LW S1A-S6A

Extraction Plan
Groundwater Technical Report

Prepared for:

Tahmoor Coal
2975 Remembrance Driveway
Tahmoor NSW 2574

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Tahmoor Coal (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
610.30637.00000-R01-v6.0	26 June 2023	Sharon Hulbert, Arash Mohajeri	Brian Rask	Brian Rask
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1 Introduction

Tahmoor Coal Mine (Tahmoor Mine) is an underground coal mine located approximately 80 kilometres (km) south-west of Sydney between the towns of Tahmoor and Bargo, New South Wales (NSW) (refer to Figure 1-1). Tahmoor Mine produces up to three million tonnes of Run of Mine (ROM) coal per annum from the Bulli Coal Seam. Tahmoor Mine produces a primary hard coking coal product and a secondary higher ash coking coal product that are used predominantly for coke manufacture for steel production. Product coal is transported via rail to Port Kembla and Newcastle for Australian domestic customers and export customers.

Operations at Tahmoor Mine commenced in 1979 using bord and pillar mining methods, and via longwall mining methods since 1987. Tahmoor Coal has previously extracted 35 longwalls to the north and west of Tahmoor Mine's current pit top location (Figure 1-1). The current mining area, the 'Western Domain', is located north-west of the Main Southern Rail between the townships of Thirlmere and Picton. The Western Domain is within the Tahmoor Mine mining area and is within Mining Lease (ML) 1376 and ML 1539 (Figure 1-1).

The 'Tahmoor South' domain is an underground coal development targeting the Bulli Coal seam coal resource within Consolidated Coal Leases (CCL) 716 and 747. On the 23rd April 2021, Tahmoor Coal received Development Consent SSD 8445 (the Consent) for the Tahmoor South Project, enabling extension of underground longwall mining to the south of the existing workings. This enables an extension of mining operations at Tahmoor Colliery until 31 December 2033 or until 10 years from the commencement of second workings, whichever is the sooner. In accordance with SSD 8445, the key aspects of Tahmoor South include the following:

- Continued mining activities using the longwall mining method into the Tahmoor South project area in the Bulli Seam within CCL 747 and CCL 716
- Continued use of the surface and ancillary infrastructure and services at the surface facilities areas
- Extraction of up to 4 Mtpa of run of mine (ROM) coal with up to 33 Mt of ROM coal extracted over the life of the project
- Continued transportation by rail to the Port Kembla Coal Terminal (PKCT) and occasionally to Newcastle using the existing rail load out, rail loop and rail infrastructure
- Transportation of up to 200,000 tpa of either product coal or reject material via road
- An increase in the height of the final landform of the reject emplacement area (REA) from the approved height of RL 300 mAHD to RL 320 mAHD, to accommodate the additional rejects produced in Tahmoor South
- Construction of a new upcast ventilation shaft (TSC1) and downcast ventilation shaft (TSC2), south of the REA
- Upgrades to the existing surface facilities, amenities, equipment and infrastructure to accommodate the extension of mining
- Progressive rehabilitation and mine closure activities

SLR Consulting Australia Pty Ltd (SLR) have been engaged by Tahmoor Coal to prepare the Groundwater Technical Report which will inform, and be appended to, the Water Management Plan developed for Longwalls (LW) South 1A to South 6A (S1A–S6A). It exists to describe the likely environmental effects and compliance with relevant internal and external regulatory requirements related to groundwater management at LW S1A - S6A within the context of Tahmoor South as a whole. This report also presents an analysis of the available baseline data for the proposed monitoring bores, results from numerical groundwater model, and outlines trigger ranges to aid in the identification of adverse mining-related impacts to the groundwater system.

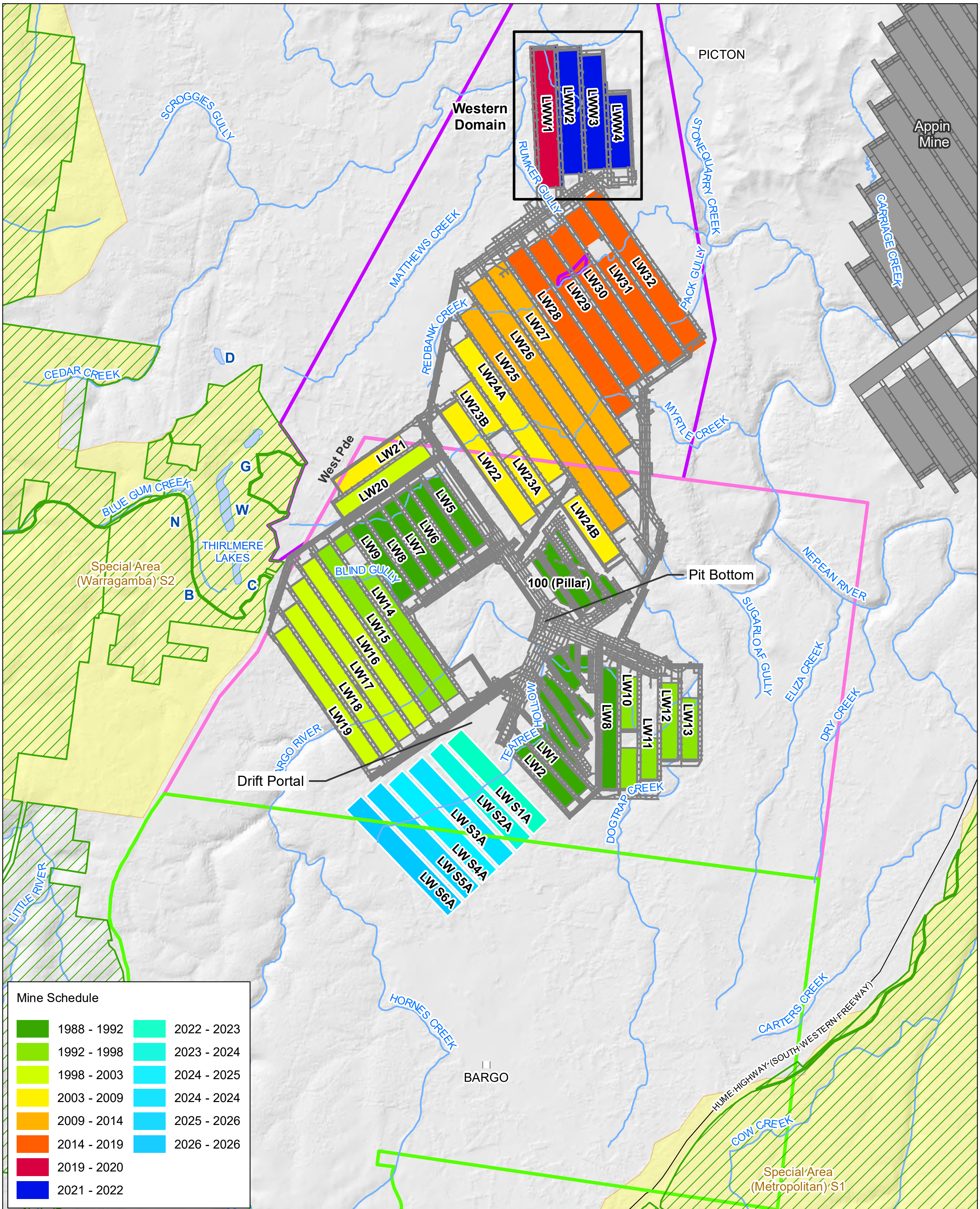
1.1 Extraction Plan Focus

LW S1A–S6A are oriented north-west to south-east, with each panel increasing slightly in length from LW S1A through to LW S6A as shown on Figure 1-2. Table 1-1 details the extraction parameters for LW S1A-S6A. Mining at Tahmoor South LW S1A commenced on 18th October 2022, with completion of mining at LW S6A predicted in December 2026 (essentially 7-9 months of extraction for each of the relevant longwall panels).

Table 1-1 LW S1A-S6A Proposed Timing

Longwall Panel	Proposed Start Date	Proposed Completion Date	Duration (days)	Panel Length (m)	Void Width (m)	Panel Width (m)
LW S1A	18-10-2022*	05-04-2023	194	1711	277.8	272.6
LW S2A	09-05-2023	12-12-2023	217	1768	279.8	274.6
LW S3A	15-01-2024	29-07-2024	196	1808	279.8	274.6
LW S4A	29-08-2024	21-03-2025	204	1860	279.8	274.6
LW S5A	23-04-2025	17-11-2025	208	1949	279.8	274.6
LW S6A	17-12-2025	25-07-2026	220	1999	279.8	274.6

*actual commencement date



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:68,000 at A4
Project Number:	610.30652
Date:	22-Apr-2022
Drawn by:	JG

- Minor Town
- Tahmoor North and Western Domain
- Major Roads
- Watercourses
- Lakes
- National Park Estate
- NSW State Forest
- WaterNSW Special Area

- Existing Mine

Tahmoor Coal Titles

- MLs 1308, 1376, 1539
- CCL 716
- CCL 747

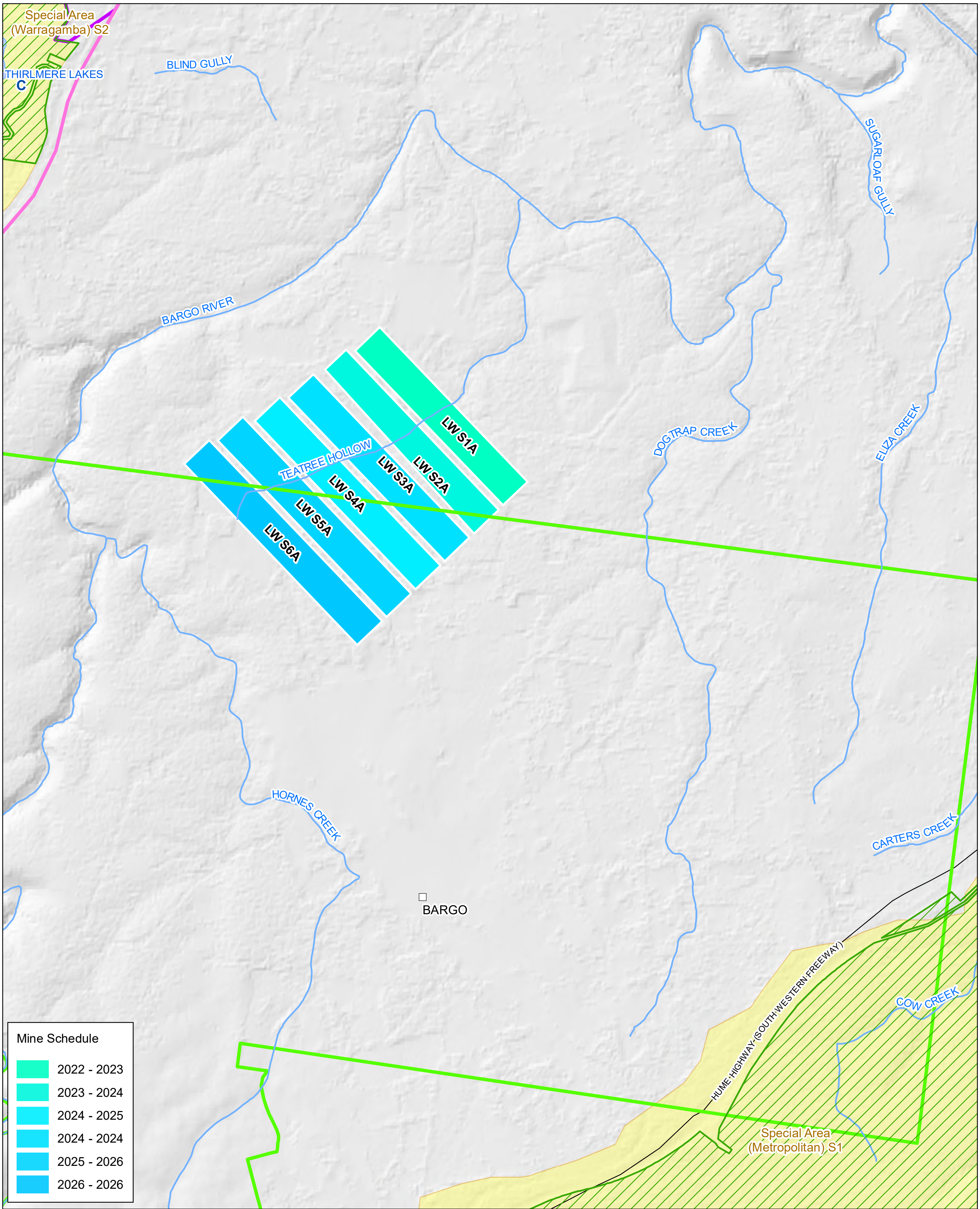
Lakes:
D = Dry Lake
G = Gandangarra
W = Werri Berri
C = Couridjah
B = Baraba
N = Nerrigorang

TAHMOOR SOUTH LW S1A – S6A GROUNDWATER TECHNICAL REPORT

Mine Plan and Extraction Schedule

FIGURE 1-1

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30637.00000 Tahmoor Coal Extraction Plan LW101A LW06 SLR Data\01 CADGIS\GIS\61030637 Fig1_1 Mine plan and extraction schedule.mxd



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Coordinate System:	GDA 1994 MGA Zone 56
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Project Number:	610.30637
Date:	22-Apr-2022
Drawn by:	NT

Minor Town
Major Roads
Watercourses
Lakes
National Park Estate
NSW State Forest
WaterNSW Special

Existing Mine

Tahmoor Coal Titles

MLs 1308, 1376, 1539
CCL 716
CCL 747

TAHMOOR SOUTH
LW S1A – S6A
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TECHNICAL REPORT

Tahmoor South
Mine Plan and
Extraction Schedule

FIGURE 1-1

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30637.00000 Tahmoor Coal Extraction Plan LW101A LW06 SLR Data\01 CADGIS\GIS\61030637 Fig1_2 Tah SouthMine plan and extraction schedule.mxd

1.2 History of Tahmoor South

An Environmental Impact Statement (EIS) was exhibited in early 2019 seeking approval for the extraction of up to 48 million tonnes (Mt) of ROM coal over a 13-year mine life. Tahmoor Coal subsequently revised the proposed mine design and submitted amended development applications on two occasions (in February and August 2020). In April 2021, Tahmoor Coal received Development Consent SSD 8445.

The Tahmoor South Groundwater Management Plan (SLR, 2022) received Directors Approval from the NSW Department of Planning and Environment on the 14th April 2022.

1.2.1 Other Leases and Licences

All development consents, leases, licences, and other relevant approvals are stored in the Cority Compliance Management database, which is administered by both site and Liberty GFG Corporate. A summary of the relevant mining leases is provided in Table 1-2. A summary of other approvals and licences is provided in Table 1-3.

Table 1-2 Mining Leases

Lease	Title	Granted	Expires
CCL 716	Original Tahmoor Leases	15/06/1990	13/03/2021(renewal documentation submitted, being assessed)
CCL 747	Bargo Mining Lease	23/05/1990	06/11/2025
ML 1376	Tahmoor North Lease	28/08/1995	28/08/2016 (renewal documentation submitted, under assessment)
ML 1308	Small Western lease, west of CCL716	02/03/1993	02/03/2035
ML 1539	Tahmoor North Extensions Lease	16/06/2003	16/06/2024
ML1642	Pit-top and REA surface Mining Lease	27/08/2010	27/08/2031

Table 1-3 Approvals/Licences

Approval Title / Description	Date Granted	Expiry Date
Environmental Protection Licence 1389	01/05/2012	No Expiry
WAL36442 and WAL25777	6/12/2013	No Expiry
WAL 43572	07/05/2021	No Expiry
WAL43656	1/08/2022	No Expiry

1.3 Structure of this Document

The Groundwater Technical Report will support the LW S1A-S6A Extraction Plan and overarching Water Management Plan (WMP), and is structured as follows:

Section 1: Provides background to the site and details of the proposed operations

Section 2: Outlines the Statutory requirements applicable to the Groundwater Technical Report.

Section 3:	Describes the existing environment pertinent to the LW S1A-S6A extraction with respect to groundwater and associated receptors
Section 4:	Details the predicted subsidence impacts and consequences to groundwater resources within the Investigative Area.
Section 5:	Describes the monitoring, mitigation, and management plan for LW S1A-S6A.
Section 6:	Details the Trigger Action Response Plans (TARPs) and adaptive management measures

2 Statutory Requirements

This section provides background to the statutory requirements associated with the broader Tahmoor Mine and for LW S1A-S6A.

2.1 Relevant Legislation and Policy

2.1.1 Water Management Act 2000

The *Water Management Act 2000* is the regulatory framework for the management and control of water use within NSW. In conjunction with the *Water Act 1912*, it governs the licensing of water to users. Further, the *Water Management Act 2000* allows for the development and implementation of Water Sharing Plans (WSPs). WSPs regulate the trade and sharing of surface and groundwaters between competing needs and users throughout NSW.

2.1.1.1 Relevant Water Sharing Plans and Groundwater Management Areas

Tahmoor Mine currently extracts groundwater that drains into underground mine workings and pumps this water to the surface via three dewatering lines before treating the water and discharging it off site.

Tahmoor Mine falls within the ‘Greater Metropolitan Region Groundwater Sources’ WSP (NOW, 2011b), which commenced in 2011. Figure 2-1 indicates the extent of this WSP, along with the various groundwater sources in this region that are regulated by the WSP. A WSP is used to manage the average long-term annual volume of water extracted from a given groundwater source.

The relevant Groundwater Source for the Tahmoor Mine is:

- Sydney Basin Nepean Sandstone

Other relevant Groundwater Sources include:

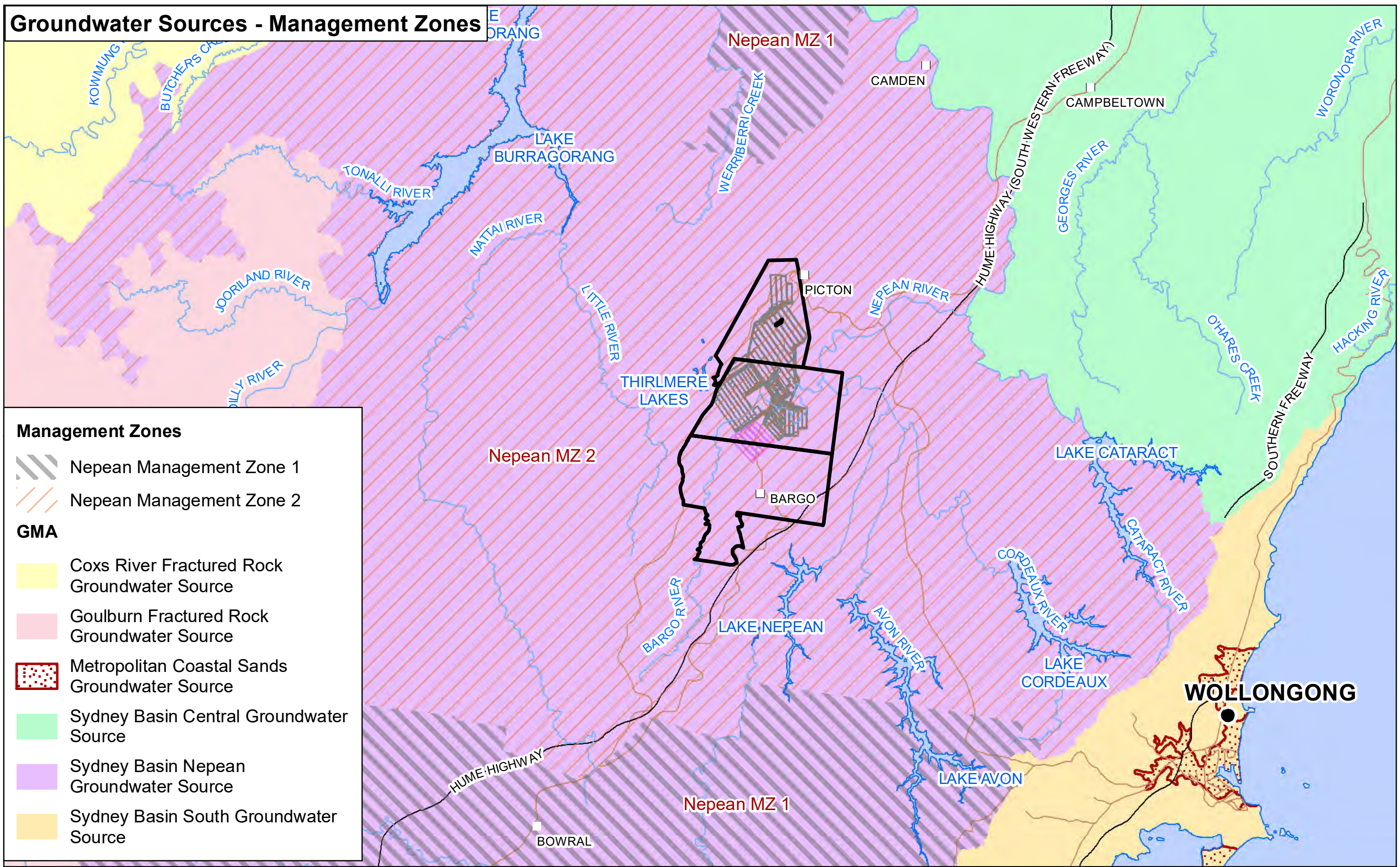
- Sydney Basin – Central, located 10 km to the east and north-east,
- Sydney Basin – South, located 15-20 km east and south-east, and
- Goulburn GMA – located over 25 km to the west and south.

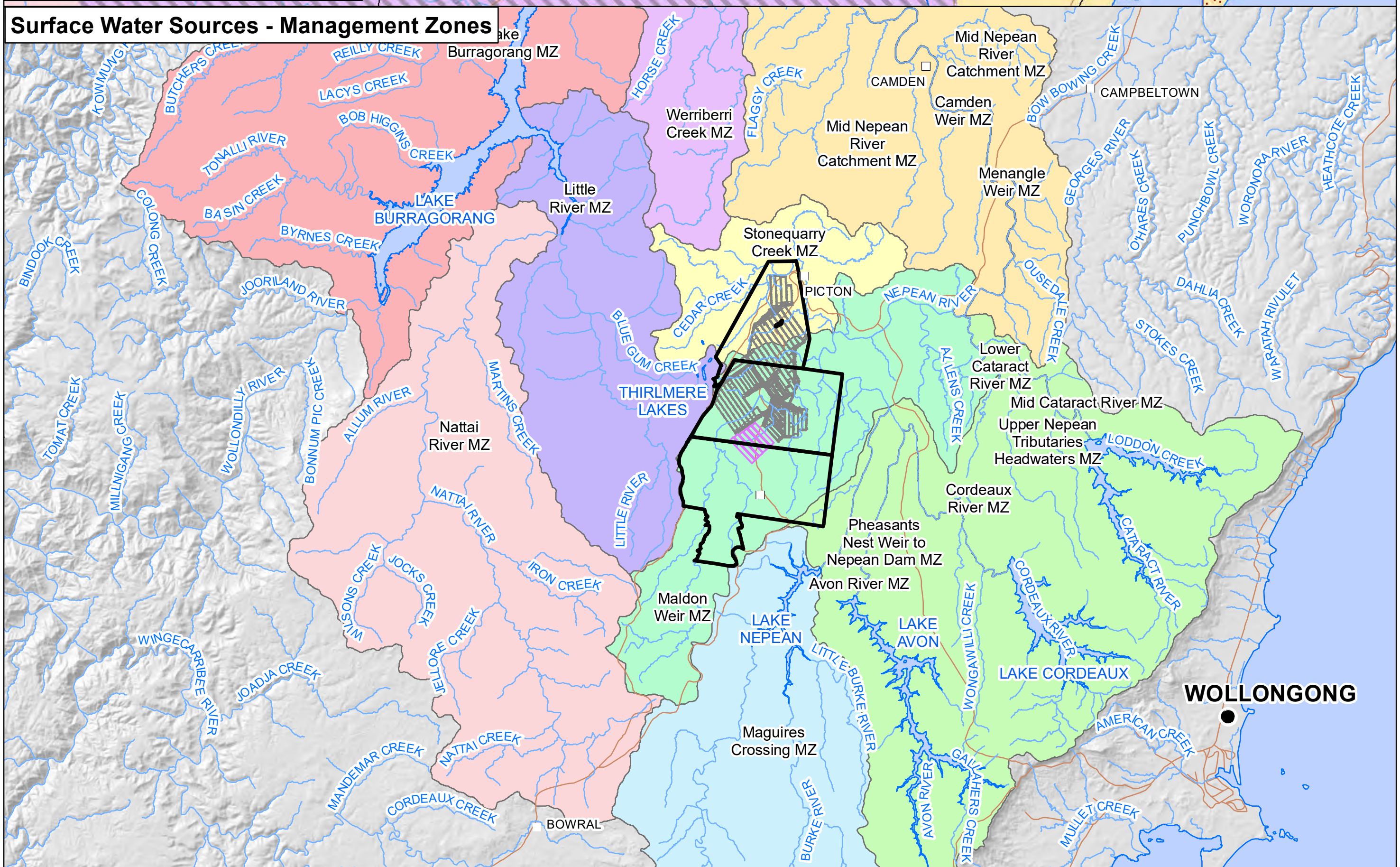
The Sydney Basin Nepean Sandstone Groundwater Source is further subdivided into Management Zones (MZ), as shown using hatching on Figure 2-1. The LW S1A-S6A Study Area lies within Nepean Management Zone 2, while Zone 1 covers the southern ‘third’ of the Groundwater Source as well as a smaller area to the west of Camden. The Sydney Basin Nepean Sandstone Groundwater Source has an annualised limit on entitlement (LTAAEL) of 99,568 ML (NOW, 2011a), while current entitlement is 31,346 ML (based on the WaterNSW Water Register 2020-2021 water year).

The Greater Metropolitan Region Unregulated River Water Sources WSP (NOW, 2011c) is the relevant plan for surface waters for the LW S1A-S6A Study Area. Within this WSP the Upper Nepean River source is the relevant Water Source, of which the following MZ cover or adjacent to the project site:

- Pheasants Nest Weir to Nepean Dam MZ;
- Stonequarry Creek MZ; and

- Maldon Weir MZ.





Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:451,550 at A4
Project Number:	610.30637
Date:	22-Apr-2022
Drawn by:	JG

Scale: 0 5 10 km

- City
- Town
- Tahmoor North (inc. Western Domain)
- Major Roads
- Railway
- Watercourses
- Lakes
- Tahmoor Coal Titles
- Tahmoor South

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Water Management Zones

FIGURE 2-1

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30637.00000 Tahmoor Coal Extraction Plan LW101A LW06 SLR Data\01 CADGIS\GIS\61030637 Fig2_1 Water licensing - maps of management areas.mxd

2.1.2 NSW Aquifer Interference Policy

Underground mining generally requires the dewatering of the geological strata. In accordance with the NSW Aquifer Interference Policy (AIP), such activity is classified as an 'Aquifer Interference'. In order to meet the requirements of the 'minimal impact considerations' of the AIP, a groundwater assessment is conducted.

The AIP requires an estimation of "all quantities of water that are likely to be taken from any water source during and following cessation of the activity and all predicted impacts associated with that activity…". Water take and impact estimation is to be based on a "complex modelling platform" for any mining activity not subject to the Gateway process, where the model makes use of the "available baseline data that has been collected at an appropriate frequency and scale and over a sufficient period of time to incorporate typical temporal variations".

The AIP was developed to provide a framework to guide the assessment of impacts that may result following the 'take' of water from an aquifer. It outlines the requirements for obtaining licences for approved aquifer interference activities, as well as considerations for the assessment of impacts (NSW Government, 2012).

The AIP specifies 'minimal harm considerations' for highly and less productive aquifers, while also defining thresholds for water table and groundwater pressure drawdown, and changes in groundwater and surface water quality. There are separate minimal impact considerations for:

- "Highly productive" groundwater;
- "Less productive" groundwater;
- "Water supply" works;
- "High Priority" Groundwater Dependent Ecosystems (GDEs); and
- "High Priority" Culturally significant sites.

The AIP categorises groundwater source productivity (highly productive or less productive) based on characteristics of salinity and aquifer yield. Tahmoor Mine undermines the 'Highly Productive' Hawkesbury Sandstone aquifer (Figure 2-1). The Hawkesbury Sandstone aquifer is the most utilised aquifer in this region. Water sourced from the Narrabeen Group and Permian Coal Measures comprises the remaining portion of water sourced around Tahmoor Mine (HydroSimulations, 2018).

It should be noted that the categorisation of groundwater source productivity does not make any vertical distinction of aquifer productivity. This is relevant as the high yielding Hawkesbury Sandstone aquifer overlies the lower-yielding Narrabeen Group/Permian Coal Measures groundwater systems which are at greater depths.

2.1.3 Water Licensing

Water Access Licences (WAL) held by Tahmoor Coal for the Sydney Basin Nepean Groundwater Source which is regulated in accordance with the *Greater Metropolitan Region Groundwater Sources Water Sharing Plan* under the authority of the Water Management Act 2000 are listed in the Table 2-1.

Table 2-1 Tahmoor Coal Water Access Licences

WAL Title	Issued	Purpose	Share
WAL 36442	06/12/2013	Mining dewatering (groundwater) (Nepean Sandstone Groundwater MZ2)	1,642ML
WAL 25777	27/10/2014	Surface Water Take (Maldon Weir MZ)	5ML

WAL Title	Issued	Purpose	Share
WAL 43572	13/04/2021	Incidental Surface Water Take (Stonequarry Creek MZ)	16ML
WAL 44608	8/2/2023	Incidental Surface Water Take (Stonequarry Creek MZ)	9ML
WAL 43656	1/8/2022	Incidental Surface Water Take (Maldon Weir MZ)	25ML
SWC828767	19/8/2022	Incidental Surface Water Take (Maldon Weir MZ) – Lease	11ML
SWC828752	19/8/2022	Incidental Surface Water Take (Stonequarry Creek MZ) – Lease	24ML

2.1.4 Licensed Discharge Points

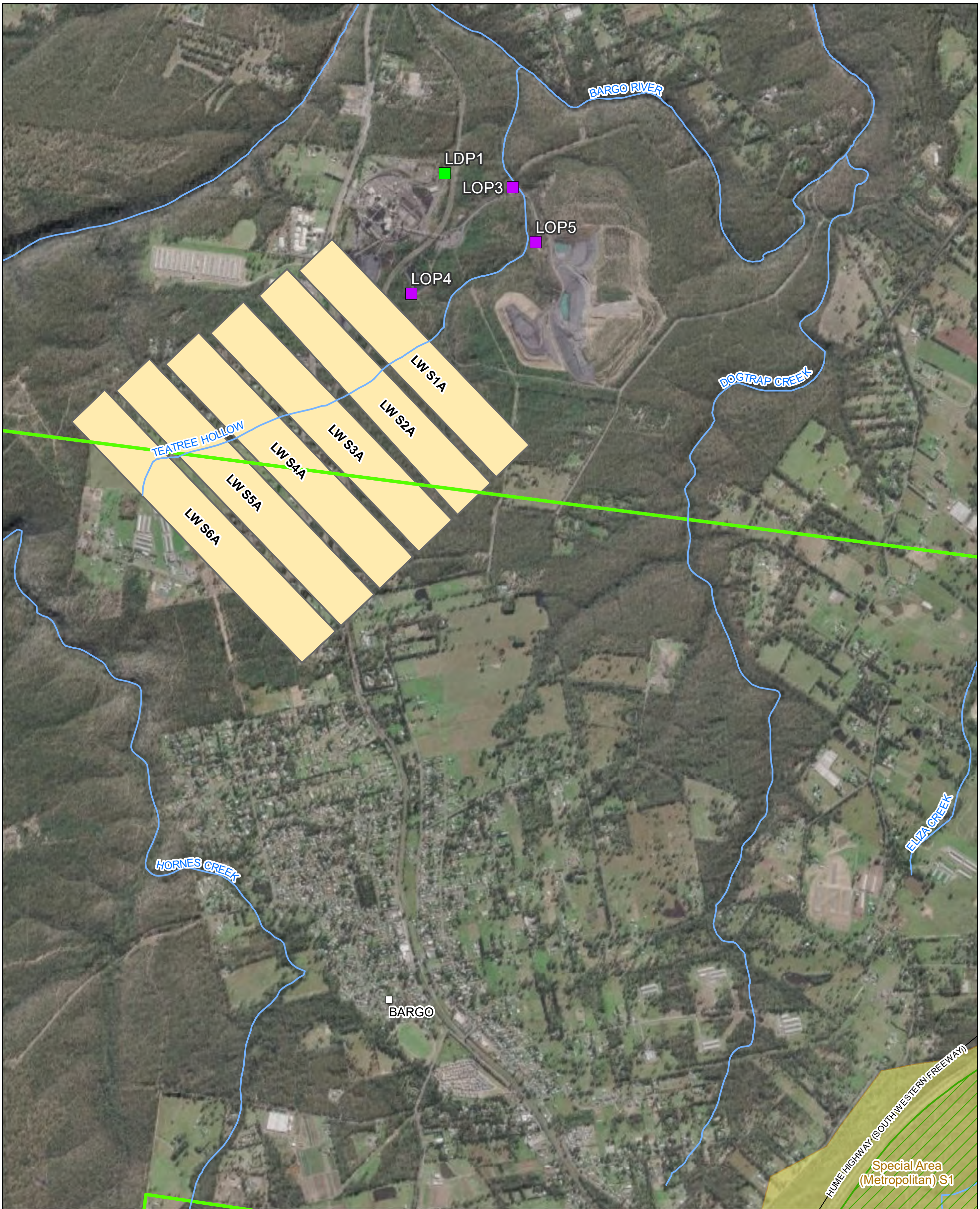
Tahmoor Coal also holds a discharge licence, issued by the NSW EPA. This licence, Environment Protection Licence (EPL) 1389, permits the discharge of wastewater and 'made water' from the underground mine to surface water.

In accordance with EPL 1389, Tahmoor Coal is licensed to discharge from one licenced discharge point (LDP) and three licenced overflow points (LOPs). The locations of the LDP and LOP's are shown on Figure 2-2, and described in Table 2-2.

Table 2-2 EPL 1389 Licenced Discharge Points

Discharge/Overflow Point	Type of Discharge Point	Location Description	Discharge Limit
LDP1	Discharge to waters Discharge quality monitoring Volume monitoring	Main water discharge – discharge drain located downstream of the final mine water treatment dam (dam M4)	15,500 kilolitres per day during low rainfall conditions Unlimited during wet weather conditions*†
LOP3	Discharge to waters	Overflow from sediment dam S9	Unlimited during wet weather conditions*†
LOP4		Overflow from sediment dam S4	
LOP5		Overflow from sediment dam S8	

* Defined as more than 10 millimetres (mm) rainfall within a 24 hour period.
† Provided that all practical measures are taken to reduce potential water quality impacts



0 0.5 1 km

Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:30,000 at A4
Project Number: 610.30637
Date: 29-Apr-2022
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- Discharge Point
- Overflow Point
- Minor Town
- Major Roads
- Watercourses
- National Park Estate
- WaterNSW Special Area

Tahmoor Coal Titles

- CCL 716
- CCL 747

Tahmoor South Mine Plan

- Approved

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Licenced Discharge Points and Licenced Overflow Points

FIGURE 2-2

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30637.00000 Tahmoor Coal Extraction Plan LW101A LW06 SLR Data\01 CADGIS\GIS\61030637 Fig2_2 Licened Discharge Points.mxd

2.2 Project Approval Conditions

This Groundwater Technical Report has been prepared as part of the Extraction Plan and overarching Water Management Plan (WMP), as prescribed under the Development Consent SSD 8445.

2.2.1 Water Management Plan

SSD 8445 provides the conditional planning approval framework for mining activities in the Tahmoor South Domain to be addressed within an Extraction Plan and supporting management plans. Conditions pertaining to groundwater are detailed in Table 2-3.

Table 2-3 Water Management Plan Requirements

Condition Reference	Condition Requirement	Where Addressed
B34	Prior to the commencement of construction activities, the Applicant must prepare a Water Management Plan for the development to the satisfaction of the Planning Secretary. This plan must: Groundwater Management Plan that includes:	
	• detailed baseline data regarding groundwater levels, yield and quality for privately-owned groundwater bores (as required under condition B25(a)) and the condition of GDEs (including Thirlmere Lakes) potentially impacted by the development;	Section 3
	• a program to periodically review and update data regarding groundwater levels, yield and quality at privately-owned groundwater bores in the vicinity of the development, including any bores potentially impacted by cumulative groundwater drawdown;	Section 5.1
	• a detailed description of the groundwater management system, including commitments to:	
	o install an additional monitoring bore in the footprint of Tahmoor North to monitor post-mining groundwater level and quality;	Section 5.1.4
	o install additional monitoring bores (minimum of four) at or near the Thirlmere Lakes;	Section 5.1
	o install bores above the initial longwalls to define profile fracturing and depressurisation in the Hawkesbury Sandstone and Bulgo Sandstone;	Section 5.1.3
	o monitor shallow groundwater within the Hawkesbury Sandstone;	Section 5.1
	o monitor volumetric take (mine inflow), including inflows to the underground mine; and	
	o regularly review the monitoring program to ensure robust and reliable monitoring is undertaken, including reviewing the performance of vibrating wire piezometers;	Section 5.1
	• groundwater performance criteria, including trigger levels for identifying and investigating any potentially adverse groundwater impacts (or trends) associated with the development, on:	Section 6
	o regional and local aquifers (alluvial and hard rock); and	
	o groundwater supply for other users such as licensed privately-owned groundwater bores;	
	• uncertainty analysis of the potential impacts of mining the proposed longwalls on the water levels in Thirlmere Lakes, based upon results from the current Thirlmere Lakes Research Program and other ongoing monitoring and investigations;	Section 4.4
	• a program to monitor and evaluate:	
	o compliance with the relevant performance measures listed in Table 4 (of the commitments) and the performance criteria of this plan;	Section 5 and 6
	o water loss/seepage from water storages into the groundwater system;	
	o groundwater inflows, outflows and storage volumes, to inform the Site Water Balance;	
	o impacts on water supply for other water users;	
	o impacts on GDEs (including Thirlmere Lakes);	
	o the hydrogeological setting of any nearby alluvial aquifers and the likelihood of any indirect impacts from the development; and	
	o the effectiveness of the groundwater management system;	
	• reporting procedures for the results of the monitoring program, including notifying other water users, the NSW Office of Environment and Heritage and Thirlmere Lakes Research Program of any elevated results;	Section 6
	• a trigger action response plan to respond to any exceedances of the relevant performance measures and groundwater performance criteria, and repair, mitigate and/or offset any adverse groundwater impacts of the development, including impacts on Thirlmere Lakes;	Section 6
	• a Groundwater Modelling Plan that:	SLR, 2021, Appendix E
	o provides details for the future groundwater model re-build and recalibration which must be completed within 2 years of the commencement of development under this consent;	
	o is independently third-party reviewed;	
	o provides for the incorporation of the outcomes of the findings of the Thirlmere Lakes Research Program and other relevant research on the Thirlmere Lakes;	
	o considers field data and the outcomes of subsidence monitoring;	
	o provides for periodic validation and where necessary recalibration, of the groundwater model for the development, including an independent review of the model every 3 years, and comparison of monitoring results with modelled predictions; and	
	a plan to respond to any exceedances of the performance measures in Table 4.	Section 6

Consent Condition E5 outlines the general requirements for all management plans. Table 2 outlines the requirements under this condition and identifies where these requirements have been addressed.

Table 2-4 Management Plan Requirements

Condition Reference	Condition	Where Addressed
E5	Management plans required under this consent must be prepared in accordance with relevant guidelines, and include:	
(a)	a summary of relevant background or baseline data;	Section 3
(b)	details of:	Section 2
(b) (i)	the relevant statutory requirements (including any relevant approval, licence or lease conditions);	
(b) (ii)	any relevant limits or performance measures and criteria; and	
(b) (iii)	the specific performance indicators that are proposed to be used to judge the performance of, or guide the implementation of, the development or any management measures;	
(c)	any relevant commitments or recommendations identified in the document/s listed in condition A2(c);	
(d)	a description of the measures to be implemented to comply with the relevant statutory requirements, limits, or performance measures and criteria;	
(e)	a program to monitor and report on the:	Section 4, 5 and 6
(e) (i)	impacts and environmental performance of the development; and	
(e) (ii)	effectiveness of the management measures set out pursuant to condition E5(d);	
(f)	a contingency plan to manage any unpredicted impacts and their consequences and to ensure that ongoing impacts reduce to levels below relevant impact assessment criteria as quickly as possible;	
(g)	a program to investigate and implement ways to improve the environmental performance of the development over time;	
(h)	a protocol for managing and reporting any:	
(h) (i)	incident, non-compliance or exceedance of any impact assessment criterion or performance criterion;	
(h) (ii)	complaint; or	
(h) (iii)	failure to comply with other statutory requirements;	
(i)	public sources of information and data to assist stakeholders in understanding environmental impacts of the development; and	
(j)	a protocol for periodic review of the plan.	

3 Existing Environment

This section provides an analysis of the natural characteristics of the Study Area, along with an assessment of available baseline data. This work builds on the previous conceptualisation completed for the Tahmoor South EIS (HydroSimulations, 2018) updated where additional information is available.

3.1 Climatic Conditions

Rainfall data in the area is available from numerous sources. Bureau of Meteorology (BoM) operate two rainfall stations, Picton Council Depot (68052) and Buxton (681660) located to the north and west of Tahmoor Mine operations respectively. Tahmoor Coal operate their own rainfall station, and the SILO climate data source provide interpolated and infilled records for 0.05°x0.05° latitude and longitude tiles.

Due to the occasional gaps in the data for the BoM sites, and the relatively short record of data held by Tahmoor (the mine's record has no gaps, but started in July 2006), the SILO record for the closest 0.05°x0.05° tile near the mine (Lat: -34.25, Long: 150.60) has been adopted for this report to understand long-term trends for the record since 1900. This record has been compared against the other data sources to verify its appropriateness for this task.

Average annual rainfall at Tahmoor is approximately 822 mm/year for the recorded period of January 1900 to May 2023). Areas with higher rainfall occur to the south and east, while areas to the north and west are typically drier. Monthly average rainfall is presented on Figure 3-1, alongside estimated actual evapotranspiration. Rainfall is generally consistent all year with the average total monthly rainfall ranging from 44mm to 95 mm. The highest monthly rainfall is typically in January, February and March (85, 95 and 85 mm respectively), while September is typically the driest month (averaging 44 mm) for the recorded period. Evaporation and evapotranspiration show similar trends with higher rates during the summer months and lower during the winter months. The average monthly potential evaporation is highest in December (188 mm).

Figure 3-2 shows the historical record of monthly rainfall and the calculated trend in rainfall (using cumulative residual departure from mean method). This trend (orange line) shows relatively wet periods as upward gradients, droughts as downward gradients, and average conditions as horizontal. Of note in recent times, there was a significant drought period from mid-2017 until January 2020, with extreme conditions in November 2019 to January 2020, producing notable bushfire conditions around Tahmoor and more widely across eastern NSW. Since then, conditions have been wetter than average, including high rainfall totals in March and November 2021 (304 and 168 mm respectively). To date, 2022 has experienced record high rainfalls, including 112 mm in January, 195 mm in February and 485 mm in March, associated with widespread flooding. In 2023, high rainfall was recorded in January (147 mm) and April (102 mm) while the remainder of months in the first half of the year have been relatively dry.

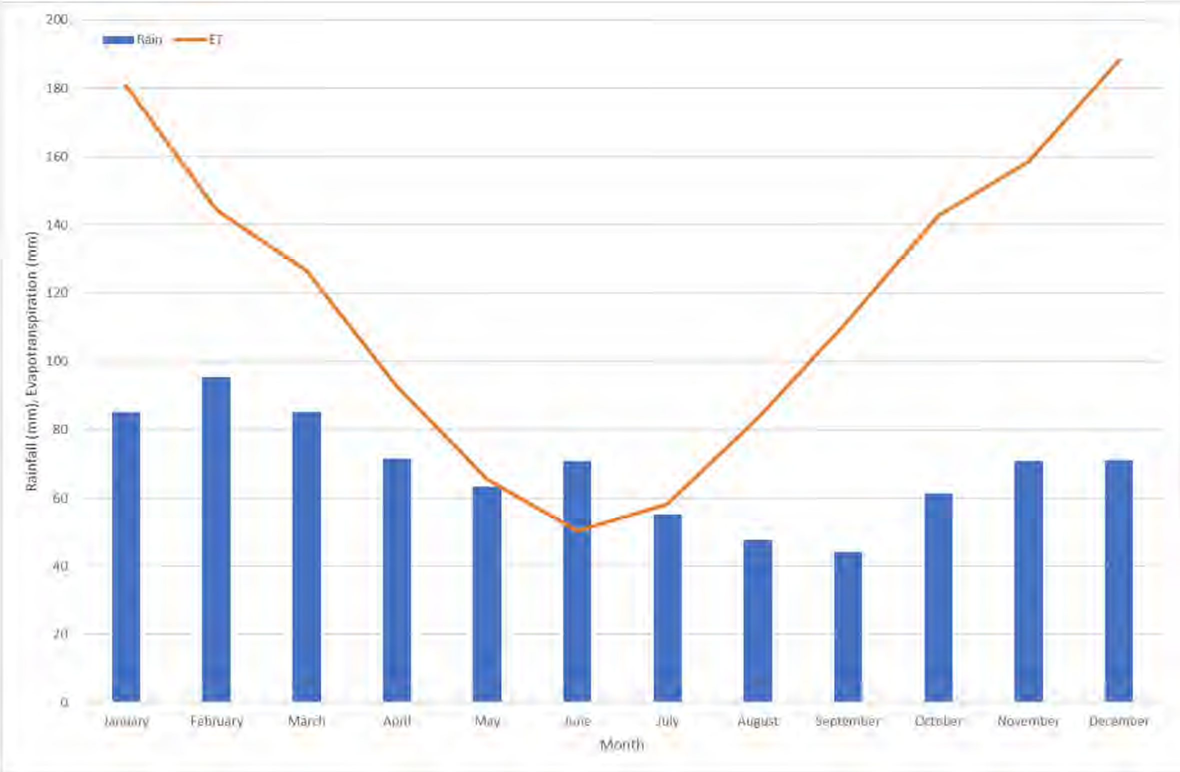


Figure 3-1 Average Monthly Rainfall and Evapotranspiration (ET)

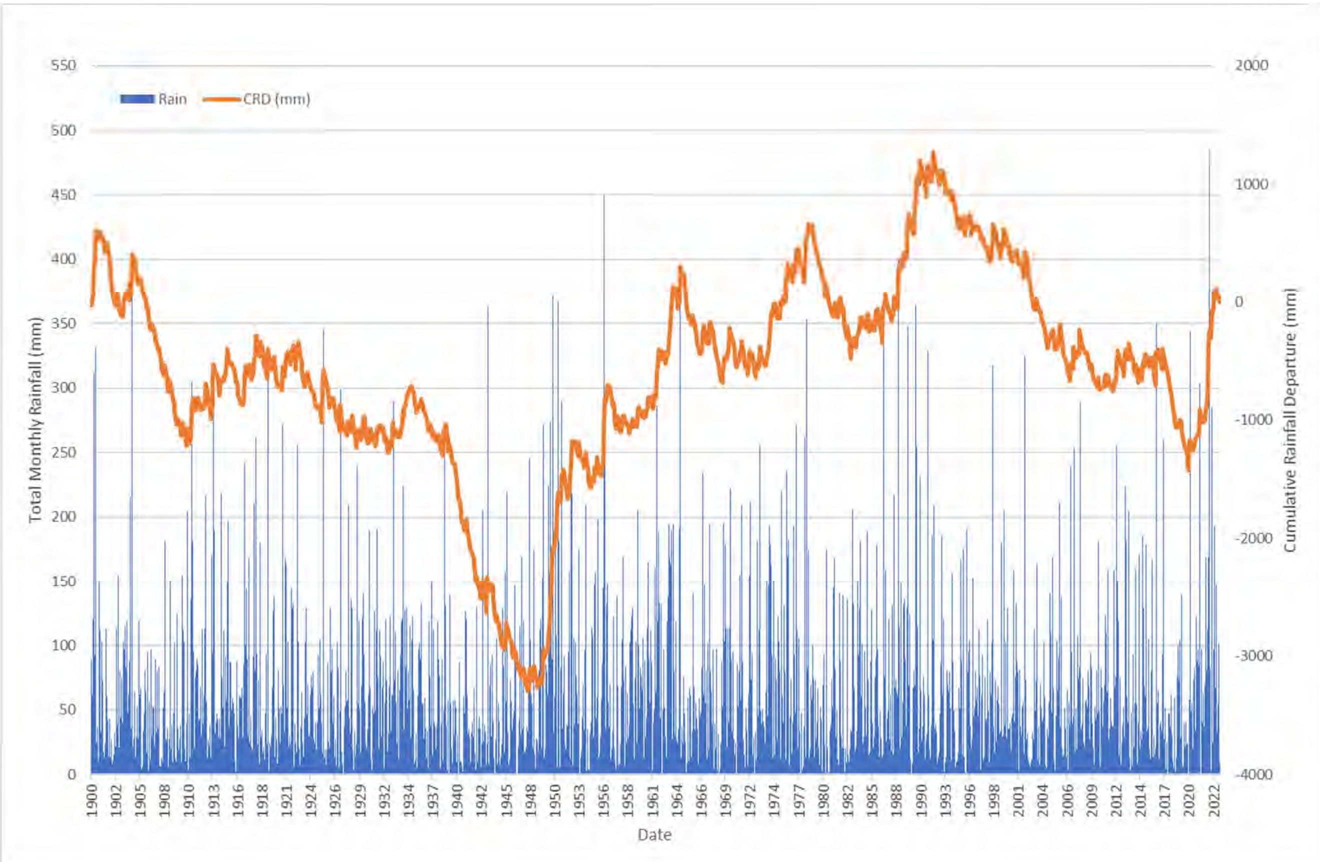
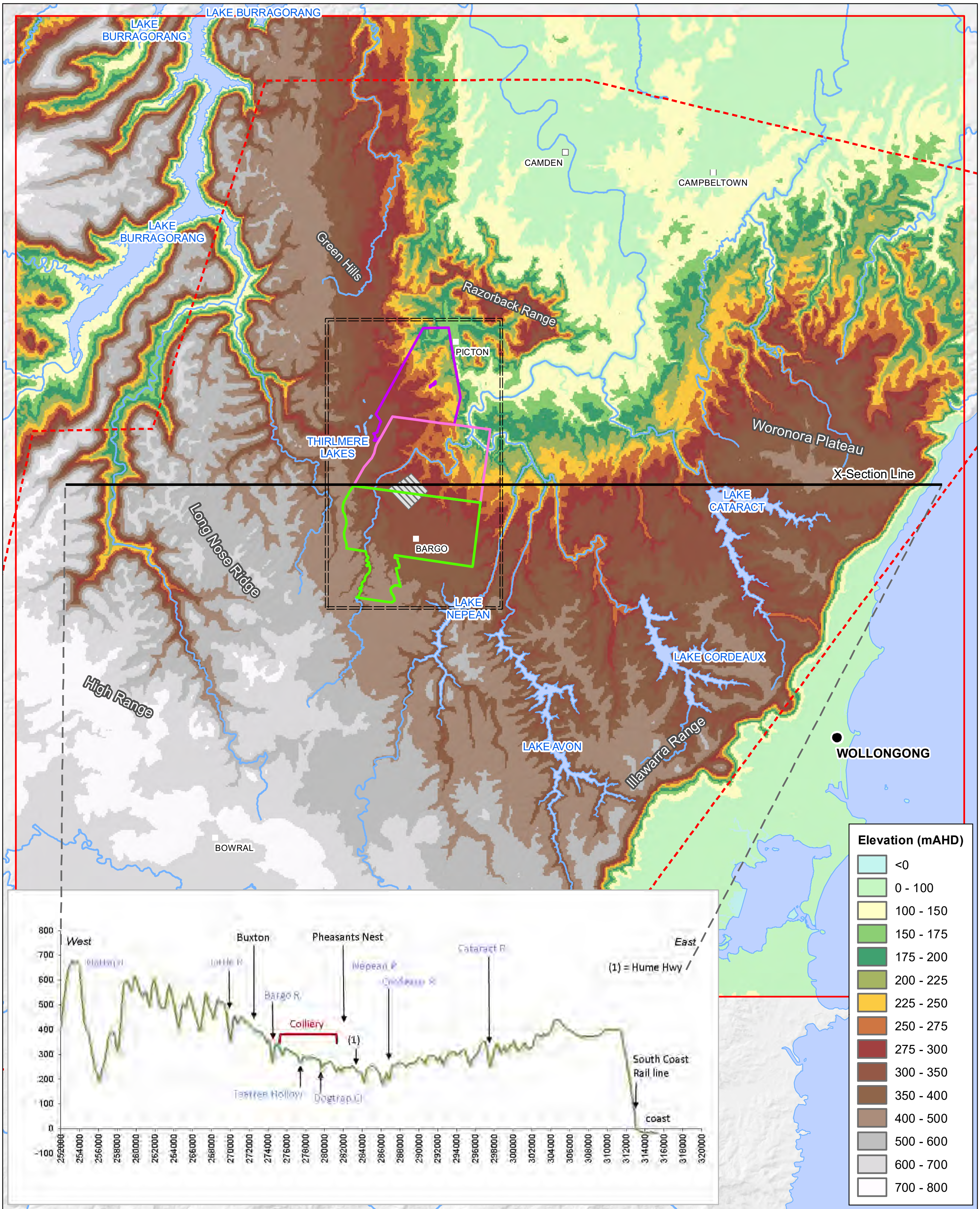


Figure 3-2 Cumulative Rainfall Departure and Total Monthly Rainfall

3.2 Topography

Tahmoor Mine is located approximately 20 km west of the Illawarra Escarpment (Figure 1-1)). It is surrounded by several deeply incised river valleys that flow in a predominantly northerly or north-easterly direction. Surface infrastructure at Tahmoor Mine lies at an elevation of approximately 280 mAHD, and the elevation of interfluves above LW S1A-S6A is typically 280-300 mAHD (Figure 3-3).



0 5 10 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
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Date:	22-Apr-2022
Drawn by:	JG

- City
- Town
- Watercourses
- Lakes

Tahmoor Coal Titles

- MLs 1308, 1376, 1539
- CCL 716
- CCL 747

- Lidar Covarage
- Southern Coalfield (approximate)
- Study Area for Groundwater Assessment
- Tahmoor South Mine Plan

TAHMOOR SOUTH LW S1A – S6A GROUNDWATER TECHNICAL REPORT

Topography

FIGURE 3-3

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30637.00000 Tahmoor Coal Extraction Plan LW101A LW06 SLR Data\01 CADGIS\GIS\61030652 Fig3_3 Topography.mxd

3.3 Surface Water

The Tahmoor mining lease is located in the Upper Hawkesbury-Nepean Catchment. The Nepean River is the major watercourse in this catchment, flowing perennially from the south through Lake Nepean. The Bargo, Avon and Cordeaux are major tributaries to the Nepean River in this area. The Bargo River flows eastward through the lower portions of the Tahmoor mine plan. The Avon and Cordeaux Rivers are positioned to the south-east of the Tahmoor mining leases and flow northward before reaching their confluences with the Nepean River 4 km and 6 km, respectively, to the east of the mining leases. These watercourses are presented on Figure 3-4.

Tahmoor South is located predominantly within the Teatree Hollow and Dogtrap Creek sub-catchments of the Bargo River catchment. Teatree Hollow is a third order stream that overlies LW S1A-S6A while Dogtrap Creek and its tributaries overlie the approved LW S1B-S6B. Teatree Hollow and Dogtrap Creek flow generally north-northeast toward the Bargo River, with Teatree Hollow traversing bushland between the Tahmoor Mine surface facilities and the Reject Emplacement Area (REA) and Dogtrap Creek traversing predominantly bushland to the east of the REA. The lower reaches of Teatree Hollow, Dogtrap Creek and the Bargo River have, to varying degrees, experienced subsidence-related effects due to historical mining operations at the Tahmoor Mine.

3.3.1 Bargo River

The Bargo River catchment area is approximately 130 square kilometres (km^2) at its confluence with the Nepean River. The Bargo River has intermittent flow in its upstream reaches which, to some degree, are regulated by the Picton Weir located at the Hornes Creek confluence, approximately 14 kilometres (km) upstream of the Nepean River confluence. Downstream of the Tahmoor Mine pit top (i.e. downstream of the Teatree Hollow confluence) flow is perennial due to persistent licensed discharges from Tahmoor Mine.

The lower 4 km of the river pass through the Bargo River Gorge, which is characterized by steep rock faces up to 110 m high. The river consists of a sequence of pools, glides and rock bars across sandstone bedrock, with occasional boulder fields and cobblestone riffles. The Bargo River flows into the Nepean River approximately 9 km downstream of the Teatree Hollow confluence. The headwaters of a second order tributary of the Bargo River overlie the western edge of the approved LW S5A. The baseline geomorphology survey identified that the Bargo River tributary was generally in good geomorphic condition (i.e. essentially natural with intact form and process) (Fluvial Systems, 2013). Sites where the redirection of surface flow to the subsurface was observed, presumed to be associated with historical mining-induced bed fracturing, were classified as having moderate geomorphic condition (Fluvial Systems, 2013).

3.3.2 Teatree Hollow

Teatree Hollow has its headwaters in the northern part of the Bargo Township, above the approved LW S1A-S6A and between the existing Tahmoor Mine surface facilities and REA. Teatree Hollow is a third order stream present from the northern boundary of the approved LW S1A to the confluence with the Bargo River and has a total catchment area of approximately 6.8 km^2. A third order tributary joins with Teatree Hollow at the eastern edge of the LW S1A.

The baseline geomorphology survey (Fluvial Systems, 2013) identified that the upper to mid reach of Teatree Hollow and the mid to lower reach of Teatree Hollow Tributary were predominantly in good geomorphic condition while the mid to lower reach of Teatree Hollow and the upper reach of Teatree Hollow Tributary were predominantly in moderate geomorphic condition. The sites of moderate geomorphic condition related to minor culvert or track crossings, low riparian vegetation cover or discharge from the LDPs (Fluvial Systems, 2013). The upper reaches of Teatree Hollow and Teatree Hollow Tributary were characterised by a low relief landscape, with a dominant bed material of mud (cohesive clay/silt/sand) and notable grass coverage (Fluvial Systems, 2013). In the mid to lower reaches, the landscape was characterised as high relief with dominant bed material of mud, sand, boulders and/or exposed bedrock and little low flow channel grass coverage.

3.3.3 Dogtrap Creek

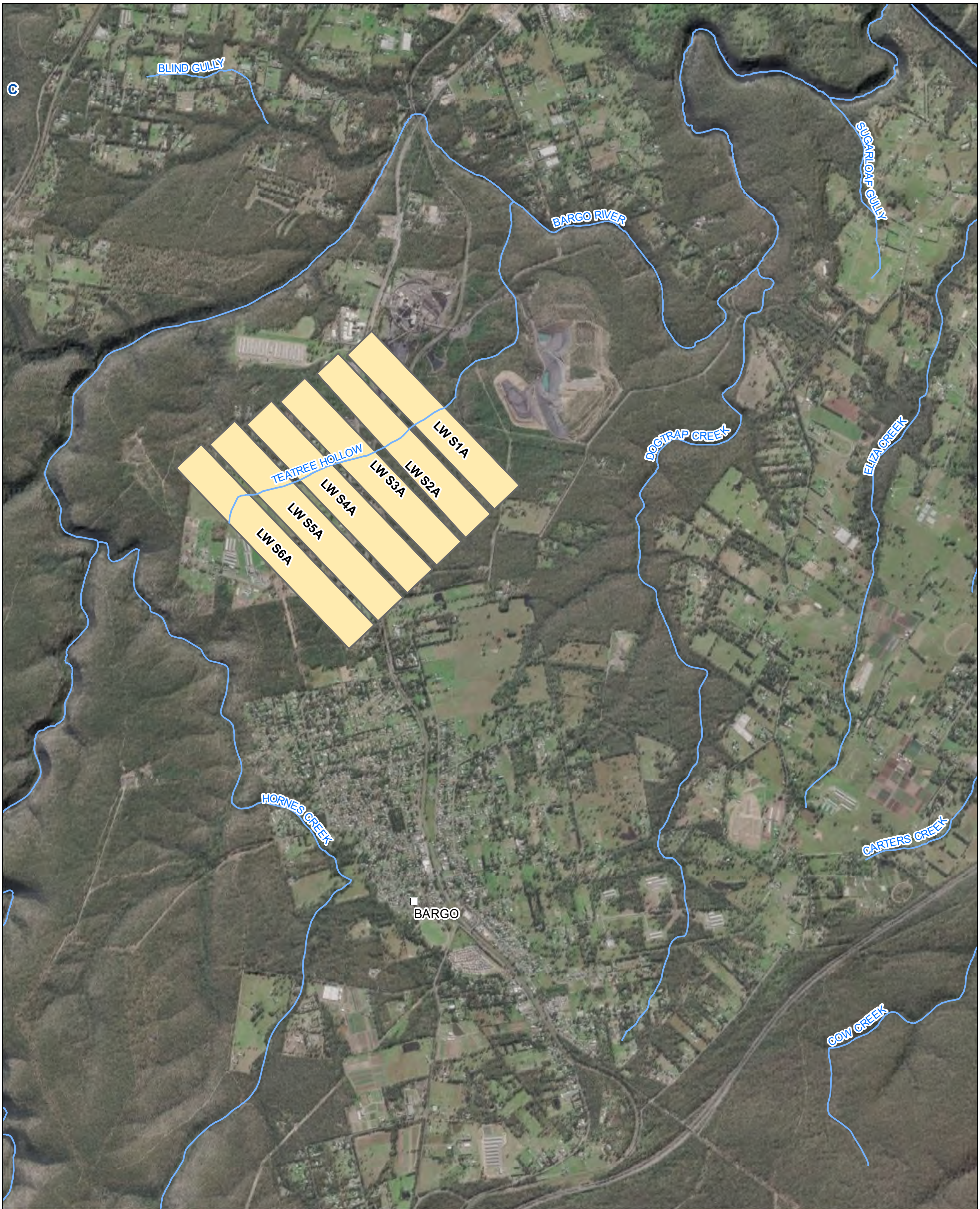
Dogtrap Creek has its headwaters in the southern part of the Bargo Township, above LW S1B-S6B and east of the REA to the Bargo River, and approximately 1 km east of the nearest part of LW S1A. Dogtrap Creek is a third order stream from approved LW S4B to the confluence with the Bargo River and has a total catchment area of approximately 13.6 km^2. Two second order tributaries join with Dogtrap Creek at the northern edge of approved LW S1B.

The outcomes of the geomorphology survey concluded that the majority of Dogtrap Creek and its tributaries were in good geomorphic condition with some sites in the upper reaches of Dogtrap Creek and its tributaries characterised as moderate geomorphic condition.

3.3.4 Thirlmere Lakes

Although spatially disparate to LW S1A-S6A, the five lakes of the Thirlmere Lakes are nominated High Priority Groundwater Dependent Ecosystems and within a World Heritage Area and consequently incorporated in this study. These lakes are formed in the alluvium along Blue Gum Creek, to the west of historical Tahmoor mine longwalls. The nearest of the Thirlmere Lakes is at least 3,500 m from LW S1A-S6A (Figure 3-4).

The Thirlmere Lakes Research Program (TLRP), a NSW government initiative, was commenced in 2018 and completed in 2022. This program aimed to provide a detailed understanding of the hydrological dynamics, water sources and water flow pathways. The summation report, “Thirlmere Lakes – A Synthesis of Current Research” was released in late March 2022, by DPE. Further information on Thirlmere Lakes is provided in Section 3.6.1.



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Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:40,000 at A4
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Drawn by:	NT

□ Minor Town

Watercourses

Tahmoor South Mine Plan

Approved

TAHMOOR SOUTH
LW S1A – S6A
GROUNDWATER
TECHNICAL REPORT

Watercourses

FIGURE 3-4

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30637.00000 Tahmoor Coal Extraction Plan LW101A LW06 SLR Data\01 CADGIS\GIS\61030637 Fig3_3 Watercourse.mxd

3.4 Geological Setting

3.4.1 Regional Stratigraphic Setting

Tahmoor Mine is situated within the Southern Coalfield in the sedimentary Sydney Basin (UOW, 2012). Figure 3-5 presents the outcropping geology at and around Tahmoor Mine. Locally, the underlying geology consists of interbedded Permo-Triassic strata, primarily sandstones, siltstones, claystones and coal seams. Table 3-1 describes the regional stratigraphic sequence.

In the vicinity of the mine the strata dips mainly towards the east and north. The fluvially-deposited Triassic Hawkesbury Sandstone (HBSS) is the dominant outcropping stratigraphic unit in this region. Its full thickness is approximately 150 m or more. The Wianamatta Group (WMFM), composed of carbonaceous shales, that overlie the Hawkesbury Sandstone and is more apparent to the north of the mine. Due to the high silica content of this sequence, the HBSS exhibits higher resistance to erosion than the WMFM. As such, soil production on the HBSS is low and the sandstone is the common bed material for the watercourses in this region (UOW, 2012), with the WMFM typically appearing as capping material at higher elevations.

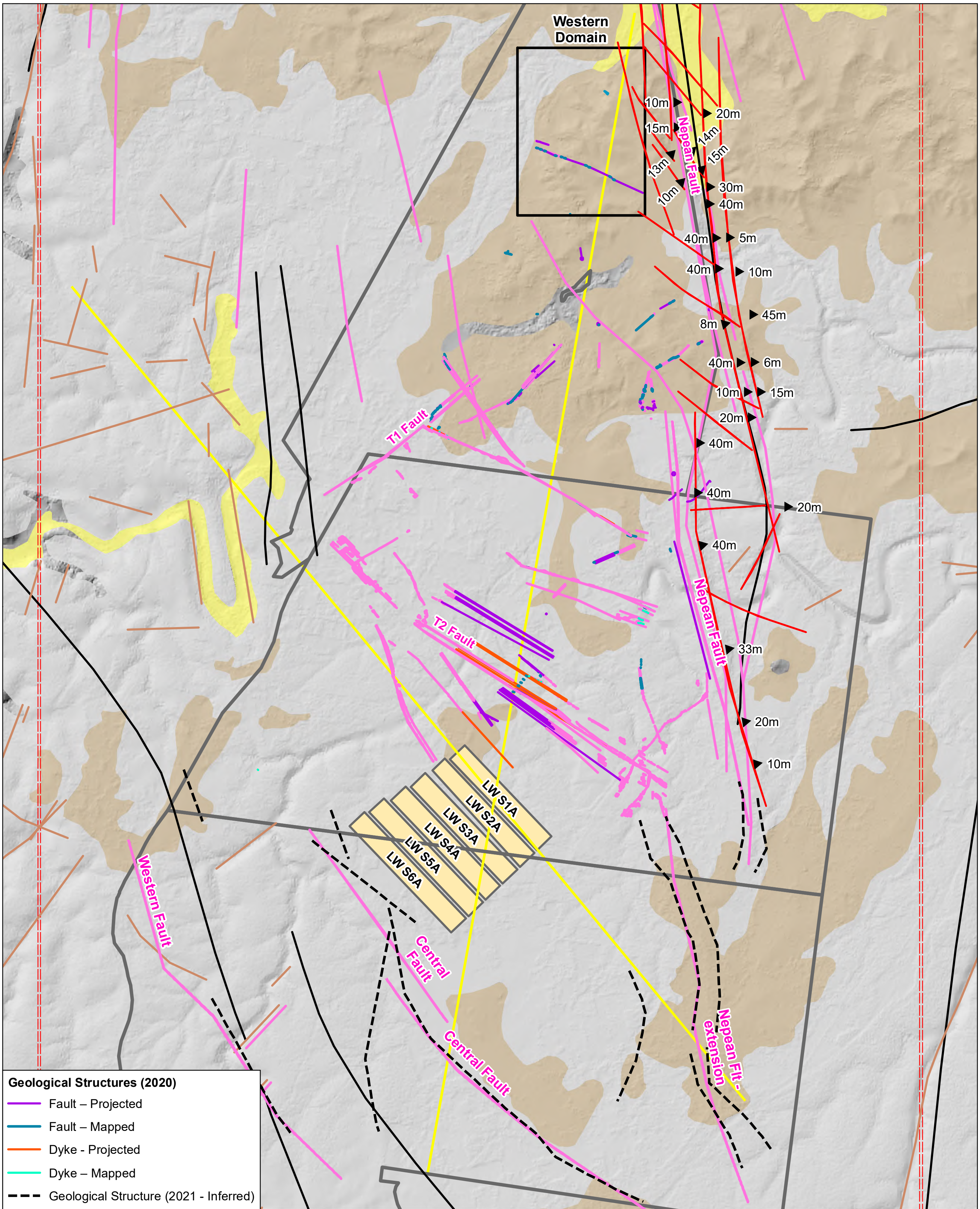
Below the HBSS are the Narrabeen Group formations, of which the main units are the Bald Hill Claystone (BHCS), which is considered to be a regional aquitard of approximately 10 m thick (varying from approximately 2-30m across the Tahmoor Mine lease), and the Bulgo Sandstone (BGSS) which is a thick (140-220 m) sandstone/siltstone sequence with minor aquifer potential.

The Bulli (BUCO) and Wongawilli Coal (WWCO) seams are the main deposits of economic significance in this region. As summarised in Table 3-1, these coal seams belong the Sydney Subgroup of the Permian-aged Illawarra Coal Measures (ICM) (UOW, 2012). The Bulli Coal Seam is the youngest coal seam of the ICM and is approximately 2-4 m thick. This is the seam targeted by Tahmoor Coal and the neighbouring Appin Mine.

Figure 3-6 and Figure 3-7 show regional south-north and west-east cross-sections respectively.

Table 3-1 Regional Stratigraphy

Period	Stratigraphic Unit		Description
Quaternary	Alluvium and colluvium and other sediments in floodplains, alluvial fans, and high terraces (Qal, Tal, Qs)		Alluvial and residual deposits comprising quartz and lithic fluvial sand, silt and clay.
Triassic	Wianamatta Group	Camden Sub-group	Shale with sporadic thin lithic sandstone.
		Liverpool Sub-group: Bringelly Shale (Rwb), Minchinbury Sandstone and Ashfield Shale (Rwa)	Dark green and black shales with thin graywacke-type sandstone lenses. Calcareous graywacke-type sandstone and black mudstones and silty shales with sideritic mudstone bands.
	Hawkesbury Sandstone (Rh)		Consists of thickly bedded or massive quartzose sandstone (with grey shale lenses up to several metres thick).
	Narrabeen Group	Newport Formation	Interbedded grey shales and sandstones
		Garie Formation	Cream to brown, massive, characteristically oolitic claystone
		Bald Hill Claystone	Brownish-red coloured “chocolate shale”, a lithologically stable unit
		Bulgo Sandstone	Strong, thickly bedded, medium to coarse-grained lithic sandstone with occasional beds of conglomerate or shale
		Stanwell Park Claystone	Greenish-grey mudstones and sandstones
		Scarborough Sandstone	Mainly of thickly bedded sandstone with shale and sandy shale lenses up to several metres thick
		Wombarra Claystone	Similar properties to the Stanwell Park Claystone
		Coal Cliff Sandstone	Basal shales and mudstones that are contiguous with the underlying Bulli Coal seam. Absent in much of the Tahmoor area.
Permian	Illawarra Coal Measures		Interbedded shales, mudstones, lithic sandstones and coals, including the:
			Bulli Coal seam (2-4 m thick);
			Eckersley Formation, including the Balgownie Seam (5-10 m below Bulli Seam), Loddon Sandstone and Lawrence Sandstone.
			Wongawilli Coal seam (8-10 m thick).
			Kembla Sandstone
	Shoalhaven Group		



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Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:68,000 at A4
Project Number:	610.30637
Date:	22-Apr-2022
Drawn by:	JG

- Faults (locally mapped)
- Southern CF Structure
- Southern CF Fold
- Local Geological model Extent

Nepean Fault Complex (SCT, 2020)

- Offset, Estimated
- Surface Trace

- Cross Section
- Tahmoor Coal Titles
- Alluvium
- Wianamatta Formation
- Hawkesbury Sandstone

Tahmoor South Mine Plan

- Approved

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Outcropping Geology and Structural Features at Tahmoor

FIGURE 3-5

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30637.00000 Tahmoor Coal Extraction Plan LW101A LW06 SLR Data\01 CADGIS\GIS\61030652 Fig3_4 Geological Outcrop.mxd

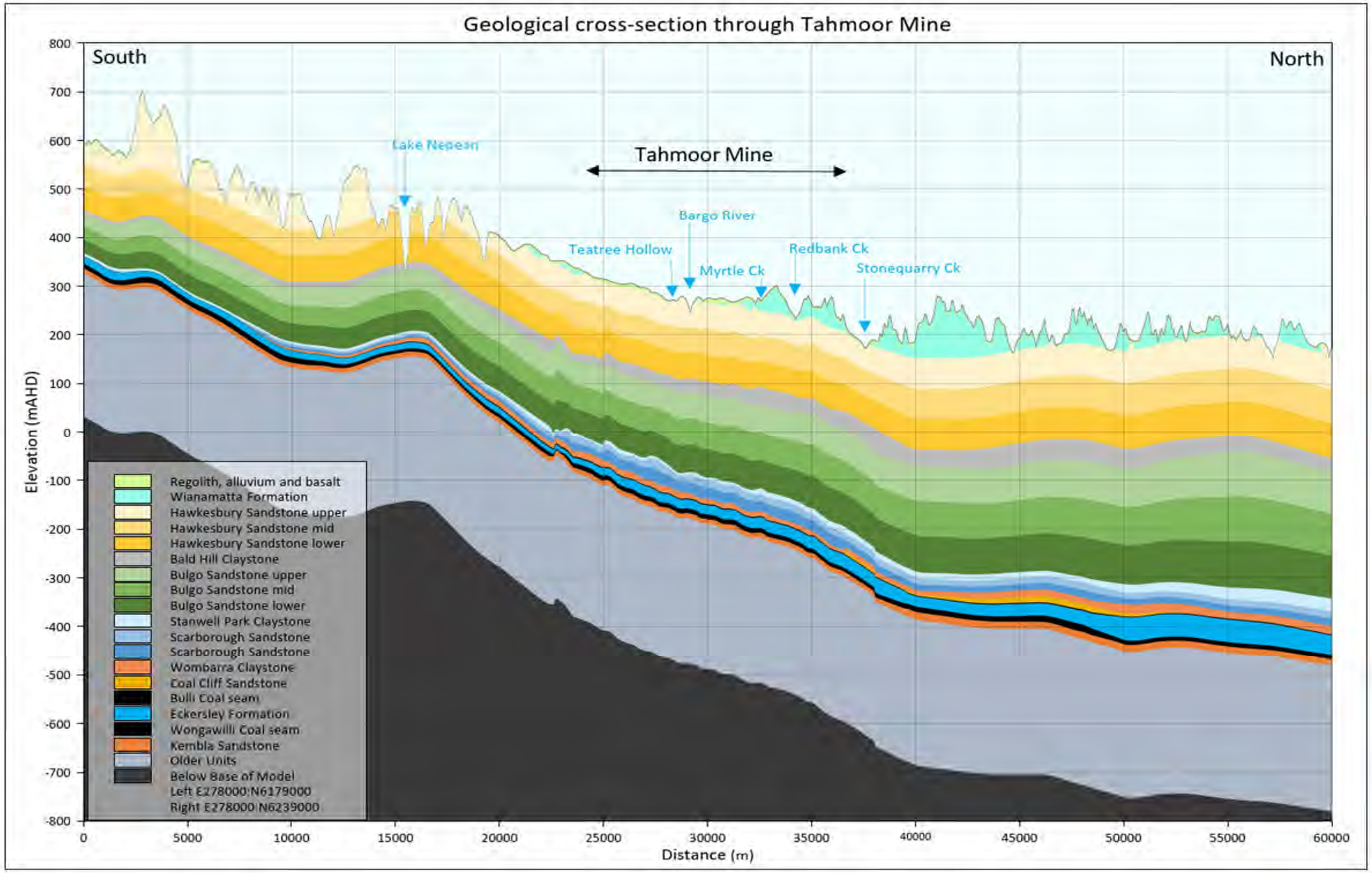


Figure 3-6 Geological Cross-Section: South to North

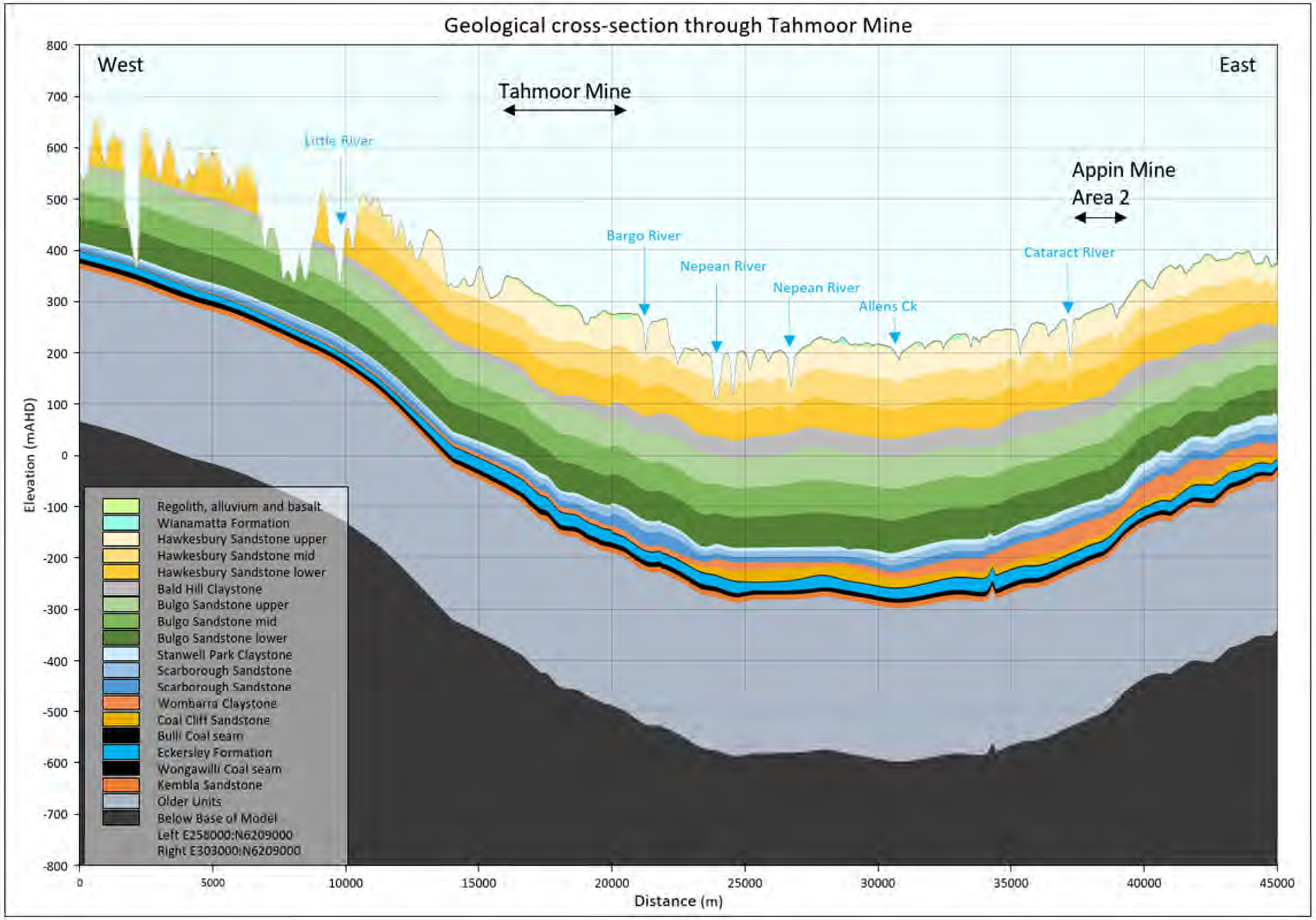


Figure 3-7 Geological Cross Section: West to East

3.4.2 Regional Structural Geology

As shown on Figure 3-5 the region is dissected by several faults, folds, and dykes of volcanic origin, varying in age from Jurassic to Tertiary. This figure presents the results of structural mapping carried out by Tahmoor Coal over the mine footprint.

The major structural feature of interest to Tahmoor Mine is the Nepean Fault. As noted in Tahmoor Coal (2019), "The Nepean Fault encountered at Tahmoor Mine is part of the regional Nepean Fault system. This system is the southern extension of the Lapstone Monocline, and at Tahmoor, it consists of closely spaced sub-vertical *en-echelon* faults in a zone up to 400 m wide." Mapping confirms that this fault extends 10 km along the eastern edge of the Tahmoor mine footprint, and extends still further north and south beyond the Tahmoor area (e.g. northward as part of the Lapstone Monocline).

This significant high angle structural feature is known to be transmissive and mine workings that intersect this zone can produce more water than areas that are located away from this zone. Tahmoor Coal (2019) described this as follows "The Nepean Fault zone is the only hydraulically charged geological structure encountered during mining to date".

Increases in inflow have been observed in mine workings as a result of intersection or proximity of the Nepean Fault zone, noting that previous workings at Tahmoor Mine have intersected or approached to within approximately 100 m of the secondary splays (typically oriented northwest-southeast), such as at Longwalls 31 and 32 in the north of the Tahmoor mining area. However, the main north-south trending faults have not been intersected by previous workings, and the closest approach by longwalls was at Longwall 32 (approximately 340 m west) and at Longwall 13 (approximately 480 m west) of such major faults. Available mapping of this structure indicates that it is 1.5 km east of LW S1A at its closest point, and further from the other "A" longwalls (LW S2A-S6A). This structural feature is closer to longwalls of the future "B" longwalls (LW S1B-S6B).

The 'T1' and 'T2' faults which are present at the western edge of the previously extracted Tahmoor longwalls between the mine and the Thirlmere Lakes. These faults lie essentially 900 m to the north of (and would not be intersected by) the Tahmoor South longwalls.

Other structural features of note include:

- The Camden Syncline, which plunges from south to north, is located approximately 3.3 km east of the eastern-most Tahmoor South longwall panels, and approximately coincident with the Nepean River at this point. At its nearest, this feature is approximately 3.3 km from LW S1A-S6A.
- Bargo Fault, heading predominantly west, which diverges from the Nepean Fault and crosses the mined area of Tahmoor North. At its nearest, this feature is approximately 1.5 km from LW S1A-S6A.
- The Central and Western Faults, which trends NW-SE, just outside the proposed southern limit of the Tahmoor South longwalls. The alignment of the Central Fault is essentially congruent with the course of Hornes Creek, suggesting that the creek might exist at this location due to the influence of this structural feature. At its nearest, the Central Fault is approximately 360 m from LW S6A, whilst the Western Fault is 3.1 km.
- Victoria Park Fault, located west of the Tahmoor North longwalls 26-31.
- Other smaller faults mapped within the extent of the historical Tahmoor workings

Dyke and sill intrusions identified from surface mapping and drilling records, include a large sill at the southern edge of the Tahmoor South domain. Tahmoor South geologists have conducted underground inseam drilling (UIS) within the Bulli Coal seam through the entire block of LW S1A, and drilling has commenced in LW S2A and LW S3A. No significant structural features have been identified. The main feature identified has been a small dyke, detailed as (J. Reid, personal communication, 26th April 2022):

- Indicative thickness (inseam drilling intersection) – 1m up to <6m
- Indicative length (inseam drilling intersection) – approx. 900m (System of potential sills and dyke)
- Dyke was soft and fullseam height
- Minimal water was reported when cutting through it

3.4.2.1 Structural Geology of the Thirlmere Lakes area

The conceptual geological model for the lakes (Section 3.3.4) environment involves a late Cretaceous to early Tertiary alluvium (clayey quartz sand) overlying Triassic Hawkesbury Sandstone (quartz sandstone having a clay matrix and sideritic cement). Beneath the Hawkesbury Sandstone the geology continues to be representative of the regional southern Sydney Basin.

Groundwater flow at shallow depths, up to approximately 200 metres below ground surface (mBGL) is suggested to be dominated by flow through fractures, while at greater depths groundwater flow is controlled mainly by the porosity of the rock matrix (Commonwealth of Australia, 2014). The Bald Hill Claystone was previously considered to be a significant low permeability formation separating Hawkesbury Sandstone from the deeper groundwater systems. The matrix permeability of the Bald Hill Claystone was suggested to be significantly lower when compared to hydraulic conductivities measured for sandstone formations. However, field packer test results indicate that the hydraulic conductivity of the Bald Hill Claystone can be quite similar to other strata (Reid, 1996; Pells & Pells, 2011) and research associated with the Thirlmere Lakes Research Program is now challenging previous theories regarding the nature and aquitard properties of the Bald Hill Claystone (DPE, 2022).

Only two structures, the Eastern and Western Fault Propagation folds (FPFs), were identified by TLRP that had demonstrable displacement and which could be classified as faults. Several other lineaments exist within the region that could not be given a more distinct classification with the available evidence. These lineaments may be either volcanic intrusions or small displacement faults, fault propagation folds, fault propagated joint swarms (see Och et al., 2009) or transfer features (DPE, 2022). The identified fracture patterns surrounding the FPFs effectively provide a much wider fault damage zone (100s rather than 10s of metres) when compared to traditional fault geometries.

Processes such as longwall mining would require a larger setback distance (i.e. wider buffer zone) to avoid the fault generated damage zone intersecting with the angle of draw that defines that area of ground movement above or adjacent to a longwall panel. In the case of Thirlmere Lakes, the Eastern FPF and the completed Tahmoor longwall panels, such a distance exists, and the identified FPFs were considered unlikely to have been directly affected by the mining.

It was hypothesised that the identified fracture patterns for the FPF zones, the Eastern and Western FPF fracture networks, are interconnected at the point of intersection between these two structures. It was therefore considered possible that any groundwater impacts experienced by the Western FPF could be transmitted along the Eastern FPF from the point of intersection between these two structures. As such, any significant groundwater abstraction along strike of the Eastern or Western FPFs (e.g. directly or indirectly related to mine dewatering or production bores) may influence the groundwater in the Hawkesbury Sandstone under the lake system through these highly transmissive, naturally produced fracture networks.

3.5 Groundwater

This section provides a summary of the hydrogeological units and groundwater use (environmental and anthropogenic) as it pertains to Tahmoor South.

3.5.1 Hydrogeological Units

The major hydrostratigraphic units that characterise the area around Tahmoor Mine are the Sydney Basin Triassic and Permian rock units, with the Hawkesbury Sandstone being the primary aquifer. These aquifers fall within the *Sydney Basin Nepean Sandstone Groundwater Source* and have been classified as being 'Highly Productive' by the NSW Government based on considerations of bore yield and groundwater quality. The Bulgo Sandstone and Illawarra Coal Measures of the Triassic Narrabeen Group supply additional water to this system; however, contributions are substantially lower. The extent of surficial geological units around Tahmoor Mine are presented on Figure 3-5. Geological cross sections have been prepared across the Tahmoor Mine area and are presented in Figure 3-6 and Figure 3-7, with the alignment of the sections shown on Figure 1-1.

Generally, there is limited extent of surficial alluvium in this region, with no notable occurrences in the vicinity of Tahmoor South LW S1A-S6A. Regionally, small areas of alluvium exist along Stonequarry Creek (located north of mining operations) and near Blue Gum Creek and Thirlmere Lakes (located west of the mine) (Figure 3-5). The shales of the Triassic Wianamatta Group are more extensive, especially to the north of Tahmoor Mine, but have limited potential as aquifers and very limited occurrence above or near LW S1A-S6A. A description of pertinent hydrogeological units is provided below.

3.5.1.1 Thirlmere Lakes Alluvium

The *Thirlmere Lakes Research Program* aimed to provide a detailed understanding of the hydrological dynamics, water sources and water flow pathways. The summation report, "Thirlmere Lakes – A Synthesis of Current Research" was released in late March 2022, by DPE.

The TLRP report (DPE, 2022) and associated specialist technical reports describe the general stratigraphy of the lakes system:

- The upper ~15 m across all surveyed lakes and sills is represented by unconsolidated alluvial/colluvial sediments.
- The upper 2–3 m of the sills are typically unsaturated sand, which generally overlay clay.
- Across the lakes, the upper 4–5 m horizon comprised saturated clay.
- In the areas to the north and east of the lakes system along the Boundary and Slades Road, the shallow dipping layers were observed to a depth of 5–6 m with a very gentle dip gradient to the south-west and north-east, typical of the Hawkesbury Sandstone constraining sediment depths (DPE, 2022).

The lake sediments are comprised of an upper peat sequence that has started to accumulate over the last 12,000 years. These organic-rich sediments represent the modern Thirlmere Lakes and this unit varies in thickness from up to 5 m in Lake Baraba to an average of ~2–3 m in the other lakes. This lithostratigraphic member has very low bulk density (0.174 ± 0.103 grams/cubic centimetre) and very high moisture content (83 ± 9%) and total organic carbon (TOC) contents of up to 40%.

This Holocene peat unit grades into a distinct oxidised silty clay that underlies all lakes. This unit represents a distinctive marker horizon in the lake sediment formation but also varies in thickness across and within any given lake. This unit has been dated in two lakes (Couridjah and Werri Berri) to be 21,000 to 12,000 years (the last glacial maximum [LGM] and the deglacial) and represents a massive hydrological change where Thirlmere Lakes dried and the lake sediments were sub-aerially exposed. This unit signifies catastrophic drying at Thirlmere Lakes and it also currently acts as a local aquitard based on the obvious saturated zone of sediment immediately overlying it.

At its closest point, the Thirlmere Lakes alluvium is mapped as being approximately 300 m west of Tahmoor Mine (Longwall 17, near Lake Couridjah) and approximately 3,500 m from LW S1A-S6A.

3.5.1.2 Wianamatta Group (WMFM)

The WMFM is composed of the Liverpool Subgroup which includes the Bringelly Shale Formation, Minchinbury Sandstone and Ashfield Shale Formations. Around the mine, the Wianamatta Group are present as hill cappings overlying the Hawkesbury Sandstone, particularly in the northern region of the Tahmoor Coal leases (Figure 3-6 and Figure 3-7). The formation predominantly comprises shales having poor permeability and water quality, and therefore is not considered a major groundwater resource in the area. The shales however, can lead to the development of springs in areas near the contact with the HBSS.

3.5.1.3 Hawkesbury Sandstone (HBSS)

The HBSS dominates the outcrop area around Tahmoor Mine, and is present beneath the WMFM and alluvium, except for where it may have been eroded away along valleys to expose the underlying Narrabeen Group (HydroSimulations, 2018) (Figure 3-5).

The unit is indicated to be greater than 150 m thick in the north of the mine, where recently drilled investigation bores show it to be up to 170 m thick (i.e. WD01; SCT, 2020). Above Tahmoor South, recent drilling shows thickness of 165 m (i.e. TSC01; SCT, 2020), as shown on Figure 3-6 and Figure 3-7.

The HBSS is a porous rock aquifer of moderate resource potential. In areas where secondary porosity has developed, such as in structural zones like the Nepean Fault zone, higher resource potential can be achieved.

3.5.1.4 Narrabeen Group

The Narrabeen Group is present across the Tahmoor Mine site beneath the HBSS. The unit consists of a sequence of interbedded sandstone, claystone, and siltstone. The main hydrostratigraphic units include the Bulgo Sandstone and Scarborough Sandstone, which have minor aquifer potential, and the BHCS, Stanwell Park Claystone and Wombarra Claystone which are considered aquitards. These units are shown, in stratigraphic order, in Figure 3-6 and Figure 3-7. Recent investigations into the structural integrity of the BHCS were conducted as part of the current Thirlmere Lakes enquiry. Findings from this investigation suggest that the BHCS is a poor aquitard that is likely to become leaky, or cease acting as an aquitard when fractured (either naturally or anthropogenically (UNSW, 2021; DPE, 2022). Recent drilling investigations completed as part of these studies (GW049046 and GW099003 nearer Dendrobium Mine and to the east of Tahmoor South), show the BHCS to have a thickness of around 6 m.

3.5.1.5 Illawarra Coal Measures

The Illawarra Coal Measures are present across Tahmoor beneath the Narrabeen Group. The formation contains the units of primary economic interest in the Sydney Basin, and consist of interbedded sandstones, shale and coal seams with a total thickness of approximately 200 m to 300 m.

The two main coal seams mined in the Southern Coalfield are the uppermost Bulli Coal seam and the Wongawilli Coal seam (Holla and Barclay, 2000). The coal seams outcrop to the east of Tahmoor Mine, where coal seams are truncated (eroded) along the Illawarra Escarpment, as well as being likely to outcrop approximately 20 km to the west of Tahmoor Mine along the Nattai River valley.

The thickness of the Bulli Coal seam is shown on Figure 3-6 and Figure 3-7. The Bulli seam is separated by approximately 8-38 m from the older Wongawilli Seam by the Eckersley Formation. The Wongawilli Seam is approximately 8-10 m thick around Tahmoor Mine (Figure 3-6 and Figure 3-7).

The Illawarra Coal Measures are not targeted for groundwater use as the water quality is poor (HydroSimulations, 2020). Publicly available data from AGL's Camden Gas Project indicated an average TDS of around 11,000 mg/L and a range of 3,200-27,500 mg/L (Parsons Brinckerhoff, 2013).

3.5.2 Hydraulic Properties

The following sub-sections describe pre-mining hydraulic properties (hydraulic conductivity and storage) for the geological units relevant to Tahmoor Mine. Subsidence due to longwall extraction can cause changes to both these properties. The changes to these are described, with some quantification, in Section 3.5.7.

3.5.2.1 Hydraulic Conductivity (K)

Geological formations are not homogenous in nature, and in this sedimentary environment are generally made up of layers of alternating sediments. This means that analysis of available permeability of hydraulic conductivity testing must take account of the influence of the different units and lithologies on horizontal and vertical flow.

Available data for hydraulic conductivities for the main lithological units relevant to Tahmoor are presented on Figure 3-8 and Figure 3-9, and summarised and tabulated in Table 3-2. Data has been sourced from packer testing with some available from core testing, conducted at Tahmoor, Appin and Dendrobium Mines. Packer testing primarily tests horizontal hydraulic conductivity (Kh), but can also be useful in characterising the likely vertical hydraulic conductivity (Kv) in sedimentary units
Data indicated that there is large range of values among formations, however it should be noted that there is limited core testing data (Kv), particularly outside of the Hawkesbury Sandstone (HBSS). Because of this, we have also added the harmonic mean from the packer testing as an estimate of 'representative' Kv to Table 3-2. Figure 3-8 shows that there is generally not a huge contrast between mean Kh for units termed as claystone and sandstone. The large range of observed Kh values are likely due to testing of more clay/sand rich layers. Figure 3-9 shows that these units termed claystone generally have lower Kv, however these units are on average less than 10 m thick and more difficult to characterise.

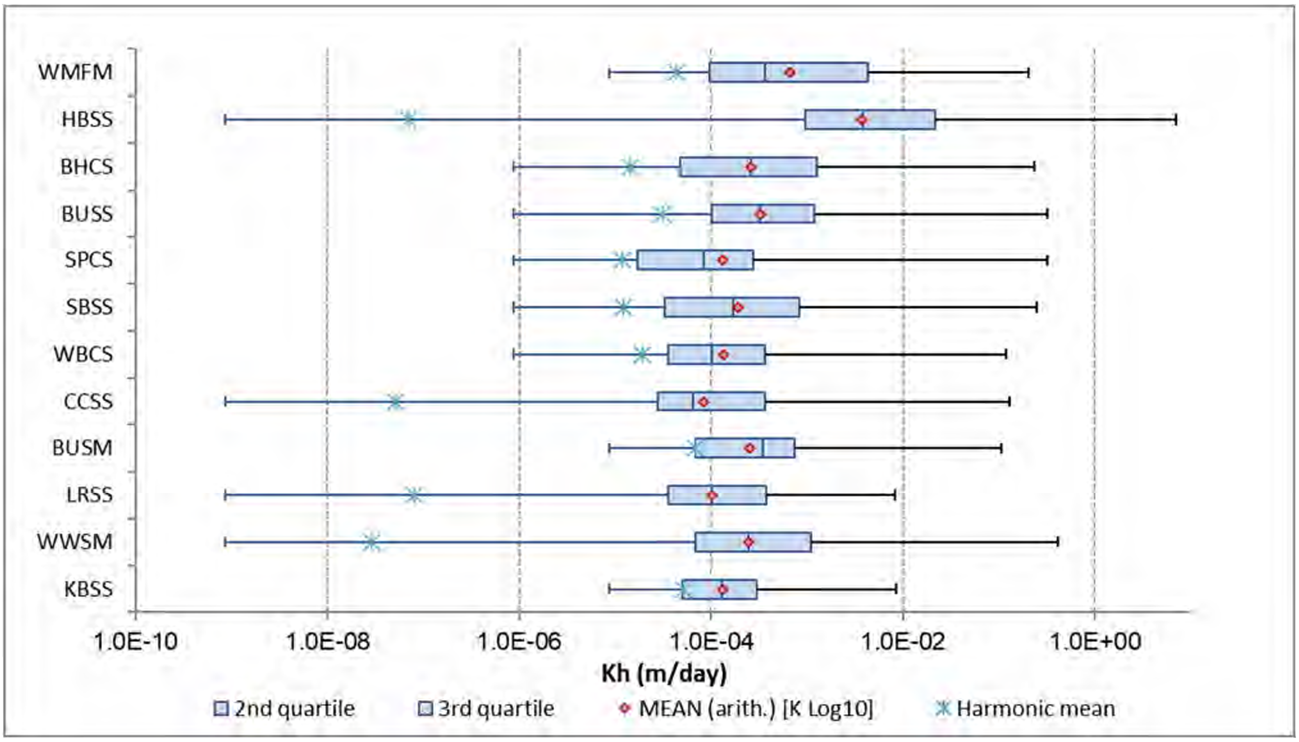


Figure 3-8 Box and whisker plot of horizontal hydraulic conductivity for each formation

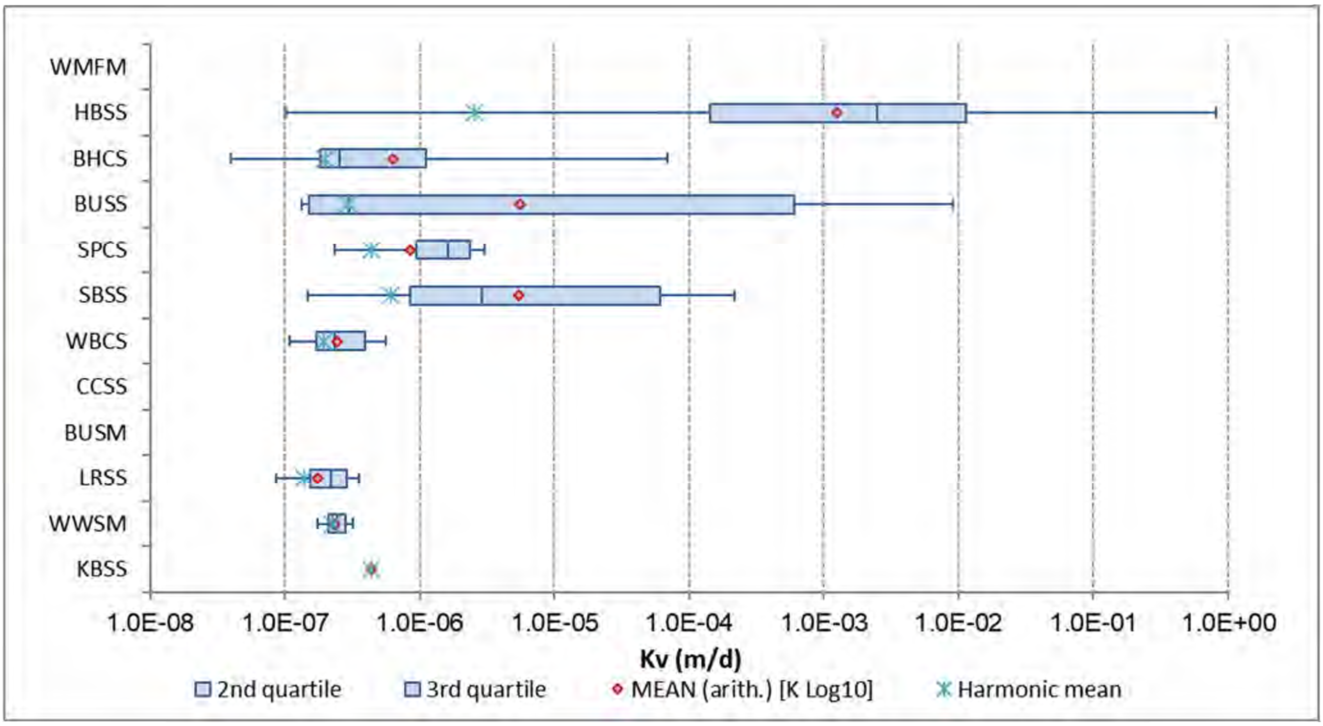


Figure 3-9 Box and whisker plot of vertical hydraulic conductivity for each formation

Table 3-2 Hydraulic conductivity data summary

Unit	Horizontal, Kh (m/d)				Vertical, Kv (m/d)				
	Packer, Arithmetic mean	Packer, 5th Perc.	Packer, Max	Packer, Population	Packer, Harmonic mean	Core testing, Arithmetic	Core, Min	Core, Max	Core, Population
WMFM	6.70E-04	8.64E-06	2.03E-01	18	4.44E-05	na	na	na	0
HBSS	3.73E-03	7.99E-05	7.07E+00	820	7.08E-08	1.25E-03	1.01E-07	0.817849	40
BHCS	2.64E-04	5.12E-06	2.33E-01	164	1.44E-05	6.34E-07	3.94E-08	6.85E-05	20
BUSS	3.30E-04	8.64E-06	3.20E-01	657	3.08E-05	5.54E-06	1.34E-07	0.00905	13
SPCS	1.34E-04	8.64E-06	3.20E-01	44	1.20E-05	8.42E-07	2.33E-07	3.04E-06	2
SBSS	1.90E-04	3.57E-06	2.51E-01	118	1.23E-05	5.47E-06	1.48E-07	0.000219	5
WBCS	1.36E-04	6.45E-06	1.21E-01	93	1.94E-05	2.41E-07	1.07E-07	5.57E-07	3
CCSS	8.40E-05	2.78E-06	1.30E-01	59	5.08E-08	na	na	na	0
BUSM	2.57E-04	1.26E-05	1.06E-01	52	6.83E-05	na	na	na	0
LRSS	1.02E-04	8.59E-06	8.29E-03	95	8.18E-08	1.74E-07	8.64E-08	3.51E-07	2
WWSM	2.48E-04	8.93E-06	4.15E-01	68	2.94E-08	2.34E-07	1.73E-07	3.17E-07	2
KBSS	1.33E-04	1.40E-05	8.55E-03	34	5.15E-05	4.34E-07	4.34E-07	4.34E-07	1

Arithmetic mean is best for describing 'average' Kh, noting that given the range in K over several orders of magnitude, average Log10 K is reported.
Harmonic mean is best for estimating 'representative Kv (Domenico and Schwartz, 1998).

Hydraulic conductivity versus depth is presented in Figure 3-10 (horizontal) and Figure 3-11 (vertical). Both figures demonstrate that there is an overall decreasing trend of hydraulic conductivity with depth. Figure 3-10 shows that Kh decreases with depth both overall (pre- and post-mining) and for each formation. Figure 3-11 shows that Kv decreases with depth overall, however there is insufficient data to assess this trend for formations other than the Hawkesbury Sandstone and Bald Hill Claystone. Decreasing hydraulic conductivity with depth is expected due to overburden pressure reducing secondary porosity (essentially fracture or defect aperture) via compression.

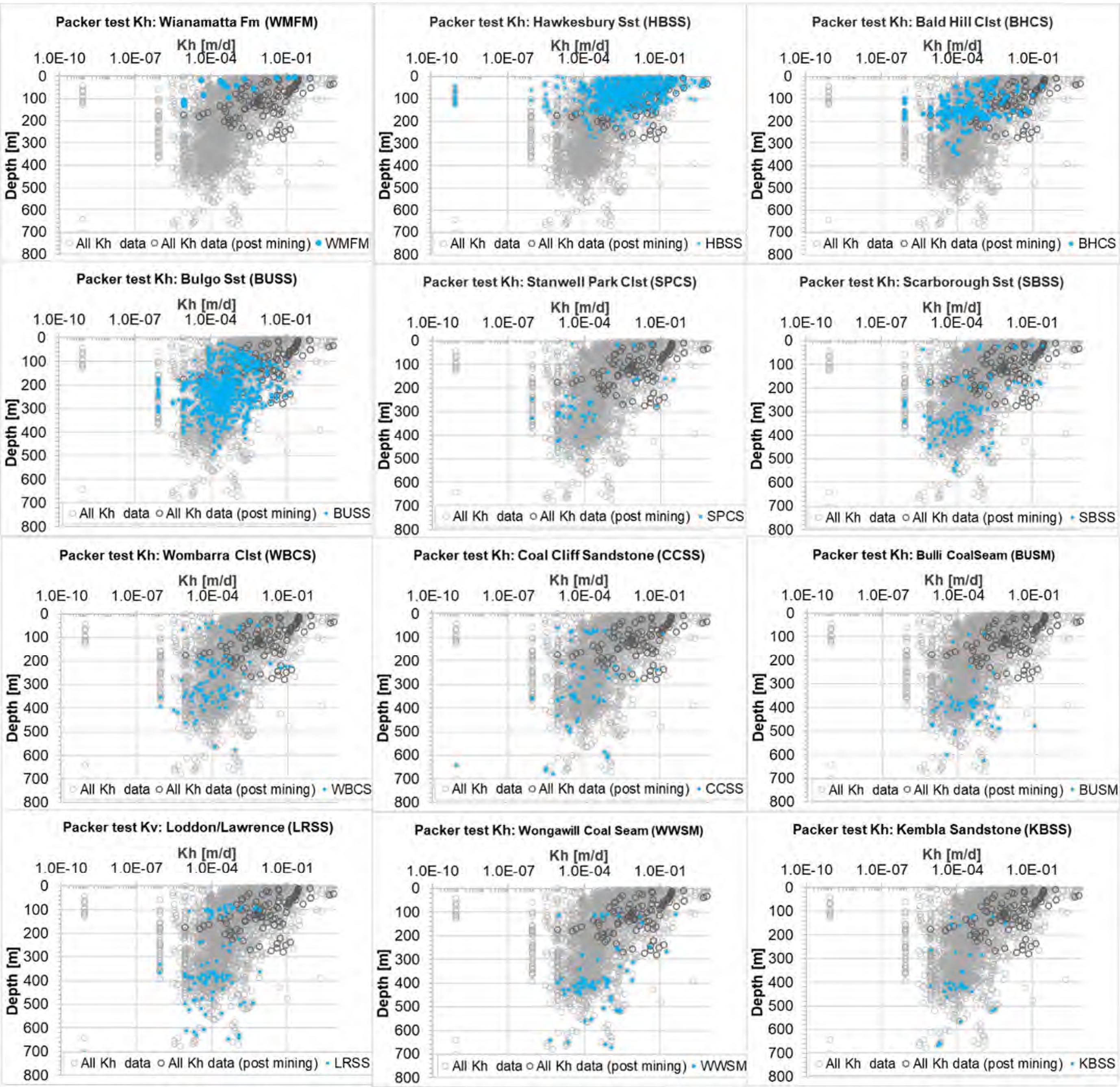


Figure 3-10 Horizontal hydraulic conductivity vs depth

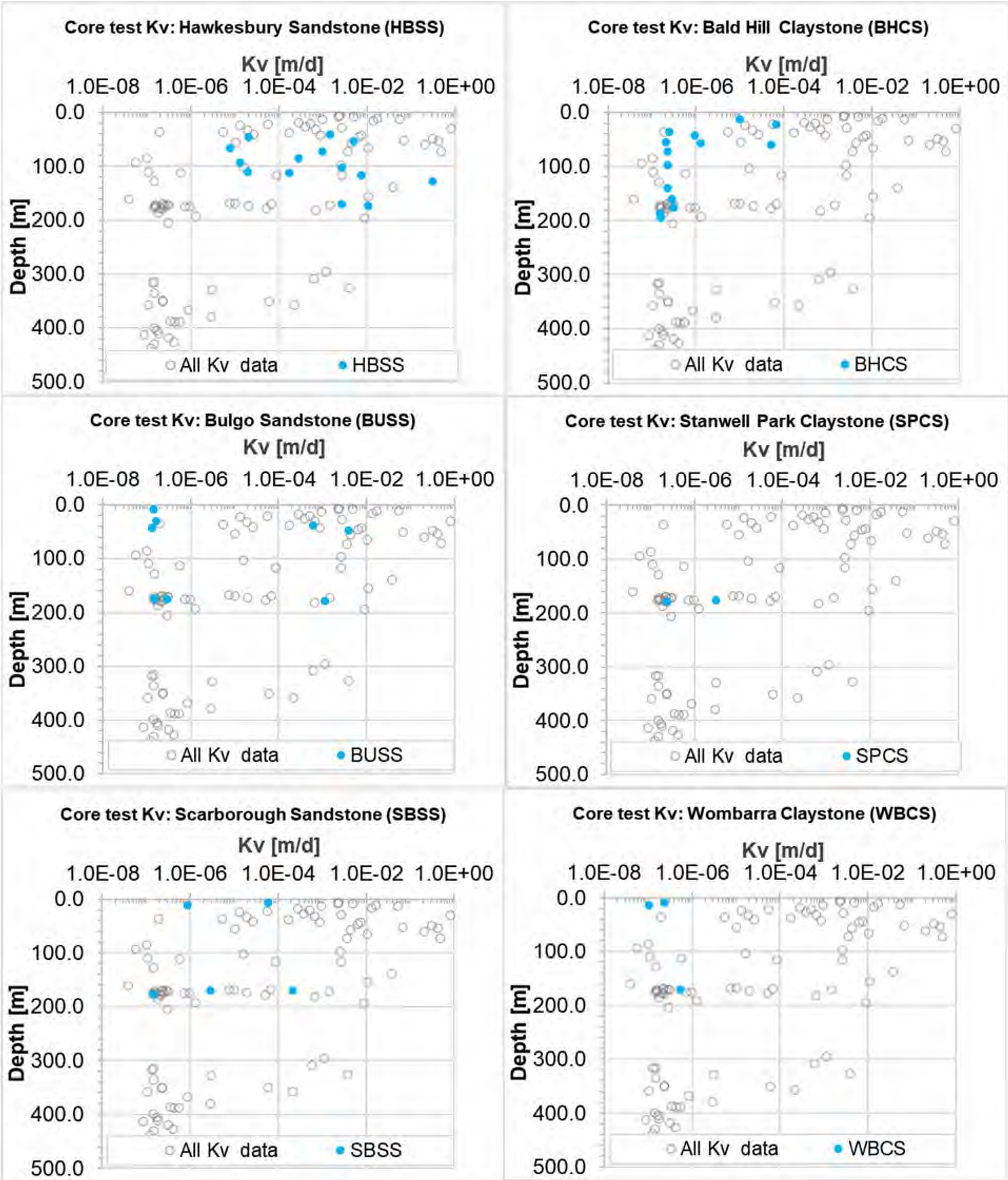


Figure 3-11 Vertical hydraulic conductivity vs depth

3.5.3 Storage Parameters

There is currently no field data concerning aquifer storage properties at Tahmoor Mine for specific yield (Sy) or specific storage (Ss), although these is some core testing of porosity. Groundwater specific storage varies by orders of magnitude, is difficult to quantify, and prone to significant uncertainty (Rau et al, 2018).

3.5.3.1 Storage Properties

HydroSimulations (2020) reports that there are three measurements of total porosity (n) (which would be the highest possible specific yield) available from core tests at bore TBC037 including:

- Two measurements from the HBSS, where n = 5.3% and 11%.
- One measurement from the BHCS, where n = 4%.

Data collected elsewhere in the Sydney Basin provides a Sy estimate of between 1 and 2% for the HBSS (Tammetta and Hewitt, 2004), appearing to confirm that Sy is lower than the total n stated above. Storage properties are expected to decrease depth due to a reduction in porosity from overburden pressure, as well as being influenced by strata lithology.

Alluvium is expected to possess a specific yield in the range of 0.03 to 0.2, i.e. 3-20% (HydroSimulations, 2020).

There is no site specific data available from Tahmoor mine to estimate specific storage. Pumping test data collected within the Sydney Basin, for intervals between ground surface and 300 m depth provide a specific storage estimate of $1.5E^{-6}$ m^{-1} (Commonwealth of Australia, 2014).

Useful estimates of specific storage can also be made based on Young's Modulus and porosity, based on calculations in Mackie (2009). Calculations for this site suggest that for coal, Ss generally lies in the range $5E^{-6}$ m^{-1} to 5E-5 m^{-1}, and interburden from $1.7E^{-6}$ (unfractured, fresh rock) to $8E^{-6}$ (fractured rock). These values are consistent with the appropriate range of Ss stated by Rau et al (2018).

Modelled storage properties from the most recent model at Tahmoor (HydroSimulations, 2020) are shown in Table 3-3.

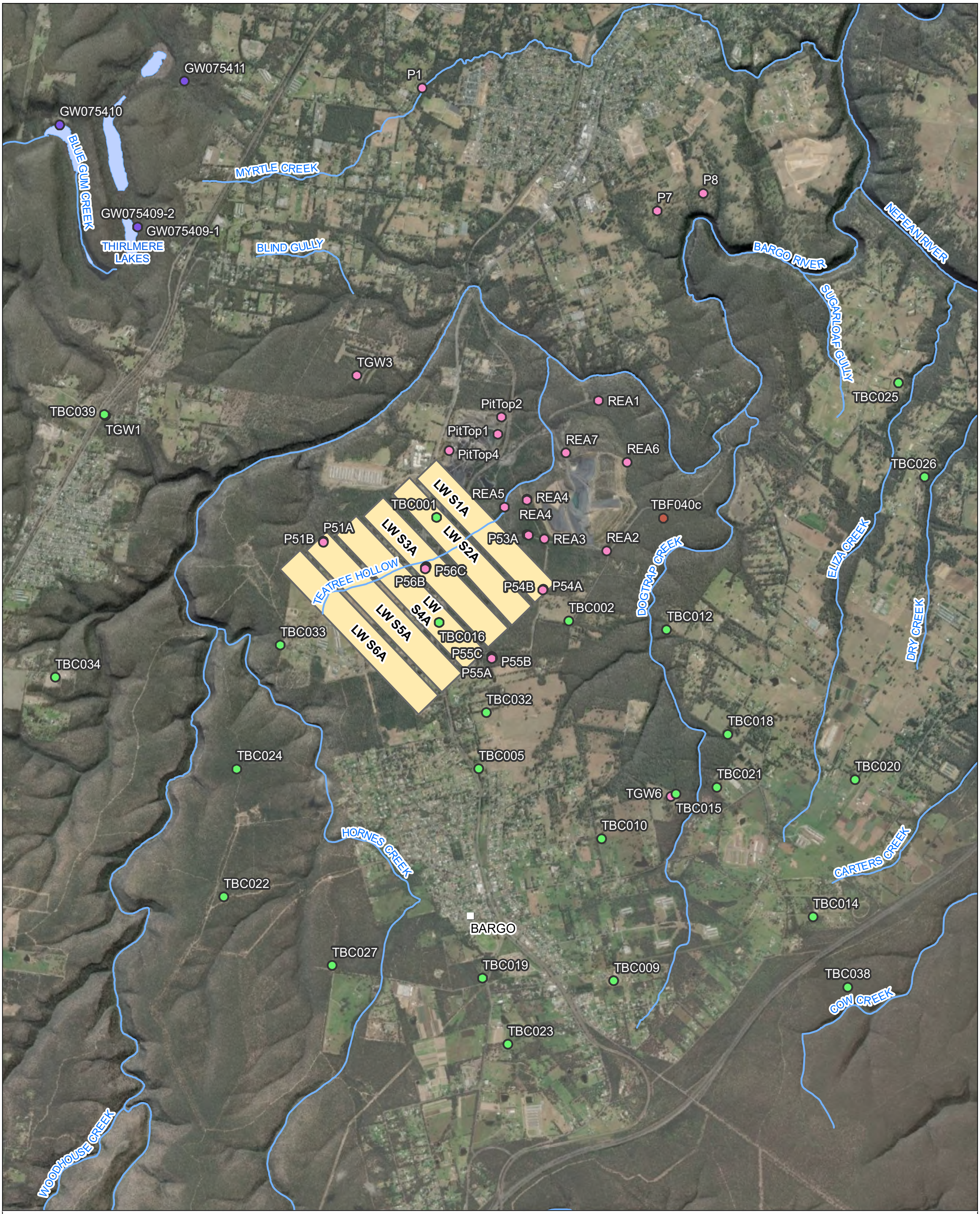
Table 3-3 Modelled storage properties (HydroSimulations, 2020)

Unit	Ss [m-1]	Sy
Alluvium	1.03E-04	1.14E-01
Alluvium – clay rich	1.03E-04	3.00E-02
Basalt	1.19E-05	2.00E-02
Wianamatta Formation	1.02E-06	1.06E-02
Hawkesbury Sandstone - upper	6.00E-06	1.60E-02
Hawkesbury Sandstone - mid	6.00E-06	1.10E-02
Hawkesbury Sandstone - lower	6.00E-06	1.10E-02
Bald Hill Claystone	6.00E-06	7.00E-03
Bulgo Sandstone - upper	6.00E-06	1.00E-02
Bulgo Sandstone - lower	7.00E-06	1.00E-02
Stanwell Park Claystone	6.00E-06	2.50E-03

Unit	Ss [m-1]	Sy
Scarborough Sandstone - upper	2.50E-06	6.00E-03
Scarborough Sandstone - lower	4.50E-06	7.50E-03
Wombarra Claystone	5.00E-06	2.00E-03
Coal Cliff Sandstone	4.00E-06	6.00E-03
Bulli Coal Seam	7.00E-06	8.00E-03
Loddon, Lawrence Sandstones	2.50E-06	5.00E-03
Wongawilli Seam	4.00E-06	5.00E-03
Kembla Sandstone	2.00E-06	5.00E-03
Lower Permian Coal Measures	1.00E-06	4.00E-03
Shoalhaven Group	3.06E-06	5.00E-03
Igneous intrusion / sill	1.02E-06	5.00E-03

3.5.4 Groundwater Levels

This Section described the current groundwater level observations for bores pertinent to Tahmoor South. Figure 3-12 shows the location of all the monitoring bores associated with LW S1A-S6A. Those with historical data records are discussed here.



N

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:50,000 at A4
Project Number:	610.30637
Date:	27-Jun-2023
Drawn by:	NT

Minor Town

Watercourses

Lakes

Tahmoor South Mine Plan

Approved

Groundwater Monitoring Locations

Centreline HOF bore

Deep GWL

NSW govt monitoring

OSP

TAHMOOR SOUTH LW S1A – S6A GROUNDWATER TECHNICAL REPORT

Monitoring Bore Locations

FIGURE 3-12

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30637.00000 Tahmoor Coal Extraction Plan LW101A LW06 SLR Data\01 CADGIS\GIS\61030637 Fig3_12 Monitoring Bore.mxd

3.5.4.1 Water Level Observations

3.5.4.1.1 Vibrating Wire Piezometers

Hydrographs for the groundwater Reference Sites identified in the Groundwater Monitoring Plan (SLR, 2021) for the Tahmoor South operations are shown on Figure 3-13, Figure 3-14, and Figure 3-15 with their locations displayed on Figure 3-12. Sites TBC024, TBC027, TBC034 and TBC038 are equipped with Vibrating Wire Piezometers and started recording groundwater levels in 2012-13. The depths of each VWP sensor and monitored strata are presented in Table 5-3.

Hydrographs for the other Tahmoor South VWP bores (not the Reference Sites) are provided in Appendix A.

Site TBC024

TBC024 is located 1,700 m south of LWS6A and 440 m east of Bargo River. It has a number of sensors placed in the Hawkesbury Sandstone and Bulgo Sandstone at various depths, as well as one in the Bulli Coal seam (BUCO) and Wongawilli Coal seam (WWCO). It also has one sensor in each of the two claystone units, the Bald Hill Claystone (BHCS) and Wombarra Claystone (WBCS). Groundwater pressure started to be recorded in April 2012 with data made available until January 2021. The uppermost sensor HBSS-95m was removed due to large fluctuation in pressure (Groundwater Exploration Services [GES], 2013) and removed from the dataset following a recent review of the data quality for VWP (GES, 2021). There is uncertainty in the position of the sensor in BHCS-168m as groundwater pressure appear higher than pressure recorded at other sensors from 2012 to 2016 (GES, 2013).

Hydrograph shown on Figure 3-13 presents a consistent decline in groundwater pressure of similar magnitude in all units from 2012 to early 2020. In the HBSS this decline ranges from 3.5-4.5 m in HBSS-117m and HBSS-139m respectively while it ranges from 3-5m in the BGSS (i.e. BGSS-185m, BGSS-240m and BGSS-295m). Minor responses to rainfall recharge is observed in the Hawkesbury Sandstone during the historical period, with responses in groundwater levels ranging from 0.2-0.5m. Groundwater pressure in the Bulli Coal seam and Wongawilli Coal seam followed the same declining trend before the sensors failed in July 2019.

Following the exceptional wetter condition in early 2020, groundwater levels stabilised in all units and increased by approximately 0.5 m in the HBSS and with a more subdued recovery in the BGSS (0.2-0.3 m rise). During late May 2020 – early June 2020, a spike in groundwater levels of approximately 2 m is observed in HBSS-117m, coincident withabove average rainfall.

A downward vertical gradient is observed in the HBSS between HBSS-117m and HBSS-139m with a head difference ranging from 1 m at the start of monitoring to 3 m in January 2021. The increase in head difference over time is due to water levels being more responsive to rainfall recharge in HBSS-117m than in HBSS-139m.

A minor upward vertical head differential from the BGSS to the HBSS is inferred at TBC024 with groundwater pressure in the BGSS being between 1 to 2 m above groundwater pressure in the HBSS. Similar groundwater pressures between the units suggests some degree of aquifer connectivity at site TBC024.

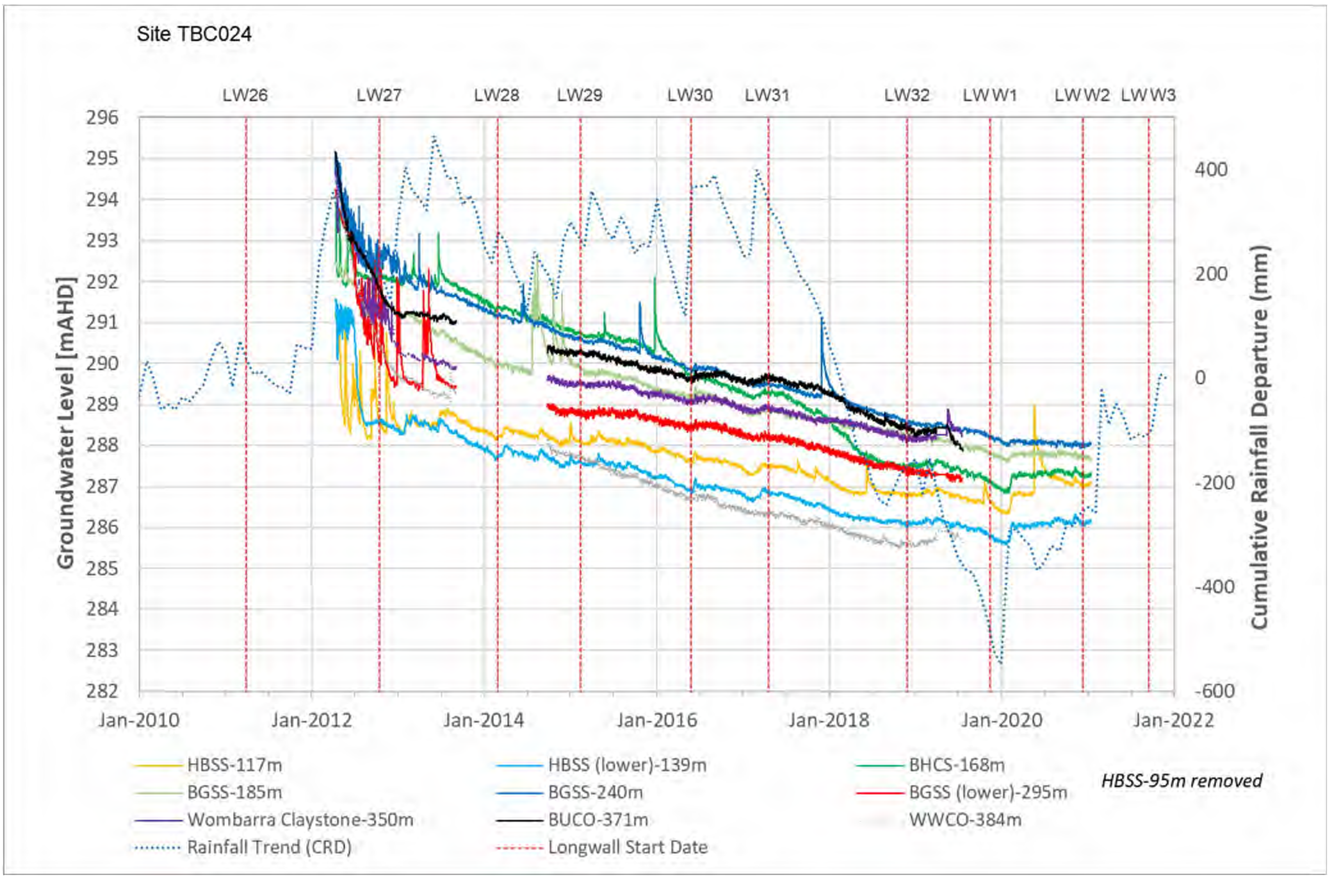


Figure 3-13 Hydrograph for TBC024

Site TBC027

TBC027 is located 2,400 m southwest of LWS6B and 500 m west of Hornes Creek. TBC027 is also located 2,200 m south of TBC024. TBC027 is equipped with three sensors in the HBSS (HBSS-95m, HBSS-132m and HBSS-169m), three sensors in the BGSS (BGSS-181m, BGSS-198m and BGSS-253m), one sensor in the Bald Hill and Wombarra claystones (BHCS-181m and WBCS-362m) as well as sensors in the Bulli Seam and Wongawilli Seam (BUCO-384m and WWCO-396m). Groundwater pressure started to be recorded in April 2013 and all sensors appear to be active as of January 2022. Groundwater levels in the HBSS have been responsive to historic rainfalls in the range of 1-2m, and more recently with the exceptional rainfalls in early 2020 showing a response in water levels of approximately 4-6m.

A head separation of approximately 6-7 m is observed between the upper (HBSS-95m) and the lower HBSS (HBSS-132m and HBSS-169m), with a clear downward vertical gradient.

Groundwater levels in upper Bulgo Sandstone are less responsive to rainfall recharge showing stable groundwater levels since the start of monitoring with water levels in BGSS-198m and BGSS-253m sitting at 308.5 mAHD in January 2022. This suggests limited aquifer connectivity between the HBSS and BGSS.

Groundwater pressures in the deeper strata are stable until mid-2016 before gradually declining by approximately 10-12 m in the lower Bulgo Sandstone and the coal seams. Depressurisation in the deeper units is likely due to regional mining (i.e. Tahmoor / Tahmoor North), although timing of the decline seems odd in the context of the location of mining in 2016-2018. From early 2020, groundwater pressure stabilised and started to recover by approximately 2 m in January 2022.

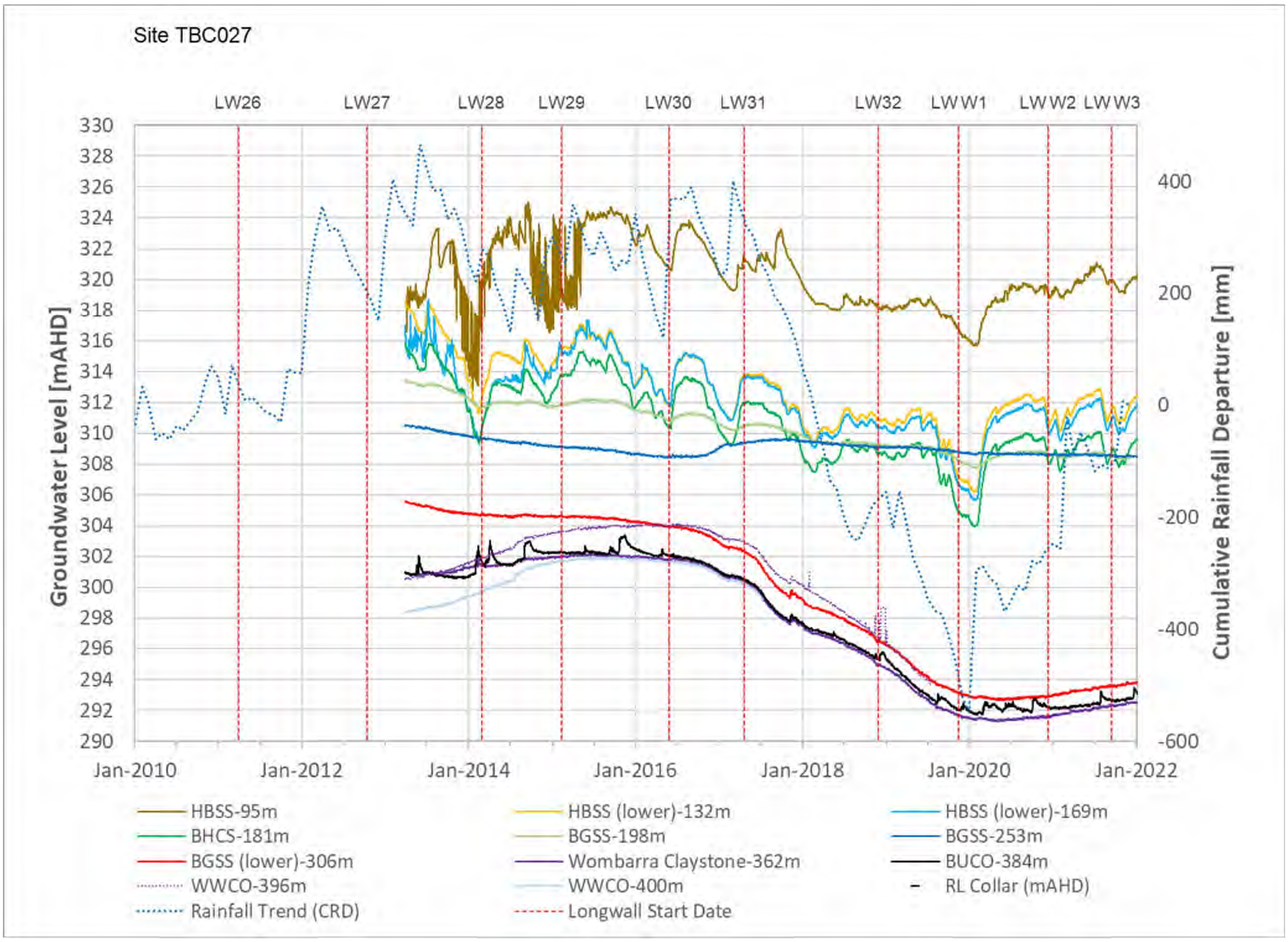


Figure 3-14 Hydrograph for TBC027

Site TBC034

TBC034 is located 2,500 m southwest of LWS6B and 1,500 m west of Bargo River. TBC034 is located to the east of the Western Fault. Similar to TBC027, TBC034 is equipped with three sensors in the Hawkesbury Sandstone (HBSS-65m, HBSS-113m and HBSS-161m), three sensors in the Bulgo Sandstone (BGSS-196m, BGSS-245m and BGSS-294m), one sensor in the Bald Hill (BHCS-176m) as well as sensors in the Bulli Seam and Wongawilli Seam (BUCO-365m and WWCO-382m). All sensors appear to be active and providing reasonable data as of January 2022 (i.e. latest available dataset) except for BGSS-294m which seemed to have failed in May 2021. Also, we note a gap in data for HBSS-113m and HBSS-161m between October 2016 and November 2020.

Figure 3-15 Hydrograph for TBC034

Groundwater levels in the Hawkesbury Sandstone are stable showing minor responses to rainfall recharge and drier periods. E.g. the shallow groundwater levels in HBSS-65 m show a minor decline of approximately 0.3 m during the recent drought (2017-2019 – Section 3.1). Groundwater levels in the Bulgo Sandstone also show limited responses to rainfall.

There is a clear downward vertical gradient observed from the upper to the lower Hawkesbury Sandstone with a consistent head separation of approximately 4 m between HBSS-65 m and HBSS- 113 m and 8 m between HBSS-113 m and HBSS-161 m. There is a smaller head gradient between the upper and mid Bulgo Sandstone, as well as a similar water level elevation as seen in HBSS-161 m. These observations suggest some degree of aquifer connectivity across the upper and mid Bulgo Sandstone and with the lower Hawkesbury Sandstone.

In the Bulgo Sandstone, there is a head separation of 40-45 m between the lowest sensor (BGSS-343.5 m) to BGSS- 294.3m showing evidence of a very strong downward vertical gradient likely to be an influence of the Western Domain fault. In the Bulli Coal and Wongawilli Coal seams a decline in groundwater pressure is observed with levels likely to be equilibrating over 2012-2014 following the installation of the VWPs. A gradual decline in groundwater pressure is observed during the monitoring period of approximately 5 m in the Bulli Seam and up to 7 m in the Wongawilli Seam between 2014 and 2020, before stabilising through 2021.

3.5.4.1.2 Reject Emplacement Area and Pit-top Bores

A series of piezometers at the pit-top and near the Reject Emplacement Area (REA). These are relatively close to the Tahmoor South domain, shown on Figure 3-12. The piezometers are not all associated with the regional aquifers (i.e. Hawkesbury sandstone) but rather some are constructed in shallow sediments and the REA and serve the following purposes:

- Pit Top piezometers (i.e.PT) are utilised to assess if the storage dams are leaking and
- REA piezometers are utilised to assess if there is any Acid Mine Drainage leaching the waste dumps.

Hydrographs for the Pit Top and REA bores are provided in Appendix B. Groundwater levels in PT1 and PT2 are highly responsive to climatic conditions (i.e. dry periods/rainfalls events) since monitoring started in November 2019. During 2020 and 2021, groundwater levels have increased by approximately 2 m at PT1. Short-term increases in water levels at PT2 are observed up to 1.5 m following rainfalls events with water levels sitting in mid-2021 approximately 1 m above the water levels observed at the end of the drought period (i.e late 2019). Groundwater levels at PT4 show less responses to rainfalls with fluctuations in the range of 0.1-0.15 m following rainfall events.

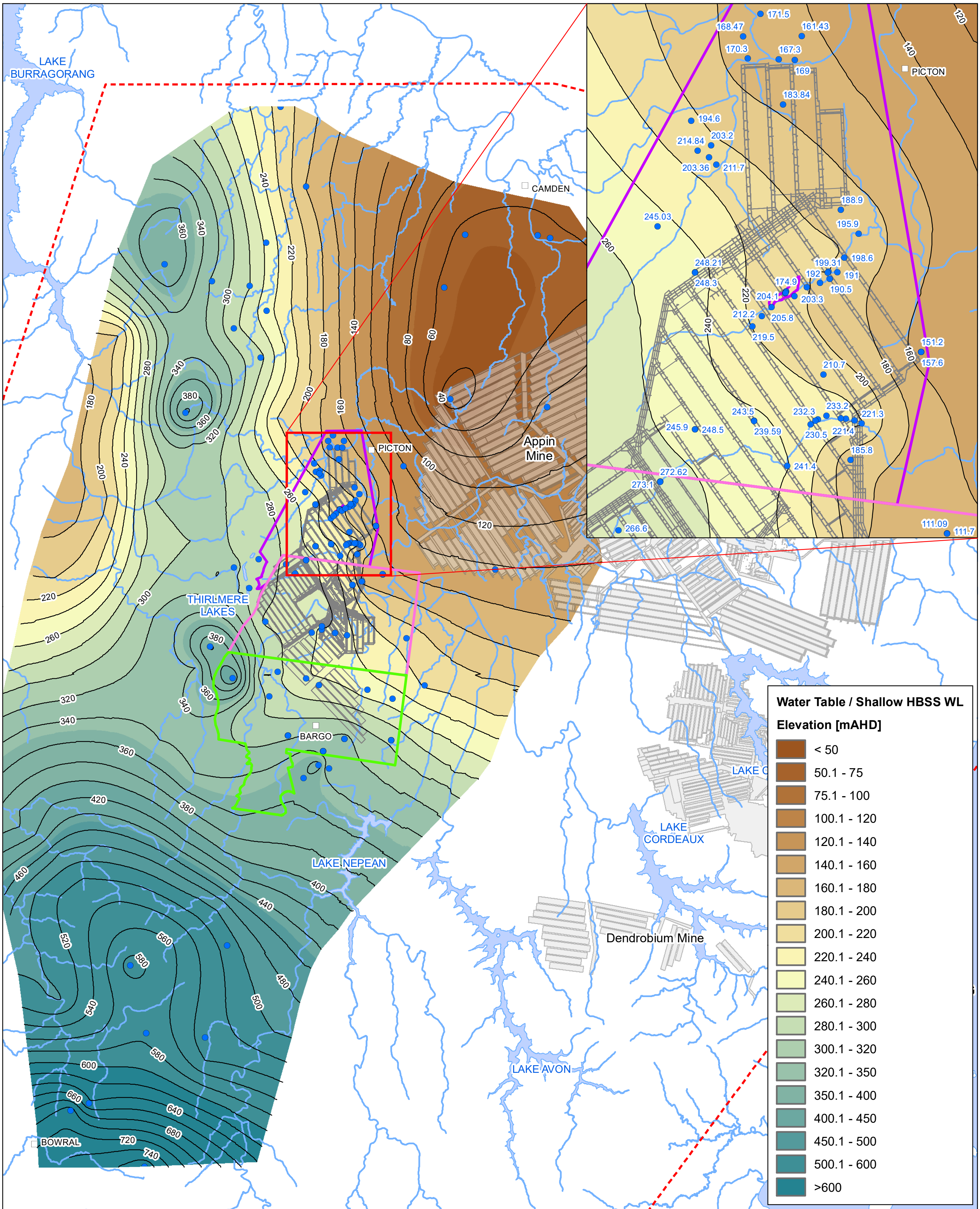
Following wet conditions in early 2020, groundwater levels at REA1, REA2, REA3, RE5, REA6 increased 0.5-0.7m. The increasing trend continued throughout 2020 at REA2 and RE3 while water levels at REA1, REA5 declined slightly (0.2-0.5 m). Throughout 2021, water levels continued to respond to rainfalls in the range of 0.2-0.5 m. At REA4 and REA7, the observed water level response to rainfall in early 2020 is larger with fluctuations in water levels of up to 7 m in REA7 while water levels in REA4 increased sharply by 1.5 m and continued to do so throughout 2021, rising by 1.5 m.

3.5.4.2 Flow, Recharge and Discharge

Interpreted water table elevations are shown on Figure 3-16 and the interpreted depth to the water table on Figure 3-17.

The interpreted groundwater conditions are based on recent available data, which ranges between 2013 and 2020. The contouring on Figure 3-16 shows that the groundwater gradient is generally flowing in an east to north-easterly direction in the area of Tahmoor Mine.

Figure 3-17 shows that groundwater levels are generally closer to the ground surface in areas where surface water drainage exists. This indicates the potential for surface drainage to contribute baseflow to the Hawkesbury Sandstone aquifer. Due to the number of watercourses surrounding Tahmoor Mine and the regional topography (see Section 3.3 and Error! Reference source not found.), the depth from the ground surface to the water table is shallower compared to the surrounding region. Over the mine, the water table is approximately 20 m below the ground surface. In areas not associated with surface drainage lines, such as that south-west of the mine, the depth to the water table is between 40 and 50 m.



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:250,000 at A4
Project Number:	610.30652
Date:	22-Apr-2022
Drawn by:	JG

- Bores (RWL)
- City
- Town
- Tahmoor North and Western Domain
- Water Table (regional)
- Watercourses
- Lakes
- Southern Coalfield (approximate)

Tahmoor Coal Titles

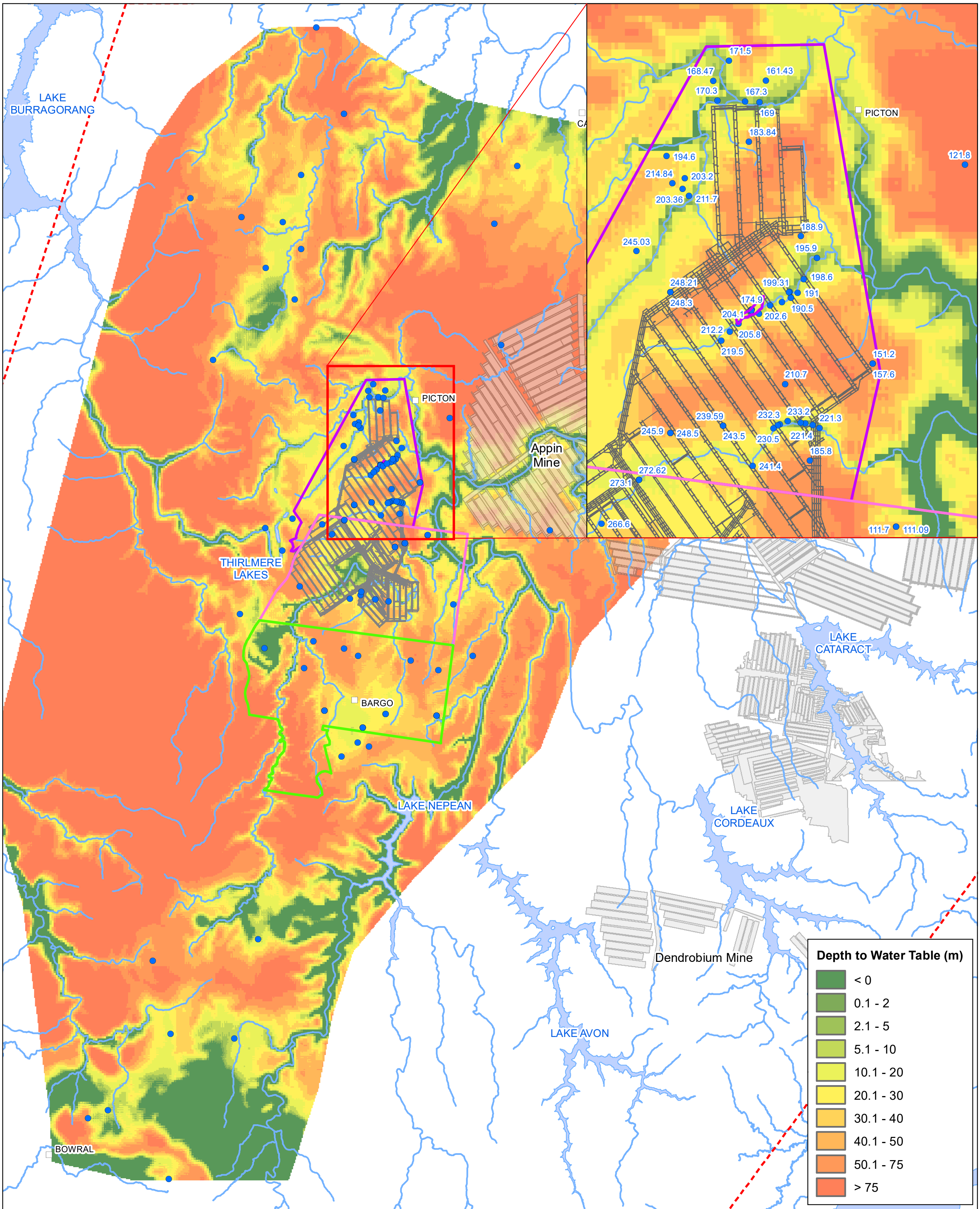
- MLs 1308, 1376, 1539
- CCL 716
- CCL 747

TAHMOOR COAL LW S1A-S6A GROUNDATER TECHNICAL REPORT

Interpreted Water Table Elevation

FIGURE 3-16

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30652.00000 Tahmoor Coal Groundwater Model Rebuild\06 SLR Data\01 CADGIS\GIS\Conceptualisation\61030652 FigXX Interpreted water table elevation.mxd



0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:230,000 at A4
Project Number: 610.30652
Date: 22-Apr-2022
Drawn by: JG

- Bore
- City
- Town
- Tahmoor North and Western Domain
- Watercourses
- Lakes
- Southern Coalfield (approximate)

Tahmoor Coal Titles

- MLs 1308, 1376, 1539
- CCL 716
- CCL 747

TAHMOOR COAL LW S1A-S6A GROUNDWATER TECHNICAL REPORT

Interpreted Depth to Water Table Elevation (Aug 2013)

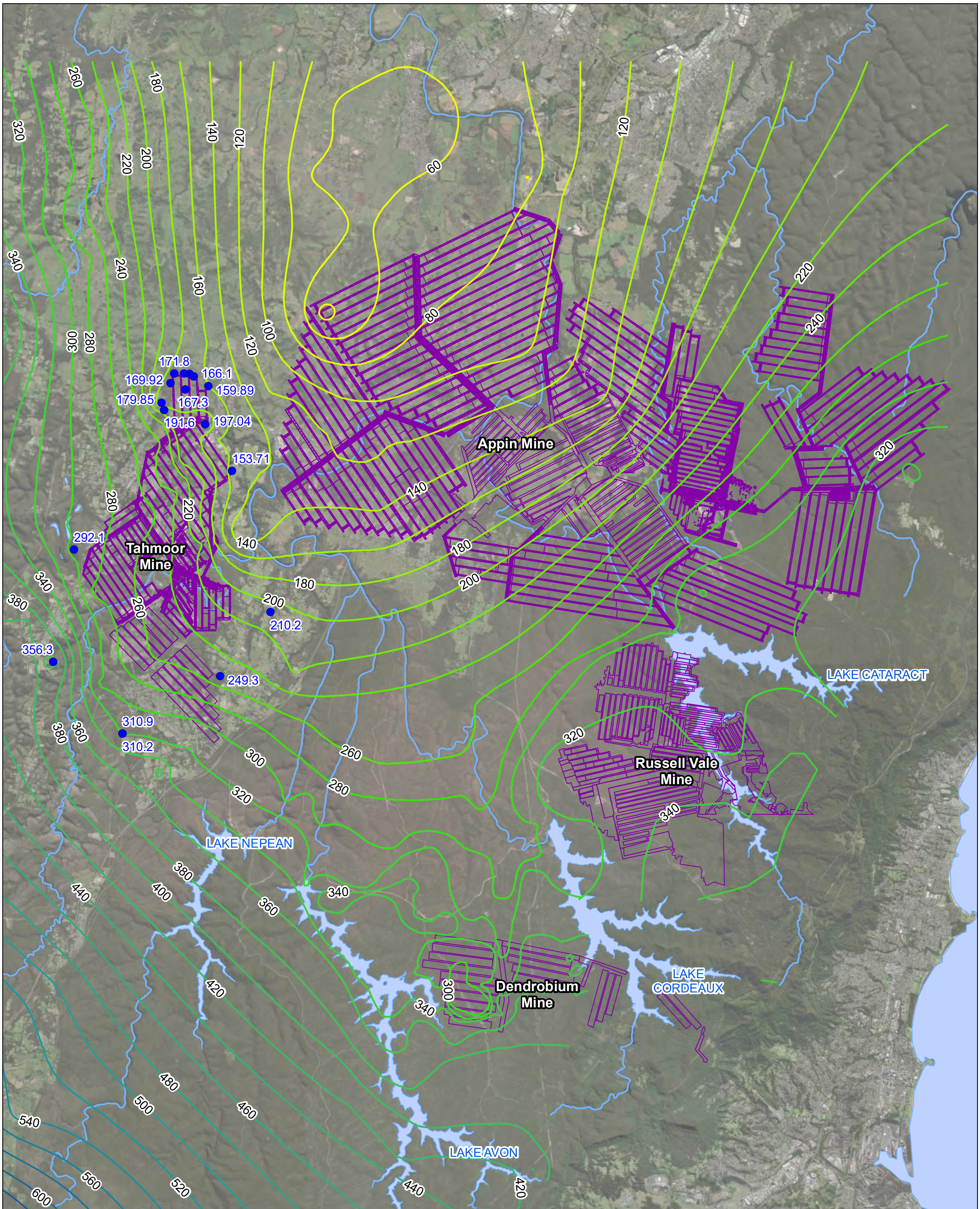
FIGURE 3-17

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30652.00000 Tahmoor Coal Groundwater Model Rebuild\06 SLR Data\01 CADGIS\GIS\Conceptualisation\61030652 FigXX Interpreted depth to water table elevation (Aug 2013).mxd

Figure 3-18 presents the interpreted groundwater level elevation contours in the lower HBSS using groundwater level data from October 2021. To the east of Tahmoor South, groundwater levels in the lower HBSS range from 380-360 mAHD down to approximately 240 mAHD to the north of LW S1B. Figure 3-18 shows the groundwater gradient flows in an eastward direction across LW S1A-S6A and in a northward direction from the south-west to the north-east across the longwalls block B.

Figure 3-19 presents the interpreted groundwater level elevation contours in the lower BGSS using groundwater level data from October 2021. To the east of Tahmoor South, groundwater levels in the lower BGSS range from 340-320 mAHD down to around 230 mAHD to the north of LW S1B. Figure 3-18 shows the groundwater gradient flows in a northward direction from the south-west to the north-east across the longwalls block A and B.

Figure 3-20 presents the interpreted groundwater level elevation contours in the Bulli Seam using recent level data where available. To the east of Tahmoor South, groundwater levels in the Bulli Seam range from 300-280 mAHD down to around 180 mAHD to the north of LW S1B. Figure 3-18 shows the groundwater gradient flows in a northward direction from the south-west to the north-east across the longwalls block A and B. The cone of depression induced by mining at Tahmoor Mine (i.e. Tahmoor North and Western Domain) slightly developed across Tahmoor South and explain the observed historic depressurisation at bores relevant to Tahmoor South area.



H:\Projects-SLR\610-SrvSYD\610-SYD\610.30652.00000 Tahmoor Coal Groundwater Model Rebuild\06 SLR Data\01 CADGIS\GIS\Conceptualisation\61030652 FXX Groundwater Elevation - Hawkesbury Sandstone.mxd

0 2.5 5 km

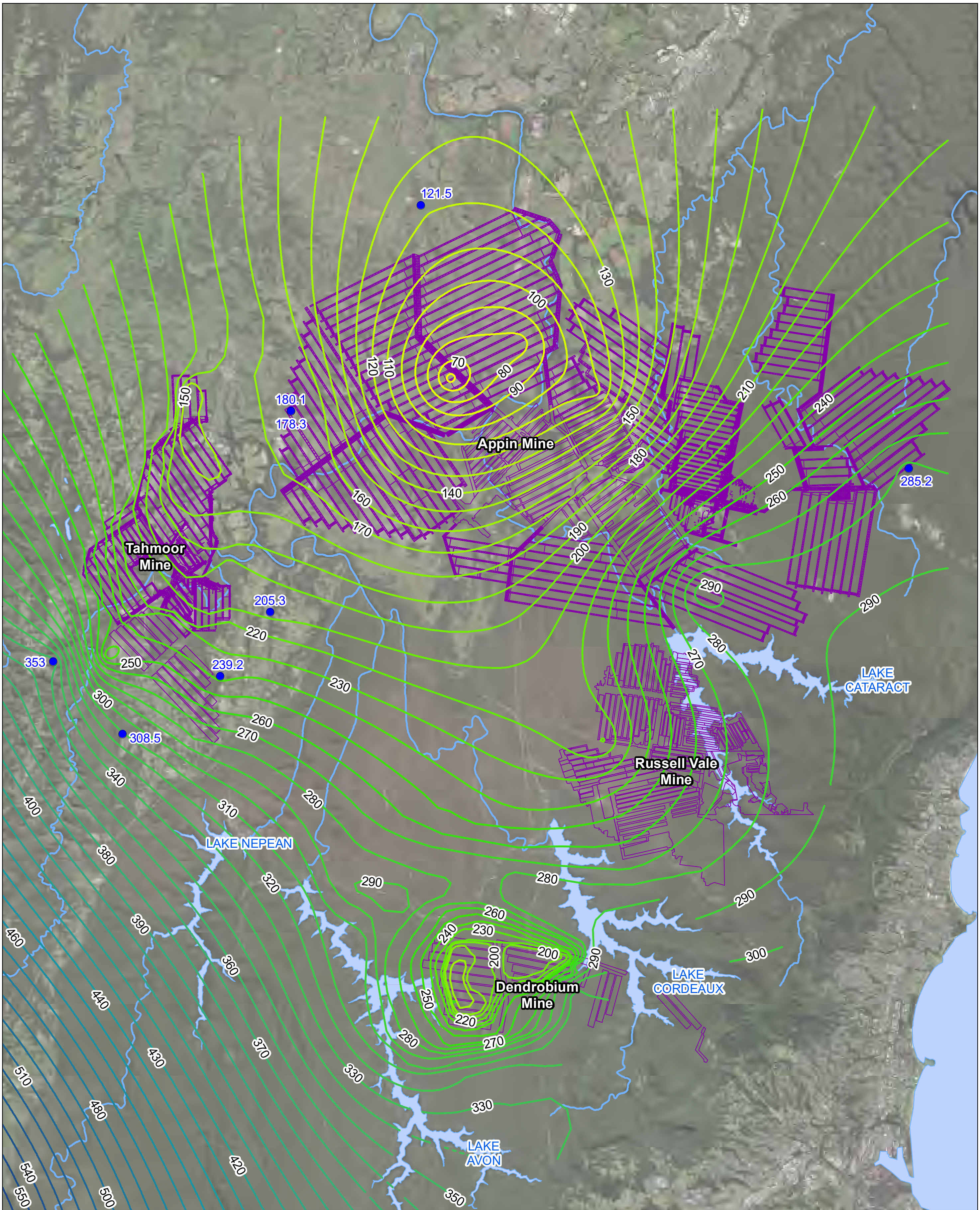
Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:200,000 at A4
Project Number:	610.30652
Date:	21-Apr-2022
Drawn by:	JG

- Bore (RWL)
- Groundwater Level (mAHD)
- Existing Mine
- Watercourses
- Watercourse Area

TAHMOOR COAL
LW S1A - S6A
GROUNDWATER TECHNICAL REPORT

Interpreted Groundwater Level Elevation in the lower Hawkesbury Sandstone

FIGURE 3-18



0 2.5 5 km

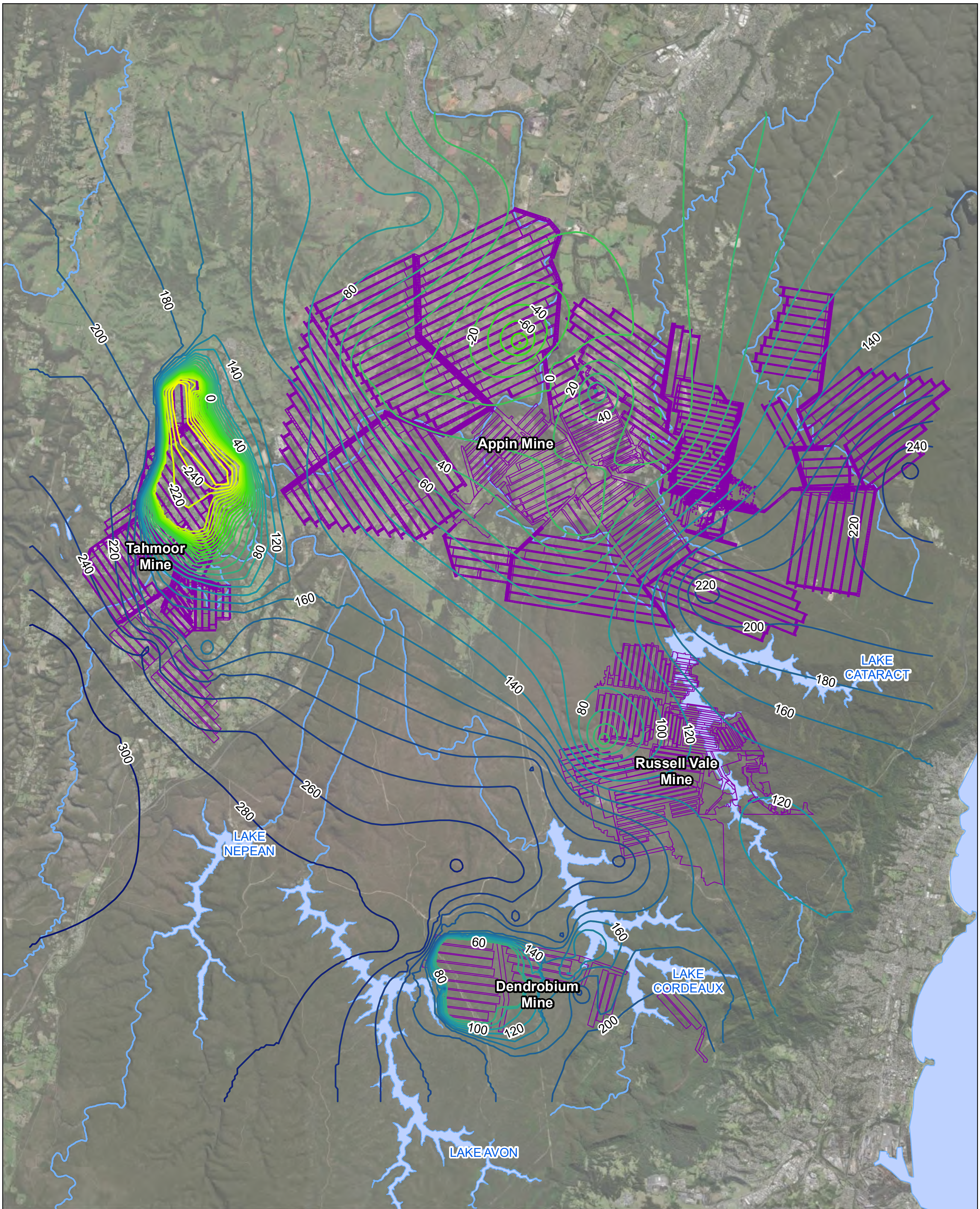
Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:200,000 at A4
Project Number:	610.30652
Date:	21-Apr-2022
Drawn by:	JG

- Bore (RWL)
- Groundwater Level (mAHD)
- Existing Mine
- Watercourses
- Watercourse Area

TAHMOOR COAL
LW S1A - S6A
GROUNDWATER TECHNICAL REPORT

Interpreted Groundwater Level Elevation in the lower Bulgo Sandstone

FIGURE 3-19



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:200,000 at A4
Project Number:	610.30652
Date:	21-Apr-2022
Drawn by:	JG

- Groundwater Level (mAHD)
- Existing Mine
- Watercourses
- Watercourse Area

TAHMOOR COAL
LW S1A - S6A
GROUNDWATER TECHNICAL REPORT

Interpreted Groundwater Level Elevation in the Bulli Seam

FIGURE 3-20

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30652.00000 Tahmoor Coal Groundwater Model Rebuild\06 SLR Data\01 CADGIS\GIS\Conceptualisation\61030652 FXX Groundwater Elevation - Bulli Seam.mxd

3.5.5 Groundwater Quality

Water quality sampling is conducted at monitoring bores located within the Pit-Top area (Pit Top 1, 2, 4) and across the Reject Emplacement Area (REA1-7) since 2019 on a quarterly basis. Additionally, field water quality, inclusive of EC and pH, has been undertaken on a monthly basis since August 2019. Appendix C presents the baseline data (EC and pH) for the Pit Top and REA bores, with the rainfall residual mass included for comparison to climatic trends.

The Private Bore Survey, conducted between January – March 2022, completed groundwater quality sampling on a total of 31 private bores. Laboratory results of this sampling program are provided in the Private Bore Survey Summary Report (SLR, 2022), provided in Appendix D.

A summary of groundwater salinity and bore depth for the private bores is provided in Table 3-4. The median groundwater salinity is 810 µS/cm, with a minimum of 165 µS/cm and a maximum of 3,378 µS/cm. There are no apparent trends with groundwater salinity and bore depth or location.

Table 3-4 Summary of Private Bore groundwater salinity

Registered Number	Field Depth (mbgl)	Recorded Depth (mbgl)	EC (µS/cm)
10CA119328	NR	NA	1,472
115NTG	~160 – 170 m	NA	689
GW032443	10.71 (measured, likely blocked)	130.1	226.2
GW059618	122.71	117	2,396
GW062068	>100	150	165
GW070245	NR	97.5	949
GW102179	NR	153	1,849
GW102344	NR	110	801
GW102452	71.41	120.5	371.6
GW103023	51.43	165	3,378
GW103036	127.42	132.5	371.2
GW103559	NR	54	487
GW104008	>100	140	1,323
GW104323	79.8	109	1,025
GW104659	50.08	132	539
GW105262	NR	104	1,828
GW105395	53.1	90	3,341
GW105803	NR	140	1,108
GW105883	NR	NA	1,686
GW110669	NR	132	677
GW111518	28.32 (potential obstruction)	150	277
GW111669	NR	120	481
GW111810	NR	142	2058
GW112415	96.96	139	1059
GW112473	NR	138	515

Registered Number	Field Depth (mbgl)	Recorded Depth (mbgl)	EC (µS/cm)
GW115773	81.87	180	820
GW116897	51.2 (potential blockage)	160	776
Heritage Well	3.12	NA	684

NR = not recorded

Installation of a the Tahmoor South Monitoring Network, completed in May 2022, has allowed for a series of water quality sampling analysis prior to release of this report. Table 3-5 describes the salinity and pH of the monitoring bores, showing a range from approximately 230 µS/cm to 8,100 µS/cm, with a median salinity of approximately 1,500 µS/cm.

Table 3-5 Summary of Monitoring Bore groundwater salinity (June, 2022)

Bore ID	Bore Depth (mbgl)	EC (µS/cm)	pH
P51A	19.36	357.6	8.82
P51B	35.38	8106	12.66
P52	41.17	1250	5.69
P53A	41	814.25	6.15
P53B	60.55	1679.6	6.89
P53C	80.78	1708	6.9
P54C	35.99	1984	6.37
P55A	41.04	1656	5.68
P55B	59.36	1544.4	n/a
P55C	81.9	1327.3	6.99
P56A	20.9	1544.5	5.54
P56B	45.56	1090	7.06
P56C	80.4	3200.1	12.19
REA4	54.31	235.9	6.87

Review of the local and regional data indicates that:

- Groundwater in the Alluvium and Wianamatta Formation are of mixed quality. It is likely that evaporative concentration of salts could occur in alluvial aquifers, especially in clayey facies. The marine origin and low permeability of the Wianamatta Shales tends to lead to higher salinities in this unit.
- There is little data for the Narrabeen Group or Illawarra Coal Measures. Older units such as the Shoalhaven Group exhibit a range of salinities from fresh to saline.
- The Hawkesbury Sandston is the primary aquifer utilised and although shows variability in groundwater salinity it is overall suitable for stock and domestic purposes and most irrigation.

A full review of the baseline groundwater chemistry will be undertaken prior to commencement of extraction (September 2022), when minimum six months of data will be available for shallow monitoring bores and private bores.

3.5.6 Historical Groundwater inflows (Tahmoor North and Western Domain)

Groundwater pumped from all sumps in the mine workings is currently, and will continue to be, monitored by means of flow meters fitted to pipelines recording pumping times and rates. This water reporting to the underground workings and sumps may include groundwater seepage inflows, supply inflows (potable supply and for operations), and some re-circulation.

Operational water balance reviews will continue to be performed monthly collating groundwater extraction, as well as imported water to inform on-site water management. Such a system has been in operation at Tahmoor since 2009 (13 years) and will continue for the life of Tahmoor South. The volumetric flux monitoring will provide data on the total groundwater inflow to all workings, where dewatering of Tahmoor North/Western Domain workings will cease soon after LW W4 is completed (in 2022). This will mean that inflow to Tahmoor South workings will be the primary component of the measured dewatering volume.

Since 2009, inflows to the Tahmoor Mine have been within the range of 2 megalitres per day (ML/d) to 6 ML/d. Figure 3-21 presents a history of the calculated inflows ('water make') at Tahmoor Mine between 2016 and 2022. The average and total inflow for recent water years is presented in Table 3-6.

Table 3-6 Historic Mine Inflow

Water Year	Inflow, average (ML/day)	Inflow, total (ML)
2018 – 2019	3.4	1,234.4
2019 – 2020	3.3	1,206.6
2020 – 2021	4.5	1,640.6
2021 – 2022	4.4	1,290
2022 – 2023*	2.4	873.0

* For January to May 2023 only

It is noted, that pumping may cease for short periods (i.e. due to equipment failure and other reasons), the water balance may estimate zero inflow for short periods (i.e. an underestimate of true inflow). Conversely, if pumping is required to be increased to make up for earlier shortfalls in pumping, the water balance may estimate higher inflow for short periods (i.e. overestimate the true inflow). As a result, longer-term averages are more reliable than the short-term inflow estimates.

The period between mid-2020 shows an increase in inflows to greater than 5 ML/day at the end of July 2020 likely due to the extraction of LW W1. Inflow declined in late 2020, before rising in February 2021 (early in LW W2), with a peak at just over 6 ML/d in March and April 2021. Inflows to the Western Domain are not metered in isolation from other parts of Tahmoor North (they are metered along with all other pump-out) but were estimated to be greater than 2.5 ML/d at analysis between February – April 2021. Other than the minor fault observed in the southern 'half' of LW W1 and LW W2 and a small fault in the northern part of LW W3, no other obvious geological structures have been noted as intersecting current workings were observed by staff in the underground mine. As a result, no obvious relationship between higher inflow and geological structure could be determined (SLR, 2021).

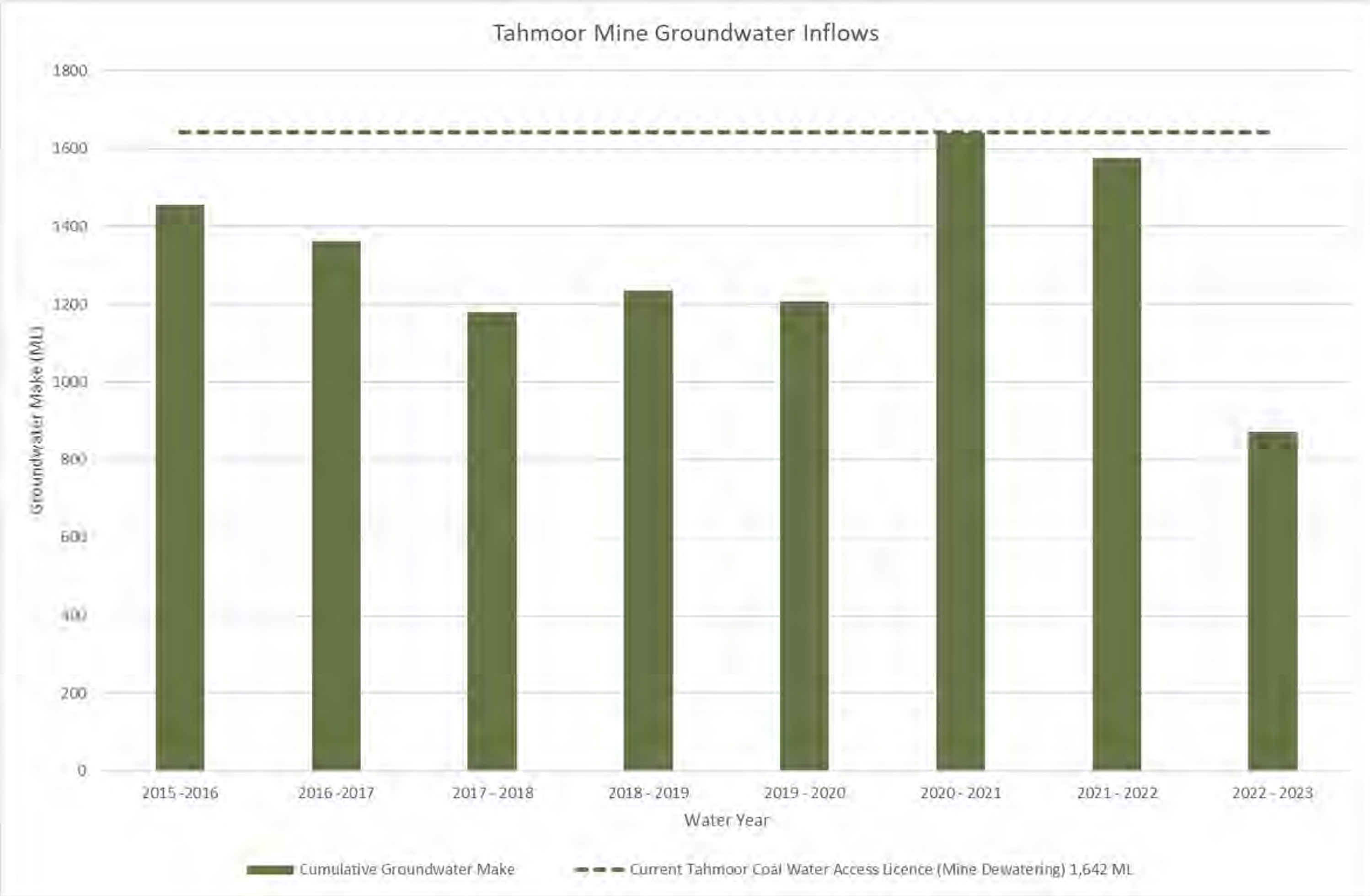


Figure 3-21 Historical Groundwater Inflow (measured) for the period July 2015 – May 2023

3.5.7 Investigation into Fracturing above Longwalls

Near-surface fracturing or "surface cracking" can occur due to horizontal tension at the edges of a subsidence trough. The depth of cracking from the surface will typically be less than 20 m; McNally and Evans (2007) stated this is usually but not always transitory. Water loss from surface features (e.g. watercourses, wetlands) into the cracks is unlikely to continue downwards towards the goaf and most will return to surface somewhere down-gradient. This has occurred in earlier mining at Tahmoor, e.g. along the Bargo River and Redbank Creek.

Investigations along Redbank Creek and Myrtle Creek have been carried out in boreholes to characterise the near surface-strata adjacent to the creeks impacted by the subsidence associated with longwall mining. These investigations involved the observations of borehole conditions and water flows, measurements of borehole diameter to identify voids and open fractures, and lugeon packer tests to measure hydraulic conductivity (SCT, 2020b).

These investigations along Redbank Creek concluded that the presence of open fractures in all boreholes coincided with intervals of increased hydraulic conductivities. Groundwater flow was observed out of these fractures in some bores (e.g. P10 and P19). However, no correlation or patterns were established between fracturing and depth below the creek bed at these targeted areas. Comparable findings were reported by SCT (2020a) along Myrtle Creek, with groundwater flows observed out of open fractures at P18, P21, P23 and P25 but no clear correlation between the zones of increased hydraulic conductivities and the depth below the creek bed was established.

Leakage of surface water into the surface cracking zone can result in the water quality of any re-emergent water being inferior to that of surface flow in an undisturbed environment (McNally and Evans, 2007). Effects of mining-induced subsidence have occurred at Tahmoor Mine, e.g. along Redbank (GeoTerra, 2019) and Myrtle Creeks.

An assessment conducted by Morrison *et al.* (2019) found that the quality of surface waters in areas directly above extracted longwall panels was degraded in the direct vicinity of surface cracking features along Redbank Creek, with higher salinity and metal concentrations measured compared to an unaffected reference site.

In many cases, metals concentrations decline downstream of the undermined sections, e.g. iron (Fe), nickel (Ni), cobalt (Co), but others remain at elevated levels, e.g. manganese (Mn), barium (Ba), strontium (Sr), noting that the sampling was conducted in dry conditions with minimal runoff present. The decline in some metals is attributed to oxidation and precipitation.

Future assessment of impacts of subsidence, will occur via monitoring and analysis of both ground and surface water levels and quality. Appropriately experienced consultants engaged by Tahmoor Coal will monitor for, analyse, and document effects on surface water levels and quality in watercourses adjacent to Tahmoor South longwalls inclusive of alterations to baseline groundwater – surface water interactions.

3.5.8 Groundwater Use

Groundwater use occurs via two predominant mechanisms; environmental and anthropogenic. Environmental groundwater use typically occurs via natural springs and Groundwater Dependent Ecosystems (GDEs). In the Tahmoor South project area, there are no identified springs (Brienen Environmental & Safety, 2022). Anthropogenic use is via specifically constructed groundwater bores, where private users extract groundwater for several purposes, primarily stock watering, domestic use and crop irrigation. Each of these methods of groundwater use is discussed in greater detail below.

3.5.8.1 Groundwater Dependent Ecosystems

The Thirlmere Lakes are the closest 'High Priority' Groundwater Dependent Ecosystem to Tahmoor Mine, being 650-700 m from historical Tahmoor longwalls at their closest points, but at least 3,500 m from LW S1A-S6A.

Thirlmere Lakes are of high conservation importance, gazetted as a National Park in 1972, and providing habitat for dependent aquatic species (Schädler & Kingsford, 2016). The Lakes are a group of waterbodies in the Greater Blue Mountains World Heritage Area that includes Lake Gandangarra, Lake Werri Berri, Lake Couridjah, Lake Baraba and Lake Nerrigorang.

The TLRP found that the lakes are a climate-sensitive wetland, primarily driven by rainfall and evaporation (DPE, 2022). Whilst the primary water input to Thirlmere Lakes and their surrounding catchments is rainfall precipitation, the lakes can also receive water via runoff, infiltration and interflow processes from their catchment. The major discharge processes (water outputs) from the lakes include evapotranspiration and streamflow. See Section 3.6.1 for further discussion on the groundwater – surface water interactions at Thirlmere Lakes.

3.5.8.2 Springs

Literature indicates that it is likely that the HBSS may contain springs that have developed in saturated and perched aquifers within the unit (HydroSimulations, 2018). However, no significant springs or soaks have been mapped or located in the vicinity of the Project. Field investigations carried out by Brienen Environment & Safety (2022) supported this finding.

3.5.8.3 Anthropogenic Use

The Groundwater Assessment in the initial EIS for Tahmoor South (HydroSimulations, 2021) presented a review of the NSW government's online database to identify registered groundwater bores within the original study or model domain. This resulted in 982 registered bores, 791 of which were matched with WALs. The HBSS, surficial alluvium and basalt aquifers were the predominant target aquifers (89% of the total) with approximately 10% from the Bulgo Sandstone.

Preliminary modelling simulated maximum drawdown impacts of the Tahmoor South Project to identify which bores may incur a drawdown resultant of mining activities of greater than 2 metres, as per the requirements of the Aquifer Interference Policy. A total of 52 bores were identified as fitting this criteria, and were subsequently incorporated into the Private Baseline Survey.

Tahmoor Coal Community Liaison Specialist attempted to contact all landholders with identified bores. Originally, 52 bores were identified that may experience greater than 2 metres drawdown due to proposed extraction operations, inclusive of both the A and B series longwalls. During the survey process an additional six bores were incorporated into the survey at the request of landholders. The "heritage well", previously identified in the *Statement of Heritage Impact* (SoHI) of the Wirrimbirra Sanctuary (EMM, 2020) was also incorporated. Consequently, a total of 59 bores are on the final baseline list, of which 40 bores were able to be surveyed, as summarised in Table 3-7. Access was unattainable for the remainder of the sites. Of these 40, it is considered likely that 20 will be affected beyond 2m drawdown by extraction of LW S1A-S6A, especially the 5 bores which directly overlie the panels of LW S1A-S6A and their chain pillars and are predicted to experience potentially greater than 10 metres of drawdown (see Section 4.4.4.1. The baseline survey was commenced on the 15th January 2022 and was concluded by 15th March 2022. The summary report documenting the outcomes of this survey is provided in Appendix D.

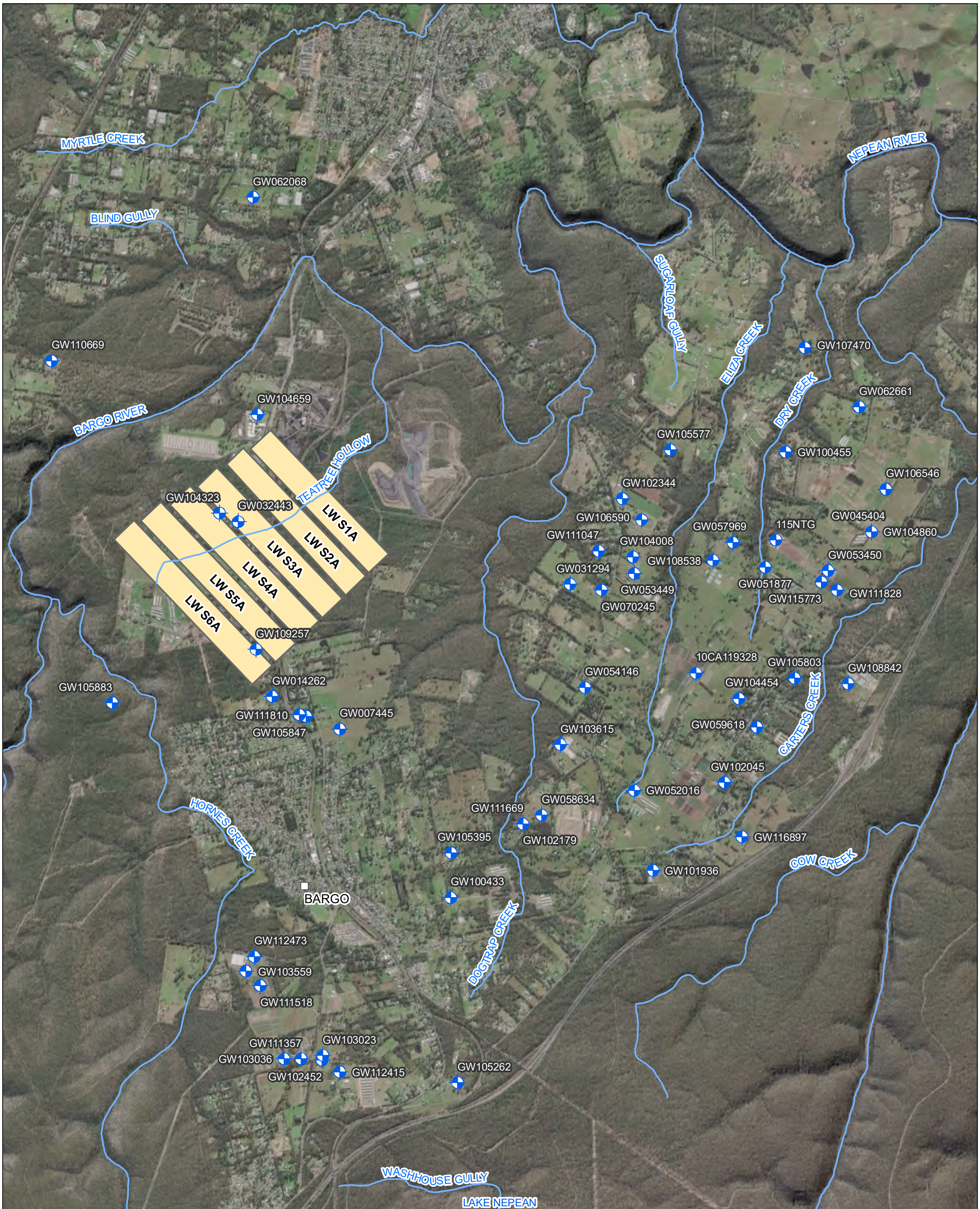
Table 3-7 Summary of Private Registered Bores predicated to have > 2m drawdown

Registered Number (RN) (if applicable)	Easting	Northing	Initial Survey Conducted	Predicted >2m Drawdown*
10CA119328	280984	6204822	yes	#N/A
115NTG	281781	6206145	yes	#N/A
GW007445	277437	6204264	no	bore with >2m DDN
GW014262	276764	6204587	no	bore with >2m DDN
GW031294	279732	6205706	no	bore with >2m DDN
GW032443	276427	6206329	yes	bore with >2m DDN
GW045404	282730	6206227	yes	bore with >2m DDN
GW051877	281673	6205875	no	bore with >2m DDN
GW052016	280369	6203655	no	bore with >2m DDN
GW053449	280369	6205813	no	bore with >2m DDN
GW053450	282301	6205841	yes	bore with >2m DDN
GW054146	279880	6204679	yes	bore with >2m DDN
GW057969	281351	6206122	yes	bore with >2m DDN
GW058634	279446	6203408	yes	bore with >2m DDN
GW059618	281589	6204282	yes	bore with >2m DDN
GW062068	276573	6209556	yes	bore with >2m DDN
GW062661	282609	6207469	no	bore with >2m DDN
GW070245	280043	6205645	yes	bore with >2m DDN
GW100433	278540	6202588	no	bore with >2m DDN
GW100455	281877	6207020	no	bore with >2m DDN
GW101936	280556	6202858	no	bore with >2m DDN
GW102045	281266	6203733	no	bore with >2m DDN
GW102179	279263	6203321	yes	bore with >2m DDN
GW102344	280251	6206554	yes	Bore with less than 2 m DDN
GW102452	277261	6200970	yes	bore with >2m DDN
GW103023	277266	6201016	yes	bore with >2m DDN
GW103036	276883	6200982	yes	bore with >2m DDN
GW103559	276504	6201854	yes	Bore with less than 2 m DDN
GW103615	279635	6204110	yes	bore with >2m DDN
GW104008	280359	6205978	yes	bore with >2m DDN
GW104323	276242	6206412	yes	bore with >2m DDN
GW104454	281410	6204568	no	bore with >2m DDN
GW104659	276616	6207392	yes	bore with >2m DDN
GW104860	282730	6206227	yes	bore with >2m DDN
GW105262	278611	6200745	yes	bore with >2m DDN
GW105395	278547	6203033	yes	bore with >2m DDN
GW105577	280728	6207041	no	bore with >2m DDN

Registered Number (RN) (if applicable)	Easting	Northing	Initial Survey Conducted	Predicted >2m Drawdown*
GW105803	281965	6204772	yes	bore with >2m DDN
GW105847	277103	6204390	no	bore with >2m DDN
GW105883	275176	6204523	yes	bore with >2m DDN
GW106546	282876	6206650	yes	bore with >2m DDN
GW106590	280442	6206344	no	bore with >2m DDN
GW107470	282069	6208057	no	bore with >2m DDN
GW108538	281155	6205941	no	bore with >2m DDN
GW108842	282500	6204716	no	bore with >2m DDN
GW109257	276604	6205057	yes	bore with >2m DDN
GW110669	274570	6207928	yes	bore with >2m DDN
GW111047	280015	6206037	no	bore with >2m DDN
GW111357	277051	6200982	no	bore with >2m DDN
GW111518	276648	6201710	yes	bore with >2m DDN
GW111669	279263	6203321	yes	bore with >2m DDN
GW111810	277035	6204405	yes	bore with >2m DDN
GW111828	282390	6205647	yes	bore with >2m DDN
GW111842	283187	6182673	yes	bore with >2m DDN
GW112415	277439	6200851	yes	bore with >2m DDN
GW112473	276586	6202000	yes	bore with >2m DDN
GW115773	282232	6205725	yes	#N/A
GW116897	281442	6203190	yes	#N/A

*Predicted drawdown from Tahmoor South EIS (HydroSimulations, 2018)

#NA not included in original assessment



Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:50,000 at A4
Project Number: 610.30637
Date: 03-May-2022
Drawn by: NT

Private Bore
Minor Town
Watercourses
Lakes

Tahmoor South Mine Plan

Approved

TAHMOOR SOUTH LW S1A – S6A GROUNDWATER TECHNICAL REPORT

Private Bore Locations

FIGURE 3-22

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30652.00000 Tahmoor Coal Groundwater Model Rebuild\06 SLR Data\01 CADGIS\GIS\ModellingReport\61030637 Fig3_22 Private Bore.mxd

3.6 Groundwater – Surface Water Interaction

3.6.1 Groundwater – surface water interactions at Thirlmere Lakes

The *Thirlmere Lakes Research Program* (TLRP) aimed to provide a detailed understanding od the hydrological dynamics, water sources and water flow pathways. The summation report, "Thirlmere Lakes – A Synthesis of Current Research" was released in late March 2022, by DPE, which aligned with previous conceptualisation.

3.6.1.1 Thirlmere Lakes – A synthesis of Current Research (DPE, 2022)

The following provides redacted notes from the released report.

Ongoing monitoring of local groundwater bores showed:

- *Monitoring of these bores illustrates the sensitivity of shallow (~15 metres below ground level) groundwater levels to significant rainfall events.*
- *There was also a clear separation between the shallow bores (~15 metres depth) and the deeper bores (~100 metres depth) in terms of water level.*

During the dry period, hydraulic heads in the shallow piezometers (< ~ 4 metres depth below land surface) near the lakes were lower than the lake levels, but generally decreased at similar rates to the lake levels probably due to a combination of downward leakage and lateral transport driven by evapotranspiration. The relative proportion of each process is not known and difficult to determine. During the February 2020 recharge event, the shallow piezometers all responded synchronously with the rising lake levels and most measured hydraulic heads align to the lake levels of their adjacent lake during the wet period. This indicated that for most of the shallow piezometers a hydraulic connection to the lake's surface water does exist despite the heterogeneous shallow lithology across the Thirlmere Lakes and the presence of low-permeable peat and clay layers. However, due to the differences in the responses between each lake and their differing absolute surface water elevation it can be inferred that each lake is individually nested within its own shallow low-permeable sediments (DPE, 2022).

Deeper piezometers further from the lakes typically had lower water levels during the dry period and showed a delayed response to the February 2020 recharge event, but typically recharged to a higher hydraulic head than the adjacent lake levels. This is interpreted as diffuse recharge through the relatively small catchment rather than via leakage or overflow from the lakes. The hydraulic head in these deeper piezometers then declined faster than the shallower piezometers, likely due to vertical leakage or groundwater flow down the catchment. Several months after the February 2020 recharge event, groundwater levels were higher around the lowest lying lakes, Lake Nerrigorang and to some extend around Lake Gandangarra, and it is likely these lakes received some groundwater discharge during this period.

Groundwater input (i.e. discharge to the lakes and/or contributions to underlying sediments) is undoubtedly a critical factor for the lakes system. Even during this exceptionally dry period with lowered water tables, we have direct evidence of nearby discharge into Blue Gum Creek and inferred discharge into or flow below Lake Baraba. Every lake showed evidence of multiple loss mechanisms including recharge to groundwater.

Mine waters exhibit starkly different chemistry (Na-HCO3 type) from the lakes (Na-Cl and/or humic), exhibiting evolved groundwater beyond that typically found in the deep wells around the lakes that are in shallower strata. Mine samples also show no evidence of evaporated stable water isotopes found in lake signatures. There is no chemical or isotopic evidence linking groundwater in the mine directly to surface water in the lakes at present. It is unlikely that a measurable signature would arise in the near future due to apparent flow rates to depth.

A lack of chemical or isotopic signature does not preclude the possibility of indirectly diminished groundwater discharge and/or runoff into to the lakes. Mining and/or agricultural and/or other water abstraction in the region have lowered historical levels of shallow groundwater surrounding the lakes. Lowered groundwater levels could be the result of either direct pumping of water supply bores, or by pumping deeper mine water and increasing downward hydraulic gradients towards underlying strata. The field and modelling results suggest that the recent water level declines are primarily associated with climate variability versus the nearby longwall mining.

3.6.1.2 Historical Interpretations

The above conclusions summarised from the TLRP (DPE, 2022) are similar to interpretations previously submitted by HydroSimulations (2018), which are summarised below.
A hydrograph for Thirlmere Lakes is shown as Figure 3-23. The figure shows that Lake Baraba levels are much higher than the other lakes. Lake Baraba is suggested to be more like a swamp (e.g. Vorst, 1974), possibly with different hydrology and subsurface conditions (HydroSimulations, 2020).

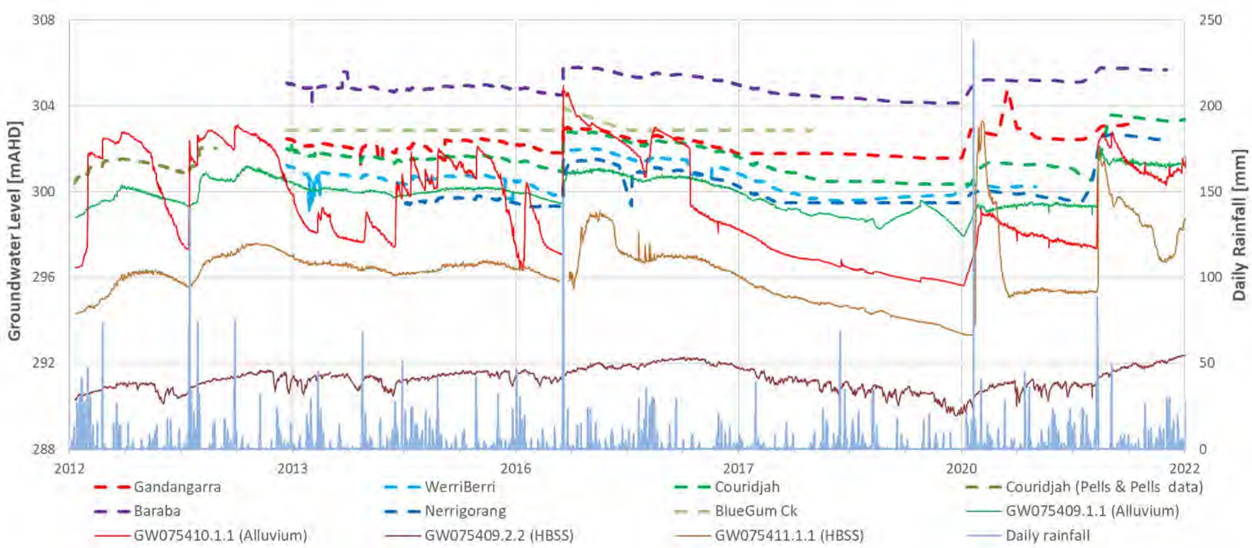


Figure 3-23 Thirlmere Lakes groundwater and lake levels

At GW075409 (near Lake Couridjah), groundwater levels in the alluvium have been consistently around 2 m below the lake level, showing that Lake Couridjah is a losing system (with the exception of during the major flood event in March 2021). At this site groundwater in the HBSS is around 10 m below the alluvium, indicating that the two aquifers are not connected, at least in regard to there being no pathway for groundwater flow from the HBSS to the alluvium, at this location.

Groundwater levels in GW075411 show that the HBSS at this location has historically not been connected to the surface, except for the high rainfall event in March 2020. This site does not monitor the alluvium, hence it is difficult to assess the connectivity to the underlying HBSS, however some connectivity is suggested during flood events. GW075411 does not show a sharp response to rainfall conditions, suggesting no direct connection with the surface.

Groundwater levels in GW075410 near Lake Nerrigorang, show that historically the lake has experienced both gaining and losing conditions, depending on rainfall conditions. Historically Lake Nerrigorang has remained wetter than the other lakes, suggesting that the lake is supported by groundwater baseflow and the others are less likely to be. This is consistent with findings from the TLRP regarding the limited connection between Thirlmere Lakes to groundwater (WRL, 2020 and Section 3.6.1).

3.6.2 Groundwater – surface water interactions adjacent to Tahmoor South

As discussed in HydroSimulations (2020) flow differentials can be used to infer losing or gaining conditions. Figure 3-24 displays daily flows and calculated differentials at Tahmoor South surface water locations Bargo River and Dogtrap Creek. The location of monitoring locations (i.e. SW-01, SW-13 and SW-15, SW-16) are shown on Figure 3-4. Because of the relatively small distances between gauges the differences are assumed to only represent any losses to and gains from groundwater between these combinations of gauges. This assumes that evaporation and surface water use and inflows from other sources (such as other ungauged tributaries) are negligible.

Figure 3-24 shows that while both Bargo River and Dogtrap Creek generally experience gaining conditions, they both lose water to the underlying HBSS aquifer for significant periods of time. This is supported by the fact flow losses are expected to be underestimated due to a lack of accounting for inflows from several small ungauged tributaries between gauging stations, particularly along the Bargo River between Site 1 (SW-01) and Site 13 (SW-13). There are few licensed groundwater abstractions along or near to this reach of the river (Figure 3-12), and hence unaccounted groundwater usage impacts on stream flows are not expected to compromise this water balance analysis. The loses could be natural, however are likely due to historical mining at Tahmoor.

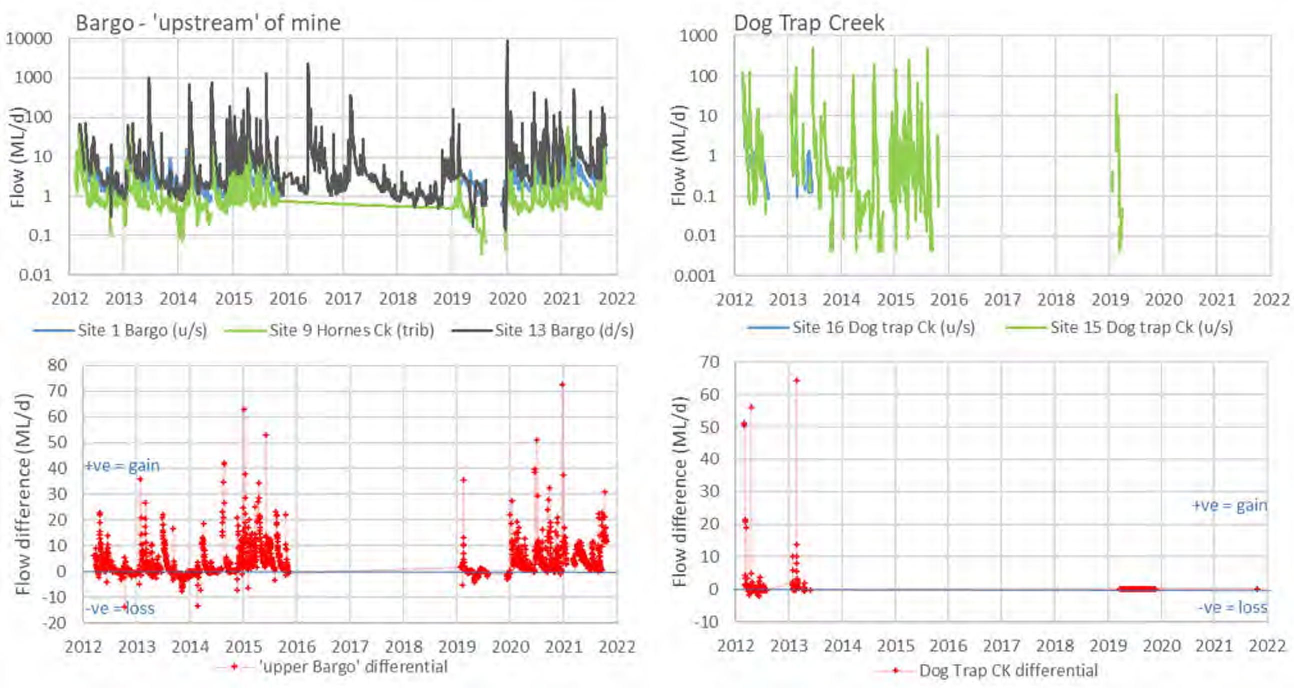


Figure 3-24 Flow differentials along Bargo River and Dogtrap Creek

3.6.3 Conceptual Model of Groundwater and Surface Water Impacts

Table 3-8 presents the anticipated mining-effects on water levels at Tahmoor South using observations across Tahmoor North and Western Domain. Details presented in Table 3-8 should remain as indicative due to limited data available for both the shallow groundwater level and surface water flow and level across Tahmoor South. Future baseline data collected from the proposed groundwater and surface water monitoring network will assist identifying any changes in surface and groundwater connectivity during mining / post mining and inferred estimates of surface water loss (if any) along relevant watercourses. As more data become available further analysis will be undertaken to understand groundwater and surface water interactions at Tahmoor South. The conceptual model will be updated to reflect those findings.

Table 3-8 Summary of anticipated mining effects on water levels at Tahmoor South

Water-course	Relevant Longwalls	Longwall distance to watercourses	Expected effects on shallow groundwater	Expected change to groundwater-surface water interaction and stream water levels
Teatree Hollow	LW S1A-S6A	Watercourse to be directly mined under	Effects are likely. Similar to shallow groundwater levels along Redbank Creek. No baseline data available over Redbank Creek to confirm magnitude of drawdown but recent response to groundwater recharge at bores along Redbank Creek typically show a groundwater recovery between 2-3 m and up to 5 m (i.e. possible historic drawdown).	Groundwater drawdown likely to reduce baseflow over under-mined reach. Expect similar observations as in Redbank Creek (i.e. loss of streamflow or re-emergence of diverted surface water downstream). A change in GW-SW condition is possible.
Bargo River	LW S1A-S6A	745 m	Minor effect is likely. Groundwater drawdown due to mining could be 0.5-1 m downstream the confluence with Hornes Creek, and to a lesser magnitude upstream of the Bargo River-Hornes Ck confluence.	Upstream of confluence with Hornes Creek – Possible reduction in baseflow during mining, with no discernible effect expected on SW post mining. Downstream of confluence with Hornes Creek –mined under by historical mining at Tahmoor, suggesting most of the mining-induced effect already occurred downstream. Cumulative mining-effect is possible, with reduction in baseflow during mining to be considered. SW-GW interaction expected to remain altered. Baseflow is likely to be reduced with surface water flow driven dominantly by surface run-off. Interactions could return to pre-mining condition if groundwater recovery is complete, otherwise medium-longer-terms impact to be considered downstream. Overall, LW S1A-S6A is not expected to cause significant change from current condition.
Hornes Creek	LW S6A; LW S6B (possibly LW S5A/B)	670 m	Minor effect is possible. Groundwater drawdown due to mining could be 0.5-1 m. Similar behaviour as observed along Cedar Creek near the Western Domain but effects are expected to be to a lesser degree due to distance; Hornes Creek is 670 m to the closest longwalls (LW S6A) while Cedar Creek is 60 m to LW W1.	Localised effect is possible during mining (i.e.as CB along Cedar Creek) but to a less degree due to distance to longwalls. Fracturing may play a role but has not been observed in Western Domain. Valley extension (opposite of closure) could occur. A change from gaining to losing condition is possible. Medium to long-terms impact to be considered.

4 Predicted Subsidence Impacts and Groundwater Impact Assessment

SLR was engaged by Tahmoor Coal to undertake a groundwater model rebuild for the Tahmoor Mine operations. Consent Condition B34 states that the Groundwater Management Plan includes;

- a Groundwater Modelling Plan that:
  - provides details for the future groundwater model re-build and recalibration which must be completed within 2 years of the commencement of development under this consent;
  - is independently third-party reviewed;
  - provides for the incorporation of the outcomes of the findings of the Thirlmere Lakes Research Program and other relevant research on the Thirlmere Lakes;
  - considers field data and the outcomes of subsidence monitoring; and
  - provides for periodic validation and where necessary recalibration, of the groundwater model for the development, including an independent review of the model every 3 years, and comparison of monitoring results with modelled predictions.

The Groundwater Modelling Plan (SLR, 2021) was completed and approved by the independent reviewer on the 23rd December 2021 (a copy of the memorandum is provided in Appendix E).

The Tahmoor Mine groundwater model is intended to inform the potential risk of environmental impacts associated with the historical, present, and future mining operations and meet Development Consent (SSD 8445) obligations as outlined in the B34 (v) and discussed above and presented in Section 2. The objectives of the groundwater model are to estimate:

- Mine inflows to the underground mine workings;
- Change in groundwater levels during and after mining, both within the Permo-Triassic strata and the alluvium associated with Thirlmere Lakes;
- Impacts on water supply for water users (i.e. private bores);
- Impacts on Groundwater Dependent Ecosystems (GDEs) including the Thirlmere Lakes;
- Change on baseflow and stream leakage to and from the Bargo and Nepean Rivers and their tributaries during and after mining;
- Estimate the storage capacity and groundwater recovery at Tahmoor Mine during and after the cessation of mining; and
- Inform possible changes in groundwater quality due to operations at Tahmoor Mine.

The numerical groundwater model builds on the previous groundwater models built for site. Tahmoor Coal recently established a data-sharing agreement with South32 who operate the nearby Dendrobium and Appin mines. This arrangement allows for the sharing of groundwater data, models and documentation. Under these agreements, the groundwater model extent is designed to incorporate both Dendrobium and Appin mines to allow for simulation of these mines as part of the cumulative impact assessment, as well as potentially allowing this numerical model to be used as a part of each mines' groundwater assessment process in the future. Of note, the current update of the groundwater model reported herein is the first iteration to include data and information from the Appin and Dendrobium sites.

A range of model updates were deemed required for the model to be considered fit for purpose. The updates to the model design from that reported in SLR (2020) included:

- Model extent and grid – adoption of an "unstructured" grid or mesh, revision of model extent and refinement of the mesh around mine areas;
- Model layers – update layers to include deepest mined seams at Tahmoor, update model layers to match Tahmoor, Dendrobium and Appin geological model surfaces, consider data from Sydney-Gunnedah Basin model in the layers, and update topography with the LiDAR data;
- Timing – extend calibration model period to December 2021 and refine timing to capture seasonality and mine progression changes;
- Boundary Conditions – update model boundary conditions with revised grid extent and regional flow; and
- Stresses – Maintain inputs, however updated with more recent and site-specific data.

A summary of updates to the model are discussed in Section 4.1, which presents how the conceptualisation has been developed as a numerical groundwater model, and Section 4.2 presents a summary of how well the model replicates observed data (calibration). A summary of how predicted groundwater impacts associated with LW S1A-S6A extraction is provided in Section 4.4. A more detailed description of the model and presentation of model results is provided in Appendix F.

4.1 Groundwater Model Design

4.1.1 Model Code

Numerical modelling was undertaken using Geographic Information Systems (GIS) in conjunction with MODFLOW-USG-Transport (Panday, 2021), which is distributed by the United States Geological Survey (USGS) and GSI Environmental. MODFLOW-USG is a relatively new version of the popular MODFLOW code (McDonald and Harbaugh, 1988) developed by the USGS. MODFLOW has been the most widely used code for groundwater modelling in the past and has long been considered an industry standard.

4.1.2 Model Extent and Mesh Design

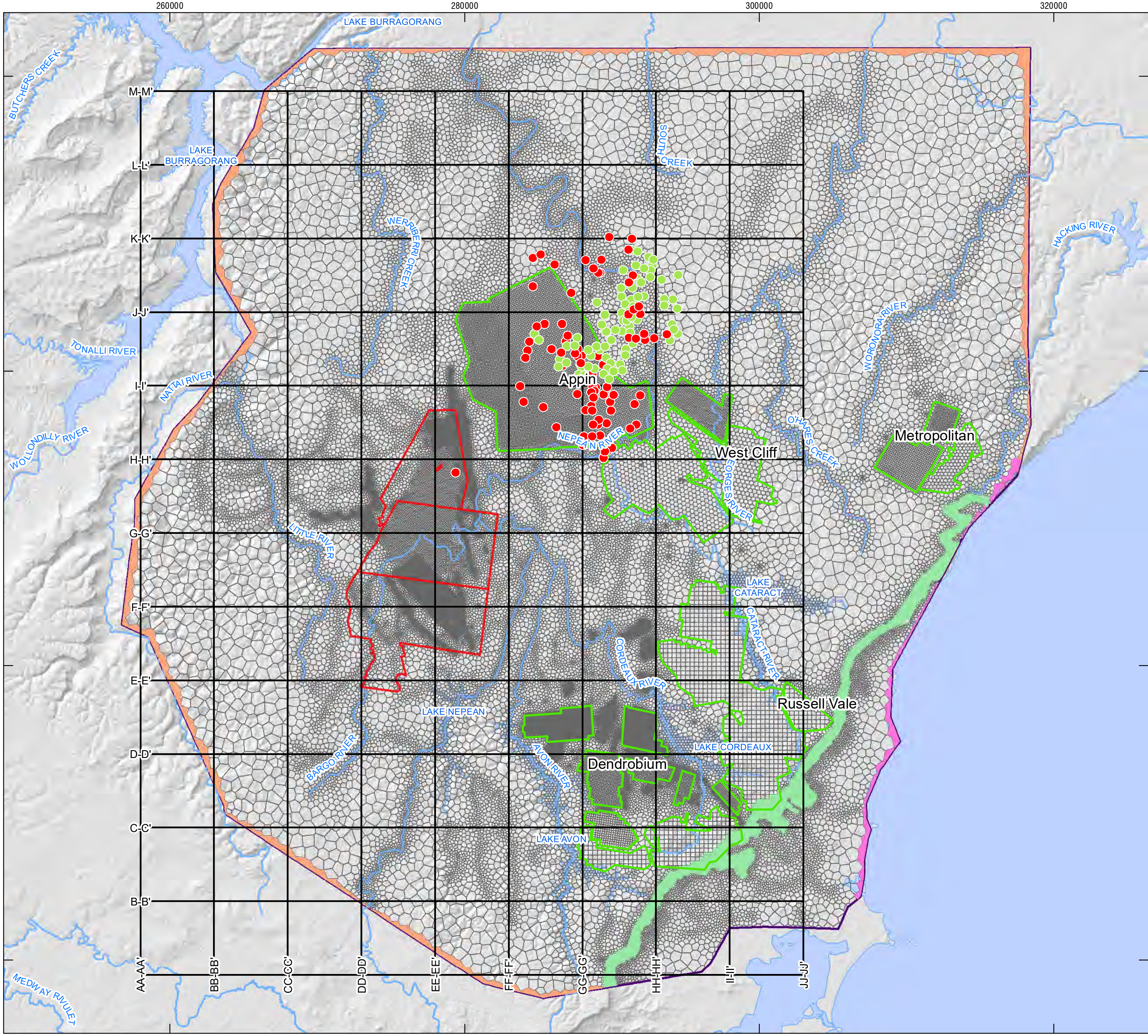
To allow for numerically stable modelling of the large spatial area of the model domain, an unstructured grid mainly comprised of Voronoi cells of varying sizes was designed using AlgoMesh (HydroAlgorithmics, 2014). Varying Voronoi cell sizes allowed refinement around areas of interest, while utilising a coarser resolution elsewhere, reduced the total cell count to a manageable number. In addition, pinch-out option of MODFLOW-USG were used, which means model layering does not need to be continuous over the model domain, and layers can stop where geological units pinch out or outcrop. This is also particularly useful when simulating thin, discontinuous hydrostratigraphic units and faults.

The model domain is shown in Figure 4-1. The horizontal and vertical extent of the numerical model is approximately 65 km N-S and 56 km W-E, exceeding that of previous models. The model domain was designed large enough to allow the adjacent mines/projects (including Appin, Dendrobium, Metropolitan, Russell Vale and Cordeaux coal mines) to be assessed for potential cumulative impacts. Additionally, the domain is large enough to prevent any influence on modelled drawdowns due to the model edge. To the east, the model extends beyond the subcrop line of the deepest coal seam (i.e. the Wongawilli Coal seam) that is likely to be mined at any of the surrounding mines in the future.

The model domain was selected based on the following considerations:

- The western and southern boundaries of the model is represented by the boundary of the Illawarra Coal Measures and Shoalhaven Group outcrops. The southern boundary of the model also follows the topographic high located approximately 21 km to the south of Tahmoor Mine;
- The eastern boundary of the model is set along the shoreline of the ocean near Wollongong and surrounding townships; and
- The northern model boundary is set approximately 25 km from the Project and is expected to be far outside the range of maximum predicted drawdown due to the Project.

The model domain was vertically discretised into 19 layers, each layer comprising up to 81,321 model cells. Areas in layers 2 to 18 were pinched out where the layer is not present based on the structural geology, resulting in a total of 1,340,263 cells in the model. In comparison to the SLR (2021) model which comprised 16 layers and 2,877,930 active model cells, the model grid provides improved discretisation of geological units and allows significantly reduced model run times, with less than half the number of active model cells.



TAHMOOR SOUTH LW S1A-S6A GROUNDWATER TECHNICAL REPORT

MODEL MESH AND BOUNDARY CONDITIONS

FIGURE 4-1

LEGEND

- Extraction Bore
- CSG Bore
- Cross Section
- Watercourse
- Tahmoor Coal Title
- Surrounding Mine
- Model Grid
- Drain Cell
- Fixed Head Cell
- General Head Boundary
- Model Domain
- Lake

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
Project Number:	610.30652
Date:	28-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

4.1.3 Layers and Features

Topography within the model domain has been defined using numerous sources. LiDAR data from the Tahmoor and the Dendrobium mine were used to define surface elevation. Outside the extents of the LiDAR dataset, public domain 25 m DEM data sourced from Geoscience Australia was used to define topography in the remainder of the model domain. Data extents of the sources used to construct model topography are shown in Figure 4-2.

The modelled strata is discretised into 19 layers, as listed in Table 4-1. Model layer extents (lateral and vertical) have been defined using data from the following sources:

- Tahmoor Coal, Tahmoor Mine Geology Model;
- South32, Dendrobium Mine Geology Model;
- South32, Appin Mine Geology Model;
- CSIRO Regolith mapping (CSIRO, 2015);
- Client/private/public bore logs;
- Geological Survey of NSW, Southern Coalfields Geological Model – Sydney Basin (herein referred to as the Sydney Basin Model); and
- NSW Government surface geology and basement geological maps.

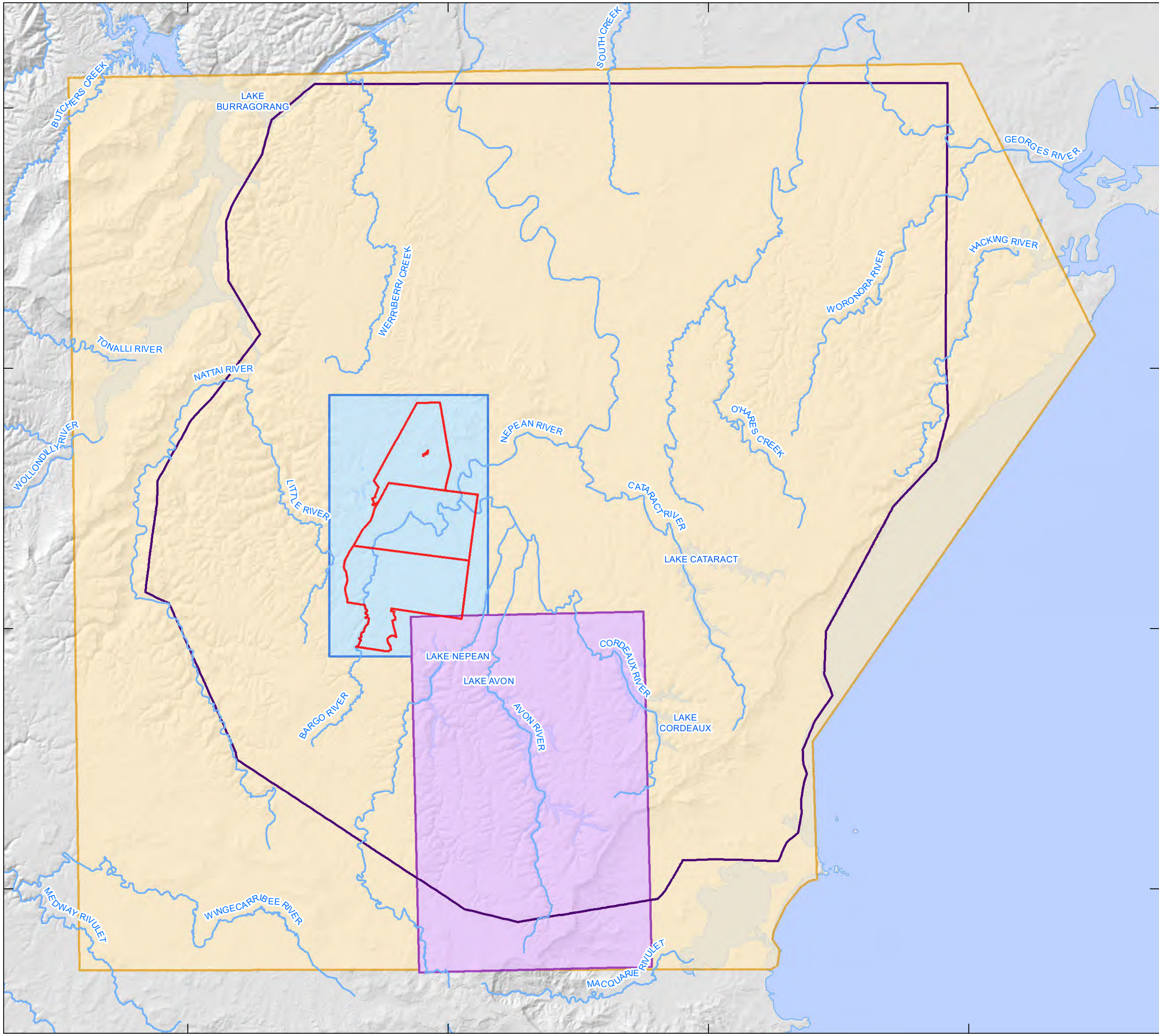
Model Layer 1 is fully extensive across the model with an average thickness of 4.3 m. In the model domain extension, the base of Layer 1 was interpreted from the national CSIRO Depth to Regolith dataset. Subsequently the base of Layer 1 was then updated to align with bore logs available across the model domain including Tahmoor monitoring bores and publicly available bore logs.

Model Layer 2 represents the Triassic Wianamatta Formation and is not fully extensive across the model domain. The extent of Layer 2 is based on the outcrop (and assumed subcrop) extent of the Wianamatta Formation shown on the Wollongong-Port Hacking 1:100,000 geological map (Geological Survey of New South Wales, 1985). Where the Wianamatta Formation is present, Layer 2 has an average thickness of 67 m. The elevation of the base of this layer was interpreted from the Sydney Basin Geological Model and available bore logs.

The lower layers are largely present across the model domain except for the river valleys and on the seaward side of the escarpment to the east. The Hawkesbury Sandstone is split into 3 layers to reduce the overall thickness, and to improve the model's ability to represent vertical hydraulic gradients and subsidence fracturing effects within this unit. Similarly, the Bulgo Sandstone and Scarborough Sandstone layers were split into multiple layers to avoid having excessive thickness in the model layers and to provide enough vertical resolution to better represent the fracturing zone above longwalls.

Within Tahmoor, Dendrobium and Appin mine areas, the layering from each mine's geology model has been adopted. Where overlap occurs between the different site geology models, the layers have either been averaged where appropriate or a specific site geology model has been given preference over another based on the proximity to the mine plan (with the assumption that the accuracy of a given site geology model is highest where the mine plans have been developed). Linear interpolation techniques were employed to achieve smooth transition between the site geology models provided.

Table 4-1 presents the average and maximum thicknesses across the model domain for each layer.



TAHMOOR SOUTH LW S1A-S6A GROUNDWATER TECHNICAL REPORT

EXTENT OF TOPOGRAPHY DATA

FIGURE 4-2

LEGEND

- Watercourse
- Tahmoor Coal Title
- Model Domain
- Lake

Topography Data Source

- Regional 25m DEM
- Dendrobium LiDAR
- Tahmoor Coal LiDAR

0 5 10 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:400,000 at A4
Project Number:	610.30652
Date:	25-Mar-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

Table 4-1 Model Layers

Layer	Lithology	Average Thickness (m) [1]	Maximum Thickness (m)	Source
1	Regolith, alluvium and basalt	4.3	25.8	CSIRO Depth of Regolith, Bore logs
2	Wianamatta Formation	67.0	307.1	Geo100k, Syd Basin Model, Bore Logs, Site Geo Models
3	Hawkesbury Sandstone - upper	49.3	182.6	Geo100k, Site Geo Models, Syd Basin Model
4	Hawkesbury Sandstone - middle	51.3	80.3	Site Geo Models, Syd Basin Model
5	Hawkesbury Sandstone - lower	54.8	82.7	Site Geo Models, Syd Basin Model
6	Bald Hill Claystone	35.1	153.8	Site Geo Models, Syd Basin Model
7	Bulgo Sandstone - upper	55.2	109.3	Site Geo Models, Syd Basin Model
8	Bulgo Sandstone - middle	55.1	109.3	Site Geo Models, Syd Basin Model
9	Bulgo Sandstone - lower	56.7	112.6	Site Geo Models, Syd Basin Model
10	Stanwell Park Claystone	10.1	106.9	Site Geo Models, Syd Basin Model
11	Scarborough Sandstone - upper	15.7	57.7	Site Geo Models, Syd Basin Model
12	Scarborough Sandstone - lower	16.4	57.7	Site Geo Models, Syd Basin Model
13	Wombarra Claystone	19.2	99.7	Site Geo Models, Syd Basin Model
14	Coal Cliff Sandstone	12.2	41.2	Site Geo Models, Syd Basin Model
15	Bulli Coal Seam	2.3	7.6	Site Geo Models, Syd Basin Model
16	Eckersley Formation	24.9	106.6	Site Geo Models, Syd Basin Model
17	Wongawilli Coal Seam	8.9	33.6	Site Geo Models, Syd Basin Model
18	Kembla Sandstone	11.5	41.3	Site Geo Models, Syd Basin Model
19	Older units (lower Permian Coal Measures and Shoalhaven Group)	293.8	369.0	300 m Below Kembla Sandstone Pre-eroded, minimum thickness of 15m

[1] Average value excludes pinched out cells/layers

Figure 4-3 and Figure 4-4 show the model layers in a horizontal and a vertical cross-section through Tahmoor Mine.

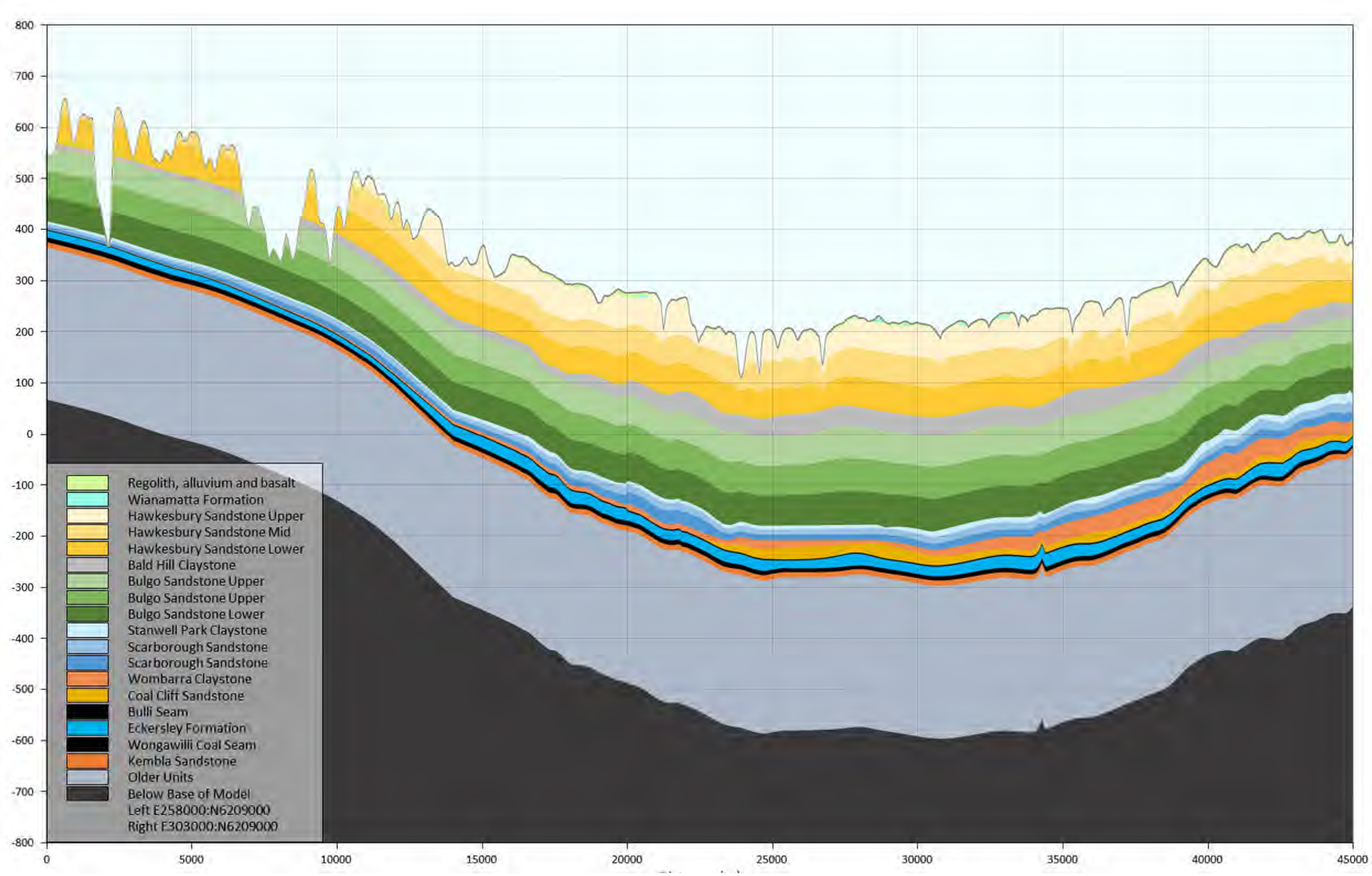


Figure 4-3 Model Layers Cross Section G-G'

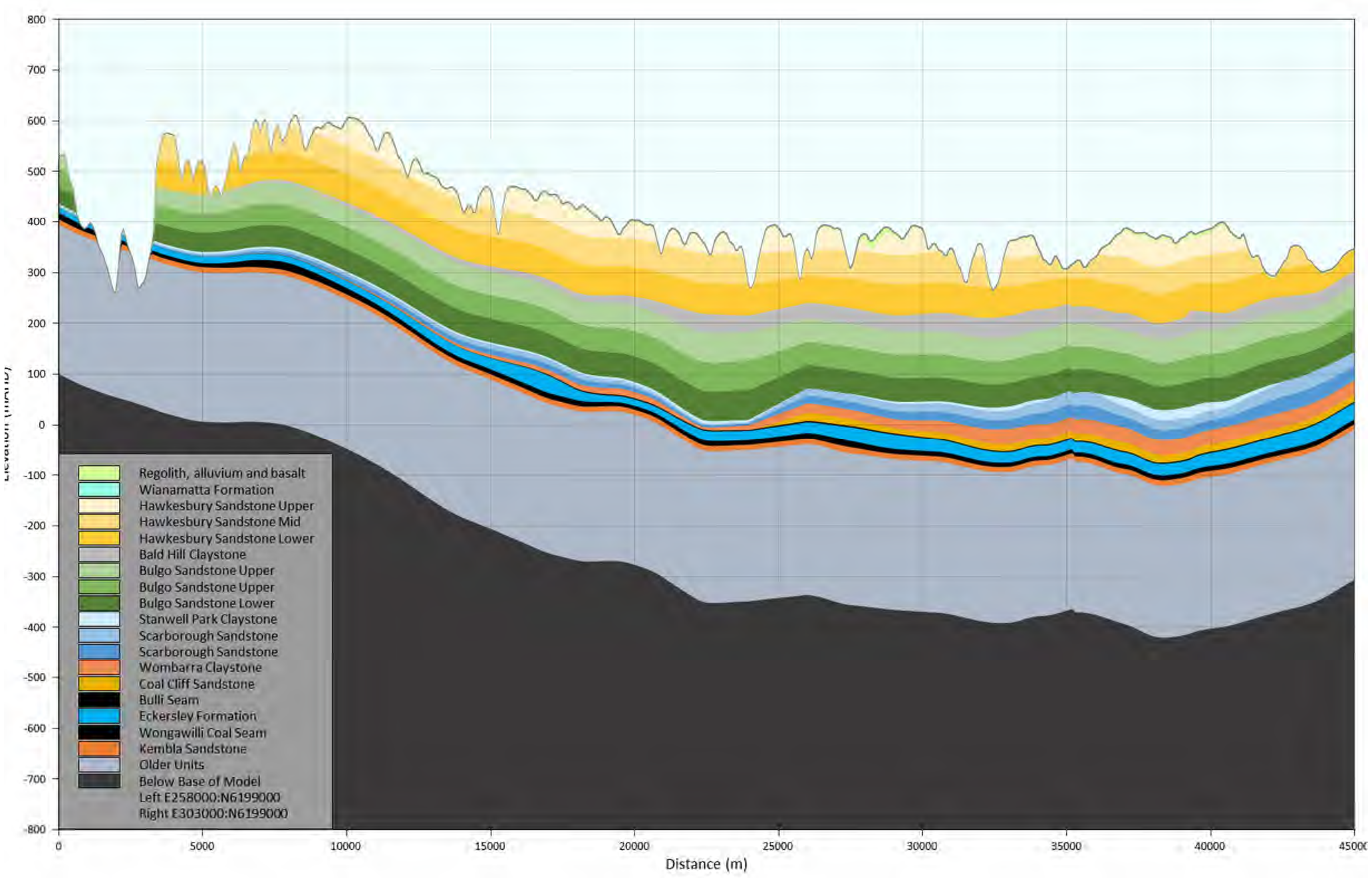
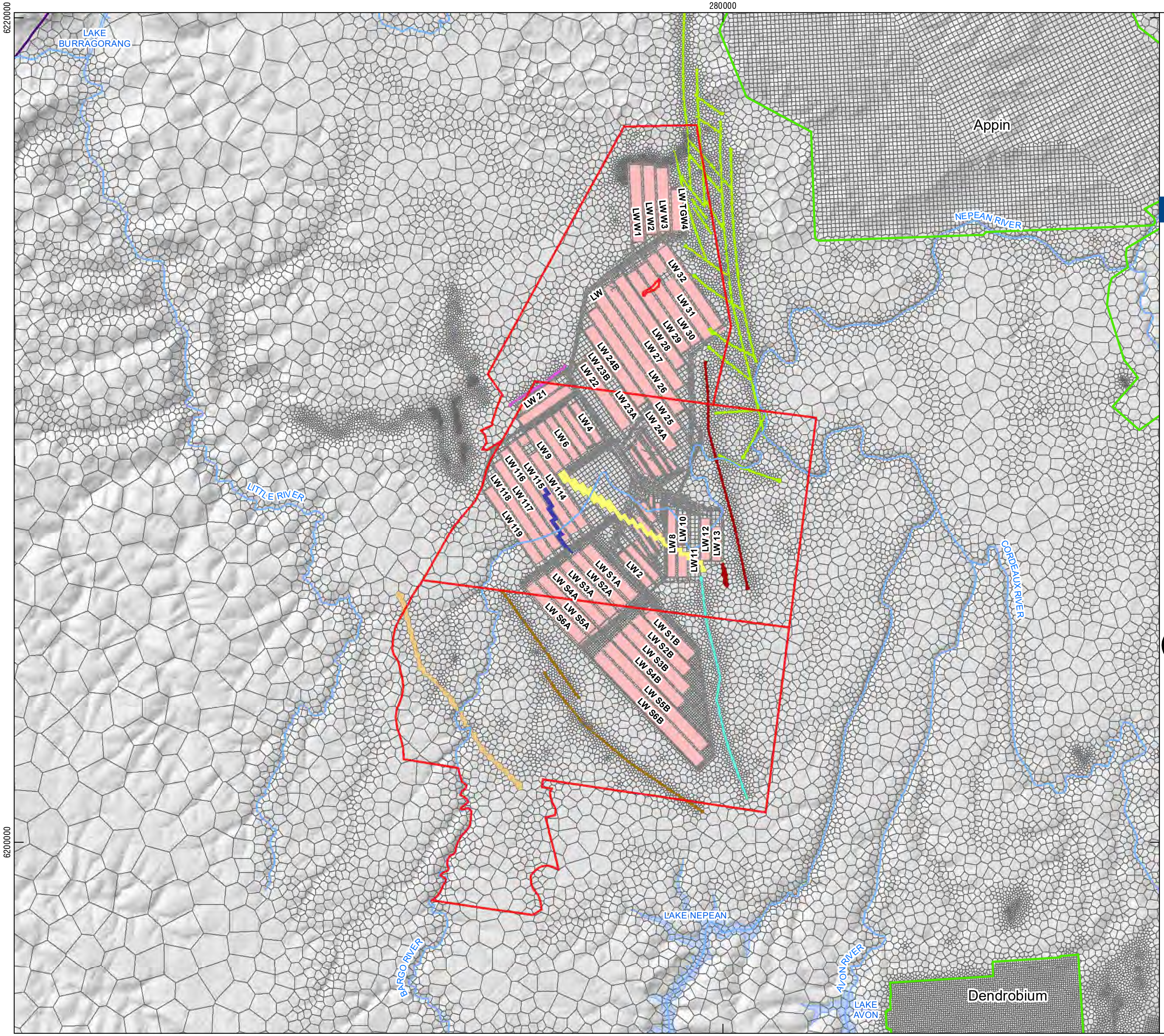


Figure 4-4 Model Layers Cross Section EE-EE'

4.1.4 Structural Geology

The structural geology at Tahmoor and surrounds is influenced by a series of folds and faults and dykes of volcanic origin, varying in age from Jurassic to Tertiary. The Nepean Fault is the major structural feature of interest to operations conducted by Tahmoor Coal. The other two major faults present at site are the 'T1' and 'T2' faults. These faults are mapped to the north and northwest of the Tahmoor South longwalls. The smaller faults near the site are the Central and Western Faults which trend NW-SE and are mapped just off the southern limit of the Tahmoor South longwalls. Further detail on structural geology was provided in Section 3.4.2.

The Nepean Fault, T1 and T2 Fault, and Central and Western Faults have been simulated in the groundwater model domain as separate hydraulic zones. The hydraulic properties of the fault zones were adjusted during the model calibration. Figure 4-5 shows the locations of geological fault zones represented in the model.



TAHMOOR COAL
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MODELLED FAULT ZONES

FIGURE 4-5

LEGEND

- Watercourse
- Tahmoor Coal Title
- Surrounding Mine
- Mine Plan
- Model Grid
- Lake

Modelled Fault

- Nepean Fault Complex
- T1 Fault
- Neapean Fault
- T2 East Fault
- T2 West Fault
- Southeastern Fault
- Central Fault
- Western Fault

0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:125,000 at A4
Project Number:	610.30652
Date:	13-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

4.1.5 Timing

A combined steady state and transient model was developed, as follows:

- Steady state to replicate pre-mining conditions;
- Transient warm-up model for pre-2009 conditions to replicate influence of historical mining;
- Transient calibration model from January 2009 to December 2021 with quarterly time intervals; and
- Transient predictive model from December 2021 to December 2026 with quarterly time intervals.

The transient warm-up model period was built to incorporate pre-2001 mining activities and their impacts on groundwater levels around the Project Area. The transient warm up model covered a time period from 1969 to January 2009 and included 8 time slices each with a length of 5 years. The warm-up model was used to change model cell properties due to the underground mining within the model extent before 2009. This then provided appropriate starting conditions for the calibration model (i.e. starting heads and hydraulic properties).

To assist the model in overcoming the numerical difficulties, MODFLOW-USG Adaptive Time-Stepping (ATS) option was used. The ATS option of MODFLOW automatically decreases time-step size when the simulation becomes numerically difficult and increases it when the difficulty passes. The minimum time step size used in the simulations was 1 day.

The new numerical model ran in 3.5 hrs (from start of the calibration to end of prediction period), which is approximately 14% of the runtime from previous model (SLR, 2021). This facilitated automated calibration techniques (leading to uncertainty analysis), including the use of pilot points for assigning hydraulic properties to important strata.

4.1.6 Boundary Conditions and Stresses

4.1.6.1 Regional Groundwater Flow

The model boundary conditions are presented in Figure 4-1. At the edges of the model domain where it is expected that groundwater will be transmitted in or out of the model domain, primarily in the west, north and south, MODFLOW General Head Boundary condition (GHB) were assigned. A ’no flow’ boundary was applied to the western boundary of the model which represents the outcrop of the older units (lower Permian Coal Measures and Shoalhaven Group). Fixed head boundaries at 0 mAHD were assigned along the eastern boundary of model in all of layers 1 to 4 to represent the ocean.

Springs emanating from the Illawarra Escarpment along and inside the south-east margin of the model domain were simulated using the MODFLOW Drain package. The Drain boundary condition allows one-way flow of water out of the model. When the computed head drops below the stage elevation of the drain, the drain cells become inactive. These drains were simulated as occurring at the ground surface along the escarpment, placing them between model layers 3 and 15 depending on local stratigraphy. A high conductance was assigned to these model cells to represent ‘spring-like’ behaviour where groundwater flow can be discharged along the face of the escarpment. Having a drain elevation set at topography means that any groundwater contributed as ‘baseflow’ to these features is discharged from the system, removing the opportunity for these features to gain water and return flow to the system.

4.1.6.2 Surface Drainages

There are a significant number of surface water features that exist within the model extent. Creeks and Rivers throughout the model domain were modelled using MODFLOW's River (RIV) package. Use of the River package allows the surface drainage features (watercourses) to remain as potential source of water to the underlying porous rock aquifers.

River cells in the model are shown in Figure 4-6. As shown in the figure, major rivers and streams as well as minor creeks were built into the model. The major rivers within and around the Project area included in the RIV package are presented in Table 4-2.

To allow climate variability to be represented in the model, variable stage height is utilised to simulate watercourses within the model domain. Where possible, the variable stage height in the RIV package was calculated using the river level data recorded in the stations within the model domain. Data from 82 surface water monitoring stations within the model domain were included in the RIV package. The stations include 37 from the NSW Government monitoring sites, 19 from Tahmoor North Monitoring Sites, 12 from Western Domain Monitoring Sites and 14 from Tahmoor South Monitoring Sites.

Rivers with multiple stream level stations were split to a few zones in the RIV package to allow information from as many stations as possible to be captured in the model. The zonation can be seen for the Stonequarry Creek, Myrtle Creek, Nepean River and Bargo River in Figure 4-6.

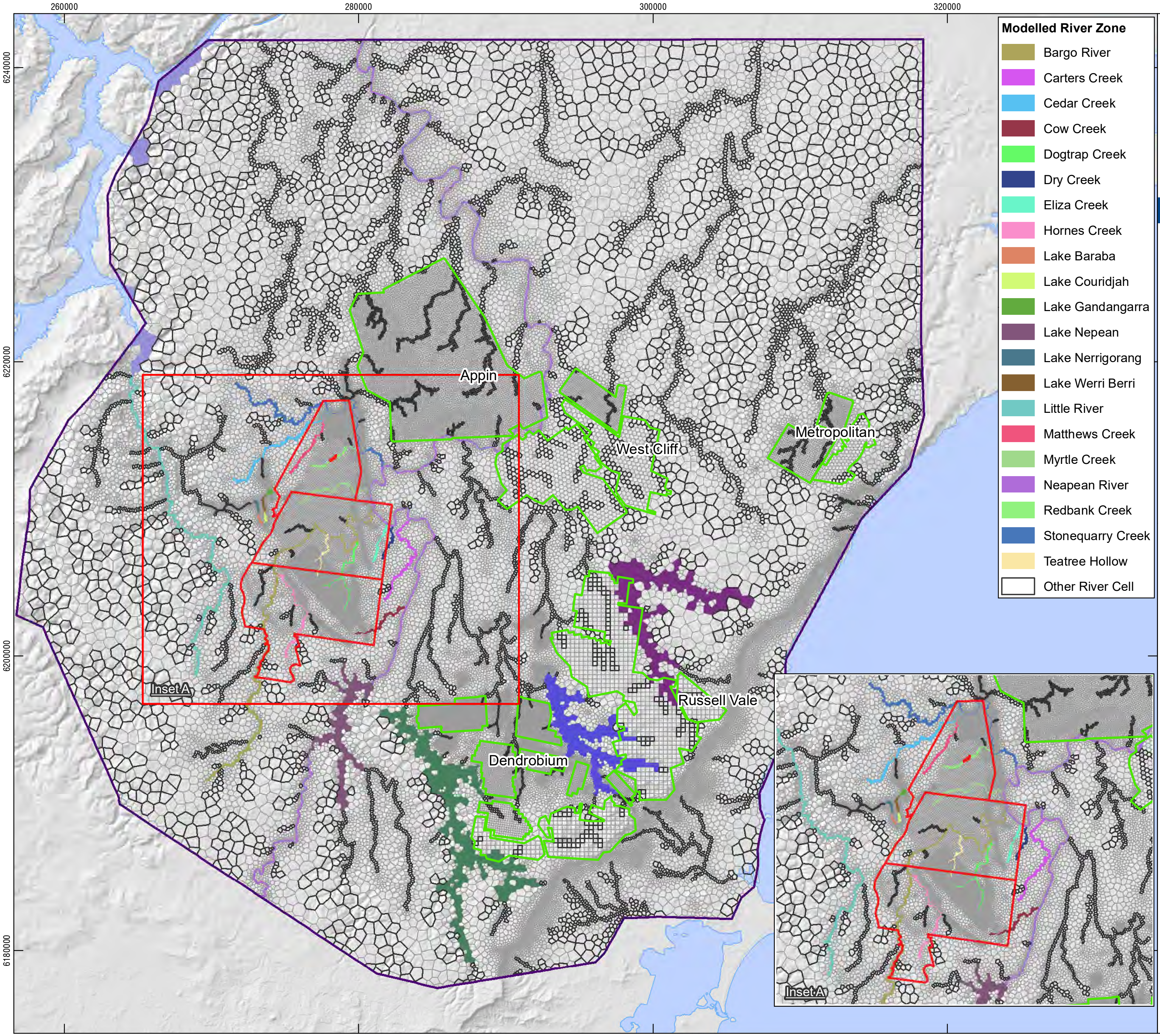
As described in Table 4-2, historical quarterly average stage heights were used in both the calibration and prediction model. Using quarterly time slices is a simplified way to tie river stage height fluctuations to rainfall trends. It is important to note that the intent of modelling is to capture the long-term impacts of groundwater and surface water interaction. Due to the model time resolution (quarterly), the model is not set up or able to adequately capture the short-term (i.e. daily) climate response and interaction between groundwater and surface water.

The river stage height (water depth) in the minor tributaries or drainage lines was set to 0 m (i.e. modelled river stage elevation was equal to river bottom elevation). Therefore, the minor tributaries or drainage lines act as drains to the groundwater system, i.e. can receive baseflow, but do not result in any recharge from surface water to the underlying groundwater system.

Table 4-2 River and Surface Water Features in the Tahmoor Model

Boundary	River Stage (m)	River Bed Kz (m/day) (Initial value)
Nepean River	- SS simulation - Long-term Average - Calibration simulation - Historical Quarterly Average - Prediction simulation- Transient Stage Height- Long Term Quarterly Average	0.005
Bargo River, Avon River, Cordeaux River	- SS simulation - Long-term Average - Calibration simulation - Historical Quarterly Average - Prediction simulation- Transient Stage Height - Long Term Quarterly Average	$1x10^{-4}$ - 0.005

Boundary	River Stage (m)	River Bed Kz (m/day) (Initial value)
Stonequarry Creek	- SS simulation - Long-term Average - Calibration simulation - Historical Quarterly Average - Prediction simulation- Transient Stage Height- Long Term Quarterly Average	0.01
Cedar Creek, Redbank Creek, Matthews Creek, Myrtle Creek, Eliza Creek, Dogtrap Creek, Cow Creek, Hornes Creek, Teatree Hollow, Carters Creek, Dry Creek	- SS simulation - Long-term Average - Calibration simulation - Historical Quarterly Average - Prediction simulation - Transient Stage Height - Long Term Quarterly Average	0.005 - 0.1
Rumker Gully, Newlands Gully	- SS simulation - Long-term Average - Calibration simulation - Historical Quarterly Average - Prediction simulation - Transient Stage Height- Long Term Quarterly Average	0.005 - 0.01
Other minor creeks	- SS simulation - Long-term Average - Calibration simulation - Fixed Stage - Prediction simulation - Fixed Stage	$1x10^{-4}$ - 0.005



TAHMOOR COAL
LW S1A-S6A
GROUNDWATER TECHNICAL REPORT

MODELLED RIVER ZONES

FIGURE 4-6

LEGEND

- Tahmoor Coal Title
- Surrounding Mine
- Model Domain
- Model Grid
- Lake

0 5 10 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
Project Number:	610.30652
Date:	05-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

4.1.6.3 Lakes and Reservoirs

The Thirlmere Lakes and the water supply reservoirs within the model domain were represented using the MODFLOW River Package. The lakes and reservoirs simulated in the model are presented in Figure 4-6. The following reservoirs were simulated in the model:

- Lake Burragorang (Warragamba Dam), 18 km northwest of Tahmoor South Domain;
- Lake Nepean 3 km south of the Tahmoor South Domain;
- Lake Avon, 6 km south-southeast of the Tahmoor South Domain;
- Lake Cordeaux, 14 km east-southeast of the Tahmoor Mine;
- Lake Cataract, 18 km east of the Tahmoor Mine; and
- Lake Woronora, 30 km east of the Tahmoor Mine.

For the calibration model, quarterly averages of the historical levels for the reservoirs were used. For the prediction period, long term quarterly averages of lakes levels were used in the model.

For the Thirlmere Lakes, bed elevations were defined based on the zero-gauge data from the government gauging stations (212063, 212065,212066,212067 and 212068) for the 2013 to 2021 period. Data is not available from the stations prior to 2013. Therefore, data from Pells (2011), HEC (2018), Schadler (2016) and Kingsford (2016) were also used to fill the gaps in lake level records prior to 2013.

For the prediction period, the lake stages were set at constant levels using the long-term historical average. The levels for the prediction model, were set as Gandangarra (302.4 mAHD), Werri Berri (302.0 mAHD), Couridjah (302.5 mAHD), Baraba (304.8 mAHD), and Nerrigorang (301 mAHD). The findings of the Thirlmere Lakes Research Program (TLRP) on the Thirlmere Lakes only became available after the groundwater model construction was complete. Therefore, the outcomes of the TLRP were not included in the model design and are considered a future improvement for the future versions of the model. However, comparing the simulated lake levels in the model against the levels presented in Table 3-1 of Research Report 268, "*Developing an integrated water balance budget for Thirlmere Lakes*" (Chen, et. al. 2020), shows a good alignment.

The initial values for riverbed conductance for all the lakes were adopted from the previous model (SLR, 2021). These values were subsequently varied during the calibration process.

4.1.6.4 Recharge

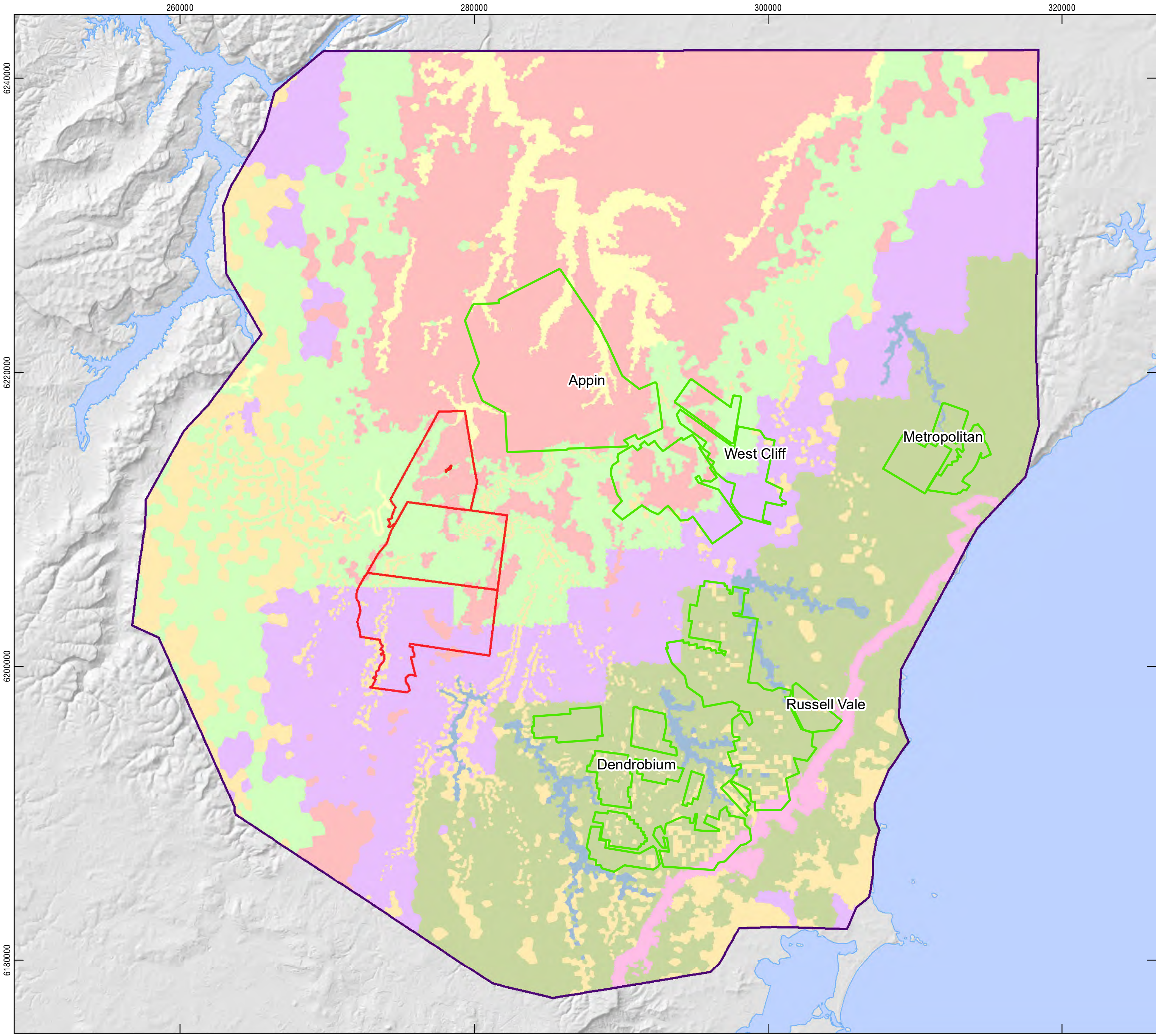
The dominant mechanism for recharge to the groundwater system is through diffuse infiltration of rainfall through the soil profile and subsequent deep drainage to underlying groundwater systems. Diffuse rainfall recharge to the model was represented using the MODFLOW-USG Recharge package (RCH).

Recharge zones have been established based on surface geology and rainfall spatial variation to simulate variation in local recharge due to these factors. Long-term precipitation data from BoM indicates higher annual rainfall in the east and south at the coast or near the escarpment, with rainfall declining inland to the north and west. Therefore, three main regions of rainfall (high, moderate, and low) have been considered in recharge zonation. The influence of outcrop geology on groundwater recharge in the Project area has previously been investigated (HydroSimulations, 2019) and is simulated using separate zones for Alluvium, Wianamatta Shale, and the Hawkesbury Sandstone (with which various other sandstones have been included).

The model included 8 recharge zones, as presented in Figure 4-7 and listed below:

- Alluvium – Zone 1;
- Alluvium – Zone 2;
- Wianamatta Formation – Low rainfall;
- Hawkesbury Sandstone – Zone 1;
- Hawkesbury Sandstone - Zone 2;
- Hawkesbury Sandstone– Zone 3;
- Coastal Escarpment; and
- Surface Water Bodies.

Recharge rates were established through the calibration process, with bounds based on the conceptual understanding of the system and comparing them with other groundwater models prepared for the region.



TAHMOOR COAL
LW S1A-S6A
GROUNDWATER
TECHNICAL REPORT

MODELLED RECHARGE ZONES

FIGURE 4-7

LEGEND

- Tahmoor Coal Title
- Surrounding Mine
- Model Domain
- Lake

Recharge Zone

- Alluvium, Low Rainfall
- Alluvium, High rainfall
- Wanamatta Formation, Low rainfall
- Hawkesbury Sandstone, Low rainfall
- Hawkesbury Sandstone, Moderate rainfall
- Hawkesbury Sandstone, High rainfall
- Escarpment
- Surface Water Bodies

0 5 10 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
Project Number:	610.30652
Date:	13-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

4.1.6.5 Evapotranspiration

Evapotranspiration from the shallow water table was simulated using the evapotranspiration package (EVT). Evapotranspiration zones (Figure 4-8) were established based on mapped land-use (ABARES), and land cover estimated through satellite imagery:

- Forest/Conservation;
- Grazing land;
- Rivers and drainage systems;
- Tree/shrub cover;
- Urban; and
- Escarpment.

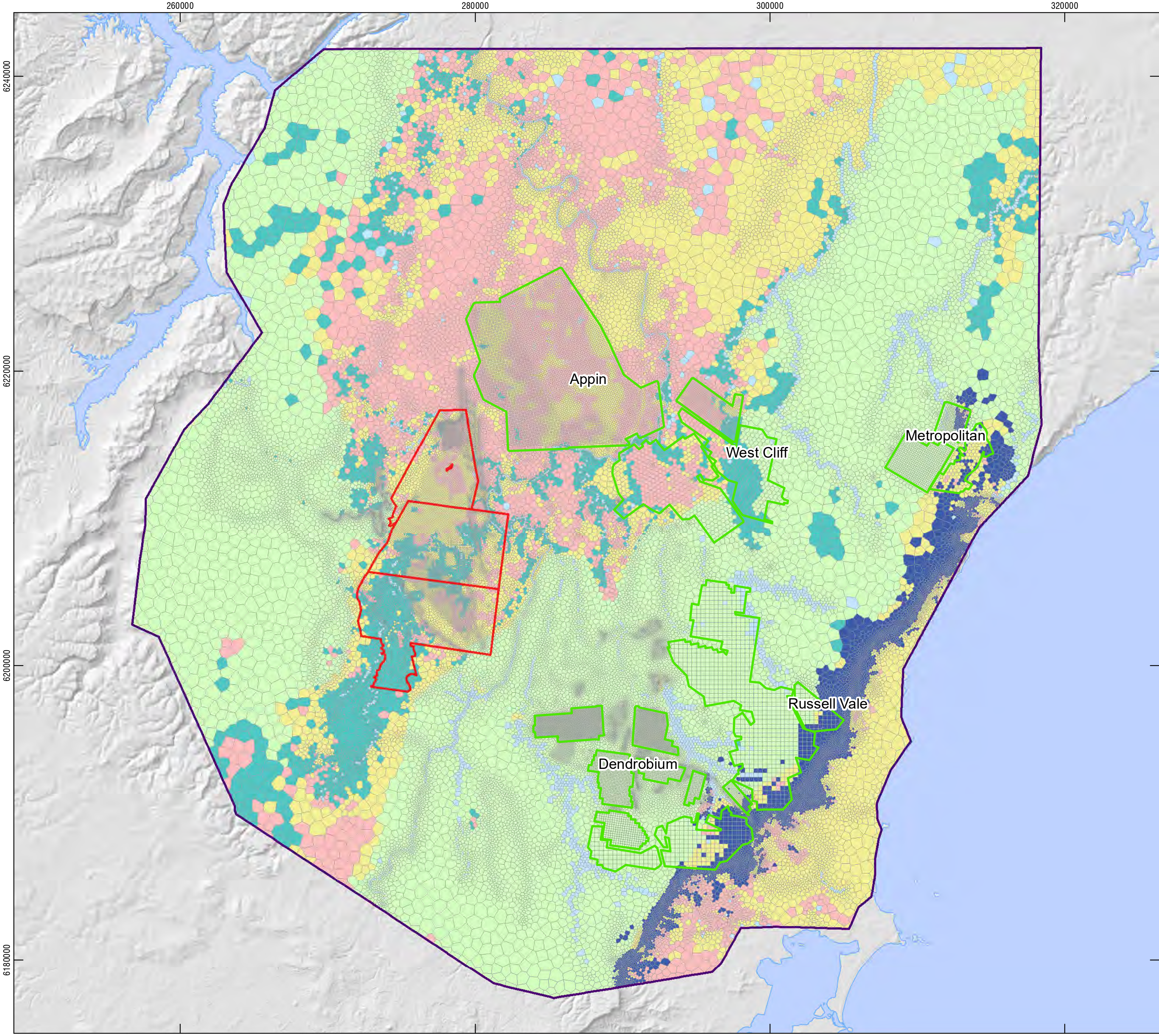
Evapotranspiration was represented in the upper most cells of the model domain to an extinction depth up to 3 m, dependent on zone. A maximum rate of evapotranspiration was set based on the data from the SILO Grid Point observations for the closest location (Lat: -34.20, Long: 150.60).

The extinction depth applied to MODFLOW for the primary vegetation or land use zones has been estimated at 0.8-1 m for urban / grassed / pasture areas, and 3 m for trees. The spatial extent of these broad vegetation types as based on the National Scale v4 land use mapping by ABARES.

TAHMOOR COAL
LW S1A-S6A GROUNDWATER TECHNICAL REPORT

MODELLED EVT ZONES

FIGURE 4-8



LEGEND

- Tahmoor Coal Title
- Surrounding Mine
- Model Domain
- Model Grid
- Lake

EVT Zone

- Forest/conservation
- Grazing
- River/drainage
- Tree/shrub cover
- Urban
- Escarpment

0 5 10 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
Project Number:	610.30652
Date:	28-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

4.1.6.6 Groundwater Use

As discussed in Section 3.5.8.3, a number of groundwater bores were identified as subject to potential impact via extraction in the Tahmoor South Domain during the EIS process (HydroSimulations, 2018). A bore census conducted between January and March of 2022 attempted to capture all 52 bores identified. Resultantly, 40 bores underwent a field survey to identify current bore condition (i.e. depth, status), groundwater conditions (i.e. depth to water, water quality) and use regime (i.e. currently used, disused). Current extraction from these bores was not included in the model because of the uncertainty associated with the actual extraction (rather than the entitlement). Consequently, the model does not account for bore pumping effects around LW S1A-S6A and the immediate surrounding area.

To the north, at and near to Appin Mine, 83 licensed registered water supply bores are located within the model domain. Majority of the groundwater usage in the area is from the Hawkesbury Sandstone or surficial alluvium and basalt aquifers. The MODFLOW-USG WELL package was used to capture the water take from 83 licensed registered water supply bores at Appin. The pumping rates for the water supply bores were adopted from the Appin Groundwater Impact Assessment (SLR, 2021).

The AGL Camden Gas Project is a located to the north of Appin Mine. The Camden Gas Project has been in operation since 2001. The Camden Gas Project comprises 137 wells (86 currently active) which target the Bulli and Balgownie seams approximately 14 km north of Tahmoor Mine. The gas extractions rates for the water supply bores were adopted from the Appin Groundwater Impact Assessment (SLR, 2021), and were derived from AGL (2013) study. The MODFLOW Well (WELL) package was used to present these Camden Gas Project production wells to replicate depressurisation within the Bulli Seam. Within the model the Camden Gas Project wells commenced operation based on the date of installation and were turned off at 2023 (AGL, 2018).

The pumping bores and the CSG wells included in the model are shown in Figure 4-1.

4.1.6.7 Mining

The MODFLOW Drain (DRN) package was used to simulate mine dewatering in the model for Tahmoor Coal operations and the surrounding mines. Drain boundary conditions allow a one-way flow of water out of the model. In both the calibration and prediction model, mining at Tahmoor (including Tahmoor North and South) was simulated based on the historical and future mine plan provided by Tahmoor Coal. The historical and proposed underground mining and dewatering activity at the following neighbouring mines were also included in the model:

- Bulli Seam Operations (BSO) and Appin Mine (historical and approved);
- Russell Vale (historical);
- Metropolitan Mine (historical and approved);
- Cordeaux Mine (historical);
- Dendrobium Mine (historical and approved domains); and
- Kemira, Mt Kembla, Nebo, Wongawilli, Elouera Mine (historical).

Historical mining at the Appin and Dendrobium operations was simulated using the model set-up from the SLR (2021) groundwater model. For other operations and periods, publicly available information was used to incorporate the mining activities. The modelled progression and timing of mining is presented in Figure 4-9.

The historical and proposed underground mining and dewatering activity at all the mines within the model domain target the Bulli Coal seam, except for parts of the Dendrobium domain, Kemira, Mt Kembla, Nebo, Wongawilli, Elouera Mine that target the Wongawilli Coal seam.

Drain cells were applied to each worked seam with drain elevations set to the base of the seam. These drain cells were applied wherever workings occur and were progressed through temporal increments in the transient model setup. A drain conductance value of 100 m^2/day was applied for all longwalls, roadways and development headings.

After goaf areas were mined out, the model Drains were inactivated in both the panel area and the neighbouring gate roads. Drains representing mains and roadways required for the continued operation of the mine were maintained as active until the end of their operational life, which could be as late as the end of the Tahmoor operation, until 2022 in Tahmoor North, or until around 2040 in Tahmoor South. The development headings were activated in advance of the active mining and subsequent subsidence, either one stress period ahead of active mining or based on a schedule provided by Tahmoor Coal.

MODFLOW-USG time varying materials (TVM) used to change the hydraulic properties of the model cells were with time to replicate the goaf and fractured zone above each longwall panel.

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LW S1A-S6A GROUNDWATER TECHNICAL REPORT

MODELLED MINE PROGRESSION

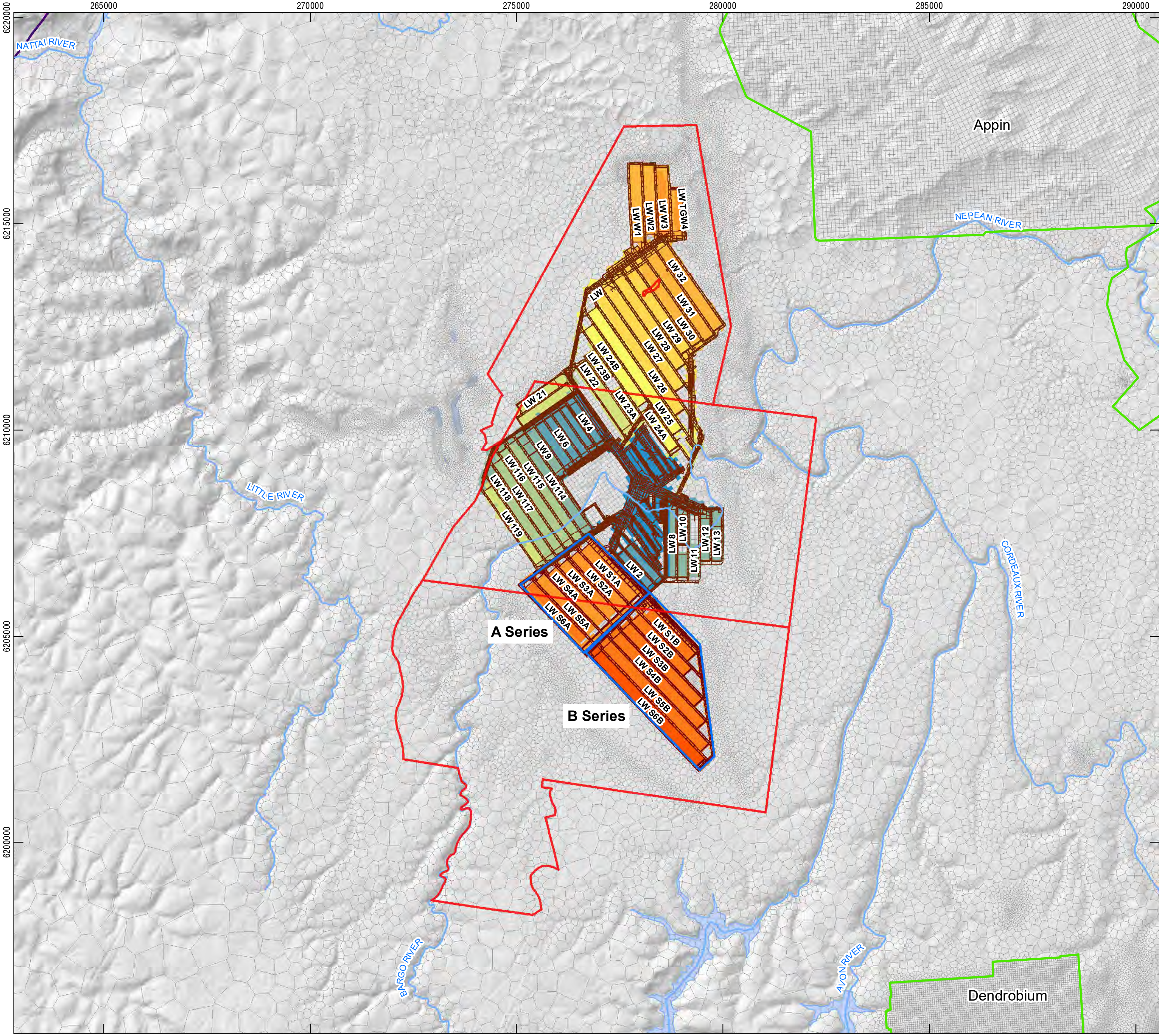

FIGURE 4-9

LEGEND

- Watercourse
- Tahmoor Coal Title
- Surrounding Mine
- Mine Plan
- Model Domain
- Model Grid
- Lake

Mine Progression (5 Years)

- 1981 - 1985
- 1986 - 1990
- 1991 - 1995
- 1996 - 2000
- 2001 - 2005
- 2006 - 2010
- 2011 - 2015
- 2016 - 2020
- 2021 - 2025
- 2026 - 2030
- 2031 - 2032

0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:125,000 at A4
Project Number:	610.30652
Date:	28-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30652.00000 Tahmoor Coal Groundwater Model Rebuild\06 SLR Data\01 CADGIS\GIS\ModellingReport\610 30652 F02_17 Modelled Mine Progression.mxd

4.1.6.8 Variation in Model Hydraulic Properties due to Longwall Mining

The Ditton method is the preferred method to represent the connected fractured zone (Zone A) as it is similar to, and in some instances, more conservative than the Tammetta (2013) method for longwall geometry at Tahmoor Mine. The Ditton A95 estimated fracture height is consistent with data collected by SCT (SCT, 2014 and 2021) at Tahmoor. Ditton (2014) also estimates the height of disconnected fracturing (Zone B).

The height of connected fracturing was estimated on a cell-by-cell basis using the method of Ditton A95 and the height of disconnected fracturing was estimated on a cell-by-cell basis using Ditton B95. Figure 4-10 shows the highest layer in the model that the height of Zone A and Zone B extend across the mine area. As shown in Figure 4-10, the connected fracturing primarily reaches Layers 7 and 8 of the model (Bulgo Sandstone middle and upper), except a small area within LW S1A and S2A where connected cracking reached Layer 6 (Bald Hill Claystone). Figure 4-10 shows the simulated disconnected fracturing reached Layer 4 and Layer 5 of the model which represent the middle and lower HBSS, respectively.

The fracture zones are represented in the groundwater model via an increase in the horizontal and vertical hydraulic conductivity, and the specific yield (only in disconnected fracturing zone) of the model layers above the seam in each extracted longwall panel using the Time-Varying Material properties (TVM) package of MODFLOW-USG-Transport.

Site-specific measurements of post-mining strata properties in the fracture profile are not available. However, data from boreholes S2398 and S2398A, which were used for pre- and post-mining investigations at Dendrobium Mine, is available (Watershed HydroGeo, 2020). The observed post-mining values at these bores were used to guide the updated post-mining properties simulated in groundwater model for Tahmoor Mine.

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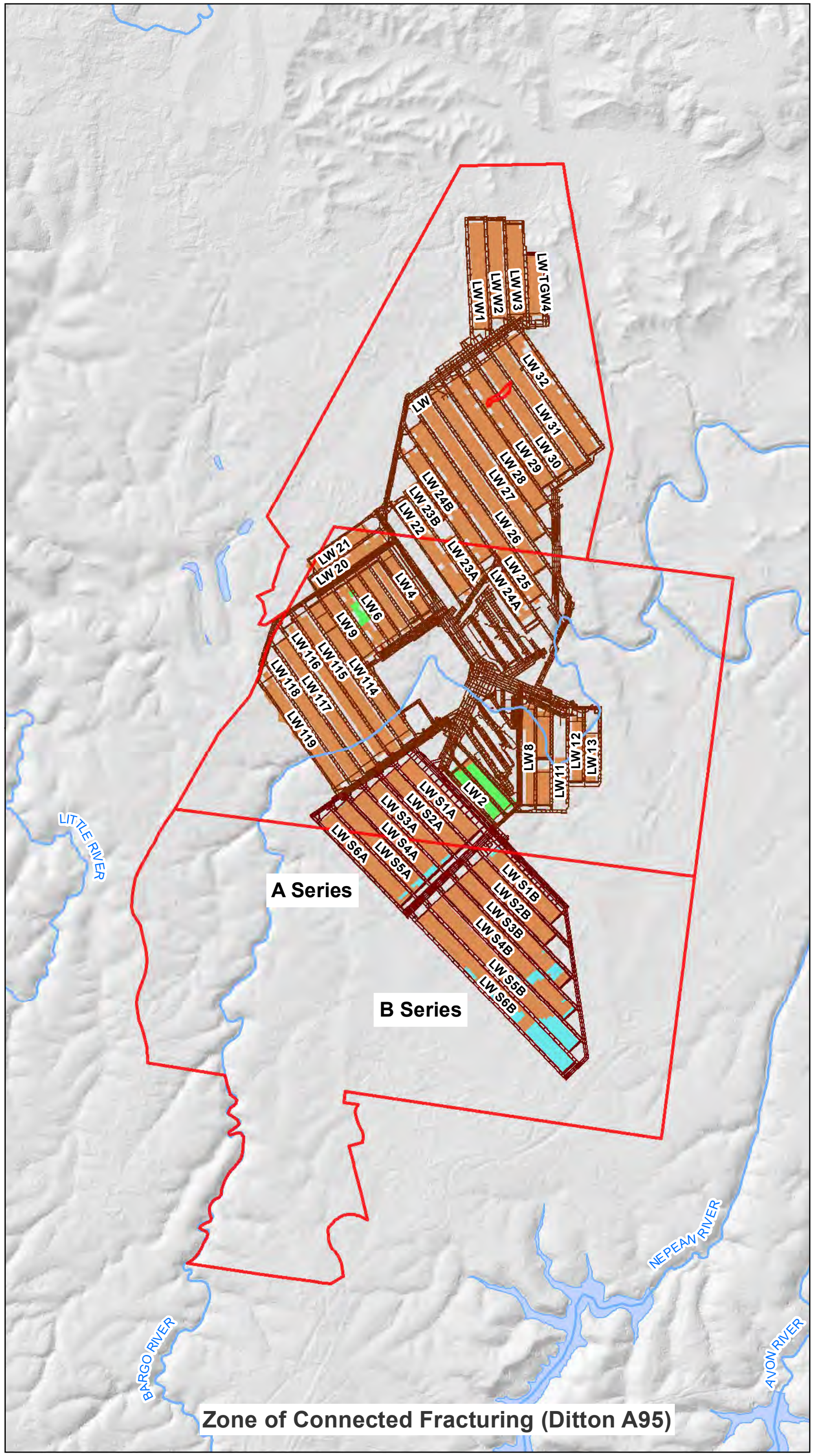
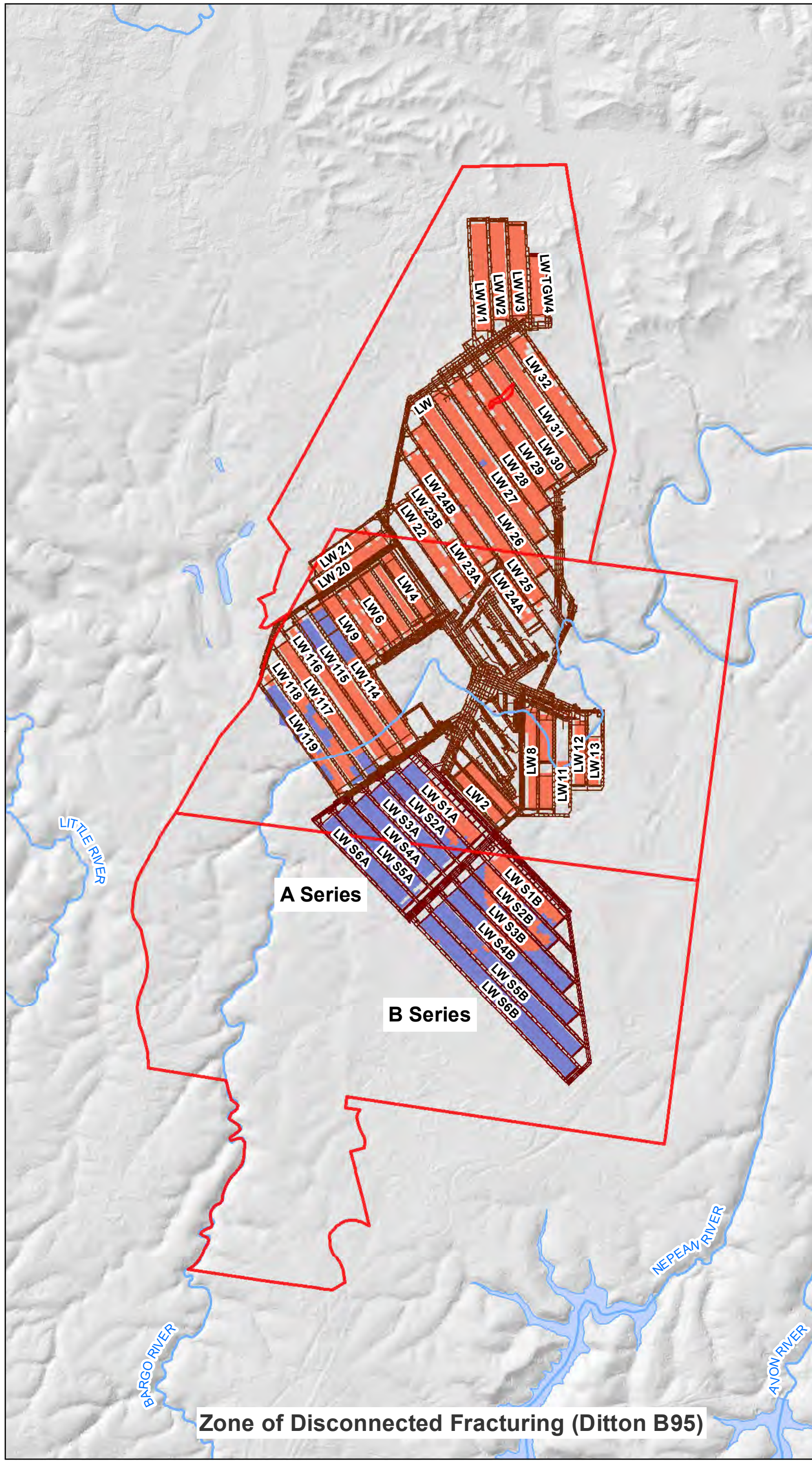
MODELLED ZONE OF CONNECTED FRACTURING (DITTON A95) AND DISCONNECTED FRACTURING (DITTON B95)

FIGURE 4-10





LEGEND

- Watercourse
- Tahmoor Coal Title
- Mine Plan
- Lake

Model Layer Intersected

- Layer 4 - Hawkesbury Sandstone, Middle
- Layer 5 - Hawkesbury Sandstone, Lower
- Layer 6 - Bald Hill Claystone
- Layer 7 - Bulgo Sandstone, Upper
- Layer 8 - Bulgo Sandstone, Middle

0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:125,000 at A4
Project Number:	610.30652
Date:	28-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

Table 4-3 shows the changes in model properties in different zones of the fracturing profile adopted in the TVM package. Within the mined coal seam (goaf), the specific yield was modified to a value of 0.1 or 10%. This value provides for an increased storage capacity by removal of coal, but also accounts for reduced volume in the workings from collapse of overlying strata into the void space left by the removal of coal. The Caved Zone located immediately above the mined seam was simulated by increasing the horizontal and vertical conductivity of the cells within the Caved Zone. The enhanced horizontal and vertical conductivity of the cells within the Caved Zone were adjusted during the calibration process.

The hydraulic properties (horizonal and vertical conductivity) of the cells that fell within this connected fracturing zone, provided in Table 4-3, were modified from the 'host' or natural values using a 'log-linear function' which was calibrated to mine inflow and hydraulic heads at site.

For the disconnected fracturing zone, the horizontal conductivity in the model cells was increased up to 100 times the host values. The horizontal conductivity was capped at a maximum absolute of 0.01 m/d. This value was suggested from Dendrobium data (Watershed HydroGeo, 2020). The enhanced vertical conductivity in the disconnected fracturing zone was increased up to 3 times of the host properties. The Dendrobium data also suggested increases in porosity within the disconnected fracturing zone. This was adopted in the model by increasing the specific yield in the model cells. The modified values for the horizontal and vertical conductivity, and specific yield were adjusted during the calibration process.

To provide a more accurate representation of subsidence-induced impacts to the groundwater and surface water systems, changes in hydraulic properties that occur in areas where surface cracking occurs or is likely to occur were simulated. The horizontal and vertical hydraulic conductivity were increased in the model cells within the surface fracture zone. Evidence from borehole P11 suggests that surface cracking does not occur at distances outside the panel footprint. (SCT, 2020b). Therefore, in the numerical model, surface cracking parameters were only adopted in model cells overlying the longwall panel. As shown in Table 4-3, the depth below the surface to where surface cracking extends was calculated as ten times the extraction height of a given longwall. In areas estimated to be affected by surface cracking, the host horizontal and vertical hydraulic conductivity were both multiplied between 5 to 10 to represent the enhanced permeability of the fracture zone. The use of these multipliers is supported by a recent investigation into the changed hydraulic properties of sections of Redbank Creek that have experienced surface subsidence (SCT, 2018b and 2020b). The multiplier for the horizontal and vertical hydraulic conductivity in the surface fracture zone were adjusted in the calibration process.

Figure 4-11 presents a conceptual illustration of the deformation zones commonly observed above longwall panels, alongside a schematic of the numerical model representation of that conceptual model. The schematic simulated change in Kz in the groundwater model is also shown in Figure 4-11. This exemplifies the departure between the host Kz and post-mining Kz that extend from the coal seam to the height of fracturing. These changes decrease with vertical distance (height) above the coal seam to the upper limit of the estimated height of fracturing and surface fracturing.

Table 4-3 Changes in the Model Properties due to Longwall Mining

Conceptual Zone	Zone	Geometry	Change in the Model Properties
Surface Fracture Zone (i.e. surface cracking)	D-zone	Depth of increased surface fracturing (due to lower depth of cover/confinement) <=20 m, with enhanced horizontal and vertical hydraulic conductivity. 8 x T (extraction height)	High Kx, Higher Kz -Enhanced Kx was calibrated between 2 to 10 times the host value. -Enhanced Kz was calibrated between 2 to 10 times the host value.
Constrained Zone	C-zone		No change

Conceptual Zone		Zone	Geometry	Change in the Model Properties
Fractured Zone	upper zone of Disconnected Fracturing	B-zone	B95 – Ditton and Merrick (2014).	High Kx, Higher Kz, Higher Sy Enhanced Kx was calibrated between 10 to 100 times the host value (capped at maximum value of 0.01 M/day) Enhanced Kz was calibrated between 1 to 3 times the host value Enhanced Sy was calibrated between 0.01 to 0.1.
	lower zone of Connected Fracturing	A-zone	A95 – Ditton and Merrick (2014).	High Kx, Higher Kz. Kx and Kz changes used a logarithmic ramp function from a max value of at the top of caved zone to a value up to host VK at the top of the Ditton A95.
Caved Zone			5-10 x t (Forster & Enever, 1992; Guo et al., 2007).	High Kx, Higher Kz. Calibrated with the range between 2 to 10 times the host values.
Mined Zone (extracted seam)			Mined seam thickness (t)	Kx= 100 m/day, Kz=100m/day, Sy=0.1

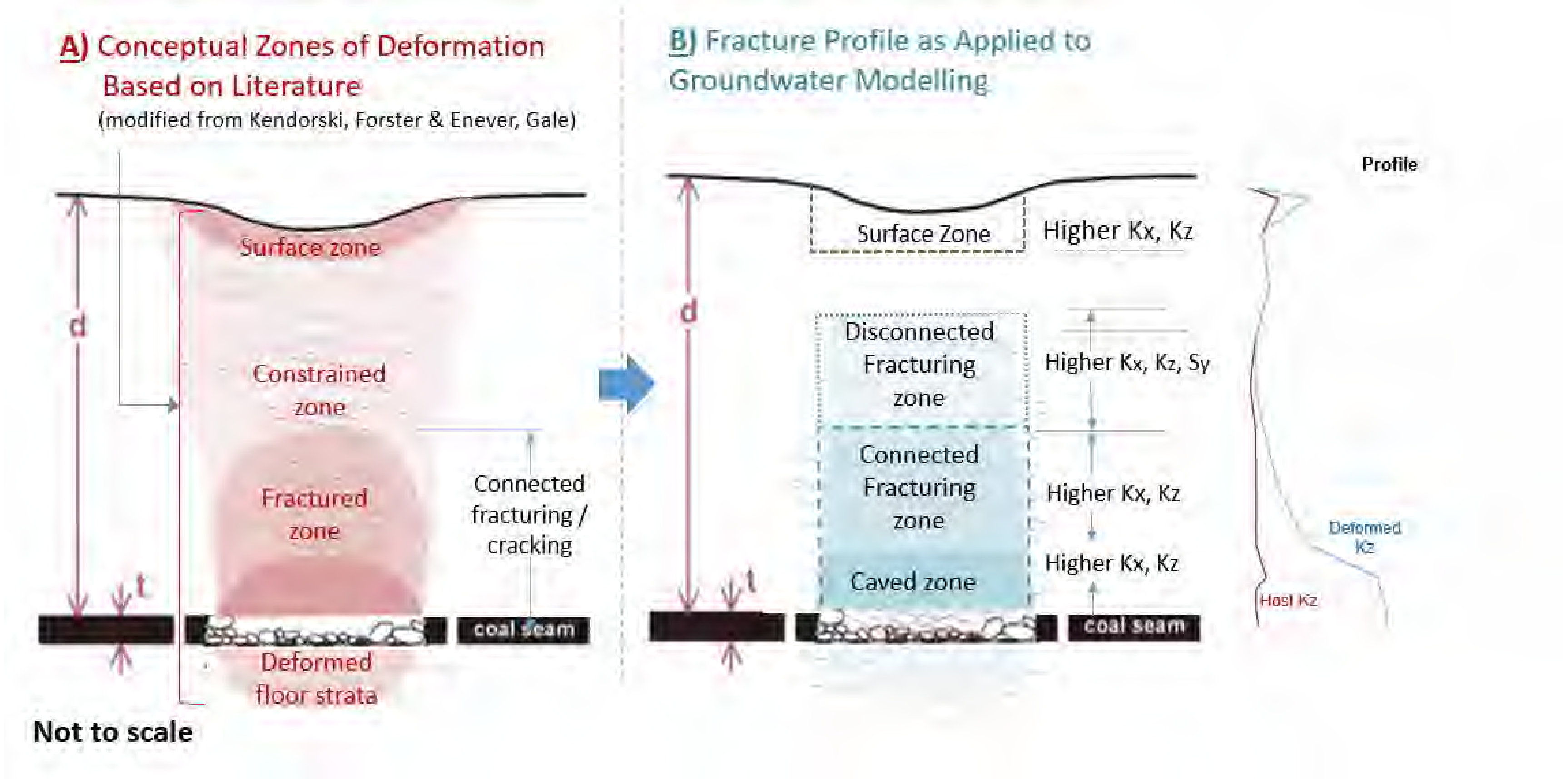


Figure 4-11 Application of Enhanced Permeability within the Groundwater Model

4.2 Model Performance

4.2.1 Calibration Dataset

The calibration dataset included a combination of targets as listed below:

- Groundwater elevation (mAHD);
- Changes in measured groundwater levels (i.e. drawdown\recovery, natural fluctuations); and
- Historic mine inflow rates at Tahmoor mine.

4.2.1.1 Groundwater Levels

Groundwater level data obtained within this model domain comprises standpipe piezometer data in conjunction with vibrating wire piezometer (VWP) data. The groundwater levels recorded between January 1979 to December 2021 were used for the model calibration. In all, 130,575 targets (heads and drawdowns combined) were established for 1,073 bores or monitoring instruments (e.g. VWPs) for calibration from the following sites:

- Tahmoor bores: 266 groundwater level sites and VWPs;
- Appin Mine bores: 241 bores or VWPs;
- Other mines including Dendrobium Mine Bores: 471 monitoring bores and VWPs; and
- Private and Government Bores: 95 other bores.

Groundwater targets were selected where valid information on bore construction or geology information was available for the site.

4.2.1.2 Change in Measure Groundwater Levels

To improve the match between simulated and observed drawdown in the bores included in the calibration, the model was also calibrated to change in groundwater levels. PEST OLPROC utility was used to extract simulated drawdowns in each observation bore. OLPROC reads model outputs (i.e. drawdowns) and then time-interpolates these outputs to approximate values at times which correspond to those at which field measurements were made.

4.2.1.3 Mine Inflows Measurements

Historical inflows (‘water make’) are available at Tahmoor Mine from 1995 until 2022. The calculation and measurement of the mine inflows was provided by Gilbert and Associates (now HEC / ATC Williams) and Tahmoor Coal. There was a period during which measurement of the inflows was not carried out (1977-2009). Inflow measurements from January 1977 until December 2021 were included as targets in the calibration process.

4.2.1.4 Calibration Weighting

Figure 4-12 shows the location of observation bores included in the calibration in conjunction with the locations for measured inflows at Tahmoor Mine. Figure 4-13 show the location of calibration bores at Tahmoor Mine.

Measured groundwater levels, drawdowns and flux observations included in the calibration had different units (mAHD, m, and m^3/day respectively). Therefore, it was expected the flux residuals be higher than water levels and drawdowns residual. The observation weighting was established so that it normalized the observations of different types in the model calibration. Lowest weights were assigned to the measured inflows to reduce the magnitude of flux errors and make them comparable to water level and drawdown errors.

Moreover, the observations at or near Tahmoor Mine were given greater priority compared to other areas in the model. Therefore, the observations at Tahmoor were weighted 5 times higher than the observations elsewhere in the model. Details on each of the observation points and their residuals are presented in the Modelling Technical Report (Appendix F).

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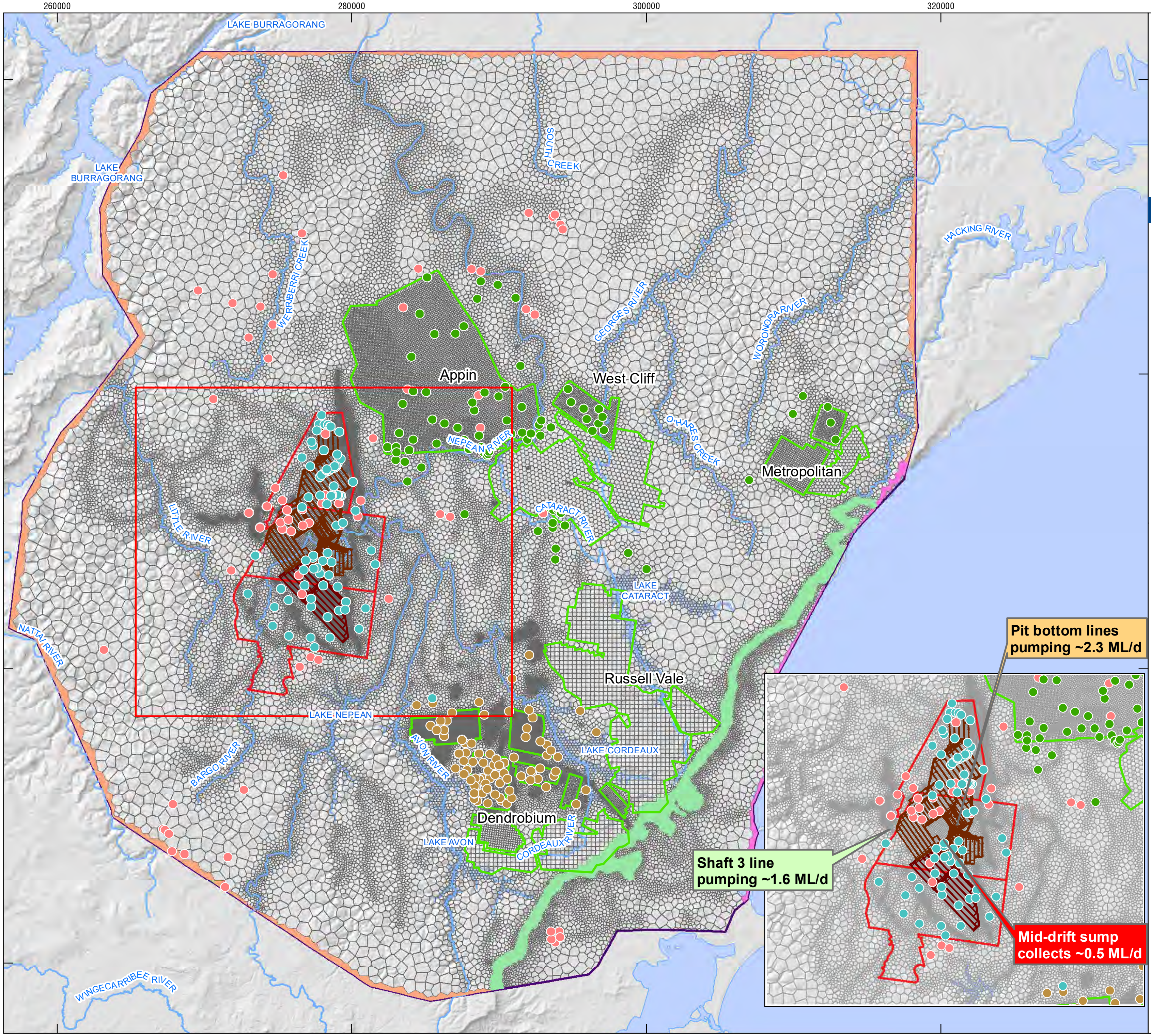
CALIBRATION BORE LOCATIONS AND LOCATION ON MEASURED INFLOWS

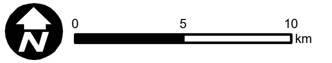
FIGURE 4-12



LEGEND

Calibration Bore - By Site

- Private Bore
- Appin
- Dendrobium
- Tahmoor
- Watercourse
- Tahmoor Coal Title
- Surrounding Mine
- Model Grid
- Drain Cell
- Fixed Head Cell
- General Head Boundary
- Model Domain
- Lake



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
Project Number:	610.30652
Date:	28-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

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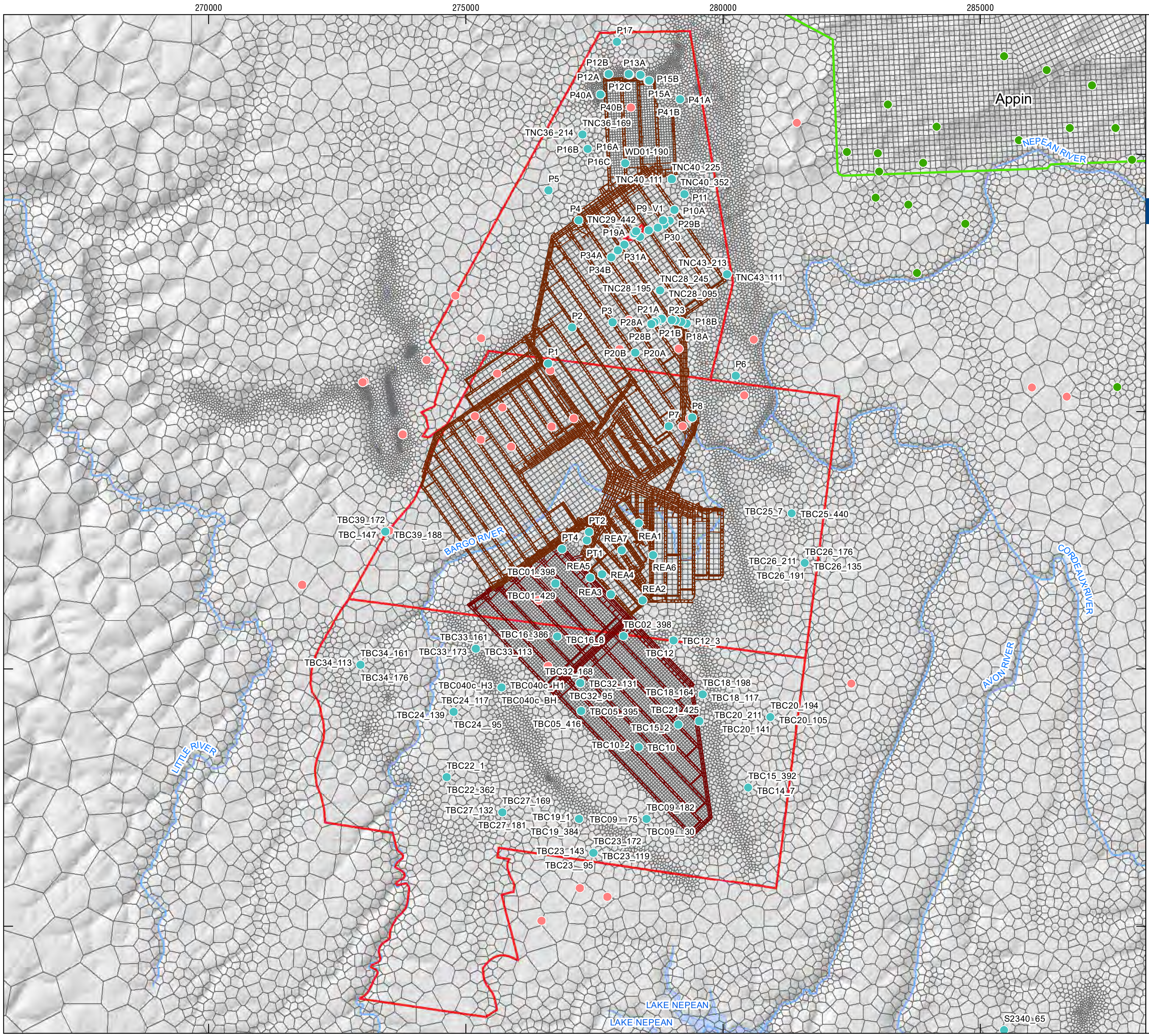

TAHMOOR COAL
LW S1A-S6A GROUNDWATER TECHNICAL REPORT

TAHMOOR CALIBRATION BORE LOCATIONS

FIGURE 4-13

LEGEND

Calibration Bore - By Site

- Private Bore
- Appin
- Dendrobium
- Tahmoor
- Watercourse
- Tahmoor Coal Title
- Surrounding Mine
- Model Grid
- Model Domain
- Lake

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:100,000 at A4
Project Number:	610.30652
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Data Source: Mining Lease NSW Mineview Coal Lease 2019

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4.3 Model Calibration Strategy

Automated parameterisation software PEST++ (Doherty 2019) was used for the model calibration. PEST++ undertakes non-intrusive, highly parameterized inversion of an environmental model. PEST++ includes significant functionality that is absent from PEST including more efficient calibration algorithms that can accommodate large, highly parameterized groundwater models. PEST++ can conduct model runs in serial or in parallel. The model variables included in the calibration were:

- Aquifer parameters including horizontal and vertical hydraulic conductivity, specific storage and specific yield;
- All the fracture profile properties;
- Faults (including Nepean Fault Complex, Southern Faults, T1-T2) horizontal and vertical hydraulic conductivity, specific storage, and specific yield;
- Stresses including recharge rates and soil moisture model parameters, and pumping rates;
- Boundary conditions including evapotranspiration (EVT) rate, General Head Boundary (GHB), River (RIV) bed conductance for watercourses and for Thirlmere Lakes;
- Horizontal and vertical hydraulic conductivity, specific storage, and specific yield for pilot points; and
- For the layers with the depth dependent hydraulic conductivity function, PEST varied the hydraulic conductivity intercept (K_0) and the slope variable in the depth dependence functions adopted for the layers.

The starting values for all the variable listed above were adopted from the previous studies. To reduce the number of model parameters a 4-staged approach to model calibration was used. A schematic showing these calibration stages is presented in Figure 4-14.

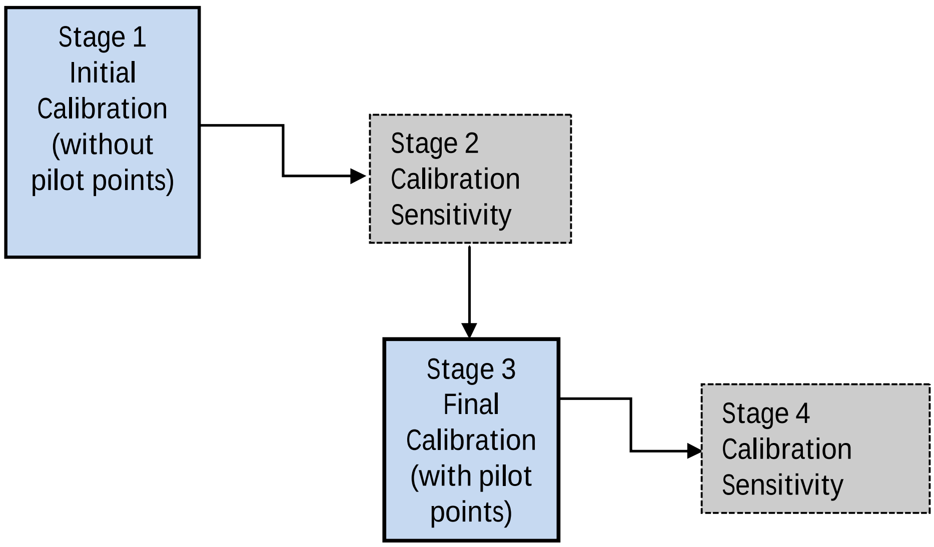

Figure 4-14 Calibration Stages

Stage 1: In the first stage the model calibration was run for two iterations using the initial values adopted. There were no pilot points included in the initial calibration.

Stage 2: Using the calibrated values from the initial calibration (Stage 1), an identifiability analysis was conducted on the initial calibration using PEST++. The identifiability analysis assesses the most sensitive properties of the model from a sensitivity (Jacobean) matrix. To calculate the Jacobian matrix, the model was run once for each variable included in the calibration. The results from the identifiability identified the most sensitive model parameters (with 0 representing not sensitive and 1 being the most sensitive) that can impact the match between measured and simulated values.

Stage 3: The final calibration was run using the parameters identified as sensitive from Stage 2. All the parameters with sensitivity of greater than 0.2 were allowed to change in the calibration and the remaining parameter values were kept unchanged. The results from Stage 2 showed very high sensitivity to HBSS Kx and Kz properties. As a part of the final calibration, pilot points were introduced in layers 3 to 5 of the model to allow more spatial variability in the HBSS Kx and Kz properties.

The location of the pilot points is shown in Figure 4-15. Pilot points were set within Tahmoor and Appin Mine operational areas and spaced uniformly. PEST++ used its PLPROC utility to interpolate between the pilot point values and creates a surface across the model domain for a targeted model parameter. This surface of model parameter values is then interrogated for values at the model cell centres to provide a value at each model cell. A total of 360 pilot points were used to assign the hydraulic parameters to layers 3 to 5 of the model. Due to the computational constraints and based upon the sensitivity results, the pilot points for horizontal conductivity in Layers 4 and 5 were tied to the pilot points in Layer 5. The pilot points for vertical conductivity were allowed to change independently in Layer 3, 4 and 5.

Stage 4: Using the calibrated values from the final calibration (Stage 3), the identifiability analysis was reconducted using calibration using PEST++. The results of the identifiability analysis are discussed in full in Appendix F.

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LOCAITON OF MODEL
PILOT POINTS

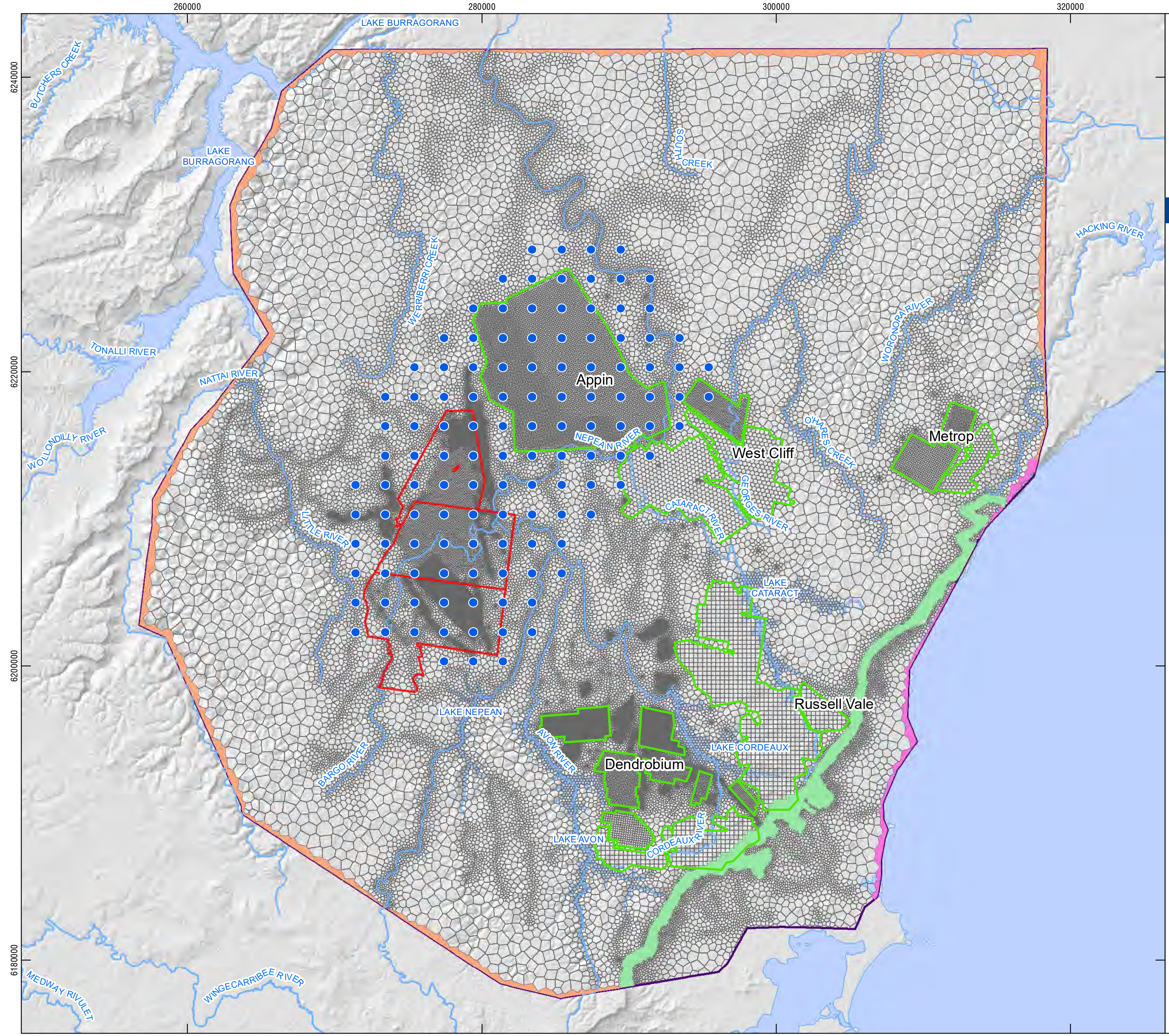

FIGURE 4-15

LEGEND

- Pilot Point
- Watercourse
- Tahmoor Coal Title
- Surrounding Mine
- Model Grid
- Drain Cell
- Fixed Head Cell
- General Head Boundary
- Model Domain
- Lake

0 5 10 km

Coordinate System:	GDA 1994 MGA Zone 56
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Data Source: Mining Lease NSW Mineview Coal Lease 2019

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4.3.1 Calibration Statistics

The full details of the calibration statistics and analyses on model calibration performance are provided in Appendix F. Below is a summary of the overall performance for calibration to Tahmoor Coal specific datasets.

One of the industry standard methods to evaluate the calibration of the model is to examine the statistical parameters associated with the calibration (as outlined in the Australian Groundwater Modelling Guidelines [AGMG]; Barnett et al, 2012). This is done by assessing the error between the modelled and observed (measured) water levels in terms of the root mean square (RMS). The RMS is defined as:

$$RMS = \left[1/n \sum (h_o - h_m)_i^2\right]^{0.5}$$

where: n = number of measurements
ho = observed water level
hm = simulated water level

RMS is considered to be the best measure of error if errors are normally distributed. The RMS error calculated for the observation sites at Tahmoor site only is 25.9 m.

The acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total head change in the system is small, the errors are considered small in relation to the overall model response(s). The ratio of RMS to the total head loss (SMRS) for entire dataset is 3.3% while SRMS for Tahmoor only is 2.6%. While there is no recommended universal SRMS error, the AGMG suggests that setting Scaled RMS targets such as 5% or 10% may be appropriate in some circumstances (Barnett et al, 2012).

The overall transient calibration statistics for Tahmoor only bores are presented in Table 4-4, which shows 85% (68,007 out of 79,474 calibration targets) are within ±20 m of the observed measurements. This provides an indication of reasonable fit for the large regional dataset.

Figure 4-16 presents the observed and simulated groundwater levels graphically as a scattergram for the initial and historic transient calibration (1977 to 2021) for the Tahmoor bores only.

Figure 4-17 shows the distribution of residuals for Tahmoor bores, which presents that the calibration residuals for the majority for data points are within ± 20 m for Tahmoor bores.

Table 4-4 Transient Calibration Statistics- Tahmoor Bores Only

Statistic	Value
Sum of Squares (m^2)	20,913,148.1
Mean of Squares (m)	263.6
Square Root of Mean of Squares (RMS) (m)	16.2
Scaled Root Mean Square (SRMS) (%)	2.6%
Sum of Residuals (m)	198,068.6
Mean Residual (m)	2.5
Scaled Mean Residual (%)	0.4%
Coefficient of Determination (tend to unity)	1.9
Targets within ±2m	9,981

Statistic	Value
Targets within ±5m	22,479
Targets within ±20	68,007

*RMFS represents the sample standard deviation of the differences between predicted values and observed values as a fraction of the observed value expressed as a percentage.
** SRMFS scales the RMFS error by the ratio of the mean observed value to the range of the observed values expressed as a percentage.

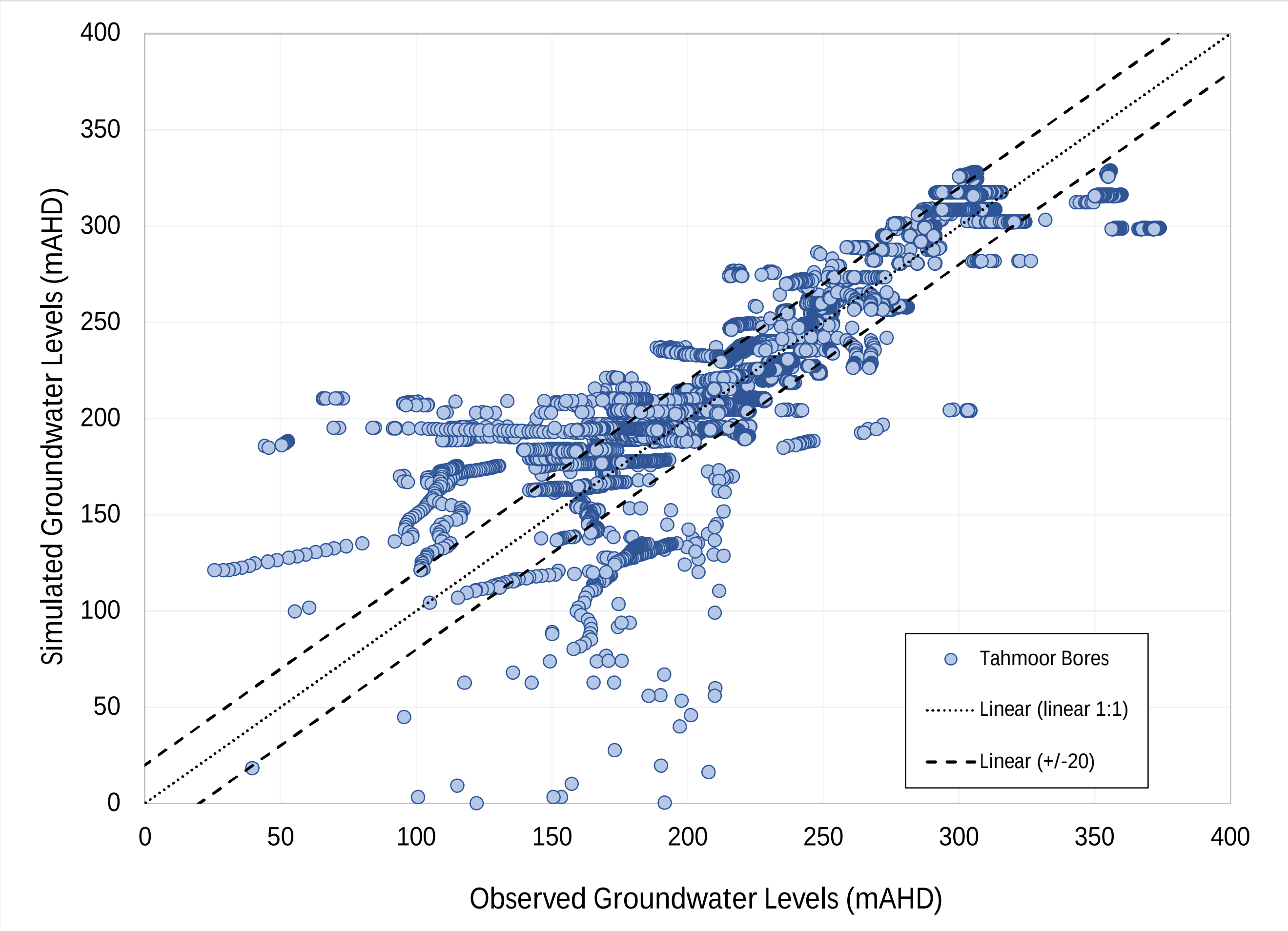


Figure 4-16 Calibration Scattergram – Modelled vs Observed Groundwater Levels for Tahmoor Bores

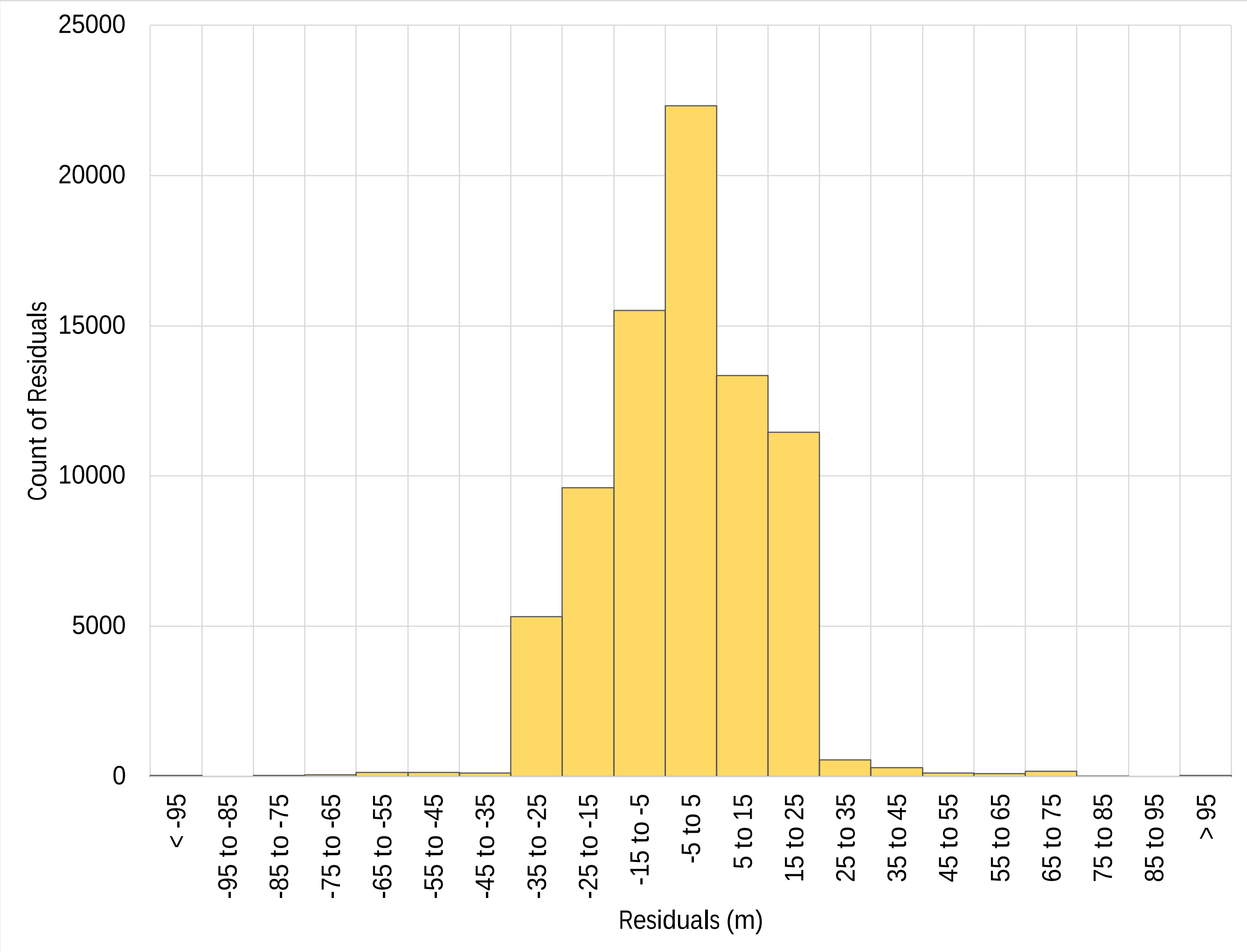


Figure 4-17 Calibration Residual Histogram – Tahmoor Bores

Table 4-5 shows a mix of over and underestimation of water levels in the model layers across the model domain. The table shows Layer 7 (Bulgo Sandstone – Upper) has the highest average and absolute average residual. Table 4-5 shows HBSS layers in the model have the highest number of observations while the average residuals in these layers are less than 9 m.

Table 4-6 shows the average calibration residual and absolute average residual per observation group. As indicated in the table, there is an overestimation of water levels in the Tahmoor bores. The table shows the Tahmoor site has the lowest average residuals.

Table 4-5 Average Residual by Model Layer

Model Layer	Formation	Average Residual (m)	Average Absolute Residual (m)	Number of Observation Targets	Number of bores
1	Regolith, alluvium and basalt	-1.2	6.2	9965	41
2	Wianamatta Formation	5.2	10.4	2211	22
3	Hawkesbury Sandstone - upper	-5.8	22.7	3839	61

Model Layer	Formation	Average Residual (m)	Average Absolute Residual (m)	Number of Observation Targets	Number of bores
4	Hawkesbury Sandstone - middle	10.0	24.6	74176	266
5	Hawkesbury Sandstone - lower	6.6	16.3	6319	114
6	Bald Hill Claystone	-10.4	28.0	289	24
7	Bulgo Sandstone - upper	-6.7	32.5	277	26
8	Bulgo Sandstone - middle	-1.6	27.2	9631	191
9	Bulgo Sandstone - lower	-8.4	37.5	748	22
10	Stanwell Park Claystone	19.9	32.3	615	10
11	Scarborough Sandstone – upper	8.9	33.5	571	19
12	Scarborough Sandstone - lower	-2.7	41.6	5789	105
13	Wombarra Claystone	-26.3	33.5	617	10
14	Coal Cliff Sandstone	-25.2	65.2	363	8
15	Bulli Coal seam	-14.7	49.5	3706	100
16	Eckersley Formation	22.6	35.9	9175	39
17	Wongawilli Coal seam	-29.7	45.9	2047	72
18	Kembla Sandstone	-92.7	92.7	43	3
19	Older units (lower Permian Coal Measures and Shoalhaven Group)	-27.1	27.1	43	1

Table 4-6 Average Residual by Site

Site	Average Residual (m)	Average Absolute Residual (m)	Number of Observation Targets	Number of Bores
Tahmoor	-1.4	12.2	79320	266
Dendrobium	-3.8	35.3	17701	471
Appin	21.0	39.4	14806	241
Private Bore	19.9	22.3	18379	84
Other	35.8	38.5	218	11

4.3.2 Calibration Fit

This section provides discussion on the modelled to observed groundwater level trends (calibration hydrographs) for key bores around the Tahmoor site. Calibration hydrographs for the full calibration dataset are presented as Appendix F.

The hydrographs for most of the bores highlight the challenge in simulating groundwater levels in the complex groundwater system which has been subjected to significant historical stresses such as pumping from registered and unregistered bores, gas extraction (near Appin) and historical mining activities that could not be replicated in the model as there was no information available on the timing and magnitude of these stresses.

The match in most of the private and government bores is good with errors of ± 5 m. Examples of this can be seen in the hydrographs for "GW" bores in Appendix F.

The hydrographs show better match in the Tahmoor bores compared to Appin and Dendrobium bores as the Tahmoor site bores were given priority in the calibration process. Comparing to the 2021 model, the hydrographs are generally consistent with the previous model.

Overall, across the model domain, there is a better match between simulated groundwater levels and observed levels in the shallow units (including the bores in alluvium and HBSS) which are connected to the surface water features and which host almost all the private bores. This is also shown through calibration residuals presented in Table 4-5. The hydrographs show increasing error in the deeper layers where there is greater, more severe drawdown and higher gradients around the mine. Potential sources of error when comparing simulated and observed water levels are:

- Imperfect simulation of mining operations, roadway development and advanced gas drainage (where present in the model). As an example, the discrepancy in observed and simulated groundwater levels between in Dendrobium mine borehole S1907 and Tahmoor bore TBC39. The hydrograph for the bores shown in Appendix F represent a timing influence, thought to be from the representation of the historical mine plan in this model compared to the actual progression of that mine;
- Structural simplifications in the model, including the vertical and horizontal discretization of the model and resulting 'coarse' representation of features and hydraulic gradients at scales of a model cell (or layer) or less. For example, strong vertical gradients may mean that a model, which predicts average water levels for a cell, will struggle to replicate an observed water level if that water level is from the upper or lower portion of that layer. For a layer that is 50 metres thick and where a gradient is 1 in 10, this leads to errors of ± 5m;
- Structural errors may also occur because of the discretisation of time in the model. In this case, stress period lengths are quarterly. Behaviour within this may significantly influence the observed water level, and the model may either not simulate the relevant stress or may smooth out the response to such a stress;
- High residuals but good match: examples are illustrated in the Bulli Coal seam piezometers in bores TN0C28 and TNC029, which show large residuals but also suggests that the model does a reasonable job of simulating groundwater levels and their response to mining;
- Processing / installation record errors: A lot of the bores with erroneous data were removed from the calibration dataset. However, given the number of bores and measurements available for the calibration, further review of the calibration data may identify more bores with erroneous that should be removed from the calibration. There were uncertainties about installation depth/formation (i.e. model layer) in some of the bores but the data from these bores were included in the calibration but were assigned lower weights; and
- Representation of fracture profile properties: It is evident that the bores screened within the fracture zone above the longwalls are impacted by post-mining properties of the fracture zone. The fracture zone properties are likely to be highly variable in different parts of the mine. However, the model uses one value across the site for the fracture zone which is a simplified representation of a highly complex stress system.

The following sections discuss the calibration hydrographs for shallow bores at Thirlmere Lakes, Tahmoor VWPs, and the Tahmoor open standpipe bores ("P" bores) around Tahmoor North and Western Domain.

4.3.2.1 Thirlmere Lakes Bores

Figure 4-18 to Figure 4-21 compares the simulated and observed groundwater levels for the shallow boreholes at Thirlmere Lakes. The hydrographs show the model simulated the groundwater levels in GW75409_1 and GW75410 are within 5 m of observed levels. The model underpredicts the groundwater levels in GW75409_1 and GW75411 by approximately 5 m. The trends and seasonal fluctuations in groundwater levels in all these bores is reasonably well replicated. The hydrographs presented show the new model was able to match in groundwater levels and trends in Thirlmere Lakes bores better comparing to the 2020 groundwater model.

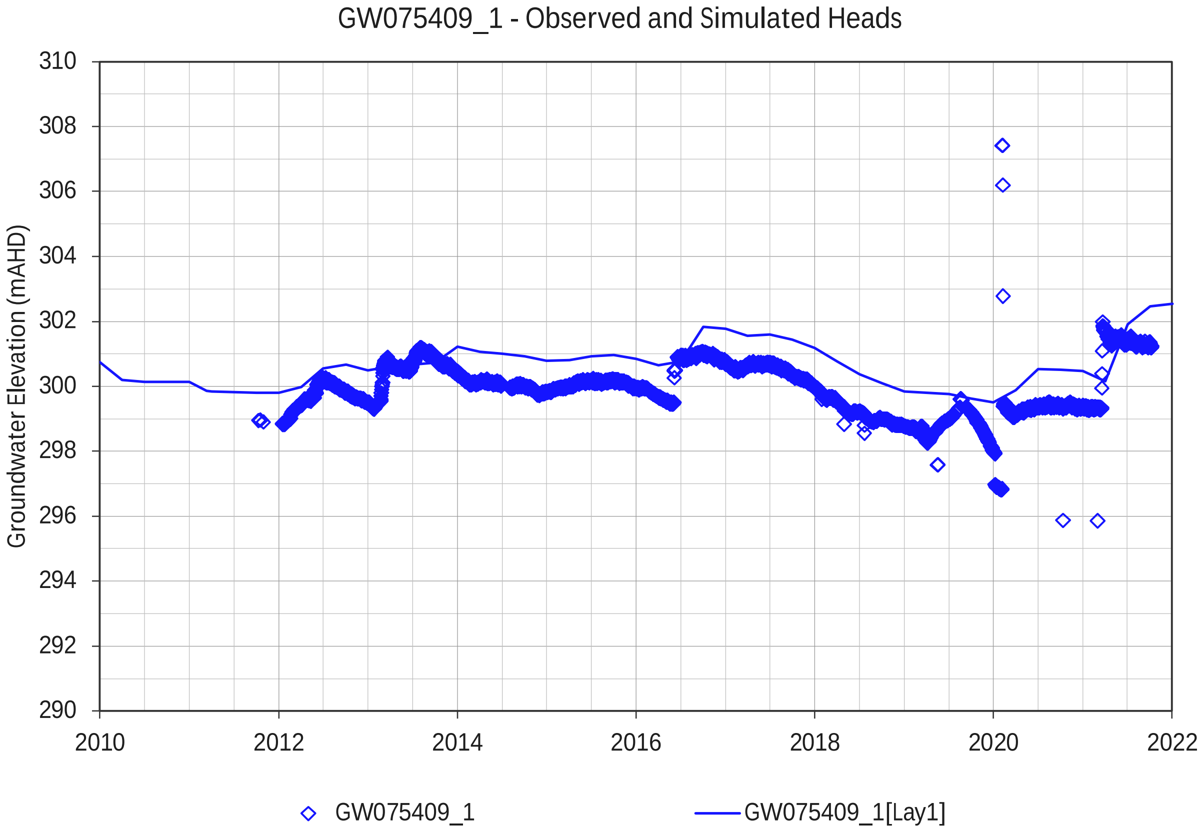


Figure 4-18 Hydrographs for Thirlmere Lakes Bore GW075409_1

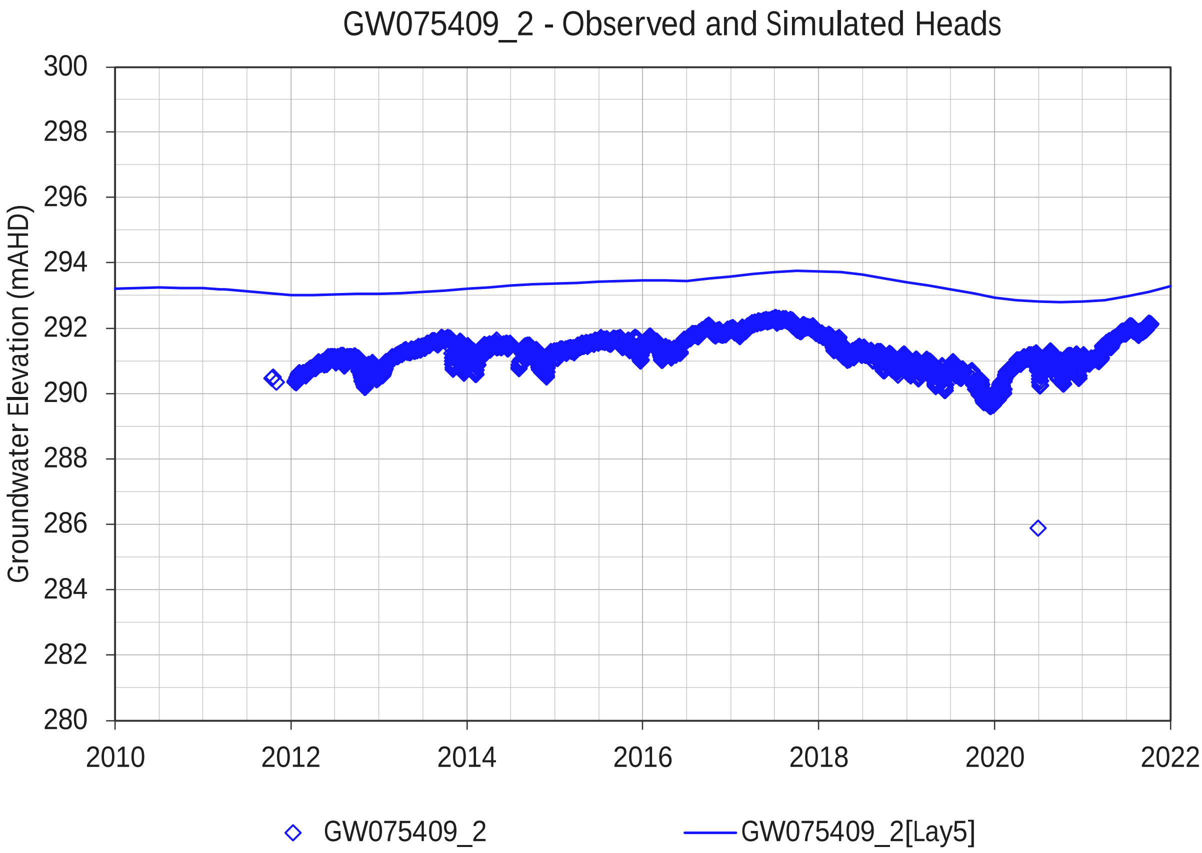


Figure 4-19 Hydrographs for Thirlmere Lakes Bore GW075409_2

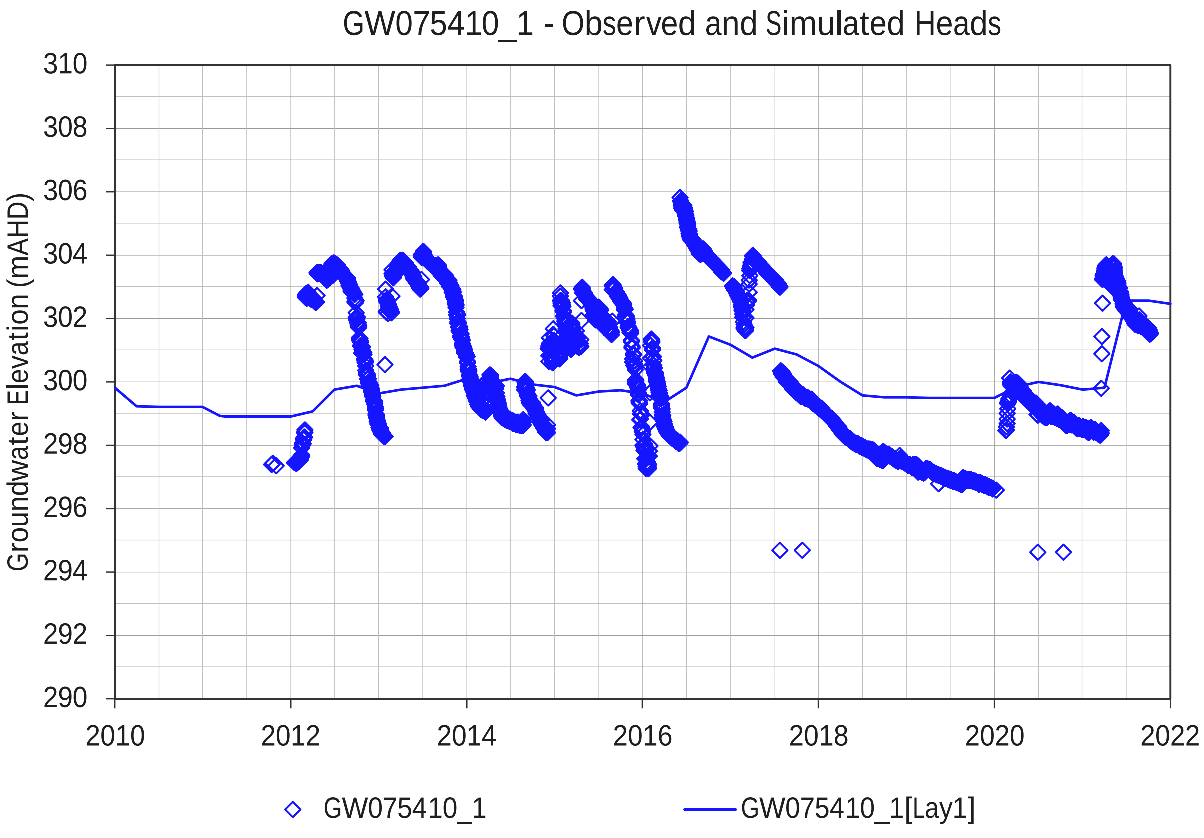


Figure 4-20 Hydrographs for Thirlmere Lakes Bore GW075410_1

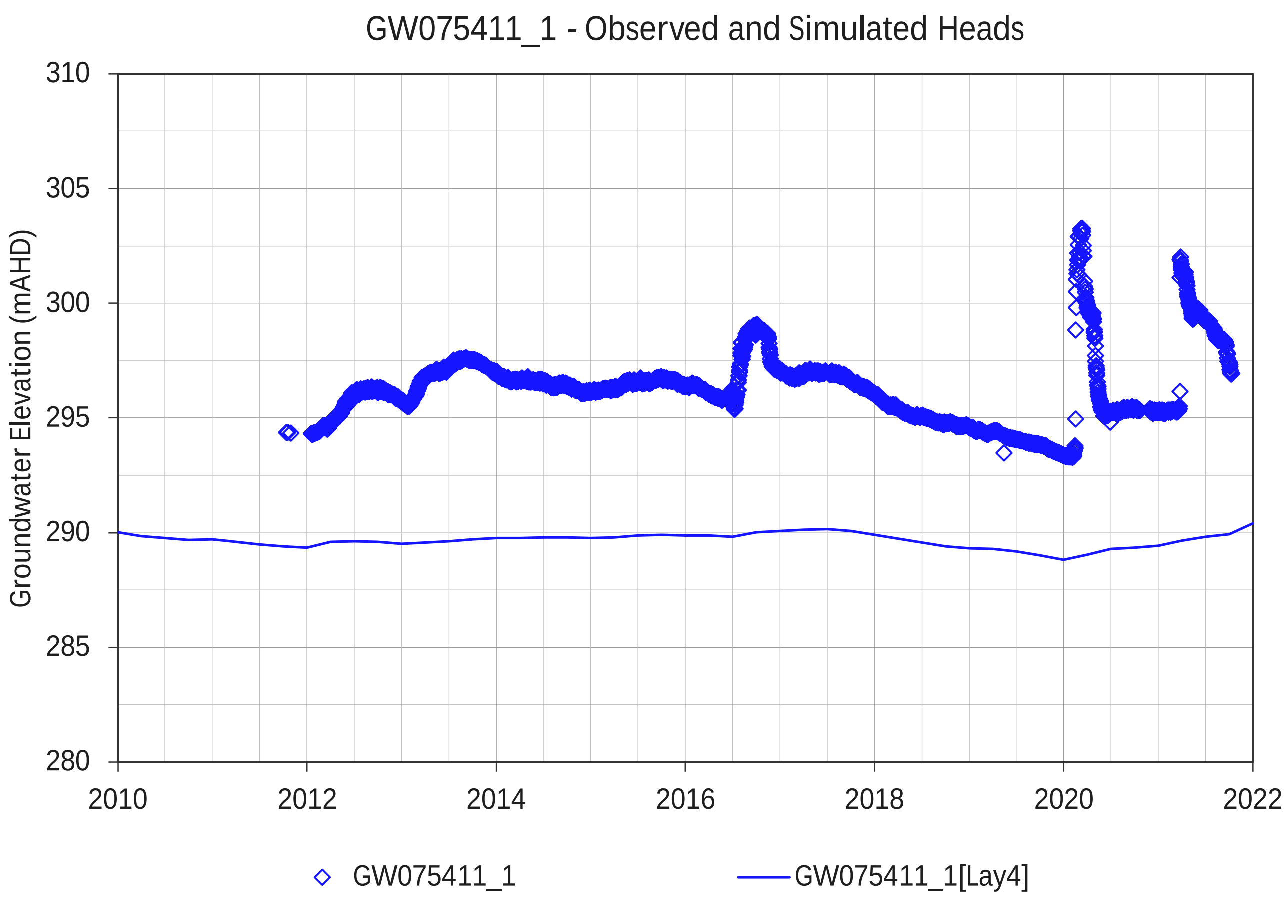


Figure 4-21 Hydrograph for Thirlmere Lakes Bore GW075411_1

4.3.2.2 Tahmoor VWPs

The following section presents the model performance at the VWPS in Tahmoor North and Western Domain bores (TNC040, TNC028, TNC029, WD01) and Tahmoor South (TBC032, TBC027, TBC039).

TNC040: TNC040 is a multi-VWP bore in Tahmoor North, located near LW32. Simulated water level profiles at bore TNC040 are shown in Figure 4-22. There is a good match between the simulated water levels and observations in most of the TNC040 sensors. The figure shows a good match down the profile, with modelled heads being a good match for those in the Hawkesbury Sandstone (both modelled and observed unaffected by mining) and the Bulgo Sandstone (both modelled and observed influenced by mining). The model tends to underpredict drawdown in the deeper units compared to the observed water levels. Overall, the model was able to simulate the depressurisation in deeper strata and minimal drawdown above the zone of connected fracturing.

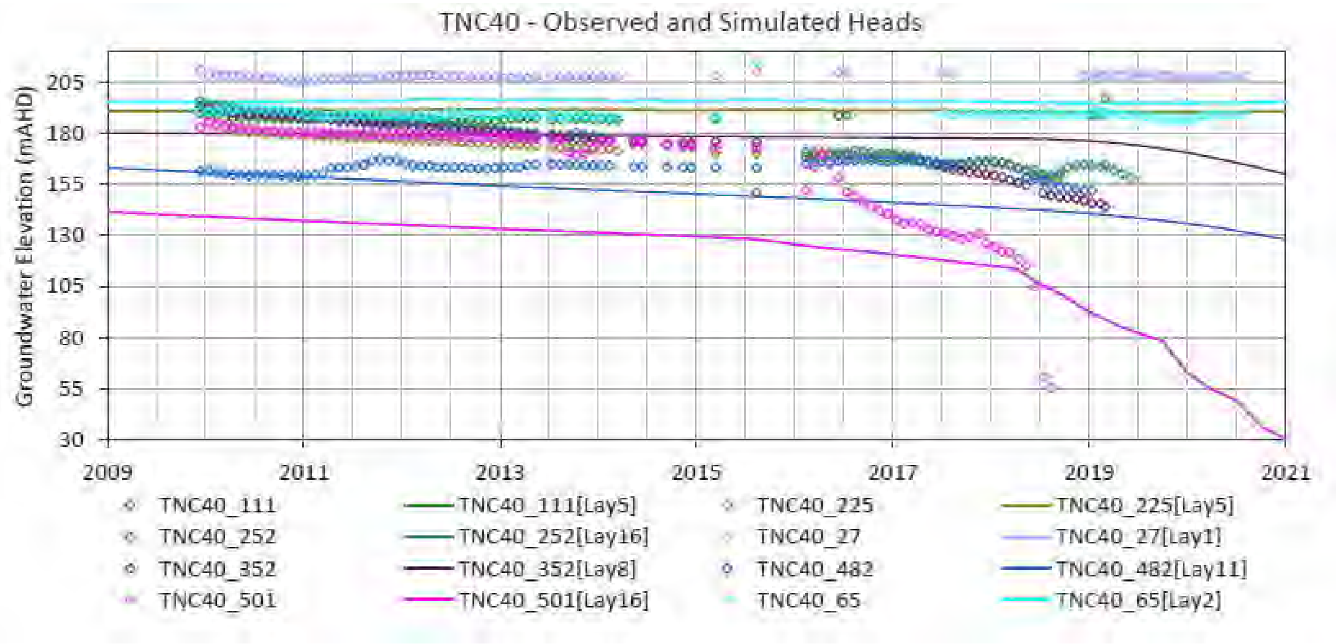


Figure 4-22 Hydrographs for VWP TNC040

TNC028 and TNC029: Figure 4-23 and Figure 4-24 show hydrographs comparing modelled and observed groundwater levels for TNC028 and TNC029 both located with the Tahmoor North mine footprint. The figures show the model was generally able to replicate the difference in heads observed at the sensors and was also able to closely simulate the drawdown due to mining at Tahmoor North. The model underpredicted the groundwater levels in the deepest VWP in TNC029.

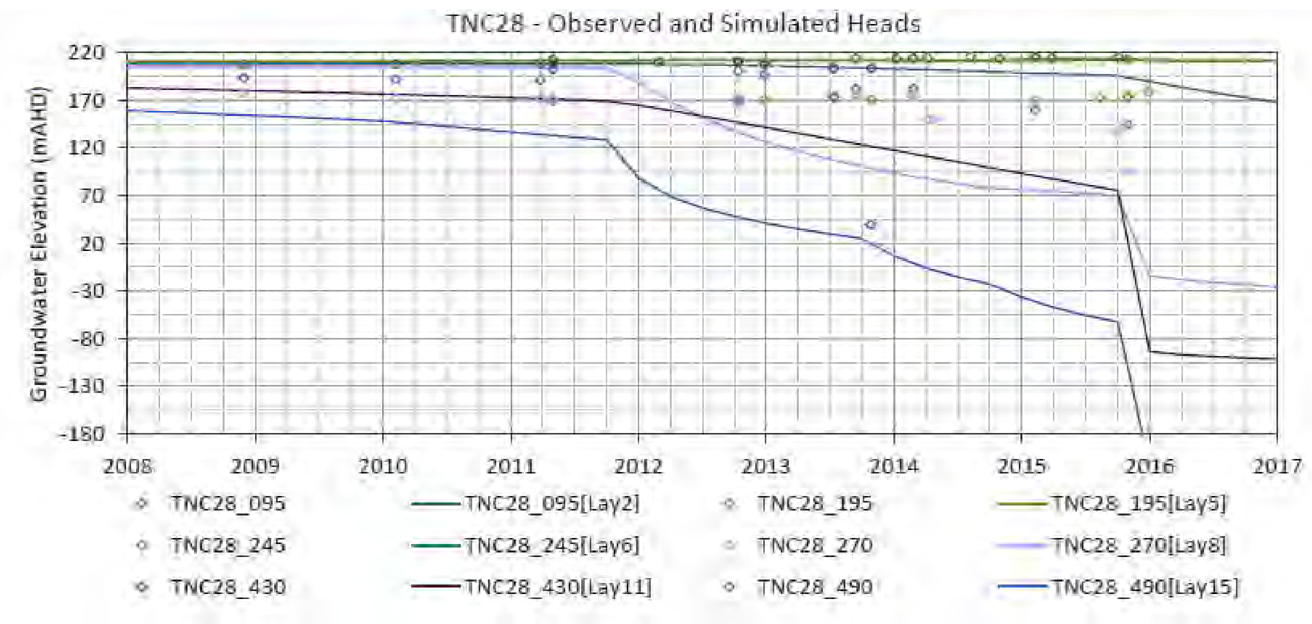


Figure 4-23 Hydrograph for VWP TNC028

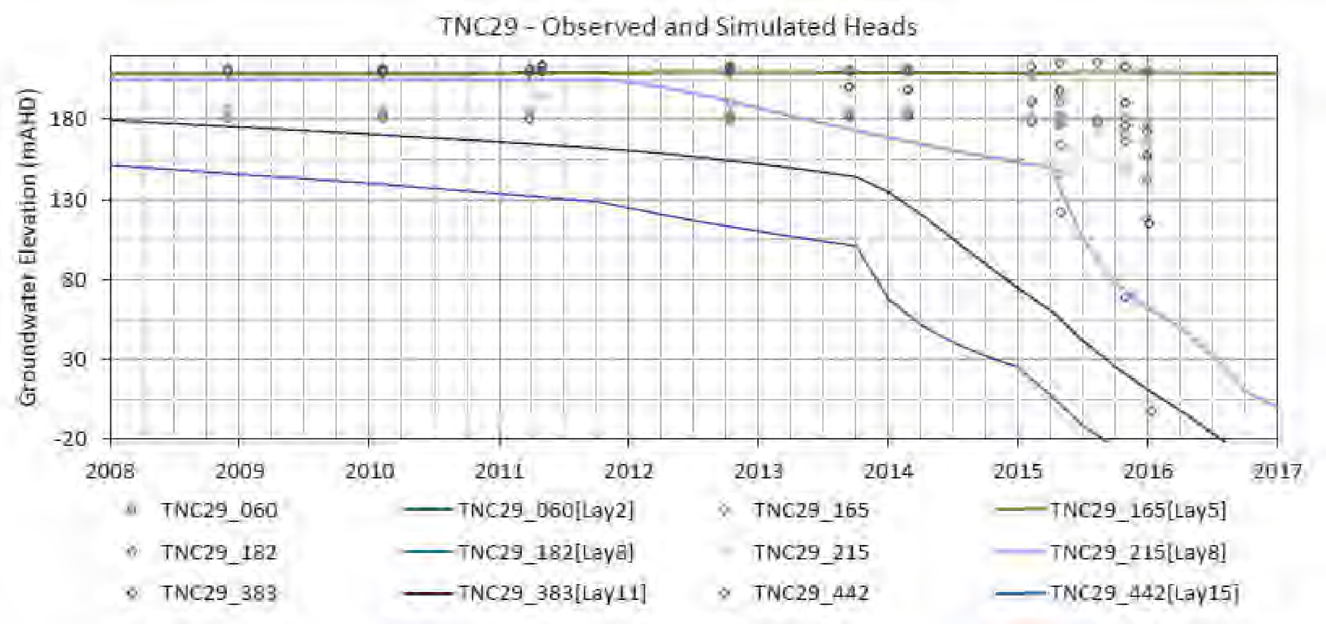


Figure 4-24 Hydrograph for VWP TNC029

WD01: Figure 4-25 compares the simulated and observed groundwater levels for sensors in WD01 which is located within Western Domain mine footprint. The figure show while the model replicated the shallow groundwater levels well, it was not able to capture the depressurisation in the lower Hawkesbury Sandstone (piezometer WD01-190m, WD01-210m and WD01-230m). The model overpredicted the groundwater levels in deeper units such as Bulgo Sandstone (piezometer WD01-300m) by between 20-50 m. Multiple piezometers in BGSS WD01-350m were simulated in the same model layer of the model due to vertical resolution of the model. This was a limitation in matching some of the groundwater levels recorded in the VWPs.

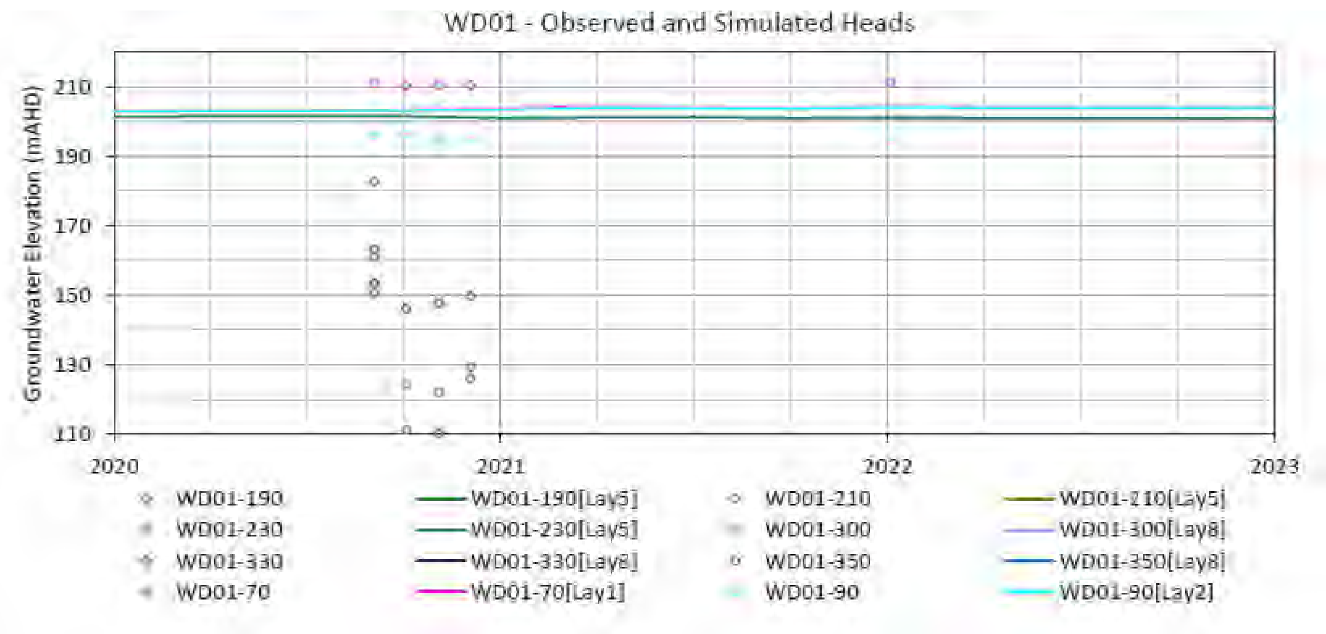


Figure 4-25 Hydrograph for VWP WD01

TBC018: Figure 4-26 shows the calibration hydrograph for TBC018 which is located to the southwest of Tahmoor South away from any historical mining. The model overpredicts the groundwater level in all the sensors at TBC018 but matches the observed trends well. In the case of the Bulli Coal piezometer (TBC18_404), the observed drawdowns are likely caused by equilibration of water levels after piezometer installation and therefore, the model was unable to replicate them.

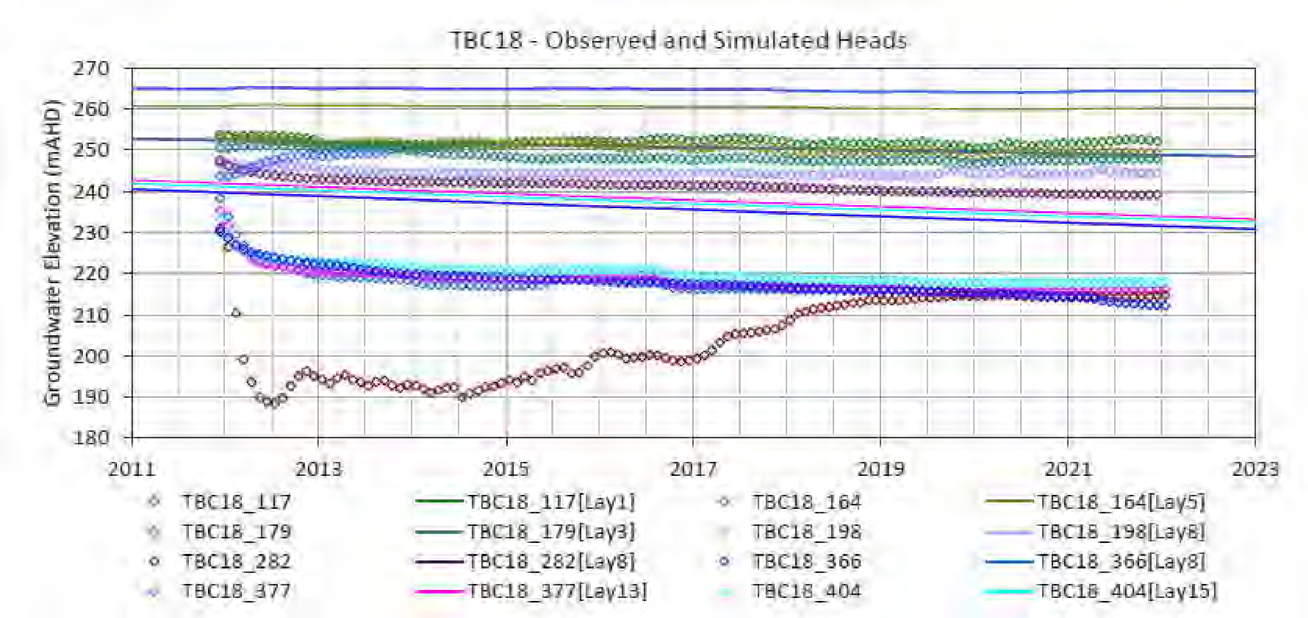


Figure 4-26 Hydrograph for VWP TB18

TBC034: TBC034 is also located to the east of Tahmoor South Panels. As shown in Figure 4-27, the model underpredicted the groundwater levels in most of the sensors. The drawdown observed in the deeper sensors in TBC034 appear to be a result of mining, but the model was not able to replicate this drawdown. The mismatch between observed in simulated and observed groundwater levels in this bore is likely due to the model structure (i.e. further away from the site resulting in a reduction of the geology model accuracy).

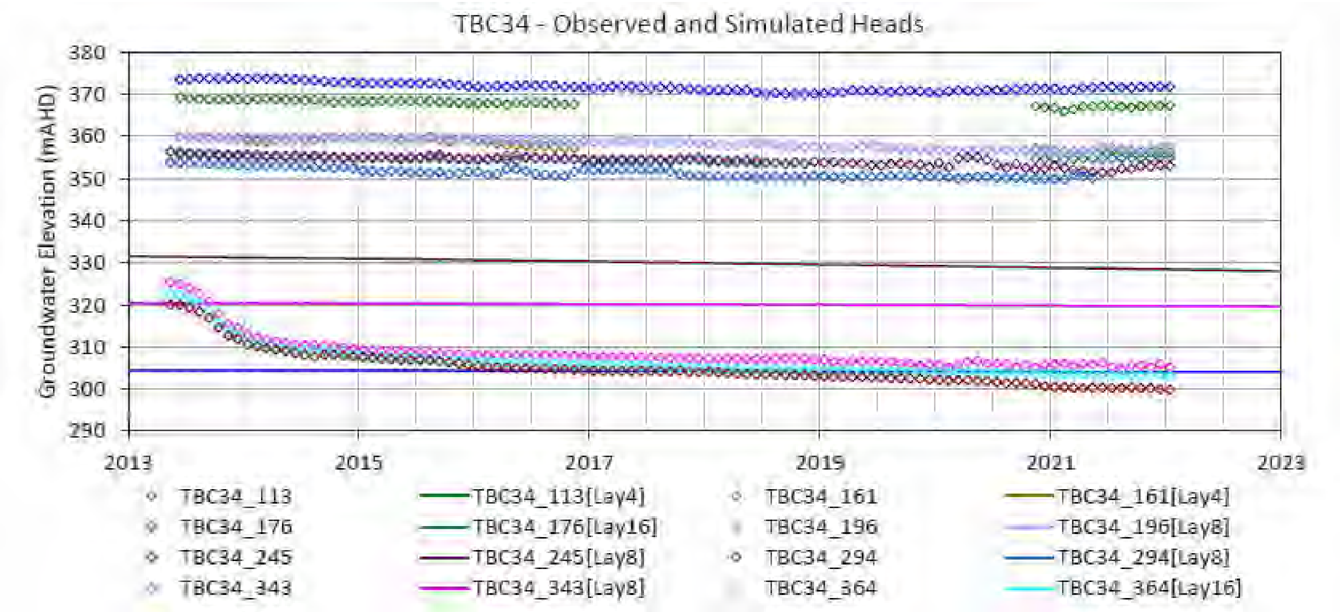


Figure 4-27 Hydrograph for VWP TBC34

TBC027: Figure 4-28 shows the hydrograph for TBC027 located to the south of Tahmoor South Panels. As shown in, the model overpredicted the groundwater levels in most of the deep VWPs in TBC027 (below HBSS). The drawdown observed in the deeper VWPs in TBC027 does not appear to be mining related and the model was not able to replicate this drawdown.

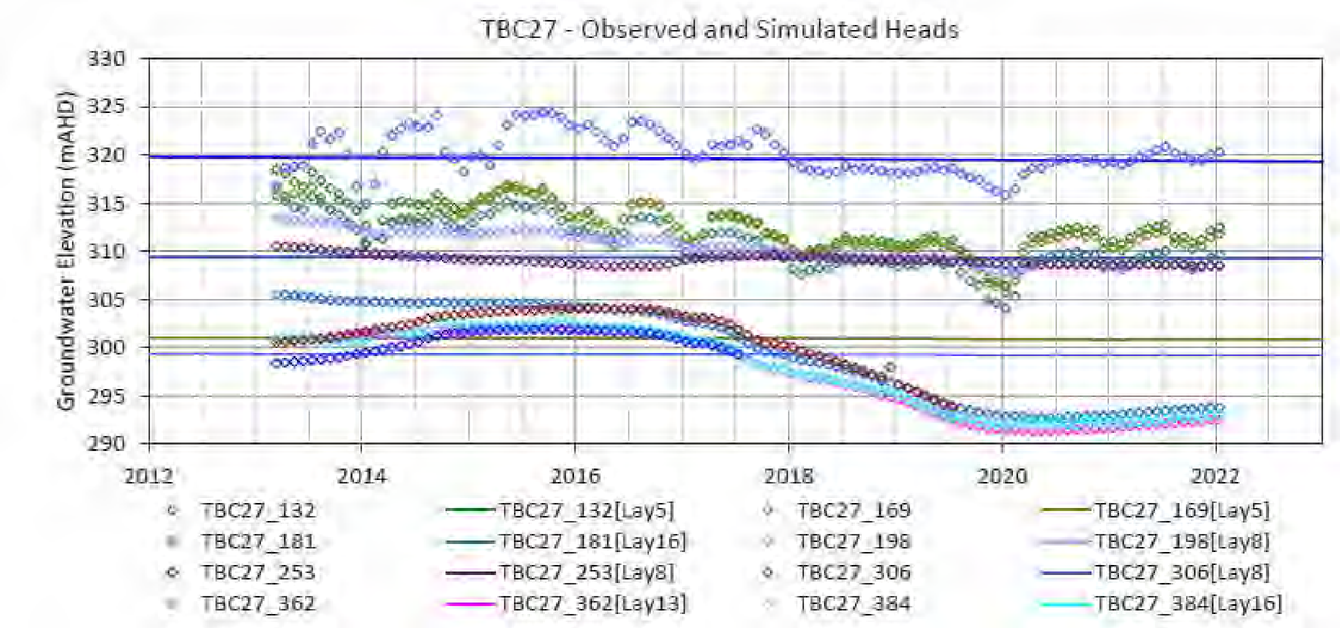


Figure 4-28 Hydrograph for VWP TB27

4.3.2.3 Tahmoor Open Standpipe Bores (P Bores)

4.3.2.3.1 Tahmoor North

This section presents hydrographs comparing modelled and observed groundwater levels for the existing groundwater monitoring bores located across Tahmoor North (P1-P8, P9) shown in Figure 4-29 to Figure 4-37, and along Redbank Creek (P10-P36) and Myrtle Creek (P18-P28) presented in Appendix F.

The comparison of modelled and historical observed groundwater levels for P1-P8 shows the model simulates a reasonable match to the trends at these bores but over or under predicts the groundwater levels between 5 to 20 m which is consistent with the previous model (SLR/HydroSimulations, 2021). P6 and P8 show the largest difference in observed and simulated groundwater levels.

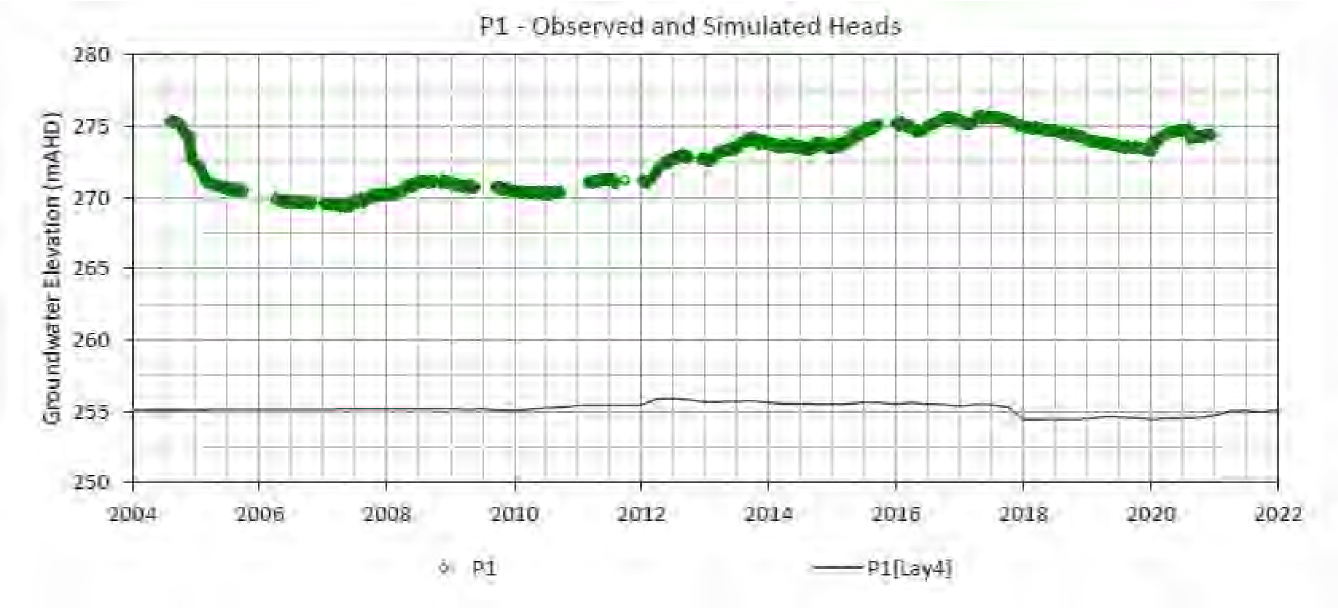


Figure 4-29 Hydrographs for P1- Tahmoor North

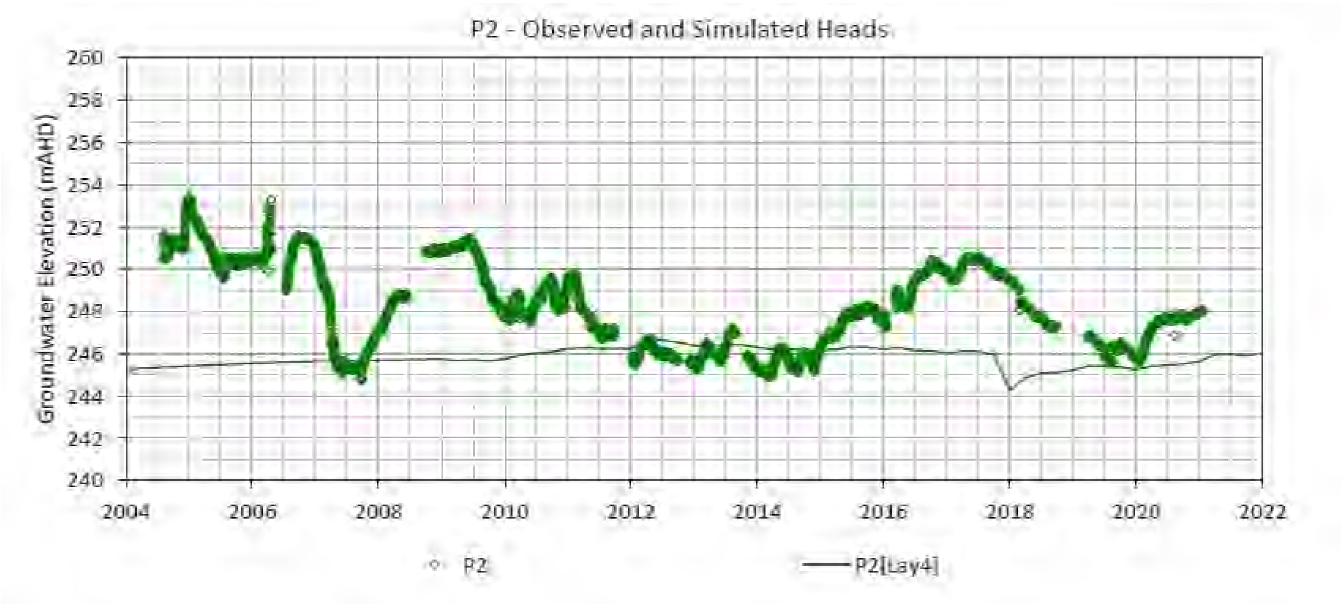


Figure 4-30 Hydrographs for P2- Tahmoor North

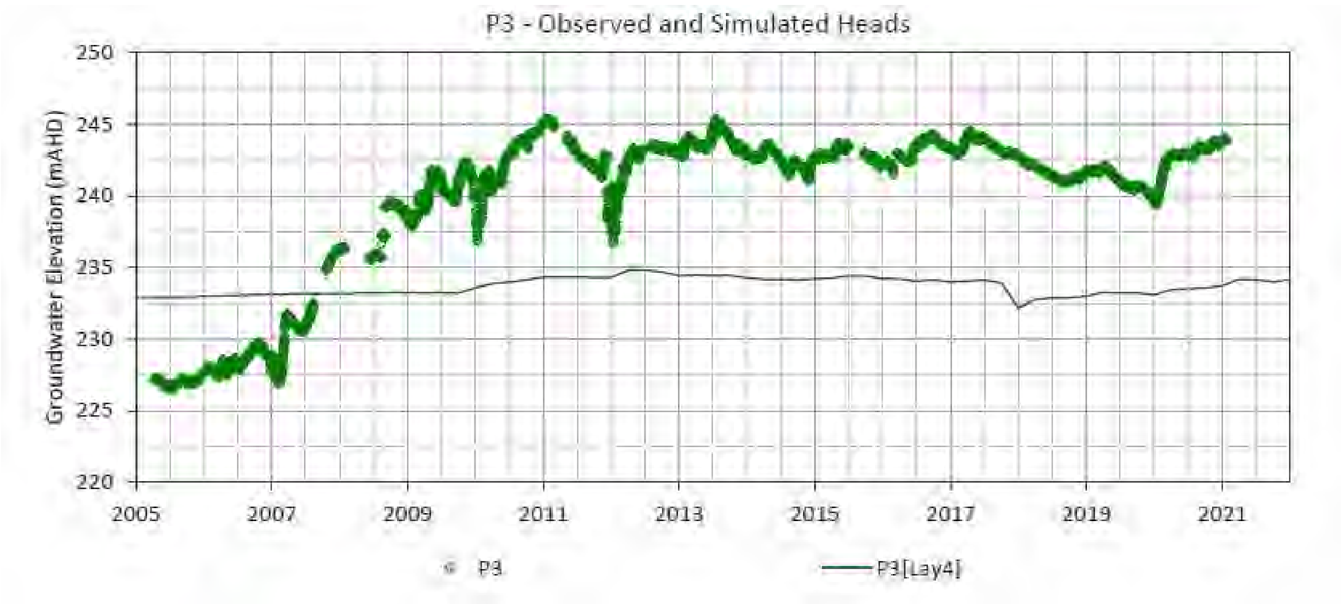


Figure 4-31 Hydrographs for P3- Tahmoor North

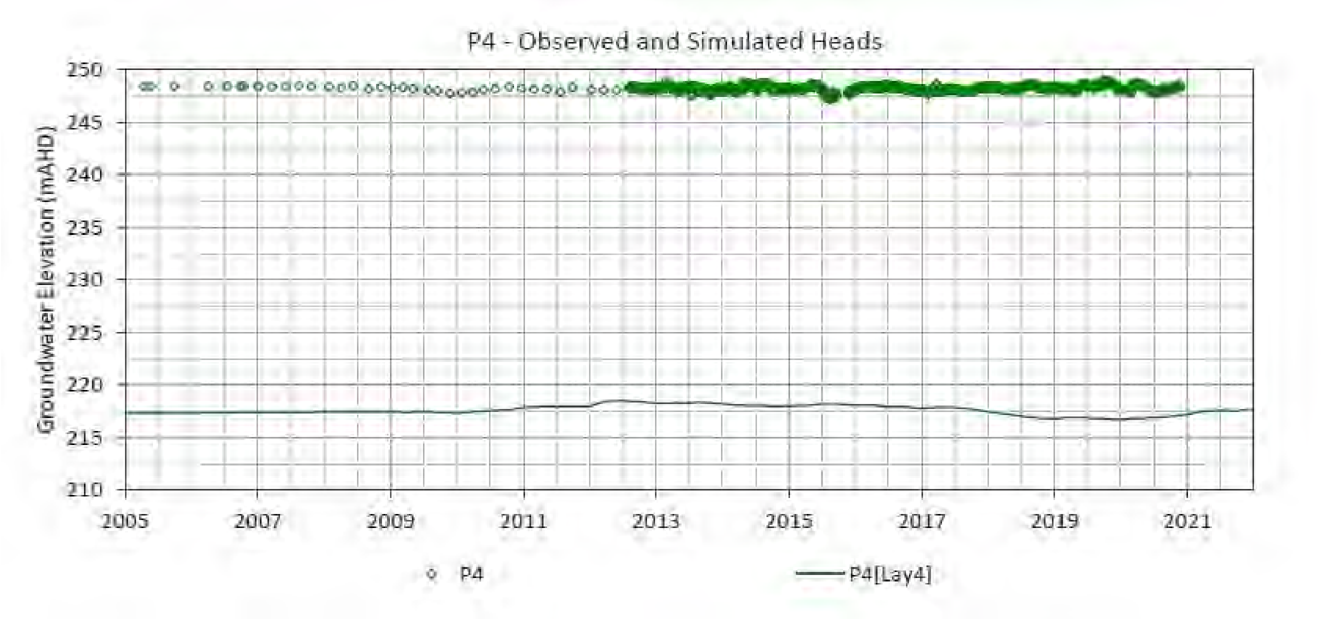


Figure 4-32 Hydrographs for P4- Tahmoor North

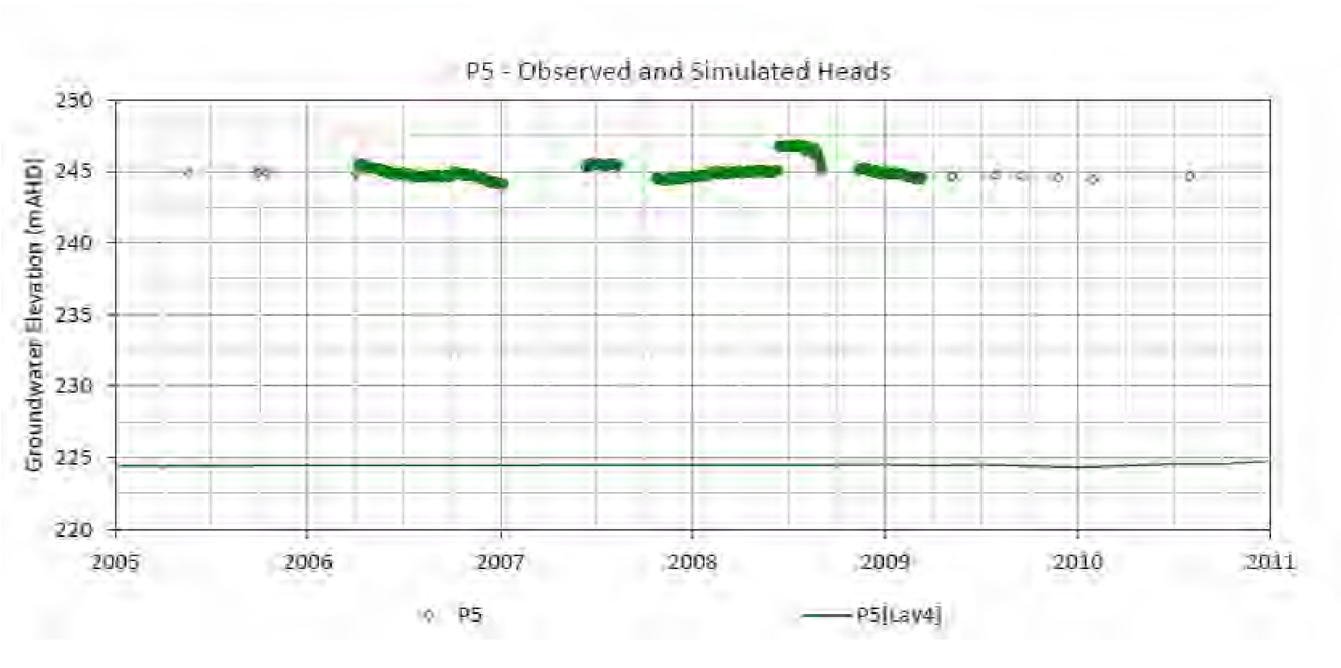


Figure 4-33 Hydrographs for P5- Tahmoor North

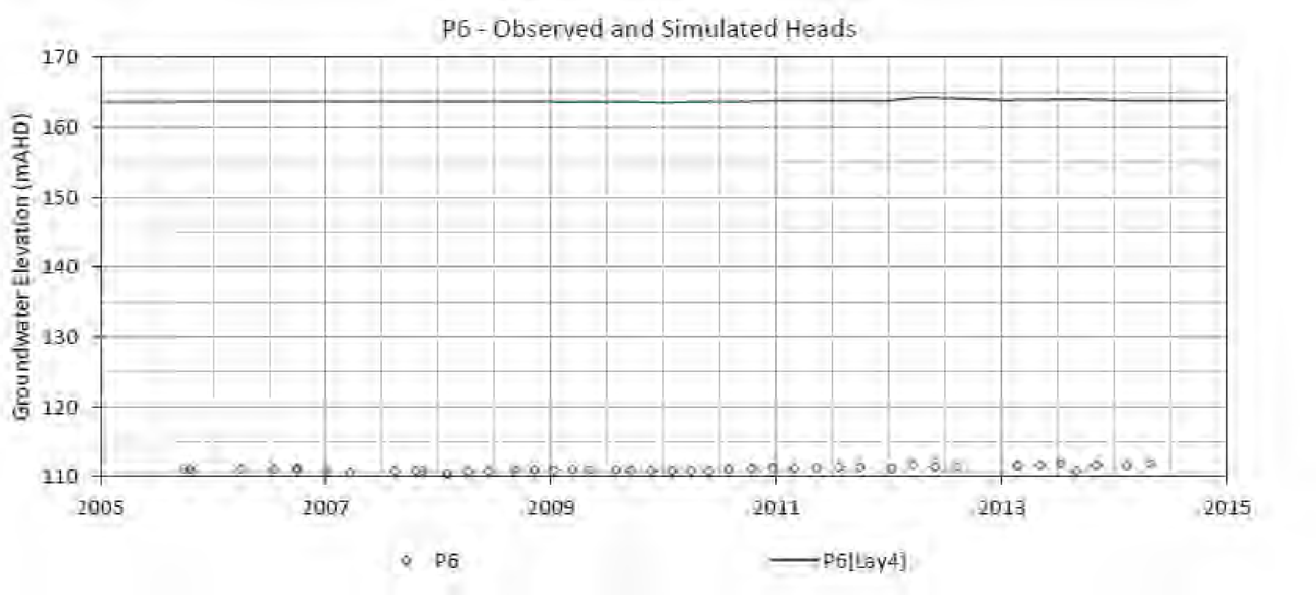


Figure 4-34 Hydrographs for P6- Tahmoor North

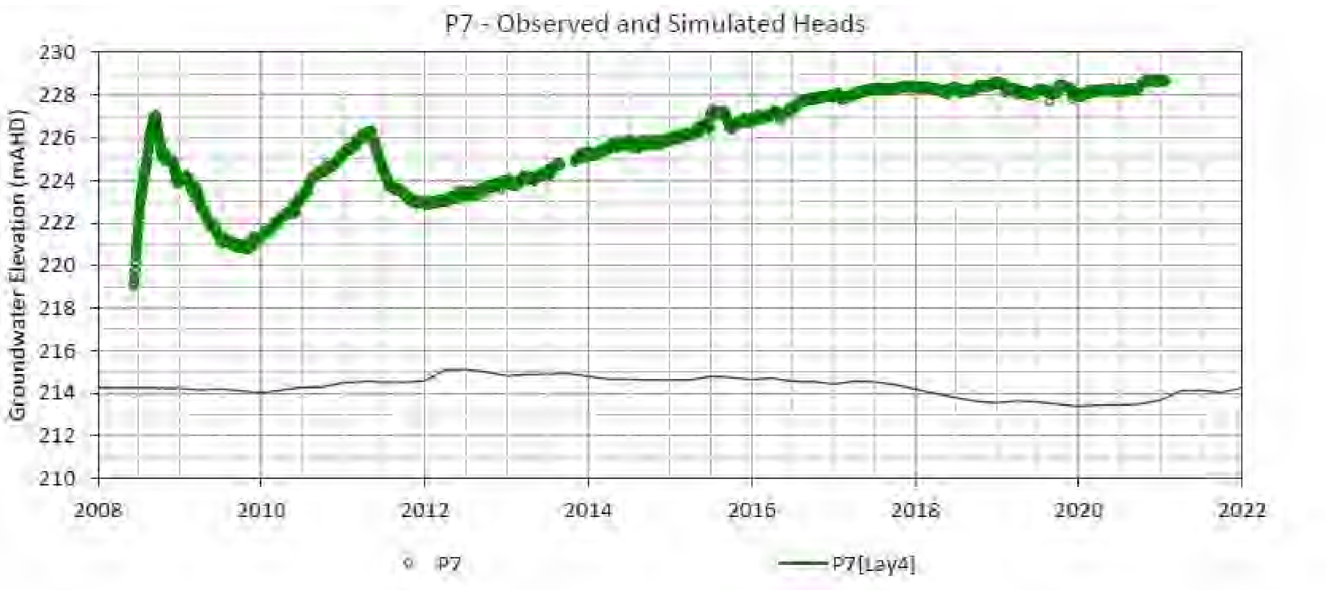


Figure 4-35 Hydrographs for P7- Tahmoor North

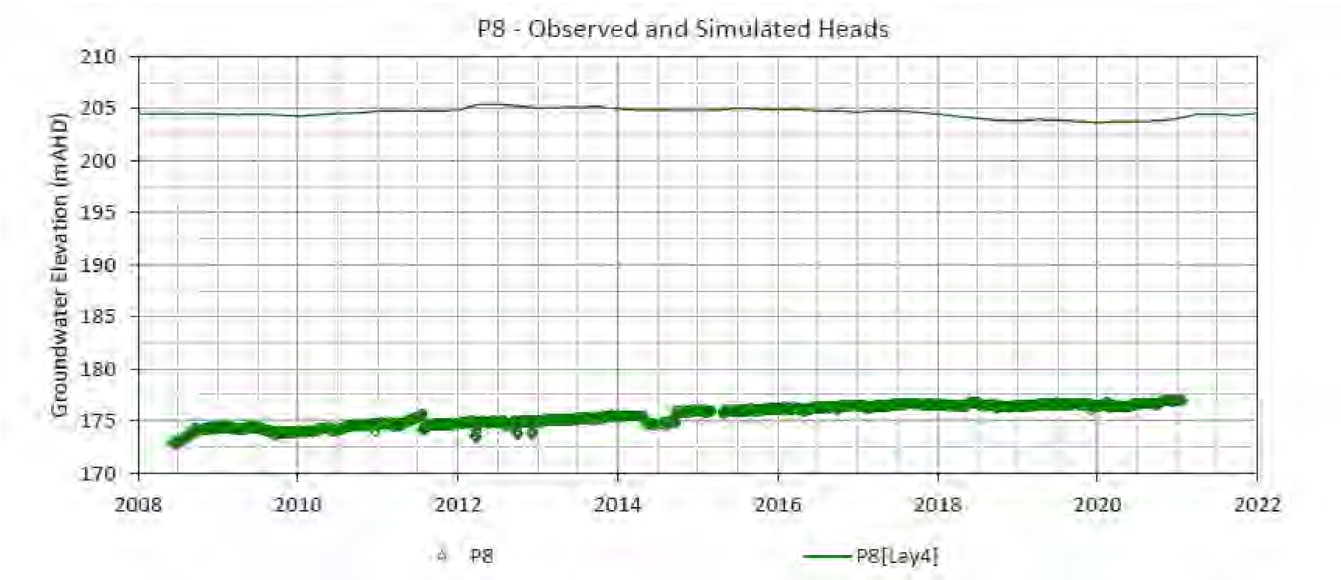


Figure 4-36 Hydrographs for P8- Tahmoor North

At bore P9 (Figure 4-37), the model replicates the LW31 and LW32 related drawdown observed in the shallow Hawkesbury Sandstones and the simulated water levels are within 5 m of observed levels (P9A, P9V1). The hydrograph for P9A shows the model was able to replicate the fluctuation in groundwater levels observed in Hawkesbury sandstone at this location. In the deeper section of the bore (P9_V3), the simulated drawdown is not as significant as the sharp decline in water levels observed after 2018. The mismatch in drawdown is likely due the properties of fractured zone and the timing of mining.

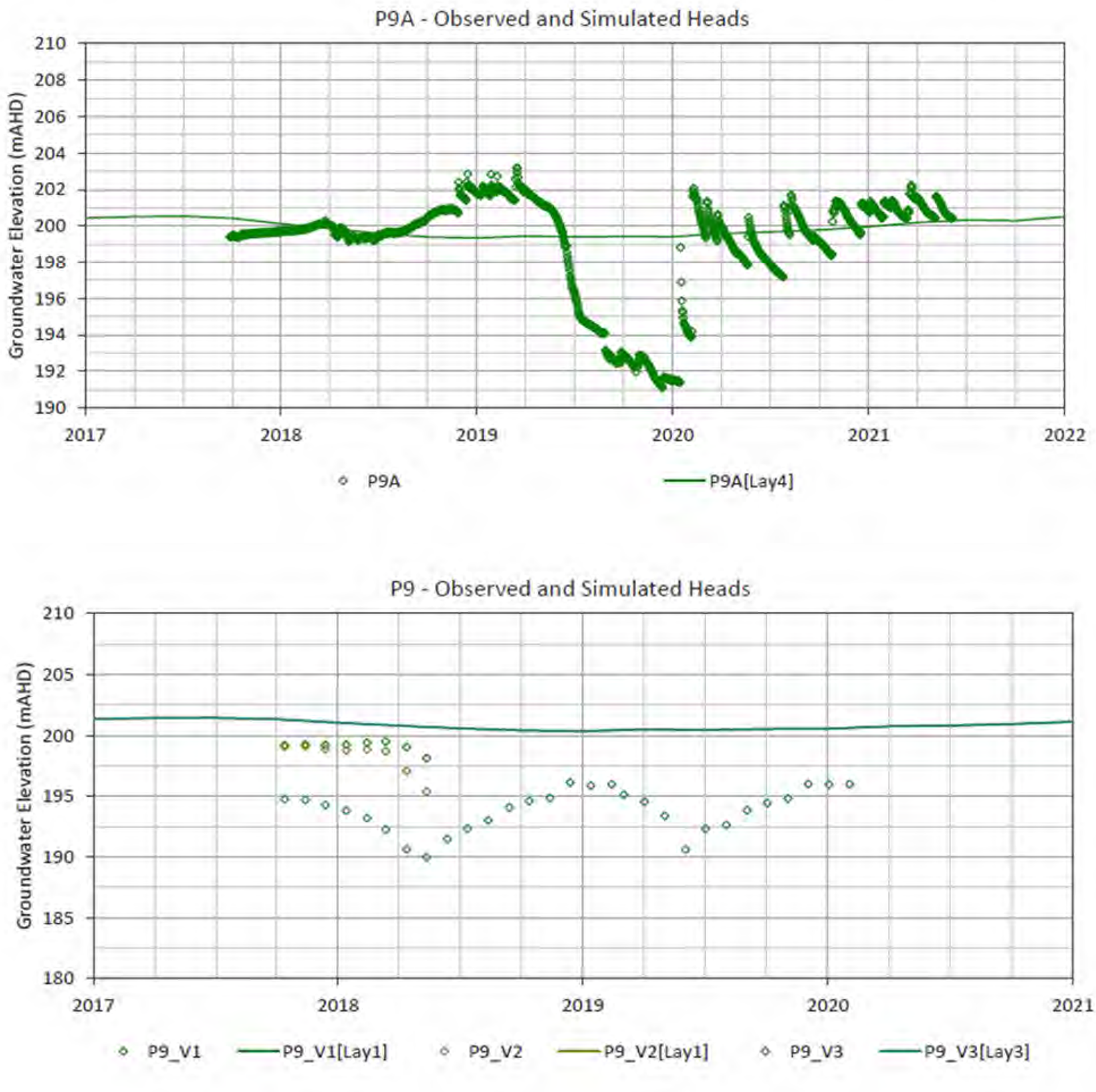


Figure 4-37 Hydrographs for P9 and P9A- Tahmoor North

Hydrographs for shallow bores along Redbank Creek (P10 A, P10) shown in Figure 4-38 indicate that in general, the model matches the groundwater levels along the creek. There is usually an offset of less than 5 m between observed and modelled. However, the simulated trends and seasonal fluctuation in the groundwater level in the Redbank Creek catchment are not significant as observed levels.

At bore P10, limited drawdown is simulated in the deep open standpipe bore (P10C) comparing to observed which is likely due to the timing of mining simulated in the model. Comparing to 2021 model, the match to observed levels in shallow bores P10 A and P10 has improved. As shown in Appendix F, overall, the match between simulated groundwater levels and observed for the bores along Redbank Creek is good and is within ± 10 m of the observed data (P11, P19, P29, P30, P32, P32, P33, P34). However, the model was not able to replicate the observed fluctuations in these bores. This can be seen in Figure 4-39 which shows the hydrographs for bores P30 and P32 along the Redbank creek.

Modelled water levels for bores along the Myrtle Creek catchment (P20B, P24A, P25, P26, P27 and P28A-B) are presented Appendix F. As shown the hydrographs, there is a consistent underprediction of groundwater levels at these bores. This underprediction of groundwater levels is likely due to the simulated mining in the model and simplifications in model layering. Although the modelled water levels do underpredict the observed levels, the model simulates the groundwater trend reasonably well.

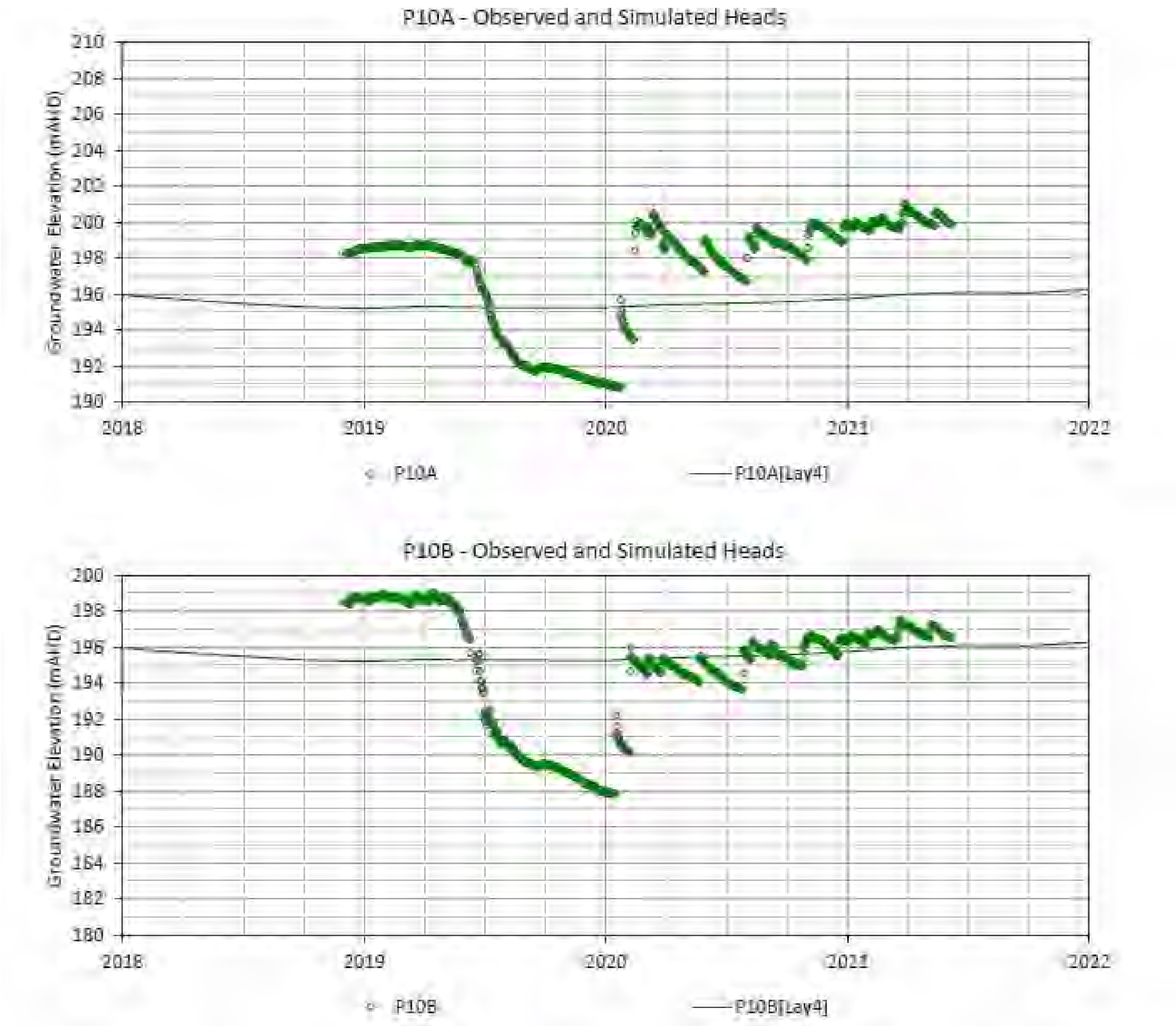
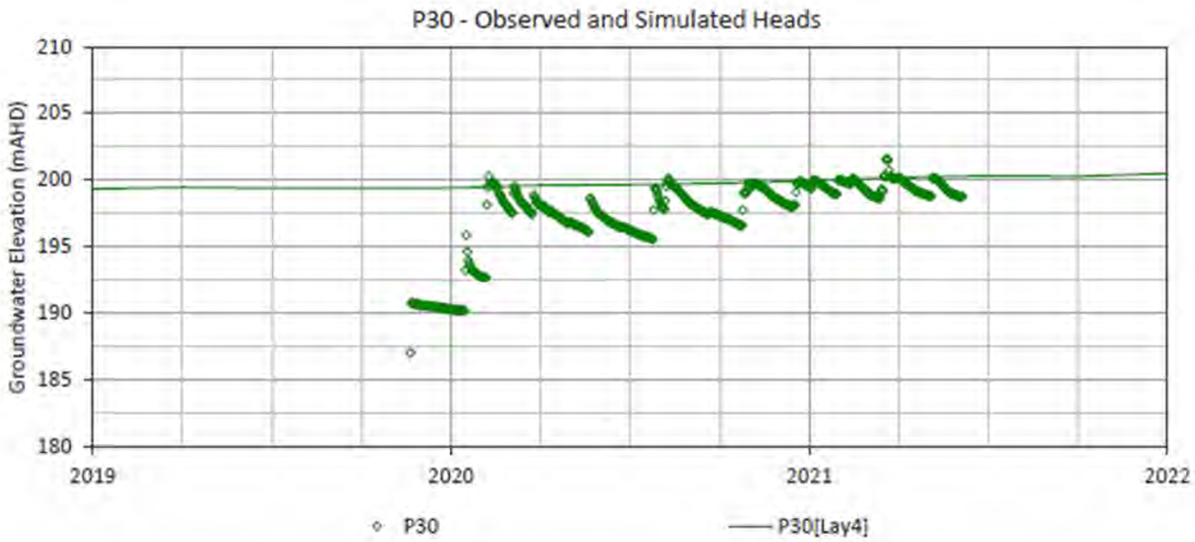


Figure 4-38 Hydrographs for P10A and P10B



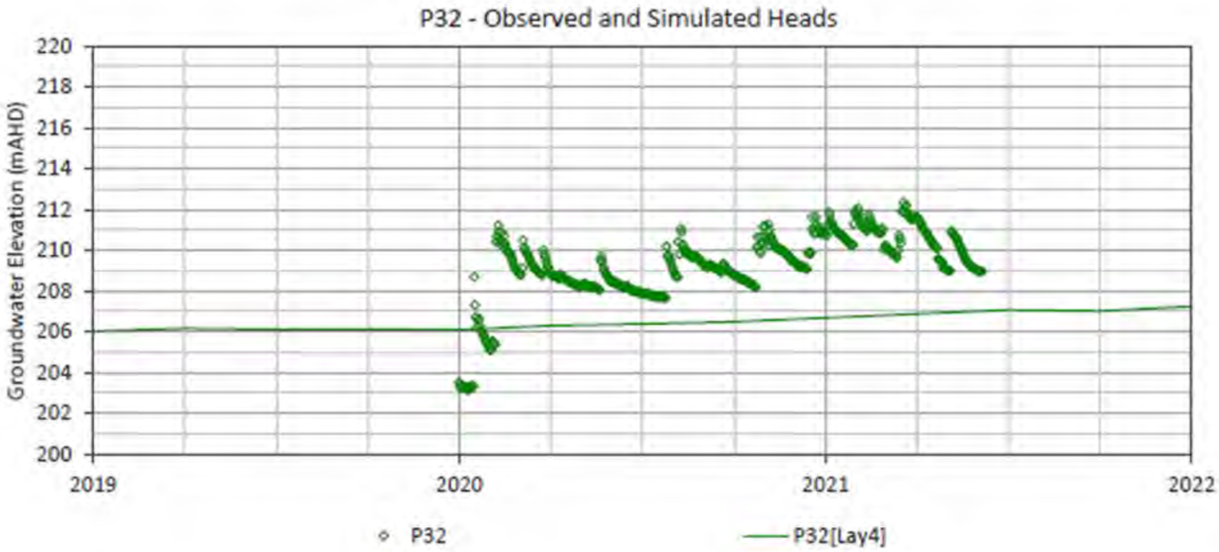


Figure 4-39 Hydrographs for P30 and P32

4.3.2.3.2 Western Domain

The hydrographs for the Western Domain Bores (P12-P17) are presented in Figure 4-40 to Figure 4-45 and in Appendix F. As shown in the figures, the model overpredicts the groundwater levels in P12 to P17 between 5 to 20 m. However, while modelled levels are offset, the trends and fluctuations are well matched. As shown in Figure 4-42, P14A that monitors the alluvium shows the model replicated the groundwater levels at this bore quite well but is not able to replicate the significant fluctuations at this bore. The over predictions of the groundwater levels in P14 to P17 is consistent with the SLR 2021 model.

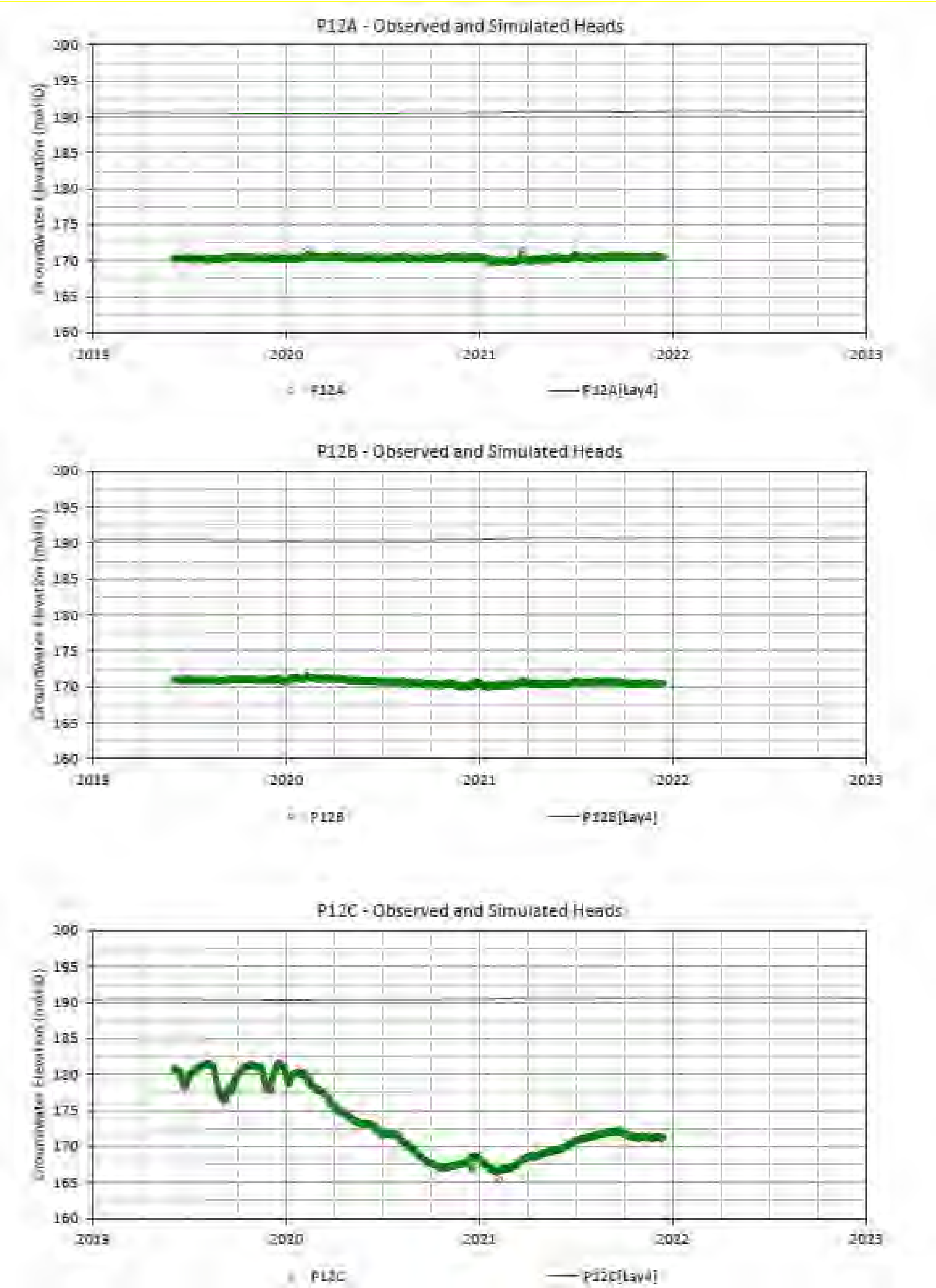


Figure 4-40 Hydrographs for P12- Western Domain

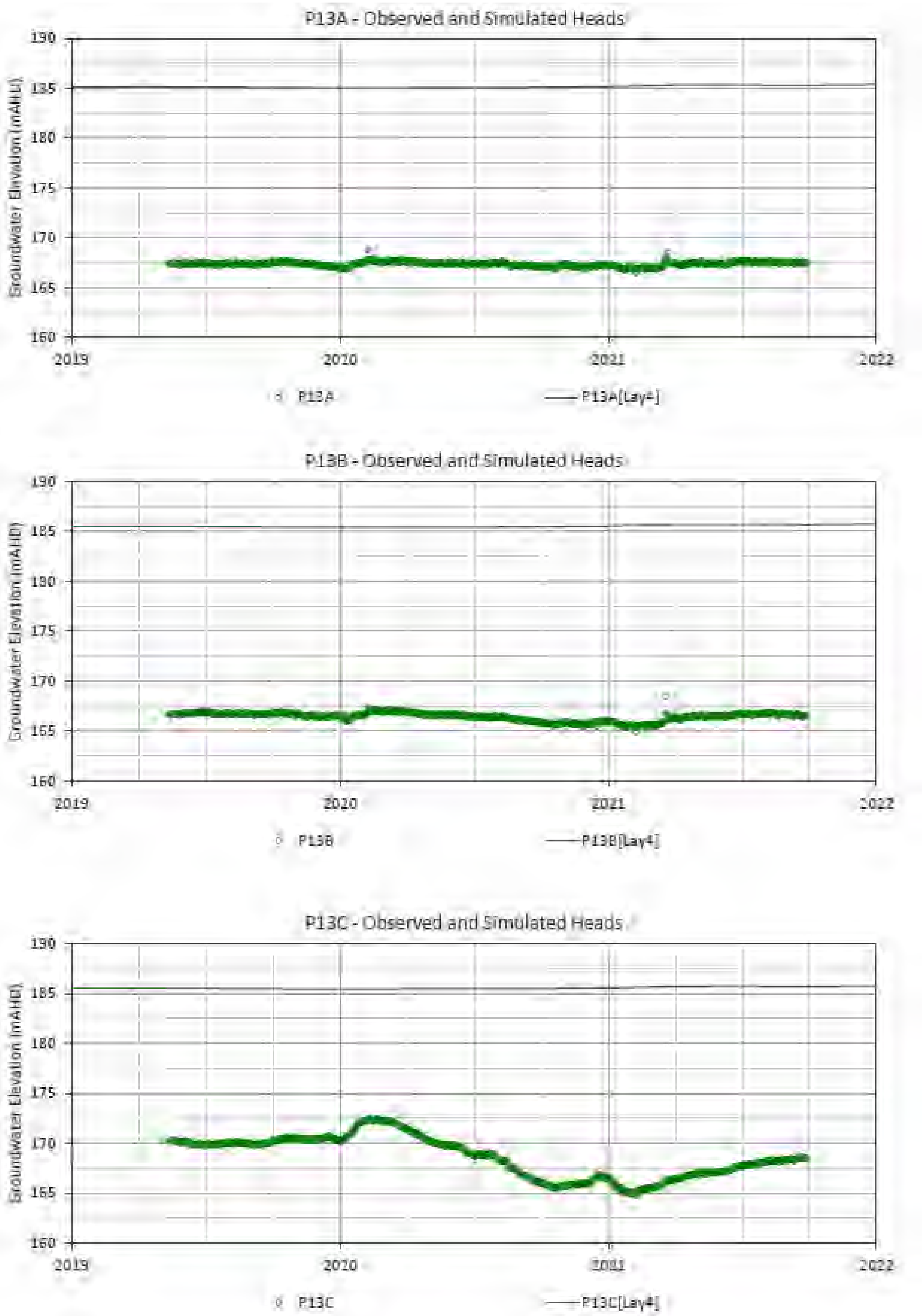


Figure 4-41 Hydrographs for P13- Western Domain

Figure 4-42 Hydrographs for P14- Western Domain

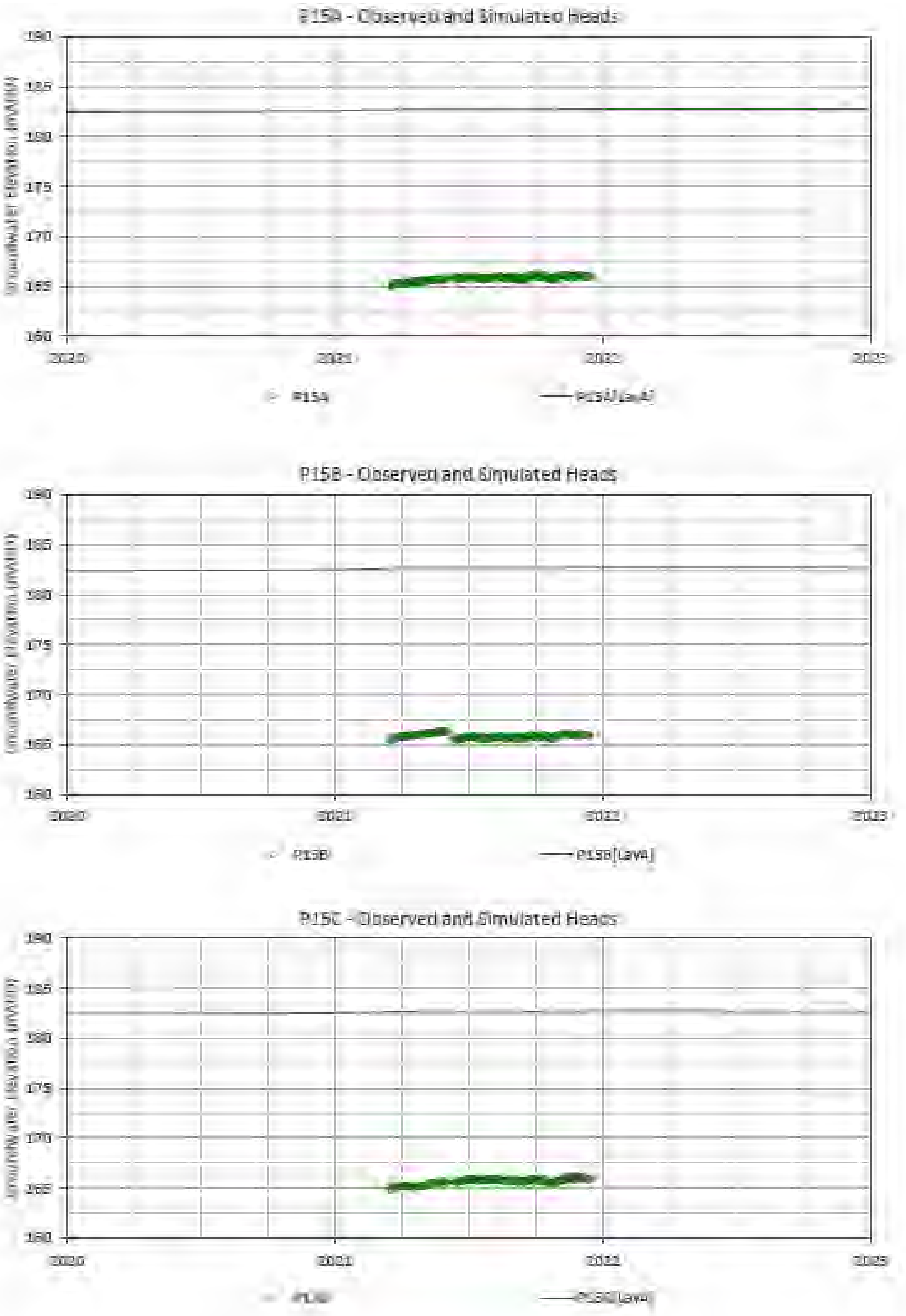


Figure 4-43 Hydrographs for P15- Western Domain

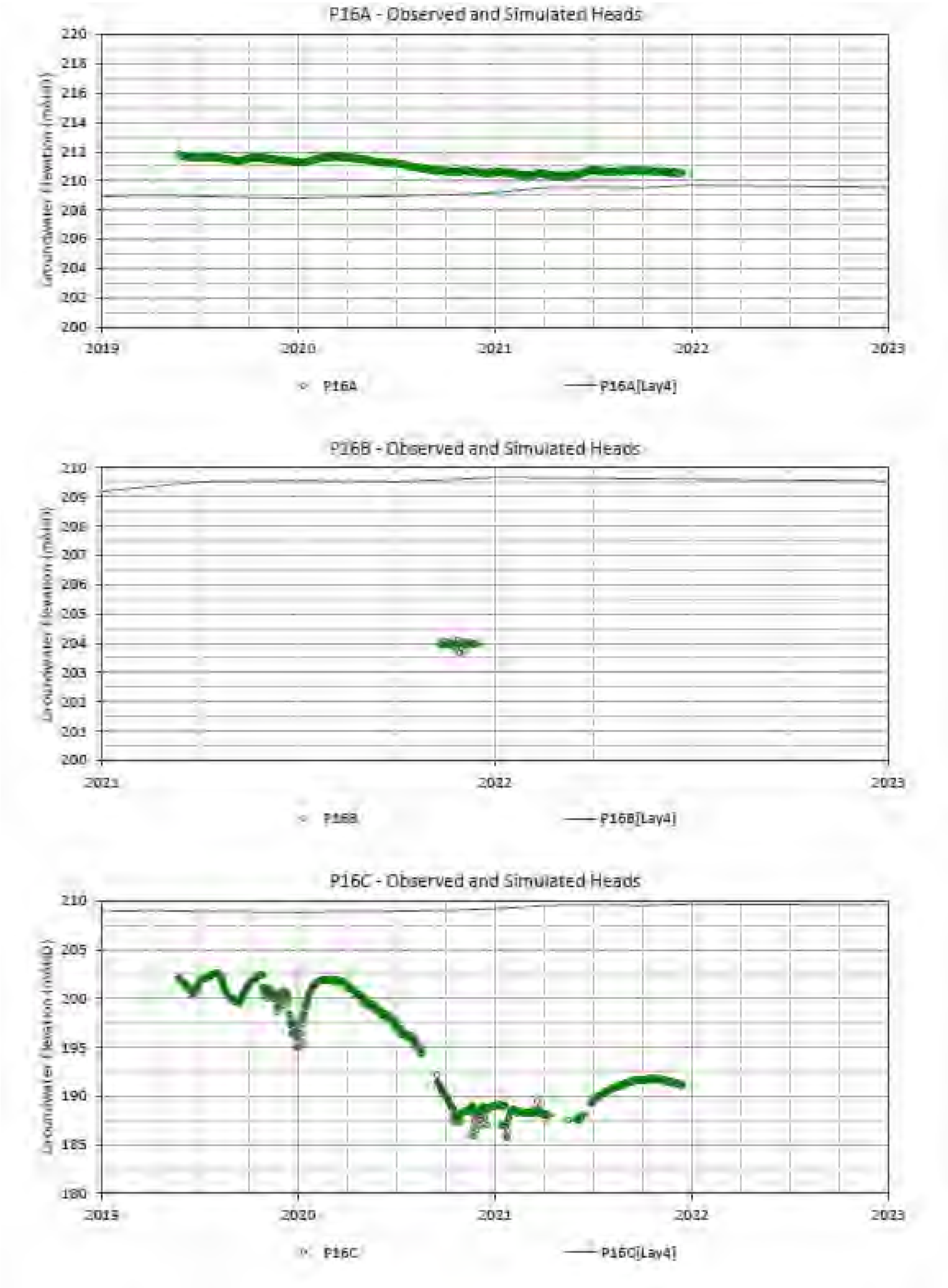


Figure 4-44 Hydrographs for P16- Western Domain

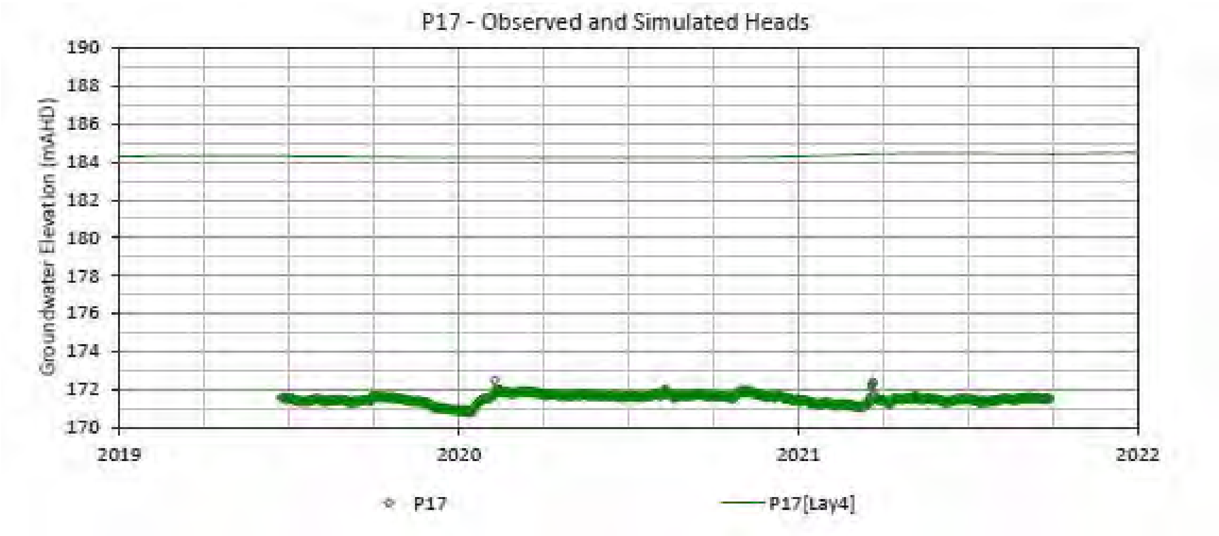


Figure 4-45 Hydrograph for P17- Western Domain

4.3.3 Inflows to Underground Mine Workings

Mine inflows were extracted from the groundwater model files using the MODFLOW-USG 'Zone Budget' utility. This was done on a zone-by-zone basis for the various mine areas within the model domain. For stress periods which were longer than 3 months, the groundwater model was setup to allow extraction of water budget information multiple times within each stress period, allowing the detail of the generally higher early-time inflows to be captured as well as the end-of-stress-period inflows.

Figure 4-46 compares the simulated mine inflows against the historical measurements at Tahmoor. The figure shows that while the model does not represent all peaks and troughs, it matches the magnitude of inflows and the general increasing trend after 2009. Figure 4-46 shows the model over predicts the historical pre-2009 inflows slightly.

For the recent period 2009-2021, the average historical measured inflows to the Tahmoor underground mine are 3.9 ML/d. The simulated average inflow for the same period is 4.1 ML/day. For the 1995-2002 period, the average measured inflows are 2.4 ML/day comparing to the modelled average inflow of 3.1 ML/day for the same period. Therefore, the model provides a more conservative estimate of inflows comparing to the measured inflows.

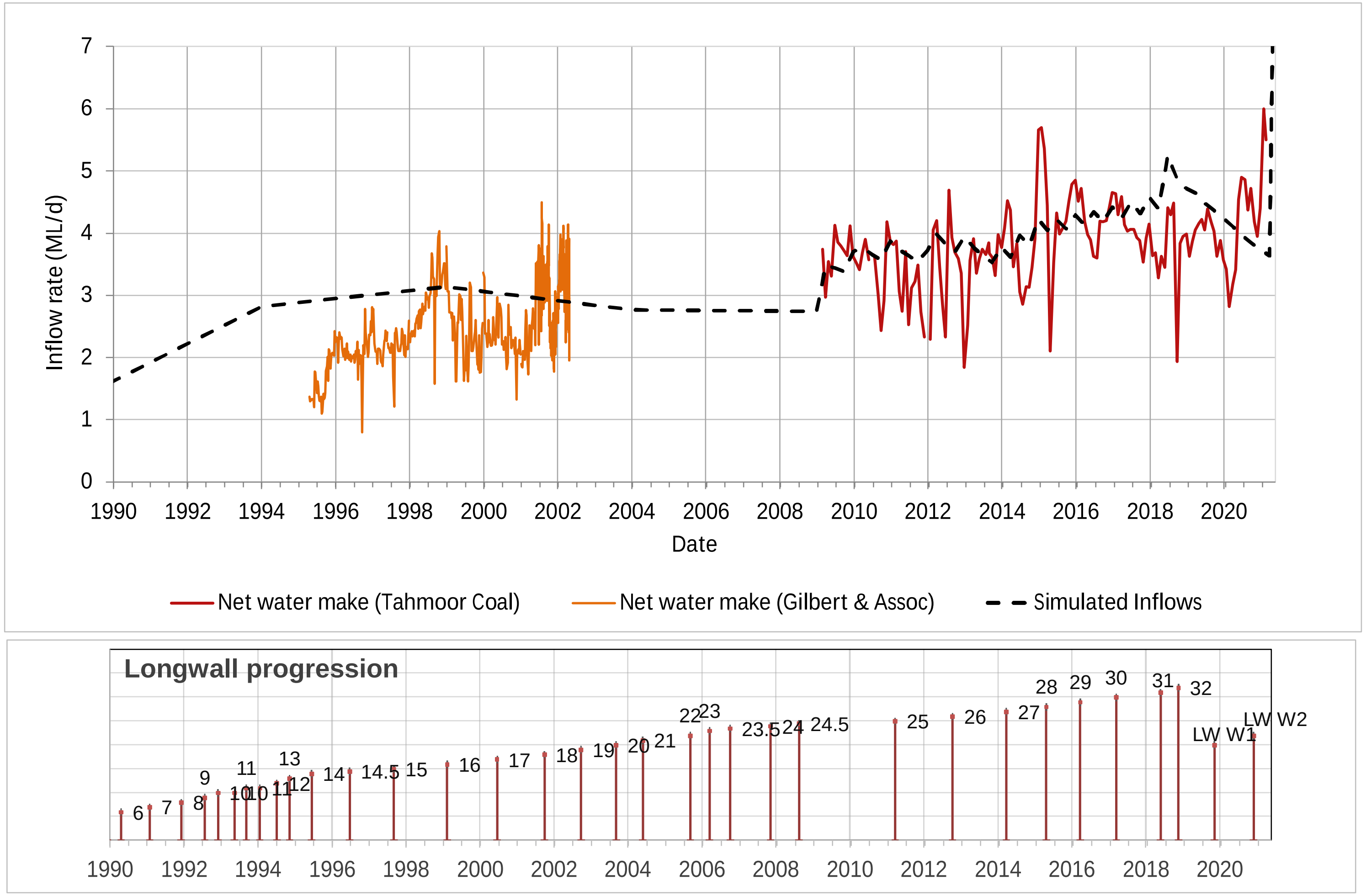


Figure 4-46 Comparison of Observed and Modelled Inflow at Tahmoor

4.4 Potential Groundwater Impacts

Predictive modelling presented herein has been conducted in support of the Extraction Plan for LW S1A-S6A. As such transient predictive modelling was used to simulate the proposed mining at LW S1A-S6A in conjunction with mining at other approved and foreseeable mines within the model domain. The predictive portion of the model comprises quarterly stress periods, starting from December 2021 to December 2026 (end of mining of LW S6A). The simulated predictive mine progression for the Project is presented Figure 4-9.

Transient predictive models have been developed for three model scenarios:

- Null run – no mining within region;
- Base case – all approved and foreseeable mining in region (including Tahmoor North), no proposed mining at Tahmoor South (LW S1A-S6A); and
- Full development of LW S1A-S6A – all approved and foreseeable mining in region plus proposed mining at LW S1A-S6A.

Mining is simulated as progressing quarterly, with MODFLOW Drain cells simulating the mining applied to the base of the target coal seam (i.e. the Bulli seam). After the Drains were removed, the MODFLOW Time Varying Materials (TVM) package was used to assign fracture properties to the cells above the longwalls.

4.4.1 Groundwater Take (mine inflow)

Predicted mine pit inflow volumes have been calculated as time weighted averages of the outflow reported by MODFLOW 'ZoneBudget' utility for model Drain cells. The inflows to the simulated LW S1A-S6A workings are presented in Figure 4-47. Inflows to the underground operations are predicted to increase over the first half of the operational life of LW S1A-S6A, reaching a maximum peak of approximately 2.5 ML/day at the beginning of 2025. Inflow rates decline gradually from 2025 until the cessation of mining in 2026, where inflows to LW S1A-S6A reach a steady rate of approximately 0.12 ML/day. The average inflow rate over the total duration of mining at LW S1A-S6A is calculated at 0.8 ML/day.

Figure 4-47 Modelled Mine Inflows

4.4.2 Loss of Flow in Streams

Estimates of predicted baseflow were calculated using the MODFLOW 'ZoneBudget' utility. The change in baseflow due LW S1A-S6A extraction was calculated by comparing the net river flow in the Full Development scenario against the Base Case scenario. The cumulative loss of baseflow was calculated by comparing the Full Development scenario against the Null scenario (i.e. no mining scenario).

Table 4-7 presents a summary of the predicted baseflow loss at several creeks directly related to LW S1A-S6A. The impact in ML/d represents the maximum baseflow impact from any time in the predictive run. The sub-catchments most affected by LW S1A-S6A are predicted to be Dogtrap Creek, and Bargo River between SW-1 and SW-13, which is consistent with the 2020 model predictions. The most recent estimation of baseflow loss was carried out by HEC (2022) which suggested a range of between 0.2 to 1.4 ML/day of inflow loss in Redbank Creek. Table 4-7 shows the predicted inflow loss from the groundwater model is close to the lower of bound of baseflow loss estimation for HEC (2022) study. In general, comparing to the 2020 EIS study, the current model predicts slightly less loss of baseflow in most of the creeks and rivers.

Table 4-7 Base Flow Impact in Local Watercourses

Watercourse	Site Used for Assessment	LW S1A-S6A Impact (ML/day)
Eliza Creek	SW-18	<0.001
Carters Creek	SW-23	<0.001
Blue Gum Creek		<0.001
Dogtrap Creek	SW-15	0.002
Teatree Hollow	SW-22	0.001
Cow Creek	SW-24	0.000
Stonequarry Creek	212053	<0.001
Bargo River	SW-1	<0.001
Bargo River	SW-13	<0.001
Bargo River	SW-14	<0.001
Hornes Creek	SW-9	<0.001
Nepean River	SW-21	<0.001
Matthews Creek		0.000
Cedar Creek		<0.001
Redbank Creek		<0.001
Avon River		<0.001
Cordeaux River		<0.001
Rumker Gully		<0.001
Newlands Gully		<0.001
Myrtle Creek		<0.001
Dry Creek		<0.001

The model did not predict drawdown to extend to the Thirlmere Lakes resultant of LW S1A-S6A extraction. Therefore, no changes in the lake leakages to the groundwater system or losses from the alluvium was predicted. This conclusion was confirmed by comparing water budgets for alluvial zones using the Base Case and Full Development scenarios.

4.4.3 Groundwater Drawdown

The process of mining reduces groundwater levels and pressures in surrounding geological units. The extent of the zone affected is dependent on the properties of the aquifers/aquitards and is referred to as the zone of depressurisation in a confined aquifer and zone of drawdown within unconfined aquifers, including the water table. Depressurisation and drawdown are greatest at the working coal-face, and reduces with distance from the mine. The predicted drawdowns due to LW S1A-S6A extraction and all the neighbouring mining operations (the 'Cumulative' mining effects) and due solely to LW S1A-S6A (incremental effects) are discussed in the following sections.

4.4.3.1 Incremental Drawdown

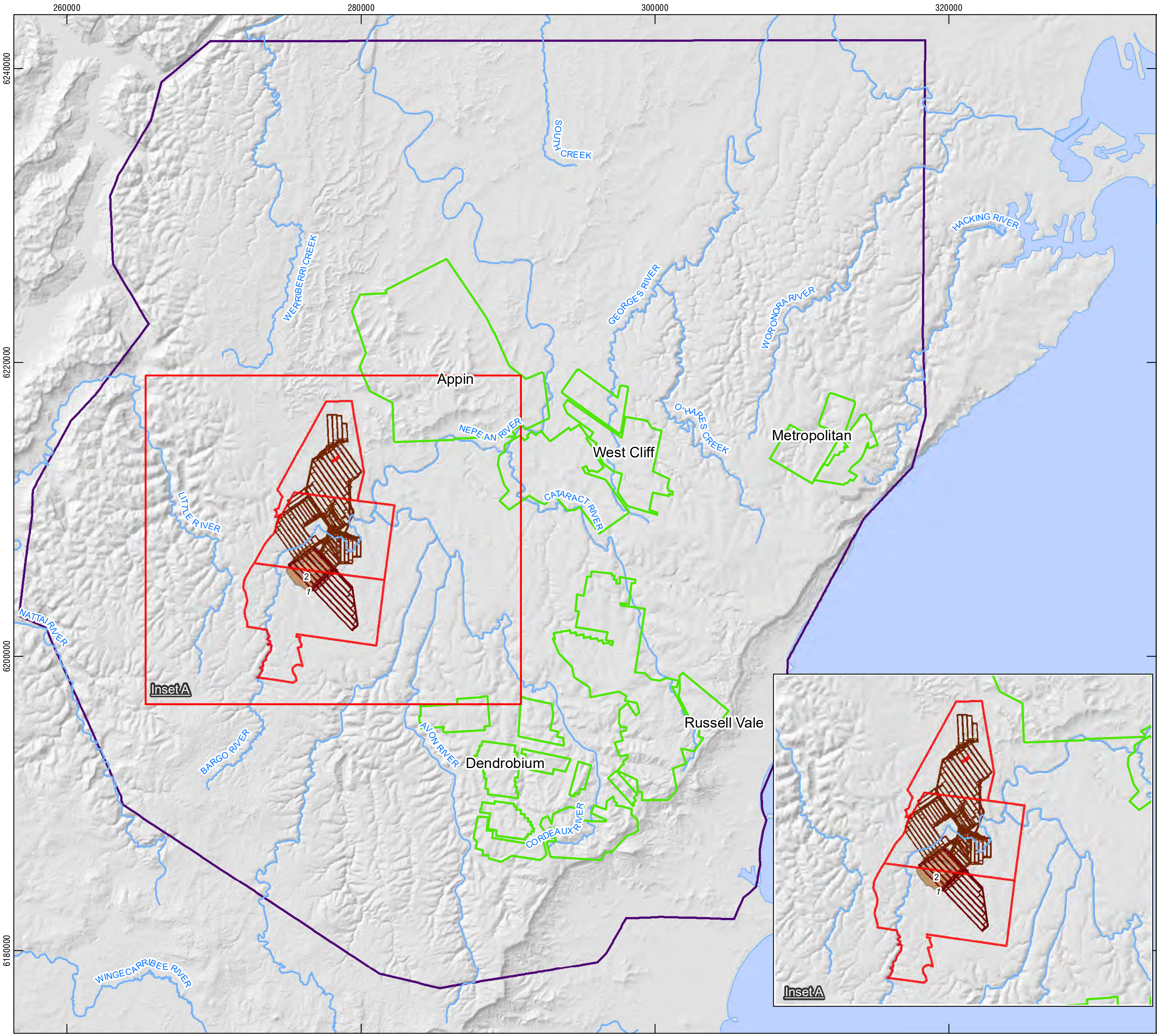
Maximum incremental drawdown due to the extraction of LW S1A-S6A was obtained by comparing the difference in groundwater levels for the Base Case scenario and the Full Development model scenario. The maximum drawdown is a combination of the maximum drawdown values recorded at each cell at any time from the start of the calibration period (January 2022) to end of mining of LW S6A (2026).

Predicted maximum drawdown due to LW S1A-S6A extraction (incremental drawdown) is presented from Figure 4-48 to Figure 4-50. Figure 4-48 shows the predicted maximum water table drawdown due to LW S1A-S6A extraction. The water table has been featured given it is the groundwater system with the highest level of connectivity to environmental (surface) features. Generally, maximum water table drawdown is <4 m across much of the Tahmoor South footprint, with the predicted drawdown extending approximately 0.5 km north or northeast, and 0.5 km southwest towards Lake Nepean.

Figure 4-49 shows the predicted maximum drawdown in lower Hawkesbury Sandstone which is the source of much of local groundwater extraction by bores. Figure 4-49 shows the maximum drawdown extends radially from the Tahmoor South longwall footprint. The 1 m contour extends to less than 1 km to the south towards Lake Nepean, and less than 1 km to the north and northeast .

Figure 4-50 shows the extent of maximum predicted depressurization (1 m contour) is approximately 2 km to the south and 2 km to the east LW S1A-S6A. The figure shows the maximum extents to the west of the panels through the faults present in that area. The cone of depression is predicted to be steepest around the mine area.

The shape of predicted drawdowns presented in the figures are similar to the predictions presented in the EIS report (SLR/HydroSimulations, 2020). However, the extent of maximum drawdown in this model is less than predicted in the EIS. The difference in drawdown extent is likely due to update in model structure, the use of depth dependence functions, and pilot points in the new model.



TAHMOOR COAL
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PREDICTED MAXIMUM WATER TABLE DRAWDOWN – TAHMOOR SOUTH ONLY

FIGURE 4-48

LEGEND

- Watercourse
- Tahmoor Coal Title
- Surrounding Mine
- Model Domain
- Mine Plan

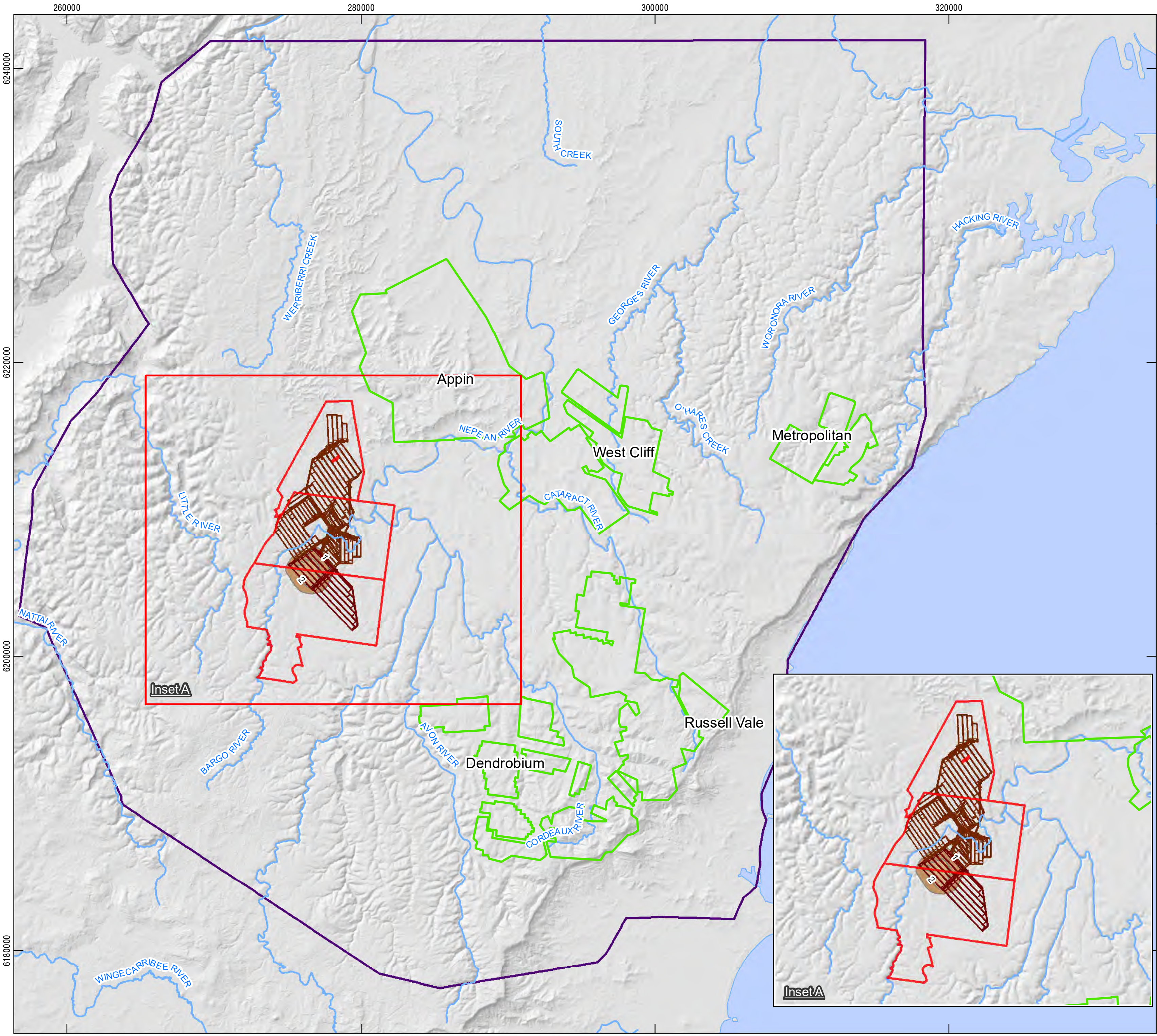
Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 500
- > 500

0 5 10 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
Project Number:	610.30652
Date:	29-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019



TAHMOOR COAL
LW S1A-S6A GROUNDWATER TECHNICAL REPORT

PREDICTED MAXIMUM DRAWDOWN IN LOWER HAWKESBURY SANDSTONE – TAHMOOR SOUTH ONLY

FIGURE 4-49

LEGEND

- Watercourse
- Tahmoor Coal Title
- Surrounding Mine
- Model Domain
- Mine Plan

Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 500
- > 500

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
Project Number:	610.30652
Date:	29-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

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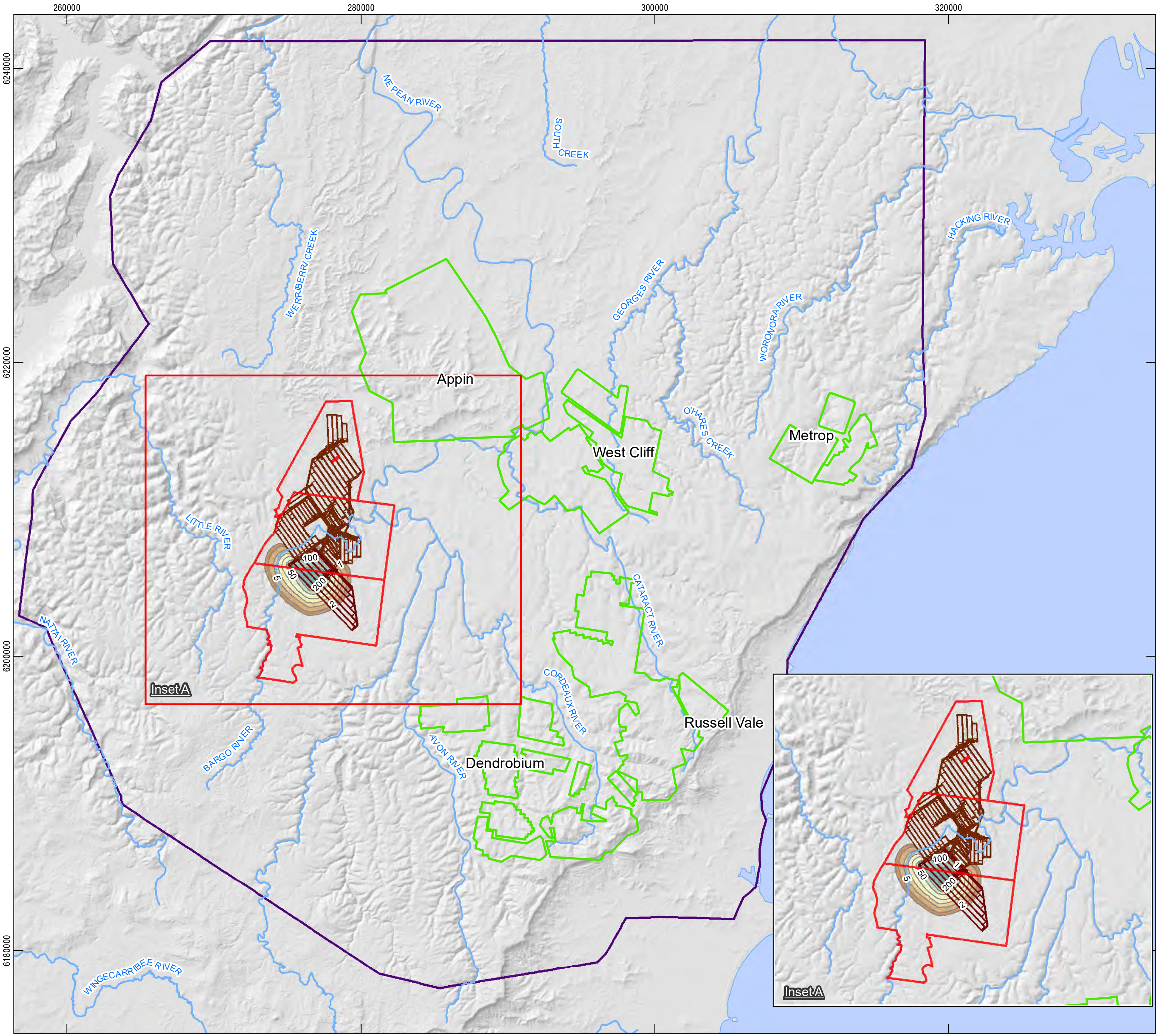

TAHMOOR COAL
LW S1A-S6A GROUNDWATER TECHNICAL REPORT

PREDICTED MAXIMUM DRAWDOWN IN BULLI SEAM – TAHMOOR SOUTH ONLY

FIGURE 4-50

LEGEND

- Watercourse
- Tahmoor Coal Title
- Surrounding Mine
- Model Domain
- Mine Plan

Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 500
- > 500

0 5 10 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
Project Number:	610.30652
Date:	29-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

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4.4.4 Cumulative Drawdown

The maximum cumulative drawdowns are obtained by the calculating the maximum difference in heads between the Full Development and Null Run model scenarios at each cell at any time, from the start of the calibration period (January 2022) to one year after end of extraction (completion of LW S6A).

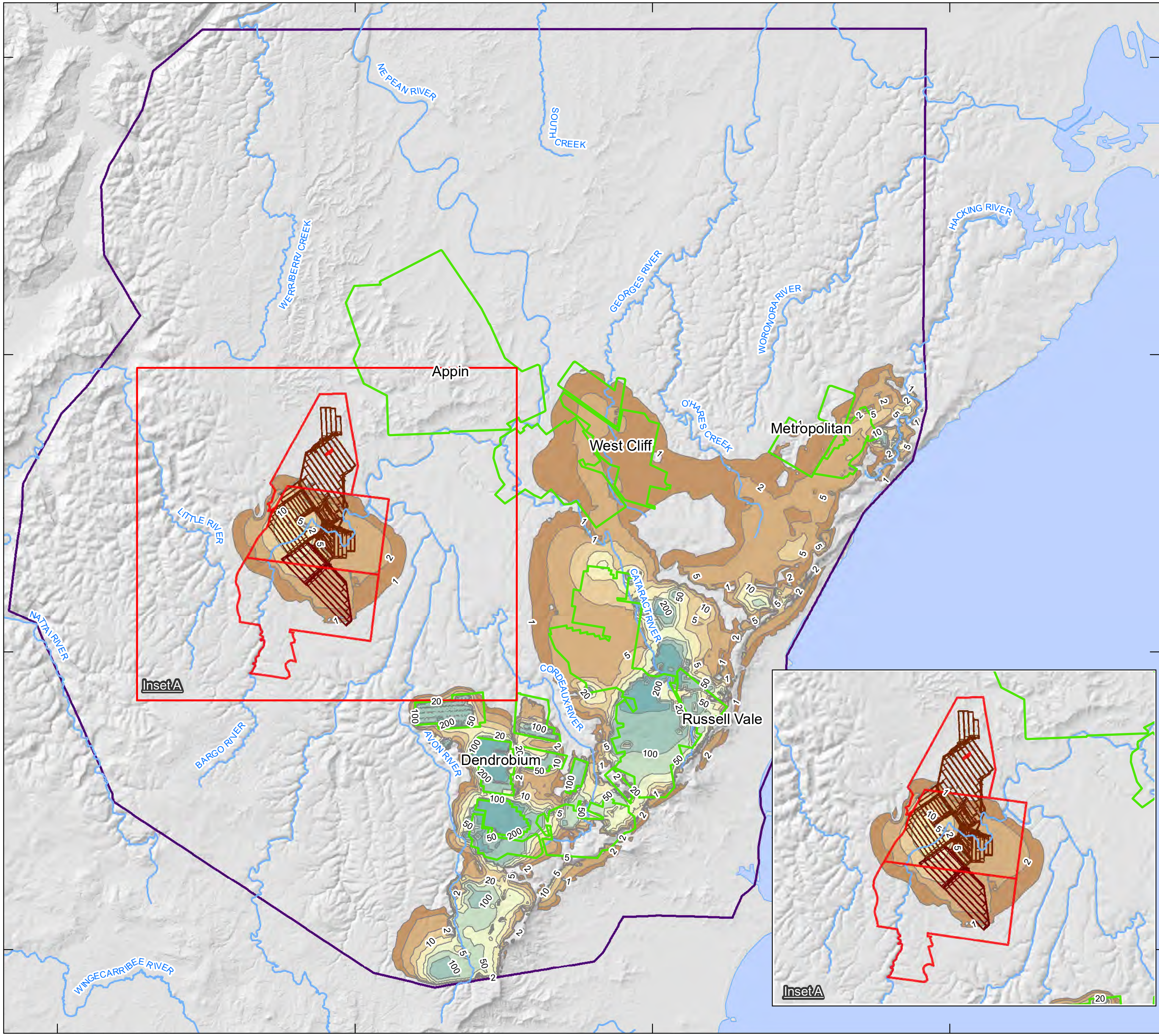
Figure 4-51 through Figure 4-53 show the maximum predicted cumulative drawdown for the water table as well as depressurisation within Lower Hawkesbury Sandstone and the Bulli Seam.

Figure 4-51 shows the extent of 0.2 m cumulative water table drawdown at LW S1A-S6A connects with the zones of impact from Tahmoor North, Appin and Dendrobium mine. Generally, 0.2 m water table drawdown extends across the footprint of the longwall mines, including all domains at Tahmoor. This is driven by the surface cracking mechanism now simulated in the model.

Figure 4-52 shows the maximum cumulative drawdown in Lower Hawkesbury Sandstone due to LW S1A-S6A extraction connects with the neighbouring sites (Tahmoor North, Appin and Dendrobium) in a similar manner as shown in the cumulative water table drawdown.

The extent of the predicted maximum cumulative drawdown shown in Figure 4-51 and Figure 4-52 are consistent with the predictions from the EIS (SLR/Hydrosimulations, 2020).

As shown in Figure 4-53, the greatest cumulative depressurisation occurs in the Bulli Seam, the extracted stratigraphic layer. Figure 4-53 shows drawdown in the Bulli Seam interacts with drawdown zone from Appin and Tahmoor North. However, the extent of depressurization due to LW S1A-S6A extraction does not interact with that from the Dendrobium Mine.



TAHMOOR COAL
LW S1A-S6A GROUNDWATER TECHNICAL REPORT

PREDICTED MAXIMUM WATER TABLE DRAWDOWN - CUMULATIVE

FIGURE 4-51

LEGEND

- Watercourse
- Tahmoor Coal Title
- Surrounding Mine
- Model Domain
- Mine Plan

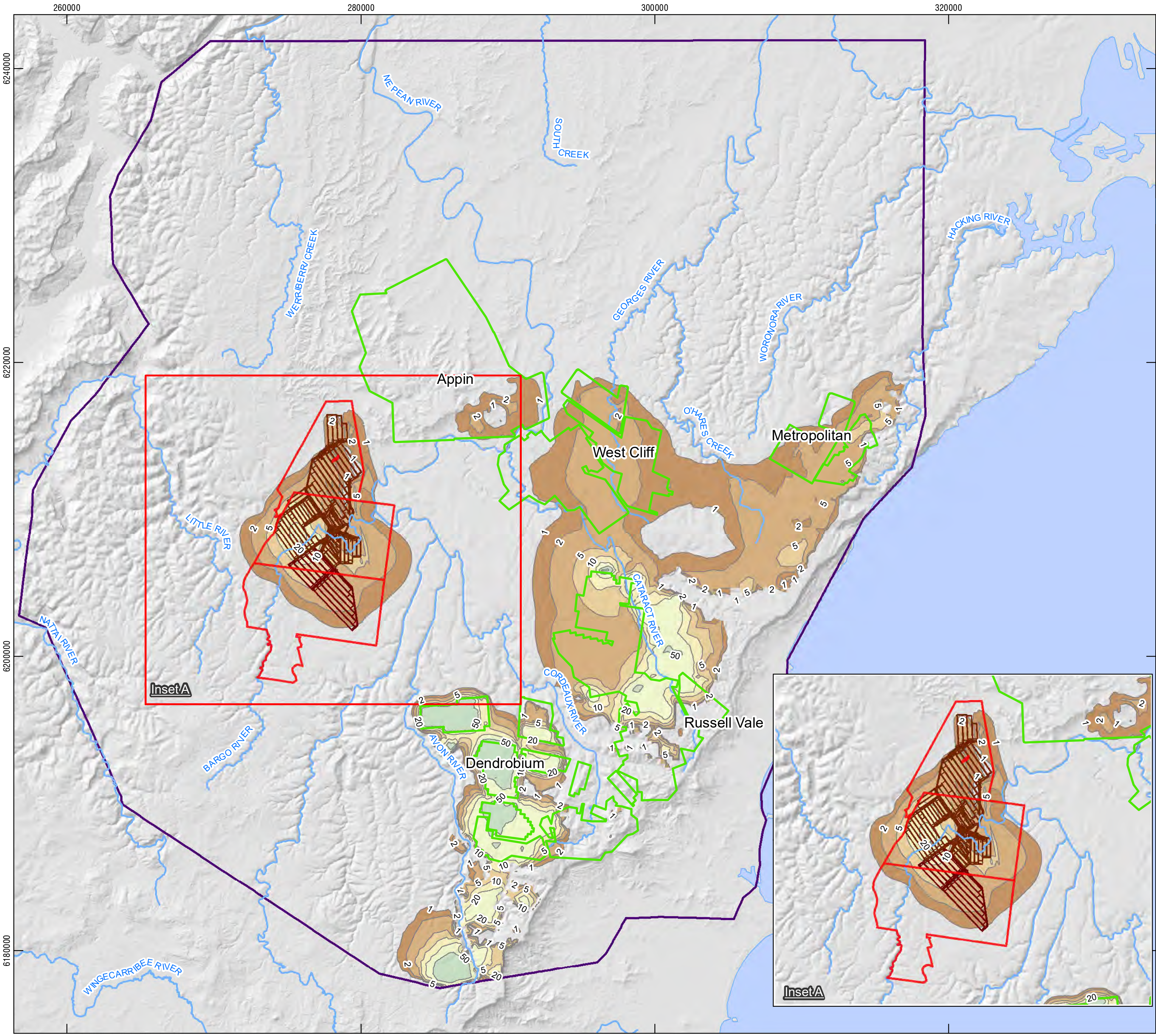
Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 500
- > 500

0 5 10 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
Project Number:	610.30652
Date:	29-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019



TAHMOOR COAL LW S1A-S6A GROUNDWATER TECHNICAL REPORT

PREDICTED MAXIMUM DRAWDOWN IN LOWER HAWKESBURY SANDSTONE - CUMULATIVE

FIGURE 4-52

LEGEND

- Watercourse
- Tahmoor Coal Title
- Surrounding Mine
- Model Domain
- Mine Plan

Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 500
- > 500

0 5 10 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
Project Number:	610.30652
Date:	29-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

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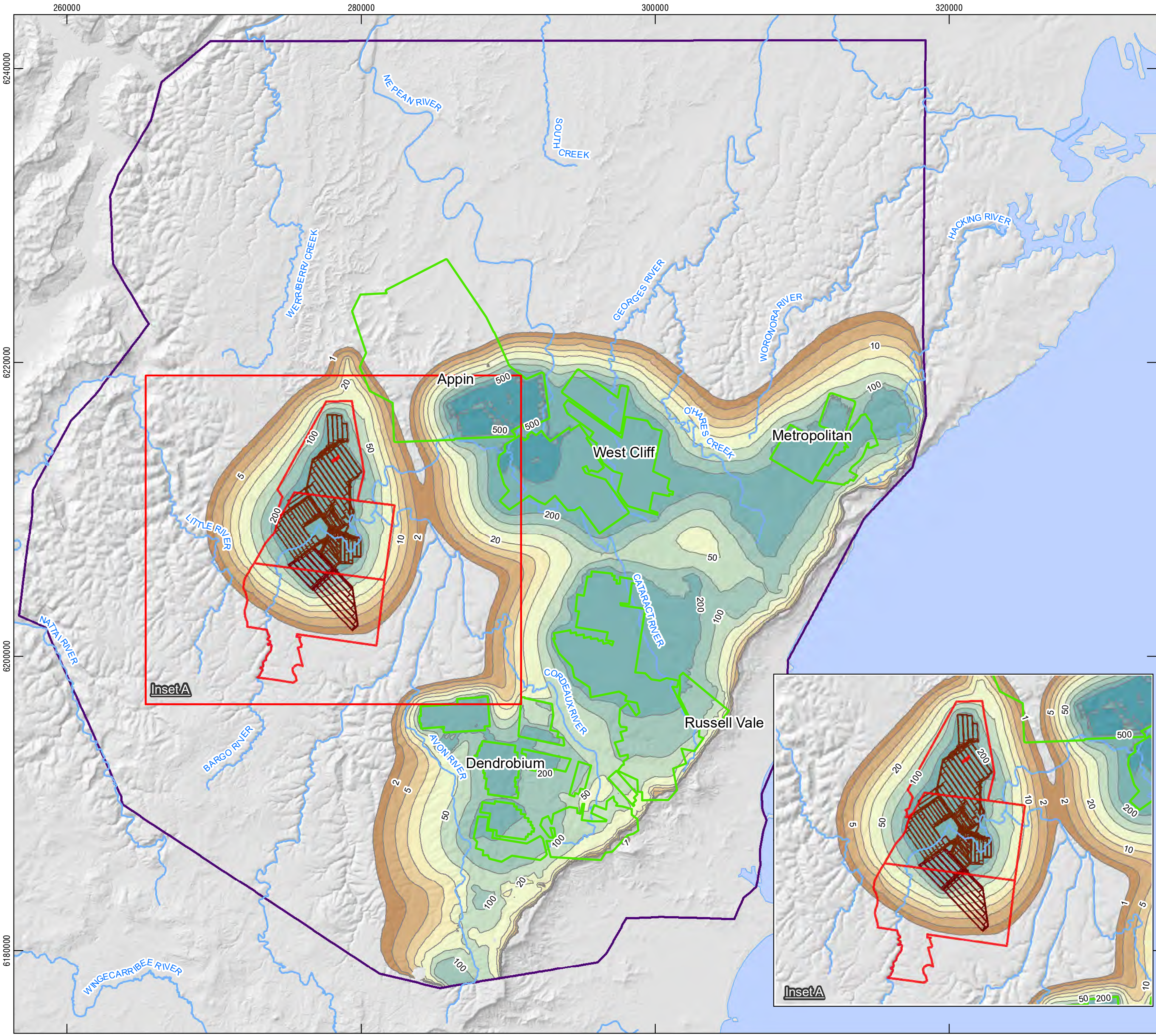

TAHMOOR COAL
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PREDICTED MAXIMUM DRAWDOWN IN BULLI SEAM - CUMULATIVE

FIGURE 4-53

LEGEND

- Watercourse
- Tahmoor Coal Title
- Surrounding Mine
- Model Domain
- Mine Plan

Drawdown (m)

- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 500
- > 500

0 5 10 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:350,000 at A4
Project Number:	610.30652
Date:	29-Apr-2022
Drawn by:	NT
Reviewed by:	DE/SH

Data Source: Mining Lease NSW Mineview Coal Lease 2019

4.4.4.1 Private Bores

The private bores incorporated in the impact assessment are discussed in detail in Section 3.5.8.3. Table 4-8 presents the simulated maximum drawdown experienced at any given point in time in the predictive model.

There are 3 bores identified with greater than 2 metres of drawdown resulting from LW S1A-S6A extraction. GW032443 is located above the longwalls and shows the largest drawdown (2.4 metres).

Table 4-8 Maximum Predicted drawdown at Private Bores due to LW S1A – S6A and cumulative mining

Bore ID	Easting	Northing	Bore Depth (m)	LW S1A-S6A Potential Impact (m)	Cumulative Mining Impact (m)
GW007445	277454	6204323	134.1	<1	3.6
GW014262	276764	6204587	48.8	1.6	4.6
GW031294	279732	6205706	90.2	<1	4.2
GW032443	276415	6206336	130.1	2.4	10.2
GW045404	282217	6206689	53.3	<1	2.2
GW051877	281673	6205875	92	<1	2.2
GW052016	280259	6203604	110	<1	1.4
GW053449	280369	6205813	105	<1	3.1
GW053450	282303	6205837	120	<1	1.8
GW054146	279886	6204676	104	<1	2.4
GW057969	281350	6206116	108	<1	2.5
GW058634	279479	6203419	122	<1	2.2
GW059618	281587	6204277	117	<1	1.2
GW062068	276581	6209579	150	<1	8.9
GW062661	282609	6207469	126.5	<1	1.6
GW070245	280090	6205714	97.5	<1	3.3
GW100433	278540	6202588	126	<1	1.5
GW100455	281877	6207020	96	<1	2.5
GW101936	280604	6202851	126	<1	1.0
GW102045	281266	6203733	120	<1	1.1
GW102179	280953	6203826	153	<1	1.3
GW102452	277234	6200992	120.5	<1	<1
GW103023	277261	6200993	165	<1	<1
GW103036	276840	6200964	132.5	<1	<1
GW103559	276504	6201854	190	<1	<1
GW103615	279720	6204034	103	<1	2.5
GW104008	280368	6205982	140	<1	3.5
GW104090	278208	6215913	150.5	<1	2.1
GW104323	279259	6203318	109	<1	2.1
GW104454	281410	6204568	66	<1	1.5
GW104659	276617	6207391	132	1.0	14.4

Bore ID	Easting	Northing	Bore Depth (m)	LW S1A-S6A Potential Impact (m)	Cumulative Mining Impact (m)
GW104860	282745	6206178	204.3	<1	1.6
GW105262	278609	6200731	104	<1	<1
GW105395	278543	6203037	90	<1	2.0
GW105577	280728	6207041	162	<1	3.5
GW105803	282278	6204644	140	<1	1.1
GW105847	277020	6204404	NA	1.1	3.9
GW105883	277040	6204629	NA	1.4	4.5
GW106546	282785	6206765	116	<1	1.6
GW106590	280442	6206344	150	<1	4.7
GW107470	282069	6208057	132	<1	1.7
GW108538	281155	6205941	66	<1	12.5
GW108842	282500	6204716	174	<1	1.0
GW109257	276603	6205052	120	2.2	6.0
GW110669	274565	6207896	132	<1	12.1
GW111047	280015	6206037	120	<1	4.6
GW111357	277051	6200982	144	<1	<1
GW111518	276882	6200987	150	<1	<1
GW111669	276232	6206450	120	2.2	10.8
GW111810	277034	6204407	142	1.1	3.9
GW111828	282391	6205638	205	<1	1.6
GW111842	282654	6205664	240	<1	1.4
GW112415	277479	6200865	139	<1	<1
GW112473	276577	6202010	138	<1	<1
GW115773	282232	6205725	81.87	<1	1.7
GW116897	281442	6203190	160	<1	<1

5 Management, Monitoring and Evaluation

In accordance with the requirements set out in Section 2.2, with the intention of monitoring the potential impacts to groundwater resulting from extraction of LW S1A-S6A, a Monitoring Program has been developed. The Groundwater Monitoring Plan (SLR, 2022) provided a review of current monitoring and outlined monitoring recommendations for pre-mining, during extraction and post-mining.

Implementation of the Groundwater Monitoring Plan is underway, with amendments made based on ongoing review of available data, the outcomes of the private bore survey and land access agreements. Provided here is the current proposed monitoring regime for LW S1A-S6A.

5.1 Groundwater Monitoring Plan

Described here are the proposed and operational monitoring regimes, aligned to the requirements outlined in Consent Condition B4, Table 2-3 and described in full in the Tahmoor South Groundwater Monitoring Plan (SLR, 2021). A summary of the monitoring pan is provided here.

The monitoring regime include monitoring of the following elements:

- Groundwater level and aquifer depressurisation;
- Groundwater quality;
- Impacts on surface water features;
- Impacts on groundwater dependent ecosystems (primarily Thirlmere Lakes, but also considering HEVAE (potential groundwater dependence) mapping by NSW government (DPIE, 2018)); and
- Potential effects on private bores.

To support the interpretation of groundwater monitoring data it is often considered in relation to the auxiliary monitoring networks, including:

- Surface water monitoring;
- Climatic monitoring; and
- Subsidence monitoring.

These monitoring plans were considered in development of the Groundwater Monitoring Plan. The monitoring network comprises both standpipe bores and multi-level VWP bores and cover major hydrogeological units and are broadly distributed across the project area. Negotiations for ongoing land access for routine monitoring of nine private registered bores is currently underway.

Table 5-1 shows how the proposed monitoring regime aligns with the groundwater receptors discussed in Section 3.5.8 and 3.6.

Table 5-1 Key Receptors and Associated Groundwater Monitoring

Receptor / Aspect	Parameter	Data Collection Frequency	Bore IDs
Teatree Hollow	Water Quality (field parameters)	Monthly	TBC032. P52, P53, P54, P55, P56
	Water Quality (speciation)	Quarterly	

Receptor / Aspect	Parameter	Data Collection Frequency	Bore IDs
	Water levels	Monthly (for manual dips and data downloads where loggers installed)	
	Water Quality (speciation)	Quarterly	
	Water levels	Monthly (for manual dips and data downloads where loggers installed)	
Other watercourses	Water Quality (field parameters)	Monthly	TBC026, TBC027, TBC033, TBC038. P51, P57
	Water Quality (speciation)	Quarterly	
	Water levels	Monthly (for manual dips and data downloads where loggers installed)	
Existing Users (bores)	Water levels / pressures	Monthly (for manual dips and data downloads where loggers installed)	TBC009, TBC018, TBC019B, TBC020, TBC027, TBC032, TBC039, P56 GW58634, GW109257, GW032443, GW104008, GW112473, GW106590, GW104659, GW062068, GW105395
	Water Quality (field parameters)	Quarterly	
	Water Quality (speciation)	Monthly/quarterly (dependent on land access agreements).	
Wirrimbirra Sanctuary (on Teatree Hollow)	Water Quality (field parameters)	Monthly	P55, P56
	Water Quality (speciation)	Quarterly	
	Water levels	Monthly (for manual dips and data downloads where loggers installed)	
Thirlmere Lakes	Water levels / pressures	Monthly (for manual dips and data downloads where loggers installed)	NSW govt: GW075409-1 & -2, GW075410, GW075411.
	Water levels / pressures	Monthly (for manual dips and data downloads where loggers installed)	TBC039.
	Water levels / pressures Water Quality (field parameters)	Monthly	P51 Proposed: P50
Cumulative effects (re: Bulli Seam Operations mine)	Water levels / pressures	Monthly (for manual dips and data downloads where loggers installed)	TBC026

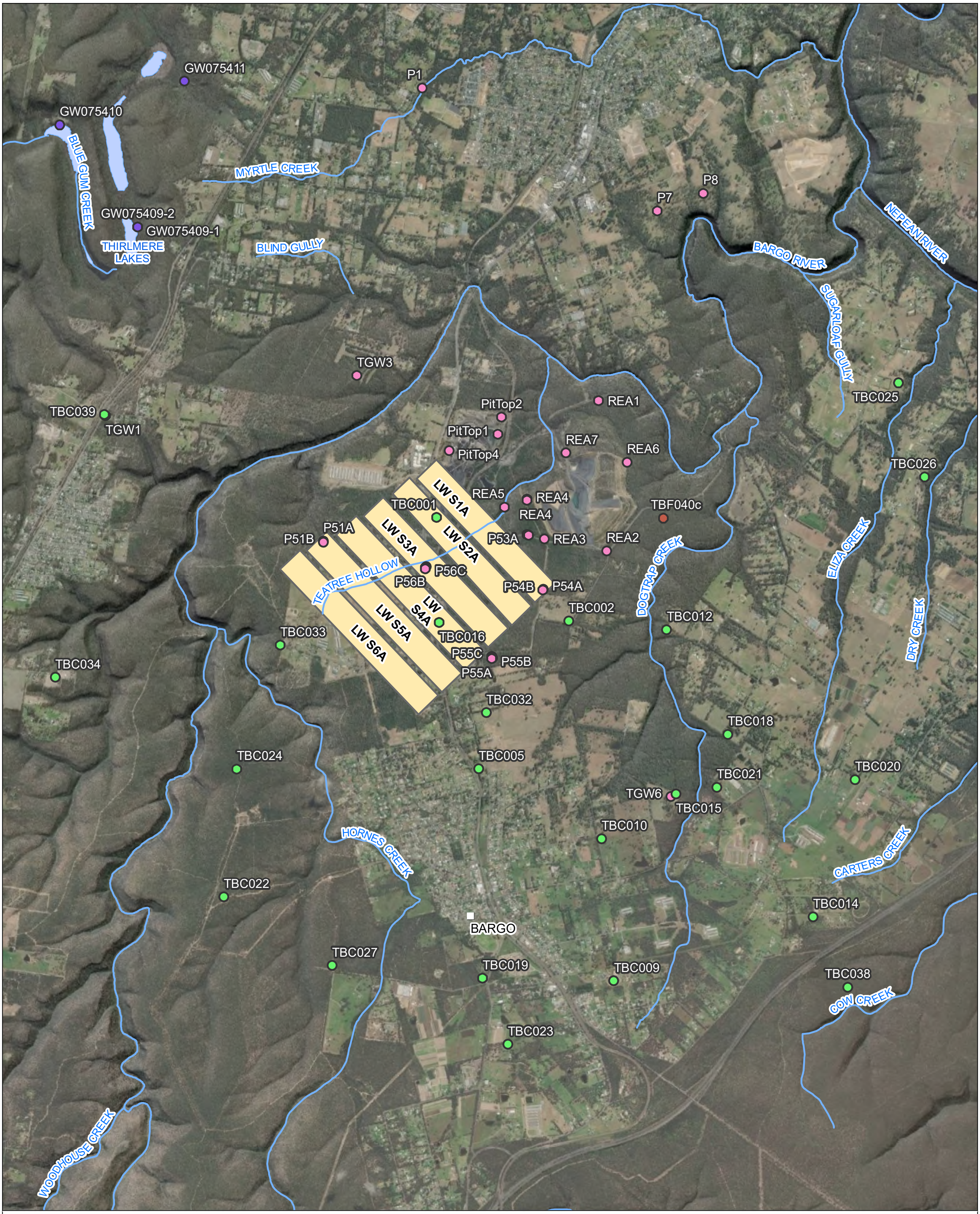
In addition to the monitoring bores described above are a series of piezometers at the pit-top and near the Reject Emplacement Area (REA) (Table 5-2). The piezometers are not associated with the regional aquifers (i.e. Hawkesbury sandstone) but rather constructed in shallow sediments and the REA and serve the following purposes:

- Pit Top piezometers are utilised to assess if the storage dams are leaking; and
- REA piezometers are utilised to assess if there is any acid mine drainage or general water quality impacts leaching the dumps.

The current network is considered adequate monitor these entities and consequently no additional monitoring bores are proposed here.

Table 5-2 Reject Emplacement Area (REA) Piezometers

Bore ID	Easting	Northing	Status	Targeted Aquifer	Type	Depth
REA1	278362.3	6207826.8	Active	REA	OSP	54.8
REA2	278441.2	6206332.2	Active	REA	OSP	58
REA3	277820.7	6206453.4	Active	REA	OSP	41
REA4	277650.8	6206835.2	Active	REA	OSP	57.5
REA5	277424.2	6206769.0	Active	REA	OSP	7.2
REA6	278643.3	6207214.8	Active	REA	OSP	46.3
REA7	278035.1	6207307.3	Active	REA	OSP	43
PitTop1	277357.6	6207494.9	Active	pit-top	OSP	55.04
PitTop2	277396.0	6207663.2	Active	pit-top	OSP	6.85
PitTop4	276872.2	6207331.6	Active	pit-top	OSP	33.7



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Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:50,000 at A4
Project Number:	610.30637
Date:	27-Jun-2023
Drawn by:	NT

Minor Town

Watercourses

Lakes

Tahmoor South Mine Plan

Approved

Groundwater Monitoring Locations

Centreline HOF bore

Deep GWL

NSW govt monitoring

OSP

TAHMOOR SOUTH LW S1A – S6A GROUNDWATER TECHNICAL REPORT

Monitoring Bore Locations

FIGURE 5 -1

5.1.1 Groundwater Levels

The Tahmoor South LW S1A-S6A shallow bore installation program is currently underway, with majority of bores installed by June 2022. A selection of seven private bores have established land access agreements for ongoing monthly water level monitoring. Additionally, the existing VWP network is installed and pertinent Tahmoor South sites upgraded to telemetry with continuous data streaming linked to trigger values and an associate alert system. The REA and Pit-top bores are operational and monthly monitoring will be continued.

A summary of the water level network is provided in Table 5-3.

Table 5-3 Summary Of Water Level Monitoring Bores

Bore ID	Status	Easting	Northing	Depth (mBNS)	Monitoring Regime
REA1	Active	278362.3	6207826.8	54.8	monthly
REA2	Active	278441.2	6206332.2	58	monthly
REA3	Active	277820.7	6206453.4	41	monthly
REA4	Active	277650.8	6206835.2	57.5	15 minute intervals
REA5	Active	277424.2	6206769	7.2	monthly
REA6	Active	278643.3	6207214.8	46.3	monthly
REA7	Active	278035.1	6207307.3	43	monthly
PitTop1	Active	277357.6	6207494.9	55.04	monthly
PitTop2	Active	277396	6207663.2	6.85	monthly
PitTop4	Active	276872.2	6207331.6	33.7	monthly
P50 a, b, c (Thirlmere1)	Approved	273900	6208500	Approx. 20, 35, 65	monthly
P51a	Active	275623.00	6206431.71	19.96	15 minute intervals
P51b	Active	275620.60	6206419.68	35.38	15 minute intervals
P57 a, b (Hornes1)	Approved	275500	6204600	Approx. 20, 35	monthly
P52a	Active	277649.84	6206848.30	41.17	15 minute intervals
P53 a	Active	277649.91	6206496.48	41	15 minute intervals
P53b	Active	277658.61	6206492.50	60.55	15 minute intervals
P53c	Active	277665.80	6206489.23	80.78	15 minute intervals
P54a	Active	277809.68	6205951.98	25	monthly
P54b	Active	277806.92	6205944.68	35.99	monthly
P55a	Active	277297.77	6205283.12	41.05	15 minute intervals
P55b	Active	277303.32	6205270.96	59.36	15 minute intervals
P55c	Active	277296.45	6205262.51	81.90	15 minute intervals
P56 a	Active	276645.55	6206175.36	20.9	15 minute intervals
P65b	Active	276639.18	6206166.92	45.56	15 minute intervals
P56c	Active	276637.06	6206154.37	80.4	15 minute intervals
GW109257	Active	276603.8	6205057	120	monthly
GW104008	Active	280359	6205978	140	monthly

Bore ID	Status	Easting	Northing	Depth (mBNS)	Monitoring Regime
GW112473	Active	276586	6202000	138	monthly
GW104659	Active	276616	6207392	132	monthly
GW062068	Active	276572.8	6209556	150	monthly
GW105395	Active	278546.8	6203033	90	monthly
GW104323	Active	276242	6206412	79.8	monthly
TBC001	Active	276749	6206665	VWPs: 398, 429 m	15 minute intervals
TBC009	Active	278511	6202058	VWPs: 30, 75, 140, 182, 192, 322, 343, 357, 381, 391, 397m	15 minute intervals
TBC018	Active	279645	6204509	VWPs: 70 (inactive), 11, 164, 179, 198, 282, 366, 377, 404, 426, 432m	15 minute intervals
TBC020	Active	280909	6204059	VWPs: 70, 105, 141, 194, 211, 293, 375, 397, 401, 434, 439m	15 minute intervals
TBC019B	Active	277200	6202080	to be drilled to mid-Bulgo (~250m)	15 minute intervals
TBC024	Active	274763	6204163	VWPs: 117, 139, 168, 185, 240, 295, 350, 371, 384, 391m	15 minute intervals
TBC026	Active	281603	6207068	VWPs: 95, 135, 176, 191, 211, 278, 344, 409, 432, 440, 460m	15 minute intervals
TBC027	Active	275708	6202210	VWPs: 95, 132, 169, 181, 198, 253, 306, 362, 384, 396, 400m	15 minute intervals
TBC032	Active	277244	6204725	VWPs: 95, 131, 168, 181, 200, 237, 294, 371, 397, 437m	15 minute intervals
TBC033	Active	275194	6205395	VWPs: 65, 113, 161, 173, 190, 247, 305, 363, 384, 408m	15 minute intervals
TBC034	Active	272956	6205076	VWPs: 65 (inactive), 113 (inactive), 161(inactive), 176, 196, 245, 294, 343, 364, 382m	15 minute intervals
TBC038	Active	280838	6201995	VWPs: 95, 129, 163, 175, 192, 249, 306, 364, 385, 408m	15 minute intervals
TBC039	Active	273445	6207688	VWPs: 65 (inactive), 106, 147, 172, 188, 243, 299, 354, 375, 402m	15 minute intervals

5.1.2 Groundwater Quality

The Tahmoor South LW S1A-S6A shallow bore installation program is currently underway, with majority of bores installed by June 2022. A selection of seven private bores have established land access agreements for ongoing monthly water level monitoring.

For the above-mentioned bores, the following suite of parameters will be analysed:

- Electrical conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO);
- Nutrients (Total N, Total P);
- Major Ions (Ca, Cl, K, Na, SO_4, HCO_3, F);
- Total Alkalinity, Bicarbonate Alkalinity, Carbonate Alkalinity, Hydroxide Alkalinity; and
- Total (Fe, Mn) and dissolved metals (Fe, Mn, Cu, Pb, Zn, Ni, Al, As, Se, Li, Sr, Co).

EC is recorded at NSW government monitoring bores at Thirlmere Lakes since 2012.

Table 5-4 provides a summary of the water quality monitoring regime for LW S1A-S6A.

Table 5-4 Groundwater Quality Monitoring Network

Bore ID	Easting	Northing	Depth (mbgl)	Monitoring Regime
REA1	278362.3	6207826.8	54.8	quarterly
REA2	278441.2	6206332.2	58	quarterly
REA3	277820.7	6206453.4	41	quarterly
REA4	277650.8	6206835.2	57.5	monthly
REA5	277424.2	6206769	7.2	quarterly
REA6	278643.3	6207214.8	46.3	quarterly
REA7	278035.1	6207307.3	43	quarterly
PitTop1	277357.6	6207494.9	55.04	quarterly
PitTop2	277396	6207663.2	6.85	quarterly
PitTop4	276872.2	6207331.6	33.7	quarterly
P51a	275623.00	6206431.71	19.96	monthly
P51b	275620.60	6206419.68	35.38	monthly
P52a	277649.84	6206848.30	41.17	monthly
P53 a	277649.91	6206496.48	41	monthly
P53b	277658.61	6206492.50	60.55	monthly
P53c	277665.80	6206489.23	80.78	monthly
P54a	277809.68	6205951.98	25	monthly
P54b	277806.92	6205944.68	35.99	monthly
P55a	277297.77	6205283.12	41.05	monthly
P55b	277303.32	6205270.96	59.36	monthly
P55c	277296.45	6205262.51	81.90	monthly
P56 a	276645.55	6206175.36	20.9	monthly

Bore ID	Easting	Northing	Depth (mbgl)	Monitoring Regime
P65b	276639.18	6206166.92	45.56	monthly
GW109257	276603.8	6205057	120	monthly
GW104008	280359	6205978	140	monthly
GW112473	276586	6202000	138	monthly
GW104659	276616	6207392	132	monthly
GW062068	276572.8	6209556	150	monthly
GW105395	278546.8	6203033	90	monthly
GW104323	276242	6206412	79.8	monthly

5.1.2.1 Monitoring Standards

Groundwater monitoring will be undertaken in accordance with the relevant Australian Standards legislation and EPA approved methods for sampling, including (but not limited to):

- NSW DECC (2004) *Approved Methods for Sampling and Analysis of Water Pollutants in New South Wales*;
- AS/NZS 5667.1:1998 *Water Quality – Sampling – Guidance on the Design of Sampling Programs, Sampling Techniques, and the Preservation and Handling of Samples*; and
- AS/NZS 5667.11:1998 *Water Quality - Sampling - Guidance on Sampling of Groundwaters*.

5.1.3 Groundwater Extraction Monitoring

Groundwater pumped from all sumps in the mine workings is currently, and will continue to be, monitored by means of flow meters fitted to pipelines recording pumping times and rates. This water reporting to the underground workings and sumps may include groundwater seepage inflows, supply inflows (potable supply and for operations), and some re-circulation.

Operational water balance reviews will continue to be performed monthly collating groundwater extractions, as well as imported water to inform on-site water management. Such a system has been in operation at Tahmoor since 2009 (13 years) and will continue for the life of Tahmoor South. Advice from Tahmoor Coal is that the volume of groundwater extracted from Tahmoor South is monitored via “shaft 3”. The total volumetric flux monitoring provides data on the total groundwater inflow to all workings, where dewatering of Tahmoor North/Western Domain workings will cease soon after LW W4 is complete (in 2022). Consequently, inflow to Tahmoor South workings will be the primary component of all the groundwater inflow.

5.1.4 Longwall fracturing investigations

Pre-mining and post-mining investigation boreholes, which facilitate acquisition of geotechnical and groundwater-related data were proposed for LW S1A and one other location above the A-longwalls (likely to be LW S4A, but dependent on land access). It was planned that at each installation, the hole would be packer tested, run geophysical and downhole camera and have VWPs installed (proposed three sensors in the HBSS and three in the BGSS). The post-mining hole will be drilled following completion of the longwall it is located above.

TCS01 is a fully cored borehole, with a full suite of geological, geotechnical and hydrogeological testing conducted through the sequence. The borehole was cored from surface to seam, with the Bulli Seam depth of 404.00 m. The location of this borehole (off the southern end of LW 1SA make it a suitable proxy for the pre-mining investigation bore proposed. The second Height of Fracturing (HoF) hole will be installed prior to the preceding longwall (e.g. prior to LW S3A if it is to be located over LW S4A).

5.2 Verify Model Predictions

Groundwater monitoring results will be compared to groundwater model predictions on an annual basis to assess actual versus predicted groundwater levels and/or drawdown (i.e. height of depressurisation), and groundwater inflows to the mine. This analysis will be incorporated in regular groundwater compliance reporting, such as the Annual Review and/or Six-monthly Review.

For this task and for the TARP triggers, the relevant model predictions are those from the newly revised groundwater model (SLR, 2022).

Aligned with completion of model re-calibration, to occur every three years, the trigger levels dependent on modelling outputs will be reviewed and updated as necessary.

5.3 Groundwater Baseline Monitoring to support future Extraction Plans

As indicated in Section 5.1 a period of post-mining monitoring is to occur for all monitoring bores of interest. These bores of interest will be established 12 months prior to completion of extraction at LW S6A and be dependent on a review of historical data, bore suitability (i.e. bore condition, access agreements, etc) and suitability for purpose.

The intention of the post-mining monitoring is to allow ongoing review of potential impacts (i.e. depressurisation lags) and degree of recovery whilst also providing continued baseline data to support future groundwater extraction plans, both in terms of conceptual understanding of the effects of longwall mining and for improving confidence in the ability to simulate these in numerical models.

5.4 Private Bore Ameliorative Actions

The monitoring network described above, provides water level and quality data at an adequate spatial and temporal scale to undertake investigations into potential impacts to existing groundwater users.

In accordance with Condition B26 – B29 of the Tahmoor South Domain Consent (SSD 8445), where a mining related impact has occurred at a private bore, Tahmoor Coal will implement a make good process.

Tahmoor Coal has been implementing this process during the life of Tahmoor/Tahmoor North. The process allows for bore owners to apply to Tahmoor Coal if they believe their bore's level or water quality has declined triggering an assessment into the potential cause (i.e. mining related). If it is deemed that the mine is responsible, then remedial action would be implemented, potentially deepening and/or replacing bores and wells, and/or providing an alternative water source to affected users.

The make good process would be staged by Tahmoor Coal in accordance with the proposed mining schedule and the results of predictive groundwater modelling. Contact has been made with landholders whose registered bores are predicted to incur a drawdown of greater than 2 m, as per the NSW Aquifer Interference Policy (AIP) criterion, or whose bores are at risk of subsidence related impacts. Following this initial contact with landholders, where access was granted a baseline field survey has been completed to verify bore details – location, depth, condition of bore and pump, standing water levels, groundwater quality and usage (where possible). Survey findings have been provided to the landholder so that they have the same baseline information as Tahmoor Coal. This information has provided both parties with a thorough understanding of the current bore condition and a reference point for comparison with subsequent bore assessments as mining progresses. The verified bore data has also been included in the recent update of the groundwater model.

In the event that a mining-related impact to a private bore has been confirmed and any further potential impacts are understood (based on groundwater modelling), the landholder and Tahmoor Coal would negotiate a make good agreement. This agreement would include specific make good mitigation measures and outline a potential timeframe for undertaking these measures, if required. The make good agreement would include and consider the conditions of any development consents, the provisions of the AIP and the NSW Coal Mine Subsidence Compensation Act 2017.

There are a number of make good options that may be adopted, based on the details and characteristics of an individual bore and the extent of mining-induced impacts. These mitigation measure options include:

- Bore maintenance where physical adjustments and regular maintenance of the bore(s) are required to return them to pre-mining conditions. This could include re-establishment of saturated thickness in the affected bore(s) through extending the depth of the pump, or deepening of the bore(s) to return yield to pre-mining conditions;
- Replacement of bore(s) to provide a yield at least equivalent to the yield of the affected bore prior to mining. This may be required where deepening of an existing bore is not possible (e.g. the bore has partially collapsed or the bore hole is not straight or vertical);
- Provision of access to an alternative source of water or compensatory water supply. This option may be offered while other measures are being undertaken and could include connection to the town water supply or the provision of on-site storage (e.g. dam or water tanks); or
- Compensation to reflect increased water extraction costs (e.g. due to lowering pumps or installation of additional or alternative pumping equipment).

Equivalent water supply should be provided (at least on an interim basis) as soon as practicable after the loss is identified, unless otherwise agreed with the landowner. The burden of proof that any loss of water supply is not due to mining impacts rests with Tahmoor Coal, in accordance with Condition B27 of SSD 8445.

If there is a dispute as to whether the loss of water is to be attributed to the development or the measures to be implemented, or there is a dispute about the implementation of these measures, then either party may refer the matter to the Planning Secretary for resolution, in accordance with Condition B28 of SSD 8445. If Tahmoor Coal is unable to provide an alternative long-term supply of water, compensation will be provided to the affected landowner, to the satisfaction of the Planning Secretary.

6 Trigger Action Response Plan (TARP)

In accordance with Condition E5 (f) of the Consent, in the event that performance measures (in the form of pre-defined triggers) are considered to have been exceeded or are likely to be exceeded, a response will be undertaken in accordance with the Trigger Action Response Plans (TARP).

The primary actions of the TARP are to:

- Define appropriate trigger levels for 'shallow' and 'deep' groundwater levels, groundwater quality (pH, EC and metals) at monitoring bores and private bores that are useful for providing insight into potential impact from extraction or mining operations;
- Develop specific actions to respond to high risk of exceedance of any performance measure to ensure that the measure is not exceeded; and
- Present a plan in the event performance measures are exceeded or are likely to be exceeded and describe the management / corrective actions to be implemented (i.e. notifications to relevant agencies, groundwater monthly/quarterly reviews, revision in any Corrective Action Management Plan and/or Annual Reviews).

Each TARP has four levels of triggers – "Normal Conditions" - being where the environment is behaving or performing within normal or expected levels, through to Level 3 (L3) each with escalating risk to the environment via deviation from baseline or expected conditions.

The success of remediation measures that have been implemented for any TARP exceedance would be reviewed as part of any Corrective Action Management Plan and Six-monthly reporting, the latter which would provide an opportunity to review and update existing triggers if deemed necessary.

A total of six TARPS (TARP WMP8 to WMP13) are required to address various components of the groundwater system and these are discussed in greater detail below. The TARPS are provided to work in conjunction with not only each other, but also other TARPS within the overarching Water Management Plan to provide a holistic approach to the overall management of the water system.

6.1 Trigger Levels

6.1.1 Methodology Development

Trigger levels have been developed utilising baseline data in conjunction with modelled drawdown predictions and climate data. Additionally, consideration of existing TARPs utilised in the Western Domain will be made to inform the most reasonable and responsible approach to monitoring and managing potential impacts to groundwater resources and associated receptors.

Historical data indicates that significant mining-related drawdown or depressurisation (tens to hundreds of metres) is typical in strata deeper than 200 mbgl, and drawdown or depressurisation is less severe and less persistent in strata shallower than 200 mbgl. Consequently, trigger levels have been set independently for these depth profiles. The Bulli Coal Seam, being the target for coal extraction and being deliberately depressurised for that purpose, is excluded from trigger development, additional commentary regarding this provided below.

6.1.2 Groundwater Levels

6.1.2.1 Shallow Monitoring Bores and Private Bores (< 200 metres depth)

The shallow OSP monitoring bores for which groundwater triggers have been or will be developed are described in Table 6-1.

Monthly manual water level monitoring and water quality monitoring commenced at all installed wells in May 2022. Data loggers have been installed in 10 shallow monitoring observation bores (those sites associated with surface water monitoring sites).

Table 6-1 Shallow Monitoring Bore included in the TARPs

Bore Identification	Bore Depth (mbgl)	Status	Trigger Level Status
P50a	20	proposed	TBC
P50b	35	proposed	TBC
P50c	65	proposed	TBC
P51a	19.96	well installed, level and quality monitoring commenced	Trigger set
P51b	35.38	well installed, level and quality monitoring commenced	Trigger set
P57a	20	proposed	TBC
P57b	35	proposed	TBC
P52a	41.17	well installed, level and quality monitoring commenced	Trigger set
REA4	54.31	well installed, level and quality monitoring commenced	Trigger set
P53a	41	well installed, level and quality monitoring commenced	Trigger set
P53b	60.55	well installed, level and quality monitoring commenced	Trigger set
P53c	80.78	well installed, level and quality monitoring commenced	Trigger set
P54a	25	well installed, level and quality monitoring commenced	Trigger set
P54b	35.99	well installed, level and quality monitoring commenced	Trigger set
P55a	41.05	well installed, level and quality monitoring commenced	Trigger set
P55b	59.36	well installed, level and quality monitoring commenced	Trigger set
P55c	81.90	well installed, level and quality monitoring commenced	Trigger set
P56a	20.9	well installed, level and quality monitoring commenced	Trigger set
P56b	45.56	well installed, level and quality monitoring commenced	Trigger set
P56c	80.4	well installed, level and quality monitoring commenced	Trigger set
GW109257	120	existing site, level and quality monitoring commenced	Trigger set
GW104008	140	existing site, level and quality monitoring commenced	Trigger set
GW112473	138	existing site, level and quality monitoring commenced	Trigger set
GW104659	132	existing site, level and quality monitoring commenced	Trigger set
GW062068	150	existing site, level and quality monitoring commenced	Trigger set
GW105395	90	existing site, level and quality monitoring commenced	Trigger set
GW104323	109	existing site, level and quality monitoring commenced	Trigger set

In the Western Domain, climatic variations alone are not considered to have caused reductions in groundwater levels at shallow open-standpipe bores in excess of 2 m, although the cumulative effect of rainfall variability and groundwater pumping during dry periods is considered to have caused declines of >2 m (e.g. at bore P12C, P16B, P16C in the Western Domain). However, such declines related to groundwater extraction are relatively short-lived. Therefore, a water level reduction of greater than 2 m for shallow standpipe bores for a period beyond 6 months was considered to be a possible indicator of greater than predicted impacts to groundwater (even if greater drawdown was predicted, the concept is to use this magnitude of drawdown as an early warning).

The TARP Significance Levels (1, 2 and 3) will be assigned a trigger corresponding to a calculated groundwater elevation for each groundwater monitoring bores. For monitoring sites with short baseline periods (<6 months), the *maximum* groundwater level observed during pre-mining has been used as reference levels in the TARP level calculations. For bores with a longer baseline, the reference level has been defined following a review of the baseline data.

Table 6-2 presents the shallow groundwater level triggers.

Table 6-2 Shallow Monitoring Bore Trigger Levels

	Groundwater Level (mAHD)		
	TARP Level 1	TARP Level 2	TARP Level 3
Shallow OSP			
P51A	296.3	292.4	288.5
P51B	297.5	293.6	289.7
P52	246.7	244.6	242.5
P53A	255.8	253.7	251.6
P53B	255.8	253.7	251.6
P53C	253.6	251.4	249.1
P54A	260.7	259.0	257.4
P54B	259.9	258.2	256.6
P55A	271.1	269.7	268.2
P55B	266.0	264.4	262.9
P55C	259.7	258.2	256.6
P56A	288.2	284.8	281.4
P56B	278.9	275.5	272.1
P56C	257.4	254.1	250.7
REA4	248.3	246.2	244.1
Private Bores			
GW062068	274.0	270.5	267.1
GW104008	234.7	234.0	233.2
GW104323	256.9	256.8	256.8
GW104659	249.8	243.6	237.4

	Groundwater Level (mAHD)		
	TARP Level 1	TARP Level 2	TARP Level 3
GW105395	322.1	Modelled drawdown is equal to 2 m	Modelled drawdown is equal to 2 m
GW109257	280.9	278.9	276.9
GW112473	317.1	Modelled drawdown is equal to 1 m	Modelled drawdown is equal to 1 m

It is emphasised that trigger levels for bores/instruments with short records of pre-mining (baseline) data are less reliable or robust than those for sites with longer records. Given extraction activities will not likely impact shallow groundwater immediately, or for those spatially disparate from LW S1A for an extended period of time, trigger levels can be re-assessed after additional data is collected that can be considered baseline (not impacted).

6.1.2.2 Shallow VWPs (<200 m Depth)

Regionally, climatic variations have been observed to cause reductions in water levels of up to 5 m in shallow (< 200 m depth) VWPs. Therefore, a water level reduction of greater 5 m for shallow VWP loggers for a period beyond 6 months is considered to be a possible indicator of greater than predicted impacts to groundwater (even if greater drawdown was predicted, the concept is to use this magnitude of drawdown as an early warning).

A reference level has been generated for each VWP sensor, based on the average groundwater level observed prior to commencement of extraction. These are presented in Table 6-3.

At most sites the average groundwater levels sits at levels observed prior to the 2017-2019 NSW drought and in some cases to levels observed during the wetter conditions in 2021. This makes the groundwater level average a conservative reference level.

TARP Level 1 (L1) was then calculated as *Reference level (mAHD) minus 5 m* which is consistent with approaches adopted elsewhere at Tahmoor Mine (i.e. for the Western Domain).

Elsewhere at Tahmoor Mine, TARP Level 3 (L3) has been based on the maximum modelled drawdown and calculated as *Reference Level minus maximum modelled drawdown*. The maximum modelled drawdown at the reference sites ranges from 0 m to 3.3 m which is smaller than the adopted 5 m natural fluctuations to derive TARP L1. This results in some cases in the TARP L3 being higher than TARP L1.

Therefore, instead of calculating TARP L3 as "*Reference Level minus maximum modelled drawdown*", TARP L3 is calculated as "*TARP L1 minus the maximum modelled drawdown*". TARP L3 now lies below TARP L1.

TARP Level 2 (L2) is calculated as the average of L1 and L3.

Some VWP sensor are assigned model Layer 1 (i.e. TBC024 HBSS-117m; TBC027-HBSS-95m, TBC034-HBSS-65m). No drawdown is simulated in Layer 1 at those sites hence no TARP Level 2 and 3 can be derived here. The proposed trigger levels are plotted against the hydrographs for each sensor, and presented in Appendix G.

The hydrograph for TBC027 shows that the elevation of the three levels of triggers (L1/L2/L3) are within 1 meter, due to small modelled drawdown. The proposed trigger levels are provided in Table 6-4.

Table 6-3 Reference Level Utilised in Development of Shallow VWP Groundwater Level Triggers

Site/VWP	Strata	Reference GW Level (mAHD)	Reference Level Justification
Shallow VWPs (<200m)			
TBC024 - HBSS 117m	Hawkesbury Sandstone	287.6	Average groundwater levels, excluding data from April 2012 to Jan 2013 due to unstable VWP. Reference level of 287.6mAHD is similar to water level observed prior to the NSW drought 2017-2019.
TBC024 - HBSS 139m	Hawkesbury Sandstone	287.0	Average groundwater levels, excluding data from April 2012 to Aug 2012 due to unstable VWP. Reference level is similar to water levels observed prior to the NSW drought 2017-2019.
TBC024 - BHCSS 168m	Bald Hill Claystone	289.5	Average groundwater levels, excluding data from April 2012 to Aug 2012 due to unstable VWP. Reference level is similar to water levels observed prior to the NSW drought 2017-2019.
TBC024 - BGSS 185m	Bulgo Sandstone	289.3	Average groundwater levels for the baseline period. Reference level is similar to water levels observed prior to the NSW drought 2017-2019.
TBC027 - HBSS-95m	Hawkesbury Sandstone	320.1	Average groundwater levels for the baseline period. Natural fluctuation up to 10m in 2013. Reference level is similar to water levels observed prior to the NSW drought 2017-2019 and to water levels observed following exceptional wet conditions in 2020/2021.
TBC027 - HBSS-132m	Hawkesbury Sandstone	312.8	Average groundwater levels for the baseline period. Reference level is similar to water levels observed prior to the NSW drought 2017-2019 and to water levels observed following exceptional wet conditions in 2020/2021.
TBC027 - HBSS-169m	Hawkesbury Sandstone	312.2	Average groundwater levels for the baseline period. Reference level is similar to water levels observed prior to the NSW drought 2017-2019 and to water levels observed following exceptional wet conditions in 2020/2021.
TBC027 - BHCS-181m	Bald Hill Claystone	310.7	Average groundwater levels. Reference level is similar to water levels observed prior to the NSW drought 2017-2019 and to water levels observed following exceptional wet conditions in 2020/2021.
TBC027 - BGSS-198m	Bulgo Sandstone	310.3	Average groundwater levels for the baseline period. Reference level is similar to water levels observed prior to the NSW drought 2017-2019.
TBC034 - HBSS-65m	Hawkesbury Sandstone	371.8	Average groundwater levels for the baseline period.

Site/VWP	Strata	Reference GW Level (mAHD)	Reference Level Justification
TBC034 - HBSS-113m	Hawkesbury Sandstone	368.0	Average groundwater levels for the baseline period.
TBC034 – HBSS-161m	Hawkesbury Sandstone	358.4	Average groundwater levels for the baseline period.
TBC034 - BHCS-176m	Bald Hill Claystone	354.9	Average groundwater levels.
TBC034 - BGSS-196m	Bulgo Sandstone	358.3	Average groundwater levels.
TBC038 - XX*			
TBC09-HBSS-30m*	Hawkesbury Sandstone	Insufficient baseline data	No groundwater level available past Feb 2014. No trigger level developed.
TBC09-HBSS-75m	Hawkesbury Sandstone	309.4	Average groundwater levels between May 2012 and July 2021.
TBC09-BHCS-182m	Bald Hill Claystone	293.0	Average groundwater levels between May 2012 and July 2021.
TBC09-BGSS-192m	Bulgo Sandstone	290.4	Average groundwater levels between May 2012 and July 2021.
TBC018 - WWFM/HBSS-70m*	Hawkesbury Sandstone	Insufficient baseline data	Average groundwater levels between Dec 2011 and Oct 2013. No groundwater data past Oct 2013. No trigger level developed.
TBC018 - WWFM/HBSS-117m	Wianamatta Form/ Hawkesbury Sandstone	251.9	Average groundwater levels between Dec 2011 and Dec 2021.
TBC018 - HBSS (lower)-164m	Hawkesbury Sandstone	250.7	Average groundwater levels between Dec 2011 and Dec 2021.

Site/VWP	Strata	Reference GW Level (mAHD)	Reference Level Justification
TBC018 - BHCS-179m	Bald Hill Claystone	248.5	Average groundwater levels between Dec 2011 and Dec 2021.
TBC018 - BGSS-198m	Bulgo Sandstone	244.7	Average groundwater levels between Dec 2011 and Dec 2021.
TBC032 – HBSS – 95m	Hawkesbury Sandstone	262.3	Average groundwater levels between May 2013 and May 2021.
TBC032 – HBSS – 131m	Hawkesbury Sandstone	255.0	Average groundwater levels between May 2013 and May 2021.
TBC032 – HBSS – 168m	Hawkesbury Sandstone	266.9	VWP appears unstable. Average groundwater levels between May 2013 and May 2021.Trigger level developed but with the caveat that groundwater level may be erroneous.
TBC032 – BHCS – 181m	Bald Hill Claystone	242.8	Average groundwater levels between May 2013 and May 2021.
TBC032 – BGSS – 200m	Bulgo Sandstone	243.8	Average groundwater levels between May 2013 and May 2021.
TBC033 - HBSS-	Hawkesbury	284.9	Average groundwater levels between April 2013 and Dec 2020.
TBC033 - WWFM/HBSS-113m	Wianamatta Form/ Hawkesbury Sandstone	278.3	Average groundwater levels between April 2013 and Dec 2020.
TBC033 - HBSS (lower)-161m	Hawkesbury Sandstone	268.6	Average groundwater levels between April 2013 and Dec 2020.
TBC033 - BHCS-173m	Bald Hill Claystone	240.4	VWP appears unstable. Average groundwater levels between April 2013 and Dec 2020. Trigger level developed but with the caveat that groundwater level may be erroneous.
TBC033 - BGSS-	Bulgo	235.2	Average groundwater levels between April 2013 and Dec 2020.

*data unavailable at time of reporting

Table 6-4 Shallow VWP Groundwater Level Triggers

Bore	Groundwater Trigger Level (mAHD)			Model Layer
	TARP Level 1	TARP Level 2	TARP Level 3	
Shallow VWPs (<200m)				
TBC024 - HBSS 117m	282.6	-	-	1
TBC024 - HBSS 139m	282.0	281.5	281.0	5
TBC024 - BHCSS 168m	284.5	283.6	282.8	6
TBC024 - BGSS 185m	284.3	282.3	280.3	8
TBC027 - HBSS-95m	315.1	-	-	1
TBC027 - HBSS-132m	307.8	307.6	307.3	5
TBC027 - HBSS-169m	307.2	307.0	306.8	5
TBC027 - BHCS-181m	305.7	305.5	305.3	16
TBC027 - BGSS-198m	305.3	305.1	304.9	8
TBC034 - HBSS-65m	366.8	-	-	1
TBC034 - HBSS-113m	363.0	362.7	362.3	4
TBC034 - HBSS-161m	353.4	353.1	352.8	4
TBC034 - BHCS-176m	349.9	349.4	348.9	16
TBC034 - BGSS-196m	353.3	352.1	350.9	8
TBC038 – XXX*	tbc	tbc	tbc	
TBC09-HBSS-30m	tbc	tbc	tbc	1
TBC09-HBSS-75m	304.4	304.2	304.1	2
TBC09-BHCS-182m	288.0	287.4	286.8	15
TBC09-BGSS-192m	285.4	285.2	285.0	8
TBC018 - WWFM/HBSS-70m	tbc	tbc	tbc	1
TBC018 - WWFM/HBSS-117m	246.9	246.6	246.2	1
TBC018 - HBSS (lower)-164m	245.7	245.4	245.1	5
TBC018 - BHCS-179m	243.5	243.1	242.8	3
TBC018 - BGSS-198m	239.7	237.8	236.0	8
TBC032 - HBSS-95m	257.3	256.7	256.2	4
TBC032 - HBSS-131m	250.0	249.3	248.6	5
TBC032 - HBSS-168m^	261.9	261.1	260.4	5
TBC032 - BHCS-181m	237.8	228.7	219.5	6
TBC032 - BGSS-200m	238.8	208.7	178.7	8
TBC033 - HBSS-65m	279.9	279.2	278.6	3
TBC033 - WWFM/HBSS-113m	273.3	272.7	272.0	1
TBC033 - HBSS (lower)-161m	263.6	262.9	262.2	5
TBC033 - BHCS-173m^	235.4	213.8	192.3	16
TBC033 - BGSS-190m	230.2	217.7	205.2	8

* Data unavailable (tbc) tbc = to be confirmed ^potential issues with VWP stability but trigger levels still reported

6.1.2.3 Deep VWPs (> 200 metres depth)

For bores that monitor depths greater than 200 m groundwater level monitoring results will be compared to groundwater model predictions (Section 4.4) on an annual basis comparing actual groundwater levels with predictions. In the event that monitoring data suggests divergence from the predicted trends (i.e. from numerical groundwater modelling predictions), the TARP would be enacted.

Each trigger level is associated with level of deviation from modelled predicted drawdown and period of time for which this deviation is experienced:

- Normal Conditions – Observed drawdown does not exceed modelled impacts predicted drawdown by greater than 30 metres. Observed drawdown exceeds the modelled predicted drawdown by greater than 30 metres for less than three consecutive months;
- Level 1 (L1) – Observed drawdown exceeds the modelled predicted drawdown, by greater than 30 metres for greater than three consecutive months;
- Level 2 (L2) – Observed drawdown exceeds modelled predicted drawdown by more than 30 metres for a greater than 6 consecutive months; and
- Level 3 (L3) – Observed drawdown exceeds modelled predicted drawdown for 12 consecutive months or more.

Bores encompassed within this TARP, including the associated model layer, are provided in Table 6-5, with associated predicted drawdown hydrographs provided in Appendix H.

Table 6-5 Deep VWP sensors and associated model layers

Sensor	Model Layer	Model Geology
TBC09_322	8	BUSS Mid
TBC09_343	8	BUSS Mid
TBC09_357	12	SBSS Lower
TBC09_381	10	SPCS
TBC09_391	15	Bulli Seam
TBC09_397	17	Wongawilli
TBC18_282	8	BUSS Mid
TBC18_366	8	BUSS Mid
TBC18_377	13	WBCS
TBC18_404	15	Bulli Seam
TBC18_426	17	Wongawilli
TBC18_432	17	Wongawilli
TBC20_211	8	BUSS Mid
TBC20_293	8	BUSS Mid
TBC20_375	8	BUSS Mid
TBC20_397	13	WBCS

Sensor	Model Layer	Model Geology
TBC20_411	7	BUSS Upper
TBC20_434	17	Wongawilli
TBC20_439	4	HBSS Mid
TBC26_211	8	BUSS Mid
TBC26_278	8	BUSS Mid
TBC26_344	8	BUSS Mid
TBC26_409	13	WBCS
TBC26_432	15	Bulli Seam
TBC26_440	16	Eckersley
TBC26_460	16	Eckersley
TBC32_200	8	BUSS Mid
TBC32_237	8	BUSS Mid
TBC32_257	8	BUSS Mid
TBC32_294	8	BUSS Mid
TBC32_314	8	BUSS Mid
TBC33_247	8	BUSS Mid
TBC33_306	8	BUSS Mid
TBC33_363	11	SBSS Upper
TBC33_384	16	Eckersley
TBC33_408	16	Eckersley
TBC39_243	8	BUSS Mid
TBC39_299	8	BUSS Mid
TBC39_354	11	SBSS Upper
TBC39_375	16	Eckersley
TBC39_402	16	Eckersley

6.1.2.4 Bulli Coal Seam Monitoring Bores

It is expected that the TARP will exclude loggers located in the Bulli Coal Seam on the basis that as this is the target coal seam, significant depressurisation effects are expected due to dewatering of mine workings. Additionally, there are no other groundwater users of this aquifer (environmental or anthropogenic), other than mines, that warrant the need to investigate head changes in this unit. However, monitoring will be undertaken and undergo review alongside the loggers included in the TARP.

6.1.3 Groundwater Quality

As discussed in Section 5.1 the shallow monitoring program designed for LW S1A-S6A has commenced, with data being collected monthly.

Historical compliance reporting for the Tahmoor Western Domain, indicates that some groundwater quality analytes can have significant natural variation not attributable to mining activities that may not be captured in a discrete monitoring period. Consequently, it is recommended that groundwater quality triggers include regional water quality data where no impact from mining has been recorded. This provides a more comprehensive and representative assessment of baseline conditions. Prior to commencement of extraction, the available baseline data collected for these bores will be reviewed against the regional data to confirm the trigger developed. A data cleanse will be undertaken prior to development of triggers to exclude erroneous or unreliable data from the baseline dataset.

The methodology for groundwater quality parameters is based primarily on the method used for the Western Domain. However, in addition, further published literature will be consulted to assist in developing meaningful triggers. Table 1 of the NSW Aquifer Interference Policy [AIP] (NOW, 2012) sets out the minimal impact considerations for aquifer interference activities for Highly Productive Groundwater Sources (refer Section 2.1.2), including:

> *Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.*

The groundwater beneficial uses, alongside published water quality parameter guidelines (i.e. the 2018 Australian and New Zealand Guidelines [ANZG, 2018] for Fresh and Marine Water Quality) will be consulted to develop triggers that represent the natural variation and reference the ability to predict potential harm to the aquifer by impacting the groundwater quality beyond recommended concentrations.

All parameters will have an assigned upper trigger level, excluding pH which will be assigned both an upper and lower pH trigger level. Table 6-6 presents the bores, parameters and groundwater quality trigger levels developed. The trigger levels are defined as;

- Normal – No observable changes in salinity, pH or metals outside of the baseline variability.
- Level 1 – observed salinity and/or metals or pH outside of defined trigger levels for three consecutive months or more. The effect does not persist after a significant rainfall event. Additionally, a similar trend or response is noted at other monitored bores or private groundwater bores.
- Level 2 – observed salinity and/or metals or pH outside of defined trigger levels, for 3 consecutive months or more. The effect persists after a significant rainfall recharge event. In addition, the change in water quality is determined not to be controlled by climatic or external anthropogenic factors.
- Level 3 – observed salinity and/or metals or pH outside of defined trigger levels, for greater than six consecutive months. In addition, the change in water quality is assessed not to be controlled by climatic or external anthropogenic factors.

6.1.3.1 Salinity

Electrical Conductivity (EC) is the measure of salinity proposed to identify potential changes in groundwater salinity. The maximum observed EC during pre-mining (and in some cases during the early mining period before any likelihood of potential impact at that site) plus 10% has been adopted for the salinity trigger level. This will be reviewed upon collection of more extensive baseline data (prior to any extraction impacts incurred).

6.1.3.2 pH

An upper and lower pH trigger has been assigned for each shallow monitoring bore and private landholder bore. Triggers are based on the minimum and maximum pH values recorded in the available dataset minus/plus 1 pH unit if the max/min pH are within four pH units (otherwise, just max/min are utilised). Again, regional data will be taken into consideration.

6.1.3.3 Metals

A single level trigger for dissolved (not total) metals be applied to the monitoring and private bores. Given the limited baseline data available at this point, the pre-mining 95th percentile for each parameter at each bore has been adopted. With collection of additional data, these trigger levels will be reviewed in conjunction with consideration of published literature on guidelines for concentrations associated with relevant beneficial uses.

Table 6-6 Groundwater Quality Triggers

Bore ID	Trigger Level			Trigger Level Concentrations (mg/L) for metals											
	EC (µS/cm)	pH lower	pH upper	Fe	Mn	Cu	Pb	Zn	Ni	Al	Li	Ba	Sr	Se	As
P50a	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	
P50b	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	
P50c	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	
P51a	299.000	5.230	12.660	0.026	0.135	0.031	0.001	0.051	0.014	0.466	0.204	0.284	1.866	0.005	0.002
P51b	3971.000	7.820	12.790	0.032	0.084	0.005	0.001	0.022	0.013	3.380	0.762	0.620	3.500	0.005	0.003
P57a	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	
P57b	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	TBC	
P52	1450.000	4.690	7.240	58.600	4.040	0.002	0.001	0.324	0.045	0.016	0.018	0.310	0.062	0.003	0.001
P53a	896.000	5.150	9.200	17.268	2.000	0.001	0.001	0.064	0.019	0.014	0.040	0.108	0.138	0.003	0.001
P53b	1848.000	5.560	8.370	11.908	2.252	0.001	0.001	0.039	0.013	0.014	0.474	0.194	0.652	0.003	0.001
P53c	1879.000	5.650	8.460	27.000	2.400	0.001	0.001	0.143	0.040	0.014	0.014	0.164	0.716	0.002	0.011
P54a	1951.000	5.000	7.620	33.800	3.100	0.400	0.400	0.024	0.043	4.001	0.067	0.568	0.310	0.400	0.003
P54b	2182.000	5.180	7.370	35.460	2.964	0.001	0.001	0.043	0.040	0.025	0.079	0.273	0.493	0.004	0.002
P55a	1822.000	4.260	8.070	37.400	3.900	0.001	0.001	0.221	0.062	0.024	0.020	0.351	0.372	0.002	0.003
P55b	1699.000	5.110	8.350	27.600	5.680	0.001	0.001	0.126	0.232	0.011	0.087	0.322	0.278	0.002	0.005
P55c	2663.000	5.090	8.420	38.000	2.780	0.001	0.001	0.007	0.141	0.014	0.256	0.296	0.644	0.002	0.001
P56a	1560.000	4.540	8.500	0.026	0.122	0.008	0.007	0.037	0.011	0.682	0.021	0.170	0.154	0.005	0.001
P56b	1526.000	7.060	11.870	0.076	1.676	0.001	0.001	0.005	0.032	0.016	0.830	0.254	1.036	0.005	0.001
P56c	3520.000	7.360	12.190	0.064	0.007	0.001	0.001	0.003	0.001	0.142	0.481	0.640	1.458	0.005	0.001
REA4	1126.000	4.200	8.010	0.050	0.005	0.003	0.002	0.058	0.002	0.040	0.005	0.011	0.110	0.002	0.002
GW109257	927.000	3.250	7.590	1.852	1.404	0.007	0.001	0.115	0.025	0.382	0.007	0.190	0.025	0.005	0.001

Bore ID	Trigger Level			Trigger Level Concentrations (mg/L) for metals											
	EC (µS/cm)	pH lower	pH upper	Fe	Mn	Cu	Pb	Zn	Ni	Al	Li	Ba	Sr	Se	As
GW104008	1983.000	4.590	7.110	32.600	2.100	0.001	0.001	0.017	0.018	0.016	0.066	0.160	0.097	0.001	0.001
GW112473	574.000	4.620	6.620	9.120	1.080	0.003	0.004	0.056	0.014	0.564	0.005	0.126	0.014	0.001	0.001
GW104659	685.000	4.320	7.050	28.600	1.660	0.009	0.001	0.038	0.010	0.014	0.015	0.152	0.028	0.001	0.001
GW062068	2070.000	2.590	6.100	0.090	2.980	0.030	0.015	0.142	0.024	7.520	0.011	0.218	0.019	0.001	0.002
GW105395	4635.000	4.660	8.240	37.800	1.880	0.001	0.001	0.038	0.040	0.014	0.077	0.081	0.176	0.001	0.001
GW104323	1541.000	2.760	6.950	0.068	2.660	2.320	0.182	4.540	0.069	3.320	0.010	0.290	0.013	0.001	0.002

6.1.4 Adaptive Management – Groundwater – Surface Water Interaction

Adaptive Management is the implementation of management strategies as required dependent on ongoing outcomes and impacts of mining. For example, if surface water losses are identified, additional management will be implemented to review this from a groundwater perspective (i.e. groundwater–surface water interaction study). Hence, adaptive management is responding to changing requirements for management based on ongoing review of data. Consequently, the two TARPs presented here have strong links to other primary TARPs and utilise the same network.

6.1.4.1 Groundwater – Surface Water Interaction

The Tahmoor South monitoring network has been developed to provide pertinent information on baseflow relationships with nested surface water and groundwater monitoring sites. Groundwater data would be reviewed alongside complementary monitoring.

This TARP defines levels of deviation in surface water - groundwater interactions from 'normal' conditions and the actions to be implemented in response to each level deviation. The instigation of this TARP will be dictated by triggers exceedances in pertinent groundwater or surface water sites requiring further investigation of groundwater – surface water interactions.

This TARP references Biodiversity Management Plan TARP – Riparian Vegetation (BMP3), which specifically defines levels of deviation in riparian vegetation condition from normal conditions and the actions required to be implemented in response to each level of deviation. The riparian vegetation can be considered a GDE with relevant Performance Measure, managed under the Riparian Vegetation TARP, supported by this TARP. TARP BMP3 will be enacted via this TARP as well as via its own specific criteria, to support investigations providing a holistic review of groundwater and surface water in relation to GDEs.

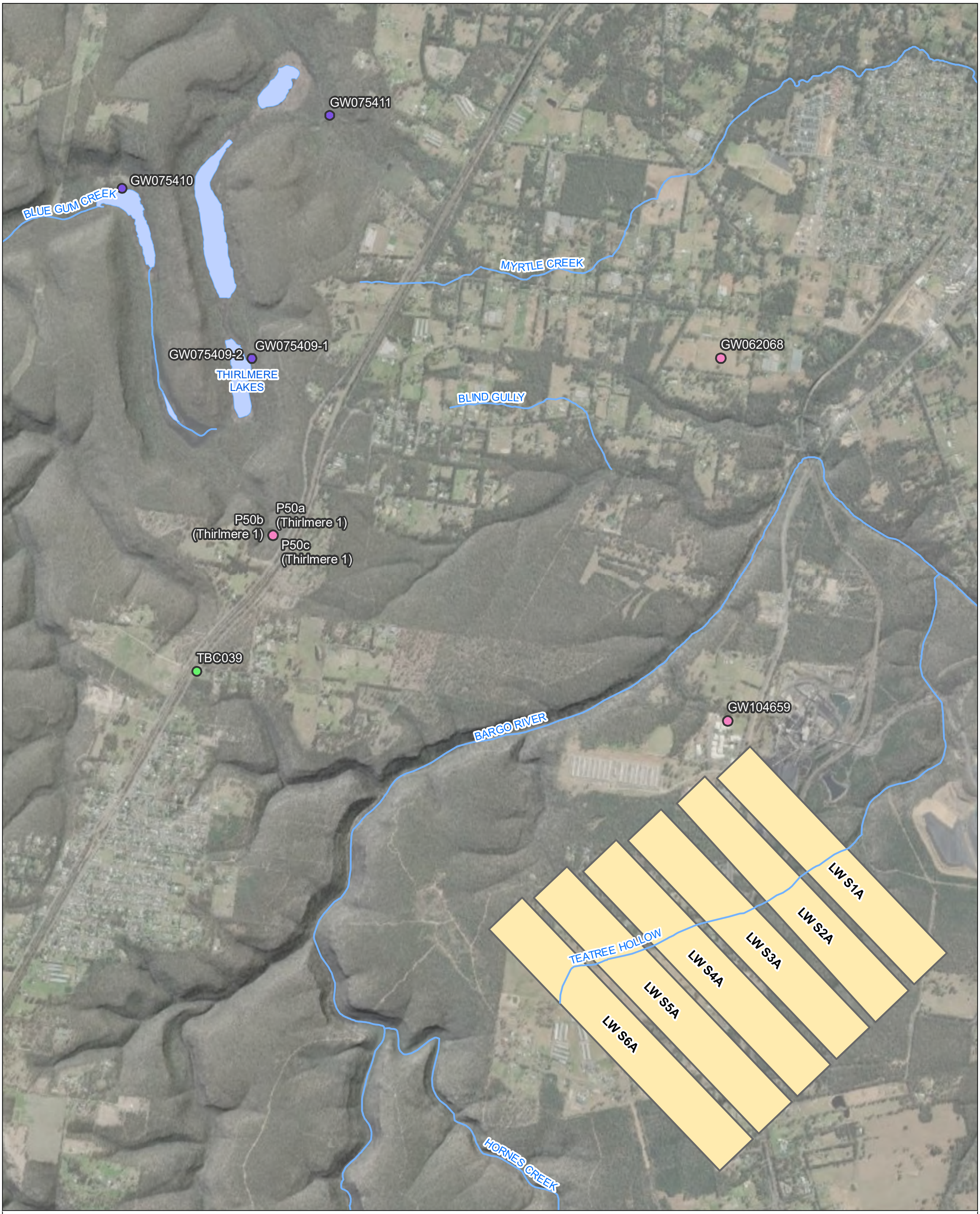
6.1.4.2 Groundwater Bores Monitoring for Thirlmere Lakes

The Thirlmere Lakes have a specific series of bores aimed at monitoring potential impacts on the Lakes resulting from longwall extraction. The network is designed to provide an early warning system of changes in groundwater conditions that may indicate a potential impact to Thirlmere Lakes, via a cross section of data between mine operations and the Lakes. Figure 6-1 shows the location of the specific network, including the following sites:

- "Early warning" bores: P51a, P51b, GW062068, GW104659, TBC039 (sensor at 65 metres in Hawkesbury Sandstone (HBSS))
- "Thirlmere Lakes" bores: GW075409–1, GW075409–2, GW075410, GW075411 (paired with gauging station 212066) and proposed sites: P50a, P50b, P50c

Trigger levels are linked to the shallow water level and water quality triggers defined in their specific TARPs. Given the Thirlmere Lakes are considered GDEs, the relevant Performance Measure is incorporated, being;

> *GDE Performance Measure: Negligible impacts including:*
>
> - *Negligible changes in groundwater levels; and*
> - *Negligible changes in groundwater quality.*



0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:30,000 at A4
Project Number:	610.30637
Date:	11-Jul-2022
Drawn by:	NT

Watercourses

Lakes

Tahmoor South Mine Plan

Approved

Groundwater Monitoring Locations

Deep GWL

NSW govt monitoring

OSP

TAHMOOR SOUTH
LW S1A – S6A
GROUNDWATER
TECHNICAL REPORT

Thirlmere Lake
Monitoring Regime

FIGURE 6 -1

H:\Projects-SLR\610-SrvSYD\610-SYD\610.30637.00000 Tahmoor Coal Extraction Plan LW101A LW06 SLR Data\01 CADGIS\GIS\61030637 Fig1 Thirlmere Lakes monitoring.mxd

6.2 Trigger Action Response Plans

A Trigger Action Response Plan has been developed for each of the aforementioned categories, namely:

- Shallow Groundwater Levels (Open standpipes and private bores): Table 6-7;
- Shallow Groundwater Pressures (VWP < 200 m): Table 6-7;
- Deep Groundwater Pressures (VWP > 200 m): Table 6-9;
- Groundwater Quality (Open standpipes and private bores): Table 6-10;
- Groundwater – Surface-water interaction: Table 6-11; and
- Groundwater Bores Monitoring for Thirlmere Lakes: Table 6-11.

Table 6-7 Trigger Action Response Plan – WMP8 Shallow Groundwater Levels (Open standpipes and private bores)

Performance Measure and Indicator, TARP Objective and Assessment Criteria	Monitoring Program	Management – Trigger	Management – Action	Management – Response
<u>Performance Measure Feature</u> No performance measure relevant. <u>TARP Objective</u> This TARP defines levels of deviation in groundwater level from 'normal' or baseline conditions and the actions to be implemented in response to each level deviation. This TARP supports TARP WMP13, where groundwater levels as they pertain to groundwater dependent ecosystems (GDEs) (Thirlmere Lakes) are covered. <u>Assessment Criteria</u> Bore specific trigger values based on baselines data for each reporting level.	<u>Locations</u> Open standpipes Existing sites: P51a, P51b, P52, REA4, P53a, P53b, P53c, P54a, P54b, P54c, P55a, P55b, P55c, P56a, P56b, P56c Proposed sites: P50a, P50b, P50c, P57a, P57b Private bores GW109257, GW104008, GW112473, GW104659, GW062068, GW105395, GW104323 All monitoring locations are shown in Figure 23 of the Water Management Plan. <u>Monitoring Frequency</u> Pre-mining Monthly manual measurements of water level. During Mining Monthly manual measurements of water level. Post-mining Quarterly manual measurements of water level for 12 months following the completion of LW S6A, or as required in accordance with a Rehabilitation Management Plan.	**Normal Condition**		
		• Groundwater level remains consistent with baseline variability and pre-mining trends with reductions in groundwater level less than two meters.	• Continue monitoring and review of data as per monitoring program.	• No response required.
		Level 1		
		• Greater than 2 m water level reduction[1] for a period of 6 months following the commencement of extraction.	For Private Bores and Open Standpipe Monitoring Bores • *Actions as required for Normal Condition.* • Undertake an investigation to assess cause and determine if mining related. • Undertake investigation to demonstrate if the decline will impact the long-term viability of the affected water supply works. • Discuss findings and obtain other relevant information from key specialists (e.g. subsidence monitoring results, surface water level results). The investigation will be commenced/completed as efficiently as practicable. If the changes have been confirmed to be related to mining effects: For Private Bores: • Initiate negotiations with impacts landowners as soon as practicable. Consider all reasonable and feasible options for remediation as relevant (e.g. extending the depth of the bore, establishment of additional bores, etc - as per Section 6.2.1.4 of the Water Management Plan. " For Open Standpipe Monitoring Bores • For monitoring sites relevant to Thirlmere Lakes or associated with surface water monitoring sites, initiate groundwater – surface water interaction TARP.	For Private Bores and Open Standpipe Monitoring Bores • Report trigger exceedance to DPE and key stakeholders. • Report trigger exceedance and investigation outcomes in Six Monthly Subsidence Impact Report and Annual Review. If the changes have been confirmed to be related to mining effects: For Private Bores: • Provide DPE and key stakeholders with proposed corrective management actions (CMAs) for consultation (e.g. extending the depth of the bore, establishment of additional bores, compensation to affected landowners as detailed in Section 6.2.1.4 of the Water Management Plan). • Implement CMAs, subject to land access (finalise negotiations and implement the agreed "make-good" arrangements) • Monitor and report on success of CMAs in Six Monthly Subsidence Impact Report and Annual Review.
		Level 2		
		• Water level declines below the average between the 'maximum modelled drawdown' (Level 3 trigger) and the '2 m drawdown' (Level 1 trigger)[1] for a period of greater than 6 months following the commencement of extraction. AND • The reduction in water level is determined not to be controlled by climatic or external anthropogenic factors.	For Private Bores and Open Standpipe Monitoring Bores • *Actions as stated in Level 1.* • Consider increasing monitoring and review of data at sites where Level 2 has been reached, subject to land access. Reasons for not increasing monitoring frequency could include solid identification causation that do not require further monitoring (e.g. singular anthropogenic impact resulting in water level change). • Compare against base case and deterministic model scenarios[2]. • Review Water Management Plan and modify if necessary. For Private Bores: • Review CMAs in light of findings from further investigations and consider additional reasonable and feasible options.	For Private Bores and Open Standpipe Monitoring Bores • *Responses as stated in Level 1.* • Advise DPE and key stakeholders of any required amendments to Water Management Plan. For Private Bores: • Provide findings of CMA review to DPE and key stakeholders for consultation. • Implement additional CMAs, subject to land access.
		Level 3		
		• Water level reduction greater than the maximum modelled drawdown[1] for a period of 6 months following the commencement of extraction. AND • The reduction in water level is determined not to be controlled by climatic or external anthropogenic factors.	For Private Bores and Open Standpipe Monitoring Bores • *Actions as stated in Level 2.* • Increase monitoring and review of data frequency for sites where Level 3 has been reached, subject to land access. • Undertake a detailed investigation to assess if the change in behaviour is related to mining effects (e.g. whether there has been subsidence induced fracturing, other catchment changes, effect unrelated to mining or the prevailing climate).	For Private Bores and Open Standpipe Monitoring Bores • *Responses as stated in Level 2.* For Private Bores: • Develop a Rehabilitation Management Plan in consultation with DPE and key stakeholders. • Implement Rehabilitation Management Plan, subject to land access.

Notes:
[1] Level 1, 2 and 3 triggers for water level reduction is provided in Table 6-3 in Appendix E of the Water Management Plan.
[2] "Deterministic" model scenario refers to the predictive scenario modelling utilised to determine the trigger level.

Table 6-8 Trigger Action Response Plan – WMP9 Shallow Groundwater Pressures (VWP sensors < 200 m)

Performance Measure and Indicator, TARP Objective and Assessment Criteria	Monitoring Program	Management		
		Trigger	Action	Response
<u>Performance Measure Feature</u> No performance measure relevant. <u>TARP Objective</u> This TARP defines levels of deviation in groundwater level from 'normal' or baseline conditions and the actions to be implemented in response to each level deviation. <u>Assessment Criteria</u> Bore specific trigger values based on baselines data for each reporting level.	<u>Locations</u> TBC032, TBC033, TBC009, TBC018, TBC0039 Monitoring of all VWP < 200 m depth intakes. Reference Sites: TBC024, TBC027, TBC034, TBC038 All monitoring locations are shown in Figure 23 of the Water Management Plan. <u>Monitoring Frequency</u> Pre-mining VWPs sensors take pressure readings hourly. The system is now telemetered so data is streamed continuously and can be accessed at any point in time. During Mining VWPs sensors take pressure readings hourly. The system is now telemetered so data is streamed continuously and can be accessed at any point in time. Post-mining Monitoring of data (streamed continuously) for 12 months following the completion of LW S6A.	**Normal Condition**		
		• No observable mining induced change at VWP intakes. • Greater than 5 m water level reduction in VWP intakes[1] following the commencement of extraction for a period of less than six months	• Continue monitoring and review of data as per monitoring program.	• No response required.
		Level 1		
		• Greater than 5 m water level reduction in VWP intakes[1] following the commencement of extraction for a period of greater than six months	• *Actions as required for Normal Condition.* • Undertake an investigation to assess cause and determine if mining related, commence/complete as soon as practicable. • Discuss findings and obtain other relevant information from key specialists (e.g. subsidence monitoring results, surface water level results).	• Report trigger exceedance to DPE and key stakeholders. • Report trigger exceedance and investigation outcomes in Six Monthly Subsidence Impact Report and Annual Review.
		Level 2		
		• Water level declines below the calculated Level 2 trigger – being the average of Level 1 (the '5 m drawdown'[1]) and Level 3 (the 'maximum modelled drawdown') – following the commencement of extraction for a period of greater than six months. AND • The reduction in water level is determined not to be controlled by climatic or external anthropogenic factors.	• *Actions as stated in Level 1.* • Review deeper VWP data at monitored sites. Determine whether additional review of data is required. Determine if review of additional existing VWP sites is required. Reasons for not increasing frequency of data review could include solid identification causation that do not require further monitoring (e.g. singular anthropogenic impact resulting in water level change). • Compare against base case and deterministic model scenarios[2]. • Review Water Management Plan and modify if necessary.	• *Responses as stated in Level 1.* • Advise DPE and key stakeholders of any required amendments to Water Management Plan.
		Level 3		
		• Water level reduction greater than the maximum modelled drawdown[1] following the commencement of extraction for a period of greater than six months. AND • The reduction in water level is determined not to be controlled by climatic or external anthropogenic factors.	• *Actions as stated in Level 2.* • Increase review of data frequency for sites where Level 3 has been reached. • Undertake a detailed investigation to assess if the change in behaviour is related to mining effects (e.g. whether there has been subsidence induced fracturing, other catchment changes, effect unrelated to mining or the prevailing climate). Commence/complete as soon as practicable • Undertake investigative to review model results in conjunction with field data.	• *Responses as stated in Level 2.*

Notes:
[1] Level 1, 2 and 3 triggers for water level reduction is provided in Table 6-4 in Appendix E of the Water Management Plan).
[2] "Deterministic" model scenario refers to the predictive scenario modelling utilised to determine the trigger level.

Table 6-9 Trigger Action Response Plan – WMP10 Groundwater level/pressure Deep VWPs (> 200 m)

Performance Measure and Indicator, TARP Objective and Assessment Criteria	Monitoring Program	Management		
		Trigger	Action	Response
Performance Measure Feature No performance measure relevant. TARP Objective This TARP defines levels of deviation in groundwater level from 'normal' or baseline conditions and the actions to be implemented in response to each level deviation. Assessment Criteria Bore specific trigger values based on modelled data for each reporting level. Model layers utilised to define predicted drawdown for each VWP logger provided in Table below.	Locations TBC009, TBC0018, TBC020, TBC026, TBC032, TBC033, TBC039 Reference sites: TBC024, TBC027, TBC034, TBC038 Monitoring of all VWP > 200 m depth intakes excluding those monitoring the Bulli Coal Seam. All monitoring locations are shown in Figure 23 of the Water Management Plan. Monitoring Frequency Pre-mining VWPs sensors take pressure readings hourly. The system is now telemetered so data is streamed continuously and can be accessed at any point in time. During Mining VWPs sensors take pressure readings hourly. The system is now telemetered so data is streamed continuously and can be accessed at any point in time. Post-mining Monitoring of data (streamed continuously) for 12 months following the completion of LW S6A.	**Normal Condition**		
		• Observed data does not exceed modelled impacts predicted drawdown by greater than 30 metres[1]. • Observed drawdown exceeds the modelled predicted drawdown[1], by greater than 30 metres for of less than three consecutive months	• Continue monitoring and review of data as per monitoring program.	• No response required.
		Level 1		
		• Observed drawdown exceeds the modelled predicted drawdown[1], by greater than 30 metres for greater than three consecutive months.	• *Actions as required for Normal Condition.* • Undertake an investigation to assess cause and determine if mining related, to be commenced/completed as soon as practicable. • Discuss findings and obtain other relevant information from key specialists (e.g. subsidence monitoring results, surface water level results).	• Report trigger exceedance to DPE and key stakeholders. • Report trigger exceedance and investigation outcomes in Six Monthly Subsidence Impact Report and Annual Review.
		Level 2		
		• Observed drawdown is exceeds modelled predicted drawdown[1], by more than 30 metres greater than 6 consecutive months. •	• *Actions as stated in Level 1.* • Determine suitability of increasing frequency of data review at sites where Level 2 has been reached. Reasons for not increasing monitoring frequency could include solid identification causation that do not require further monitoring (e.g. singular anthropogenic impact resulting in water level change). • Review data in conjunction with VWP data from additional existing VWP sites. • Compare against base case and deterministic model scenarios[2]. • Review Water Management Plan and modify if necessary.	• *Responses as stated in Level 1.* • Inclusion of more regional VWPs into data review to determine likely extent and depth of depressurisation. • Advise DPE and key stakeholders of any required amendments to Water Management Plan.
		Level 3		
		• Observed drawdown exceeds modelled predicted drawdown[1] by 30 m, for 12 consecutive months or more.	• *Actions as stated in Level 2.* • Increase review of data frequency for sites where Level 3 has been reached. • Undertake a detailed investigation to assess if the change in behaviour is related to mining effects (e.g. whether there has been subsidence induced fracturing, other catchment changes, effect unrelated to mining or the prevailing climate). To be commenced/completed as soon as practicable. • Review base case and deterministic model scenarios[2] in conjunction with water pressure data and report findings.	• *Responses as stated in Level 2.*

Notes:
[1] Predicted drawdown refers to the drawdown as generated by the groundwater model and varies over time as extraction progresses. Observed drawdown will be plotted on a monthly basis against the predicted drawdown to determine if a trigger has occurred. Therefore, as the predicted drawdown will be constantly changing according to extraction progression, it is not possible to set a specific trigger limit.
[2] "Deterministic" model scenario refers to the predictive scenario modelling utilised to determine the trigger level.

Sensor	Model Layer	Model Geology	Sensor	Model Layer	Model Geology
TBC09_322	8	BUSS Mid	TBC26_344	8	BUSS Mid
TBC09_343	8	BUSS Mid	TBC26_409	13	WBCS
TBC09_357	12	SBSS Lower	TBC26_432	15	Bulli Seam
TBC09_381	10	SPCS	TBC26_440	16	Eckersley
TBC09_391	15	Bulli Seam	TBC26_460	16	Eckersley
TBC09_397	17	Wongawilli	TBC32_200	8	BUSS Mid
TBC18_282	8	BUSS Mid	TBC32_237	8	BUSS Mid
TBC18_366	8	BUSS Mid	TBC32_257	8	BUSS Mid

TBC18_377	13	WBCS		TBC32_294	8	BUSS Mid
TBC18_404	15	Bulli Seam		TBC32_314	8	BUSS Mid
TBC18_426	17	Wongawilli		TBC33_247	8	BUSS Mid
TBC18_432	17	Wongawilli		TBC33_306	8	BUSS Mid
TBC20_211	8	BUSS Mid		TBC33_363	11	SBSS Upper
TBC20_293	8	BUSS Mid		TBC33_384	16	Eckersley
TBC20_375	8	BUSS Mid		TBC33_408	16	Eckersley
TBC20_397	13	WBCS		TBC39_243	8	BUSS Mid
TBC20_411	7	BUSS Upper		TBC39_299	8	BUSS Mid
TBC20_434	17	Wongawilli		TBC39_354	11	SBSS Upper
TBC20_439	4	HBSS Mid		TBC39_375	16	Eckersley
TBC26_211	8	BUSS Mid		TBC39_402	16	Eckersley
TBC26_278	8	BUSS Mid				

Table 6-10 Trigger Action Response Plan – WMP11 Groundwater Quality (open standpipes and private bores)

Performance Measure and Indicator, TARP Objective and Assessment Criteria	Monitoring Program	Management		
		Trigger	Action	Response
Performance Measure Feature No performance measure relevant. TARP Objective This TARP defines levels of deviation in groundwater level from 'normal' or baseline conditions and the actions to be implemented in response to each level deviation. This TARP supports TARP WMP13, where groundwater quality as it pertains to groundwater dependent ecosystems (GDEs) (Thirlmere Lakes) is covered. Assessment Criteria Bore specific trigger values based on baselines data for each reporting level.	Locations Open standpipes Existing sites: P51a, P51b, P52, REA4, P53a, P53b, P53c, P54a, P54b, P55a, P55b, P55c, P56a, P56b, P56c Proposed sites: P50a, P50b, P50c, P57a, P57b Private bores GW109257, GW104008, GW112473, GW104659, GW062068, GW105395, GW104323 All monitoring locations are shown in Figure 23 of the Water Management Plan. Monitoring Frequency Pre-mining Monthly water quality sampling. During Mining Monthly water quality sampling Post-mining Quarterly water quality sampling. Water Quality sample parameters: **Field Parameters** PH EC TDS DO **Laboratory Analysis**	**Normal Condition**		
		• No observable changes in salinity, pH or metals outside of the baseline variability.	• Continue monitoring and review of data as per monitoring program.	• No response required.
		Level 1		
		• Observed salinity and/or metals or pH outside of defined trigger levels[1] for 3 consecutive months or more. The effect *does not persist* after a significant rainfall recharge event. AND • A similar trend or response is noted at other monitored bores or private groundwater bores.	For Private Bores and Open Standpipe Monitoring Bores • *Actions as required for Normal Condition.* • Undertake an investigation to assess cause and determine if mining related. • Undertake investigation to demonstrate if the change in quality will impact the long-term viability of the affected water supply works. • Discuss findings and obtain other relevant information from key specialists (e.g. subsidence monitoring results, surface water level results). If the changes have been confirmed to be related to mining effects: For Private Bores: • Initiate negotiations with impacted landholders as soon as practicable. Consider all reasonable and feasible options for remediation as relevant. This could include potential for implementation of make-good provisions as per Section 6.2.1.4 of the Water Management Plan for affected private bore owners (e.g. provision of access to an alternative source of water). For Open Standpipe Monitoring Bores • For monitoring sites relevant to Thirlmere Lakes or associated with surface water monitoring sites, initiate groundwater – surface water interaction TARP.	For Private Bores and Open Standpipe Monitoring Bores • Report trigger exceedance to DPE and key stakeholders. • Report trigger exceedance and investigation outcomes in Six Monthly Subsidence Impact Report and Annual Review. If the changes have been confirmed to be related to mining effects: For Private Bores: • Provide DPE and key stakeholders with proposed corrective management actions (CMAs) for consultation (e.g. provision of access to an alternative source of water as detailed in Section 6.2.1.4 of the Water Management Plan). • Implement CMAs, subject to land access. • Monitor and report on success of CMAs in Six Monthly Subsidence Impact Report and Annual Review.
		Level 2		
		• Observed salinity and/or metals or pH outside of defined trigger levels[1], for 3 consecutive months or more. The effect *persists* after a significant rainfall recharge event. AND • The change in water quality is determined not to be controlled by climatic or external anthropogenic factors.	For Private Bores and Open Standpipe Monitoring Bores • *Actions as stated in Level 1.* • Consider increasing monitoring and review of data at sites where Level 2 has been reached, subject to land access. Reasons for not increasing monitoring frequency could include solid identification causation that do not require further monitoring (e.g. singular anthropogenic impact resulting in water quality change). • Review Water Management Plan and modify if necessary.	For Private Bores and Open Standpipe Monitoring Bores • *Responses as stated in Level 1.* • Advise DPE and key stakeholders of any required amendments to Water Management Plan. For Private Bores: • Provide findings of CMA review to DPE and key stakeholders for consultation. • Implement additional CMAs, subject to land access.

	Total alkalinity as CaCO3, HCO3, CO3, DOC Dissolved Major Cations (Ca, K, Na, Mg, F, Cl, SO4) Dissolved Metals (Al, As, Ba, Co, Cu, Pb, Li, Mn, Ni, Se, Sr, Zn, Fe) Total Metals (Al, As, Ba, Co, Cu, Pb, Li, Mn, Ni, Se, Sr, Zn, Fe) Total Nitrogen Total Phosphorus Ionic Balance (Total Anions and Total Cations)		For Private Bores: • Review CMAs in light of findings from further investigations and consider additional reasonable and feasible options.	
		Level 3		
		• Observed salinity and/or metals or pH outside of defined trigger levels[1], for greater than 6 consecutive months. AND • The change in water quality is determined not to be controlled by climatic or external anthropogenic factors.	For Private Bores and Open Standpipe Monitoring Bores • *Actions as stated in Level 2.* • Increase monitoring and review of data frequency for sites where Level 3 has been reached, subject to land access. • Undertake a detailed investigation to assess if the change in behaviour is related to mining effects (e.g. whether there has been subsidence induced fracturing, other catchment changes, effect unrelated to mining or the prevailing climate). • Undertake investigative report to demonstrate if the water quality change will impact the long-term viability of any affected water supply works.	Private Bores and Open Standpipe Monitoring Bores • *Responses as stated in Level 2.* For Private Bores: If ascertained impact is due to mining activities and has potential to impact long-term viability of supply for private groundwater bores: • Develop a Rehabilitation Management Plan in consultation with DPE and landowner. • Implement Rehabilitation Management Plan, subject to land access.

Notes:
[1] Defined trigger levels for groundwater quality are listed in Table 6-5 of Appendix E of the Water Management Plan.

Table 6-11 Trigger Action Response Plan – WMP12 Groundwater – surface water Interaction

Performance Measure and Indicator, TARP Objective and Assessment Criteria	Monitoring Program	Management		
		Trigger	Action	Response
Performance Measure Feature No performance measure relevant. TARP Objective This TARP defines levels of deviation in surface water - groundwater interactions from 'normal' conditions and the actions to be implemented in response to each level deviation. The instigation of this TARP will be dictated by triggers exceedances in pertinent groundwater or surface water sites requiring further investigation of groundwater – surface water interactions. Where groundwater – surface water connectivity indicates in a gaining stream, there is potential for groundwater supporting riparian vegetation. Consequently, Riparian vegetation in these situations could be a Groundwater Dependent Ecosystem (GDE), and the pertinent Performance Measure applicable: Negligible impacts including: • Negligible change in groundwater levels; and • Negligible change in groundwater quality. Riparian GDEs are addressed through the Riparian Vegetation TARP (BMP3). Consultation through the ERG will link this TARP (WMP12) to BMP3 via actions in BMP3 to consider groundwater – surface water relationships when pertinent. Assessment Criteria	Locations Open standpipes P51a, P51b, P52, REA4, P53a, P53b, P53c P54a, P54b, P54c, P55a, P55b, P55c The aligned surface water and groundwater sites are as follows: • P51a, P51b with surface water site BR2-Qla • P52, REA4 with surface water site-TT14-QLa • P53a, P53b, P53c with surface water site-TT14-Qla • P54a, P54b, P54c with surface water site TT3-QLa • P55a, P55b, P55c with surface water site TT1-QRLa All monitoring locations are shown in Figure 23 of the Water Management Plan. Monitoring Frequency Pre-mining Monthly manual measurements of water level and water quality. During Mining Monthly manual measurements of water level and water quality. Post-mining	**Normal Condition**		
		• Observed (or inferred where not immediately neighbouring a surface water site) groundwater and surface water interaction remains consistent with baseline variability and/pre-mining trends, and decrease in groundwater inflow not persisting after significant rainfall recharge events.	• Continue monitoring and review of data as per monitoring program.	• No response required.
		Level 1		
		• Observed (or inferred where not immediately neighbouring a surface water site) groundwater levels at surface water monitoring site decline below Level 1 (in TARP WMP8) following the commencement of extraction.	• *Actions as required for Normal Condition.* • Undertake an investigation to assess cause and determine if mining related. • Discuss findings and obtain other relevant information from key specialists (e.g. subsidence monitoring results, surface water level results).	• Report trigger exceedance to DPE and key stakeholders. • Report trigger exceedance and investigation outcomes in Six Monthly Subsidence Impact Report and Annual Review. If the changes have been confirmed to be related to mining effects: • Provide DPE and key stakeholders with proposed corrective management actions (CMAs) for consultation (e.g. extending the depth of the bore, establishment of additional bores, compensation to affected landowners as detailed in Section 6.2.1.4 of the Water Management Plan). • Implement CMAs, subject to land access. • Monitor and report on success of CMAs in Six Monthly Subsidence Impact Report and Annual Review.
		Level 2		
		• Observed (or inferred where not immediately neighbouring a surface water site) groundwater levels at aligned surface water monitoring site decline below Level 2 (in TARP WMP8) following the commencement of extraction. AND • The reduction in water level is determined not to be controlled by climatic or external anthropogenic factor.	• *Actions as stated in Level 1.* • Increase frequency of data review to fortnightly at sites where Level 2 has been reached, subject to land access. Reasons for not increasing frequency could include solid identification causation that do not require further monitoring (e.g. singular anthropogenic impact resulting in water level change). • Compare against base case and deterministic model scenarios[1]. • Review manual water level measurements for additional monitoring sites to identify potential spatial trends in water level decline. • Review surface water data to assess for surface water level decline at relevant site.	• *Responses as stated in Level 1.* • Provide findings of CMA review to DPE and key stakeholders for consultation. • Implement additional CMAs, subject to land access. • Advise DPE and key stakeholders of any required amendments to Water Management Plan, including reporting on relationship of observations to baseline and deterministic model scenarios, as necessary.

Bore specific trigger values based on baselines data for each reporting level. For this TARP, the aligned groundwater and surface water sites would be considered collectively to interpret potential changes/impacts to groundwater – surface water interaction.	Quarterly manual measurements of water level for 12 months following the completion of LW S6A, or as required in accordance with a Rehabilitation Management Plan.		• Review CMAs in light of findings from further investigations and consider additional reasonable and feasible options. • Review Water Management Plan and modify if necessary.	
		Level 3		
		• Inferred groundwater levels at surface water monitoring site decline below Level 3 (in TARP WMP8) following the commencement of extraction. AND • The reduction in water level is determined not to be controlled by climatic or external anthropogenic factor.	• *Actions as stated in Level 2.* • Increase frequency of data review for sites where Level 3 has been reached, subject to land access. • Undertake a detailed investigation to assess if the change in behaviour is related to mining effects (e.g. whether there has been subsidence induced fracturing, other catchment changes, effect unrelated to mining or the prevailing climate). Report to be commenced and completed as soon as practicable.	• *Responses as stated in Level 2.* • Develop a Rehabilitation Management Plan in consultation with DPE and key stakeholders. • Implement Rehabilitation Management Plan, subject to land access.
Notes: [1] "Deterministic" model scenario refers to the predictive scenario modelling utilised to determine the trigger level.				

Table 6-12 Trigger Action Response Plan – WMP13 Groundwater Bore Monitoring for Thirlmere Lakes

<table>
<tr><th rowspan="2">Performance Measure and Indicator, TARP Objective and Assessment Criteria</th><th rowspan="2">Monitoring Program</th><th colspan="3">Management</th></tr>
<tr><th>Trigger</th><th>Action</th><th>Response</th></tr>
<tr><td rowspan="8">Performance Measure Feature
GDEs including Thirlmere Lakes[1].

Performance Measure
Negligible impacts including:
• Negligible change in groundwater levels; and
• Negligible change in groundwater quality.

Performance Indicator
The performance measure will be considered to be exceeded if the groundwater levels or groundwater quality decline below Level 3 (in the relevant groundwater TARP triggers for water level and water quality – TARP WMP8 or WMP11) following the commencement of extraction, and the investigation outcomes indicate a mining related impact based on monitoring data for the Thirlmere Lakes.

TARP Objective
This TARP defines levels of deviation at Thirlmere Lakes from 'normal' conditions and the actions to be implemented in response to each level deviation.

Assessment Criteria
Bore specific trigger values based on baselines data for each reporting level.</td><td rowspan="8">Locations
"Early warning" bores
Existing sites:
GW062068, GW104659, TBC039 (sensor at 65 metres in Hawkesbury Sandstone (HBSS))
Proposed sites:
P50a, P50b, P50c

Thirlmere Lakes bores (not trigger bores)
Existing sites:
GW075409–1, GW075409–2, GW075410, GW075411 (paired with gauging station 212066)

All monitoring locations are shown in Figure 23 of the Water Management Plan.

Monitoring Frequency (for "early warning" bores)
Pre-mining
Monthly manual measurements of water level and water quality.

During Mining
Monthly manual measurements of water level and water quality.

Post-mining
Quarterly manual measurements of water level for 12 months following the completion of LW S6A, or as required in accordance with a Rehabilitation Management Plan.

Water Quality sample parameters:
Field Parameters
PH
EC
TDS
DO
Laboratory Analysis
Total alkalinity as CaCO3, HCO3, CO3, DOC
Dissolved Major Cations (Ca, K, Na, Mg, F, Cl, SO4)
Dissolved Metals (Al, As, Ba, Co, Cu, Pb, Li, Mn, Ni, Se, Sr, Zn, Fe)
Total Metals (Al, As, Ba, Co, Cu, Pb, Li, Mn, Ni, Se, Sr, Zn, Fe)
Total Nitrogen
Total Phosphorus
Ionic Balance (Total Anions and Total Cations)</td><td colspan="3">Normal Condition</td></tr>
<tr><td>• Groundwater levels and quality remain consistent with baseline variability and/pre-mining trends, and changes in groundwater levels/quality not persisting after significant rainfall recharge events.</td><td>• Continue monitoring and review of data as per monitoring program.</td><td>• No response required.</td></tr>
<tr><td colspan="3">Level 1</td></tr>
<tr><td>• Level 1 trigger of TARP WMP8 for a minimum of two "early warning" bores.
OR
• Level 1 trigger of TARP WMP11 for a minimum of two "early warning" bores.</td><td>• Actions as required for Normal Condition.
• Undertake an investigation to assess cause and determine if mining related.
• Discuss findings and obtain other relevant information from key specialists (e.g. subsidence monitoring results, surface water level results).
If the changes have been confirmed to be related to mining effects:
• Consider all reasonable and feasible options for remediation as relevant (e.g. extending the depth of the bore, establishment of additional bores). This could include potential for implementation of make-good provisions as per Section 6.2.1.4 of the Water Management Plan for affected private bore owners.
• For monitoring sites relevant to Thirlmere Lakes or associated with surface water monitoring sites, initiate groundwater – surface water interaction TARP.</td><td>• Report trigger exceedance to DPE and key stakeholders.
• Report trigger exceedance and investigation outcomes in Six Monthly Subsidence Impact Report and Annual Review.
If the changes have been confirmed to be related to mining effects:
• Provide DPE and key stakeholders with proposed corrective management actions (CMAs) for consultation (e.g. extending the depth of the bore, establishment of additional bores, compensation to affected landowners as detailed in Section 6.2.1.4 of the Water Management Plan).
• Implement CMAs, subject to land access.
• Monitor and report on success of CMAs in Six Monthly Subsidence Impact Report and Annual Review.</td></tr>
<tr><td colspan="3">Level 2</td></tr>
<tr><td>• Level 2 trigger of TARP WMP8 for a minimum of three bores "early warning" bores
OR
• Level 2 trigger of TARP WMP11 for a minimum of three bores ("early warning" bores and Thirlmere Lakes bores).</td><td>• Actions as stated in Level 1.
If the changes have been confirmed to be related to mining effects:
• Consider increasing monitoring and review of data at sites where Level 2 has been reached, subject to land access. Reasons for not increasing monitoring frequency could include solid identification causation that do not require further monitoring (e.g. singular anthropogenic impact resulting in water level change).
Review Thirlmere Lakes monitoring bore data
• Compare against base case and deterministic model scenarios[2].
• Review manual water level measurements for additional monitoring sites to identify potential spatial trends in water level decline.
• Review surface water data to assess for surface water level decline at relevant site.
• Review CMAs in light of findings from further investigations and consider additional reasonable and feasible options.
• Review Water Management Plan and modify if necessary.
• Undertake an investigation to determine if an exceedance of the performance measure is likely. To be commenced/completed as soon as practicable.</td><td>• Responses as stated in Level 1.
• Provide findings of CMA review to DPE and key stakeholders for consultation.
• Implement additional CMAs, subject to land access.
• Advise DPE and key stakeholders of any required amendments to Water Management Plan.
• If relevant, notify DAWE of any predictions of an exceedance of a performance measure within two business days.</td></tr>
<tr><td colspan="3">Exceeds Performance Measure</td></tr>
<tr><td>• Level 3 trigger of TARPs WMP8 for a minimum of four bores "early warning" bores)
OR
• Level 3 trigger of TARPs WMP11 for a minimum of four bores ("early warning" bores and Thirlmere Lakes bores).
AND
• Review of Thirlmere Lakes bores indicated potential impacts resulting from extraction</td><td>• Actions as stated in Level 2.
If the changes have been confirmed to be related to mining effects:
• Increase monitoring and review of data frequency for sites where Level 3 has been reached, subject to land access.
• Investigate reasons for the performance measure exceedance. To be commenced/completed as soon as practicable.
• Review predictions of subsidence impacts and environmental consequences associated with further longwall extraction based on the outcomes of the investigation.</td><td>• Responses as stated in Level 2.
• Submit a report to DPE (in accordance with Condition E4 of SSD 8445) within 14 days of the exceedance occurring (or other timeframe agreed by DPE) describing remediation options and any preferred remediation measures or other course of action.
• Implement any reasonable remediation measures as directed by DPE, subject to land access.
• Notify DAWE of any detection or predictions of an exceedance of a performance measure within two business days.</td></tr>
</table>

			• Consider modifying mine plan.	• Submit an Impact Response Plan to DAWE (in accordance with Condition 11 of the DAWE Consent for the Tahmoor South Project). • Update numerical groundwater model and re-run predictive scenarios to determine the likely extent and depth of depressurisation in the vicinity of Thirlmere Lakes, and to determine whether any additional management actions are required such as modifying the mine plan
Notes: [1] It is noted that the only Groundwater Dependent Ecosystem (GDE) pertinent to the Tahmoor South Project is that of Thirlmere Lakes[2] "Deterministic" model scenario refers to the predictive scenario modelling utilised to determine the trigger level.				

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