000) *Agricultural Irrigation (short-term trigger values up to 20 years)* (including Tables 4.2.10 and 4.2.11); and
- Australian Drinking Water Guidelines 6 (2011) version 3.5 (NHMRC, 2011) *Quality Assurance & Quality Control*.

## 3.10 FIELD PROTOCOLS

The Quality Assurance and Quality Control (QA/QC) protocols used during the Bore Census fieldwork are shown below in Table 2.

**Table 2: Field QA/QC**

| Protocol | Description |
|---|---|
| Census Team | Personnel comprised qualified Hydrogeologists & technical staff trained in conducting groundwater bore surveys. |
| Field Records | Bore data recorded both manually in designated field sheets and digitally. |
| Sampling Protocols | Samples for laboratory analysis were taken after purging of bores and parameters were allowed to stabilise. |
| Sample Equipment | All field equipment calibrated prior to operation. Sample equipment decontaminated between sample sites. |

## 3.11 LABORATORY ANALYTICAL METHODS

Analyses of samples was conducted by ALS (a NATA accredited laboratory). QA/QC results are reported in the Laboratory Certificates of Analysis.

## 3.12 DATA INTEGRITY ASSESSMENT

Where available this Bore Census has utilised formal sources of information issued by government. These formal sources are supplemented by information provided by NCOPL, landholders, and observations made by ENRS groundwater professionals during site inspections. Review and comparison of the groundwater records is conducted to assess for and identify any significant data gaps or inconsistencies to trigger further investigations. Hence, the sources and content of this assessment may be considered to provide a reliable and satisfactory level of accuracy to support this record of groundwater bores.

## 3.13 QA/QC DISCUSSION

The QA/QC indicators complied with the required standards. It is therefore concluded that the QA/QC results are adequate, and the quality of the Bore Census data is acceptable for use. A summary of the Data Quality performance is provided in Table 3**.**

**Table 3: Data Quality Objectives and Criteria**

| Data Quality Objective (DQO) | Evaluation Criteria | Status |
|---|---|---|
| Documentation completeness | Completion of field records, equipment calibration, site photos. | ✓ |
| Data comparability | Use of appropriate techniques for gauging, sampling, storage and transportation of samples. Use of NATA certified laboratory (if any). | ✓ |
| Data representativeness | The Bore Census site inspections covered all areas of concern. | ✓ |
| Precision & accuracy | Experienced and qualified field personnel. Appropriate field techniques and calibrated equipment. | ✓ |

# 4 SUMMARY OF BORE CENSUS RESULTS

## 4.1 REGISTERED BORE RECORDS

A desktop review of the WaterNSW Registered Groundwater Bore Database (2019) was conducted on 29 May 2019 (Section 2.1). The search identified 341 potential groundwater bores (Figure 1). Five bores are registered within MLAs 1 and 2, 106 bores are registered within ML 1609, with the remaining 230 groundwater bores registered outside of these areas. Of these, 209 groundwater bores were registered either on properties owned by NCOPL or privately owned properties which were contacted as part of the bore census.

The search results for registered bores was expanded further following the provision of initial groundwater modelling results from AGE.

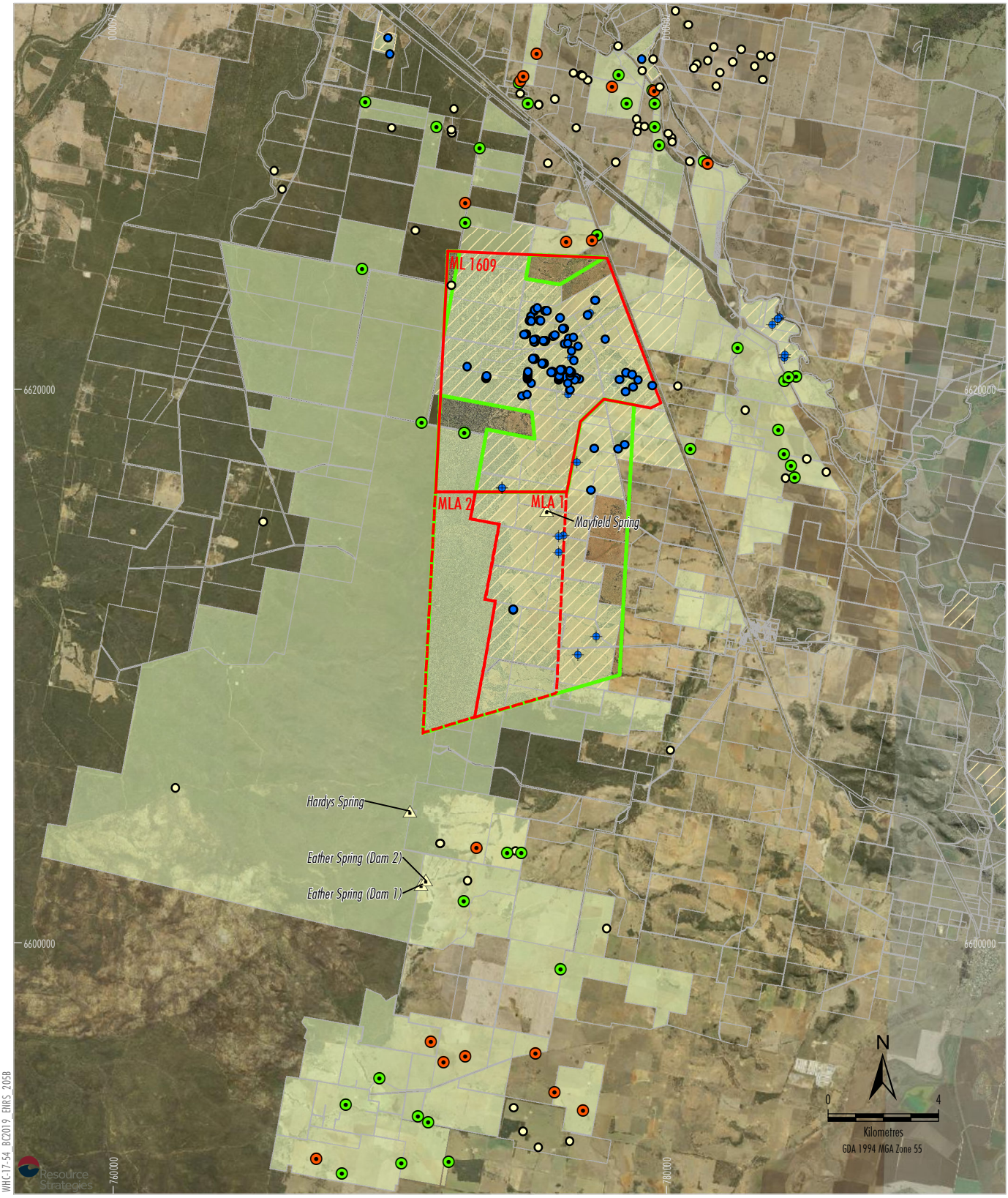
## 4.2 PROPERTIES INSPECTED

A total of 83 landholders were contacted to partake in the bore census. Of these, 33[1] privately owned and/or leased properties agreed to partake in the Bore Census and were inspected by the Bore Census team (Figure 1). Areas of NCOPL owned land were also inspected (Figure 1). The indicative location of the inspected properties is depicted in Figure 2.

Twenty-two of these privately owned properties were confirmed through the Bore Census to contain active groundwater bores (Figure 2), and/or potential features of interest (Sections 4.3 to 4.4).

Where a landholder did not elect to participate in the Bore Census (Section 3.1), any Registered Groundwater Records (Section 4.1) within their property were assumed to be present.

[1] The landholders of an additional 11 properties participated in the Bore Census. These landholders stated that no groundwater bores or potential groundwater features were present on their property at the time of the Bore Census. Therefore, these properties were not inspected during the Bore Census.




LEGEND

Mining Lease Boundary (ML 1609)
Exploration Licence (EL 6243)
Provisional Mining Lease Application Area
Bore Census Property Extent*
Whitehaven Owned Land

Feature Status (ENRS Bore Census 2019)

- Inspected Groundwater Bore (In Use)
- Inspected Groundwater Bore (Not In Use)
- Inspected Groundwater Bore (Mine Owned)
- Registered Groundwater Bore (Mine Owned)
- Registered Groundwater Bore (Landholder Contacted - Not Inspected)
- Inspected Potential Groundwater Feature

*Source: The State of New South Wales (2017, 2018, 2019); NCOPL (2020); ENRS (2019; 2020).*

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**Bore Census Features and Properties Inspected**

**Figure 2**

** Note: The landholders of eleven (11) of these properties stated that no bores were present on their property during initial consultation and therefore these properties were not inspected during the Bore Census.*

## 4.3 BORES INSPECTED

A total of 91 groundwater bore locations were inspected during the Bore Census. The locations of the bores inspected are provided in Appendix A.

Of the 91 bores inspected, 25 bores were reported as 'not in use' (Figure 2). 16 registered bores were confirmed to not be present at their registered coordinates and two were unable to be located during the site inspections. The remaining 48 bores were identified as being 'in use' and are summarised below and shown in Figure 2:

- 11 Domestic;
- 1 Exploration;
- 7 Irrigation;
- 12 Monitoring;
- 12 Stock; and
- 5 Stock and Domestic.

The depth of the 73 present groundwater bores inspected during the Bore Census (registered on either NCOPL owned, or privately owned land) ranged from 1.25 m to 167 m below top of casing (mbtoc), as summarised below:

- 0-9 m: 4 bores;
- 10-19 m: 7 bores;
- 20-50 m: 26 bores;
- 50-100 m: 20 bores;
- >100 m: 5 bores; and
- 11 bores where the depth was not able to be gauged.

The Standing Water Level (SWL) measured across 52 of the inspected groundwater bores ranged between approximately 1.4 to 90 m below ground level (mbgl). The SWL for 19 groundwater bores were unable to be obtained (either from field measurements, or government records), and two bores were inspected as dry.

Records of the field Bore Census data are further summarised in the Bore Census Database provided in Appendix A and the Bore Identification Cards provided in Appendix B.

## 4.4 FEATURES OF INTEREST

### 4.4.2 Potential Groundwater Features

The locations of potential groundwater features identified during the Bore Census are listed in Table 4, and discussed further in the subsections below.

**Table 4: Potential Groundwater Features**

| Feature Name | Approximate Easting (GDA MGA Zone 56) | Approximate Northing (GDA MGA Zone 56) |
|---|---|---|
| Mayfield Spring | 775670 | 6615617 |
| Hardys Spring | 770726 | 6604763 |
| Eather Spring (Dam 1) | 771133 | 6602103 |
| Eather Spring (Dam 2) | 771292 | 6602251 |

***Mayfield Spring***

The Mayfield Spring was identified through landholder consultation and the desktop data review. The Mayfield Spring was observed to have visible groundwater discharge at the time of inspection and was therefore determined to be a feature with surface expression of groundwater (Table 4, Figure 2). The Mayfield Spring has been described in the Narrabri Coal Mine Stage 2 Groundwater Assessment (Aquaterra, 2009) and the Narrabri Gas Project EIS, however it is noted the location reported in previous documentation has been inconsistent. Other potential locations of the Mayfield Spring (i.e. identified during the desktop review) were also inspected by ENRS to confirm no additional groundwater features were present (Section 4.4.2).

Water chemistry from samples taken at the Mayfield Spring (Section 4.6) had a similar signature to the water chemistry of the Mayfield Spring presented in Aquaterra (2009). No water sample of the Mayfield Spring was taken as part of the Narrabri Gas Project EIS.

A photograph of the Mayfield Spring is provided as Plate 1.

***Hardys Spring***

The Hardys Spring was identified at two potential locations through the desktop data review. Hardys Spring Location #1 was identified through review of Santos (2017), and Hardys Spring Location #2 was identified through review of topographic maps (Section 2.3). Following landholder consultation and inspection, the Hardys Spring was confirmed to be present at Hardys Spring Location #2 (Table 4, Figure 2). Hardys Spring Location #1 was also inspected by ENRS to confirm no additional groundwater features were present (Section 4.4.2).

The Hardys Spring was observed as a moist, soiled, grass-lined drainage channel with no surface ponding, flow or visible seepage. At the time of inspection, the landholder stated that Hardys Spring has not been known to flow for approximately 10 years. Given the ground conditions and vegetation indicated a persistent source of groundwater interaction, it is considered the Hardys Spring is potentially a feature with a surface expression of groundwater.

A photograph of Hardys Spring is provided as Plate 2.



**Plate 1: Mayfield Spring**



**Plate 2: Hardys Spring**

### *Eather Spring*

The Eather Spring was identified through desktop data review. Following landholder consultation and inspection, the Eather Spring was identified as two adjacent dams built along a drainage line (i.e. Eather Spring [Dam 1] and Eather Spring [Dam 2]) (Table 4, Figure 2).

The uppermost reaches of the drainage line were noted to have erosional features consistent with historic subsurface inflows; however, no visible soil seepage or moisture was present at the time of inspection. Furthermore, the landholder reported that the Eather Spring had not flowed in approximately 10 years. At the time of inspection, both dams contained rainwater from a recent rainfall event. Based on this, Eather Spring is not considered to be a feature with a recent surface expression of groundwater, however, some observations indicate a historic surface expression of groundwater.

Photographs of Eather Spring (Dam 1) and Eather Spring (Dam 2) are provided as Plates 3 and 4 respectively.



**Plate 3: Eather Spring (Dam 1)**



**Plate 4: Eather Spring (Dam 2)**

### 4.4.2 Other Features

In addition to the potential groundwater features above, a number of other features of interest were inspected during the Bore Census.

Eight features of interest identified through the desktop review (Section 2.4) were surveyed as part of the Bore Census and were determined to have no identifiable interaction with groundwater at the time of inspection. These include:

- Four farm dams (Yarranabee Dams #1 and #2, and Longsight Dams #1 and #2) inspected on 10 October 2019 with no observable flow or distinguishing geology and, as such, not identifiable as groundwater features;
- The location of the Mayfield Spring reported in the Narrabri Gas Project EIS and the Narrabri Coal Mine EA was surveyed on 10 October 2019 and determined to be a natural drainage depression by ENRS, which is dammed on both the up and downstream ends, and was determined to not be a groundwater feature (noting that the location of the Mayfield Spring inspected by ENRS is provided in Table 4);
- The location of the Hardys Spring reported in the Narrabri Gas Project EIS (Hardys Spring Location #1) was surveyed on 20 May 2020 and had no distinguishing features consistent with a potential groundwater spring at the time of inspection (noting that the location of the Hardys Spring inspected by ENRS is provided in Table 4). The landholder also confirmed no spring is known to exist at this location; and

- Two small man-made dams (Towri Dams #1 and #2), constructed in the vicinity of the Eather Spring dams, were surveyed on 19 May 2020 and had no distinguishing features or observable flow. Landholder consultation confirmed that the dams had historically been constructed to capture flow from the Eather Spring.

One feature of interest identified through landholder consultation (the Merulana Feature) was surveyed as part of the bore census by NCOPL personnel. The Merulana Feature had not been reported previously, was anecdotally reported to dry up regularly in periods of low rainfall, and had no distinguishing geology. On this basis, the Merulana Feature was determined to not be a potential groundwater feature.

Two creeks in the vicinity of the Project were surveyed and subject to water sampling in May 2020 at the request of AGE (to assist in characterising these creeks). These were:

- Tulla Mullen Creek – Old Narrabri Road Bridge: identified as a series of separated pools along the creek line. Soil soak was noted between upstream of the bridge with no visible water movement, however trickle flows were observed between pools downstream of the bridge (which was inferred as stream baseflow based off the elevation offset and observed soil soak between pools and not groundwater upwelling);
- Tulla Mullen Creek – Kamilaroi Highway Bridge: identified as a single pool downstream of the Kamilaroi Highway Bridge. Soil soak was observed upstream of the bridge, however no visible flows or pooling were noted. No visible out flow of the pool was observed, however the soil along the outflow channel was noted to be saturated; and
- Kurrajong Creek Tributary: identified as an isolated pool of water downstream of a mine access track. The pool of water is located along a natural drainage line is likely formed by a natural topographic rise downstream of the mine access track. At the time of sampling the pool of water was turbid and not flowing past the natural topographical rise.

## 4.5 GROUNDWATER QUALITY RESULTS

Field groundwater samples were obtained from 48 of the 74 present and inspected groundwater bores.

Groundwater salinity measured in the inspected groundwater bores reported a wide range in EC from a minimum of 68 µS/cm to a maximum of 27,956 µS/cm. Average EC of groundwater sampled in the Bore Census area was calculated to be 3,435.7 µS/cm.

The pH in the inspected sampled groundwater bores was reported between 5.32 and 9.05 pH units with a calculated average of 7.31 pH units, which indicates the majority of groundwater in the area is relatively neutral.

Groundwater samples from 29 groundwater bores, six farm dams, three potential groundwater features, and three surface water features were submitted to ALS, a NATA accredited laboratory for analyses and testing. Upon receipt, the laboratory results were tabulated for comparison against the relevant groundwater assessment criteria. The laboratory Certificates of Analysis (COA) are provided in Appendix C with a summary of the results tabulated in Appendix D.

## 4.6 PIPER DIAGRAM

The Piper diagram below (Figure 3) illustrates the relative concentrations of cations (lower left of diagram) and anions (lower right of diagram) in each sample. The cations are grouped into three major divisions: sodium (Na+) plus potassium (K+); calcium (Ca++); and magnesium (Mg++). Whilst the anions are similarly grouped into three major categories: Bicarbonate (HCO3-) plus carbonate (CO3--); sulfate (SO4--); and chloride (Cl-). The Piper diagram (Figure 3) may be used as a method of identifying groups of water samples with like compositions or to indicate potential mixing of waters.

The Piper diagram indicates that water chemistry is variable at sampled locations across the bore census area, with anions generally being bicarbonate and chloride dominant, and cations generally being mixed or sodium plus potassium dominant.

The locations of the water samples are provided in Appendix A.

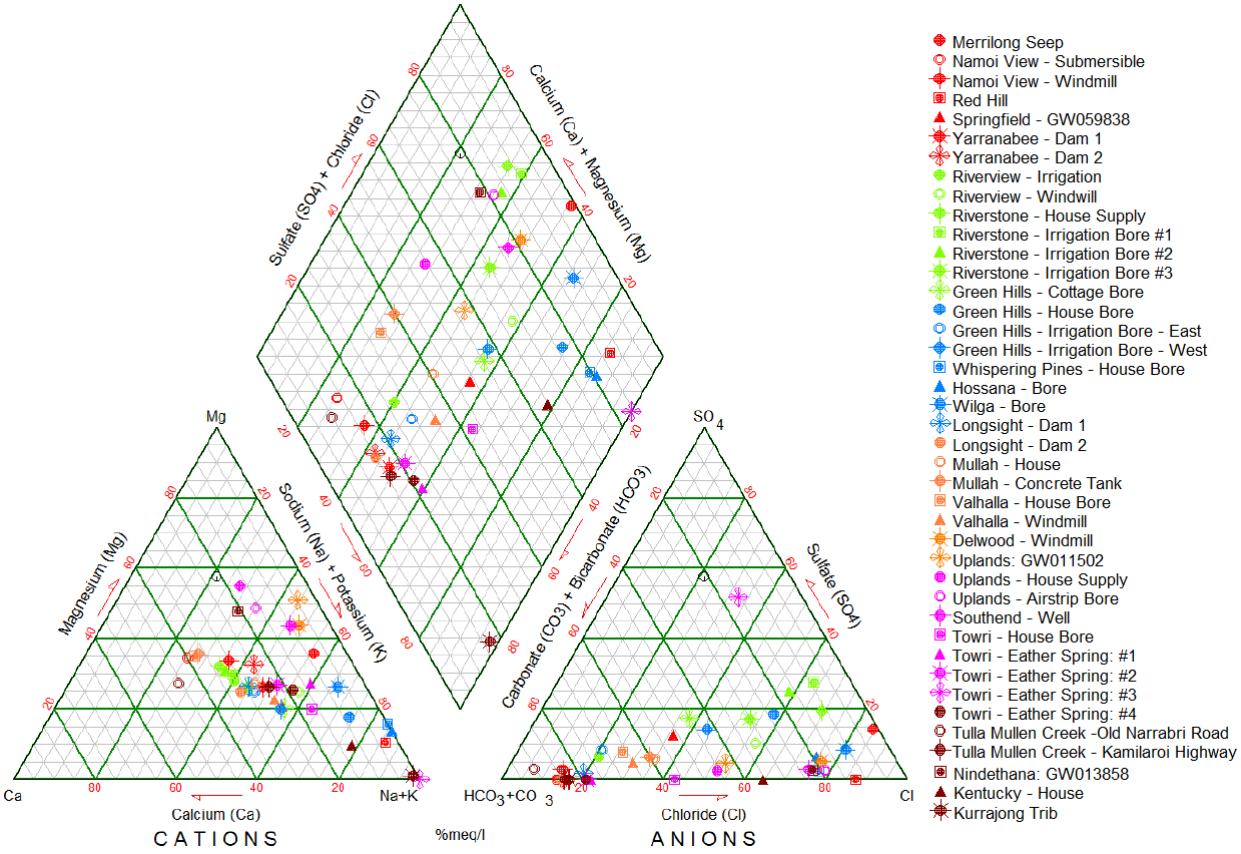


**Figure 3: Piper Diagram**

# 5 CONCLUSIONS AND RECOMMENDATIONS

Based on the findings made during the scope of works the following conclusions and recommendations are provided:

- Bore Census was conducted over two rounds (between 15 August to 11 October 2019, and between 18 May and 20 May 2020) comprising site inspections across 33 properties;
- 11 landholders confirmed no groundwater bores were present on their property at the time of inspection and, as such, were not inspected during the Bore Census;
- the Bore Census database combines staged results from desktop reviews, communications with landholders, site inspections and groundwater bore head surveys, supplemented by driller's records and registered groundwater bore reports;
- the Bore Census has culminated in a database with ground-truthed records for 73 groundwater bores (private and NCOPL owned) comprising of (Figure 2):
    - 11 Domestic;
    - 1 Exploration;
    - 7 Irrigation;
    - 12 Monitoring;
    - 12 Stock;
    - 5 Stock and Domestic; and
    - 25 Groundwater Bores not in use.
- the Bore Census confirmed that 16 registered groundwater bores were not present at their registered coordinates;
- the Bore census was unable to located one registered groundwater bore and one groundwater bore anecdotally thought to exist by a landholder;
- the Bore Census identified three potential groundwater features (the Mayfield Spring, Eather Spring and Hardys Spring);
- the Bore Census confirmed that eight features of interest identified during the desktop data review had no identifiable interaction with groundwater at the time of inspection, and one feature of interest identified through landholder consultation was not a potential groundwater feature;
- Bore Census database records were provided to landholders, with relevant feedback incorporated into the final Bore Census report;
- a summary of the Bore Census records is provided in the Bore Census database (Appendix A), supported by Bore Identification Cards (Appendix B);
- the Bore Census methodology QA/QC indicators complied with the required standards. Hence, the census results are considered satisfactory and the quality of the census data is acceptable for further application; and
- it is recommended that the results of the Bore Census be provided to the EIS groundwater modelling team to support assessment of any potential impacts on existing bores and relevant features of interest.

Note that this report must be read in conjunction with the Statement of Limitations in Section 7.

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# 7 LIMITATIONS

This report and the associated services performed by ENRS are in accordance with the scope of services set out in the contract between ENRS and the Client. The scope of services was defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the Site.

ENRS derived the data in this report primarily from visual inspections and limited sample collection and analysis made on the dates indicated. The report has been prepared on the basis that, while ENRS believes all the information in it is deemed reliable and accurate at the time of preparing the report, it does not warrant its accuracy or completeness and to the full extent allowed by law excludes liability in contract, tort or otherwise, for any loss or damage sustained by the Client arising from or in connection with the supply or use of the whole or any part of the information in the report through any cause whatsoever.

Limitations also apply to analytical methods used in the identification of substances (or parameters). These limitations may be due to non-homogenous material being sampled (i.e. the sample to be analysed may not be representative), low concentrations, the presence of 'masking' agents and the restrictions of the approved analytical technique. As such, non-statistically significant sampling results can only be interpreted as 'indicative' and not used for quantitative assessments.

The data, findings, observations, conclusions and recommendations in the report are based solely upon the state of the Site at the time of the investigation. The passage of time, manifestation of latent conditions or impacts of future events (e.g. changes in legislation, scientific knowledge, land uses, etc.) may render the report inaccurate. In those circumstances, ENRS shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on, the contents of the report.

This report has been prepared on behalf of, and for the exclusive use of, the Client, and is subject to and issued in connection with the provisions of the agreement between ENRS and the Client. ENRS accepts no liability or responsibility whatsoever and expressly disclaims any responsibility for, or in respect of any use of or reliance upon, this report by any third party or parties.

It is the responsibility of the Client to accept if the Client so chooses any recommendations contained within and implement them in an appropriate, suitable and timely manner.

# APPENDICES

# Appendix A
## Bore Census Database

| ENRS ID | Bore Census Confirmed | Status | Local Bore Name | Easting | Northing | Property | Inspection Data | Depth (MbTOC) | StickUp (magl) | Casing | ID (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2019100901 | Confirmed Present | Not In Use | Darjeerling Well | 777315 | 6625379 | Darjeerling | 9/10/2019 | 2.2 | 0.43 | Wood | 1000 |
| 2019081609 | Confirmed Present | Not In Use | GW060976 | 776762 | 6617358 | Haylen Views | 16/10/2019 | 28.35 | 0.215 | Steel | 155 |
| 2020051807 | Confirmed Present | In Use | Airstrip Bore | 772124 | 6592077 | Uplands | 18/05/2020 | 55 | 0.23 | - | - |
| 2019100906 | Confirmed Present | In Use | House Bore | 782571 | 6621493 | Greenhills | 9/10/2019 | - | 1.21 | PVC | 125 |
| 2019101103 | Confirmed Present | In Use | Windmill | 779489 | 6630808 | Vallhalla | 11/10/2019 | 12 | 0.33 | Steel | 125 |
| 2020051809 | Confirmed Present | In Use | Windmill | 771011 | 6593723 | Delwood Downs | 18/05/2020 | 30 | 0.68 | Steel | 150 |
| 2019081502_1 | Confirmed Present | In Use | GW273294 Shallow | 784032 | 6622561 | Springfield | 15/08/2019 | 13 | 1.05 | PVC | 50 |
| 2020051901 | Confirmed Present | Not In Use | Sweet Water Bore | 772927 | 6597093 | South End | 19/05/2020 | 68 | 0 | - | - |
| 2019081502_2 | Confirmed Present | In Use | GW273294 Deep | 784032 | 6622561 | Springfield | 15/08/2019 | 25.82 | 1.05 | PVC | 75 |
| 2019101102 | Confirmed Present | Not In Use | Irrigation | 779567 | 6630770 | Vallhalla | 11/10/2019 | 41.5 | 0.54 | Steel | 203 |
| 2019101105 | Confirmed Present | Not In Use | Shearing Shed | 778032 | 6630936 | Mullah | 11/10/2019 | 11.72 | 0.18 | Steel | 140 |
| 2019081601 | Inspected | Potential Groundwater Feature | Mayfield Feature | 775670 | 6615617 | Merrilong | 16/08/2019 | - | 0 | Wood | - |
| 2019101106 | Confirmed Present | In Use | Cement Tank | 778566 | 6630340 | Mullah | 11/10/2019 | 28.4 | 0.5 | PVC | 125 |
| 2020051810 | Confirmed Present | In Use | Well | 771387 | 6593513 | South End | 18/05/2020 | 22.3 | 0.2 | Concrete | 1200 |
| 2019101101 | Confirmed Present | In Use | House Bore | 779575 | 6630314 | Vallhalla | 11/10/2019 | 23.5 | 0.36 | Steel | 150 |
| 2019081605 | Confirmed Not Present | - | GW060977 | 774351 | 6617299 | Mayfield | 16/08/2019 | - | - | - | - |
| 2019081504 | Confirmed Present | Not In Use | GW901410 | 783828 | 6622341 | Springfield | 15/08/2019 | 33.9 | 0.34 | Steel | 232 |
| 2020052003 | Confirmed Present | Not In Use | GW067919 | 774820 | 6631314 | Kentucky | 20/05/2020 | 39.6 | 0.72 | PVC | 150 |
| 2019081608 | Confirmed Not Present | - | GW060978 | 777651 | 6616999 | Matilda | 16/10/2019 | - | - | - | - |
| 2019081505 | Confirmed Present | In Use | GW059838 | 784275 | 6621148 | Springfield | 15/08/2019 | 20 | 0.755 | Steel | 150 |
| 2019100904 | Confirmed Present | In Use | Windmill Bore | 779733 | 6628836 | Riverview | 9/10/2019 | 20 | 0.53 | Steel | 140 |
| 2019100905 | Confirmed Present | In Use | Irrigation Bore | 779587 | 6629491 | Riverview | 9/10/2019 | - | 0.61 | Steel | 125 |
| 2019081506 | Confirmed Present | In Use | Windmill | 781461 | 6628198 | Namoi View | 15/08/2019 | 11.6 | 0.75 | Steel | 200 |
| 2019081507 | Confirmed Present | In Use | Submersable | 781359 | 6628242 | Namoi View | 15/08/2019 | 13 | 1.005 | PVC | 125 |
| 2019100909 | Confirmed Present | In Use | Cottage Bore | 784426 | 6620439 | Greenhills | 9/10/2019 | - | 0.42 | PVC | 125 |
| 2020051806 | Confirmed Present | In Use | Delwood House Bore | 768405 | 6594152 | Delwood Downs | 18/05/2020 | 49.6 | 0.4 | PVC | 125 |
| 2020051801 | Confirmed Present | In Use | House Supply | 770412 | 6592027 | Uplands | 18/05/2020 | 32 | 0.33 | Steel | 130 |
| 2019100910 | Confirmed Present | In Use | House Supply | 784253 | 6617655 | Riverstone | 9/10/2019 | - | 1.02 | PVC | 125 |
| 2020052007 | Confirmed Present | Not In Use | GW026121 | 773126 | 6603421 | Nindethena | 20/05/2020 | 20.1 | 0.28 | Steel | - |
| 2020051802 | Confirmed Present | In Use | GW011502 | 768275 | 6591664 | Uplands | 18/05/2020 | 60.9 | 0.45 | Steel | 150 |
| 2020051905 | Confirmed Present | Not In Use | GW019223 | 776983 | 6593938 | N/A | 19/05/2020 | 82 | 0.44 | Steel | 140 |
| 2020052002 | Confirmed Present | Not In Use | Windmill | 774721 | 6631155 | Kentucky | 20/05/2020 | 30.4 | 0.3 | Steel | 163 |
| 2020051811 | Confirmed Present | Not In Use | Richardson's | 772725 | 6595906 | South End | 18/05/2020 | 63 | 0.57 | Steel | 140 |
| 2019101107 | Confirmed Present | In Use | WB2 | 776449 | 6619822 | Claremont | 11/10/2019 | 30 | 0.43 | PVC | 125 |
| 2019100903 | Confirmed Present | In Use | GW968438 | 777490 | 6625553 | Darjeerling | 9/10/2019 | 31 | 0.875 | PVC | 50 |
| 2019100915 | Inspected | Other Feature | Yarranabee Dam #1 | 774936 | 6612839 | Yarranabee | 9/10/2019 | - | - | - | - |
| 2019100916 | Inspected | Other Feature | Yarranabee Dam #2 | 776014 | 6613131 | Yarranabee | 9/10/2019 | - | - | - | - |
| 2020051902 | Confirmed Present | Not In Use | Plums Block | 771484 | 6596438 | South End | 19/05/2020 | 61.5 | 0.16 | Steel | 140 |
| 2019081603 | Confirmed Present | In Use | GW968435 | 776117 | 6614693 | Longsight | 16/08/2019 | 51.64 | 0.954 | PVC | 50 |
| 2019081606 | Confirmed Present | In Use | GW968633 | 774063 | 6616446 | Mayfield | 16/08/2019 | 131.3 | 0.96 | PVC | 50 |
| 2019101004 | Confirmed Not Present | - | GW003604 | 770631 | 6623218 | Jacks Creek State Forest | 10/10/2019 | - | - | - | - |
| 2019101005 | Confirmed Not Present | - | GW003052 | 767261 | 6620743 | Jacks Creek State Forest | 10/10/2019 | - | - | - | - |
| 2020051808 | Confirmed Present | In Use | Solar | 769617 | 6595118 | Delwood Downs | 18/05/2020 | - | 0.48 | Steel | 125 |
| 2020051907 | Confirmed Present | In Use | House Bore | 772678 | 6601496 | Towri and Other Properties | 19/05/2020 | - | 0.22 | - | - |
| 2019081512 | Confirmed Present | In Use | New Bore | 774986 | 6630330 | Acacia Ridge | 15/08/2019 | 50.2 | 0.655 | PVC | 125 |
| 2020051906 | Confirmed Present | In Use | GW008847 | 776179 | 6599045 | Towri and Other Properties | 19/05/2020 | 51.3 | 0.44 | Steel | 140 |
| 2019101010 | Confirmed Not Present | - | GW005892 | 775863 | 6613839 | Longsight | 10/10/2019 | - | - | - | - |
| 2019101011 | Confirmed Not Present | - | GW005023 | 775642 | 6614554 | Longsight | 10/10/2019 | - | - | - | - |
| 2019101012 | Inspected | Other Feature | Longsight Dam #1 | 774353 | 6613824 | Longsight | 10/10/2019 | - | - | - | - |
| 2019101013 | Inspected | Other Feature | Longsight Dam #2 | 774916 | 6614015 | Longsight | 10/10/2019 | - | - | - | - |
| 2019081607 | Confirmed Present | In Use | GW968634 | 774066 | 6616447 | Mayfield | 16/10/2019 | 40.2 | 0.97 | PVC | 50 |
| 2020051904 | Confirmed Present | Not In Use | Windmill | 775950 | 6594595 | N/A | 19/05/2020 | 137.1 | 0.42 | - | - |
| 2019081604 | Confirmed Present | Not In Use | House Bore | 776105 | 6614120 | Longsight | 16/08/2019 | - | 0.28 | Steel | 140 |
| 2019101108 | Confirmed Present | Not In Use | WB9 | 776556 | 6621162 | WHC Land | 11/10/2019 | 31.15 | 0.495 | PVC | 125 |
| 2019101002 | Confirmed Present | In Use | Bore | 771693 | 6629488 | Hosanna | 10/10/2019 | 54.9 | 0.18 | Steel | 140 |
| 2019101001 | Confirmed Present | In Use | House Bore | 769114 | 6630381 | Whispering Pines | 10/10/2019 | 60 | 0.37 | Steel | 140 |
| 2019101008 | Confirmed Present | In Use | Unknown 2 | 772695 | 6618428 | Pilliga State Forest | 10/10/2019 | 154 | 0.48 | PVC | 100 |
| 2019101109 | Confirmed Present | Not In Use | WB1 | 777251 | 6622763 | WHC Land | 11/10/2019 | 169.1 | 0.29 | Steel | 140 |
| 2019101007 | Confirmed Present | In Use | GW968631 | 772698 | 6618426 | Pilliga State Forest | 10/10/2019 | 63.3 | 0.86 | PVC | 50 |
| 2019101110 | Confirmed Not Present | - | WB8 | 777682 | 6623409 | Omeo | 11/10/2019 | - | - | - | - |
| 2019081509 | Confirmed Present | In Use | GW971254 | 773245 | 6628719 | Red Hill | 15/08/2019 | 68 | 0.44 | PVC | 125 |
| 2019101009 | Confirmed Present | In Use | Bore | 780874 | 6617836 | Wilga | 10/10/2019 | - | 0.81 | Steel | 150 |
| 2019101003 | Confirmed Present | In Use | GW968441 | 769001 | 6624344 | Jacks Creek State Forest | 10/10/2019 | 90.61 | 0.93 | PVC | 50 |
| 2020051804 | Confirmed Not Present | - | GW017093 | 766521 | 6594133 | Uplands | 18/05/2020 | - | - | - | - |
| 2020051805 | Confirmed Not Present | - | GW005209 | 766683 | 6594222 | Uplands | 18/05/2020 | - | - | - | - |

m - metres
mm - millimetres
L - Litres
mbTOC - metres below top of casing
maGL - metres above ground level
mbGL - metres below ground level
EST - Eastern Standard Time
L - Litres
uScm - microsiemens per centimetre
L/H - litres per hour

**Appendix A. Bore Census Database**

| ENRS ID | Year Drilled | DTW (mbTOC) | SWL (mbgl) | Time of Measurement | Time Since Pumping | Purpose | Pump Type | Power | Intake Depth | Pump Rate | Storage (L) | EC (µScm) | Temp | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2019100901 | - | 1.8 | 1.37 | 7:17:00 AM | 6 Months | Stock | Mobile Suction | Petrol | Variable | 1800L/h | - | - | - | - |
| 2019081609 | 1985 | 3.01 | 2.795 | 1:00:00 PM | - | Stock | - | - | - | - | - | 20900 | 21.9 | 8.39 |
| 2020051807 | - | 6.07 | 5.84 | 2:30:00 PM | - | Stock | Submersable | Solar | 50 | 60L/min | - | 5608 | 20.9 | 7.19 |
| 2019100906 | - | 8.09 | 6.88 | 10:22:00 AM | Pumping at time of measurement | Domestic | Submersable | Electric | - | - | - | 4993 | 21.06 | 7.47 |
| 2019101103 | 1959 | 7.76 | 7.43 | 7:25:00 AM | 12 Hours | Stock | Piston | Windmill | - | - | 22000 | 734 | 20 | 7.33 |
| 2020051809 | - | 8.19 | 7.51 | 3:40:00 PM | Pumping at time of measurement | Stock | Piston | Windmill | 24.3 | - | 20000 | 5891 | 16.39 | 7.92 |
| 2019081502_1 | 2013 | 8.838 | 7.788 | 8:00:00 AM | - | Monitoring | - | - | - | - | - | 923.6 | 18.11 | 6.73 |
| 2020051901 | - | 7.9 | 7.9 | 9:38:00 AM | - | Stock | Piston | Windmill | - | - | - | 435 | 21.2 | 8.51 |
| 2019081502_2 | 2013 | 9.057 | 8.007 | 8:00:00 AM | - | Monitoring | - | - | - | - | - | 905.6 | 18.5 | 7.13 |
| 2019101102 | 1992 | 8.69 | 8.15 | 7:17:00 AM | 3 years | Irrigation | Screw | Diesel | - | - | - | - | - | - |
| 2019101105 | 1968 | 8.46 | 8.28 | 8:51:00 AM | 5 years | Stock | - | Windmill | - | - | - | 889 | 20.1 | 6.95 |
| 2019081601 | - | 0 | 0 | 8:00:00 AM | Discharging at time of measurement | Stock | - | - | - | - | 30000 | 5224 | 17.7 | 5.32 |
| 2019101106 | - | 9.115 | 8.615 | 9:15:00 AM | 18 Hours | Stock | Piston | Windmill | - | - | 90000 | 685 | 19.4 | 7.23 |
| 2020051810 | 1870 | 8.86 | 8.66 | 4:23:00 PM | 2 weeks | Stock and Domestic | Submersable | Solar | 19.2 | 45L/min | 30000 | 6031 | 22 | 7.2 |
| 2019101101 | 1976 | 9.56 | 9.2 | 6:40:00 AM | Pumping at time of measurement | Domestic | Submersable | Electric | 16 | - | - | 733 | 18.5 | 7.04 |
| 2019081605 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2019081504 | - | 9.67 | 9.33 | 8:50:00 AM | 5 years | Stock | Screw | - | - | - | - | - | - | - |
| 2020052003 | - | 10.24 | 9.52 | 8:08:00 AM | 5 years | Domestic | Submersable | Electric | - | - | - | - | - | - |
| 2019081608 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2019081505 | 1984 | 10.56 | 9.805 | 9:31:00 AM | Pumping at time of measurement | Domestic | Submersable | Electric | - | - | 10000 | 1572 | 16.5 | 7.2 |
| 2019100904 | 1999 | 10.52 | 9.99 | 8:30:00 AM | 18 Hours | Stock | Suction | Petrol | 19 | - | - | 1456 | 19.7 | 6.73 |
| 2019100905 | - | 10.61 | 10 | 9:10:00 AM | Pumping at time of measurement | Irrigation | Submersable | Solar | - | - | - | 676 | 21 | 7.02 |
| 2019081506 | - | 10.9 | 10.15 | 10:30:00 AM | 24 Hours | Domestic | Piston | Windmill | - | - | 20000 | 756 | 14.34 | 7.94 |
| 2019081507 | 1996 | 11.52 | 10.515 | 10:53:00 AM | Pumping at time of measurement | Stock and Domestic | Submersable | Electric | - | 3600L/h | - | 640 | 21.9 | 6.8 |
| 2019100909 | - | 11.08 | 10.66 | 11:45:00 AM | Pumping at time of measurement | Domestic | Submersable | Electric | - | - | - | 1145 | 24.4 | 7.19 |
| 2020051806 | - | 11.1 | 10.7 | 1:18:00 PM | - | Stock and Domestic | Submersable | Electric | 30.5 | - | - | - | - | - |
| 2020051801 | - | 11.26 | 10.93 | 9:40:00 AM | Pumping at time of measurement | Domestic | Submersable | Solar | 30 | - | 40000 | 1889 | 19.1 | 7.92 |
| 2019100910 | - | 12.38 | 11.36 | 1:46:00 AM | Pumping at time of measurement | Domestic | Submersable | Solar | - | - | - | 4118 | 21.7 | 6.68 |
| 2020052007 | - | 11.98 | 11.7 | 12:36:00 PM | - | Stock | Screw | - | - | - | - | - | - | - |
| 2020051802 | - | 12.24 | 11.79 | 10:20:00 AM | - | Stock | Submersable | Solar | 36.6 | - | 30000 | 2746 | 16.6 | 7.78 |
| 2020051905 | - | 12.38 | 11.94 | 1:08:00 PM | - | Stock | - | - | - | - | - | 4641 | 22.4 | 7.63 |
| 2020052002 | - | 13.01 | 12.71 | 7:23:00 AM | - | Stock and Domestic | Submersable | Electric | - | - | - | 1027 | 18.6 | 7.82 |
| 2020051811 | - | 14.8 | 14.23 | 5:02:00 PM | 40 years | Stock | - | - | - | - | - | 1598 | 21.6 | 9.05 |
| 2019101107 | 1994 | 14.81 | 14.38 | 11:41:00 AM | - | Stock | Suction | Petrol | - | - | - | - | - | - |
| 2019100903 | - | 18.09 | 17.215 | 8:06:00 AM | - | Monitoring | - | - | - | - | - | 27956 | 20.26 | 6.41 |
| 2019100915 | - | - | 0 | 4:08:00 PM | - | Stock | - | - | - | - | 40000 | 318 | 22.6 | 7.79 |
| 2019100916 | - | - | 0 | 4:40:00 PM | - | Stock | - | - | - | - | 40000 | 338 | 24 | 8.11 |
| 2020051902 | - | 18.46 | 18.3 | 10:44:00 AM | - | Stock | Venturi | Firefighting Pump | 55 | - | - | 3414 | 22.2 | 8 |
| 2019081603 | 2007 | 21.483 | 20.529 | 8:45:00 AM | - | Monitoring | - | - | - | - | - | 4617 | 19.1 | 7.29 |
| 2019081606 | 2009 | 23.24 | 22.28 | 11:27:00 AM | - | Monitoring | - | - | - | - | - | 11510 | 19.35 | 6.92 |
| 2019101004 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2019101005 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2020051808 | - | 23.18 | 22.7 | 3:07:12 AM | - | Stock | Submersable | Solar | 45.72 | - | - | - | - | - |
| 2020051907 | - | 23.03 | 22.81 | 2:35:00 PM | - | Stock and Domestic | Submersable | Electric | - | - | 30000 | 513 | 19.1 | 8.62 |
| 2019081512 | 2019 | 24.64 | 23.985 | 4:00:00 PM | - | Stock | - | - | - | - | - | 8143 | 22.6 | 7.36 |
| 2020051906 | - | 26.81 | 26.37 | 1:54:00 PM | - | Stock | - | - | - | - | 30000 | 7,513 | 22.2 | 7.06 |
| 2019101010 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2019101011 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2019101012 | - | - | 0 | 3:13:00 PM | - | Stock | - | - | - | - | - | 156 | 25.8 | 7.97 |
| 2019101013 | - | - | 0 | 3:30:00 PM | - | Stock | - | - | - | - | - | 384 | 24.2 | 8.71 |
| 2019081607 | 2009 | 28.385 | 27.415 | 11:30:00 AM | - | Monitoring | - | - | - | - | - | 7508 | 20.15 | 7.2 |
| 2020051904 | - | 29.24 | 28.82 | 11:55:00 AM | - | Stock | Piston | Windmill | - | - | - | - | - | - |
| 2019081604 | - | 30.4 | 30.12 | 9:40:00 AM | 5 Years | Stock and Domestic | Submersable | Solar | - | - | 10000 | - | - | - |
| 2019101108 | - | 30.98 | 30.485 | 11:56:00 AM | - | - | - | Windmill | - | - | - | - | - | - |
| 2019101002 | 1990 | 39.58 | 39.4 | 9:18:00 AM | 1 Hour | Domestic | Submersable | Electric | 55 | - | - | 153 | 19.8 | 5.89 |
| 2019101001 | 1938 | 42.14 | 41.77 | 7:30:00 AM | 12 Hours | Domestic | Submersable | Electric | 54 | 3360L/h | 10000 | 219 | 20.9 | 6.11 |
| 2019101008 | - | 45.945 | 45.465 | 12:21:00 PM | - | Exploration | - | - | - | - | - | 74 | 20.7 | 7.06 |
| 2019101109 | 1945 | 48.3 | 48.01 | 12:15:00 PM | - | Exploration | - | - | - | - | - | 11211 | 22.3 | 6.69 |
| 2019101007 | - | 51.47 | 50.61 | 12:19:00 PM | - | Monitoring | - | - | - | - | - | 698 | 23 | 6.48 |
| 2019101110 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2019081509 | 2014 | 52.86 | 52.42 | 12:38:00 PM | 24 Hours | Stock and Domestic | Submersable | Genset | 66 | 1500L/h | 10000 | 220 | 21.84 | 5.75 |
| 2019101009 | - | 58 | 57.19 | 1:46:00 PM | Pumping at time of measurement | Stock | Pneumatic | Compressor | - | - | - | 14217 | 24.7 | 6.37 |
| 2019101003 | - | 64.33 | 63.4 | 10:44:00 AM | - | Monitoring | - | - | - | - | - | 163 | 21.6 | 5.44 |
| 2020051804 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2020051805 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

m - metres
mm - millimetres
L - Litres
mbTOC - metres below top of casing
maGL - metres above ground level
mbGL - metres below ground level
EST - Eastern Standard Time
L - Litres
uScm - microsiemens per centimetre
L/H - litres per hour

| ENRS ID | ORP (mV) | DO (mg/L) | Sample Source | Submitted for Analysis (Y/N) | Personnel |
|---|---|---|---|---|---|
| 2019100901 | - | - | - | No | MV + ML |
| 2019081609 | -1.3 | 1.6 | Bailer | No | MV + ML |
| 2020051807 | -40.2 | 4.69 | Tap | Yes | ML+MV |
| 2019100906 | -69 | 7.34 | Tap | Yes | MV + ML |
| 2019101103 | 83.7 | 7.61 | tank | Yes | MV + ML |
| 2020051809 | 134 | 7.81 | Tap | Yes | ML+MV |
| 2019081502_1 | -121 | 2.53 | Bailer | No | MV + ML |
| 2020051901 | 38.1 | 2.78 | Bailer | No | ML+MV |
| 2019081502_2 | -168.1 | 1.89 | Bailer | No | MV + ML |
| 2019101102 | - | - | - | No | MV + ML |
| 2019101105 | -195 | 2.1 | Bailer | No | MV + ML |
| 2019081601 | 145 | 1.97 | - | Yes | MV + ML |
| 2019101106 | 43.8 | 10.12 | tank | Yes | MV + ML |
| 2020051810 | 139 | 1.27 | Tap | Yes | ML+MV |
| 2019101101 | 104.9 | 7.11 | tap | Yes | MV + ML |
| 2019081605 | - | - | - | No | SN + ML |
| 2019081504 | - | - | - | No | MV + ML |
| 2020052003 | - | - | - | No | ML+MV |
| 2019081608 | - | - | - | No | MV + ML |
| 2019081505 | 19.4 | 4.27 | tap | Yes | MV + ML |
| 2019100904 | -95 | 2.89 | tap | Yes | MV + ML |
| 2019100905 | 0.1 | 3.92 | tap | Yes | MV + ML |
| 2019081506 | 98.3 | 8.88 | tap | Yes | MV + ML |
| 2019081507 | -151 | 3.29 | tap | Yes | MV + ML |
| 2019100909 | 129.4 | 4.7 | tap | Yes | MV + ML |
| 2020051806 | - | - | - | No | ML+MV |
| 2020051801 | 201 | 8.4 | Tap | Yes | ML+MV |
| 2019100910 | 234.3 | 2.05 | Tap | Yes | MV + ML |
| 2020052007 | - | - | - | No | ML+MV |
| 2020051802 | 169 | 13.9 | Tank | Yes | ML+MV |
| 2020051905 | -102 | 3.06 | Bailer | No | ML+MV |
| 2020052002 | 61.9 | 4.89 | Bailer | No | ML+MV |
| 2020051811 | 103 | 1.7 | Bailer | No | ML+MV |
| 2019101107 | - | - | - | No | MV + ML |
| 2019100903 | -79 | 2.69 | Bailer | No | MV + ML |
| 2019100915 | 2.04 | 8.18 | dam | Yes | MV + ML |
| 2019100916 | 123 | 8.53 | dam | Yes | MV + ML |
| 2020051902 | -151 | 2.25 | Bailer | No | ML+MV |
| 2019081603 | 15.4 | 2.07 | Bailer | No | MV + ML |
| 2019081606 | -87.9 | 3.04 | Bailer | No | SN + ML |
| 2019101004 | - | - | - | No | SN + ML |
| 2019101005 | - | - | - | No | SN + ML |
| 2020051808 | - | - | - | No | ML+MV |
| 2020051907 | 98.6 | 8.12 | Tank | Yes | ML+MV |
| 2019081512 | -40.4 | 2.99 | Bailer | No | MV + ML |
| 2020051906 | -86.5 | 1.36 | Bailer | No | ML+MV |
| 2019101010 | - | - | - | No | SN + ML |
| 2019101011 | - | - | - | No | SN + ML |
| 2019101012 | 158 | 6.3 | dam | Yes | SN + ML |
| 2019101013 | 201 | 17.16 | dam | Yes | SN + ML |
| 2019081607 | -132 | 2.91 | Bailer | No | SN + ML |
| 2020051904 | - | - | - | No | ML+MV |
| 2019081604 | - | - | - | No | MV + ML |
| 2019101108 | - | - | - | No | MV + ML |
| 2019101002 | 131.8 | 6.92 | tap | Yes | SN + ML |
| 2019101001 | 125 | 4.43 | tap | Yes | SN + ML |
| 2019101008 | -13.2 | 2.95 | bailer | No | SN + ML |
| 2019101109 | 20.2 | 2.61 | Bailer | No | MV + ML |
| 2019101007 | 165 | 4.3 | bailer | No | SN + ML |
| 2019101110 | - | - | - | No | MV + ML |
| 2019081509 | 142.8 | 7 | tap | Yes | MV + ML |
| 2019101009 | 182 | 2.27 | Tap | Yes | SN + ML |
| 2019101003 | 149.3 | 5.34 | bailer | No | SN + ML |
| 2020051804 | - | - | - | No | ML+MV |
| 2020051805 | - | - | - | No | ML+MV |

m - metres
mm - millimetres
L - Litres
mbTOC - metres below top of casing
maGL - metres above ground level
mbGL - metres below ground level
EST - Eastern Standard Time
L - Litres
uScm - microsiemens per centimetre
L/H - litres per hour

**Appendix A. Bore Census Database**

| ENRS ID | Bore Census Confirmed | Status | Local Bore Name | Easting | Northing | Property | Inspection Data | Depth (MbTOC) | StickUp (magl) | Casing | ID (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2019081511 | Confirmed Present | In Use | GW968440 | 772725 | 6626016 | Moon Hill | 15/08/2019 | 92.75 | 0.874 | PVC | 50 |
| 2019081610 | Confirmed Present | Not In Use | GW022596 | 776807 | 6610415 | Yarranabee | 16/08/2019 | 1.25 | 0.515 | Steel | 125 |
| 2019081508 | Confirmed Present | Not In Use | Dry Bore | 781486 | 6628145 | Namoi View | 15/08/2019 | 6.1 | 0.4 | Steel | 140 |
| 2019101104 | Confirmed Present | In Use | House Bore | 778284 | 6631347 | Mullah | 11/10/2019 | 10 | 0.55 | PVC | 125 |
| 2019100902 | Confirmed Present | Not In Use | Old Bore | 776377 | 6625331 | Darjeerling | 9/10/2019 | 14.5 | 0.6 | Steel | 125 |
| 2020052004 | Confirmed Present | In Use | Irrigation Bore | 775317 | 6632125 | Kentucky | 20/05/2020 | 22 | 0.34 | - | - |
| 2020052001 | Confirmed Present | In Use | Kentucky House | 774670 | 6631085 | Kentucky | 20/05/2020 | 33.5 | 0.34 | PVC | 125 |
| 2020051813 | Confirmed Not Present | - | GW002683 | 771271 | 6595648 | Delwood Downs | 18/05/2020 | - | - | - | - |
| 2020051814 | Confirmed Not Present | - | GW967834 | 773336 | 6594954 | South End | 18/05/2020 | - | - | - | - |
| 2020051815 | Confirmed Not Present | - | GW016336 | 773623 | 6593924 | South End | 18/05/2020 | - | - | - | - |
| 2020052006 | Confirmed Present | In Use | GW013858 | 774254 | 6603250 | Nindethena | 20/05/2020 | 33.5 | 0.2 | - | - |
| 2019100907 | Confirmed Present | In Use | Irrigation Bore - West | 784275 | 6620313 | Greenhills | 9/10/2019 | 44.5 | 0.4 | - | - |
| 2019081501 | Confirmed Present | Not In Use | GW901842 | 784286 | 6621266 | Springfield | 15/08/2019 | 45.5 | 0.37 | Steel | 140 |
| 2019100908 | Confirmed Present | In Use | Irrigation Bore - East | 784687 | 6620457 | Greenhills | 9/10/2019 | 47.2 | 0.58 | - | - |
| 2019100912 | Confirmed Present | In Use | Irrigation Bore #2 | 784644 | 6616816 | Riverstone | 9/10/2019 | 52 | 0.465 | - | - |
| 2019100913 | Confirmed Present | In Use | Irrigation Bore #3 | 784058 | 6618526 | Riverstone | 9/10/2019 | 53 | 0.62 | - | - |
| 2019100911 | Confirmed Present | In Use | Irrigation Bore #1 | 784505 | 6617246 | Riverstone | 9/10/2019 | 61 | 0.2 | - | - |
| 2020051908 | Inspected | Potential Groundwater Feature | Eather Spring #1 | 771133 | 6602103 | Towri and Other Properties | 19/05/2020 | - | - | - | - |
| 2020051909 | Inspected | Potential Groundwater Feature | Eather Spring #2 | 771292 | 6602251 | Towri and Other Properties | 19/05/2020 | - | - | - | - |
| 2020051910 | Inspected | Other Feature | Towri Dam #1 | 771455 | 6601981 | Towri and Other Properties | 19/05/2020 | - | - | - | - |
| 2020051911 | Inspected | Other Feature | Towri Dam #2 | 771559 | 6601660 | Towri and Other Properties | 19/05/2020 | - | - | - | - |
| 2020051912 | Unable to locate | Assumed In Use | A. Bore 1 | 777847 | 6600507 | Towri and Other Properties | 19/05/2020 | - | - | - | - |
| 2020051913 | Confirmed Not Present | - | GW043721 | 772823 | 6602235 | Towri and Other Properties | 19/05/2020 | - | - | - | - |
| 2020051914 | Confirmed Not Present | - | GW902351 | 775676 | 6600282 | Towri and Other Properties | 19/05/2020 | - | - | - | - |
| 2020051915 | Confirmed Not Present | - | GW011261 | 777362 | 6595430 | Towri and Other Properties | 19/05/2020 | - | - | - | - |
| 2020051916 | Confirmed Not Present | - | GW006605 | 777165 | 6595004 | Towri and Other Properties | 19/05/2020 | - | - | - | - |
| 2019100914 | Confirmed Present | Not In Use | Windmill #2 | 777472 | 6611082 | Yarranabee | 9/10/2019 | 67 | 0.81 | Steel | 130 |
| 2019081510 | Confirmed Present | Not In Use | GW003623 | 772727 | 6626728 | Irvine Acres | 15/08/2019 | 91.34 | 0.16 | Steel | 150 |
| 2020051903 | Confirmed Present | Not In Use | GW028468 | 775263 | 6596017 | N/A | 19/05/2020 | 125.8 | 0.71 | Steel | - |
| 2019081503 | Confirmed Present | In Use | Monitoring Bore | 784102 | 6622605 | Springfield | 15/08/2019 | - | 1 | - | - |
| 2019081602 | Confirmed Present | In Use | Unknown 1 | 776274 | 6614726 | Merrilong | 16/08/2019 | - | - | VWP | - |
| 2019101006 | Confirmed Present | In Use | GW273315 | 771146 | 6618793 | Pilliga State Forest | 10/10/2019 | - | 0.9 | - | - |
| 2020052008 | Confirmed Not Present | Other Feature | Hardys Spring #1 | 771588 | 6604095 | Nindethena | 20/05/2020 | - | - | - | - |
| 2020052009 | Inspected | Potential Groundwater Feature | Hardys Spring #2 | 770726 | 6604763 | Nindethena | 20/05/2020 | - | - | - | - |
| 2020052010 | Unable to locate | Not In Use | GW013851 | 771818 | 6603586 | Nindethena | 20/05/2020 | - | - | - | - |
| 2020052011 | Inspected | Other Feature | Tulla Mullen Crk: Old Narrabri Road Bridge | 782655 | 6622645 | N/A | 20/05/2020 | - | - | - | - |
| 2020052012 | Inspected | Other Feature | Tulla Mullen Crk: Kamilaroi Highway Bridge | 7822688 | 6612308 | N/A | 20/05/2020 | - | - | - | - |
| 2020052701 | Inspected | Other Feature | Kurrajong Creek Tributary | 7822688 | 6612308 | N/A | 27/05/2020 | - | - | - | - |
| - | Inspected | Other Feature | Mayfield Feature 1 | 774630 | 6613917 | Mayfield | 10/10/2019 | - | - | - | - |
| - | Inspected | Other Feature | Merulana Feature | 779109 | 6623753 | Merulana | 16/10/2019 | - | - | - | - |

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mm - millimetres
L - Litres
mbTOC - metres below top of casing
maGL - metres above ground level
mbGL - metres below ground level
EST - Eastern Standard Time
L - Litres
uScm - microsiemens per centimetre
L/H - litres per hour

**Appendix A. Bore Census Database**

| ENRS ID | Year Drilled | DTW (mbTOC) | SWL (mbgl) | Time of Measurement | Time Since Pumping | Purpose | Pump Type | Power | Intake Depth | Pump Rate | Storage (L) | EC (µScm) | Temp | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2019081511 | 2007 | 90.76 | 89.886 | 3:07:00 PM | - | Monitoring | - | - | - | - | - | - | - | - |
| 2019081610 | 1965 | Dry | - | 1:43:00 PM | - | stock | - | - | - | - | - | - | - | - |
| 2019081508 | - | Dry | - | 11:30:00 AM | - | - | - | - | - | - | - | - | - | - |
| 2019101104 | 1979 | - | - | 8:40:00 AM | Pumping at time of measurement | Domestic | Submersable | Electric | 9.5 | - | - | 944.6 | 18.7 | 6.96 |
| 2019100902 | - | Dry | - | 7:30:00 AM | - | - | - | - | - | - | - | - | - | - |
| 2020052004 | - | - | - | 8:24:00 AM | 5 years | Irrigation | Screw | Diesel Engine | - | - | - | - | - | - |
| 2020052001 | - | - | - | 7:10:00 AM | - | Domestic | Submersable | Electric | - | - | 60000 | 89.2 | 16.7 | 7.9 |
| 2020051813 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2020051814 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2020051815 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2020052006 | - | - | - | 11:41:00 AM | - | Stock | Submersable | Electric | - | - | 30000 | 4788 | 21.9 | 7.06 |
| 2019100907 | 1999 | - | - | 10:56:00 AM | Pumping at time of measurement | Irrigation | Screw | Diesel | - | - | - | 1137 | 21.3 | 7.18 |
| 2019081501 | 1992 | - | - | 7:15:00 AM | 5 years | Stock | Screw | Diesel | - | - | - | - | - | - |
| 2019100908 | 1983 | - | - | 11:38:00 AM | Pumping at time of measurement | Irrigation | Screw | Electric | - | - | - | 532 | 21.2 | 7.21 |
| 2019100912 | 1986 | - | - | 2:38:00 PM | Pumping at time of measurement | Irrigation | Screw | Diesel | - | - | - | 2585 | 23.3 | 6.93 |
| 2019100913 | 1999 | - | - | 2:58:00 PM | Pumping at time of measurement | Irrigation | Screw | Diesel | - | - | - | 1306 | 23.4 | 7.19 |
| 2019100911 | 1986 | - | - | 2:21:00 PM | Pumping at time of measurement | Irrigation | Screw | Diesel | - | - | - | 5173 | 21.1 | 7.34 |
| 2020051908 | - | - | - | 3:20:00 PM | - | - | - | - | - | - | - | 143.9 | 21.9 | 8.8 |
| 2020051909 | - | - | - | 3:35:00 PM | - | - | - | - | - | - | - | 80 | 21.33 | 8.87 |
| 2020051910 | - | - | - | 4:00:00 PM | - | - | - | - | - | - | - | 68 | 19.5 | 8.77 |
| 2020051911 | - | - | - | 4:20:00 PM | - | - | - | - | - | - | - | 156 | 18.9 | 8.6 |
| 2020051912 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2020051913 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2020051914 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2020051915 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2020051916 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2019100914 | 1913 | - | - | 3:32:00 PM | - | - | - | - | - | - | - | - | - | - |
| 2019081510 | 1938 | Dry | - | 2:50:00 PM | - | - | - | - | - | - | - | - | - | - |
| 2020051903 | - | - | - | 11:22:00 AM | - | Stock | Piston | Windmill | - | - | 24000 | - | - | - |
| 2019081503 | 2013 | - | - | 8:21:00 AM | - | Monitoring | - | - | - | - | - | - | - | - |
| 2019081602 | - | - | - | 8:30:00 AM | - | Monitoring | - | - | - | - | - | - | - | - |
| 2019101006 | - | - | - | - | - | Monitoring | - | - | - | - | - | - | - | - |
| 2020052008 | - | - | - | 1:45:00 PM | - | - | - | - | - | - | - | - | - | - |
| 2020052009 | - | - | - | 2:20:00 PM | - | - | - | - | - | - | - | - | - | - |
| 2020052010 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2020052011 | - | - | - | 9:00:00 AM | - | - | - | - | - | - | - | 367 | 14.3 | 8.39 |
| 2020052012 | - | - | - | 9:50:00 AM | - | - | - | - | - | - | - | 121.9 | 14.9 | 8.48 |
| 2020052701 | - | - | - | 3:00:00 PM | - | - | - | - | - | - | - | - | - | - |
| - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| - | - | - | - | 12:00:00 PM | - | - | - | - | - | - | - | - | - | - |

m - metres
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L - Litres
mbTOC - metres below top of casing
maGL - metres above ground level
mbGL - metres below ground level
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L - Litres
uScm - microsiemens per centimetre
L/H - litres per hour

| ENRS ID | ORP (mV) | DO (mg/L) | Sample Source | Submitted for Analysis (Y/N) | Personnel |
|---|---|---|---|---|---|
| 2019081511 | - | - | - | No | MV + ML |
| 2019081610 | - | - | - | No | MV + ML |
| 2019081508 | - | - | - | No | MV + ML |
| 2019101104 | -37.7 | 4.65 | Tap | Yes | MV + ML |
| 2019100902 | - | - | - | No | MV + ML |
| 2020052004 | - | - | - | No | ML+MV |
| 2020052001 | 64.2 | 8.52 | Tank | Yes | ML+MV |
| 2020051813 | - | - | - | No | ML+MV |
| 2020051814 | - | - | - | No | ML+MV |
| 2020051815 | - | - | - | No | ML+MV |
| 2020052006 | 98.1 | 2.43 | Tap | Yes | ML+MV |
| 2019100907 | 81.2 | 4.26 | Discharge | Yes | MV + ML |
| 2019081501 | - | - | - | No | MV + ML |
| 2019100908 | 140.4 | 5.74 | Pivot | Yes | MV + ML |
| 2019100912 | 333 | 7.37 | Discharge | Yes | MV + ML |
| 2019100913 | 208 | 2.41 | Discharge | Yes | MV + ML |
| 2019100911 | 215 | 7.33 | Discharge | Yes | MV + ML |
| 2020051908 | 92.8 | 9.07 | Dam | Yes | ML+MV |
| 2020051909 | 100 | 10.57 | Dam | Yes | ML+MV |
| 2020051910 | 89 | 8.05 | Dam | Yes | ML+MV |
| 2020051911 | 104 | 12.23 | Dam | Yes | ML+MV |
| 2020051912 | - | - | - | No | ML+MV |
| 2020051913 | - | - | - | No | ML+MV |
| 2020051914 | - | - | - | No | ML+MV |
| 2020051915 | - | - | - | No | ML+MV |
| 2020051916 | - | - | - | No | ML+MV |
| 2019100914 | - | - | - | No | MV + ML |
| 2019081510 | - | - | - | No | MV + ML |
| 2020051903 | - | - | - | No | ML+MV |
| 2019081503 | - | - | - | No | MV + ML |
| 2019081602 | - | - | - | No | MV + ML |
| 2019101006 | - | - | - | No | SN + ML |
| 2020052008 | - | - | - | No | ML+MV |
| 2020052009 | - | - | - | No | ML+MV |
| 2020052010 | - | - | - | No | ML+MV |
| 2020052011 | - | - | Grab Sample | Yes | ML |
| 2020052012 | - | - | Grab Sample | Yes | ML |
| 2020052701 | - | - | Grab Sample | Yes | MV |
| - | - | - | - | No | MV + ML |
| - | - | - | - | No | MV |

m - metres
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L - Litres
mbTOC - metres below top of casing
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# Appendix B

## Bore Identification Cards

# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081501**

**SURVEY DATE:** 15/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Springfield | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW901842 |
| **Easting (GDA94 Zone 55):** | 784286 | **Northing:** | 6621266 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 45.5 | **Casing Stick Up (m Above Ground Level):** | 0.37 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | Stock |
| **Pump Type:** | Screw | **Power Source:** | Diesel |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 07:15 |
| **Approximate time since pumping:** | 5 Years | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Dip meter unable to pass 11m. Not used in 5 years. Depth from Government Log.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081503**

**SURVEY DATE:** 15/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Springfield | | |
| **Local Bore Name:** | Monitoring Bore | **Ref No/GW Number:** | GW273293 |
| **Easting (GDA94 Zone 55):** | 784102 | **Northing:** | 6622605 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | 1 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Monitoring |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 08:21 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Locked. Nested monitoring bore belonging to University of New England. Equipped with telemetry. Screened interval 14-15 m and 29-32 m.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081504**

**SURVEY DATE:** 15/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Springfield | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW901410 |
| **Easting (GDA94 Zone 55):** | 783828 | **Northing:** | 6622341 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 33.9 | **Casing Stick Up (m Above Ground Level):** | 0.34 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 232 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | Stock |
| **Pump Type:** | Screw | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 9.67 | **Time of Measurement:** | 08:50 |
| **Approximate time since pumping:** | 5 Years | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Bore not in use. Landholder claimed 25,000 GPh when drilled. Bore dried out shortly after installation, not used since.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081505**

**SURVEY DATE:** 15/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Springfield | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW059838 |
| **Easting (GDA94 Zone 55):** | 784275 | **Northing:** | 6621148 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 20 | **Casing Stick Up (m Above Ground Level):** | 0.755 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 150 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 10.56 | **Time of Measurement:** | 09:31 |

**Approximate time since pumping:** Pumping at time of measurement.

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 16.5 |
| **Electrical Conductivity (µS/cm):** | 1572 | **pH:** | 7.2 |

COMMENTS:

Dip meter unable to pass pump string. Depth from Government Log.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081506**

**SURVEY DATE:** 15/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Namoi View | | |
| **Local Bore Name:** | Windmill | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 781461 | **Northing:** | 6628198 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 11.6 | **Casing Stick Up (m Above Ground Level):** | 0.75 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 200 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Domestic |
| **Pump Type:** | Piston | **Power Source:** | Windmill |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 10.9 | **Time of Measurement:** | 10:30 |
| **Approximate time since pumping:** | 24 Hours | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 14.34 |
| **Electrical Conductivity (µS/cm):** | 756 | **pH:** | 7.94 |

COMMENTS:

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081507**

**SURVEY DATE:** **15/08/2019** **SURVEY PERSONNEL:** **MV + ML**

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Namoi View | | |
| **Local Bore Name:** | Submersable | **Ref No/GW Number:** | GW966352 |
| **Easting (GDA94 Zone 55):** | 781359 | **Northing:** | 6628242 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 13 | **Casing Stick Up (m Above Ground Level):** | 1.005 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Stock and domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | 3600L/h |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 11.52 | **Time of Measurement:** | 10:53 |
| **Approximate time since pumping:** | Pumping at time of measurement. | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 21.9 |
| **Electrical Conductivity (µS/cm):** | 640 | **pH:** | 6.8 |

COMMENTS:

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081508**

**SURVEY DATE:** **15/08/2019** **SURVEY PERSONNEL:** **MV + ML**

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Namoi View | | |
| **Local Bore Name:** | Dry Bore | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 781486 | **Northing:** | 6628145 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 6.1 | **Casing Stick Up (m Above Ground Level):** | 0.4 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | Dry | **Time of Measurement:** | 11:30 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Landholder stated that the bore has never been known to have had water.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081509**

**SURVEY DATE:** 15/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Red Hill | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW971254 |
| **Easting (GDA94 Zone 55):** | 773245 | **Northing:** | 6628719 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 68 | **Casing Stick Up (m Above Ground Level):** | 0.44 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Stock and domestic |
| **Pump Type:** | Submersable | **Power Source:** | Genset |
| **Pump Intake Depth (mBTOC):** | 66 | **Pump / Flow Rate:** | 1500L/h |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 52.86 | **Time of Measurement:** | 12:38 |
| **Approximate time since pumping:** | 24 Hours | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 21.84 |
| **Electrical Conductivity (µS/cm):** | 220 | **pH:** | 5.75 |

COMMENTS:

SWL 53.18mbTOC after ~500L purge. Driller reported SWL 68m at time of drilling.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081510**

**SURVEY DATE:** 15/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Irvine Acres | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW003623 |
| **Easting (GDA94 Zone 55):** | 772727 | **Northing:** | 6626728 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 91.34 | **Casing Stick Up (m Above Ground Level):** | 0.16 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 150 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | Dry | **Time of Measurement:** | 14:50 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Partial collapse. Reported as dry for 20 years.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081511**

**SURVEY DATE:** 15/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Moon Hill | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW968440 |
| **Easting (GDA94 Zone 55):** | 772725 | **Northing:** | 6626016 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 92.75 | **Casing Stick Up (m Above Ground Level):** | 0.874 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 50 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Monitoring |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 90.76 | **Time of Measurement:** | 15:07 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Unable to collect sample.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081512**

**SURVEY DATE:** 15/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Acacia Ridge | | |
| **Local Bore Name:** | New Bore | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 774986 | **Northing:** | 6630330 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 50.2 | **Casing Stick Up (m Above Ground Level):** | 0.655 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 24.64 | **Time of Measurement:** | 16:00 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 22.6 |
| **Electrical Conductivity (µS/cm):** | 8143 | **pH:** | 7.36 |

COMMENTS:

New bore. Driller reported as salty. Never used.

Water sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081601**

**SURVEY DATE:** 16/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Merrilong | | |
| **Local Bore Name:** | Mayfield Spring | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 775670 | **Northing:** | 6615617 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | 0 |
| **Casing Material:** | Wood | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Other feature | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 0 | **Time of Measurement:** | 08:00 |
| **Approximate time since pumping:** | Discharging at time of measurement. | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Spring | **Temp. (°C):** | 17.7 |
| **Electrical Conductivity (µS/cm):** | 5224 | **pH:** | 5.32 |

COMMENTS:

Sample Labelled 'Merrilong Seep'. Square wooden 'well head' constructed to utilise the seep. Slight trickle observed at headworks. Silty sand noted as the primary medium. No larger cobbles or outcrops present.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081602**

**SURVEY DATE:** 16/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Merrilong | | |
| **Local Bore Name:** | Unknown 1 | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 776274 | **Northing:** | 6614726 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | VWP | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Monitoring |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 08:30 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Fully grouted Vibrating Wire Piezometer. Logger S/N 06823. Data collected.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081603**

**SURVEY DATE:** 16/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Longsight | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW968435 |
| **Easting (GDA94 Zone 55):** | 776117 | **Northing:** | 6614693 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 51.64 | **Casing Stick Up (m Above Ground Level):** | 0.954 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 50 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Monitoring |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 21.483 | **Time of Measurement:** | 08:45 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 19.1 |
| **Electrical Conductivity (µS/cm):** | 4617 | **pH:** | 7.29 |

COMMENTS:

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081604**

**SURVEY DATE:** 16/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Longsight | | |
| **Local Bore Name:** | House Bore | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 776105 | **Northing:** | 6614120 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | 0.28 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | Stock and domestic |
| **Pump Type:** | Submersable | **Power Source:** | Solar |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 30.4 | **Time of Measurement:** | 09:40 |
| **Approximate time since pumping:** | 5 Years | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Standing Water Level taken from sonic gauge, as such may be base of well; landholder reports bore depth was 100 ft. Connected to solar pump.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081606**

**SURVEY DATE:** 16/08/2019 **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Mayfield | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW968633 |
| **Easting (GDA94 Zone 55):** | 774063 | **Northing:** | 6616446 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 131.3 | **Casing Stick Up (m Above Ground Level):** | 0.96 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 50 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Monitoring |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 23.24 | **Time of Measurement:** | 11:27 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 19.35 |
| **Electrical Conductivity (µS/cm):** | 11510 | **pH:** | 6.92 |

COMMENTS:

Too deep to acquire representative sample.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081607**

**SURVEY DATE:** 16/08/2019 **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Mayfield | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW968634 |
| **Easting (GDA94 Zone 55):** | 774066 | **Northing:** | 6616447 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 40.2 | **Casing Stick Up (m Above Ground Level):** | 0.97 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 50 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Monitoring |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 28.385 | **Time of Measurement:** | 11:30 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 20.15 |
| **Electrical Conductivity (µS/cm):** | 7508 | **pH:** | 7.2 |

COMMENTS:

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081609**

**SURVEY DATE:** 16/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Haylen Views | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW060976 |
| **Easting (GDA94 Zone 55):** | 776762 | **Northing:** | 6617358 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 28.35 | **Casing Stick Up (m Above Ground Level):** | 0.215 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 155 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 3.01 | **Time of Measurement:** | 13:00 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 21.9 |
| **Electrical Conductivity (µS/cm):** | 20900 | **pH:** | 8.39 |

COMMENTS:

Bore not equipped.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081610**

**SURVEY DATE:** 16/08/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Yarranabee | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW022596 |
| **Easting (GDA94 Zone 55):** | 776807 | **Northing:** | 6610415 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 1.25 | **Casing Stick Up (m Above Ground Level):** | 0.515 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | Dry | **Time of Measurement:** | 13:43 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Bore collapsed.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100901**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Darjeerling | | |
| **Local Bore Name:** | Darjeerling Well | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 777315 | **Northing:** | 6625379 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 2.2 | **Casing Stick Up (m Above Ground Level):** | 0.43 |
| **Casing Material:** | Wood | **Nominal Casing Diameter (mm):** | 1000 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | Stock |
| **Pump Type:** | Mobile Suction | **Power Source:** | Petrol |
| **Pump Intake Depth (mBTOC):** | Variable | **Pump / Flow Rate:** | 1800L/h |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 1.8 | **Time of Measurement:** | 07:17 |
| **Approximate time since pumping:** | 6 Months | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Reported to previously hold steady state at 30 L/min. Well significantly collapsed at 2.2 m. Not sampled due to presence of dead lamb in well.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100902**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Darjeerling | | |
| **Local Bore Name:** | Old Bore | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 776377 | **Northing:** | 6625331 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 14.5 | **Casing Stick Up (m Above Ground Level):** | 0.6 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | Dry | **Time of Measurement:** | 07:30 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Groundwater bore never used by landholder. Originally reported as salty.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100903**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Darjeerling | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW968438 |
| **Easting (GDA94 Zone 55):** | 777490 | **Northing:** | 6625553 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 31 | **Casing Stick Up (m Above Ground Level):** | 0.875 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 50 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Monitoring |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 18.09 | **Time of Measurement:** | 08:06 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 20.26 |
| **Electrical Conductivity (µS/cm):** | 27956 | **pH:** | 6.41 |

COMMENTS:

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100904**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Riverview | | |
| **Local Bore Name:** | Windmill Bore | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 779733 | **Northing:** | 6628836 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 20 | **Casing Stick Up (m Above Ground Level):** | 0.53 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Stock |
| **Pump Type:** | Suction | **Power Source:** | Petrol |
| **Pump Intake Depth (mBTOC):** | 19 | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 10.52 | **Time of Measurement:** | 08:30 |
| **Approximate time since pumping:** | 18 Hours | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 19.7 |
| **Electrical Conductivity (µS/cm):** | 1456 | **pH:** | 6.73 |

COMMENTS:

Land manager reports the water precipitates a black slime. Total depth from land manager.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100905**

**SURVEY DATE:** **9/10/2019** **SURVEY PERSONNEL:** **MV + ML**

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Riverview | | |
| **Local Bore Name:** | Irrigation Bore | **Ref No/GW Number:** | GW902579 |
| **Easting (GDA94 Zone 55):** | **779587** | **Northing:** | 6629491 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | 0.61 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Irrigation |
| **Pump Type:** | Submersable | **Power Source:** | Solar |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 10.61 | **Time of Measurement:** | 09:10 |

**Approximate time since pumping:** Pumping at time of measurement.

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 21 |
| **Electrical Conductivity (µS/cm):** | 676 | **pH:** | 7.02 |

COMMENTS:

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100906**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Greenhills | | |
| **Local Bore Name:** | House Bore | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 782571 | **Northing:** | 6621493 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | 1.21 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 8.09 | **Time of Measurement:** | 10:22 |

**Approximate time since pumping:** Pumping at time of measurement.

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 21.06 |
| **Electrical Conductivity (µS/cm):** | 4993 | **pH:** | 7.47 |

COMMENTS:

Only used for house supply.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100907**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Greenhills | | |
| **Local Bore Name:** | Irrigation Bore - West | **Ref No/GW Number:** | GW965354 |
| **Easting (GDA94 Zone 55):** | 784275 | **Northing:** | 6620313 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 44.5 | **Casing Stick Up (m Above Ground Level):** | 0.4 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Irrigation |
| **Pump Type:** | Screw | **Power Source:** | Diesel |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 10:56 |
| **Approximate time since pumping:** | Pumping at time of measurement. | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Discharge | **Temp. (°C):** | 21.3 |
| **Electrical Conductivity (µS/cm):** | 1137 | **pH:** | 7.18 |

COMMENTS:

Borehead Sealed. Depth from WaterNSW groundwater records. Equipped with diesel pump. No dipline. Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100908**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Greenhills | | |
| **Local Bore Name:** | Irrigation Bore - East | **Ref No/GW Number:** | GW053849 |
| **Easting (GDA94 Zone 55):** | 784687 | **Northing:** | 6620457 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 47.2 | **Casing Stick Up (m Above Ground Level):** | 0.58 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Irrigation |
| **Pump Type:** | Screw | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 11:38 |
| **Approximate time since pumping:** | Pumping at time of measurement. | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Pivot | **Temp. (°C):** | 21.2 |
| **Electrical Conductivity (µS/cm):** | 532 | **pH:** | 7.21 |

COMMENTS:

Borehead Sealed. Depth from WaterNSW groundwater records. Water sample collected from pivot.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100909**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Greenhills | | |
| **Local Bore Name:** | Cottage Bore | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 784426 | **Northing:** | 6620439 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | 0.42 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 11.08 | **Time of Measurement:** | 11:45 |

**Approximate time since pumping:** Pumping at time of measurement.

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 24.4 |
| **Electrical Conductivity (µS/cm):** | 1145 | **pH:** | 7.19 |

COMMENTS:

Only used for house supply. Pressure switch operated.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100910**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Riverstone | | |
| **Local Bore Name:** | House Supply | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 784253 | **Northing:** | 6617655 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | 1.02 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Solar |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 12.38 | **Time of Measurement:** | 01:46 |

**Approximate time since pumping:** Pumping at time of measurement.

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 21.7 |
| **Electrical Conductivity (µS/cm):** | 4118 | **pH:** | 6.68 |

COMMENTS:

Equipped with solar submersible pump.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100911**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Riverstone | | |
| **Local Bore Name:** | Irrigation Bore #1 | **Ref No/GW Number:** | GW060267 |
| **Easting (GDA94 Zone 55):** | 784505 | **Northing:** | 6617246 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 61 | **Casing Stick Up (m Above Ground Level):** | 0.2 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Irrigation |
| **Pump Type:** | Screw | **Power Source:** | Diesel |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 14:21 |
| **Approximate time since pumping:** | Pumping at time of measurement. | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Discharge | **Temp. (°C):** | 21.1 |
| **Electrical Conductivity (µS/cm):** | 5173 | **pH:** | 7.34 |

COMMENTS:

Borehead Sealed. Depth from WaterNSW groundwater records.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100912**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Riverstone | | |
| **Local Bore Name:** | Irrigation Bore #2 | **Ref No/GW Number:** | GW060422 |
| **Easting (GDA94 Zone 55):** | 784644 | **Northing:** | 6616816 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 52 | **Casing Stick Up (m Above Ground Level):** | 0.465 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Irrigation |
| **Pump Type:** | Screw | **Power Source:** | Diesel |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 14:38 |
| **Approximate time since pumping:** | Pumping at time of measurement. | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Discharge | **Temp. (°C):** | 23.3 |
| **Electrical Conductivity (µS/cm):** | 2585 | **pH:** | 6.93 |

COMMENTS:

Borehead Sealed. Depth from WaterNSW groundwater records

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100913**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Riverstone | | |
| **Local Bore Name:** | Irrigation Bore #3 | **Ref No/GW Number:** | GW965964 |
| **Easting (GDA94 Zone 55):** | 784058 | **Northing:** | 6618526 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 53 | **Casing Stick Up (m Above Ground Level):** | 0.62 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Irrigation |
| **Pump Type:** | Screw | **Power Source:** | Diesel |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 14:58 |
| **Approximate time since pumping:** | Pumping at time of measurement. | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Discharge | **Temp. (°C):** | 23.4 |
| **Electrical Conductivity (µS/cm):** | 1306 | **pH:** | 7.19 |

COMMENTS:

Borehead Sealed. Depth from WaterNSW groundwater records.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100914**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Yarranabee | | |
| **Local Bore Name:** | Windmill #2 | **Ref No/GW Number:** | GW005094 |
| **Easting (GDA94 Zone 55):** | 777472 | **Northing:** | 6611082 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 67 | **Casing Stick Up (m Above Ground Level):** | 0.81 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 130 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 15:32 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Plate welded onto standpipe; unable to get access to groundwater bore. Windmill recirculating water from dam.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100915**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Yarranabee | | |
| **Local Bore Name:** | Yarranabee Dam #1 | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 774935.68 | **Northing:** | 6612839.09 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not a groundwater feature | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 16:08 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Dam | **Temp. (°C):** | 22.6 |
| **Electrical Conductivity (µS/cm):** | 318 | **pH:** | 7.79 |

COMMENTS:

Feature thought to be a potential groundwater feature now identified as Yarranabee Dam. No observable flow. Visible geology: SANDY SILT (medium) with some medium gravel (fine sandstone and coarse conglomerate).

Water sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019100916**

**SURVEY DATE:** 9/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Yarranabee | | |
| **Local Bore Name:** | Yarranabee Dam #2 | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 776014 | **Northing:** | 6613131 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Other feature | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 16:40 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Dam | **Temp. (°C):** | 24 |
| **Electrical Conductivity (µS/cm):** | 338 | **pH:** | 8.11 |

COMMENTS:

Noted as Feature of Interest 3. No observable flow. Visible geology: SILTY SAND (medium) with some coarse gravel and cobbles (fine sandstone).

Water sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101001**

**SURVEY DATE:** 10/10/2019 **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Whispering Pines | | |
| **Local Bore Name:** | House Bore | **Ref No/GW Number:** | GW003599 |
| **Easting (GDA94 Zone 55):** | 769114 | **Northing:** | 6630381 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 60 | **Casing Stick Up (m Above Ground Level):** | 0.37 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | 54 | **Pump / Flow Rate:** | 3360L/h |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 42.14 | **Time of Measurement:** | 07:30 |
| **Approximate time since pumping:** | 12 Hours | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 20.9 |
| **Electrical Conductivity (µS/cm):** | 219 | **pH:** | 6.11 |

COMMENTS:

Land manager reported the standing water level in was 2009 41 mbTOC. Total depth from land manager.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101002**

**SURVEY DATE:** 10/10/2019 **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Hosanna | | |
| **Local Bore Name:** | Bore | **Ref No/GW Number:** | GW068591 |
| **Easting (GDA94 Zone 55):** | 771693 | **Northing:** | 6629488 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 54.9 | **Casing Stick Up (m Above Ground Level):** | 0.18 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | 55 | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 39.58 | **Time of Measurement:** | 09:18 |
| **Approximate time since pumping:** | 1 Hour | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 19.8 |
| **Electrical Conductivity (µS/cm):** | 153 | **pH:** | 5.89 |

COMMENTS:

Some iron floc present. Total depth from land manager.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101003**

**SURVEY DATE:** 10/10/2019 **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Jacks Creek State Forest | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW968441 |
| **Easting (GDA94 Zone 55):** | 769001 | **Northing:** | 6624344 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 90.61 | **Casing Stick Up (m Above Ground Level):** | 0.93 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 50 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Monitoring |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 64.33 | **Time of Measurement:** | 10:44 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 21.6 |
| **Electrical Conductivity (µS/cm):** | 163 | **pH:** | 5.44 |

COMMENTS:

Bore head not locked - Casing damaged. Retrieved groundwater visually noted to have high suspended solids.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101006**

**SURVEY DATE:** 10/10/2019 **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Pilliga State Forest | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW273315 |
| **Easting (GDA94 Zone 55):** | 771146 | **Northing:** | 6618793 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | 0.9 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Monitoring |
| **Pump Type:** | | **Power Source:** | |
| **Pump Intake Depth (mBTOC):** | | **Pump / Flow Rate:** | |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | | **Time of Measurement:** | 00:00 |
| **Approximate time since pumping:** | | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | | **Temp. (°C):** | |
| **Electrical Conductivity (µS/cm):** | | **pH:** | |

COMMENTS:

Locked monument.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101007**

**SURVEY DATE:** 10/10/2019 **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Pilliga State Forest | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW968631 |
| **Easting (GDA94 Zone 55):** | 772698 | **Northing:** | 6618426 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 63.3 | **Casing Stick Up (m Above Ground Level):** | 0.86 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 50 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Monitoring |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 51.47 | **Time of Measurement:** | 12:19 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 23 |
| **Electrical Conductivity (µS/cm):** | 698 | **pH:** | 6.48 |

COMMENTS:

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101008**

**SURVEY DATE:** 10/10/2019 **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Pilliga State Forest | | |
| **Local Bore Name:** | Unknown 2 | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 772695 | **Northing:** | 6618428 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 154 | **Casing Stick Up (m Above Ground Level):** | 0.48 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 100 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Exploration |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 45.945 | **Time of Measurement:** | 12:21 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 20.7 |
| **Electrical Conductivity (µS/cm):** | 74 | **pH:** | 7.06 |

COMMENTS:

Possible exploration bore hole. Water column potentially heavily stratified.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101009**

**SURVEY DATE:** 10/10/2019 **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Wilga | | |
| **Local Bore Name:** | Bore | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 780874 | **Northing:** | 6617836 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | 0.81 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 150 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Stock |
| **Pump Type:** | Pneumatic | **Power Source:** | Compressor |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 58 | **Time of Measurement:** | 13:46 |

**Approximate time since pumping:** Pumping at time of measurement.

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 24.7 |
| **Electrical Conductivity (µS/cm):** | 14217 | **pH:** | 6.37 |

COMMENTS:

New groundwater bore. Driller reported as salty and advised landholder to develop to improve water quality.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101012**

**SURVEY DATE:** 10/10/2019 **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Longsight | | |
| **Local Bore Name:** | Longsight Dam #1 | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 774353 | **Northing:** | 6613824 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not a groundwater feature | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 15:13 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Dam | **Temp. (°C):** | 25.8 |
| **Electrical Conductivity (µS/cm):** | 156 | **pH:** | 7.97 |

COMMENTS:

No observable flow/seepage. Silty sand (medium/coarse) with some medium gravel (medium sandstone). Water appears turbid.

Water sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101013**

**SURVEY DATE:** 10/10/2019 **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Longsight | | |
| **Local Bore Name:** | Longsight Dam #2 | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 774916 | **Northing:** | 6614015 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not a groundwater feature | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 15:30 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Dam | **Temp. (°C):** | 24.2 |
| **Electrical Conductivity (µS/cm):** | 384 | **pH:** | 8.71 |

COMMENTS:

No observable flow/seepage. Silty sand (medium) with trace medium gravel (medium sandstone). Water turbid with algae.

Water sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101101**

**SURVEY DATE:** 11/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Vallhalla | | |
| **Local Bore Name:** | House Bore | **Ref No/GW Number:** | GW044923 |
| **Easting (GDA94 Zone 55):** | 779575 | **Northing:** | 6630314 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 23.5 | **Casing Stick Up (m Above Ground Level):** | 0.36 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 150 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | 16 | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 9.56 | **Time of Measurement:** | 06:40 |
| **Approximate time since pumping:** | Pumping at time of measurement. | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 18.5 |
| **Electrical Conductivity (µS/cm):** | 733 | **pH:** | 7.04 |

COMMENTS:

For garden supply.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101102**

**SURVEY DATE:** 11/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Vallhalla | | |
| **Local Bore Name:** | Irrigation | **Ref No/GW Number:** | GW070534 |
| **Easting (GDA94 Zone 55):** | 779567 | **Northing:** | 6630770 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 41.5 | **Casing Stick Up (m Above Ground Level):** | 0.54 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 203 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In use | **Purpose:** | Irrigation |
| **Pump Type:** | Screw | **Power Source:** | Diesel |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 8.69 | **Time of Measurement:** | 07:17 |
| **Approximate time since pumping:** | 3 Years | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Not used in 3 years. Pump not functional.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101103**

**SURVEY DATE:** 11/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Vallhalla | | |
| **Local Bore Name:** | Windmill | **Ref No/GW Number:** | GW005294 |
| **Easting (GDA94 Zone 55):** | 779489 | **Northing:** | 6630808 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 12 | **Casing Stick Up (m Above Ground Level):** | 0.33 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Stock |
| **Pump Type:** | Piston | **Power Source:** | Windmill |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 7.76 | **Time of Measurement:** | 07:25 |
| **Approximate time since pumping:** | 12 Hours | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tank | **Temp. (°C):** | 20 |
| **Electrical Conductivity (µS/cm):** | 734 | **pH:** | 7.33 |

COMMENTS:

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101104**

**SURVEY DATE:** 11/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Mullah | | |
| **Local Bore Name:** | House Bore | **Ref No/GW Number:** | GW050214 |
| **Easting (GDA94 Zone 55):** | 778284 | **Northing:** | 6631347 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 10 | **Casing Stick Up (m Above Ground Level):** | 0.55 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | 9.5 | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 08:40 |
| **Approximate time since pumping:** | Pumping at time of measurement. | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 18.7 |
| **Electrical Conductivity (µS/cm):** | 944.6 | **pH:** | 6.96 |

COMMENTS:

Bore not accessable due to pump. Depth and pump placement from landholder.

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101105**

**SURVEY DATE:** 11/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Mullah | | |
| **Local Bore Name:** | Shearing Shed | **Ref No/GW Number:** | GW029220 |
| **Easting (GDA94 Zone 55):** | 778032 | **Northing:** | 6630936 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 11.72 | **Casing Stick Up (m Above Ground Level):** | 0.18 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | Windmill |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 8.46 | **Time of Measurement:** | 08:51 |
| **Approximate time since pumping:** | 5 Years | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 20.1 |
| **Electrical Conductivity (µS/cm):** | 889 | **pH:** | 6.95 |

COMMENTS:

Windmill not connected.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101106**

**SURVEY DATE:** 11/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Mullah | | |
| **Local Bore Name:** | Cement Tank | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 778566 | **Northing:** | 6630340 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 28.4 | **Casing Stick Up (m Above Ground Level):** | 0.5 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Stock |
| **Pump Type:** | Piston | **Power Source:** | Windmill |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 9.115 | **Time of Measurement:** | 09:15 |
| **Approximate time since pumping:** | 18 Hours | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tank | **Temp. (°C):** | 19.4 |
| **Electrical Conductivity (µS/cm):** | 685 | **pH:** | 7.23 |

COMMENTS:

Sampled taken from tank. Tank has no top (open).

Groundwater sample taken.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101107**

**SURVEY DATE:** 11/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Claremont | | |
| **Local Bore Name:** | WB2 | **Ref No/GW Number:** | GW966839 |
| **Easting (GDA94 Zone 55):** | 776449 | **Northing:** | 6619822 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 30 | **Casing Stick Up (m Above Ground Level):** | 0.43 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Stock |
| **Pump Type:** | Suction | **Power Source:** | Petrol |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 14.81 | **Time of Measurement:** | 11:41 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Previously sampled by Australian Laboratory Solutions (ALS) on 17/09/2019 (results not supplied). Depth from WaterNSW groundwater records. Dip meter unable to pass 14.94 mbTOC.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101108**

**SURVEY DATE:** 11/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | WHC Land | | |
| **Local Bore Name:** | WB9 | **Ref No/GW Number:** | No Registered Groundwater Number |
| **Easting (GDA94 Zone 55):** | 776556 | **Northing:** | 6621162 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 31.15 | **Casing Stick Up (m Above Ground Level):** | 0.495 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | Windmill |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 30.98 | **Time of Measurement:** | 11:56 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Bore partially collapsed, unable to sample. Windmill not functional.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101109**

**SURVEY DATE:** 11/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | WHC Land | | |
| **Local Bore Name:** | WB1 | **Ref No/GW Number:** | GW017215 |
| **Easting (GDA94 Zone 55):** | 777253 | **Northing:** | 6622762 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 167.6 | **Casing Stick Up (m Above Ground Level):** | 0.29 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not in use | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 48.3 | **Time of Measurement:** | 12:15 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 22.3 |
| **Electrical Conductivity (µS/cm):** | 11211 | **pH:** | 6.69 |

COMMENTS:

Depth from WaterNSW groundwater records. Field measured depth 58.4 mbTOC. WaterNSW groundwater record might be recorded in feet.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081502_1**

**SURVEY DATE:** **15/08/2019** **SURVEY PERSONNEL:** **MV + ML**

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Springfield | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW273294 - shallow |
| **Easting (GDA94 Zone 55):** | 784032 | **Northing:** | 6622561 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 13 | **Casing Stick Up (m Above Ground Level):** | 1.05 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 50 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In use | **Purpose:** | Monitoring |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 8.838 | **Time of Measurement:** | 08:00 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 18.11 |
| **Electrical Conductivity (µS/cm):** | 923.6 | **pH:** | 6.73 |

COMMENTS:

Screened 8-11 m. Nested monitoring bores belonging to University of New England. Groundwater bore quipped with telemetry.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081502_2**

**SURVEY DATE:** **15/08/2019** **SURVEY PERSONNEL:** **MV + ML**

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Springfield | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW273294 |
| **Easting (GDA94 Zone 55):** | **784032** | **Northing:** | 6622561 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 25.82 | **Casing Stick Up (m Above Ground Level):** | 1.05 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 75 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Monitoring |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 9.057 | **Time of Measurement:** | 08:00 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | bailer | **Temp. (°C):** | 18.5 |
| **Electrical Conductivity (µS/cm):** | 905.6 | **pH:** | 7.13 |

COMMENTS:

Screened 21-24m. Nested monitoring bores belonging to UNE. Equipped with telemetry

## PHOTOGRAPHIC RECORD



**GROUNDWATER BORE REPORT CARD**

| **BORE ID:** | **Mayfield Feature 1** |
|---|---|

**SURVEY DATE:** 10/10/2019 **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Longsight | | |
| **Local Bore Name:** | Mayfield Feature 1 | **Ref No/GW Number:** | Mayfield Feature 1 |
| **Easting (GDA94 Zone 55):** | 774630 | **Northing:** | 6613917 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | |
|---|---|
| **Depth (m Below Top of Casing):** | **Casing Stick Up (m Above Ground Level):** |
| **Casing Material:** | **Nominal Casing Diameter (mm):** |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not a groundwater feature | **Purpose:** | |
| **Pump Type:** | | **Power Source:** | |
| **Pump Intake Depth (mBTOC):** | | **Pump / Flow Rate:** | |

## WATER LEVEL INFORMATION

| | |
|---|---|
| **Depth to Water (mBTOC):** | **Time of Measurement:** - |
| **Approximate time since pumping:** | |

## WATER QUALITY

| | |
|---|---|
| **Sample Method:** | **Temp. (°C):** |
| **Electrical Conductivity (µS/cm):** | **pH:** |

COMMENTS:

Feature Inspected - confirmed not a groundwater feature. Slight natural drainage depression which is dammed on either end (refer to Longsight Dam #1 and Longsight Dam #2).

## PHOTOGRAPHIC RECORD

No Photograph Available

**GROUNDWATER BORE REPORT CARD**

| **BORE ID:** | **Merulana Feature** |
|---|---|

**SURVEY DATE:** 16/10/2019 **SURVEY PERSONNEL:** MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Merulana | | |
| **Local Bore Name:** | Merulana Feature | **Ref No/GW Number:** | Merulana Feature |
| **Easting (GDA94 Zone 55):** | 779109.28 | **Northing:** | 6623752.79 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | |
|---|---|
| **Depth (m Below Top of Casing):** | **Casing Stick Up (m Above Ground Level):** |
| **Casing Material:** | **Nominal Casing Diameter (mm):** |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Other feature | **Purpose:** | |
| **Pump Type:** | | **Power Source:** | |
| **Pump Intake Depth (mBTOC):** | | **Pump / Flow Rate:** | |

## WATER LEVEL INFORMATION

| | |
|---|---|
| **Depth to Water (mBTOC):** | **Time of Measurement:** **12:00:00 AM** |
| **Approximate time since pumping:** | |

## WATER QUALITY

| | |
|---|---|
| **Sample Method:** | **Temp. (°C):** |
| **Electrical Conductivity (µS/cm):** | **pH:** |

COMMENTS:

Feature Inspected by NCOPL personell visually - confirmed to not be a groundwater feature.

Dry at the time of inspection and the landholder noted that it does not always contain surface water.

## PHOTOGRAPHIC RECORD

# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051903**

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW028468 |
| **Easting (GDA94 Zone 55):** | 775263 | **Northing:** | 6596017 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 125.8 | **Casing Stick Up (m Above Ground Level):** | 0.71 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In Use | **Purpose:** | Stock |
| **Pump Type:** | Piston | **Power Source:** | Windmill |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 11:22 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Bore depth obtained from government record. Borehead sealed. Windmill not engaged. Storage tank empty.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051904**

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | Windmill | **Ref No/GW Number:** | GW020611 |
| **Easting (GDA94 Zone 55):** | 775950 | **Northing:** | 6594595 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 137.1 | **Casing Stick Up (m Above Ground Level):** | 0.42 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In Use | **Purpose:** | Stock |
| **Pump Type:** | Piston | **Power Source:** | Windmill |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 29.24 | **Time of Measurement:** | 11:55 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Bore depth obtained from government record. Borehead closed. Windmill in poor condition.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051905**

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW019223 |
| **Easting (GDA94 Zone 55):** | 776983 | **Northing:** | 6593938 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 82 | **Casing Stick Up (m Above Ground Level):** | 0.44 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In Use | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 12.38 | **Time of Measurement:** | 13:08 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 22.4 |
| **Electrical Conductivity (µS/cm):** | 4641 | **pH:** | 7.63 |

COMMENTS:

Bore not equiped. Formerly windmill.

## PHOTOGRAPHIC RECORD



## GROUNDWATER BORE REPORT CARD

| BORE ID: | 2020051912 |
|---|---|

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

### LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | A. Bore 1 | **Ref No/GW Number:** | |
| **Easting (GDA94 Zone 55):** | 777847 | **Northing:** | 6600507 |

### BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

### WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Assumed In Use | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

### WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

### WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Coordinates approximate as bore Indicated on map by Land Manager. Unable to locate bore.

### PHOTOGRAPHIC RECORD

**GROUNDWATER BORE REPORT CARD**

| **BORE ID:** | **2020051915** |
|---|---|

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW011261 |
| **Easting (GDA94 Zone 55):** | 777362 | **Northing:** | 6595430 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Bore destroyed by land owner.

## PHOTOGRAPHIC RECORD

**GROUNDWATER BORE REPORT CARD**

| **BORE ID:** | **2020051916** |
|---|---|

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW006605 |
| **Easting (GDA94 Zone 55):** | 777165 | **Northing:** | 6595004 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Land owner confirms no bore present.

## PHOTOGRAPHIC RECORD

# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051806**

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Delwood Downs | | |
| **Local Bore Name:** | Delwood House Bore | **Ref No/GW Number:** | GW006454 |
| **Easting (GDA94 Zone 55):** | 768405 | **Northing:** | 6594152 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 49.6 | **Casing Stick Up (m Above Ground Level):** | 0.4 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Stock and Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | 30.5 | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 11.1 | **Time of Measurement:** | 13:18 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Bore depth obtained from government record. House currently using rainwater. Taps closed and pump not able to be operated.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051808**

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Delwood Downs | | |
| **Local Bore Name:** | Solar | **Ref No/GW Number:** | |
| **Easting (GDA94 Zone 55):** | 769617 | **Northing:** | 6595118 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | 0.48 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Stock |
| **Pump Type:** | Submersable | **Power Source:** | Solar |
| **Pump Intake Depth (mBTOC):** | 45.72 | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 23.18 | **Time of Measurement:** | 15.13 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Land Manager reports poor water quality. Solar pump not able to be activated.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051809**

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Delwood Downs | | |
| **Local Bore Name:** | Windmill | **Ref No/GW Number:** | GW002732 |
| **Easting (GDA94 Zone 55):** | 771011 | **Northing:** | 6593723 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 30 | **Casing Stick Up (m Above Ground Level):** | 0.68 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 150 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Stock |
| **Pump Type:** | Piston | **Power Source:** | Windmill |
| **Pump Intake Depth (mBTOC):** | 24.3 | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 8.19 | **Time of Measurement:** | 15:40 |
| **Approximate time since pumping:** | Pumping at time of measurement | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 16.39 |
| **Electrical Conductivity (µS/cm):** | 5891 | **pH:** | 7.92 |

COMMENTS:

Bore depth obtained from government record.

## PHOTOGRAPHIC RECORD



**GROUNDWATER BORE REPORT CARD**

| **BORE ID:** | **2020051813** |
|---|---|

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Delwood Downs | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW002683 |
| **Easting (GDA94 Zone 55):** | 771271 | **Northing:** | 6595648 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Location in cultivated field. Land owner confirmed not groundwater bore is not present.

## PHOTOGRAPHIC RECORD

# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020052001**

**SURVEY DATE:** **20/5/2020** **SURVEY PERSONNEL:** **ML+MV**

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Kentucky | | |
| **Local Bore Name:** | Kentucky House | **Ref No/GW Number:** | GW029262 |
| **Easting (GDA94 Zone 55):** | 774670 | **Northing:** | 6631085 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 33.5 | **Casing Stick Up (m Above Ground Level):** | 0.34 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 125 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 7:10 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tank | **Temp. (°C):** | 16.7 |
| **Electrical Conductivity (µS/cm):** | 89.2 | **pH:** | 7.9 |

COMMENTS:

Recently redrilled as orignial bore had colapsed. Land owner reports that at time of drilling bore depth 110 ft and DTW 85 ft. Sample collected from holding tank.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020052002**

**SURVEY DATE:** 20/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Kentucky | | |
| **Local Bore Name:** | Windmill | **Ref No/GW Number:** | GW029261 |
| **Easting (GDA94 Zone 55):** | 774721 | **Northing:** | 6631155 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 30.4 | **Casing Stick Up (m Above Ground Level):** | 0.3 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 163 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In Use | **Purpose:** | Stock and Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 13.01 | **Time of Measurement:** | 7:23 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 18.6 |
| **Electrical Conductivity (µS/cm):** | 1027 | **pH:** | 7.82 |

COMMENTS:

Pump not currently deployed.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020052003**

**SURVEY DATE:** 20/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Kentucky | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW067919 |
| **Easting (GDA94 Zone 55):** | 774820 | **Northing:** | 6631314 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 39.6 | **Casing Stick Up (m Above Ground Level):** | 0.72 |
| **Casing Material:** | PVC | **Nominal Casing Diameter (mm):** | 150 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In Use | **Purpose:** | Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 10.24 | **Time of Measurement:** | 8:08 |
| **Approximate time since pumping:** | 5 years | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Bore depth obtained from government record. Bore reported as partially collapsed. Water quality reported to be 'sour' 5-10 years prior, noting of strong sulphur odour. Pump not operational.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020052004**

**SURVEY DATE:** 20/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Kentucky | | |
| **Local Bore Name:** | Irrigation Bore | **Ref No/GW Number:** | GW901138 |
| **Easting (GDA94 Zone 55):** | 775317 | **Northing:** | 6632125 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 22 | **Casing Stick Up (m Above Ground Level):** | 0.34 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Irrigation |
| **Pump Type:** | Screw | **Power Source:** | Diesel Engine |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 8:24 |
| **Approximate time since pumping:** | 5 years | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Bore depth obtained from government record. Borehead sealed. Pump not operational currently, but equipped and able to be used.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020052006**

**SURVEY DATE:** 20/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Nindethena | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW013858 |
| **Easting (GDA94 Zone 55):** | 774254 | **Northing:** | 6603250 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 33.5 | **Casing Stick Up (m Above Ground Level):** | 0.2 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Stock |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 11:41 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 21.9 |
| **Electrical Conductivity (µS/cm):** | 4788 | **pH:** | 7.06 |

COMMENTS:

Bore depth obtained from government record. Borehead sealed.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020052007**

**SURVEY DATE:** 20/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Nindethena | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW026121 |
| **Easting (GDA94 Zone 55):** | 773126 | **Northing:** | 6603421 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 20.1 | **Casing Stick Up (m Above Ground Level):** | 0.28 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In Use | **Purpose:** | Stock |
| **Pump Type:** | Screw | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 11.98 | **Time of Measurement:** | 12:36 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Bore depth obtained from goverment record. Borehead closed.

## PHOTOGRAPHIC RECORD



## GROUNDWATER BORE REPORT CARD

| BORE ID: | 2020052008 |
|---|---|

**SURVEY DATE:** 20/5/2020 **SURVEY PERSONNEL:** ML+MV

### LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Nindethena | | |
| **Local Bore Name:** | Hardys Spring #1 | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 771588 | **Northing:** | 6604095 |

### BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

### WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Other Feature | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

### WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 13:45 |
| **Approximate time since pumping:** | - | | |

### WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Area investigated. No feature identified as present. Land owner not aware of spring at this location.

### PHOTOGRAPHIC RECORD

# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020052009**

**SURVEY DATE:** **20/5/2020** **SURVEY PERSONNEL:** **ML+MV**

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Nindethena | | |
| **Local Bore Name:** | Hardys Spring #2 | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 770726 | **Northing:** | 6604763 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Potential Groundwater Feature | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 14:20 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

No surface flows or visable seepage. Drainage channel with vibrant green grass. Soils characterised by silty sand (medium). Ground moist. Not know to flow for 10 years.

## PHOTOGRAPHIC RECORD



## GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020052010**

**SURVEY DATE:** **20/5/2020** **SURVEY PERSONNEL:** **ML+MV**

### LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Nindethena | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW013851 |
| **Easting (GDA94 Zone 55):** | 771818 | **Northing:** | 6603586 |

### BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

### WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In Use | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

### WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

### WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Area investigated. No bore present at registered coordinates. Land owner not aware of bore at this location, but gave directions to actual bore. Unable to locate bore at revised coordinates. Landholder advised bore not in use.

### PHOTOGRAPHIC RECORD

# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051810**

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | South End | | |
| **Local Bore Name:** | Well | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 771387 | **Northing:** | 6593513 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 22.3 | **Casing Stick Up (m Above Ground Level):** | 0.2 |
| **Casing Material:** | Concrete | **Nominal Casing Diameter (mm):** | 1200 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Stock and Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Solar |
| **Pump Intake Depth (mBTOC):** | 19.2 | **Pump / Flow Rate:** | 45L/min |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 8.86 | **Time of Measurement:** | 16:23 |
| **Approximate time since pumping:** | 2 weeks | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 22 |
| **Electrical Conductivity (µS/cm):** | 6031 | **pH:** | 7.2 |

COMMENTS:

Land Manager depth 103 ft. Concrete cased 0 to 8 mbGL, timbers below. New solar pump. Only ~50 L purged.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051811**

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | South End | | |
| **Local Bore Name:** | Richardson's | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 772725 | **Northing:** | 6595906 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 63 | **Casing Stick Up (m Above Ground Level):** | 0.57 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In Use | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 14.8 | **Time of Measurement:** | 17:02 |
| **Approximate time since pumping:** | 40 years | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 21.6 |
| **Electrical Conductivity (µS/cm):** | 1598 | **pH:** | 9.05 |

COMMENTS:

Not used since early 80's. Land owner developed bore 12 months prior.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051812**

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | South End | | |
| **Local Bore Name:** | Neales | **Ref No/GW Number:** | GW006712 |
| **Easting (GDA94 Zone 55):** | 771939 | **Northing:** | 6595685 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 8.3 | **Casing Stick Up (m Above Ground Level):** | 0.23 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In Use | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | Dry | **Time of Measurement:** | 17:32 |
| **Approximate time since pumping:** | Never Used | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Never been equiped. Bore collapsed.

## PHOTOGRAPHIC RECORD



## GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051814**

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

### LOCATION AND GROUNDWATER WORKS NUMBER

| | |
|---|---|
| **Property Name:** South End | |
| **Local Bore Name:** - | **Ref No/GW Number:** GW967834 |
| **Easting (GDA94 Zone 55):** 773336 | **Northing:** 6594954 |

### BORE CONSTRUCTION DETAILS (SUMMARY)

| | |
|---|---|
| **Depth (m Below Top of Casing):** - | **Casing Stick Up (m Above Ground Level):** - |
| **Casing Material:** - | **Nominal Casing Diameter (mm):** - |

### WATER USAGE AND PUMPING DETAILS

| | |
|---|---|
| **Status:** Not Present | **Purpose:** - |
| **Pump Type:** - | **Power Source:** - |
| **Pump Intake Depth (mBTOC):** - | **Pump / Flow Rate:** - |

### WATER LEVEL INFORMATION

| | |
|---|---|
| **Depth to Water (mBTOC):** - | **Time of Measurement:** - |
| **Approximate time since pumping:** - | |

### WATER QUALITY

| | |
|---|---|
| **Sample Method:** - | **Temp. (°C):** - |
| **Electrical Conductivity (µS/cm):** - | **pH:** - |

COMMENTS:

Land owner reports bore was a shallow piezometer assessing salinity. No longer present.

### PHOTOGRAPHIC RECORD

**GROUNDWATER BORE REPORT CARD**

**BORE ID:** **2020051815**

**SURVEY DATE:** **18/5/2020** **SURVEY PERSONNEL:** **ML+MV**

## LOCATION AND GROUNDWATER WORKS NUMBER

| | |
|---|---|
| **Property Name:** South End | |
| **Local Bore Name:** - | **Ref No/GW Number:** GW016336 |
| **Easting (GDA94 Zone 55):** 773623 | **Northing:** 6593924 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | |
|---|---|
| **Depth (m Below Top of Casing):** - | **Casing Stick Up (m Above Ground Level):** - |
| **Casing Material:** - | **Nominal Casing Diameter (mm):** - |

## WATER USAGE AND PUMPING DETAILS

| | |
|---|---|
| **Status:** Not Present | **Purpose:** - |
| **Pump Type:** - | **Power Source:** - |
| **Pump Intake Depth (mBTOC):** - | **Pump / Flow Rate:** - |

## WATER LEVEL INFORMATION

| | |
|---|---|
| **Depth to Water (mBTOC):** - | **Time of Measurement:** - |
| **Approximate time since pumping:** - | |

## WATER QUALITY

| | |
|---|---|
| **Sample Method:** - | **Temp. (°C):** - |
| **Electrical Conductivity (µS/cm):** - | **pH:** - |

COMMENTS:

Land owner confirms no such bore present.

## PHOTOGRAPHIC RECORD

# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051901**

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | South End | | |
| **Local Bore Name:** | Sweet Water Bore | **Ref No/GW Number:** | GW008634 |
| **Easting (GDA94 Zone 55):** | 772927 | **Northing:** | 6597093 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 68 | **Casing Stick Up (m Above Ground Level):** | 0 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In Use | **Purpose:** | Stock |
| **Pump Type:** | Piston | **Power Source:** | Windmill |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 7.9 | **Time of Measurement:** | 9:38 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 21.2 |
| **Electrical Conductivity (µS/cm):** | 435 | **pH:** | 8.51 |

COMMENTS:

Windmill not in use/pump rods out of bore. Casing below ground level. Land owner developed bore 12 months prior.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051902**

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | South End | | |
| **Local Bore Name:** | Plums Block | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 771484 | **Northing:** | 6596438 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 61.5 | **Casing Stick Up (m Above Ground Level):** | 0.16 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In Use | **Purpose:** | Stock |
| **Pump Type:** | Venturi | **Power Source:** | Firefighting Pump |
| **Pump Intake Depth (mBTOC):** | 55 | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 18.46 | **Time of Measurement:** | 10:44 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 22.2 |
| **Electrical Conductivity (µS/cm):** | 3414 | **pH:** | 8 |

COMMENTS:

Planned to be equiped in near future with solar pump.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051906**

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW008847 |
| **Easting (GDA94 Zone 55):** | 776179 | **Northing:** | 6599045 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 51.3 | **Casing Stick Up (m Above Ground Level):** | 0.44 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 140 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Stock |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 26.81 | **Time of Measurement:** | 13:54 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Bailer | **Temp. (°C):** | 22.2 |
| **Electrical Conductivity (µS/cm):** | 7,513 | **pH:** | 7.06 |

COMMENTS:

Not currently equiped. Land owner reports bore as a 'good' bore.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051907**

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | House Bore | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 772678 | **Northing:** | 6601496 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | 0.22 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Stock and Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Electric |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 23.03 | **Time of Measurement:** | 14:35 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tank | **Temp. (°C):** | 19.1 |
| **Electrical Conductivity (µS/cm):** | 513 | **pH:** | 8.62 |

COMMENTS:

Sample collected from open top tank. Bore sample tap not able to be used.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051908**

**SURVEY DATE:** **19/5/2020** **SURVEY PERSONNEL:** **ML+MV**

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | Eather Sping (Dam 1) | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 771133 | **Northing:** | 6602103 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Potential Groundwater Feature | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 15:20 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Dam | **Temp. (°C):** | 21.9 |
| **Electrical Conductivity (µS/cm):** | 143.9 | **pH:** | 8.8 |

COMMENTS:

Spring not know to flow for 10 years. Dam present at Site, surface water present likely due to recent rainfall. No rock outcrop, soil clayey sand (coarse). Soil moisture present along drainage lines.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051909**

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | Eather Sping (Dam 2) | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 771292 | **Northing:** | 6602251 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Potential Groundwater Feature | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 15:35 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Dam | **Temp. (°C):** | 21.33 |
| **Electrical Conductivity (µS/cm):** | 80 | **pH:** | 8.87 |

COMMENTS:

Spring not know to flow for 10 years. Dam present at Site, surface water present likely due to recent rainfall. No rock outcrop, soil clayey sand (medium to coarse) with some sandstone gravel/boulders. Indications of recent surface flow on up gradient side. No inflow/outflow.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051910**

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | Towri Dam 1 | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 771455 | **Northing:** | 6601981 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Other Feature | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 16:00 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Dam | **Temp. (°C):** | 19.5 |
| **Electrical Conductivity (µS/cm):** | 68 | **pH:** | 8.77 |

COMMENTS:

Machine excavated, dug into hillside (soil clayey sand overlying fine to medium, heavily weathered sandstone). Moisture present on up gradient side (2 m lateral distance, 0.2 m vertical). No visable inflow/outflow. Surface water present in dam is likely due to recent rainfall.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051911**

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | Towri Dam 2 | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 771559 | **Northing:** | 6601660 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Other Feature | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 16:20 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Dam | **Temp. (°C):** | 18.9 |
| **Electrical Conductivity (µS/cm):** | 156 | **pH:** | 8.6 |

COMMENTS:

Machine excavated, dug into sandstone (fine to medium, moderately weathered). Moisture present on up gradient side (2 m lateral distance, 0.2 m vertical). No visable inflow/outflow. Surface water present in dam is likely due to recent rainfall.

## PHOTOGRAPHIC RECORD



## GROUNDWATER BORE REPORT CARD

| BORE ID: | 2020051913 |
|---|---|

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

### LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW043721 |
| **Easting (GDA94 Zone 55):** | 772823 | **Northing:** | 6602235 |

### BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

### WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

### WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

### WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Land owner confirms no bore present.

### PHOTOGRAPHIC RECORD

## GROUNDWATER BORE REPORT CARD

| BORE ID: | 2020051914 |
|---|---|

**SURVEY DATE:** 19/5/2020 **SURVEY PERSONNEL:** ML+MV

### LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Towri and Other Properties | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW902351 |
| **Easting (GDA94 Zone 55):** | 775676 | **Northing:** | 6600282 |

### BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

### WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

### WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

### WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Land owner confirms no bore present.

### PHOTOGRAPHIC RECORD

# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051801**

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Uplands | | |
| **Local Bore Name:** | House Supply | **Ref No/GW Number:** | |
| **Easting (GDA94 Zone 55):** | 770412 | **Northing:** | 6592027 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 32 | **Casing Stick Up (m Above Ground Level):** | 0.33 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 130 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Domestic |
| **Pump Type:** | Submersable | **Power Source:** | Solar |
| **Pump Intake Depth (mBTOC):** | 30 | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 11.26 | **Time of Measurement:** | 9:40 |
| **Approximate time since pumping:** | Pumping at time of measurement | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 19.1 |
| **Electrical Conductivity (µS/cm):** | 1889 | **pH:** | 7.92 |

COMMENTS:

Bore depth obtained from land manager. Converted windmill. Sample from house tap.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051802**

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Uplands | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW011502 |
| **Easting (GDA94 Zone 55):** | 768275 | **Northing:** | 6591664 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 60.9 | **Casing Stick Up (m Above Ground Level):** | 0.45 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 150 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Stock |
| **Pump Type:** | Submersable | **Power Source:** | Solar |
| **Pump Intake Depth (mBTOC):** | 36.6 | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 12.24 | **Time of Measurement:** | 10:20 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tank | **Temp. (°C):** | 16.6 |
| **Electrical Conductivity (µS/cm):** | 2746 | **pH:** | 7.78 |

COMMENTS:

Bore depth obtained from government record.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051803**

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Uplands | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW017228 |
| **Easting (GDA94 Zone 55):** | 767334 | **Northing:** | 6592202 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 39.9 | **Casing Stick Up (m Above Ground Level):** | 0.66 |
| **Casing Material:** | Steel | **Nominal Casing Diameter (mm):** | 120 |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not In Use | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | Dry | **Time of Measurement:** | 11:10 |
| **Approximate time since pumping:** | Greater than 8 years | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Reported as dry for over 8 years.

## PHOTOGRAPHIC RECORD



**GROUNDWATER BORE REPORT CARD**

| **BORE ID:** | **2020051804** |
|---|---|

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Uplands | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW017093 |
| **Easting (GDA94 Zone 55):** | 766521 | **Northing:** | 6594133 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Land Owner not aware of bore presence. Registered coordinates visited and no bore present.

## PHOTOGRAPHIC RECORD

**GROUNDWATER BORE REPORT CARD**

| **BORE ID:** | **2020051805** |
|---|---|

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Uplands | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW005209 |
| **Easting (GDA94 Zone 55):** | 766683 | **Northing:** | 6594222 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

Land Owner not aware of bore presence. Registered coordinates visited and no bore present.

## PHOTOGRAPHIC RECORD

# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020051807**

**SURVEY DATE:** 18/5/2020 **SURVEY PERSONNEL:** ML+MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Uplands | | |
| **Local Bore Name:** | Airstrip Bore | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 772124 | **Northing:** | 6592077 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | 55 | **Casing Stick Up (m Above Ground Level):** | 0.23 |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | In Use | **Purpose:** | Stock |
| **Pump Type:** | Submersable | **Power Source:** | Solar |
| **Pump Intake Depth (mBTOC):** | 50 | **Pump / Flow Rate:** | 60L/min |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | 6.07 | **Time of Measurement:** | 14:30 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Tap | **Temp. (°C):** | 20.9 |
| **Electrical Conductivity (µS/cm):** | 5608 | **pH:** | 7.19 |

COMMENTS:

Land owner provided water quality results and 6 hour pump test data (21/08/19).

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020052011**

**SURVEY DATE:** 20/05/2020 **SURVEY PERSONNEL:** ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | - | | |
| **Local Bore Name:** | Tulla Mullen Crk: Old Narrabri Road Bridge | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 782655 | **Northing:** | 6622645 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Other Feature | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 9:00 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Grab sample | **Temp. (°C):** | 14.3 |
| **Electrical Conductivity (µS/cm):** | 367 | **pH:** | 8.39 |

COMMENTS:

Series of separated pools along a creek line which are separated by a fall in topography in a downstream direction.

No observable surface flow upstream of bridge. Soak abserved along flow path between pools.

Trickle surface flow observed downstream of bridge between pools (which was inferred as stream baseflow, rather than groundwater upwelling based off the elevation offset and observed soak between pools, Water present in pools likely to be due to recent rainfall.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020052012**

**SURVEY DATE:** 20/05/2020 **SURVEY PERSONNEL:** ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | - | | |
| **Local Bore Name:** | Tulla Mullen Crk: Kamilaroi Highway Bridge | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 7822688 | **Northing:** | 6612308 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Other Feature | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 9:50 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Grab sample | **Temp. (°C):** | 14.9 |
| **Electrical Conductivity (µS/cm):** | 121.9 | **pH:** | 8.48 |

COMMENTS:

Upstream of bridge, culvert under railway bridge dry.

No observable surface flow. Soak along flow path of creek.

Large pond downstream of bridge. No observable inflow/outflow at lower pond. Water present likely to be from recent rainfall.

## PHOTOGRAPHIC RECORD



# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2020052701**

**SURVEY DATE:** 27/05/2020 **SURVEY PERSONNEL:** MV

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | - | | |
| **Local Bore Name:** | Kurrajong Crk Tributary | **Ref No/GW Number:** | - |
| **Easting (GDA94 Zone 55):** | 7822688 | **Northing:** | 6612308 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Other Feature | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | 15:00 |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | Grab sample | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:

No Field parameters collected. The location is to the east and downstream of one of the main mine tracks (through the Trees Rd). The sampled area is a pool of water formed from natural topographical rise downstream and the mine track upstream. It is likely the pool of water remains until it either evaporates or a rainfall event flushes the water through. At the time of sampling the pool of water was turbid and not flowing passed the natural topographical rise downstream.

## PHOTOGRAPHIC RECORD



## GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081605**

**SURVEY DATE:** **16/08/2019** **SURVEY PERSONNEL:** SN + ML

### LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Mayfield | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW060977 |
| **Easting (GDA94 Zone 55):** | 774351 | **Northing:** | 6617299 |

### BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

### WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

### WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

### WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:
Coordinates visited, no bore present: land manager not aware of bore presence.

### PHOTOGRAPHIC RECORD

## GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019081608**

**SURVEY DATE:** **16/10/2019** **SURVEY PERSONNEL:** MV + ML

### LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Matilda | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW060978 |
| **Easting (GDA94 Zone 55):** | 777651 | **Northing:** | 6616999 |

### BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

### WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

### WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

### WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:
Coordinates visited, no bore present: land manager not aware of bore presence.

### PHOTOGRAPHIC RECORD

# GROUNDWATER BORE REPORT CARD

**BORE ID:** **2019101004**

**SURVEY DATE:** **10/10/2019** **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Jacks Creek State Forest | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW003604 |
| **Easting (GDA94 Zone 55):** | 770631 | **Northing:** | 6623218 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:
Coordinates visited, no bore present.

## PHOTOGRAPHIC RECORD

**GROUNDWATER BORE REPORT CARD**

**BORE ID:** **2019101005**

**SURVEY DATE:** **10/10/2019** **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Jacks Creek State Forest | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW003052 |
| **Easting (GDA94 Zone 55):** | 767261 | **Northing:** | 6620743 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:
Coordinates visited, no bore present.

## PHOTOGRAPHIC RECORD

**GROUNDWATER BORE REPORT CARD**

**BORE ID:** **2019101010**

**SURVEY DATE:** **10/10/2019** **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Longsight | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW005892 |
| **Easting (GDA94 Zone 55):** | 775863 | **Northing:** | 6613839 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:
Coordinates visited, no bore present: land manager not aware of bore presence.

## PHOTOGRAPHIC RECORD

**GROUNDWATER BORE REPORT CARD**

**BORE ID:** 2019101011

**SURVEY DATE:** **10/10/2019** **SURVEY PERSONNEL:** SN + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Longsight | | |
| **Local Bore Name:** | - | **Ref No/GW Number:** | GW005023 |
| **Easting (GDA94 Zone 55):** | 775642 | **Northing:** | 6614554 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | - |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | - |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:
Coordinates visited, no bore present: land manager not aware of bore presence.

## PHOTOGRAPHIC RECORD

**GROUNDWATER BORE REPORT CARD**

| **BORE ID:** | **2019101110** |
|---|---|

**SURVEY DATE:** **11/10/2019** **SURVEY PERSONNEL:** MV + ML

## LOCATION AND GROUNDWATER WORKS NUMBER

| | | | |
|---|---|---|---|
| **Property Name:** | Omeo | | |
| **Local Bore Name:** | WB8 | **Ref No/GW Number:** | |
| **Easting (GDA94 Zone 55):** | 777682 | **Northing:** | 6623409 |

## BORE CONSTRUCTION DETAILS (SUMMARY)

| | | | |
|---|---|---|---|
| **Depth (m Below Top of Casing):** | - | **Casing Stick Up (m Above Ground Level):** | |
| **Casing Material:** | - | **Nominal Casing Diameter (mm):** | |

## WATER USAGE AND PUMPING DETAILS

| | | | |
|---|---|---|---|
| **Status:** | Not Present | **Purpose:** | - |
| **Pump Type:** | - | **Power Source:** | - |
| **Pump Intake Depth (mBTOC):** | - | **Pump / Flow Rate:** | - |

## WATER LEVEL INFORMATION

| | | | |
|---|---|---|---|
| **Depth to Water (mBTOC):** | - | **Time of Measurement:** | - |
| **Approximate time since pumping:** | - | | |

## WATER QUALITY

| | | | |
|---|---|---|---|
| **Sample Method:** | - | **Temp. (°C):** | - |
| **Electrical Conductivity (µS/cm):** | - | **pH:** | - |

COMMENTS:
Coordinates visited, no bore present: land manager not aware of bore presence.

## PHOTOGRAPHIC RECORD

# Appendix C

## Laboratory Chain of Custody (COC) & Certificates of Analysis (COA)

## Reconciliation of COC and COA's

| ALS Sample ID | COC Sample Name | COA Sample Name | Reason for revised name in COA |
|---|---|---|---|
| EW1903612-001 | Merrilong Seep | Mayfield Spring | Incorrectly labelled – COC and COA should state "Mayfield Spring". |
| EW1904451-001 | Yarranabee Dam | Yarranabee Dam 1 | Incorrectly labelled – COC and COA should state "Yarranabee Dam 1". |
| EW2002425-001 | Delwood: House Bore | Delwood: Windmill | Incorrectly labelled – COC and COA should state "Delwood: Windmill". |
| EW2002425-009 | Eather Spring #3 | Towri Dam 1 | Incorrectly labelled – COC and COA should state "Towri Dam 1". |
| EW2002425-010 | Eather Spring #4 | Towri Dam 2 | Incorrectly labelled – COC and COA should state "Towri Dam 2". |

ENRS
Environment & Natural Resource Solutions

# Chain of Custody

ALS

SYDNEY 277-289 Woodpark Road Smithfield NSW 2164
Ph: 02 8784 8555 E: samples.sydney@alsglobal.com

QUNQWRA 4-13 Geary Place North Nowra NSW 2541
Ph: 02 4423 2063 E: nowra@alsglobal.com

WOLLONGONG 99 Kenny Street Wollongong NSW 2500
Ph: 02 4225 3125 E: wollongong@alsglobal.com

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLIENT: | ~~Minter Ellison Rural Services Strategies~~ ENRS | TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g., Ultra Trace Organics) | ☒ Standard TAT (List due date): | FOR LABORATORY USE ONLY (Circle) | | | | | | | | | | |
| OFFICE: | - | | ☐ Non Standard or urgent TAT (List due date): | Custody Seal Intact? | | | | | | | | Yes | No | N/A |
| PROJECT NO./PO: | ENRS1049 | ALS QUOTE NO.: | | COC SEQUENCE NUMBER (Circle) | | | | | | | | | | |
| SITE/DESCRIPTION: | NCOPL | COUNTRY OF ORIGIN: | | COC: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Free ice / frozen ice bricks present upon receipt? | Yes | No | N/A |
| PROJECT MANAGER: | Rohan Last | CONTACT PH: 02 9037 4708 | | OF: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Random Sample Temperature on Receipt: | | °C | |
| SAMPLER: | M.L. | SAMPLER MOBILE: 0403526292 | | | | | | | | | | Other comment: | | | |

| RELINQUISHED BY: | RECEIVED BY: | RELINQUISHED BY: | RECEIVED BY: |
|---|---|---|---|
| M. Lemcke | Anete | | |
| DATE/TIME: 19/08/2019 | DATE/TIME: 2318/19 | DATE/TIME: | DATE/TIME: |

| | |
|---|---|
| COC Emailed to ALS? (YES / ~~NO~~) | EDD FORMAT (or default): |
| Email Reports to (will default to PM if no other addresses are listed): | lab@enrs.com.au |
| Email Invoice to (will default to PM if no other addresses are listed): | lab@enrs.com.au |

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

| ALS USE ONLY | SAMPLE DETAILS (MATRIX: Solid(S) Water(W)) | | | CONTAINER INFORMATION | | ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required). | | | | | | | | | Additional Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAB ID | SAMPLE ID | DATE / TIME | MATRIX | TYPE & PRESERVATIVE (refer to codes below) | HOLD | W-3T (Total 15 metals) | W-3 (Dissolved 15 metals) | Total Metals: Al, Ag, U | Dissolved Metals: Al, Ag, U | NT-3A (NO2, NO3, NH3, TN, TP, PO3) | NT-1D (major ions (Ca, Mg, Na, K) + Hardness) | NT-2A (F, SO4, Cl, Alkalinity) | TSS, pH, EC | Total Dissolved Solids (TDS) by gravimetric analysis | Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc. |
| | Merrilong Seep | 16/08/2019 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | Namoi View - Submersible | 15/08/2019 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | Namoi View - Windmill | 15/08/2019 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | Red Hill | 15/08/2019 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | GW059838 | 15/08/2019 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | TOTAL | 5 | 5 | 5 | 5 | 6 | 5 | 9 | 9 | | | |

Environmental Division
Wollongong
Work Order Reference
EW1903612

Telephone : 02 42253125

***Water Container Codes:*** P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP = Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preser
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag; LI = Lugols Iodine Preserved Bottles; STT = Sterile Sodium Thiosulfate Preserved Bottles.

ALS Environmental

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| **Work Order** | : **EW1903612** | Page | : 1 of 5 |
| **Amendment** | : **2** | | |
| Client | : **ENVIRONMENT & NATURAL RESOURCE SOLUTIONS** | Laboratory | : Environmental Division NSW South Coast |
| Contact | : Mr Rohan Last | Contact | : Aneta Prosaroski |
| Address | : 25 River Rd<br>Shoalhaven Heads 2535 | Address | : 1/19 Ralph Black Dr, North Wollongong 2500<br>4/13 Geary Pl, North Nowra 2541<br>Australia NSW Australia |
| Telephone | : ---- | Telephone | : +61 2 4225 3125 |
| Project | : ENRS1049 | Date Samples Received | : 23-Aug-2019 11:00 |
| Order number | : ENRS1049 | Date Analysis Commenced | : 23-Aug-2019 |
| C-O-C number | : ---- | Issue Date | : 30-Jun-2020 10:11 |
| Sampler | : Matt L | | |
| Site | : NCOPL | | |
| Quote number | : EN/222 | | |
| No. of samples received | : 5 | | |
| No. of samples analysed | : 5 | | |

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

**Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.**

## *Signatories*

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Ankit Joshi | Inorganic Chemist | Sydney Inorganics, Smithfield, NSW |
| Ivan Taylor | Analyst | Sydney Inorganics, Smithfield, NSW |

## General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020: It is recognised that total concentration is less than dissolved for some metal analytes. However, the difference is within experimental variation of the methods.
- Amendment (18/09/2019): This report has been amended and re-released to allow the reporting of additional analytical data.
- Amendment (30/06/2020): This report has been amended as a result of a request to change sample identification numbers (IDs) received by ALS from Matt Lemcke on 26/06/2020. All analysis results are as per the previous report.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | Client sample ID | Mayfield Spring | Namoi View - Submersible | Namoi View - Windmill | Red Hill | GW059838 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 16-Aug-2019 00:00 | 15-Aug-2019 00:00 | 15-Aug-2019 00:00 | 15-Aug-2019 00:00 | 15-Aug-2019 00:00 |
| Compound | CAS Number | LOR | Unit | EW1903612-001 | EW1903612-002 | EW1903612-003 | EW1903612-004 | EW1903612-005 |
| | | | | Result | Result | Result | Result | Result |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| pH Value | ---- | 0.01 | pH Unit | 6.09 | 7.51 | 8.20 | 6.72 | 7.71 |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 4540 | 511 | 720 | 195 | 1240 |
| **EA015: Total Dissolved Solids dried at 180 ± 5 °C** | | | | | | | | |
| Total Dissolved Solids @180°C | ---- | 10 | mg/L | 2460 | 298 | 406 | 114 | 652 |
| **EA025: Total Suspended Solids dried at 104 ± 2°C** | | | | | | | | |
| Suspended Solids (SS) | ---- | 5 | mg/L | <5 | 46 | <5 | <5 | <5 |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | 932 | 195 | 249 | 11 | 282 |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | 29 | 216 | 301 | 10 | 326 |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | 29 | 216 | 301 | 10 | 326 |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | 268 | <1 | 8 | <1 | 64 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | 1180 | 20 | 29 | 44 | 134 |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | 70 | 42 | 47 | 1 | 60 |
| Magnesium | 7439-95-4 | 1 | mg/L | 184 | 22 | 32 | 2 | 32 |
| Sodium | 7440-23-5 | 1 | mg/L | 536 | 29 | 63 | 30 | 163 |
| Potassium | 7440-09-7 | 1 | mg/L | 14 | 3 | 3 | 2 | 2 |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Silver | 7440-22-4 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | 0.020 | 0.002 | <0.001 | 0.001 |
| Boron | 7440-42-8 | 0.05 | mg/L | 0.08 | <0.05 | <0.05 | <0.05 | <0.05 |
| Barium | 7440-39-3 | 0.001 | mg/L | 0.101 | 0.070 | 0.034 | 0.056 | 0.028 |
| Beryllium | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | 0.0007 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | 7440-48-4 | 0.001 | mg/L | 0.103 | 0.001 | <0.001 | 0.002 | <0.001 |
| Uranium | 7440-61-1 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Mayfield Spring | Namoi View - Submersible | Namoi View - Windmill | Red Hill | GW059838 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 16-Aug-2019 00:00 | 15-Aug-2019 00:00 | 15-Aug-2019 00:00 | 15-Aug-2019 00:00 | 15-Aug-2019 00:00 |
| Compound | CAS Number | LOR | Unit | | EW1903612-001 | EW1903612-002 | EW1903612-003 | EW1903612-004 | EW1903612-005 |
| | | | | | Result | Result | Result | Result | Result |
| **EG020F: Dissolved Metals by ICP-MS - Continued** | | | | | | | | | |
| Chromium | 7440-47-3 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper | 7440-50-8 | 0.001 | mg/L | | **0.001** | <0.001 | **0.013** | **0.004** | **0.003** |
| Manganese | 7439-96-5 | 0.001 | mg/L | | **0.902** | **1.44** | **0.011** | **0.003** | <0.001 |
| Nickel | 7440-02-0 | 0.001 | mg/L | | **0.586** | <0.001 | <0.001 | **0.001** | <0.001 |
| Lead | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | **0.003** | <0.001 |
| Selenium | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Vanadium | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | 7440-66-6 | 0.005 | mg/L | | **0.222** | <0.005 | **0.012** | **0.031** | <0.005 |
| Iron | 7439-89-6 | 0.05 | mg/L | | <0.05 | **16.0** | <0.05 | <0.05 | <0.05 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | | **0.02** | **0.01** | <0.01 | **0.03** | <0.01 |
| Silver | 7440-22-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | | <0.001 | **0.025** | **0.002** | <0.001 | **0.001** |
| Boron | 7440-42-8 | 0.05 | mg/L | | **0.09** | <0.05 | <0.05 | <0.05 | <0.05 |
| Barium | 7440-39-3 | 0.001 | mg/L | | **0.102** | **0.099** | **0.035** | **0.058** | **0.030** |
| Beryllium | 7440-41-7 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | | **0.0008** | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | 7440-48-4 | 0.001 | mg/L | | **0.103** | **0.001** | <0.001 | **0.002** | <0.001 |
| Uranium | 7440-61-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | **0.002** |
| Chromium | 7440-47-3 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper | 7440-50-8 | 0.001 | mg/L | | **0.002** | **0.004** | **0.016** | **0.009** | **0.004** |
| Manganese | 7439-96-5 | 0.001 | mg/L | | **0.892** | **1.54** | **0.016** | **0.004** | **0.006** |
| Nickel | 7440-02-0 | 0.001 | mg/L | | **0.595** | **0.001** | <0.001 | **0.002** | <0.001 |
| Lead | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | **0.004** | <0.001 |
| Selenium | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Vanadium | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | 7440-66-6 | 0.005 | mg/L | | **0.230** | **0.006** | **0.014** | **0.036** | **0.006** |
| Iron | 7439-89-6 | 0.05 | mg/L | | **0.15** | **19.1** | **0.06** | **0.06** | **0.36** |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | | |
| Fluoride | 16984-48-8 | 0.1 | mg/L | | **0.1** | **0.2** | **0.4** | <0.1 | **0.4** |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Mayfield Spring | Namoi View - Submersible | Namoi View - Windmill | Red Hill | GW059838 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 16-Aug-2019 00:00 | 15-Aug-2019 00:00 | 15-Aug-2019 00:00 | 15-Aug-2019 00:00 | 15-Aug-2019 00:00 |
| Compound | CAS Number | LOR | Unit | | EW1903612-001 | EW1903612-002 | EW1903612-003 | EW1903612-004 | EW1903612-005 |
| | | | | | Result | Result | Result | Result | Result |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | | |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | | <0.01 | **0.70** | <0.01 | <0.01 | **0.02** |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | | |
| **Nitrite as N** | 14797-65-0 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | | |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | | **4.07** | **0.02** | **1.60** | **0.29** | **4.42** |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | | |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | | **4.07** | **0.02** | **1.60** | **0.29** | **4.42** |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | | **0.2** | **0.7** | **0.2** | <0.1 | **0.6** |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | | |
| **^ Total Nitrogen as N** | ---- | 0.1 | mg/L | | **4.3** | **0.7** | **1.8** | **0.3** | **5.0** |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | | **0.08** | **0.73** | **0.34** | <0.01 | **0.25** |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | | |
| **Reactive Phosphorus as P** | 14265-44-2 | 0.01 | mg/L | | **0.05** | <0.01 | **0.32** | <0.01 | **0.24** |

ENRS
Environment & Natural Resource Solutions

# Chain of Custody

ALS

SYDNEY 277-289 Woodpark Road Smithfield NSW 2164
Ph: 02 8784 8555 E: samples.sydney@alsglobal.com
NOWRA 4/13 Geary Place North Nowra NSW 2541
Ph: 02 4423 2063 E: nowra@alsglobal.com
WOLLONGONG 39 Kenny Street Wollongong NSW 2500
Ph: 02 4225 3125 E: wollongong@alsglobal.com

| | | | | | |
|---|---|---|---|---|---|
| CLIENT: | Environment and Natural Resource Solutions | TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g., Ultra Trace Organics) | ☒ Standard TAT (List due date): | FOR LABORATORY USE ONLY (Circle) | |
| OFFICE: | - | | ☐ Non Standard or urgent TAT (List due date): | Custody Seal Intact? | Yes No N/A |
| PROJECT NO./PO: | ENRS1048 | ALS QUOTE NO.: | COC SEQUENCE NUMBER (Circle) | Free Ice / frozen Ice bricks present upon receipt? | Yes No N/A |
| SITE/DESCRIPTION: | NCOPL | COUNTRY OF ORIGIN: | COC: 1 2 3 4 5 6 7 | Random Sample Temperature on Receipt: | °C |
| PROJECT MANAGER: | Rohan Last | CONTACT PH: 02 9037 4708 | OF: 1 2 3 4 5 6 7 | Other comment: | |
| SAMPLER: | M.L. | SAMPLER MOBILE: 0403826292 | RELINQUISHED BY: | RECEIVED BY: | RELINQUISHED BY: / RECEIVED BY: |
| COC Emailed to ALS? (YES / NO) | | EDD FORMAT (or default): | M. Lemcke | | |
| Email Reports to (will default to PM if no other addresses are listed): | lab@enrs.com.au | | DATE/TIME: 14/10/2019 | DATE/TIME: 14/10/2019 10:30 | DATE/TIME: / DATE/TIME: |
| Email Invoice to (will default to PM if no other addresses are listed): | lab@enrs.com.au | | | | |

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

| ALS USE ONLY | SAMPLE DETAILS (MATRIX: Solid(S) Water(W)) | | | CONTAINER INFORMATION | | ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required). | | | | | | | | | | Additional Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAB ID | SAMPLE ID | DATE / TIME | MATRIX | TYPE & PRESERVATIVE (refer to codes below) | HOLD | W-ST (Total 15 metals) | W-3 (Dissolved 15 metals) | Total Metals: Al, Ag, U, Fe | Dissolved Metals: Al, Ag, U, Fe | NT-8A (NO2, NO3, NH3, TN, TP, PO3) | NT-1D (major ions (Ca, Mg, Na, K) + Hardness) | NT-2A (F, SO4, Cl, Alkalinity) | TSS, pH, EC | Total Dissolved Solids (TDS) by gravimetric analysis | Total Cyanide | Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc. |
| | | | | | | | | | | | | | | | | pH / EC |
| 1 | Yarranabee - Dam | 9/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 2 | Yarranabee - Dam 2 | 9/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 3 | Riverview - Irrigation | 9/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 4 | Riverview - Windmill | 9/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 5 | Riverstone - House Supply | 9/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 6 | Riverstone - Irrigation Bore #1 | 9/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 7 | Riverstone - Irrigation Bore #2 | 9/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 8 | Riverstone - Irrigation Bore #3 | 9/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 9 | Green Hills - Cottage Bore | 9/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 10 | Green Hills - House Bore | 9/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 11 | Green Hills - Irrigation Bore - East | 9/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 12 | Green Hills - Irrigation Bore - West | 9/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 13 | Whispering Pines - House Bore | 10/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 14 | Hossana - Bore | 10/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 15 | Wilga - Bore | 10/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 16 | Longsight - Dam 1 | 10/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 17 | Longsight - Dam 2 | 10/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 18 | Mullah - House | 11/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 19 | Mullah - Concrete Tank | 11/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 20 | Valhalla - House Bore | 11/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 21 | Valhalla - Windmill | 11/10/2019 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | | | | TOTAL | | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | |

**Water Container Codes:** P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP = Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag; LI = Lugols Iodine Preserved Bottles; STT = Sterile Sodium Thiosulfate Preserved Bottles.

Environmental Division
Wollongong
Work Order Reference
EW1904451

Telephone : 02 4225 3125

ALS Environmental

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| **Work Order** | : **EW1904451** | Page | : 1 of 17 |
| **Amendment** | : **1** | | |
| Client | : **ENVIRONMENT & NATURAL RESOURCE SOLUTIONS** | Laboratory | : Environmental Division NSW South Coast |
| Contact | : Mr Matt L | Contact | : Aneta Prosaroski |
| Address | : 25 River Rd<br>Shoalhaven Heads 2535 | Address | : 1/19 Ralph Black Dr, North Wollongong 2500<br>4/13 Geary Pl, North Nowra 2541<br>Australia NSW Australia |
| Telephone | : 02 9037 4708 | Telephone | : +61 2 4225 3125 |
| Project | : ENRS1049 | Date Samples Received | : 14-Oct-2019 11:11 |
| Order number | : ENRS1049 | Date Analysis Commenced | : 09-Oct-2019 |
| C-O-C number | : ---- | Issue Date | : 30-Jun-2020 10:13 |
| Sampler | : Matt L | | |
| Site | : ---- | | |
| Quote number | : EN/222 | | |
| No. of samples received | : 21 | | |
| No. of samples analysed | : 21 | | |

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

**Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.**

## *Signatories*

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Ankit Joshi | Inorganic Chemist | Sydney Inorganics, Smithfield, NSW |
| Glenn Davies | Environmental Services Representative | Laboratory - Wollongong, NSW |
| Ivan Taylor | Analyst | Sydney Inorganics, Smithfield, NSW |

## General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EK061G:: LOR raised for TKN on sample No 15 due to sample matrix.
- EG020: It is recognised that total concentration is less than dissolved for some metal analytes. However, the difference is within experimental variation of the methods.
- EG035: Positive Hg result EW1904451 # 15 has been confirmed by reanalysis.
- TDS by method EA-015 may bias high for various samples due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.
- EK055G: It has been noted that Ammonia is greater than TKN on sample NO 3, however this difference is within the limits of experimental variation.
- EK071G: It has been noted that Reactive P is greater than Total P on sample No 5 & 6 however this difference is within the limits of experimental variation.
- Amendment (30/06/2020): This report has been amended as a result of a request to change sample identification numbers (IDs) received by ALS from Matt Lemcke on 26/06/2020. All analysis results are as per the previous report.
- pH and Conductivity data supplied by ALS Wollongong.
- pH and Conductivity tests completed on day of receipt.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | Client sample ID | Yarranabee - Dam 1 | Yarranabee - Dam 2 | Riverview - Irrigation | Riverview - Windwill | Riverstone - House Supply |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 |
| Compound | CAS Number | LOR | Unit | EW1904451-001 | EW1904451-002 | EW1904451-003 | EW1904451-004 | EW1904451-005 |
| | | | | Result | Result | Result | Result | Result |
| **EA005FD: Field pH** | | | | | | | | |
| pH | ---- | 0.1 | pH Unit | 8.5 | 8.1 | 7.0 | 6.7 | 6.8 |
| **EA010FD: Field Conductivity** | | | | | | | | |
| Conductivity @ 25oC | ---- | 1 | µS/cm | 300 | 329 | 654 | 1400 | 3990 |
| **EA015: Total Dissolved Solids dried at 180 ± 5 °C** | | | | | | | | |
| Total Dissolved Solids @180°C | ---- | 1 | mg/L | 182 | 187 | 380 | 758 | 2480 |
| **EA025: Total Suspended Solids dried at 104 ± 2°C** | | | | | | | | |
| Suspended Solids (SS) | ---- | 1 | mg/L | 18 | 16 | 2 | 10 | <1 |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | 81 | 93 | 202 | 280 | 1260 |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | 119 | 141 | 252 | 256 | 273 |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | 119 | 141 | 252 | 256 | 273 |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | <1 | <1 | 18 | 65 | 372 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | 14 | 15 | 42 | 267 | 975 |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | 16 | 16 | 43 | 46 | 256 |
| Magnesium | 7439-95-4 | 1 | mg/L | 10 | 13 | 23 | 40 | 150 |
| Sodium | 7440-23-5 | 1 | mg/L | 30 | 28 | 62 | 174 | 303 |
| Potassium | 7440-09-7 | 1 | mg/L | 8 | 7 | 1 | 3 | 3 |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | 0.03 | 0.01 | <0.01 | <0.01 | <0.01 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 |
| Boron | 7440-42-8 | 0.05 | mg/L | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Barium | 7440-39-3 | 0.001 | mg/L | 0.091 | 0.093 | 0.021 | 0.060 | 0.117 |
| Beryllium | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | 7440-48-4 | 0.001 | mg/L | 0.001 | 0.002 | <0.001 | <0.001 | <0.001 |
| Chromium | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper | 7440-50-8 | 0.001 | mg/L | <0.001 | 0.001 | <0.001 | 0.001 | 0.004 |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Yarranabee - Dam 1 | Yarranabee - Dam 2 | Riverview - Irrigation | Riverview - Windwill | Riverstone - House Supply |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 |
| Compound | CAS Number | LOR | Unit | | EW1904451-001 | EW1904451-002 | EW1904451-003 | EW1904451-004 | EW1904451-005 |
| | | | | | Result | Result | Result | Result | Result |
| **EG020F: Dissolved Metals by ICP-MS - Continued** | | | | | | | | | |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | | **0.090** | **0.488** | **0.118** | **0.053** | **1.05** |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | | **0.004** | **0.005** | <0.001 | <0.001 | **0.001** |
| **Lead** | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | | <0.005 | <0.005 | <0.005 | **0.008** | **0.058** |
| **Silver** | 7440-22-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Uranium** | 7440-61-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | **0.003** |
| **Iron** | 7439-89-6 | 0.05 | mg/L | | **0.21** | <0.05 | **0.12** | **4.69** | <0.05 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | | |
| **Aluminium** | 7429-90-5 | 0.01 | mg/L | | **0.60** | **0.54** | <0.01 | <0.01 | <0.01 |
| **Arsenic** | 7440-38-2 | 0.001 | mg/L | | **0.003** | <0.001 | **0.001** | <0.001 | <0.001 |
| **Boron** | 7440-42-8 | 0.05 | mg/L | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| **Barium** | 7440-39-3 | 0.001 | mg/L | | **0.110** | **0.103** | **0.027** | **0.066** | **0.120** |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | | **0.002** | **0.003** | <0.001 | <0.001 | <0.001 |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Copper** | 7440-50-8 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | **0.007** | **0.004** |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | | **0.158** | **0.575** | **0.127** | **0.054** | **1.04** |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | | **0.006** | **0.006** | <0.001 | <0.001 | **0.002** |
| **Lead** | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | | <0.005 | <0.005 | <0.005 | **0.011** | **0.058** |
| **Silver** | 7440-22-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Uranium** | 7440-61-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | **0.004** |
| **Iron** | 7439-89-6 | 0.05 | mg/L | | **1.77** | **0.75** | **1.19** | **6.33** | <0.05 |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EK026SF: Total CN by Segmented Flow Analyser** | | | | | | | | | |
| **Total Cyanide** | 57-12-5 | 0.004 | mg/L | | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Yarranabee - Dam 1 | Yarranabee - Dam 2 | Riverview - Irrigation | Riverview - Windwill | Riverstone - House Supply |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 |
| Compound | CAS Number | LOR | Unit | | EW1904451-001 | EW1904451-002 | EW1904451-003 | EW1904451-004 | EW1904451-005 |
| | | | | | Result | Result | Result | Result | Result |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | | **0.3** | **0.2** | **0.4** | **0.2** | **0.1** |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | | |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | | **0.05** | **0.20** | **0.12** | <0.01 | <0.01 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | | |
| **Nitrite as N** | 14797-65-0 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | | |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | | **0.02** | **0.03** | **0.09** | **0.12** | **3.15** |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | | |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | | **0.02** | **0.03** | **0.09** | **0.12** | **3.15** |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | | **1.0** | **0.9** | <0.1 | <0.1 | <0.1 |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | | |
| ^ **Total Nitrogen as N** | ---- | 0.1 | mg/L | | **1.0** | **0.9** | <0.1 | **0.1** | **3.2** |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | | **0.09** | **0.08** | **0.39** | **0.12** | **0.11** |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | | |
| **Reactive Phosphorus as P** | 14265-44-2 | 0.01 | mg/L | | <0.01 | <0.01 | **0.24** | <0.01 | **0.11** |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Riverstone - Irrigation Bore #1 | Riverstone - Irrigation Bore #2 | Riverstone - Irrigation Bore #3 | Green Hills - Cottage Bore | Green Hills - House Bore |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 |
| Compound | CAS Number | LOR | Unit | | EW1904451-006 | EW1904451-007 | EW1904451-008 | EW1904451-009 | EW1904451-010 |
| | | | | | Result | Result | Result | Result | Result |
| **EA005FD: Field pH** | | | | | | | | | |
| pH | ---- | 0.1 | pH Unit | | 6.9 | 6.9 | 7.1 | 7.2 | 7.6 |
| **EA010FD: Field Conductivity** | | | | | | | | | |
| Conductivity @ 25oC | ---- | 1 | µS/cm | | 5110 | 2630 | 1330 | 1120 | 4870 |
| **EA015: Total Dissolved Solids dried at 180 ± 5 °C** | | | | | | | | | |
| Total Dissolved Solids @180°C | ---- | 1 | mg/L | | 3120 | 1530 | 784 | 581 | 2840 |
| **EA025: Total Suspended Solids dried at 104 ± 2°C** | | | | | | | | | |
| Suspended Solids (SS) | ---- | 1 | mg/L | | <1 | 3 | <1 | <1 | <1 |
| **EA065: Total Hardness as CaCO3** | | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | | 1570 | 807 | 356 | 238 | 640 |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | | <1 | <1 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | | 281 | 272 | 231 | 271 | 678 |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | | 281 | 272 | 231 | 271 | 678 |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | | 675 | 326 | 104 | 83 | 421 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | | 1140 | 562 | 236 | 133 | 974 |
| **ED093F: Dissolved Major Cations** | | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | | 321 | 165 | 75 | 51 | 83 |
| Magnesium | 7439-95-4 | 1 | mg/L | | 186 | 96 | 41 | 27 | 105 |
| Sodium | 7440-23-5 | 1 | mg/L | | 459 | 213 | 130 | 141 | 827 |
| Potassium | 7440-09-7 | 1 | mg/L | | 3 | 3 | 3 | 2 | 4 |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 |
| Boron | 7440-42-8 | 0.05 | mg/L | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Barium | 7440-39-3 | 0.001 | mg/L | | 0.082 | 0.098 | 0.020 | 0.015 | 0.069 |
| Beryllium | 7440-41-7 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | 7440-48-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Chromium | 7440-47-3 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper | 7440-50-8 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | 0.039 | <0.001 |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Riverstone - Irrigation Bore #1 | Riverstone - Irrigation Bore #2 | Riverstone - Irrigation Bore #3 | Green Hills - Cottage Bore | Green Hills - House Bore |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 |
| Compound | CAS Number | LOR | Unit | | EW1904451-006 | EW1904451-007 | EW1904451-008 | EW1904451-009 | EW1904451-010 |
| | | | | | Result | Result | Result | Result | Result |
| **EG020F: Dissolved Metals by ICP-MS - Continued** | | | | | | | | | |
| Manganese | 7439-96-5 | 0.001 | mg/L | | **0.105** | **0.390** | **0.038** | <0.001 | **0.629** |
| Nickel | 7440-02-0 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Lead | 7439-92-1 | 0.001 | mg/L | | <0.001 | **0.002** | <0.001 | <0.001 | <0.001 |
| Selenium | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Vanadium | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | 7440-66-6 | 0.005 | mg/L | | <0.005 | <0.005 | <0.005 | **0.026** | <0.005 |
| Silver | 7440-22-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Uranium | 7440-61-1 | 0.001 | mg/L | | **0.006** | **0.003** | **0.001** | **0.002** | **0.010** |
| Iron | 7439-89-6 | 0.05 | mg/L | | <0.05 | <0.05 | <0.05 | <0.05 | **0.13** |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | **0.002** |
| Boron | 7440-42-8 | 0.05 | mg/L | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Barium | 7440-39-3 | 0.001 | mg/L | | **0.087** | **0.103** | **0.021** | **0.016** | **0.076** |
| Beryllium | 7440-41-7 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | 7440-48-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Chromium | 7440-47-3 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper | 7440-50-8 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | **0.040** | **0.005** |
| Manganese | 7439-96-5 | 0.001 | mg/L | | **0.106** | **0.406** | **0.037** | <0.001 | **0.642** |
| Nickel | 7440-02-0 | 0.001 | mg/L | | <0.001 | <0.001 | **0.001** | <0.001 | <0.001 |
| Lead | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Selenium | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Vanadium | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | 7440-66-6 | 0.005 | mg/L | | <0.005 | <0.005 | <0.005 | **0.027** | **0.006** |
| Silver | 7440-22-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Uranium | 7440-61-1 | 0.001 | mg/L | | **0.006** | **0.004** | **0.002** | **0.002** | **0.010** |
| Iron | 7439-89-6 | 0.05 | mg/L | | <0.05 | <0.05 | <0.05 | <0.05 | **0.65** |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EK026SF: Total CN by Segmented Flow Analyser** | | | | | | | | | |
| Total Cyanide | 57-12-5 | 0.004 | mg/L | | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Riverstone - Irrigation Bore #1 | Riverstone - Irrigation Bore #2 | Riverstone - Irrigation Bore #3 | Green Hills - Cottage Bore | Green Hills - House Bore |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 |
| Compound | CAS Number | LOR | Unit | | EW1904451-006 | EW1904451-007 | EW1904451-008 | EW1904451-009 | EW1904451-010 |
| | | | | | Result | Result | Result | Result | Result |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | | **0.2** | **0.2** | **0.1** | **0.3** | **0.6** |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | | |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | **0.06** |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | | |
| **Nitrite as N** | 14797-65-0 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | | |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | | **7.02** | **0.66** | **1.20** | **5.30** | **0.10** |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | | |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | | **7.02** | **0.66** | **1.20** | **5.30** | **0.10** |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | | **0.3** | <0.1 | **0.1** | **0.3** | **0.1** |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | | |
| ^ **Total Nitrogen as N** | ---- | 0.1 | mg/L | | **7.3** | **0.7** | **1.3** | **5.6** | **0.2** |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | | **0.14** | **0.10** | **0.07** | **0.22** | **0.37** |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | | |
| **Reactive Phosphorus as P** | 14265-44-2 | 0.01 | mg/L | | **0.12** | **0.10** | **0.05** | **0.15** | **0.29** |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Green Hills - Irrigation Bore - East | Green Hills - Irrigation Bore - West | Whispering Pines - House Bore | Hossana - Bore | Wilga - Bore |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 10-Oct-2019 00:00 | 10-Oct-2019 00:00 | 10-Oct-2019 00:00 |
| Compound | CAS Number | LOR | Unit | | EW1904451-011 | EW1904451-012 | EW1904451-013 | EW1904451-014 | EW1904451-015 |
| | | | | | Result | Result | Result | Result | Result |
| **EA005FD: Field pH** | | | | | | | | | |
| pH | ---- | 0.1 | pH Unit | | 7.2 | 7.2 | 5.6 | 5.5 | 6.7 |
| **EA010FD: Field Conductivity** | | | | | | | | | |
| Conductivity @ 25oC | ---- | 1 | µS/cm | | 513 | 1100 | 265 | 141 | 13800 |
| **EA015: Total Dissolved Solids dried at 180 ± 5 °C** | | | | | | | | | |
| Total Dissolved Solids @180°C | ---- | 1 | mg/L | | 396 | 638 | 143 | 86 | 8820 |
| **EA025: Total Suspended Solids dried at 104 ± 2°C** | | | | | | | | | |
| Suspended Solids (SS) | ---- | 1 | mg/L | | <1 | <1 | <1 | 7 | 1 |
| **EA065: Total Hardness as CaCO3** | | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | | 141 | 237 | 12 | 8 | 2330 |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | | <1 | <1 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | | 193 | 255 | 21 | 14 | 993 |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | | 193 | 255 | 21 | 14 | 993 |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | | 18 | 68 | 2 | 4 | 601 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | | 33 | 154 | 48 | 34 | 4250 |
| **ED093F: Dissolved Major Cations** | | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | | 30 | 52 | <1 | <1 | 196 |
| Magnesium | 7439-95-4 | 1 | mg/L | | 16 | 26 | 3 | 2 | 446 |
| Sodium | 7440-23-5 | 1 | mg/L | | 56 | 136 | 26 | 22 | 2120 |
| Potassium | 7440-09-7 | 1 | mg/L | | 2 | 2 | 7 | 3 | 37 |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Boron | 7440-42-8 | 0.05 | mg/L | | <0.05 | <0.05 | <0.05 | <0.05 | 0.07 |
| Barium | 7440-39-3 | 0.001 | mg/L | | 0.006 | 0.011 | 0.085 | 0.036 | 0.099 |
| Beryllium | 7440-41-7 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | 7440-48-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | 0.002 | 0.012 |
| Chromium | 7440-47-3 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper | 7440-50-8 | 0.001 | mg/L | | <0.001 | <0.001 | 0.002 | 0.001 | <0.001 |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Green Hills - Irrigation Bore - East | Green Hills - Irrigation Bore - West | Whispering Pines - House Bore | Hossana - Bore | Wilga - Bore |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 10-Oct-2019 00:00 | 10-Oct-2019 00:00 | 10-Oct-2019 00:00 |
| Compound | CAS Number | LOR | Unit | | EW1904451-011 | EW1904451-012 | EW1904451-013 | EW1904451-014 | EW1904451-015 |
| | | | | | Result | Result | Result | Result | Result |
| **EG020F: Dissolved Metals by ICP-MS - Continued** | | | | | | | | | |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | | **0.079** | <0.001 | **0.017** | **0.002** | **0.986** |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | | <0.001 | <0.001 | **0.002** | **0.001** | **0.006** |
| **Lead** | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | | <0.005 | <0.005 | **0.008** | <0.005 | **0.050** |
| **Silver** | 7440-22-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Uranium** | 7440-61-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | **0.039** |
| **Iron** | 7439-89-6 | 0.05 | mg/L | | <0.05 | <0.05 | **0.06** | <0.05 | **0.07** |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | | |
| **Aluminium** | 7429-90-5 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Arsenic** | 7440-38-2 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Boron** | 7440-42-8 | 0.05 | mg/L | | <0.05 | <0.05 | <0.05 | <0.05 | **0.07** |
| **Barium** | 7440-39-3 | 0.001 | mg/L | | **0.006** | **0.013** | **0.093** | **0.039** | **0.100** |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | **0.002** | **0.012** |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | | <0.001 | <0.001 | **0.001** | **0.002** | <0.001 |
| **Copper** | 7440-50-8 | 0.001 | mg/L | | <0.001 | <0.001 | **0.004** | <0.001 | <0.001 |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | | **0.078** | <0.001 | **0.031** | **0.002** | **0.993** |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | | <0.001 | <0.001 | **0.002** | **0.001** | **0.005** |
| **Lead** | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | **0.002** | <0.001 | <0.001 |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | | <0.005 | <0.005 | **0.010** | <0.005 | **0.053** |
| **Silver** | 7440-22-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Uranium** | 7440-61-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | **0.040** |
| **Iron** | 7439-89-6 | 0.05 | mg/L | | <0.05 | <0.05 | **0.72** | **3.18** | **0.15** |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | **0.0002** |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | **0.0003** |
| **EK026SF: Total CN by Segmented Flow Analyser** | | | | | | | | | |
| **Total Cyanide** | 57-12-5 | 0.004 | mg/L | | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Green Hills - Irrigation Bore - East | Green Hills - Irrigation Bore - West | Whispering Pines - House Bore | Hossana - Bore | Wilga - Bore |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 09-Oct-2019 00:00 | 09-Oct-2019 00:00 | 10-Oct-2019 00:00 | 10-Oct-2019 00:00 | 10-Oct-2019 00:00 |
| Compound | CAS Number | LOR | Unit | | EW1904451-011 | EW1904451-012 | EW1904451-013 | EW1904451-014 | EW1904451-015 |
| | | | | | Result | Result | Result | Result | Result |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | | **0.3** | **0.2** | <0.1 | <0.1 | **0.4** |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | | |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | **0.07** |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | | |
| **Nitrite as N** | 14797-65-0 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | **0.05** |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | | |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | | **0.10** | **1.04** | **0.26** | **0.14** | **1.05** |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | | |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | | **0.10** | **1.04** | **0.26** | **0.14** | **1.10** |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | | <0.1 | **0.2** | <0.1 | <0.1 | <0.2 |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | | |
| ^ **Total Nitrogen as N** | ---- | 0.1 | mg/L | | **0.1** | **1.2** | **0.3** | **0.1** | **1.1** |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | | **0.10** | **0.12** | **0.05** | **0.05** | **0.05** |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | | |
| **Reactive Phosphorus as P** | 14265-44-2 | 0.01 | mg/L | | **0.10** | **0.10** | <0.01 | <0.01 | <0.01 |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | Client sample ID | Longsight - Dam 1 | Longsight - Dam 2 | Mullah - House | Mullah - Concrete Tank | Valhalla - House Bore |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 10-Oct-2019 00:00 | 10-Oct-2019 00:00 | 11-Oct-2019 00:00 | 11-Oct-2019 00:00 | 11-Oct-2019 00:00 |
| Compound | CAS Number | LOR | Unit | EW1904451-016 | EW1904451-017 | EW1904451-018 | EW1904451-019 | EW1904451-020 |
| | | | | Result | Result | Result | Result | Result |
| **EA005FD: Field pH** | | | | | | | | |
| pH | ---- | 0.1 | pH Unit | **7.6** | **8.9** | **7.0** | **7.2** | **7.3** |
| **EA010FD: Field Conductivity** | | | | | | | | |
| Conductivity @ 25oC | ---- | 1 | µS/cm | **149** | **381** | **1060** | **698** | **715** |
| **EA015: Total Dissolved Solids dried at 180 ± 5 °C** | | | | | | | | |
| Total Dissolved Solids @180°C | ---- | 1 | mg/L | **366** | **602** | **590** | **374** | **396** |
| **EA025: Total Suspended Solids dried at 104 ± 2°C** | | | | | | | | |
| Suspended Solids (SS) | ---- | 1 | mg/L | **34** | **52** | **4** | **2** | **1** |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | **43** | **112** | **286** | **251** | **265** |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | **55** | **158** | **329** | **216** | **248** |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | **55** | **159** | **329** | **216** | **248** |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | **1** | <1 | **26** | **18** | **23** |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | **8** | **16** | **113** | **70** | **57** |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | **9** | **25** | **57** | **51** | **55** |
| Magnesium | 7439-95-4 | 1 | mg/L | **5** | **12** | **35** | **30** | **31** |
| Sodium | 7440-23-5 | 1 | mg/L | **10** | **30** | **110** | **43** | **44** |
| Potassium | 7440-09-7 | 1 | mg/L | **10** | **16** | **2** | **2** | **2** |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | **0.14** | <0.01 | <0.01 | <0.01 | <0.01 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | **0.002** | <0.001 | <0.001 | <0.001 |
| Boron | 7440-42-8 | 0.05 | mg/L | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Barium | 7440-39-3 | 0.001 | mg/L | **0.040** | **0.135** | **0.041** | **0.048** | **0.038** |
| Beryllium | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | 7440-48-4 | 0.001 | mg/L | **0.001** | **0.003** | <0.001 | <0.001 | <0.001 |
| Chromium | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Copper | 7440-50-8 | 0.001 | mg/L | **0.002** | **0.001** | <0.001 | **0.002** | **0.003** |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Longsight - Dam 1 | Longsight - Dam 2 | Mullah - House | Mullah - Concrete Tank | Valhalla - House Bore |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 10-Oct-2019 00:00 | 10-Oct-2019 00:00 | 11-Oct-2019 00:00 | 11-Oct-2019 00:00 | 11-Oct-2019 00:00 |
| Compound | CAS Number | LOR | Unit | | EW1904451-016 | EW1904451-017 | EW1904451-018 | EW1904451-019 | EW1904451-020 |
| | | | | | Result | Result | Result | Result | Result |
| **EG020F: Dissolved Metals by ICP-MS - Continued** | | | | | | | | | |
| Manganese | 7439-96-5 | 0.001 | mg/L | | **0.221** | **0.526** | **0.010** | **0.033** | **0.002** |
| Nickel | 7440-02-0 | 0.001 | mg/L | | **0.001** | **0.006** | <0.001 | <0.001 | <0.001 |
| Lead | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Selenium | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Vanadium | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | 7440-66-6 | 0.005 | mg/L | | <0.005 | <0.005 | <0.005 | **0.033** | <0.005 |
| Silver | 7440-22-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Uranium | 7440-61-1 | 0.001 | mg/L | | <0.001 | <0.001 | **0.002** | <0.001 | <0.001 |
| Iron | 7439-89-6 | 0.05 | mg/L | | **0.12** | <0.05 | **0.88** | <0.05 | <0.05 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | | **14.1** | **1.34** | <0.01 | <0.01 | <0.01 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | | **0.003** | **0.003** | <0.001 | <0.001 | <0.001 |
| Boron | 7440-42-8 | 0.05 | mg/L | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Barium | 7440-39-3 | 0.001 | mg/L | | **0.094** | **0.175** | **0.043** | **0.051** | **0.042** |
| Beryllium | 7440-41-7 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | 7440-48-4 | 0.001 | mg/L | | **0.006** | **0.005** | <0.001 | <0.001 | <0.001 |
| Chromium | 7440-47-3 | 0.001 | mg/L | | **0.012** | **0.001** | <0.001 | <0.001 | <0.001 |
| Copper | 7440-50-8 | 0.001 | mg/L | | **0.005** | <0.001 | **0.001** | **0.001** | **0.002** |
| Manganese | 7439-96-5 | 0.001 | mg/L | | **0.395** | **0.909** | **0.009** | **0.034** | **0.002** |
| Nickel | 7440-02-0 | 0.001 | mg/L | | **0.008** | **0.008** | <0.001 | <0.001 | <0.001 |
| Lead | 7439-92-1 | 0.001 | mg/L | | **0.010** | <0.001 | <0.001 | <0.001 | <0.001 |
| Selenium | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Vanadium | 7440-62-2 | 0.01 | mg/L | | **0.02** | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | 7440-66-6 | 0.005 | mg/L | | **0.020** | <0.005 | <0.005 | **0.035** | <0.005 |
| Silver | 7440-22-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Uranium | 7440-61-1 | 0.001 | mg/L | | <0.001 | <0.001 | **0.002** | <0.001 | <0.001 |
| Iron | 7439-89-6 | 0.05 | mg/L | | **14.6** | **1.67** | **0.90** | **0.06** | <0.05 |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EK026SF: Total CN by Segmented Flow Analyser** | | | | | | | | | |
| Total Cyanide | 57-12-5 | 0.004 | mg/L | | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Longsight - Dam 1 | Longsight - Dam 2 | Mullah - House | Mullah - Concrete Tank | Valhalla - House Bore |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 10-Oct-2019 00:00 | 10-Oct-2019 00:00 | 11-Oct-2019 00:00 | 11-Oct-2019 00:00 | 11-Oct-2019 00:00 |
| Compound | CAS Number | LOR | Unit | | EW1904451-016 | EW1904451-017 | EW1904451-018 | EW1904451-019 | EW1904451-020 |
| | | | | | Result | Result | Result | Result | Result |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | | **0.2** | **0.3** | **0.2** | **0.2** | **0.2** |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | | |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | | **0.32** | **0.54** | <0.01 | **0.04** | <0.01 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | | |
| **Nitrite as N** | 14797-65-0 | 0.01 | mg/L | | <0.01 | **0.12** | <0.01 | <0.01 | <0.01 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | | |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | | **0.21** | **0.27** | <0.01 | **0.07** | **0.04** |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | | |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | | **0.21** | **0.39** | <0.01 | **0.07** | **0.04** |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | | **2.6** | **2.4** | <0.1 | <0.1 | <0.1 |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | | |
| ^ **Total Nitrogen as N** | ---- | 0.1 | mg/L | | **2.8** | **2.8** | <0.1 | <0.1 | <0.1 |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | | **0.30** | **0.16** | **0.20** | **0.05** | **0.15** |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | | |
| **Reactive Phosphorus as P** | 14265-44-2 | 0.01 | mg/L | | **0.02** | <0.01 | **0.01** | **0.03** | **0.14** |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | Client sample ID | Valhalla - Windmill | ---- | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 11-Oct-2019 00:00 | ---- | ---- | ---- | ---- |
| Compound | CAS Number | LOR | Unit | EW1904451-021 | -------- | -------- | -------- | -------- |
| | | | | Result | ---- | ---- | ---- | ---- |
| **EA005FD: Field pH** | | | | | | | | |
| **pH** | ---- | 0.1 | pH Unit | **7.4** | ---- | ---- | ---- | ---- |
| **EA010FD: Field Conductivity** | | | | | | | | |
| **Conductivity @ 25oC** | ---- | 1 | µS/cm | **716** | ---- | ---- | ---- | ---- |
| **EA015: Total Dissolved Solids dried at 180 ± 5 °C** | | | | | | | | |
| **Total Dissolved Solids @180°C** | ---- | 1 | mg/L | **410** | ---- | ---- | ---- | ---- |
| **EA025: Total Suspended Solids dried at 104 ± 2°C** | | | | | | | | |
| **Suspended Solids (SS)** | ---- | 1 | mg/L | <1 | ---- | ---- | ---- | ---- |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| **Total Hardness as CaCO3** | ---- | 1 | mg/L | **170** | ---- | ---- | ---- | ---- |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| **Hydroxide Alkalinity as CaCO3** | DMO-210-001 | 1 | mg/L | <1 | ---- | ---- | ---- | ---- |
| **Carbonate Alkalinity as CaCO3** | 3812-32-6 | 1 | mg/L | <1 | ---- | ---- | ---- | ---- |
| **Bicarbonate Alkalinity as CaCO3** | 71-52-3 | 1 | mg/L | **241** | ---- | ---- | ---- | ---- |
| **Total Alkalinity as CaCO3** | ---- | 1 | mg/L | **241** | ---- | ---- | ---- | ---- |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| **Sulfate as SO4 - Turbidimetric** | 14808-79-8 | 1 | mg/L | **14** | ---- | ---- | ---- | ---- |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| **Chloride** | 16887-00-6 | 1 | mg/L | **65** | ---- | ---- | ---- | ---- |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| **Calcium** | 7440-70-2 | 1 | mg/L | **35** | ---- | ---- | ---- | ---- |
| **Magnesium** | 7439-95-4 | 1 | mg/L | **20** | ---- | ---- | ---- | ---- |
| **Sodium** | 7440-23-5 | 1 | mg/L | **86** | ---- | ---- | ---- | ---- |
| **Potassium** | 7440-09-7 | 1 | mg/L | **2** | ---- | ---- | ---- | ---- |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| **Aluminium** | 7429-90-5 | 0.01 | mg/L | <0.01 | ---- | ---- | ---- | ---- |
| **Arsenic** | 7440-38-2 | 0.001 | mg/L | <0.001 | ---- | ---- | ---- | ---- |
| **Boron** | 7440-42-8 | 0.05 | mg/L | <0.05 | ---- | ---- | ---- | ---- |
| **Barium** | 7440-39-3 | 0.001 | mg/L | **0.020** | ---- | ---- | ---- | ---- |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | <0.001 | ---- | ---- | ---- | ---- |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | <0.0001 | ---- | ---- | ---- | ---- |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | <0.001 | ---- | ---- | ---- | ---- |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | <0.001 | ---- | ---- | ---- | ---- |
| **Copper** | 7440-50-8 | 0.001 | mg/L | **0.036** | ---- | ---- | ---- | ---- |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | **0.002** | ---- | ---- | ---- | ---- |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Valhalla - Windmill | ---- | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 11-Oct-2019 00:00 | ---- | ---- | ---- | ---- |
| Compound | CAS Number | LOR | Unit | | EW1904451-021 | -------- | -------- | -------- | -------- |
| | | | | | Result | ---- | ---- | ---- | ---- |
| **EG020F: Dissolved Metals by ICP-MS - Continued** | | | | | | | | | |
| Nickel | 7440-02-0 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| Lead | 7439-92-1 | 0.001 | mg/L | | **0.002** | ---- | ---- | ---- | ---- |
| Selenium | 7782-49-2 | 0.01 | mg/L | | <0.01 | ---- | ---- | ---- | ---- |
| Vanadium | 7440-62-2 | 0.01 | mg/L | | <0.01 | ---- | ---- | ---- | ---- |
| Zinc | 7440-66-6 | 0.005 | mg/L | | **0.009** | ---- | ---- | ---- | ---- |
| Silver | 7440-22-4 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| Uranium | 7440-61-1 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| Iron | 7439-89-6 | 0.05 | mg/L | | <0.05 | ---- | ---- | ---- | ---- |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | | <0.01 | ---- | ---- | ---- | ---- |
| Arsenic | 7440-38-2 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| Boron | 7440-42-8 | 0.05 | mg/L | | <0.05 | ---- | ---- | ---- | ---- |
| Barium | 7440-39-3 | 0.001 | mg/L | | **0.024** | ---- | ---- | ---- | ---- |
| Beryllium | 7440-41-7 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | | <0.0001 | ---- | ---- | ---- | ---- |
| Cobalt | 7440-48-4 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| Chromium | 7440-47-3 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| Copper | 7440-50-8 | 0.001 | mg/L | | **0.171** | ---- | ---- | ---- | ---- |
| Manganese | 7439-96-5 | 0.001 | mg/L | | **0.058** | ---- | ---- | ---- | ---- |
| Nickel | 7440-02-0 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| Lead | 7439-92-1 | 0.001 | mg/L | | **0.020** | ---- | ---- | ---- | ---- |
| Selenium | 7782-49-2 | 0.01 | mg/L | | <0.01 | ---- | ---- | ---- | ---- |
| Vanadium | 7440-62-2 | 0.01 | mg/L | | <0.01 | ---- | ---- | ---- | ---- |
| Zinc | 7440-66-6 | 0.005 | mg/L | | **0.021** | ---- | ---- | ---- | ---- |
| Silver | 7440-22-4 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| Uranium | 7440-61-1 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| Iron | 7439-89-6 | 0.05 | mg/L | | **0.12** | ---- | ---- | ---- | ---- |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | ---- | ---- | ---- | ---- |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | ---- | ---- | ---- | ---- |
| **EK026SF: Total CN by Segmented Flow Analyser** | | | | | | | | | |
| Total Cyanide | 57-12-5 | 0.004 | mg/L | | <0.004 | ---- | ---- | ---- | ---- |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | | |

## Analytical Results

| Sub-Matrix: GROUNDWATER (Matrix: WATER) | | | | Client sample ID | Valhalla - Windmill | ---- | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 11-Oct-2019 00:00 | ---- | ---- | ---- | ---- |
| Compound | CAS Number | LOR | Unit | | EW1904451-021 | -------- | -------- | -------- | -------- |
| | | | | | Result | ---- | ---- | ---- | ---- |
| **EK040P: Fluoride by PC Titrator - Continued** | | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | | **0.2** | ---- | ---- | ---- | ---- |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | | |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | | <0.01 | ---- | ---- | ---- | ---- |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | | |
| **Nitrite as N** | 14797-65-0 | 0.01 | mg/L | | <0.01 | ---- | ---- | ---- | ---- |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | | |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | | **0.03** | ---- | ---- | ---- | ---- |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | | |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | | **0.03** | ---- | ---- | ---- | ---- |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | | <0.1 | ---- | ---- | ---- | ---- |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | | |
| **^ Total Nitrogen as N** | ---- | 0.1 | mg/L | | <0.1 | ---- | ---- | ---- | ---- |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | | **0.33** | ---- | ---- | ---- | ---- |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | | |
| **Reactive Phosphorus as P** | 14265-44-2 | 0.01 | mg/L | | **0.32** | ---- | ---- | ---- | ---- |

ENRS
Environment & Natural Resource Solutions

# Chain of Custody

ALS

ALS SYDNEY 277-289 Woodpark Road Smithfield NSW 2164
Ph: 02 8784 8555 E: samples.sydney@alsglobal.com
ALS NEWCASTLE 5/19 Asset Way Morisset NSW 2264
Ph: 02 4014 2500 E: newcastle@alsglobal.com
ALS WOLLONGONG 99 Kenny Street Wollongong NSW 2500
Ph: 02 4225 3125 E: wollongong@alsglobal.com

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLIENT: | Environment and Natural Resource Solutions | TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g., Ultra Trace Organics) | ☒ Standard TAT (List due date): | | | | | | | FOR LABORATORY USE ONLY (Circle) | | | | |
| OFFICE: | - | | ☐ Non Standard or urgent TAT (List due date): | | | | | | | Custody Seal Intact? | | | Yes | No | N/A |
| PROJECT NO./PO: | ENRS1049 | ALS QUOTE NO.: | | COC SEQUENCE NUMBER (Circle) | | | | | | Free Ice / frozen ice bricks present upon receipt? | | | Yes | No | N/A |
| SITE/DESCRIPTION: | NCOPL | COUNTRY OF ORIGIN: | | COC: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Random Sample Temperature on Receipt: | | | °C |
| PROJECT MANAGER: | Rohan Last | CONTACT PH: | 02 9037 4708 | OF: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Other comment: | | | |

| | | | | | |
|---|---|---|---|---|---|
| SAMPLER: | M.L. | SAMPLER MOBILE: | 0403526292 | RELINQUISHED BY: M. Lemcke | RECEIVED BY: Aneta |
| COC Emailed to ALS? (YES / NO) | | EDD FORMAT (or default): | | DATE/TIME: 21/05/2020 | DATE/TIME: 21/5/20 |
| Email Reports to (will default to PM if no other addresses are listed): | lab@enrs.com.au | | | RELINQUISHED BY: | RECEIVED BY: |
| Email Invoice to (will default to PM if no other addresses are listed): | lab@enrs.com.au | | | DATE/TIME: | DATE/TIME: |

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

| ALS USE ONLY | SAMPLE DETAILS (MATRIX: Solid(S) Water(W)) | | | CONTAINER INFORMATION | | ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price). Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required). | | | | | | | | | | Additional Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAB ID | SAMPLE ID | DATE / TIME | MATRIX | TYPE & PRESERVATIVE (refer to codes below) | HOLD | W-3T (Total 15 metals) | W-3 (Dissolved 15 metals) | Total Metals: Al, As, Li, Fe | Dissolved Metals: Al, As, Li, Fe | NT-8A (NO2, NO3, NH3, TN, TP, PO3) | NT-1D (major ions (Ca, Mg, Na, K) + Hardness) | NT-2A (F, SO4, Cl, Alkalinity) | TSS, pH, EC | Total Dissolved Solids (TDS) by gravimetric analysis | Total Cyanide | Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc. |
| 1 | Delwood: House Bore | 18/05/2020 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 2 | Uplands: GW011502 | 18/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 3 | Uplands: House Supply | 18/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 4 | Uplands: Airstrip Bore | 18/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 5 | Southend: Well | 18/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 6 | Towri: House Bore | 19/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 7 | Eather Spring: #1 | 19/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 8 | Eather Spring: #2 | 19/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 9 | Eather Spring: #3 | 19/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | Please filter from green |
| 10 | Eather Spring: #4 | 19/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 11 | T-Ck: ONR | 20/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 12 | T-Ck: KHWY | 20/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 13 | Nindethana: GW013858 | 20/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 14 | Kentucky: House | 20/05/2020 | GW | P, 2xN, SP | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
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| | | | | | | | | | | | | | | | | |
| | | | | TOTAL | | 14 | 13 | 14 | 13 | 14 | 14 | 14 | 14 | 14 | | |

Environmental Division
Wollongong
Work Order Reference
EW2002425

Telephone : 02 4225 3125

**Water Container Codes:** P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Pre
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag; U = Lugols Iodine Preserved Bottles; STT = Sterile Sodium Thiosulfate Preserved Bottles.

ALS Environmental

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| **Work Order** | : **EW2002425** | Page | : 1 of 11 |
| **Amendment** | : **2** | | |
| Client | : **ENVIRONMENT & NATURAL RESOURCE SOLUTIONS** | Laboratory | : Environmental Division NSW South Coast |
| Contact | : LAB ENRS | Contact | : Aneta Prosaroski |
| Address | : 25 River Rd<br>Shoalhaven Heads 2535 | Address | : 1/19 Ralph Black Dr, North Wollongong 2500<br>4/13 Geary Pl, North Nowra 2541<br>Australia NSW Australia |
| Telephone | : 02 9037 4708 | Telephone | : +61 2 4225 3125 |
| Project | : ENRS1049 | Date Samples Received | : 21-May-2020 14:00 |
| Order number | : ENRS1049 | Date Analysis Commenced | : 21-May-2020 |
| C-O-C number | : ---- | Issue Date | : 30-Jun-2020 10:21 |
| Sampler | : Matt L | | |
| Site | : NCOPL | | |
| Quote number | : EN/222 | | |
| No. of samples received | : 14 | | |
| No. of samples analysed | : 14 | | |

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

**Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.**

## *Signatories*

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Ankit Joshi | Inorganic Chemist | Sydney Inorganics, Smithfield, NSW |
| Ivan Taylor | Analyst | Sydney Inorganics, Smithfield, NSW |

## General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- **Analytical work for this work order will be conducted at ALS Sydney.**
- EG035: Poor matrix spike recovery was obtained for Mercury on sample ES2017495 # 1. Confirmed by re-analysis.
- ED041G:: LOR raised for Sulfate on sample No 6 due to sample matrix.
- EG020: It has been confirmed by re-digestion and re-analysis that total Barium concentration is less than dissolved for sample EW2002425-#007, #008 and #010. For all other samples and analytes where dissolved is greater than total, the difference is within experimental variation of the methods.
- TDS by method EA-015 may bias high for various samples due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.
- EK071G: It has been noted that Reactive P is greater than Total P on sample NO 1 , however this difference is within the limits of experimental variation.
- Amendment (30/06/2020): This report has been amended as a result of a request to change sample identification numbers (IDs) received by ALS from Matt Lemcke on 26/06/2020. All analysis results are as per the previous report.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | Client sample ID | Delwood: Windmill | Uplands: GW011502 | Uplands: House Supply | Uplands: Airstrip Bore | Southend: Well |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 18-May-2020 00:00 | 18-May-2020 00:00 | 18-May-2020 00:00 | 18-May-2020 00:00 | 18-May-2020 00:00 |
| Compound | CAS Number | LOR | Unit | EW2002425-001 | EW2002425-002 | EW2002425-003 | EW2002425-004 | EW2002425-005 |
| | | | | Result | Result | Result | Result | Result |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| pH Value | ---- | 0.01 | pH Unit | 7.99 | 8.59 | 8.04 | 7.55 | 7.56 |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 6450 | 2960 | 2100 | 5830 | 6490 |
| **EA015: Total Dissolved Solids dried at 180 ± 5 °C** | | | | | | | | |
| Total Dissolved Solids @180°C | ---- | 10 | mg/L | 4260 | 1480 | 1190 | 3760 | 3920 |
| **EA025: Total Suspended Solids dried at 104 ± 2°C** | | | | | | | | |
| Suspended Solids (SS) | ---- | 5 | mg/L | 12 | 7 | 5 | 16 | 7 |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | 1660 | 888 | 801 | 1910 | 1780 |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | 92 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | 728 | 659 | 576 | 685 | 895 |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | 728 | 751 | 576 | 685 | 895 |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | 157 | 72 | 24 | 73 | 87 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | 1740 | 613 | 383 | 1650 | 1700 |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | 100 | 29 | 75 | 190 | 132 |
| Magnesium | 7439-95-4 | 1 | mg/L | 342 | 198 | 149 | 349 | 351 |
| Sodium | 7440-23-5 | 1 | mg/L | 711 | 324 | 144 | 473 | 701 |
| Potassium | 7440-09-7 | 1 | mg/L | 3 | 5 | 1 | 6 | 3 |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Silver | 7440-22-4 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Boron | 7440-42-8 | 0.05 | mg/L | <0.05 | <0.05 | 0.06 | <0.05 | <0.05 |
| Barium | 7440-39-3 | 0.001 | mg/L | 0.074 | 0.024 | 0.007 | 0.186 | 0.217 |
| Beryllium | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | 7440-48-4 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 |
| Uranium | 7440-61-1 | 0.001 | mg/L | 0.002 | 0.001 | 0.002 | 0.002 | 0.003 |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | | Client sample ID | Delwood: Windmill | Uplands: GW011502 | Uplands: House Supply | Uplands: Airstrip Bore | Southend: Well |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 18-May-2020 00:00 | 18-May-2020 00:00 | 18-May-2020 00:00 | 18-May-2020 00:00 | 18-May-2020 00:00 |
| Compound | CAS Number | LOR | Unit | | EW2002425-001 | EW2002425-002 | EW2002425-003 | EW2002425-004 | EW2002425-005 |
| | | | | | Result | Result | Result | Result | Result |
| **EG020F: Dissolved Metals by ICP-MS - Continued** | | | | | | | | | |
| Chromium | 7440-47-3 | 0.001 | mg/L | | **0.001** | <0.001 | **0.002** | <0.001 | <0.001 |
| Copper | 7440-50-8 | 0.001 | mg/L | | **0.025** | **0.001** | <0.001 | **0.001** | **0.020** |
| Manganese | 7439-96-5 | 0.001 | mg/L | | **0.001** | **0.001** | <0.001 | **0.224** | **0.041** |
| Nickel | 7440-02-0 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Lead | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | **0.002** |
| Selenium | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Vanadium | 7440-62-2 | 0.01 | mg/L | | **0.02** | **0.01** | **0.03** | <0.01 | **0.02** |
| Zinc | 7440-66-6 | 0.005 | mg/L | | **0.012** | <0.005 | <0.005 | **0.167** | **0.009** |
| Iron | 7439-89-6 | 0.05 | mg/L | | <0.05 | <0.05 | <0.05 | **0.94** | <0.05 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | | **0.04** | <0.01 | <0.01 | **0.01** | <0.01 |
| Silver | 7440-22-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Boron | 7440-42-8 | 0.05 | mg/L | | <0.05 | <0.05 | **0.05** | <0.05 | <0.05 |
| Barium | 7440-39-3 | 0.001 | mg/L | | **0.079** | **0.026** | **0.012** | **0.200** | **0.226** |
| Beryllium | 7440-41-7 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | 7440-48-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | **0.001** | <0.001 |
| Uranium | 7440-61-1 | 0.001 | mg/L | | **0.003** | **0.001** | **0.003** | **0.003** | **0.004** |
| Chromium | 7440-47-3 | 0.001 | mg/L | | **0.002** | <0.001 | **0.002** | **0.006** | **0.002** |
| Copper | 7440-50-8 | 0.001 | mg/L | | **0.034** | **0.002** | <0.001 | **0.002** | **0.022** |
| Manganese | 7439-96-5 | 0.001 | mg/L | | **0.007** | **0.002** | <0.001 | **0.230** | **0.043** |
| Nickel | 7440-02-0 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | **0.001** | <0.001 |
| Lead | 7439-92-1 | 0.001 | mg/L | | **0.002** | <0.001 | <0.001 | <0.001 | **0.002** |
| Selenium | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Vanadium | 7440-62-2 | 0.01 | mg/L | | **0.03** | **0.01** | **0.04** | **0.02** | **0.02** |
| Zinc | 7440-66-6 | 0.005 | mg/L | | **0.016** | **0.006** | <0.005 | **0.188** | **0.011** |
| Iron | 7439-89-6 | 0.05 | mg/L | | **0.21** | <0.05 | <0.05 | **4.74** | **0.12** |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EK026SF: Total CN by Segmented Flow Analyser** | | | | | | | | | |
| Total Cyanide | 57-12-5 | 0.004 | mg/L | | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | | Client sample ID | Delwood: Windmill | Uplands: GW011502 | Uplands: House Supply | Uplands: Airstrip Bore | Southend: Well |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 18-May-2020 00:00 | 18-May-2020 00:00 | 18-May-2020 00:00 | 18-May-2020 00:00 | 18-May-2020 00:00 |
| Compound | CAS Number | LOR | Unit | | EW2002425-001 | EW2002425-002 | EW2002425-003 | EW2002425-004 | EW2002425-005 |
| | | | | | Result | Result | Result | Result | Result |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | | **0.2** | **0.2** | **0.2** | **0.1** | **0.2** |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | | |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | | <0.01 | **0.04** | <0.01 | **0.02** | <0.01 |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | | |
| **Nitrite as N** | 14797-65-0 | 0.01 | mg/L | | <0.01 | **0.14** | <0.01 | **0.08** | **0.10** |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | | |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | | **2.20** | **2.89** | **9.91** | **0.93** | **1.86** |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | | |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | | **2.20** | **3.03** | **9.91** | **1.01** | **1.96** |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | | **0.2** | **0.5** | **1.4** | <0.1 | **0.1** |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | | |
| **^ Total Nitrogen as N** | ---- | 0.1 | mg/L | | **2.4** | **3.5** | **11.3** | **1.0** | **2.1** |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | | **0.05** | **0.02** | <0.01 | **0.04** | **0.12** |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | | |
| **Reactive Phosphorus as P** | 14265-44-2 | 0.01 | mg/L | | **0.06** | <0.01 | <0.01 | <0.01 | **0.02** |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | Client sample ID | Towrl: House Bore | Eather Spring: #1 | Eather Spring: #2 | Towri Dam 1 | Towri Dam 2 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 19-May-2020 00:00 | 19-May-2020 00:00 | 19-May-2020 00:00 | 19-May-2020 00:00 | 19-May-2020 00:00 |
| Compound | CAS Number | LOR | Unit | EW2002425-006 | EW2002425-007 | EW2002425-008 | EW2002425-009 | EW2002425-010 |
| | | | | Result | Result | Result | Result | Result |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| pH Value | ---- | 0.01 | pH Unit | 8.18 | 7.58 | 7.42 | 6.36 | 7.32 |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 546 | 150 | 84 | 73 | 175 |
| **EA015: Total Dissolved Solids dried at 180 ± 5 °C** | | | | | | | | |
| Total Dissolved Solids @180°C | ---- | 10 | mg/L | 328 | 135 | 141 | 710 | 206 |
| **EA025: Total Suspended Solids dried at 104 ± 2°C** | | | | | | | | |
| Suspended Solids (SS) | ---- | 5 | mg/L | 10 | 28 | 33 | 112 | 58 |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | 98 | 30 | 22 | <1 | 36 |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | 157 | 61 | 32 | 5 | 65 |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | 157 | 61 | 32 | 5 | 65 |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | <10 | <1 | <1 | 13 | <1 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | 68 | 10 | 5 | 6 | 10 |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | 18 | 4 | 4 | <1 | 6 |
| Magnesium | 7439-95-4 | 1 | mg/L | 13 | 5 | 3 | <1 | 5 |
| Sodium | 7440-23-5 | 1 | mg/L | 69 | 17 | 8 | 7 | 5 |
| Potassium | 7440-09-7 | 1 | mg/L | 16 | 6 | 5 | 9 | 27 |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | <0.01 | 0.07 | 2.74 | 1.76 | 0.38 |
| Silver | 7440-22-4 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | 0.002 | 0.004 | 0.001 | 0.002 |
| Boron | 7440-42-8 | 0.05 | mg/L | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Barium | 7440-39-3 | 0.001 | mg/L | 0.044 | 0.134 | 0.232 | 0.016 | 0.157 |
| Beryllium | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | 7440-48-4 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 |
| Uranium | 7440-61-1 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Chromium | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | 0.002 | 0.002 | <0.001 |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | | Client sample ID | Towrl: House Bore | Eather Spring: #1 | Eather Spring: #2 | Towri Dam 1 | Towri Dam 2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 19-May-2020 00:00 | 19-May-2020 00:00 | 19-May-2020 00:00 | 19-May-2020 00:00 | 19-May-2020 00:00 |
| Compound | CAS Number | LOR | Unit | | EW2002425-006 | EW2002425-007 | EW2002425-008 | EW2002425-009 | EW2002425-010 |
| | | | | | Result | Result | Result | Result | Result |
| **EG020F: Dissolved Metals by ICP-MS - Continued** | | | | | | | | | |
| Copper | 7440-50-8 | 0.001 | mg/L | | <0.001 | <0.001 | **0.002** | **0.002** | **0.003** |
| Manganese | 7439-96-5 | 0.001 | mg/L | | **0.013** | **0.021** | **0.020** | **0.011** | **0.071** |
| Nickel | 7440-02-0 | 0.001 | mg/L | | **0.002** | <0.001 | **0.002** | <0.001 | **0.002** |
| Lead | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | **0.002** | <0.001 | **0.001** |
| Selenium | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Vanadium | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Zinc | 7440-66-6 | 0.005 | mg/L | | <0.005 | **0.030** | **0.022** | <0.005 | **0.019** |
| Iron | 7439-89-6 | 0.05 | mg/L | | <0.05 | **0.37** | **2.62** | **0.60** | **2.29** |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | | **0.16** | **0.16** | **5.45** | **31.2** | **0.79** |
| Silver | 7440-22-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | | <0.001 | **0.003** | **0.010** | **0.013** | **0.004** |
| Boron | 7440-42-8 | 0.05 | mg/L | | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Barium | 7440-39-3 | 0.001 | mg/L | | **0.049** | **0.025** | **0.035** | **0.238** | **0.067** |
| Beryllium | 7440-41-7 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cobalt | 7440-48-4 | 0.001 | mg/L | | <0.001 | <0.001 | **0.002** | **0.005** | **0.002** |
| Uranium | 7440-61-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | **0.001** | <0.001 |
| Chromium | 7440-47-3 | 0.001 | mg/L | | <0.001 | <0.001 | **0.004** | **0.029** | **0.002** |
| Copper | 7440-50-8 | 0.001 | mg/L | | <0.001 | **0.002** | **0.004** | **0.024** | **0.004** |
| Manganese | 7439-96-5 | 0.001 | mg/L | | **0.081** | **0.089** | **0.146** | **0.117** | **0.202** |
| Nickel | 7440-02-0 | 0.001 | mg/L | | **0.003** | **0.002** | **0.003** | **0.007** | **0.002** |
| Lead | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | **0.006** | **0.025** | **0.002** |
| Selenium | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Vanadium | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | **0.01** | **0.05** | <0.01 |
| Zinc | 7440-66-6 | 0.005 | mg/L | | **0.013** | <0.005 | **0.011** | **0.037** | **0.010** |
| Iron | 7439-89-6 | 0.05 | mg/L | | **0.36** | **1.55** | **9.48** | **20.7** | **7.83** |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EK026SF: Total CN by Segmented Flow Analyser** | | | | | | | | | |
| Total Cyanide | 57-12-5 | 0.004 | mg/L | | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | | |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | | Client sample ID | Towrl: House Bore | Eather Spring: #1 | Eather Spring: #2 | Towri Dam 1 | Towri Dam 2 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 19-May-2020 00:00 | 19-May-2020 00:00 | 19-May-2020 00:00 | 19-May-2020 00:00 | 19-May-2020 00:00 |
| Compound | CAS Number | LOR | Unit | | EW2002425-006 | EW2002425-007 | EW2002425-008 | EW2002425-009 | EW2002425-010 |
| | | | | | Result | Result | Result | Result | Result |
| **EK040P: Fluoride by PC Titrator - Continued** | | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | | **0.3** | **0.2** | <0.1 | <0.1 | **0.1** |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | | |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | | **0.45** | <0.01 | **0.57** | **0.08** | **0.02** |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | | |
| **Nitrite as N** | 14797-65-0 | 0.01 | mg/L | | <0.01 | <0.01 | **0.02** | **0.03** | <0.01 |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | | |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | | **0.08** | **0.02** | **0.25** | **2.58** | **0.02** |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | | |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | | **0.08** | **0.02** | **0.27** | **2.61** | **0.02** |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | | **1.3** | **3.0** | **2.6** | **3.5** | **5.5** |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | | |
| **^ Total Nitrogen as N** | ---- | 0.1 | mg/L | | **1.4** | **3.0** | **2.9** | **6.1** | **5.5** |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | | **0.02** | **0.17** | **0.32** | **0.68** | **0.60** |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | | |
| **Reactive Phosphorus as P** | 14265-44-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | Client sample ID | T-Ck: ONR | T-Ck: KHWY | Nindethana: GW013858 | Kentucky: House | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 20-May-2020 00:00 | 20-May-2020 00:00 | 20-May-2020 00:00 | 20-May-2020 00:00 | ---- |
| Compound | CAS Number | LOR | Unit | EW2002425-011 | EW2002425-012 | EW2002425-013 | EW2002425-014 | -------- |
| | | | | Result | Result | Result | Result | ---- |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| pH Value | ---- | 0.01 | pH Unit | 8.03 | 7.66 | 7.40 | 6.79 | ---- |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 367 | 126 | 4960 | 96 | ---- |
| **EA015: Total Dissolved Solids dried at 180 ± 5 °C** | | | | | | | | |
| Total Dissolved Solids @180°C | ---- | 10 | mg/L | 203 | 92 | 3130 | 59 | ---- |
| **EA025: Total Suspended Solids dried at 104 ± 2°C** | | | | | | | | |
| Suspended Solids (SS) | ---- | 5 | mg/L | <5 | 10 | 10 | <5 | ---- |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | 143 | 31 | 1700 | 9 | ---- |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | <1 | <1 | <1 | ---- |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | <1 | <1 | <1 | ---- |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | 189 | 55 | 646 | 17 | ---- |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | 189 | 55 | 646 | 17 | ---- |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | 5 | <1 | 62 | <1 | ---- |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | 8 | 6 | 1290 | 18 | ---- |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | 36 | 6 | 206 | 2 | ---- |
| Magnesium | 7439-95-4 | 1 | mg/L | 13 | 4 | 287 | 1 | ---- |
| Sodium | 7440-23-5 | 1 | mg/L | 22 | 12 | 354 | 14 | ---- |
| Potassium | 7440-09-7 | 1 | mg/L | 4 | 4 | 4 | 2 | ---- |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | <0.01 | 0.17 | <0.01 | <0.01 | ---- |
| Silver | 7440-22-4 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | ---- |
| Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | ---- |
| Boron | 7440-42-8 | 0.05 | mg/L | <0.05 | <0.05 | <0.05 | <0.05 | ---- |
| Barium | 7440-39-3 | 0.001 | mg/L | 0.100 | 0.065 | 0.071 | 0.030 | ---- |
| Beryllium | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | ---- |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | ---- |
| Cobalt | 7440-48-4 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | ---- |
| Uranium | 7440-61-1 | 0.001 | mg/L | <0.001 | <0.001 | 0.002 | <0.001 | ---- |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | | Client sample ID | T-Ck: ONR | T-Ck: KHWY | Nindethana: GW013858 | Kentucky: House | ---- |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 20-May-2020 00:00 | 20-May-2020 00:00 | 20-May-2020 00:00 | 20-May-2020 00:00 | ---- |
| Compound | CAS Number | LOR | Unit | | EW2002425-011 | EW2002425-012 | EW2002425-013 | EW2002425-014 | -------- |
| | | | | | Result | Result | Result | Result | ---- |
| **EG020F: Dissolved Metals by ICP-MS - Continued** | | | | | | | | | |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | ---- |
| **Copper** | 7440-50-8 | 0.001 | mg/L | | <0.001 | **0.001** | **0.002** | **0.032** | ---- |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | | **0.047** | **0.004** | **0.098** | <0.001 | ---- |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | | **0.002** | **0.002** | **0.006** | **0.001** | ---- |
| **Lead** | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | ---- |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | ---- |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | ---- |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | | <0.005 | <0.005 | **0.029** | **0.040** | ---- |
| **Iron** | 7439-89-6 | 0.05 | mg/L | | <0.05 | **0.26** | **0.08** | <0.05 | ---- |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | | |
| **Aluminium** | 7429-90-5 | 0.01 | mg/L | | **0.13** | **2.82** | **0.02** | <0.01 | ---- |
| **Silver** | 7440-22-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | ---- |
| **Arsenic** | 7440-38-2 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | ---- |
| **Boron** | 7440-42-8 | 0.05 | mg/L | | <0.05 | <0.05 | <0.05 | <0.05 | ---- |
| **Barium** | 7440-39-3 | 0.001 | mg/L | | **0.106** | **0.080** | **0.073** | **0.031** | ---- |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | ---- |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | ---- |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | ---- |
| **Uranium** | 7440-61-1 | 0.001 | mg/L | | <0.001 | <0.001 | **0.002** | <0.001 | ---- |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | | <0.001 | **0.004** | **0.002** | <0.001 | ---- |
| **Copper** | 7440-50-8 | 0.001 | mg/L | | **0.001** | **0.002** | **0.004** | **0.036** | ---- |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | | **0.066** | **0.022** | **0.102** | <0.001 | ---- |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | | **0.002** | **0.004** | **0.006** | <0.001 | ---- |
| **Lead** | 7439-92-1 | 0.001 | mg/L | | <0.001 | <0.001 | <0.001 | <0.001 | ---- |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | ---- |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | ---- |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | | <0.005 | **0.009** | **0.035** | **0.042** | ---- |
| **Iron** | 7439-89-6 | 0.05 | mg/L | | **0.17** | **3.07** | **0.67** | <0.05 | ---- |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | ---- |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | <0.0001 | <0.0001 | <0.0001 | ---- |
| **EK026SF: Total CN by Segmented Flow Analyser** | | | | | | | | | |
| **Total Cyanide** | 57-12-5 | 0.004 | mg/L | | <0.004 | <0.004 | <0.004 | <0.004 | ---- |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | | Client sample ID | T-Ck: ONR | T-Ck: KHWY | Nindethana: GW013858 | Kentucky: House | ---- |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 20-May-2020 00:00 | 20-May-2020 00:00 | 20-May-2020 00:00 | 20-May-2020 00:00 | ---- |
| Compound | CAS Number | LOR | Unit | | EW2002425-011 | EW2002425-012 | EW2002425-013 | EW2002425-014 | -------- |
| | | | | | Result | Result | Result | Result | ---- |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | | **0.3** | <0.1 | <0.1 | <0.1 | **----** |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | | |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | | <0.01 | <0.01 | **0.12** | **0.06** | **----** |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | | |
| **Nitrite as N** | 14797-65-0 | 0.01 | mg/L | | <0.01 | <0.01 | **0.02** | <0.01 | **----** |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | | |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | | **0.02** | **0.02** | **5.18** | **0.18** | **----** |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | | |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | | **0.02** | **0.02** | **5.20** | **0.18** | **----** |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | | **0.2** | **0.5** | **0.6** | <0.1 | **----** |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | | |
| **^ Total Nitrogen as N** | ---- | 0.1 | mg/L | | **0.2** | **0.5** | **5.8** | **0.2** | **----** |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | | **0.02** | **0.04** | **0.05** | <0.01 | **----** |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | | |
| **Reactive Phosphorus as P** | 14265-44-2 | 0.01 | mg/L | | <0.01 | <0.01 | <0.01 | <0.01 | **----** |

46.20

HT

ENRS
Environment & Natural Resource Solutions

# Chain of Custody

ALS


ENVIRONMENTAL: 127 239 Woodstock Road Orchard Hills NSW 2748
PH: 0434 [illegible] E: [illegible]@enrsaustralia.com

ENVIRONMENTAL: [illegible] Suite 2, 6-8 [illegible] Road Mudgeeraba QLD 4213
PH: 0434 [illegible] E: [illegible]@enrsaustralia.com

ENVIRONMENTAL: [illegible] Level 2, 343 George Street Wollongong NSW 2500
PH: 0434 [illegible] E: [illegible]@enrsaustralia.com


| | | | | | |
|---|---|---|---|---|---|
| CLIENT: | Environment and Natural Resource Solutions | TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g., Ultra Trace Organics) | ☒ Standard TAT (List due date): | FOR LABORATORY USE ONLY (Circle) | |
| OFFICE: | - | | ☐ Non Standard or urgent TAT (List due date): | Custody Seal Intact? | (Yes) No N/A |
| PROJECT NO./PO: | ENRS1049 | ALS QUOTE NO.: | COC SEQUENCE NUMBER (Circle) | Free ice / frozen ice bricks present upon receipt? | Yes No N/A |
| SITE/DESCRIPTION: | NCOPL | COUNTRY OF ORIGIN: | COC: 1 2 3 4 5 6 7 | Random Sample Temperature on Receipt: | 1.5 °C |
| PROJECT MANAGER: | Rohan Last | CONTACT PH: 02 9037 4708 | OF: 1 2 3 4 5 6 7 | Other comment: | |
| SAMPLER: | M.L. | SAMPLER MOBILE: 0403526292 | RELINQUISHED BY: | RECEIVED BY: | RELINQUISHED BY: / RECEIVED BY: |
| COC Emailed to ALS? (YES / NO) | | EDD FORMAT (or default): | M. Lemcke | SO 8/11/20 | |
| Email Reports to (will default to PM if no other addresses are listed) | lab@enrs.com.au | | DATE/TIME: 28/05/2020 | DATE/TIME: 29/5/20 1430 | DATE/TIME: / DATE/TIME: |
| Email Invoice to (will default to PM if no other addresses are listed) | lab@enrs.com.au | | | | |

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

| ALS USE ONLY | SAMPLE DETAILS (MATRIX: Solid(S) Water(W)) | | | CONTAINER INFORMATION | | ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) (Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).) | | | | | | | | | | Additional Information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAB ID | SAMPLE ID | DATE / TIME | MATRIX | TYPE & PRESERVATIVE (refer to codes below) | HOLD | W-3T (Total 15 metals) | W-3 (Dissolved 15 metals) | Total Metals: Al, Ag, U, Fe | Dissolved Metals: Al, Ag, U, Fe | NT-9A (NO2, NO3, NH3, TN, TP, PO3) | NT-1D (major ions (Ca, Mg, Na, K) + Hardness) | NT-2A (F, SO4, Cl, Alkalinity) | TSS, pH, EC | Total Dissolved Solids (TDS) by gravimetric analysis | Total Cyanide | Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc. |
| 1 | Kurrajong Trib | 27/05/2020 | GW | P, 2xN, SP, S | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | ALS to prepare a filtered sample for metals analysis |
| | | | | | | | | | | | | | | | | |
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| | | | | TOTAL | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP = Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag; LI = Lugols Iodine Preserved Bottles; STT = Sterile Sodium Thiosulfate Preserved Bottles.

Environmental Division
Sydney
Work Order Reference
ES2018696

Telephone : + 61-2-8784 8555

ALS Environmental

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| **Work Order** | : **ES2018696** | Page | : 1 of 5 |
| Client | : **ENVIRONMENT & NATURAL RESOURCE SOLUTIONS** | Laboratory | : Environmental Division Sydney |
| Contact | : Mr Rohan Last | Contact | : Aneta Prosaroski |
| Address | : 25 River Rd<br>Shoalhaven Heads 2535 | Address | : 277-289 Woodpark Road Smithfield NSW Australia 2164 |
| Telephone | : ---- | Telephone | : +61 2 4225 3125 |
| Project | : ENRS1049 | Date Samples Received | : 29-May-2020 14:30 |
| Order number | : ---- | Date Analysis Commenced | : 29-May-2020 |
| C-O-C number | : ---- | Issue Date | : 04-Jun-2020 13:33 |
| Sampler | : M.L | | |
| Site | : NCOPL | | |
| Quote number | : EN/222 | | |
| No. of samples received | : 1 | | |
| No. of samples analysed | : 1 | | |

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

**Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.**

## *Signatories*

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| Ankit Joshi | Inorganic Chemist | Sydney Inorganics, Smithfield, NSW |
| Ivan Taylor | Analyst | Sydney Inorganics, Smithfield, NSW |

## General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EK071G: LOR raised for Reactive P due to sample matrix.
- ED041G: LOR raised for Sulfate due to sample matrix.
- EK057G: LOR raised for Nitrite due to sample matrix.
- TDS by method EA-015 may bias high for sample 1 due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | Client sample ID | Kurrajong Trib | ---- | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 27-May-2020 00:00 | ---- | ---- | ---- | ---- |
| Compound | CAS Number | LOR | Unit | ES2018696-001 | -------- | -------- | -------- | -------- |
| | | | | Result | ---- | ---- | ---- | ---- |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| pH Value | ---- | 0.01 | pH Unit | **9.22** | ---- | ---- | ---- | ---- |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | **1480** | ---- | ---- | ---- | ---- |
| **EA015: Total Dissolved Solids dried at 180 ± 5 °C** | | | | | | | | |
| Total Dissolved Solids @180°C | ---- | 10 | mg/L | **1970** | ---- | ---- | ---- | ---- |
| **EA025: Total Suspended Solids dried at 104 ± 2°C** | | | | | | | | |
| Suspended Solids (SS) | ---- | 5 | mg/L | **123** | ---- | ---- | ---- | ---- |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | ---- | ---- | ---- | ---- |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | **177** | ---- | ---- | ---- | ---- |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | **538** | ---- | ---- | ---- | ---- |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | **715** | ---- | ---- | ---- | ---- |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | <10 | ---- | ---- | ---- | ---- |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | **105** | ---- | ---- | ---- | ---- |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | **4** | ---- | ---- | ---- | ---- |
| Magnesium | 7439-95-4 | 1 | mg/L | **2** | ---- | ---- | ---- | ---- |
| Sodium | 7440-23-5 | 1 | mg/L | **366** | ---- | ---- | ---- | ---- |
| Potassium | 7440-09-7 | 1 | mg/L | **6** | ---- | ---- | ---- | ---- |
| **ED093F: SAR and Hardness Calculations** | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | **18** | ---- | ---- | ---- | ---- |
| **EG020F: Dissolved Metals by ICP-MS** | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | **0.24** | ---- | ---- | ---- | ---- |
| Arsenic | 7440-38-2 | 0.001 | mg/L | **0.005** | ---- | ---- | ---- | ---- |
| Boron | 7440-42-8 | 0.05 | mg/L | **0.05** | ---- | ---- | ---- | ---- |
| Barium | 7440-39-3 | 0.001 | mg/L | **0.023** | ---- | ---- | ---- | ---- |
| Beryllium | 7440-41-7 | 0.001 | mg/L | <0.001 | ---- | ---- | ---- | ---- |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | ---- | ---- | ---- | ---- |
| Cobalt | 7440-48-4 | 0.001 | mg/L | **0.004** | ---- | ---- | ---- | ---- |
| Chromium | 7440-47-3 | 0.001 | mg/L | **0.002** | ---- | ---- | ---- | ---- |
| Copper | 7440-50-8 | 0.001 | mg/L | **0.009** | ---- | ---- | ---- | ---- |
| Manganese | 7439-96-5 | 0.001 | mg/L | **0.005** | ---- | ---- | ---- | ---- |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | | Client sample ID | Kurrajong Trib | ---- | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 27-May-2020 00:00 | ---- | ---- | ---- | ---- |
| Compound | CAS Number | LOR | Unit | | ES2018696-001 | -------- | -------- | -------- | -------- |
| | | | | | Result | ---- | ---- | ---- | ---- |
| **EG020F: Dissolved Metals by ICP-MS - Continued** | | | | | | | | | |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | | **0.014** | ---- | ---- | ---- | ---- |
| **Lead** | 7439-92-1 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | | <0.01 | ---- | ---- | ---- | ---- |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | | **0.02** | ---- | ---- | ---- | ---- |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | | <0.005 | ---- | ---- | ---- | ---- |
| **Silver** | 7440-22-4 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| **Uranium** | 7440-61-1 | 0.001 | mg/L | | **0.002** | ---- | ---- | ---- | ---- |
| **Iron** | 7439-89-6 | 0.05 | mg/L | | **0.88** | ---- | ---- | ---- | ---- |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | | |
| **Aluminium** | 7429-90-5 | 0.01 | mg/L | | **52.8** | ---- | ---- | ---- | ---- |
| **Arsenic** | 7440-38-2 | 0.001 | mg/L | | **0.008** | ---- | ---- | ---- | ---- |
| **Boron** | 7440-42-8 | 0.05 | mg/L | | **0.06** | ---- | ---- | ---- | ---- |
| **Barium** | 7440-39-3 | 0.001 | mg/L | | **0.503** | ---- | ---- | ---- | ---- |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | | **0.002** | ---- | ---- | ---- | ---- |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | | <0.0001 | ---- | ---- | ---- | ---- |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | | **0.031** | ---- | ---- | ---- | ---- |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | | **0.074** | ---- | ---- | ---- | ---- |
| **Copper** | 7440-50-8 | 0.001 | mg/L | | **0.032** | ---- | ---- | ---- | ---- |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | | **0.583** | ---- | ---- | ---- | ---- |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | | **0.075** | ---- | ---- | ---- | ---- |
| **Lead** | 7439-92-1 | 0.001 | mg/L | | **0.028** | ---- | ---- | ---- | ---- |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | | <0.01 | ---- | ---- | ---- | ---- |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | | **0.12** | ---- | ---- | ---- | ---- |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | | **0.087** | ---- | ---- | ---- | ---- |
| **Silver** | 7440-22-4 | 0.001 | mg/L | | <0.001 | ---- | ---- | ---- | ---- |
| **Uranium** | 7440-61-1 | 0.001 | mg/L | | **0.004** | ---- | ---- | ---- | ---- |
| **Iron** | 7439-89-6 | 0.05 | mg/L | | **53.2** | ---- | ---- | ---- | ---- |
| **EG035F: Dissolved Mercury by FIMS** | | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | ---- | ---- | ---- | ---- |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | | <0.0001 | ---- | ---- | ---- | ---- |
| **EK026SF: Total CN by Segmented Flow Analyser** | | | | | | | | | |
| **Total Cyanide** | 57-12-5 | 0.004 | mg/L | | <0.004 | ---- | ---- | ---- | ---- |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | | |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | | Client sample ID | Kurrajong Trib | ---- | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Client sampling date / time | 27-May-2020 00:00 | ---- | ---- | ---- | ---- |
| Compound | CAS Number | LOR | Unit | | ES2018696-001 | -------- | -------- | -------- | -------- |
| | | | | | Result | ---- | ---- | ---- | ---- |
| **EK040P: Fluoride by PC Titrator - Continued** | | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | | **0.5** | ---- | ---- | ---- | ---- |
| **EK055G: Ammonia as N by Discrete Analyser** | | | | | | | | | |
| **Ammonia as N** | 7664-41-7 | 0.01 | mg/L | | **0.04** | ---- | ---- | ---- | ---- |
| **EK057G: Nitrite as N by Discrete Analyser** | | | | | | | | | |
| **Nitrite as N** | 14797-65-0 | 0.01 | mg/L | | <0.10 | ---- | ---- | ---- | ---- |
| **EK058G: Nitrate as N by Discrete Analyser** | | | | | | | | | |
| **Nitrate as N** | 14797-55-8 | 0.01 | mg/L | | **0.14** | ---- | ---- | ---- | ---- |
| **EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser** | | | | | | | | | |
| **Nitrite + Nitrate as N** | ---- | 0.01 | mg/L | | **0.14** | ---- | ---- | ---- | ---- |
| **EK061G: Total Kjeldahl Nitrogen By Discrete Analyser** | | | | | | | | | |
| **Total Kjeldahl Nitrogen as N** | ---- | 0.1 | mg/L | | **9.4** | ---- | ---- | ---- | ---- |
| **EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser** | | | | | | | | | |
| ^ **Total Nitrogen as N** | ---- | 0.1 | mg/L | | **9.5** | ---- | ---- | ---- | ---- |
| **EK067G: Total Phosphorus as P by Discrete Analyser** | | | | | | | | | |
| **Total Phosphorus as P** | ---- | 0.01 | mg/L | | **3.10** | ---- | ---- | ---- | ---- |
| **EK071G: Reactive Phosphorus as P by discrete analyser** | | | | | | | | | |
| **Reactive Phosphorus as P** | 14265-44-2 | 0.01 | mg/L | | <0.05 | ---- | ---- | ---- | ---- |
| **EN055: Ionic Balance** | | | | | | | | | |
| ø **Total Anions** | ---- | 0.01 | meq/L | | **17.2** | ---- | ---- | ---- | ---- |
| ø **Total Cations** | ---- | 0.01 | meq/L | | **16.4** | ---- | ---- | ---- | ---- |
| ø **Ionic Balance** | ---- | 0.01 | % | | **2.40** | ---- | ---- | ---- | ---- |

# Appendix D

## Comparison of Laboratory Results Against Groundwater Assessment Criteria

**TABLE A: Water Quality Results.**

| ANZG 2018 - Trigger Values for Freshwater (Protection of 95% of Species) [A] | ANZECC 2000 - Agricultural Irrigation (Short-term Irrigation Trigger Value up to 20 years)[B] | Australian Drinking Water Guidelines (2018)[C] | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Health | Aesthetic | | | | Mayfield Spring: EW1903612001 | Namoi View: GW963632 - Submersible: EW1903612002 | Namoi View - Jet Water: EW1903612003 | Red Hill: GW971254 EW1903612004 | Springfield: GW963633 EW1903612005 | Yarranabee - Dam 1 EW1904451001 | Yarranabee - Dam 2: EW1904451002 | Riverview - Jet Water: EW1904451003 | Riverview: GW902579 - Windmill: EW1904451004 | Riverstone - House Supply: EW1904451005 | Riverstone: GW063627 - Irrigation Bore #1: EW1904451006 | Riverstone: GW063422 - Irrigation Bore #2: EW1904451007 | Riverstone: GW963984 - Irrigation Bore #3: EW1904451008 | Green Hills - Cattle Bore: EW1904451009 |
| | | | | | Date Sampled | | 16/08/2019 | 15/08/2019 | 15/08/2019 | 15/08/2019 | 15/08/2019 | 9/10/2019 | 9/10/2019 | 9/10/2019 | 9/10/2019 | 9/10/2019 | 9/10/2019 | 9/10/2019 | 9/10/2019 | 9/10/2019 | 9/10/2019 |
| | | | | | ENRS ID | | 2019081601 | 2019081507 | 2019081506 | 2019081509 | 2019081505 | 2019100915 | 2019100916 | 2019100905 | 2019100904 | 2019100910 | 2019100911 | 2019100912 | 2019100913 | 2019100909 |
| | | | | | Units | Laboratory PQL | | | | | | | | | | | | | | |
| 0.055 | 20 | - | 0.20 | Total Metals | Aluminium | mg/L | 0.001 | 0.02 | 0.01 | <0.01 | 0.03 | <0.01 | 0.6 | 0.54 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 0.024 (As III) | 2 | 0.1 | - | | Arsenic | mg/L | 0.001 | <0.001 | 0.025 | 0.002 | <0.001 | 0.001 | 0.003 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| - | 0.5 | 0.06 | - | | 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 |
| - | - | 2 | - | | Barium | mg/L | 0.001 | 0.102 | 0.099 | 0.035 | 0.058 | 0.03 | 0.11 | 0.103 | 0.027 | 0.066 | 0.12 | 0.087 | 0.103 | 0.021 | 0.016 |
| 0.37 | Footnote D | 4 | - | | Boron | mg/L | 0.05 | 0.09 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| 0.0002 | 0.05 | 0.002 | - | | Cadmium | mg/L | 0.0001 | 0.0008 | <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 (CrVI) | 1 | 0.05 | - | | 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 |
| - | 0.1 | - | - | | Cobalt | mg/L | 0.001 | 0.103 | 0.001 | <0.001 | 0.002 | <0.001 | 0.002 | 0.003 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| 0.0014 | 5 | 2 | 1 | | Copper | mg/L | 0.001 | 0.002 | 0.004 | 0.016 | 0.009 | 0.004 | <0.001 | <0.001 | <0.001 | 0.007 | 0.004 | <0.001 | <0.001 | <0.001 | 0.04 |
| - | 10 | 50 | 0.30 | | Iron | mg/L | 0.01 | 0.15 | 19.1 | 0.06 | 0.06 | 0.36 | 1.77 | 0.75 | 1.19 | 6.33 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| 0.0034 | 5 | 0.01 | - | | Lead | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | 0.004 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| 1.9 | 10 | 0.5 | 0.1 | | Manganese | mg/L | 0.001 | 0.892 | 1.540 | 0.016 | 0.004 | 0.006 | 0.158 | 0.575 | 0.127 | 0.054 | 1.040 | 0.106 | 0.406 | 0.037 | <0.001 |
| 0.0006 | 0.002 | 0.001 | - | | 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 |
| 0.011 | 2 | 0.02 | - | | Nickel | mg/L | 0.001 | 0.595 | 0.001 | <0.001 | 0.002 | <0.001 | 0.006 | 0.006 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | 0.001 | <0.001 |
| 0.011 | 0.05 | 0.01 | - | | 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 |
| 0.00005 | - | 0.1 | - | | Silver | mg/L | 0.01 | <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 |
| - | 0.1 | 0.02 | - | | Uranium | mg/L | 0.01 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | 0.004 | 0.006 | 0.004 | 0.002 | 0.002 |
| - | 0.5 | - | - | | 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 | <0.01 |
| 0.008 | 5 | - | 3 | | Zinc | mg/L | 0.005 | 0.230 | 0.006 | 0.014 | 0.036 | 0.006 | <0.005 | <0.005 | 0.058 | 0.011 | 0.058 | <0.005 | <0.005 | <0.005 | 0.027 |
| 0.055 | 20 | - | 0.20 | Dissolved Metals | Aluminium | mg/L | 0.001 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.03 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 0.024 (As III) | 2 | 0.1 | - | | Arsenic | mg/L | 0.001 | <0.001 | 0.02 | 0.002 | <0.001 | 0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| - | 0.5 | 0.06 | - | | 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 |
| - | - | 2 | - | | Barium | mg/L | 0.001 | 0.101 | 0.07 | 0.034 | 0.056 | 0.028 | 0.091 | 0.093 | 0.021 | 0.06 | 0.117 | 0.082 | 0.098 | 0.02 | 0.015 |
| 0.37 | Footnote D | 4 | - | | Boron | mg/L | 0.05 | 0.08 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| 0.0002 | 0.05 | 0.002 | - | | Cadmium | mg/L | 0.0001 | 0.00007 | <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 (CrVI) | 1 | 0.05 | - | | 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 |
| - | 0.1 | - | - | | Cobalt | mg/L | 0.001 | 0.103 | 0.001 | <0.001 | 0.002 | <0.001 | 0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| 0.0014 | 5 | 2 | 1 | | Copper | mg/L | 0.001 | 0.001 | <0.001 | 0.013 | 0.004 | 0.003 | <0.001 | 0.001 | <0.001 | 0.001 | 0.004 | <0.001 | <0.001 | <0.001 | 0.039 |
| - | 10 | 50 | 0.30 | | Iron | mg/L | 0.01 | <0.05 | 16 | <0.05 | <0.05 | <0.05 | 0.21 | <0.05 | 0.12 | 4.69 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| 0.0034 | 5 | 0.01 | - | | Lead | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | 0.00 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 |
| 1.9 | 10 | 0.5 | 0.1 | | Manganese | mg/L | 0.001 | 0.902 | 1.440 | 0.011 | 0.003 | <0.001 | 0.090 | 0.488 | 0.118 | 0.053 | 1.050 | 0.105 | 0.390 | 0.038 | <0.001 |
| 0.0006 | 0.002 | 0.001 | - | | 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 |
| 0.011 | 2 | 0.02 | - | | Nickel | mg/L | 0.001 | 0.586 | <0.001 | <0.001 | 0.001 | <0.001 | 0.004 | 0.005 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| 0.011 | 0.05 | 0.01 | - | | 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 |
| 0.00005 | - | 0.1 | - | | Silver | mg/L | 0.01 | <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 |
| - | 0.1 | 0.02 | - | | Uranium | mg/L | 0.01 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | 0.003 | 0.006 | 0.003 | 0.001 | 0.002 |
| - | 0.5 | - | - | | 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 | <0.01 |
| 0.008 | 5 | - | 3 | | Zinc | mg/L | 0.005 | 0.222 | <0.005 | 0.012 | 0.031 | <0.005 | <0.005 | <0.005 | <0.005 | 0.008 | 0.058 | <0.005 | <0.005 | <0.005 | 0.026 |
| - | - | - | - | Alkalinity - as CaCo3 | Hydroxide Alkalinity | mg/L | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| - | - | - | - | | Carbonate Alkalinity | mg/L | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| - | - | - | - | | Bicarbonate Alkalinity | mg/L | 1 | 29 | 216 | 301 | 10 | 326 | 119 | 141 | 252 | 256 | 273 | 281 | 272 | 231 | 271 |
| - | - | - | - | | Total Alkalinity | mg/L | 1 | 29 | 216 | 301 | 10 | 326 | 119 | 141 | 252 | 256 | 273 | 281 | 272 | 231 | 271 |
| - | - | - | - | Major Cations | Calcium | mg/L | 1 | 70 | 42 | 47 | 1 | 60 | 16 | 16 | 43 | 46 | 256 | 321 | 165 | 75 | 51 |
| - | - | - | - | | Magnesium | mg/L | 1 | 184 | 22 | 32 | 2 | 32 | 10 | 13 | 23 | 40 | 150 | 186 | 96 | 41 | 27 |
| - | - | - | - | | Sodium | mg/L | 1 | 536 | 29 | 63 | 30 | 163 | 30 | 28 | 62 | 174 | 303 | 469 | 213 | 130 | 141 |
| - | - | - | - | | Potassium | mg/L | 1 | 14 | 3 | 3 | 2 | 2 | 8 | 7 | 1 | 3 | 3 | 3 | 3 | 3 | 2 |
| - | - | - | 250 | | Chloride | mg/L | 1 | 1180 | 20 | 29 | 44 | 134 | 14 | 15 | 42 | 267 | 975 | 1140 | 562 | 236 | 133 |
| - | 2 | - | 250 | | Fluoride | mg/L | 1 | 0 | 0.2 | 0.4 | <0.1 | 0.4 | 0.3 | 0.2 | 0.4 | 0.2 | 0.1 | 0.2 | 0.2 | 0.1 | 0.3 |
| - | - | 500 | 250 | | Sulphate | mg/L | 1 | 268 | <1 | 8 | <1 | 64 | <1 | <1 | 18 | 65 | 372 | 675 | 326 | 104 | 83 |
| 0.007 | - | 0.08 | - | | Cyanide (Total) | mg/L | 0.1 | - | - | - | - | - | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| 0.9 | - | - | 0.5 | | Ammonia | mg/L | 0.1 | <0.01 | 0.7 | <0.01 | <0.01 | 0.02 | 0.05 | 0.2 | 0.12 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| - | - | - | - | | Total Kjeldahl Nitrogen as N | mg/L | 0.1 | 0.2 | 0.7 | 0.2 | <0.1 | 0.6 | 1 | 0.9 | <0.1 | <0.1 | 0.3 | <0.1 | 0.1 | 0.1 | 0.3 |
| - | 25-125 | - | - | | Total Nitrogen as N | mg/L | 0.1 | 4.3 | 0.7 | 1.8 | 0.3 | 5 | 1 | 0.9 | <0.1 | 0.1 | 3.2 | 7.3 | 0.7 | 1.3 | 5.6 |
| - | 0.8-12 | - | - | | Total Phosphorus as P | mg/L | 0.01 | 0.08 | 0.73 | 0.34 | <0.01 | 0.25 | 0.09 | 0.08 | 0.39 | 0.12 | 0.11 | 0.14 | 0.1 | 0.07 | 0.22 |
| - | 0.8-12 | - | - | | Reactive Phosphorus as P | mg/L | 0.01 | 0.05 | <0.01 | 0.32 | <0.01 | 0.24 | <0.01 | <0.01 | 0.24 | <0.01 | 0.11 | 0.12 | 0.1 | 0.05 | 0.15 |
| 6.5 - 8.0 | - | 6.5 - 8.0 | 6.5 - 8.0 | | pH (lab) | pH units | 0.01 | 6.09 | 7.51 | 8.2 | 6.72 | 7.71 | 8.5 | 8.1 | 7 | 6.7 | 6.8 | 6.9 | 6.9 | 7.1 | 7.2 |
| 6.5 - 8.0 | - | 6.5 - 8.0 | 6.5 - 8.0 | | pH (Field) | pH units | 0.01 | 5.32 | 6.8 | 7.94 | 5.75 | 7.2 | 7.79 | 8.11 | 7.02 | 6.73 | 6.68 | 7.34 | 6.93 | 7.19 | 7.19 |
| - | - | - | - | | Redox / ORP (field) | mV | 0.01 | 145 | -151 | 98.3 | 142.8 | 19.4 | 2.04 | 123 | 0.1 | -95 | 234.3 | 215 | 333 | 208 | 129.4 |
| 2200 | - | - | - | | Electrical Conductivity (Lab) | µS/cm | 1 | 4540 | 511 | 720 | 195 | 1240 | 300 | 329 | 654 | 1400 | 3990 | 5110 | 2630 | 1330 | 1120 |
| 2200 | - | - | - | | Electricval Conductivity (field) | µS/cm | 1 | 5224 | 640 | 756 | 220 | 1572 | 318 | 338 | 676 | 1456 | 4118 | 5173 | 2585 | 1306 | 1145 |
| - | - | - | - | | Temperature (field) | °C | 0.1 | 17.7 | 21.9 | 14.34 | 21.84 | 16.5 | 22.6 | 24 | 21 | 19.7 | 21.7 | 21.1 | 23.3 | 23.4 | 24.4 |
| 7 - 11 | - | - | >85% | | Dissolved Oxygen (field) | ppm | 0.01 | 1.97 | 3.29 | 8.88 | 7 | 4.27 | 8.18 | 8.53 | 3.92 | 2.89 | 2.05 | 7.33 | 7.37 | 2.41 | 4.7 |
| - | - | - | 500 | | Total Dissolved Solids | mg/L | 5 | 2460 | 298 | 406 | 114 | 682 | 182 | 187 | 380 | 758 | 2480 | 3120 | 1530 | 784 | 581 |
| - | - | - | - | | Total Suspended Solids | mg/L | 5 | <5 | 46 | <5 | <5 | <5 | 18 | 16 | 2 | 10 | <1 | 3 | <1 | <1 | <1 |
| - | - | - | | | Total Hardness as CaC03 | mg/L | 1 | 932 | 195 | 249 | 11 | 282 | 81 | 93 | 202 | 280 | 1260 | 1570 | 807 | 356 | 238 |

A Investigation levels apply to typical slightly-moderately disturbed systems. Trigger Levels for 95% of species. See ANZG (2018) which replaces ANZECC & ARMCANZ (2000) for guidance on applying these levels to different ecosystem conditions.

B ANZECC 2000 - pH Upper and Lower Limit for NSW Lowland Rivers ( Table 3.3.2).

C ANZECC 2000 - pH Upper and Lower Limit for NSW Lowland Rivers ( Table 3.3.2).

D Refer to table 9.2.18 (ANZECC 2000 - Volume 3: Primary Industries)

TABLE A: Water Quality Results.

| ANZG 2018 - Trigger Values for Freshwater (Protection of 95% of Species) [A] | ANZECC 2000 - Agricultural Irrigation (Short-term Irrigation Trigger Value up to 20 years)[B] | Australian Drinking Water Guidelines (2018)[C] | | | | | | Green Hills - House Bore: EW1904451010 | Green Hills: GW053849 - Irrigation Bore - East: EW1904451011 | Green Hills: GW965354 - Irrigation Bore - West: EW1904451012 | Whispering Pines: GW003599 - House Bore: EW1904451013 | Hossana: GW068591 - Bore: EW1904451014 | Wilga - Bore: EW1904451015 | Longsight - Dam 1: EW1904451016 | Longsight - Dam 2: EW1904451017 | Mullah: GW050214 - House: EW1904451018 | Mullah - Concrete Tank: EW1904451019 | Valhalla: GW044923 House Bore: EW1904451020 | Valhalla: GW005294 Windmill: EW1904451021 | Delwood - Windmill: EW2002425001 | Uplands: GW011502: EW2002425002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Health | Aesthetic | | | Date Sampled | | 9/10/2019 | 9/10/2019 | 9/10/2019 | 10/10/2019 | 10/10/2019 | 10/10/2019 | 10/10/2019 | 10/10/2019 | 11/10/2019 | 11/10/2019 | 11/10/2019 | 11/10/2019 | 18/05/2020 | 18/05/2020 |
| | | | | | | ENRS ID | | 2019100906 | 2019100908 | 2019100907 | 2019101001 | 2019101002 | 2019101009 | 2019101012 | 2019101013 | 2019101104 | 2019101106 | 2019101101 | 2019101103 | 2020051809 | 2020051802 |
| | | | | | | Units | Laboratory PQL | | | | | | | | | | | | | | |
| 0.055 | 20 | - | 0.20 | Total Metals | Aluminium | mg/L | 0.001 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 14.1 | 1.34 | <0.01 | <0.01 | <0.01 | <0.01 | 0.04 | <0.01 |
| 0.024 (As III) | 2 | 0.1 | - | | Arsenic | mg/L | 0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.003 | 0.003 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| - | 0.5 | 0.06 | - | | 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 |
| - | - | 2 | - | | Barium | mg/L | 0.001 | 0.076 | 0.006 | 0.013 | 0.093 | 0.039 | 0.1 | 0.094 | 0.175 | 0.043 | 0.051 | 0.042 | 0.024 | 0.079 | 0.026 |
| 0.37 | Footnote D | 4 | - | | Boron | mg/L | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.07 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| 0.0002 | 0.05 | 0.002 | - | | 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 (CrVI) | 1 | 0.05 | - | | Chromium | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.002 | <0.001 | 0.012 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 |
| - | 0.1 | - | - | | Cobalt | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.012 | 0.006 | 0.005 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| 0.0014 | 5 | 2 | 1 | | Copper | mg/L | 0.001 | 0.005 | <0.001 | <0.001 | 0.004 | <0.001 | <0.001 | 0.005 | <0.001 | 0.001 | 0.001 | 0.002 | 0.171 | 0.034 | 0.002 |
| - | 10 | 50 | 0.30 | | Iron | mg/L | 0.01 | 0.65 | <0.05 | <0.05 | 0.72 | 3.18 | 0.15 | 14.6 | 1.67 | 0.9 | 0.06 | <0.05 | 0.12 | 0.21 | <0.05 |
| 0.0034 | 5 | 0.01 | - | | Lead | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | 0.01 | <0.001 | <0.001 | <0.001 | <0.001 | 0.020 | 0.002 | <0.001 |
| 1.9 | 10 | 0.5 | 0.1 | | Manganese | mg/L | 0.001 | 0.642 | 0.078 | <0.001 | 0.031 | 0.002 | 0.993 | 0.395 | 0.909 | 0.009 | 0.034 | 0.002 | 0.058 | 0.007 | 0.002 |
| 0.0006 | 0.002 | 0.001 | - | | Mercury | mg/L | 0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0003 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| 0.011 | 2 | 0.02 | - | | Nickel | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.001 | 0.005 | 0.008 | 0.008 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| 0.011 | 0.05 | 0.01 | - | | 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 |
| 0.00005 | - | 0.1 | - | | Silver | mg/L | 0.01 | <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 |
| - | 0.1 | 0.02 | - | | Uranium | mg/L | 0.01 | 0.01 | <0.001 | <0.001 | <0.001 | <0.001 | 0.04 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | 0.003 | 0.001 |
| - | 0.5 | - | - | | Vanadium | mg/L | 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 | 0.03 | 0.01 |
| 0.008 | 5 | - | 3 | | Zinc | mg/L | 0.005 | 0.006 | <0.005 | <0.005 | 0.01 | <0.005 | 0.053 | 0.02 | <0.005 | <0.005 | 0.035 | <0.005 | 0.021 | 0.016 | 0.006 |
| 0.055 | 20 | - | 0.20 | Dissolved Metals | Aluminium | mg/L | 0.001 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.14 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 0.024 (As III) | 2 | 0.1 | - | | Arsenic | mg/L | 0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| - | 0.5 | 0.06 | - | | 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 |
| - | - | 2 | - | | Barium | mg/L | 0.001 | 0.069 | 0.006 | 0.011 | 0.085 | 0.036 | 0.099 | 0.04 | 0.135 | 0.041 | 0.048 | 0.038 | 0.02 | 0.074 | 0.024 |
| 0.37 | Footnote D | 4 | - | | Boron | mg/L | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.07 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| 0.0002 | 0.05 | 0.002 | - | | 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 (CrVI) | 1 | 0.05 | - | | 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 |
| - | 0.1 | - | - | | Cobalt | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.012 | 0.001 | 0.003 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| 0.0014 | 5 | 2 | 1 | | Copper | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.001 | <0.001 | 0.002 | 0.001 | <0.001 | 0.002 | 0.003 | 0.036 | 0.025 | 0.001 |
| - | 10 | 50 | 0.30 | | Iron | mg/L | 0.01 | 0.13 | <0.05 | <0.05 | 0.06 | <0.05 | 0.07 | 0.12 | <0.05 | 0.88 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| 0.0034 | 5 | 0.01 | - | | 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 | 0.002 | <0.001 | <0.001 |
| 1.9 | 10 | 0.5 | 0.1 | | Manganese | mg/L | 0.001 | 0.629 | 0.079 | <0.001 | 0.017 | 0.002 | 0.986 | 0.221 | 0.526 | 0.010 | 0.033 | 0.002 | 0.002 | 0.001 | 0.001 |
| 0.0006 | 0.002 | 0.001 | - | | Mercury | mg/L | 0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0002 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| 0.011 | 2 | 0.02 | - | | Nickel | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.001 | 0.006 | 0.001 | 0.006 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| 0.011 | 0.05 | 0.01 | - | | 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 |
| 0.00005 | - | 0.1 | - | | Silver | mg/L | 0.01 | <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 |
| - | 0.1 | 0.02 | - | | Uranium | mg/L | 0.01 | 0.01 | <0.001 | <0.001 | <0.001 | <0.001 | 0.039 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | <0.001 | 0.002 | 0.001 |
| - | 0.5 | - | - | | 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 | 0.02 | 0.01 |
| 0.008 | 5 | - | 3 | | Zinc | mg/L | 0.005 | <0.005 | <0.005 | <0.005 | 0.008 | <0.005 | 0.05 | <0.005 | <0.005 | <0.005 | 0.033 | <0.005 | 0.009 | 0.012 | <0.005 |
| - | - | - | - | Alkalinity - as CaC03 | Hydroxide Alkalinity | mg/L | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| - | - | - | - | | Carbonate Alkalinity | mg/L | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 92 |
| - | - | - | - | | Bicarbonate Alkalinity | mg/L | 1 | 678 | 193 | 255 | 21 | 14 | 993 | 55 | 158 | 329 | 216 | 248 | 241 | 728 | 659 |
| - | - | - | - | | Total Alkalinity | mg/L | 1 | 678 | 193 | 255 | 21 | 14 | 993 | 55 | 159 | 329 | 216 | 248 | 241 | 728 | 751 |
| - | - | - | - | Major Cations | Calcium | mg/L | 1 | 83 | 30 | 52 | <1 | <1 | 196 | 9 | 25 | 57 | 51 | 55 | 35 | 100 | 29 |
| - | - | - | - | | Magnesium | mg/L | 1 | 105 | 16 | 26 | 3 | 2 | 446 | 5 | 12 | 35 | 30 | 31 | 20 | 342 | 198 |
| - | - | - | - | | Sodium | mg/L | 1 | 827 | 56 | 136 | 26 | 22 | 2120 | 10 | 30 | 110 | 43 | 44 | 86 | 711 | 324 |
| - | - | - | - | | Potassium | mg/L | 1 | 4 | 2 | 2 | 7 | 3 | 37 | 10 | 16 | 2 | 2 | 2 | 2 | 3 | 5 |
| - | - | - | 250 | | Chloride | mg/L | 1 | 974 | 33 | 154 | 48 | 34 | 4250 | 8 | 16 | 113 | 70 | 57 | 65 | 1740 | 613 |
| - | 2 | - | 250 | | Fluoride | mg/L | 1 | 0.6 | 0.3 | 0.2 | <0.1 | <0.1 | 0.4 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| - | - | 500 | 250 | | Sulphate | mg/L | 1 | 421 | 18 | 68 | 2 | 4 | 601 | 1 | <1 | 26 | 18 | 23 | 14 | 157 | 72 |
| 0.007 | - | 0.08 | - | | Cyanide (Total) | mg/L | 0.1 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| 0.9 | - | - | 0.5 | | Ammonia | mg/L | 0.1 | 0.06 | <0.01 | <0.01 | <0.01 | <0.01 | 0.07 | 0.32 | 0.54 | <0.01 | 0.04 | <0.01 | <0.01 | <0.004 | <0.004 |
| - | - | - | - | | Total Kjeldahl Nitrogen as N | mg/L | 0.1 | 0.1 | <0.1 | 0.2 | <0.1 | <0.1 | <0.2 | 2.6 | 2.4 | <0.1 | <0.1 | <0.1 | <0.1 | 0.2 | 0.5 |
| - | 25-125 | - | - | | Total Nitrogen as N | mg/L | 0.1 | 0.2 | 0.1 | 1.2 | 0.3 | 0.1 | 1.1 | 2.8 | 2.8 | <0.1 | <0.1 | <0.1 | <0.1 | 2.4 | 3.5 |
| - | 0.8-12 | - | - | | Total Phosphorus as P | mg/L | 0.01 | 0.37 | 0.1 | 0.12 | 0.05 | 0.05 | 0.05 | 0.3 | 0.16 | 0.2 | 0.05 | 0.15 | 0.33 | 0.05 | 0.02 |
| - | 0.8-12 | - | - | | Reactive Phosphorus as P | mg/L | 0.01 | 0.29 | 0.1 | 0.1 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | 0.01 | 0.03 | 0.14 | 0.32 | 0.06 | <0.01 |
| 6.5 - 8.0 | - | 6.5 - 8.0 | 6.5 - 8.0 | | pH (lab) | pH units | 0.01 | 7.6 | 7.2 | 7.2 | 5.6 | 5.5 | 6.7 | 7.6 | 8.9 | 7 | 7.2 | 7.3 | 7.4 | 7.99 | 8.59 |
| 6.5 - 8.0 | - | 6.5 - 8.0 | 6.5 - 8.0 | | pH (Field) | pH units | 0.01 | 7.47 | 7.21 | 7.18 | 6.11 | 5.89 | 6.37 | 7.97 | 8.71 | 6.96 | 7.23 | 7.04 | 7.33 | 7.92 | 7.78 |
| - | - | - | - | | Redox / ORP (field) | mV | 0.01 | -69 | 140.4 | 81.2 | 125 | 131.8 | 182 | 158 | 201 | -37.7 | 43.8 | 104.9 | 83.7 | 134 | 169 |
| 2200 | - | - | - | | Electrical Conductivity (Lab) | µS/cm | 1 | 4870 | 513 | 1100 | 265 | 141 | 13800 | 149 | 381 | 1060 | 698 | 715 | 716 | 6450 | 2960 |
| 2200 | - | - | - | | Electrivcal Conductivity (field) | µS/cm | 1 | 4993 | 532 | 1137 | 219 | 153 | 14217 | 156 | 384 | 944.6 | 685 | 733 | 734 | 5891 | 2746 |
| - | - | - | - | | Temperature (field) | °C | 0.1 | 21.06 | 21.2 | 21.3 | 20.9 | 19.8 | 24.7 | 25.8 | 24.2 | 18.7 | 19.4 | 18.5 | 20 | 16.39 | 16.6 |
| 7 - 11 | - | - | >85% | | Dissolved Oxygen (field) | ppm | 0.01 | 7.34 | 5.74 | 4.26 | 4.43 | 6.92 | 2.27 | 6.3 | 17.16 | 4.65 | 10.12 | 7.11 | 7.61 | 7.81 | 13.9 |
| - | - | - | 500 | | Total Dissolved Solids | mg/L | 5 | 2840 | 396 | 638 | 143 | 86 | 8820 | 366 | 602 | 590 | 374 | 396 | 410 | 4260 | 1480 |
| - | - | - | - | | Total Susspended Solids | mg/L | 5 | <1 | <1 | <1 | <1 | 7 | 1 | 34 | 52 | 4 | 2 | 1 | <1 | 12 | 7 |
| - | - | - | | | Total Hardness as CaC03 | mg/L | 1 | 640 | 141 | 237 | 12 | 8 | 2330 | 43 | 112 | 286 | 251 | 265 | 170 | 1660 | 888 |

A Investigation levels apply to typical slightly-moderately disturbed systems. Trigger Levels for 95% of species. See ANZG (201

B ANZECC 2000 - pH Upper and Lower Limit for NSW Lowland Rivers ( Table 3.3.2).

C ANZECC 2000 - pH Upper and Lower Limit for NSW Lowland Rivers ( Table 3.3.2).

D Refer to table 9.2.18 (ANZECC 2000 - Volume 3: Primary Industries)

**TABLE A: Water Quality Results.**

| ANZG 2018 - Trigger Values for Freshwater (Protection of 95% of Species) [A] | ANZECC 2000 - Agricultural Irrigation (Short-term Irrigation Trigger Value up to 20 years)[B] | Australian Drinking Water Guidelines (2018)[C] Health | Australian Drinking Water Guidelines (2018)[C] Aesthetic | | | Units | Laboratory PQL | Uplands - House Supply: EW2002425003 | Uplands - Airstrip Bore: EW2002425004 | Southend - Well: EW2002425005 | Towri - House Bore: EW2002425006 | Towri - Eather Spring: Dam 1: EW2002425007 | Towri - Eather Spring: Dam 2: EW2002425008 | Towri - Towri Dam 1: EW2002425009 | Towri - Towri Dam 2: EW2002425010 | Tulla Mullen Creek - Old Narrabri Road: EW2002425011 | Tulla Mullen Creek - Kamilaroi Highway: EW2002425012 | Nindethana: GW013858: EW2002425013 | Kentucky - House: EW2002425014 | Kurrajong Trib: ES2018696001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Date Sampled | | | 18/05/2020 | 18/05/2020 | 18/05/2020 | 19/05/2020 | 19/05/2020 | 19/05/2020 | 19/05/2020 | 19/05/2020 | 20/05/2020 | 20/05/2020 | 20/05/2020 | 20/05/2020 | 27/05/2020 |
| | | | | | ENRS ID | | | 2020051801 | 2020051807 | 2020051810 | 2020051907 | 2020051908 | 2020051909 | 2020051910 | 2020051911 | - | - | 2020052006 | 2020052001 | - |
| 0.055 | 20 | - | 0.20 | Total Metals | Aluminium | mg/L | 0.001 | <0.01 | 0.01 | <0.01 | 0.16 | 0.16 | 5.45 | 31.2 | 0.79 | 0.13 | 2.82 | 0.02 | <0.01 | 52.8 |
| 0.024 (As III) | 2 | 0.1 | - | | Arsenic | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.003 | 0.01 | 0.013 | 0.004 | <0.001 | <0.001 | <0.001 | <0.001 | 0.008 |
| - | 0.5 | 0.06 | - | | 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 | 0.002 |
| - | - | 2 | - | | Barium | mg/L | 0.001 | 0.012 | 0.2 | 0.226 | 0.049 | 0.025 | 0.035 | 0.238 | 0.067 | 0.106 | 0.08 | 0.073 | 0.031 | 0.503 |
| 0.37 | Footnote D | 4 | - | | 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 | <0.05 | <0.05 | 0.06 |
| 0.0002 | 0.05 | 0.002 | - | | 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 (CrVI) | 1 | 0.05 | - | | Chromium | mg/L | 0.001 | 0.002 | 0.006 | 0.002 | <0.001 | <0.001 | 0.004 | 0.029 | 0.002 | <0.001 | 0.004 | 0.002 | <0.001 | 0.074 |
| - | 0.1 | - | - | | Cobalt | mg/L | 0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.005 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | 0.031 |
| 0.0014 | 5 | 2 | 1 | | Copper | mg/L | 0.001 | <0.001 | 0.002 | 0.022 | <0.001 | 0.002 | 0.004 | 0.024 | 0.004 | 0.001 | 0.002 | 0.004 | 0.036 | 0.032 |
| - | 10 | 50 | 0.30 | | Iron | mg/L | 0.01 | <0.05 | 4.74 | 0.12 | 0.36 | 1.55 | 9.48 | 20.7 | 7.83 | 0.17 | 3.07 | 0.67 | <0.05 | 53.2 |
| 0.0034 | 5 | 0.01 | - | | Lead | mg/L | 0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | 0.01 | 0.03 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | 0.028 |
| 1.9 | 10 | 0.5 | 0.1 | | Manganese | mg/L | 0.001 | <0.001 | 0.230 | 0.043 | 0.081 | 0.089 | 0.146 | 0.117 | 0.202 | 0.066 | 0.022 | 0.102 | <0.001 | 0.583 |
| 0.0006 | 0.002 | 0.001 | - | | 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 |
| 0.011 | 2 | 0.02 | - | | Nickel | mg/L | 0.001 | <0.001 | 0.001 | <0.001 | 0.003 | 0.002 | 0.003 | 0.007 | 0.002 | 0.002 | 0.004 | 0.006 | <0.001 | 0.075 |
| 0.011 | 0.05 | 0.01 | - | | 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 |
| 0.00005 | - | 0.1 | - | | Silver | mg/L | 0.01 | <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 |
| - | 0.1 | 0.02 | - | | Uranium | mg/L | 0.01 | 0.003 | 0.003 | 0.004 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | 0.004 |
| - | 0.5 | - | - | | Vanadium | mg/L | 0.01 | 0.04 | 0.02 | 0.02 | <0.01 | <0.01 | 0.01 | 0.05 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.12 |
| 0.008 | 5 | - | 3 | | Zinc | mg/L | 0.005 | <0.005 | 0.188 | 0.011 | 0.013 | <0.005 | 0.011 | 0.037 | 0.01 | <0.005 | 0.009 | 0.035 | 0.042 | 0.087 |
| 0.055 | 20 | - | 0.20 | Dissolved Metals | Aluminium | mg/L | 0.001 | <0.01 | <0.01 | <0.01 | <0.01 | 0.07 | 2.74 | 1.76 | 0.38 | <0.01 | 0.17 | <0.01 | <0.01 | 0.24 |
| 0.024 (As III) | 2 | 0.1 | - | | Arsenic | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.004 | 0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | 0.005 |
| - | 0.5 | 0.06 | - | | 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 |
| - | - | 2 | - | | Barium | mg/L | 0.001 | 0.007 | 0.186 | 0.217 | 0.044 | 0.134 | 0.232 | 0.016 | 0.157 | 0.1 | 0.065 | 0.071 | 0.03 | 0.023 |
| 0.37 | Footnote D | 4 | - | | Boron | mg/L | 0.05 | 0.06 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 0.05 |
| 0.0002 | 0.05 | 0.002 | - | | 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 (CrVI) | 1 | 0.05 | - | | Chromium | mg/L | 0.001 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | 0.002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 |
| - | 0.1 | - | - | | 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 | 0.004 |
| 0.0014 | 5 | 2 | 1 | | Copper | mg/L | 0.001 | <0.001 | 0.001 | 0.02 | <0.001 | <0.001 | 0.002 | 0.002 | 0.003 | <0.001 | 0.001 | 0.002 | 0.032 | 0.009 |
| - | 10 | 50 | 0.30 | | Iron | mg/L | 0.01 | <0.05 | 0.94 | <0.05 | <0.05 | 0.37 | 2.62 | 0.6 | 2.29 | <0.05 | 0.26 | 0.08 | <0.05 | 0.88 |
| 0.0034 | 5 | 0.01 | - | | Lead | mg/L | 0.001 | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 | 0.002 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| 1.9 | 10 | 0.5 | 0.1 | | Manganese | mg/L | 0.001 | <0.001 | 0.224 | 0.041 | 0.013 | 0.021 | 0.020 | 0.011 | 0.071 | 0.047 | 0.004 | 0.098 | <0.001 | 0.005 |
| 0.0006 | 0.002 | 0.001 | - | | 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 |
| 0.011 | 2 | 0.02 | - | | Nickel | mg/L | 0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | 0.002 | <0.001 | 0.002 | 0.002 | 0.002 | 0.006 | 0.001 | 0.014 |
| 0.011 | 0.05 | 0.01 | - | | 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 |
| 0.00005 | - | 0.1 | - | | Silver | mg/L | 0.01 | <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 |
| - | 0.1 | 0.02 | - | | Uranium | mg/L | 0.01 | 0.002 | 0.002 | 0.003 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.002 | <0.001 | 0.002 |
| - | 0.5 | - | - | | Vanadium | mg/L | 0.01 | 0.03 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 |
| 0.008 | 5 | - | 3 | | Zinc | mg/L | 0.005 | <0.005 | 0.167 | 0.009 | <0.005 | 0.03 | 0.022 | <0.005 | 0.019 | <0.005 | <0.005 | 0.029 | 0.04 | <0.005 |
| - | - | - | - | Alkalinity - as CaC03 | Hydroxide Alkalinity | mg/L | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| - | - | - | - | | Carbonate Alkalinity | mg/L | 1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 177 |
| - | - | - | - | | Bicarbonate Alkalinity | mg/L | 1 | 576 | 685 | 895 | 157 | 61 | 32 | 5 | 65 | 189 | 55 | 646 | 17 | 538 |
| - | - | - | - | | Total Alkalinity | mg/L | 1 | 576 | 685 | 895 | 157 | 61 | 32 | 5 | 65 | 189 | 55 | 646 | 17 | 715 |
| - | - | - | - | Major Cations | Calcium | mg/L | 1 | 75 | 190 | 132 | 18 | 4 | 4 | <1 | 6 | 36 | 6 | 206 | 2 | 4 |
| - | - | - | - | | Magnesium | mg/L | 1 | 149 | 349 | 351 | 13 | 5 | 3 | <1 | 5 | 13 | 4 | 287 | 1 | 2 |
| - | - | - | - | | Sodium | mg/L | 1 | 144 | 473 | 701 | 69 | 17 | 8 | 7 | 5 | 22 | 12 | 354 | 14 | 366 |
| - | - | - | - | | Potassium | mg/L | 1 | 1 | 6 | 3 | 16 | 6 | 5 | 9 | 27 | 4 | 4 | 4 | 2 | 6 |
| - | - | - | 250 | | Chloride | mg/L | 1 | 383 | 1650 | 1700 | 68 | 10 | 5 | 6 | 10 | 8 | 6 | 1290 | 18 | 105 |
| - | 2 | - | 250 | | Fluoride | mg/L | 1 | 0.2 | 0.1 | 0.2 | 0.3 | 0.2 | <0.1 | <0.1 | 0.1 | 0.3 | <0.1 | <0.1 | <0.1 | 0.5 |
| - | - | 500 | 250 | | Sulphate | mg/L | 1 | 24 | 73 | 87 | <10 | <1 | <1 | 13 | <1 | 5 | <1 | 62 | <1 | <10 |
| 0.007 | - | 0.08 | - | | Cyanide (Total) | mg/L | 0.1 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| 0.9 | - | - | 0.5 | | Ammonia | mg/L | 0.1 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | 0.04 |
| - | - | - | - | | Total Kjeldahl Nitrogen as N | mg/L | 0.1 | 1.4 | <0.1 | 0.1 | 1.3 | 3 | 2.6 | 3.5 | 5.5 | 0.2 | 0.5 | 0.6 | <0.1 | 9.4 |
| - | 25-125 | - | - | | Total Nitrogen as N | mg/L | 0.1 | 11.3 | 1 | 2.1 | 1.4 | 3 | 2.9 | 6.1 | 5.5 | 0.2 | 0.5 | 5.8 | 0.2 | 9.5 |
| - | 0.8-12 | - | - | | Total Phosphorus as P | mg/L | 0.01 | <0.01 | 0.04 | 0.12 | 0.02 | 0.17 | 0.32 | 0.68 | 0.6 | 0.02 | 0.04 | 0.05 | <0.01 | 3.1 |
| - | 0.8-12 | - | - | | Reactive Phosphorus as P | mg/L | 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 | <0.05 |
| 6.5 - 8.0 | - | 6.5 - 8.0 | 6.5 - 8.0 | | pH (lab) | pH units | 0.01 | 8.04 | 7.55 | 7.56 | 8.18 | 7.58 | 7.42 | 6.36 | 7.32 | 8.03 | 7.66 | 7.4 | 6.79 | 9.22 |
| 6.5 - 8.0 | - | 6.5 - 8.0 | 6.5 - 8.0 | | pH (Field) | pH units | 0.01 | 7.92 | 7.19 | 7.2 | 8.62 | 8.8 | 8.87 | 8.77 | 8.6 | 8.39 | 8.48 | 7.06 | 7.9 | - |
| - | - | - | - | | Redox / ORP (field) | mV | 0.01 | 201 | -40.2 | 139 | 98.6 | 92.8 | 100 | 89 | 104 | 60.4 | 74.3 | 98.1 | 64.2 | - |
| 2200 | - | - | - | | Electrical Conductivity (Lab) | µS/cm | 1 | 2100 | 5830 | 6490 | 546 | 150 | 84 | 73 | 175 | 367 | 126 | 4960 | 96 | 1480 |
| 2200 | - | - | - | | Electrivcal Conductivity (field) | µS/cm | 1 | 1889 | 5608 | 6031 | 513 | 143.9 | 80 | 68 | 156 | 367 | 121.9 | 4788 | 89.2 | - |
| - | - | - | - | | Temperature (field) | °C | 0.1 | 19.1 | 20.9 | 22 | 19.1 | 21.9 | 21.33 | 19.5 | 18.9 | 14.3 | 14.9 | 21.9 | 16.7 | - |
| 7 - 11 | - | - | >85% | | Dissolved Oxygen (field) | ppm | 0.01 | 8.4 | 4.69 | 139 | 98.6 | 92.8 | 100 | 89 | 104 | 8.72 | 8.03 | 2.43 | 8.52 | - |
| - | - | - | 500 | | Total Dissolved Solids | mg/L | 5 | 1190 | 3760 | 3920 | 328 | 135 | 141 | 710 | 206 | 203 | 92 | 3130 | 59 | 1970 |
| - | - | - | - | | Total Susspended Solids | mg/L | 5 | 5 | 16 | 7 | 10 | 28 | 33 | 112 | 58 | <5 | 10 | 10 | <5 | 123 |
| - | - | - | | | Total Hardness as CaC03 | mg/L | 1 | 801 | 1910 | 1780 | 98 | 30 | 22 | <1 | 36 | 143 | 31 | 1700 | 9 | 18 |

A Investigation levels apply to typical slightly-moderately disturbed systems. Trigger Levels for 95% of species. See ANZG (201

B ANZECC 2000 - pH Upper and Lower Limit for NSW Lowland Rivers ( Table 3.3.2).

C ANZECC 2000 - pH Upper and Lower Limit for NSW Lowland Rivers ( Table 3.3.2).

D Refer to table 9.2.18 (ANZECC 2000 - Volume 3: Primary Industries)

# Appendix H Mining & Petroleum Gateway Panel and Department of Environment and Energy requirements and recommendations

## Table H 1 Commonwealth Department of Environment and Energy assessment requirements relating to groundwater

| Reference | Requirement/Recommendation | Addressed in report sections |
|---|---|---|
| *Introduction* | | |
| 3 | The Applicant must undertake an assessment of all protected matters that may be impacted by the development under the controlling provisions identified in paragraph 1. The DoEE considers that the proposed action is likely to have a significant impact on the following:<br><br>ii. a water resource, in relation to coal seam gas development and large coal mining development (sections 24D and 24E):<br>a) the proposed action is likely to result in changes to groundwater and surface water. | Section 7 |
| *Comments* | | |
| 20. | To date, the Applicant has provided preliminary hydrological information that is insufficient for an adequate assessment of the impacts of the proposed action on water resources, however the Department considers key impacts to water resources are likely to arise from altered surface hydrology and quality as well as increased groundwater drawdown. The Department understands that the Applicant will provide detailed water modelling as part of the EIS which will allow a detailed assessment of the potential impacts of the proposed action on water resources be undertaken. A Gas and Large Coal Mining Development (I ESC) will need to be developed for this project. | Sections 6 and 7 and Appendix D |
| *Assessment Requirements* | | |
| | The EIS must include a detailed water assessment. The water assessment must be undertaken in accordance with the IESC Information Guidelines (http://iesc.erlvirurlrnerll.yov.Clu/publiGCllions/information-guidelines-independent-expertscientific- committee-advice-coal-seam-gas) and provide the information outlined in these guidelines including: | Sections 3 to 7 |
| *Improved groundwater modelling* | | |
| 21. | Include a refined groundwater model that uses a wider variety of parameters and predictions to enable clarification of potential drawdown impacts and revise, accordingly, the assessment of impacts on both the Upper Namoi Alluvium and the Namoi River. | An overview of refinements is provided in Section 6.2 Further detail in the remainder of Section 6, Section 7 and Appendix D |
| 22. | Include a groundwater model that has been integrated with the subsidence model to provide an improved understanding of impacts on surface water and alluvium. | Integration of the groundwater model and subsidence modelling work is discussed in Section 7.2 and in Appendix D (Section D2.5.6) [1] |

[1] The impacts of subsidence on flows in ephemeral creeks within the Project area is assessed in Appendix C of the EIS.

| Reference | Requirement/Recommendation | Addressed in report sections |
|---|---|---|
| 23. | Address the issues identified in Paragraph 3 of the IESC 2019-102: Narrabri Underground Mine Stage 3 Extension Project (Narrabri Mine Extension) (State Ref No 9882) - Expansion, February 2019 (IESC advice) in regards to further information and refinements to the groundwater model. | Issues 3a to 3g which relate to the model design are addressed in Section 6 with further detail provided in Appendix D. Revised impacts addressing the remaining issues (3h to 3n) are provided in Section 7 |
| *Analysing potential impacts to groundwater dependent ecosystems (GDEs)* | | |
| 24. | Confirm the distribution of GDEs in the region and the depth to groundwater in areas of potential GDE's. | Sections 5.7 and 7.6.2[2] |
| 25. | Conduct a detailed cumulative impact assessment of potential risks to groundwater and surface water ecosystems of the Namoi River catchment that may be impacted by the project. | Cumulative impacts on groundwater levels and groundwater discharge to surface water are assessed in Sections 7.4, 7.5 and 7.6 [2] |
| 26. | Include an assessment of GDEs as outlined in Paragraph 18 of the IESC advice. | Impacts on GDEs are quantified in Section 7.6.2 [2] |
| *Comprehensive and detailed monitoring* | | |
| 29. | The EIS should derive site-specific water quality guidelines and provide more information on how they plan to monitor impacts. For example, the parameters and frequency of monitoring should be detailed. | Section 8 and the latest approved Water Management Plan |
| 30. | The groundwater monitoring network should be expanded to include locations to the west and south of the project. | Section 5.2.1 and Section 8 |

## Table H 2 Conditional Gateway Certificate requirements relating to groundwater

| Reference | Requirement/Recommendation | Addressed in report sections |
|---|---|---|
| 7H4(a)(iv) | Consideration:<br>The Gateway Panel recognises that the groundwater modelling work completed to date is adequate for this early stage of assessment of water impacts under the Aquifer interference policy<br><br>Recommendations:<br>The Panel requires more geological detail and baseline data acquisition in any upgraded groundwater model that is to be used in an EIS. Also, any future groundwater flow modelling should include cumulative impact studies of the nearby (proposed) Santos Coal Seam Gas Project. Additional studies are required to more fully identify and evaluate cracking formed from the effects of mining and the possible loss of water in ephemeral streams due to surface cracking. | Geological detail – Section 4<br>Baseline data Section 5.2.1<br>Overview of numerical modelling – Section 6.2<br>Cumulative impacts – Section 7 |

[2] *The distribution of terrestrial GDEs and the significance of predicted drawdowns and flow reductions on these ecosystems is assessed in Appendix D of the EIS.*

## Table H 3 IESC Advice relating to groundwater

| Reference | Requirement/Recommendation | Addressed in report sections |
|---|---|---|
| *Groundwaters* | | |
| 2. | The IESC notes that the modelling provided by the proponent exceeds that required for the Gateway process and acknowledges the extensive model validation. However, the IESC also notes that the model will need to be further refined and developed to meet the Secretary's Environmental Assessment Requirements (SEARs) when issued, the IESC's Information Guidelines, and further issues covered in paragraphs 3 and 4 below. This further work will include a cumulative impact assessment incorporating the nearby Narrabri Gas Project, additional groundwater level data and the results of core permeability test work, among other updates. The IESC suggests that these should be fully addressed in the proposed EIS. | An overview of refinements is provided in Section 6.2 Further detail in the remainder of Section 6, Section 7 and Appendix D.<br><br>Additional groundwater level data availability is discussed in Section 5.2.1 and hydraulic parameters in Section 5.3. |
| 3. | The current groundwater model predictions provided by the proponent (Hydro Simulations, 2019, p. 51) indicate that the impacts from the project will largely be within the minimal impact considerations of the NSW Aquifer Interference Policy, and will not result in any significant impacts to the highly productive Upper Namoi Alluvium or Great Artesian Basin (GAB). The IESC notes that impact predictions could change when the model is updated as planned. Consideration and discussion of the issues outlined below would further increase confidence in the groundwater impact assessment and associated modelling. | See below |
| | a. Further model refinements should attempt to incorporate pumping from licenced bores as this would provide a more complete understanding of the actual conditions in the groundwater system. | Appendix D (Section D2.5.4) |
| | b. Discussion and justification of boundary conditions, and their sensitivities, applied in the groundwater model are needed, including for the large area of 'no-flow' in the eastern area of the groundwater model (Hydro Simulations, 2019, Figures 13 and 14, pp. 84-85) and the general head boundary condition applied in the north-west of the groundwater model (Hydro Simulations, 2019, Figure 13, p. 84). | Appendix D (Section D2.4.1) |
| | c. The implementation of recharge in the model should be clearly explained. Currently, it is unclear whether the recharge applied in the transient modelling is a fixed rate defined as an arbitrary portion of average annual rainfall or whether the amount varies to accommodate temporal variability in rainfall. When the model is updated, an appropriate time series of rainfall record should be considered to represent the likely variability in recharge rates. Further, the modelled recharge rate should be justified and validated using independent methods such as chloride mass balance and water table fluctuation methods. | Section 5.4 and Appendix D (Section D2.5.1) |
| | d. A maximum ET rate of 146 mm/year has been adopted (Hydro Simulations, 2019, p. 32), which appears to be unusually low for the local climate. The defensibility of the ET parameters will need to be further explored in future work, and evaluated in conjunction with recharge parameters in an uncertainty and sensitivity framework. | Appendix D (Section D2.5.3) |
| | e. The specific storage values applied in the current model are noted by the proponent to have been updated, resulting in better model calibration results. However, these specific storage values require justification, including why values have increased and the sensitivity of the model's transmissivity and recharge values to these changes. Discussion that outlines the revised values from those used previously, the basis for the new values and the implications of these changes on the predicted magnitude and spatial extent of drawdown should be provided in the EIS. | Appendix D (Section D3.3) |

| Reference | Requirement/Recommendation | Addressed in report sections |
|---|---|---|
| | f. The influence of faults has not been discussed. The EIS should consider the behaviour of faults, as either barriers, conduits or both. Their potential impacts on the connectivity between groundwater and surface water also need to be considered. | Section 4 and Appendix D (Section D2.4.4) |
| | g. The IESC commends the proponent for undertaking some sensitivity and uncertainty analysis at this early project stage. This analysis should be extended further in the EIS given the extensive utilisation and importance of groundwater in the region. | Appendix D (Section D3.5.6 and D5) |
| | h. Future modelling should clearly identify whether the proposed project will cause drawdown in the Namoi Alluvium and, if so, quantify the volumes and timing of inter-aquifer leakage and discuss connectivity or impacts to the GAB. | Sections 7.4, 7.5 and 7.7 |
| | i. The saturated extent of the alluvium should be included on maps of potential drawdown to aid interpretation of potential impacts. Additionally, the extent of drawdown in the Pamboola Formation which appears to directly underlie areas of alluvium to the east of the project (based on the proponent's conceptual models) should be shown to determine if there is potential for drawdown within that formation to impact the alluvium. | Section 7.4 [3] |
| | j. All maps of potential drawdown should show the full predicted extent of drawdown in each formation. A map of the maximum predicted extent of drawdown should be included, with the expected timing of this maximum drawdown clearly identified. | Figure 7.2 to Figure 7.14 |
| | k. Groundwater quality data should be provided. Discussion on the potential for, and possible changes to, groundwater quality arising from groundwater interaction with the goaf and fractured strata, or leakage of mine-affected water into aquifers should also be provided. | Sections 5.5 and 7.8 |
| | l. Baseflow changes should be quantified for the reaches identified as RIV21 and RIV23-27 on Figure 13 (Hydro Simulations, 2019, p. 84) to inform a full ecological and surface water resource assessment of potential changes to these creeks. | Section 7.5.2 |
| | m. All GDEs (including groundwater-dependent vegetation) should be clearly identified on maps of predicted drawdown and drawdown at each GDE quantified with the maps showing the depth to the water table (in metres below ground level) when modelling is updated. | Sections 5.7 and 7.6.2 |
| | n. Regional and site-specific data and information on surface-groundwater interactions and GDEs should be provided in the EIS. | Sections 5.7 and 5.8 [2] |
| 4. | Given the preliminary nature of the current modelling and the suggested improvements outlined in paragraph 3, the IESC notes that it is not currently clear if the project aligns with the Namoi Catchment Action Plan 2010–2020 targets and thresholds. These include the target that seeks an improvement in the ability of groundwater systems to support GDEs and designated beneficial uses by 2020 (Namoi CMA, 2010, p. 36) and the threshold for alluvial aquifers to never exceed historical maximum drawdown levels (Namoi CMA, 2010, p. 36). The IESC suggests that the proponent specifically considers these targets within their EIS. | Sections 7.7 and 7.8.1 |

[3] *Whilst both drawdown in the Pamboola Formation and impacts on the overlying alluvium have been calculated, results are currently not presented for this unit since few if any receptors in this unit are within the zone of influence of the mine.*

| Reference | Requirement/Recommendation | Addressed in report sections |
|---|---|---|
| 5. | Given the nature of the Gateway Application process, limited information on planned mitigation measures was provided. If the project progresses, the 2013 monitoring program should be updated to reflect changes needed due to the proposed project and will need to be provided within the EIS. In particular, the spatial coverage of the groundwater monitoring network should be expanded where there are currently no monitoring bores to the west and south of the proposed project. | Sections 5.2.1 and 8 |
| 6. | The IESC also notes that the proponent currently may not hold sufficient licences for predicted take from some water sources under certain climatic conditions. The proponent should provide a plan for obtaining further licences and discuss options including operational changes that may be required if sufficient licence volumes cannot be obtained. | Section 7.7 |
| *Groundwater-dependent ecosystems (GDEs)* | | |
| 12. | A detailed assessment of potential impacts on GDEs is not provided because the Gateway Certificate Application process does not require assessments relating to flora and fauna at this stage of the development. However, the IESC considers that given the current pressures on groundwater from multiple users, the proposed project is likely to have potential impacts on the following GDEs: | |
| | a. groundwater-dependent vegetation, especially along creeklines and on the Namoi River alluvium in areas where groundwater drawdown is predicted; | Section 7.6.2 [2] |
| | b. nearby springs such as Hardys, Eather and Mayfield Springs where cumulative impacts associated with the Narrabri Gas Project are likely; and | Section 7.6.2 |
| | c. the Namoi River in the vicinity of the project which is mapped as a potential GDE (GDE Atlas) and forms part of the state-listed Lowland Darling River Aquatic Ecological Community (NSW DPI, 2007). In particular, potential changes to groundwater–surface water interactions between the saturated alluvium and the Namoi River and its tributaries should be assessed because of the likely importance of upwelling groundwater supplying dissolved carbon and other crucial resources to the river's food-web (e.g. Burrows et al. 2018) that includes this state-listed community. | Sections 7.5.2 and 7.6.2 [2] |