WAMBO COAL PTY LIMITED

WAMBO COAL MINE
LONGWALL 24 TO 26 MODIFICATION

MODIFICATION REPORT

For the Modification of DA 305-7-2003 (MOD 19)
Optimisation and Continued Operation
of the Approved South Bates Extension Underground Mine

APPENDIX B
Groundwater Assessment

Peabody

WAMBO COAL MINE

Longwalls 24-26 Modification Groundwater Assessment

Prepared for:

Wambo Coal Pty Ltd
PMB1, Singleton
NSW, 2330

SLR Ref: 665.10008.00815-R01
Version No: -v4.0
July 2022

EXECUTIVE SUMMARY

Wambo Coal Mine (Wambo) is located approximately 15 kilometres west of Singleton, near the village of Warkworth, New South Wales (NSW). Wambo is owned and operated by Wambo Coal Pty Limited (WCPL), a subsidiary of Peabody Energy Australia Pty Ltd.

Wambo is operated under Development Consent (DA 305-7-2003). WCPL is seeking approval for a Modification to Development Consent (DA 305-7-2003) under section 4.55(2) of the NSW *Environmental Planning & Assessment Act 1979* (the Modification).

Underground mining operations are currently being undertaken in the approved South Bates Extension (SBX) Underground Mine (Whybrow seam). As a result of ongoing evaluation and mine planning, WCPL has identified an opportunity for the continuation and improved efficiency of the SBX Underground Mine by reorienting Longwalls 24 and 25 and adding Longwall 26.

SLR Consulting Australia Pty Ltd has been engaged by WCPL to undertake a Groundwater Assessment in support of the application to modify Development Consent (DA 305-7-2003). The Groundwater Assessment has been undertaken in accordance with relevant NSW Government and Commonwealth Government requirements.

This Groundwater Assessment for the Modification has been conducted with reference to the work done for five earlier modifications: Heritage Computing (2012) for North Wambo Underground Longwalls 9 and 10; HydroSimulations (2014) for North Wambo Underground Longwall 10A; HydroSimulations (2015) for South Bates (Wambo Seam) Underground Mine; HydroSimulations (2016) for South Wambo Underground Mine; and HydroSimulations (2017) for South Bates Extension Underground Mine.

Wambo is located in the Upper Hunter Valley region where landforms are characterised by gently sloping floodplains associated with the Hunter River and the undulating foothills, to the ridges and escarpments of the Mount Royal Range and Great Dividing Range. The temperate climate of the Wambo area is characterised by hot summers and mild dry winters.

The primary aquifer units in the Wambo area are the deposits of Quaternary Alluvium and less productive coal seams of the Permian Coal Measures. Key areas of alluvium and their associated watercourses considered in this assessment are ephemeral watercourses North Wambo Creek, Wambo Creek and Waterfall Creek, and perennial/ semi-perennial watercourses Wollombi Brook and the Hunter River.

There are a number of potential anthropogenic and environmental users of groundwater in the Wambo area. Potential impacts to registered bores on private land and potential groundwater dependent ecosystems (GDEs) near Wambo operations are a consideration of this assessment.

The assessment of potential groundwater-related impacts of the Modification have been assessed using numerical groundwater modelling. The groundwater modelling carried out for the Modification was based on that used for South Bates Extension Underground Mine reporting (HydroSimulations, 2017), and the United Wambo Open Cut Project (Australian Groundwater and Environmental Consultants Pty Ltd, 2016) using MODFLOW-USG Beta software. The model used has been developed consistent with relevant NSW Government and Commonwealth Government requirements and has been peer reviewed.

The key findings of this assessment are:

- The maximum groundwater inflows to the modified SBX Underground Mine are predicted to not change from the approved mine plan.
- The maximum total groundwater inflows for all Wambo underground mining are predicted to increase from 1.6 megalitres (ML/day) to 1.8 ML/day. This peak occurs during the South Wambo Underground Mine operations.
- The Modification would result in additional drawdown at the water table and within the Whybrow Seam above and to the north of the modified Longwalls 24 to 26. This additional drawdown is predicted to not impact any registered bores, alluvium, surface water, or groundwater dependant ecosystems identified in this study.
- The Modification would not have a significant impact on water levels in the Permian coal measures from a regional perspective due to the regional zone of depressurisation within the Permian coal measures created by historical and ongoing open cut and underground mining.
- There is expected to be negligible impact on the highly productive alluvium associated with Wollombi Brook and the Hunter River as a result of the Modification.
- The Modification would not lower the beneficial use category of the groundwater within the Permian aquifers, as there would be no migration of groundwater away from the underground mining areas in the Permian aquifers either during mining or following completion of mining activities.
- The Modification would not result in reduced beneficial uses of the alluvium (from a water quality perspective).
- The alluvium adjacent to the SBX Underground Mine footprint at North Wambo Creek has been affected by open cut mining activities. The Modification longwalls underlie a smaller area of North Wambo Creek than approved mining and are unlikely to cause additional impacts.
- There are no bores above the SBX Underground Mine footprint that are used for irrigation, domestic or stock use.
- WCPL hold sufficient entitlements under the NSW *Water Management Act 2000* for the predicted groundwater take associated with the approved and modified Wambo operations.

An additional groundwater monitoring location is recommended to be installed at Waterfall Creek, north of the modified Longwalls 24 to 26. This paired monitoring bore would target shallow unconsolidated and weathered strata and would aim to improve the understanding of the nature and saturation level of unconsolidated material, any potential interaction with the underlying groundwater system, or potential interaction with the nearby high potential GDE. Data collected at the recently installed VWPs north and west of the modified Longwalls 24 to 26 should continue to be monitored to validate conceptual model assumptions and numerical model predictions.

No additional groundwater impact mitigation measures are proposed for the Modification. Groundwater levels and quality should continue to be monitored at Wambo in accordance with the GWMP approved under the Development Consent.

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APPENDICES

1 Introduction

1.1 Overview

Wambo Coal Mine (Wambo) is located approximately 15 kilometres (km) west of Singleton, near the village of Warkworth, New South Wales (NSW). Wambo is owned and operated by Wambo Coal Pty Ltd (WCPL), a subsidiary of Peabody Energy Australia Pty Ltd.

Wambo is operated under Development Consent (DA 305-7-2003). WCPL is seeking approval for a modification to Development Consent (DA 305-7-2003) under section 4.55(2) of the NSW *Environmental Planning & Assessment Act 1979* (the EP&A Act) (the Modification).

SLR Consulting Australia Pty Ltd (SLR) has been engaged by WCPL to undertake a Groundwater Assessment in support of the application to modify Development Consent (DA 305-7-2003). WCPL require assessment of incremental and cumulative groundwater impacts of Wambo including the Modification.

1.2 Approved Wambo Coal Mine

Wambo is operated in accordance with Development Consent (DA 305-7-2003) which was granted in February 2004. Both open cut and underground mining operations under Development Consent (DA 305-7-2003) commenced in 2004. In November 2014, Glencore and Peabody Energy Australia Pty Limited agreed to form a 50:50 Joint Venture to develop an open cut coal mine project that combined the extraction and exploration rights for a number of mining tenements held by United Collieries Pty Limited (United) (a subsidiary of Glencore) and WCPL. The Joint Venture proposed that United would manage the combined open cut mining operations utilising Wambo's existing infrastructure. WCPL would continue to operate its underground mining operations, the coal handling and preparation plant (CHPP) and rail loading facilities. An application to modify the Development Consent (DA 305-7-2003 MOD 16) and a State Significant Development application (SSD-7142) to support the United Wambo Open Cut Project (UWOCP) were approved on 28 August 2019.

Development associated with DA 305-7-2003 and SSD-7142 will be staged. From 1 December 2020, Wambo transitioned into Phase 2 operations which includes underground mining and coal handling and processing. Development Consent (DA 305-7-2003) covers the following mining operations at Wambo (see **Figure 1-1**):

- Underground mining operations in the approved North Wambo Underground Mine (Wambo seam) (completed).
- Underground mining operations in the approved South Bates Underground Mine (Wambo and Whybrow seams) (completed).
- Underground mining operations in the approved South Bates Extension (SBX) Underground Mine (Whybrow seam) (in progress).
- Underground mining operations in the approved South Wambo Underground Mine (Woodlands Hill and Arrowfield Seams) (future operation).
- Ongoing operation of the CHPP and processing of coal from the underground mining operation and the UWOCP, with up to 14.7 million tonnes per annum of run-of-mine coal processed at the CHPP in any calendar year.

1.3 Modification overview

WCPL is currently mining Longwall 22 and developing first workings for Longwalls 23 and 24 in accordance with the approved SBX Underground Mine plan. As a result of ongoing evaluation and mine planning, WCPL has identified an opportunity for the continuation and improved efficiency of the SBX Underground Mine by reorienting Longwalls 24 and 25 and adding Longwall 26 (see **Figure 1-1**). The longwalls would target the Whybrow Seam and would use the existing approved infrastructure at the SBX Underground Mine.

Although the Modification would not change the approved South Wambo Underground Mine layout, sequence or peak mining rate, longwall mining in the South Wambo Underground Mine would commence two years later than currently scheduled due to the extension of the SBX Underground Mine life. The period that longwall mining occurs concurrently in the Woodlands Hill Seam and Arrowfield Seam at the South Wambo Underground Mine would also increase from four to six years to allow underground mining operations to finish within the approved mine life of Wambo (i.e. 31 August 2042).

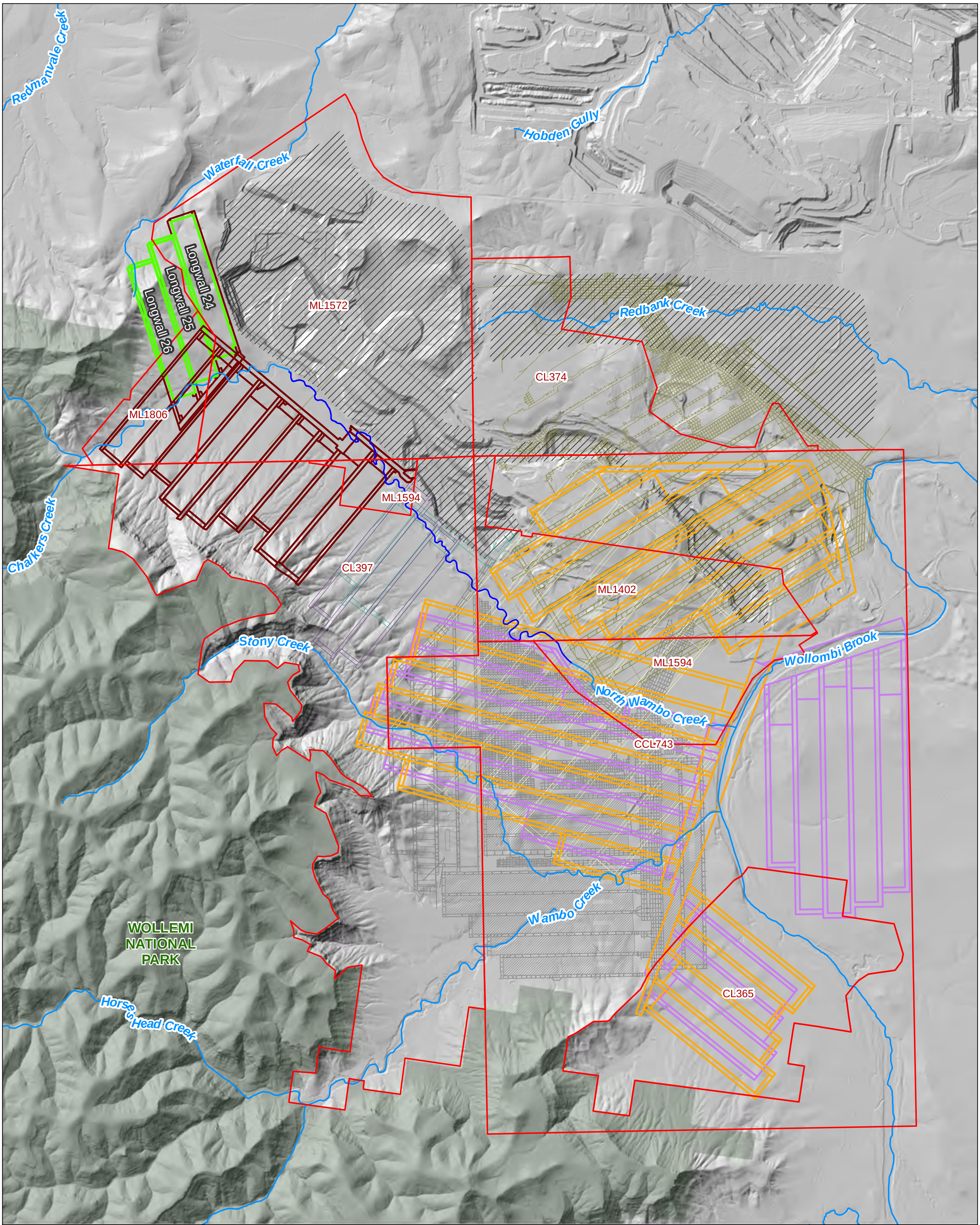
Components of the Modification will be referred to the Commonwealth Minister for the Environment under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

1.4 Objectives

The Groundwater Assessment has been undertaken in accordance with relevant NSW Government and Commonwealth Government requirements. The Groundwater Assessment comprises two parts, a description of the existing hydrogeological environment and an assessment of the potential groundwater-related impacts of the Modification.

The scope of the work completed included:

- Review all available hydrogeological data for the Wambo area and relevant previous studies (hydrogeological, geotechnical, and environmental), to characterise the hydrogeological setting of Wambo.
- Define the hydrostratigraphy of the Wambo area and collate the available data on hydraulic properties of the key hydrostratigraphic units.
- Assess the potential hydrogeological interaction between the alluvium of nearby watercourses (North Wambo Creek, Waterfall Creek, Wollombi Brook, and the Hunter River), and the underlying formations and target coal seams within the Wambo area.
- Identify groundwater dependent assets in the Wambo area that may be impacted by the Modification.
- Conceptualise the groundwater regime of the Wambo area.
- Construct and calibrate a numerical groundwater flow model suitable for assessment of potential impacts of the Modification, in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett *et al*., 2012).
- Perform predictive modelling to assess the impacts associated with the cumulative and incremental impacts of Wambo (including the Modification) on groundwater levels, groundwater quality and groundwater dependent assets at various stages during mine operations and post closure.
- Review the suitability of the existing Wambo groundwater monitoring program and management measures and develop additional monitoring and management measure recommendations (if required).



Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:55,000 at A4
Project Number: 665.0008.00815
Date: 26-Jul-2022
Drawn by: ANP

Named Watercourse
NWC Diversion
Mining Lease
Approved Open Cut Mining
NPWS Reserve

Proposed Mining

South Bates Extension LW24-26 MOD - Whybrow Seam

Approved Mining

South Wambo - Woodlands Hill Seam
South Wambo - Arrowfield Hill Seam
South Bates Extension - Whybrow Seam

Historical/Completed Mining

South Bates - Whybrow Seam
South Bates - Wambo Seam
North Wambo UG - Wambo Seam
United UG - Arrowfield Seam
Homestead-Wollemi UG - Whybrow Seam

Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION

Plan of Wambo mining and surrounds

FIGURE 1-1

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_G2_SitePlanDetailed_003.mxd

1.5 Information sources

The following information sources have been relied upon for the development of this Groundwater Assessment:

- WCPL provided information:
  - Indicative approved and modified Wambo mine plan information in Geographic Information System (GIS) format.
  - Wambo groundwater and surface water monitoring database (to December 2021).
  - Previous Wambo annual groundwater reporting and associated information/datasets.
  - Previous Wambo numerical modelling reporting and associated information/datasets.
- Publicly available information:
  - Bureau of Meteorology (BoM) (2021) Groundwater Dependent Ecosystems (GDE) Atlas.
  - Water NSW real time data registered bore database.
  - NSW Government's NSW Planning Portal.
  - NSW legislation.

2 Legislative requirements and guidelines

2.1 Commonwealth Regulatory Framework

2.1.1 *Environment Protection and Biodiversity Conservation Act 1999*

The EPBC Act is administered by the Commonwealth Department of Climate Change, Energy, the Environment and Water. The EPBC Act is designed to protect Matters of National Environmental Significance, including water resources in relation to coal seam gas (CSG) and large coal mining (the water trigger). As described in **Section 1.3**, components of the Modification will be referred to the Commonwealth Minister for the Environment under the EPBC Act.

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) is a statutory body established under the EPBC Act that provides scientific advice to the Commonwealth Minister for the Environment and relevant state ministers.

The IESC (2018a) has developed the *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals* (the Information Guidelines) to outline the information considered necessary to enable the IESC to provide robust scientific advice to government regulators on the water-related impacts of CSG and large coal mining development proposals. This includes completion of an independent peer review of numerical groundwater modelling undertaken to support development proposals, in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett *et al*. 2012).

The Information Guidelines have been considered during the preparation of this Groundwater Assessment. A summary checklist against the requirements is presented in **Appendix A**.

2.2 New South Wales Regulatory Framework

2.2.1 Water Management Act 2000

The NSW *Water Management Act 2000* (WM Act) is the primary legislation regulating groundwater resources in NSW. The main purpose of the WM Act is to provide for the sustainable and integrated management of water sources in the State, and a means to manage and safeguard the existence of rivers and aquifers used for commercial purposes. The WM Act also governs the issues of groundwater licences across the State, and therefore any take of water required for the Modification would require a water access licence under the WM Act to ensure that "no more than minimal harm" is caused to a water source or water receptors.

2.2.2 Water Sharing Plans

The WM Act is enacted under a framework of catchment specific Water Sharing Plans (WSPs). These WSPs set out the rules for water trading (buying and selling of water licences as well as water allocations), so that the equitable sharing of water and resources can occur sustainably and under a strict licensing and approvals process.

Each WSP is split into several Water Sources; water can generally only be traded within a Water Source, and these act as the primary zones of water management. The potential impacts of the Modification will be required to be assessed in the context of these Water Sources. Assessment of licences will be based on the water available in each Water Source, and the "no more than minimal harm" rules governing each.

There are two WSPs of relevance to the Modification:

- *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009* (Department of Primary Industries [DPI], 2009).
- *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources* 2016 (DPI, 2016b).

The key relevant Water Sources are:

- Lower Wollombi Brook Alluvial Water Source within the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*.
- Upstream Glennies Creek Management Zone of the Hunter Regulated River Alluvial Water Source and Unnamed Alluvium within Jerrys Water Source (associated with the alluvial deposits to the north of the Modification) within the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*.
- Sydney Basin North Coast Groundwater Source (associated with the Permian bedrock strata in the vicinity of the Modification within the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016.*

2.2.3 Aquifer Interference Policy 2012

The purpose of the *Aquifer Interference Policy 2012* (AIP) (DPI – Office of Water, 2012) is to clarify the role and requirements of the administering authority of the water licensing and assessment processes for any activity that can be classed as an aquifer interference under the WM Act. Furthermore, the AIP aims to clarify the requirements for licensing for aquifer interference activities to ensure that the take is accounted for in the water budget and water sharing arrangements.

The AIP divides groundwater sources into "highly productive" and "less productive" categories based on salinity and aquifer yield. Within the AIP, "Minimal Impact Considerations for Aquifer Interference Activities" are provided for both "highly productive" and "less productive" groundwater sources. With respect to the Modification, the Hunter River Alluvium, and the North Wambo Creek alluvium of the Lower Wollombi Brook Water Source would be classified as a "Highly Productive Groundwater Source" under the AIP. Of note to the Modification, there are limits as to the allowable groundwater drawdown (water table and/or water pressure) of this source without the need to undertake additional studies to prove the long-term viability of GDEs, culturally significant sites, or water supply works.

2.2.4 NSW Strategic Regional Land Use Policy

Under the EP&A Act, the Strategic Regional Land Use Policy requires any State Significant mining development requiring a new mining lease to assess potential impacts on Biophysical Strategic Agricultural Land (BSAL). BSAL is land with high quality soil and water resources capable of sustaining high levels of productivity. The closest mapped BSAL is associated with the Hunter River and is located approximately 1 km to the north of the Modification.

A Site Verification Certificate issued in July 2022 for the Modification area outside of existing mining tenements verified that the area is not BSAL.

2.2.5 *Protection of the Environment Operations Act 1997*

The NSW *Protection of the Environment Operations Act 1997* (POEO Act) seeks to manage pollution impacts for a variety of operations in NSW. The main objects of the POEO Act are to protect and restore the quality of the environment, to promote ecologically sustainable development and environmental protection, and strengthen the regulatory framework for environmental protection. The POEO Act is administered by the NSW Environment Protection Authority, which issues environment protection licences (EPLs) for certain activities scheduled in the POEO Act, including those that may impact on groundwater quality.

WCPL holds EPL 529 which permits activities scheduled under the POEO Act (coal works and mining for coal) at Wambo. An approval to vary the premises of EPL 529 will be required as part of this Modification.

2.3 Relevant guidelines

The Groundwater Assessment for the Modification has been prepared in accordance with several relevant guidelines that are designed to assist project proponents meet the relevant legislative requirements for projects. These guidelines include:

- Australian Groundwater Modelling Guideline 2012 (Barnett *et al.*, 2012).
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Agriculture and Resource Management Council of Australia and New Zealand (Agriculture and Resource Management Council of Australia and New Zealand [ARMCANZ] and Australian and New Zealand Environment and Construction Council [ANZECC]), 2000).
- Information Guidelines Explanatory Note: Assessing Groundwater-dependent Ecosystems (Doody *et al.*, 2019).
- Information guidelines for proponents preparing coal seam gas and large coal mining development proposals (IESC, 2018a) – See **Appendix A**.
- Groundwater Assessment Toolbox Project for major projects in NSW – Overview Document (Department of Planning and Environment [DPE], 2022) – See **Appendix B.**
- Guidelines for the Assessment & Management of Groundwater Contamination (NSW Department of Environment and Conservation, 2007).
- Guidelines for Groundwater Protection in Australia (Commonwealth of Australia, 2013).
- National Water Quality Management Strategy (Department of Sustainability, Environment, Water, Population and Communities, 1994).
- National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ and ANZECC, 1995).
- NSW Water Quality and River Flow Objectives (Department of Environment, Climate Change and Water [DECCW], 2006).
- Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Serov et al, 2012).

3 Data requirements

Based on the legislation and guidance outlined in **Section 2**, a summary of baseline groundwater information required to prepare the Groundwater Assessment and where the requirements are addressed in the Groundwater Assessment is presented in **Table 3-1**.

Table 3-1 Groundwater baseline information

Approval Data/ Information	Monitoring Requirement	Reference Legislation/ Guidance	Groundwater Assessment Section
Baseline groundwater levels (including understanding of seasonal variability)	Groundwater level data collected over a minimum of two years and consisting of at least eight data points for each aquifer unit.	IESC Section 4, AIP	**Section 6.3**
Baseline groundwater quality (including understanding of seasonal variability)	Groundwater quality data collected over a minimum of two years and consisting of at least eight data points for each aquifer unit. Analytes to include acidity/alkalinity, electrical conductivity (EC), metals, and major ions.	IESC Section 4, ANZECC (2000) Section 7, ANZG (2018) Online pages: Guideline Values & Monitoring, AIP	**Section 6.4**
Understanding of vertical gradients between hydrostratigraphic units	Installation of Vibrating Wire Piezometers (VWPs) / nested arrays of monitoring bores to provide hydrogeological data of multiple hydrostratigraphic units at a single location.	IESC Section 4	**Section 6.1**
Understanding of vertical gradients between surface water features and hydrostratigraphic units	Installation of nested arrays of monitoring bores to provide hydrogeological data of multiple hydrostratigraphic units at a single location. Stage height monitoring on surface water features.	AIP	**Section 6.3.7**
Hydraulic parameters of each hydrostratigraphic units (Kh, Kv, Specific Yield [Sy], Specific Storage [Ss], Transmissivity)	Pump or slug testing of monitoring bores to determine representative hydraulic properties of each hydrostratigraphic unit	IESC Section 4	**Section 6.2**
Baseline monitoring from unimpacted reference and control sites to distinguish between background variation and impacts of the Modification	Designation of monitoring bores as reference sites. Reference bores are required for each hydrostratigraphic unit and should include an upstream location outside of any areas that will potentially be impacted by the development of the Modification.	IESC Section 5	**Section 6.3**[1]

Approval Data/ Information	Monitoring Requirement	Reference Legislation/ Guidance	Groundwater Assessment Section
Identification and characterisation of groundwater receptors (natural and anthropogenic)	Baseline (pre-project) characterisation of specific location and groundwater usage of existing groundwater receptors.	IESC Section 4 AIP	**Section 6.5 and Section 6.6**

ANZECC & ARMCANZ, 2000, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

ANZG, 2018, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia, Available at www.waterquality.gov.au/anz-guidelines

DPI – Office of Water, 2012. *NSW Aquifer Interference Policy*

IESC, 2018a, Information guidelines for proponents preparing coal seam gas and large coal mining development proposals, Commonwealth of Australia, 2018

[1] Designation of reference bores outside of areas of potential impact difficult due to size of some hydrostratigraphic zones monitored (e.g. alluvial bodies) and the scale of regional mining operations. Pre mining variation in observations used when considering impacts of the Modification.

4 Existing conditions

4.1 Climate

The temperate climate of the Wambo area is characterised by hot summers and mild dry winters. Locally, daily rainfall has been recorded at Bulga (South Wambo) (BoM Station 061191) from 01 January 1959 to 30 September 2020. To supplement this data and provide a long-term uninterrupted data set, Scientific Information for Land Owners (SILO) Grid Point Data (Latitude -32.55, Longitude 150.95) was utilised to assess long-term rainfall trends. This dataset is interpolated from quality checked observational timeseries data collected at nearby stations by the BoM. **Figure 4-1** presents the long-term average monthly and annual rainfall for the previously mentioned data sets, representative of the local temperate climate.

Table 4-1 Average monthly rainfall (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Wambo[1]	75.7	73.2	62.1	45.2	39.2	48.0	44.9	35.6	43.9	50.8	61.3	66.5	646.4
Bulga (South Wambo)[2]	86.2	86.1	67.7	45.9	39.9	43.9	30.6	33.7	38.5	54.3	61.8	71.5	660.1

[1]Based on SILO dataset date range January 1900 to September 2020 [2] Based on BoM dataset date range January 1959 to September 2020

The long-term SILO data was also used to generate a cumulative rainfall deficit (CRD) plot, as seen in **Figure 4-1**. A CRD plot is provided as a comparative tool to illustrate long term climate trends and their influence on groundwater in the Wambo area. The CRD graphically shows trends in recorded rainfall compared to long-term averages and provides a historical record of relatively wet and dry periods. A rising trend in slope in the CRD graph indicates periods of above average rainfall, whilst a declining slope indicates periods when rainfall is below average. A level slope indicates average rainfall conditions.

The CRD plot shows significant periods of rainfall both below and above the long-term average over the record period. Recently, the Wambo area experienced below average rainfall from 2017 to early 2020, followed by above average rainfall from January 2020.

SILO also provides pan evaporation data and calculated plant evapotranspiration (ET) (using the Penman-Monteith formulation) for the Wambo area. The bimodal plot (**Figure 4-2**) indicates higher rainfall, evaporation, and ET during the summer months, with ET exceeding rainfall in September through until March. During the mid-year winter months evaporation and ET is lowest.

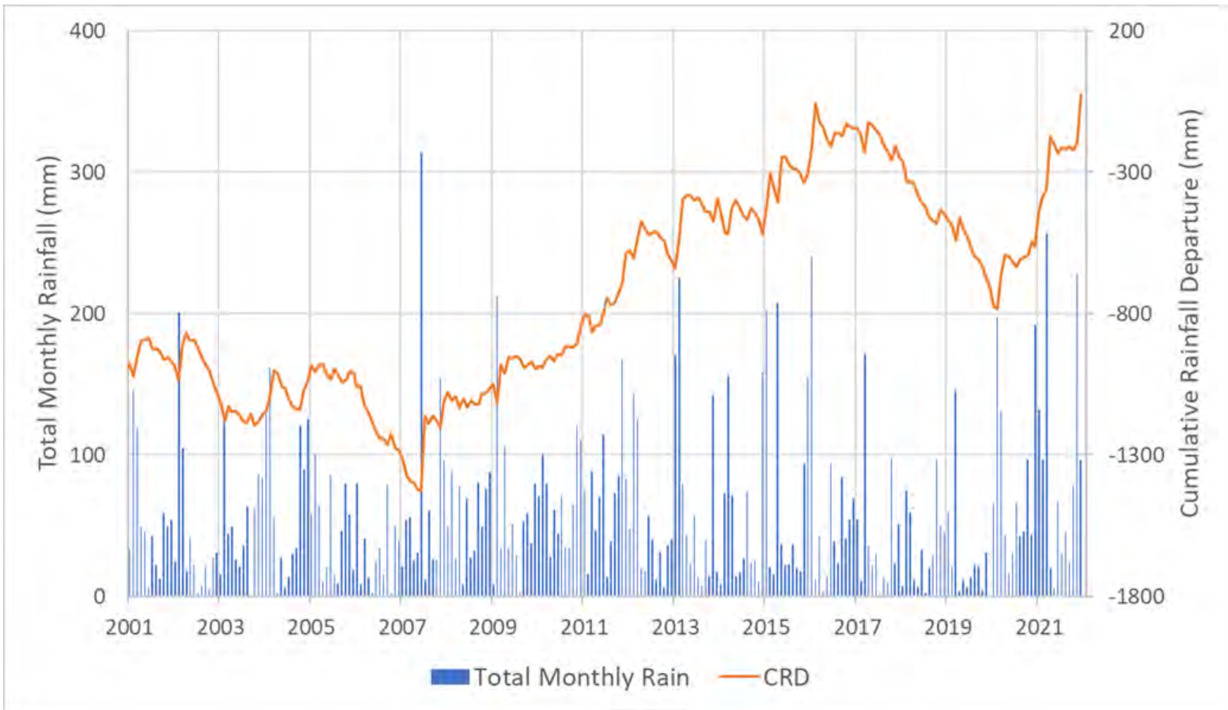


Figure 4-1 Wambo (SILO) long-term monthly rainfall and Cumulative Residual Deviation plot

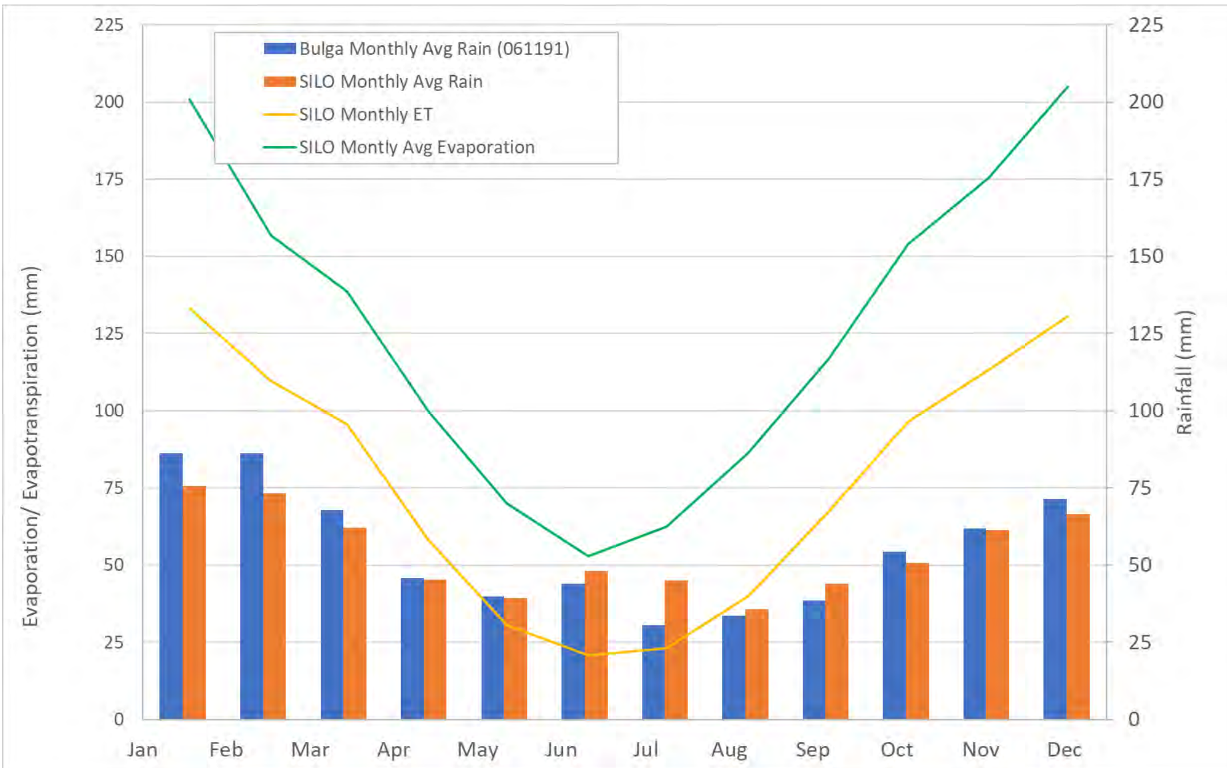


Figure 4-2 Wambo (SILO) long-term average monthly rainfall, evaporation, and evapotranspiration

4.2 Topography, land use and drainage

Wambo is located in the Upper Hunter Valley region where landforms are characterised by gently sloping floodplains associated with the Hunter River and the undulating foothills, to the ridges and escarpments of the Mount Royal Range and Great Dividing Range. Elevations in the vicinity of Wambo range from approximately 60 metres Australian Height Datum (mAHD) at Wollombi Brook to approximately 650 mAHD within the Wollemi National Park to the west of Wambo (WCPL, 2003). Topographic data available for the site includes site LIDAR with <1 metres (m) refinement (used for key water courses and site features); publicly available data with 1 to 2 m refinement (used where available); and SRTM (satellite) Digital Elevation Model (DEM) with 1 to approximately 30 m refinement (used for the remaining model domain).

Due to historical farming and mining, the majority of the Wambo area is cleared of vegetation. Wollemi National Park, to the west (see **Figure 1-1**), is densely vegetated with various plant communities, including open forests dominated by eucalypt species (Australasian Groundwater and Environmental Consultants Pty Ltd [AGE] 2016).

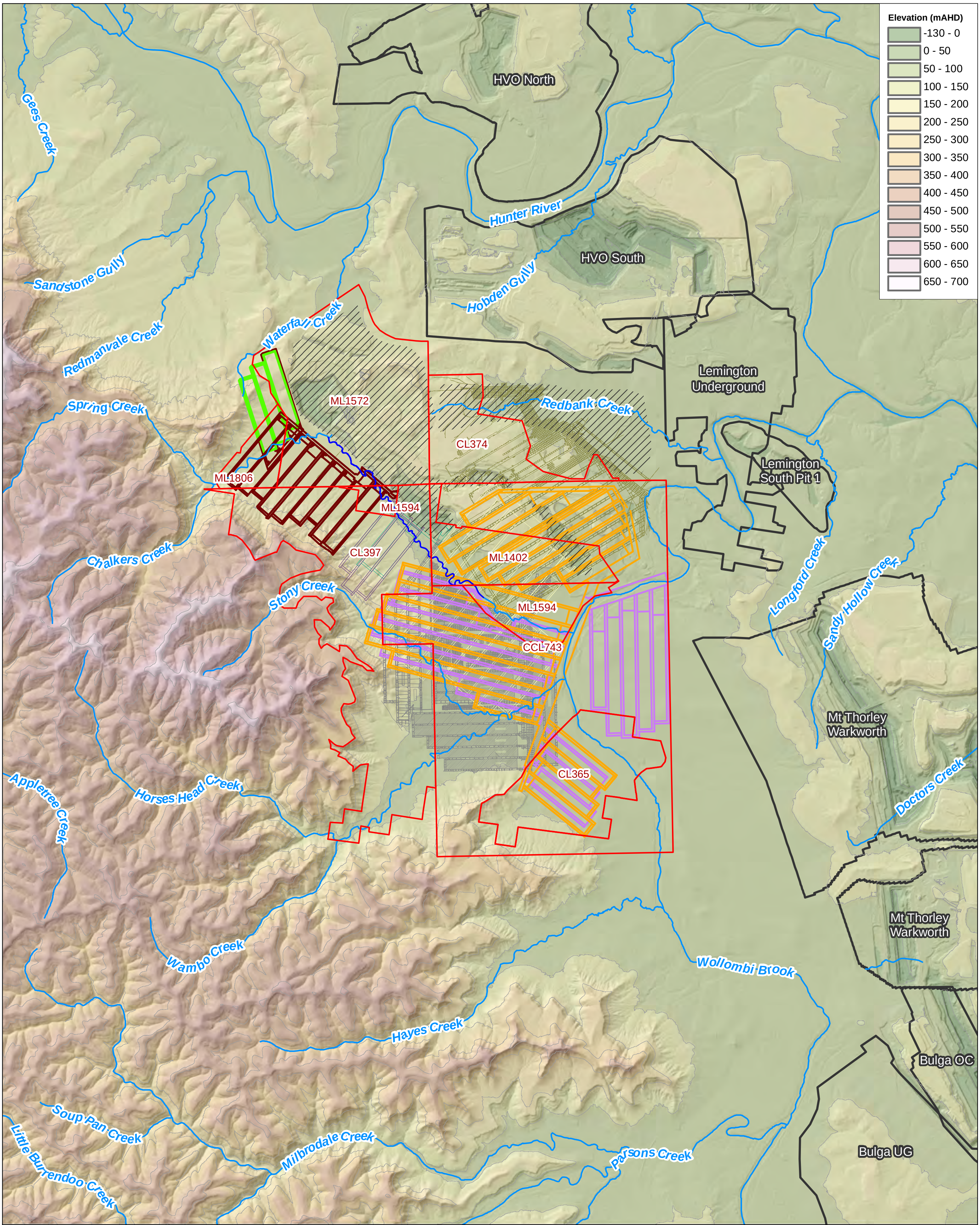
Figure 4-3 shows regional topography and major drainage features in the Wambo area. The primary drainage features of the Wambo area are the perennial Hunter River and Wollombi Brook. Wambo is situated adjacent to the Wollombi Brook, south-west of its confluence with the Hunter River. Wollombi Brook drains an area of approximately 1,950 square kilometres (km^2) and joins the Hunter River some 5 km north-east of Wambo. The Wollombi Brook sub-catchment is bound by the Myall Range to the south-east, Doyles Range to the west, the Hunter Range to the south-west and Broken Back Range to the north-east (Hunter Catchment Management Trust, 2002). Ephemeral surface water features include North Wambo, Wambo and Redbank Creeks which drain into Wollombi Brook, Stony Creek which drains into Wambo Creek, and Waterfall Creek which drains into the Hunter River. These watercourses are discussed in greater detail below.

4.2.1 Ephemeral creeks

North Wambo, Wambo and Redbank Creeks, which drain into Wollombi Brook, Stony Creek which drains into Wambo Creek prior to its confluence with Wollombi Brook, and Waterfall Creek which drains into the Hunter River are all ephemeral in nature (See **Figure 4-3**). Ephemeral creeks most relevant to this groundwater assessment are North Wambo Creek and Waterfall Creek, which overlie, or are near approved or modified SBX Underground Mine operations.

4.2.1.1 North Wambo Creek

North Wambo Creek traverses from west to south-east, through the centre of the Wambo and flows into Wollombi Brook. At its upstream end it drains to the north-east across the southern end of the modified SBX Underground Mine footprint. Recent installation of monitoring bores has shown the alluvium along North Wambo Creek to be 4 to 10 m deep comprising mainly sands, silts, and gravels, overlying weathered sandstones (regolith). Most of the south-west draining channel section of North Wambo Creek is an artificial realignment as open cut operations to the west mined out the natural channel.



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:100,000 at A4
Project Number:	665.0008.00815
Date:	08-Jul-2022
Drawn by:	ANP

SLR

Named Watercourse
NWC Diversion
Mining Lease
Approved Open Cut Mining
Surrounding Mine

Proposed Mining
South Bates Extension LW24-26 MOD - Whybrow Seam

Approved Mining
South Wambo - Woodlands Hill Seam
South Wambo - Arrowfield Hill Seam
South Bates Extension - Whybrow Seam

Historical/Completed Mining
South Bates - Whybrow Seam
South Bates - Wambo Seam
North Wambo UG - Wambo Seam
United UG - Arrowfield Seam
Homestead-Wollemi UG - Whybrow Seam

Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION

Topography and Drainage

FIGURE 4-3

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_4_3_TopoDrainage_004.mxd

North Wambo Creek is usually dry and only flows in response to heavy rainfall events. During peak flow events, conditions are likely to be losing (surface water leaking to the underlying aquifer). However, if rainfall and surface water flow sufficiently recharge the North Wambo Creek alluvium, gaining conditions can be observed (groundwater discharging to surface water).

A complete dataset of flow or stage height is not available for North Wambo Creek or other ephemeral creeks near Wambo. Alluvium Consulting (2020) undertook a comparison of available rainfall and flow data at North Wambo Creek gauging stations with the aim of identifying a minimum threshold of rainfall that is required prior to the onset of flow. Establishing this threshold aimed to identify historical rainfall events that would have likely resulted in surface water flow to bridge gaps in the monitoring record.

The use of Antecedent Precipitation Index (API) which considers a combined estimate of catchment wetness and rainfall was found by Alluvium Consulting (2020) to be a reliable approach. The API is a day-by-day estimate of catchment wetness based on the rainfall that has occurred over preceding days, with the most recent rain contributing more to the API than rain from previous days. It can be thought of as today's rain, plus a decay factor times yesterday's API. High values of API indicate wetter catchment conditions, with any rain more likely to run off. Conversely, low values mean the catchment is dry, so rain is more likely to soak in.

The Alluvium Consulting (2020) assessment compared API from the Bulga (South Wambo) rainfall gauge (BoM Station 061191) with available data from the FM1 flow station on North Wambo Creek and found that the onset of surface flow generally occurs when API exceeds a value of 100 millimetres (mm). It is conceptualised that flow events on North Wambo Creek contribute to the saturation of its alluvial aquifer, and that incorporation of this API-flow relationship into the numerical model will enable simulation of likely flow events not captured in the incomplete monitoring dataset.

4.2.1.2 Waterfall Creek

Waterfall Creek is located in a catchment to the north of North Wambo Creek, and generally flows in a north easterly direction to the Hunter River. The UWOCP Surface Water Management Plan (United, 2022) describes Waterfall Creek as "*ephemeral and frequently dry. Its channel is generally shallow and poorly defined along its length as its catchment is predominantly drained by overland sheet flow. As such, Waterfall Creek's riparian zone is also poorly defined.*"

The northern end of modified Longwalls 24 and 25 extend to within 100 to 300 m of Waterfall Creek, while modified Longwall 26 underlies the first and second order drainage lines that form the headwaters of Waterfall Creek (**Figure 4-3**). A review of Aerial imagery and the DEM shows that just north of modified SBX Underground Mine footprint, the channel is either poorly defined or not discernible along the floor of a reasonably steep sided valley in this location, with a floor elevation approximately 50 m lower than the valley sides. A farm dam has been constructed on the upper reach of the creek which holds water, and a small pond is present within the valley just north of modified Longwall 24.

There is currently no data on the frequency and duration of flows, creek bed material, surface water – groundwater interactions, and or the presence of alluvium along Waterfall Creek. It is noted, however, that the presence of surface water flow within Waterfall Creek is rarely encountered in routine and rain event surface water monitoring. Only 2 events from 36 attempts (5.5%) at midstream Waterfall Creek (SW39) and 6 events from 36 attempts (17%) at downstream Waterfall Creek (SW41) encountered flow from October 2019 to December 2021. Infrequent flows monitored at Waterfall Creek, despite generally above average rainfall conditions is consistent with the *ephemeral and frequently dry* description above (United, 2022).

4.2.2 Wollombi Brook

Wollombi Brook flows north to north-easterly before reporting to the Hunter River approximately 4 km to the east of the SBX Underground Mine area. Alluvium along Wollombi Brook comprises up to 10 to 20 m of unconsolidated sediment including gravel, sand, silt, and clay (Mackie Environmental Research [MER], 2009). Stream flow analysis was undertaken by AGE (2016) to assess the contribution of baseflow in Wollombi Brook with results showing flow is largely a function of rainfall. AGE (2016) estimated that groundwater contributes up to 70 megalitres[1] per day (ML/day) to the flow in the Wollombi Brook. Although Wollombi Brook is predominantly a gaining environment (receiving groundwater) there are also areas where the Wollombi Brook recharges the underlying alluvium (losing environment), particularly in high flow events.

Monitoring of Wollombi Brook occurs at two key gauging stations, Wollombi Brook at Bulga (ID: 210028) and Wollombi Brook at Warkworth (ID: 210004) (**Table 4-2**). **Figure 4-4** presents stage height at the two gauges alongside the Wambo (SILO) CRD data.

Table 4-2 Wollombi Brook gauging stations

Station	WaterNSW ID	Easting	Northing	Zero Stage Elevation (mAHD)
Wollombi Brook at Bulga	210028	314360	6385900	65.7
Wollombi Brook at Warkworth	210004	314228	6395064	49.4

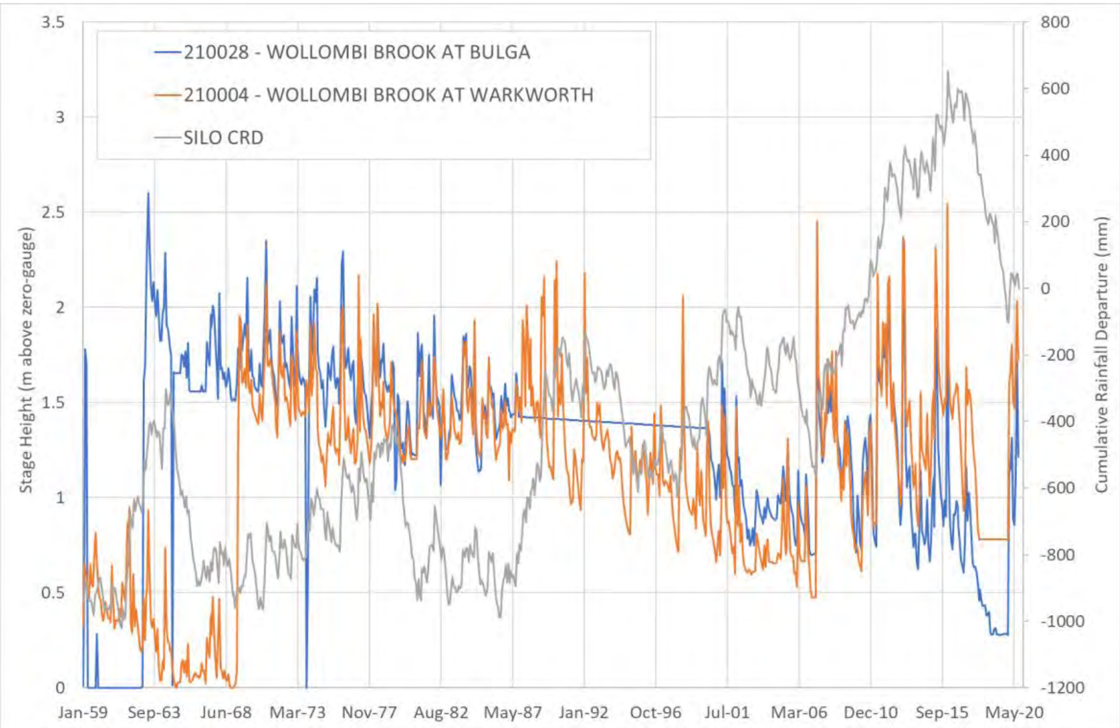


Figure 4-4 Wollombi Brook stage height (above zero-gauge level) and Wambo (SILO) Cumulative Residual Deviation plot

[1] Note one megalitre is one million litres (1,000,000 L)

4.2.3 Hunter River

Within the Wambo area, the Hunter River is around 20 to 50 m wide and flows in a south to south-easterly direction. The surface water is used for industrial and agricultural purposes, as well as town water supplies. Flowing perennially, daily flows generally range between 100 ML/day and 1,000 ML/day (from WaterNSW gauging station data). Flood events, recorded in May 2001, June 2007, September 2008, June 2011, and March 2013, experience daily flows of over 2,000 ML/day. Monitoring of gauging stations occurs via the Hunter Integrated Telemetry System operated by WaterNSW, with gauging stations relevant to the development of this model presented in **Table 4-3.**

Table 4-3 Hunter River gauging stations

Station	WaterNSW ID	Easting	Northing	Zero Stage Elevation (mAHD)
Hunter River at Liddell	210083	304903	6403439	177.2
Hunter River u/s Foy Bk	210126	316688	6404138	67.1
Hunter River u/s Glennies Ck	210127	317946	6402556	66.0
Hunter River at Mason Dieu	210128	316729	6401337	58.4

Gauging station data (stage height) is presented against the Wambo (SILO) CRD in **Figure 4-5** and illustrates that water levels within the Hunter River varied by ± 0.5 m between 2001 and 2019. These levels remained relatively stable due to regulated releases from Glenbawn Dam.

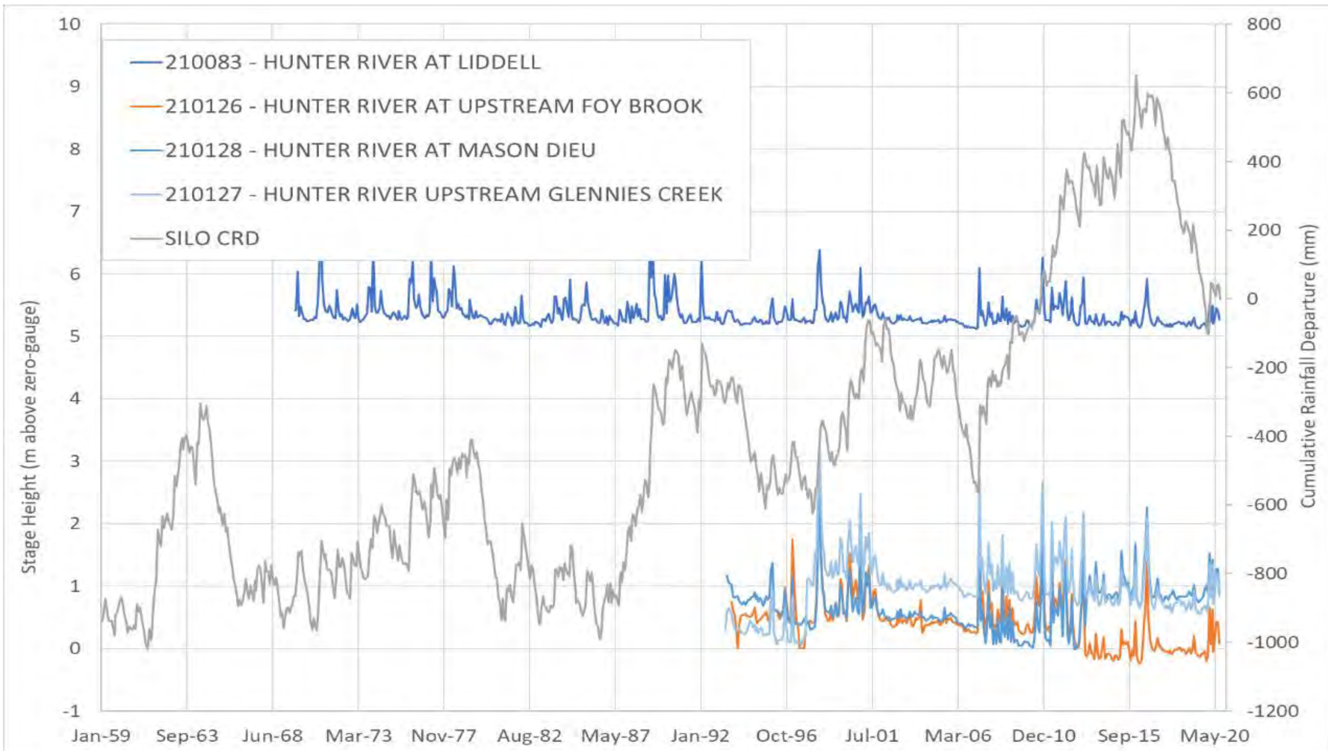


Figure 4-5 Hunter River stage height and Wambo (SILO) Cumulative Residual Deviation

Baseflow separation completed by AGE (2016) indicates that surface water flow within Hunter River is largely a function of rainfall. However, it is estimated that groundwater contributes up to 231 ML/day to the Hunter River. The baseflow in the Hunter River is likely to be less than estimated due to releases from the Glenbawn Dam that maintains a permanent flow for downstream users. Although the Hunter River is predominantly a gaining environment (receiving groundwater) there are also areas where the river recharges the underlying alluvium (losing environment), particularly in high flow events.

4.3 Mining

Historically coal mining in the region has been undertaken via both open cut and underground mining techniques. Currently, mining is still occurring via both mechanisms undertaken by several operators. **Table 4-4** summarises the mine activities in the area, with those operational shown in bold.

Table 4-4 Summary of mine activities (those in bold currently operational)

Operator	Mine Name	Seam(s) Mined	Date Operational	Mine Type
WCPL	Homestead Underground	Whybrow	1969 – 1977	Underground
	Wollemi Underground	Whybrow	1997 – 2002	Underground
	Ridge Underground	Whybrow	1973 – 1983	Underground
	Wombat Pit	Whybrow to Whynot	1969 – 2009	Open Cut
	Hunter Pit	Whybrow to Whynot	1969 – 2011	Open Cut
	Bates / Bates South Pit	Whybrow to Whynot	1986 – 2016	Open cut
	Glen Munro Pit	Glen Munro	2016 – 2017	Open Cut
	South Bates Underground	Whybrow Wambo	2016 – 2019	Underground
	South Bates Extension (SBX)	Whybrow	2018 – 2024	Underground
	Montrose Pit	Whybrow to Whynot	2013 – 2020	Open Cut
	Homestead Pit	Whybrow to Whynot	1969 – 2009	Open Cut
	North Wambo Underground	Wambo	2007 – 2016	Underground
	South Wambo Underground (Approved)	Arrowfield Bowfield	To 2042	Underground
	South Bates Extension (SBX) – Longwalls 24-26 Modification (the Modification)	Whybrow	2023 – 2025	Underground
United Colliery	United Open Cut	Wambo to Whynot	1989 – 1992	Open Cut
	United Underground	Arrowfield	1992 – 2010	Underground
United Wambo Joint Venture	**UWOCP**	Whynot to Vaux	2020 – 2039	Open Cut
Hunter Valley Operations	**Hunter Valley Operations (HVO) North**	Mt Arthur Bayswater	1979 – 2025	Open Cut

Operator	Mine Name	Seam(s) Mined	Date Operational	Mine Type
	HVO South	Arrowfield to Bayswater	1997 – 2030	Open Cut
	Lemington Underground	Mt Arthur Seam	1971 – 1992	Underground
	North Lemington	Mt Arthur to Vaux	1971 – 1999	Open Cut
Mount Thorley Operations Pty Ltd and Warkworth Mining Ltd	**Mount Thorley Warkworth (MTW)**	Woodlands Hill to Bayswater	1981 – 2035	Open Cut

4.3.1 Subsidence

The Subsidence Assessment for the Modification (Mine Subsidence Engineering Consultants [MSEC], 2022) has been considered in this Groundwater Assessment and summarised in **Table 4-5**.

Table 4-5 Comparison of subsidence impacts between Approved and Proposed operations

Overview of predicted subsidence impacts for the modified SBX Underground Mine
• The maximum predicted subsidence effects of the modified longwalls are expected to be the same or slightly less than those based on the approved layout – maximum predicted subsidence effects are 1,950 mm vertical subsidence (i.e. 65% of the maximum extraction height of 3.0 m), 80 mm/m tilt (i.e. 8.0% or 1 in 12) and greater than 3.0 km^{-1} curvature (i.e. a minimum radius of curvature less than 0.3 km). • North Wambo Creek is located above the mining area based on both the approved and modified layout. However, the length of North Wambo Creek located above the longwalls based on the modified layout is approximately 2.1 km less than that based on the approved layout. The predicted subsidence effects and the assessed impacts on North Wambo Creek, based on the modified layout, are similar to or less than those based on the approved layout. • The upper reaches (i.e. first and second order sections) of Waterfall Creek are located above the northern end of the modified Longwall 26. The third order section of this creek is located at a minimum distance of 180 m north of the modified longwalls. The predicted subsidence effects and assessed impacts for the first and second order sections of Waterfall Creek, based on the modified layout, are greater than those assessed based on the approved layout which did not mine directly beneath the Waterfall Creek. • Fracturing and compression heaving are expected to develop along the sections of watercourses located directly above the longwall panels. The impacts are expected to be similar to those observed along the streams above the previously extracted Wambo Seam longwalls at the North Wambo Underground Mine, South Bates Underground Mine and the SBX Underground Mine. • Compression and dilation is also expected to impact the upper 10 m to 20 m of bedrock (regolith), which has the potential to affect groundwater conditions within the regolith. Compression can also result in buckling of the upper bedrock resulting in heaving in the overlying surface soils.

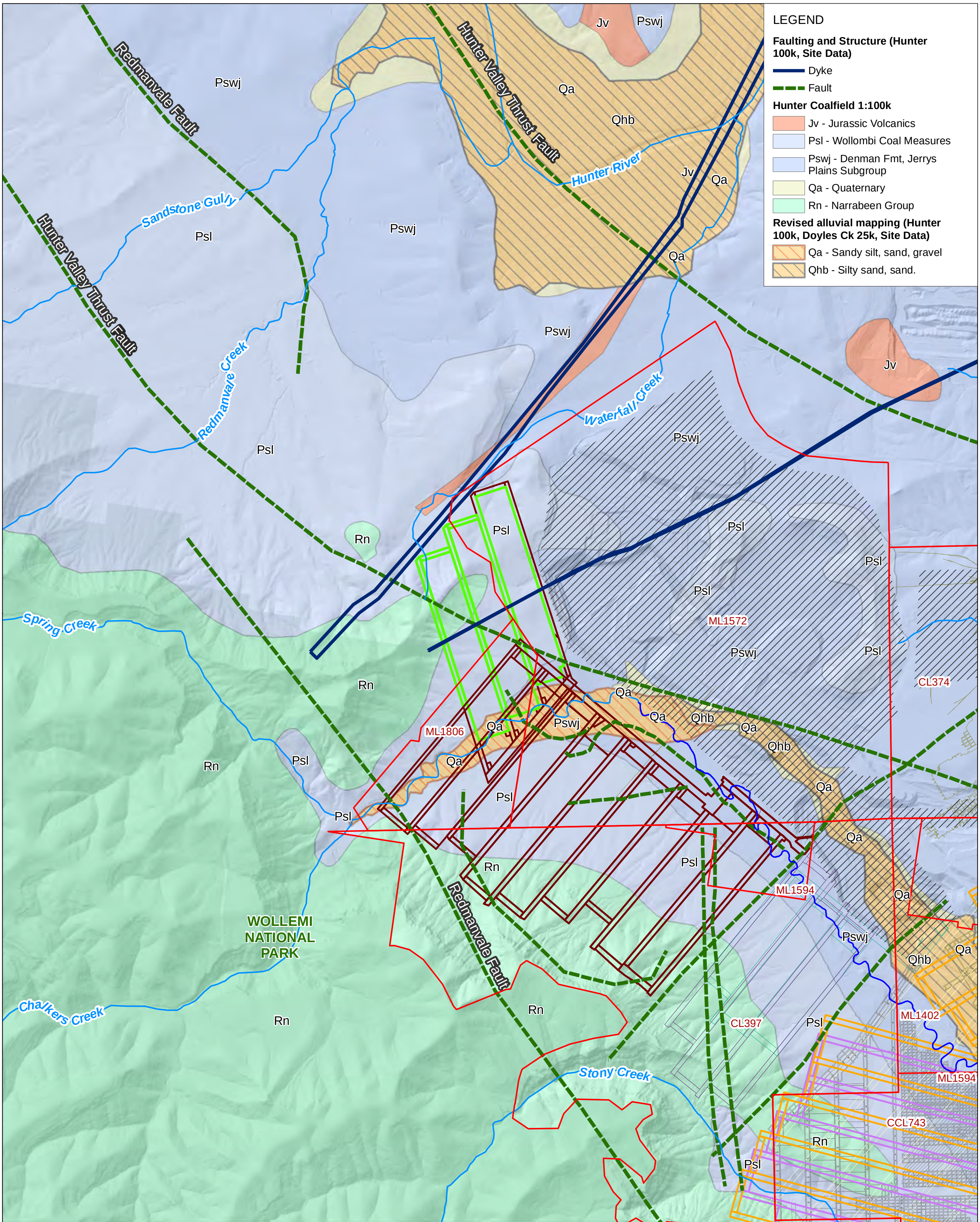
5 Geology

5.1 Regional geology

Wambo is situated within the Hunter Coalfield subdivision of the Sydney Basin, which makes up the southern part of the Sydney-Gunnedah-Bowen Basin. The basin was formed during the Late Carboniferous to Early Permian as a result of continental rifting processes and deposition of Permian and Triassic sediments (AGE, 2016). Regionally, the geological stratigraphic profile is characterised by surficial alluvium, overlying shallow bedrock (regolith), Jurassic Volcanics (intrusions), Triassic Sandstone and Permian coal measures (including the target seams for regional mining activities). A summary of the stratigraphic profile is provided in **Table 5-1**, whilst the outcrop geology relevant to Wambo is presented in **Figure 5-1**.

Table 5-1 Regional stratigraphic profile

<table>
<tr><th>Era</th><th colspan="4">Stratigraphic unit</th><th>Description</th></tr>
<tr><td>Quaternary</td><td colspan="4">Quaternary alluvium (Qha/Qhb)</td><td>Shallow sequences of clay, silty sand, and sand (Qhb) and Basal sands and gravels along major watercourses (i.e. Hunter River) (Qha)</td></tr>
<tr><td rowspan="4">Tertiary</td><td colspan="4">Tertiary alluvium (Cza)</td><td>Alluvial terraces – Silt, sand and gravel</td></tr>
<tr><td colspan="4">Aeolian Dunes (Czb)</td><td>Sand</td></tr>
<tr><td colspan="4">Silicified Weathering Profile (Czas)</td><td>Silcrete</td></tr>
<tr><td colspan="4">Alluvial Terraces (Cza)</td><td>Silt sand and gravel</td></tr>
<tr><td>Jurassic</td><td colspan="4">Volcanics (Jv)</td><td>Flows, sills and dykes</td></tr>
<tr><td>Triassic</td><td colspan="4">Narrabeen Group (Rn)</td><td>Sandstone, interbedded sandstone, siltstone and claystone. Localised at Wollemi National Park.</td></tr>
<tr><td rowspan="7">Permian</td><td rowspan="6">Late</td><td rowspan="6">Singleton Supergroup</td><td>Newcastle Coal Measures (Psl)</td><td>Glen Gallic Sub-group, Doyles Creek Sub-group, Horseshoe Creek Sub-group, Apple Tree Flat Sub-group</td><td>Coal seams, claystone (tuffaceous), siltstone, sandstone and conglomerate.</td></tr>
<tr><td colspan="2">Watts Sandstone</td><td>Medium to coarse grained sandstone</td></tr>
<tr><td rowspan="4">Wittingham Coal Measures</td><td>Jerrys Plains Subgroup (Pswj)</td><td>Interbedded coal measures with siltstone, sandstone and shale. Coal seams include Whybrow, Redbank Creek, Wambo, Whynot, Blakefield, Glen Munro, Woodlands Hill, Arrowfield, Bowfield, Warkworth, Mt Arthur, Piercefield, Vaux, Broonie and Bayswater.</td></tr>
<tr><td>Archerfield Sandstone (Psws)</td><td>Massive coarse-grained lithic sandstone.</td></tr>
<tr><td>Vane Subgroup (Pswv)</td><td>Interbedded coal measures with siltstone, sandstone, and shale. Coal seams include Lemington, Pikes Gully, Arties, Lidell, Barrett and Hebden.</td></tr>
<tr><td>Saltwater Creek Formation (Pswc)</td><td>Sandstone and siltstone, minor coaly bands, marine siltstones intercalated towards base.</td></tr>
<tr><td>Mi</td><td>Ma</td><td colspan="2">Mulbring Siltstone (Pmm)</td><td>Dark grey shale and siltstone, bioturbated and fossiliferous.</td></tr>
</table>



Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:40,000 at A4
Project Number: 665.0008.00815
Date: 26-Jul-2022
Drawn by: ANP

Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION

Outcrop geology and geological structure

FIGURE 5-1

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_G19_OutcropStructuralGeology_001.mxd

5.2 Local geology

Geology relevant to the Wambo area is discussed in **Sections 5.2.1** to **5.2.5**.

5.2.1 Alluvium

The alluvial deposits in the Wambo area unconformably overlie Triassic and Permian erosion surfaces and are associated with the perennial and ephemeral watercourses (**Section 2.2**). Alluvium associated with each of the watercourses in the vicinity of the Wambo area is described in greater detail below.

5.2.1.1 Hunter River alluvium

The alluvium along the Hunter River comprises 10 m to 20 m of unconsolidated sediments including gravel, sand, silt, and clay (MER, 2009). For representation within the numerical model, the alluvial and regolith mapping completed by CSIRO (2015) was used and refined using data from local bore logs.

Within the Hunter River flood plains, the surficial alluvium is commonly underlain by basal sands and gravels. The ‘highly productive’ basal sands and gravels are thickest along the alignment of the Hunter River and thin out at the edges of the alluvium where it transitions to the ‘less productive’ clays and silts (AGE, 2016). The basal sands and gravels are not present within the Wambo site. The alluvium unconformably overlies the Permian coal measures (AGE, 2016).

5.2.1.2 North Wambo Creek alluvium

Geological information from monitoring bore installation logs shows the alluvium along the upper reaches of North Wambo Creek is around 4 m to 10 m thick. The alluvium generally comprises sand and gravel, overlying weathered sandstones (regolith). The North Wambo Creek alluvium is outside of mapped areas of Highly Productive Groundwater (HydroSimulations, 2017); however, no site-specific hydraulic testing has been undertaken on the North Wambo Creek alluvium. The coarser material encountered in drilling may be consistent with coarser material along Wollombi Brook.

The current extent of alluvium along North Wambo Creek in the vicinity of the modified Longwalls 24 to 26 is limited by the footprint of Montrose Pit (SLR, 2020). Some alluvium along the south-east draining reach of North Wambo Creek has been removed through open cut mining at Montrose Pit, with much of the channel being realigned to the south-west of the open cut (i.e. the North Wambo Creek Diversion). The alluvium within and adjacent to the Longwalls 24 to 26 has been disconnected from the regional alluvial system due to the removal of alluvium downstream across the full width of the channel by the approved open cut mining operations (and associated construction of the North Wambo Creek Diversion) (HydroSimulations, 2017).

5.2.1.3 Waterfall Creek

Due to the small catchment size when compared with other ephemeral watercourses in the Wambo area (North Wambo Creek, Wambo Creek), and the relatively confined valley it is located in (**Section 4.2.1.2**), it is likely that any alluvial material will be limited in extent.

However, a review of aerial imagery from 2014-2021 and the DEM has identified the following features on Waterfall Creek that may indicate the presence of permeable and saturated shallow strata north of the modified SBX Underground Mine footprint:

- A small pond is present within the Waterfall Creek valley 100 m north of modified Longwall 24. This pond appears to hold water persistently and may intersect a shallow water-table.
- The creek channel is observed to disappear within the valley north of modified Longwall 24. Flow would not be able to dissipate laterally within the valley, and it is possible that permeable strata exist within the valley that can transport flow from upstream below ground surface.

5.2.1.4 Wollombi Brook alluvium

The Wollombi Brook Alluvium comprises 10 to 20 m of unconsolidated sediments including gravel, sand, silt, and clay (MER, 2009). Within the Wollombi Brook floodplain, basal sands and gravels are typically between 7 to 20 m thick (AGE, 2016).

5.2.1.5 Wambo Creek alluvium

Alluvium along Wambo Creek is approximately 4 to 7 m thick and comprises clayey to sandy, brown silt with areas of localised fine to medium grained sand (HLA-Envirosciences, 1999). There are also indications that the alluvial aquifer is discontinuous, probably due to bedrock highs (HLA-Envirosciences, 1999).

5.2.2 Sediment and weathered bedrock (regolith)

Sediment and weathered shallow bedrock outside of areas of alluvium form the regolith. The regolith consists of sandy or silty-clayey lithology where some coal seams outcrop/sub-crop, with a sandier lithology associated with the inter-seam units and some coal seams. The regolith thickness map developed by CSIRO (2015) indicates the regolith in the vicinity of the Wambo area has a variable thickness ranging from less than 1 to 11 m outside of the mapped alluvium extents. At higher elevation areas the regolith was found to be thin and is generally thicker in areas of lower elevation.

5.2.3 Volcanics

Jurassic volcanics have been observed at outcrops to the north and northeast of the Wambo area and have been encountered by many mining operations. The unit is comprised of Volcanic sills and dykes at surface and sub-surface and are likely recharged from rainfall recharge and surface water flow.

5.2.4 Triassic sandstone

The Triassic sandstone (Narrabeen Group) forms the prominent escarpment on elevated areas to the south-west of Wambo and unconformably overlies the Permian coal measures. The unit comprises mainly interbedded sandstone, with some siltstone and claystone. The Triassic sandstone is present in the south-western part of the Wambo mining lease area (HydroSimulations, 2017).

5.2.5 Permian coal measures

The coal measures are Permian age sediments which contain numerous coal seams and associated splits. These are separated by interburden comprising interbedded sandstones and laminated mudstones and siltstones. The Permian coal measures are regionally extensive and occur at surface and unconformably underlie Quaternary alluvium. The coal measures can also underlie and be intruded with volcanic sills in localised areas. The Permian coal measures comprise stratified sequences of sandstone, siltstone and claystone referred as interburden or overburden, and coal. Economic coal seams within the Wambo area include the Bayswater, Broonie, Vaux, Piercefield, Mt Arthur, Warkworth, Arrowfield, Woodlands Hill, Glen Munro, Blakefield, Whynot, Wambo, Redbank Creek and Whybrow seams.

5.3 Structural geology

Figure 5-1 shows the structural geology of the Wambo area overlain on the regional geological mapping. The Permian coal measures have undergone brittle and ductile deformation resulting in several northeast to southwest trending faults, and large-scale north to northwest trending folds such as the Muswellbrook Anticline and Bayswater Syncline which are located to the east of the Wambo area (AGE, 2016).

The Permian coal measures generally dip at approximately three degrees to the south-west with structure complicated by some local variations in seam dip and direction. Coal seams generally have consistent thicknesses and interburden intervals (SLR, 2020). There are several northeast to southwest trending faults in the area. The major fault structures in the area include the Redmanvale fault and Hunter Valley Thrust Faults which occur to the north and west and southwest of the project area respectively. Drill logs indicate that the Hunter Valley Cross fault has a maximum displacement of approximately 10 m (AGE, 2016). There are several other north-east to south-west minor fault structures in the area; these have been mapped indicating up to 5 m displacement within the Permian coal measures (AGE, 2016).

Several dykes and intrusions occur within the Permian strata across the Wambo area. These can be observed at outcrop to the northeast of the site and have been encountered by many mining operations near the Wambo area (AGE, 2016).

6 Hydrogeology

Based on the understanding of the geological setting presented in **Section 5**, the primary water bearing units occurring locally are the Quaternary Alluvium and less productive coal seams of the Permian Coal Measures. The regolith also has capacity to yield water.

6.1 Groundwater monitoring

Groundwater monitoring at the site is undertaken in accordance with the Groundwater Management Plan (GWMP) (WCPL, 2021a) and the UWOCP and Wambo Water Monitoring Program (WMP) (WCPL, 2021b). The purpose of the network is to monitor groundwater quality and levels to detect potential impacts on surrounding groundwater users, consumptive or environmental, and assess the performance of the Wambo and UWOCP against the performance indicators.

The WMP categorises bores as:

1. Part of the combined network (monitored for both Wambo and the UWOCP), including 30 bores and 7 VWPs (with 35 sensors).
2. Part of the UWOCP network only, including a further 9 bores (5 currently installed) and 16 VWPs (with 56 sensors).
3. Part of the Wambo only network including 14 VWPs (15 sensors) and 22 bores.

The monitoring network near SBX is provided in **Table 6-1** and shown in **Figure 6-1**. This includes the combined network, Wambo-only, and UWOCP-only monitoring bores as categorised in the WMP (WCPL, 2021b), as well as recently installed monitoring sites not yet in the WMP. The current groundwater monitoring network around Wambo and UWOCP that has water level or water quality data includes:

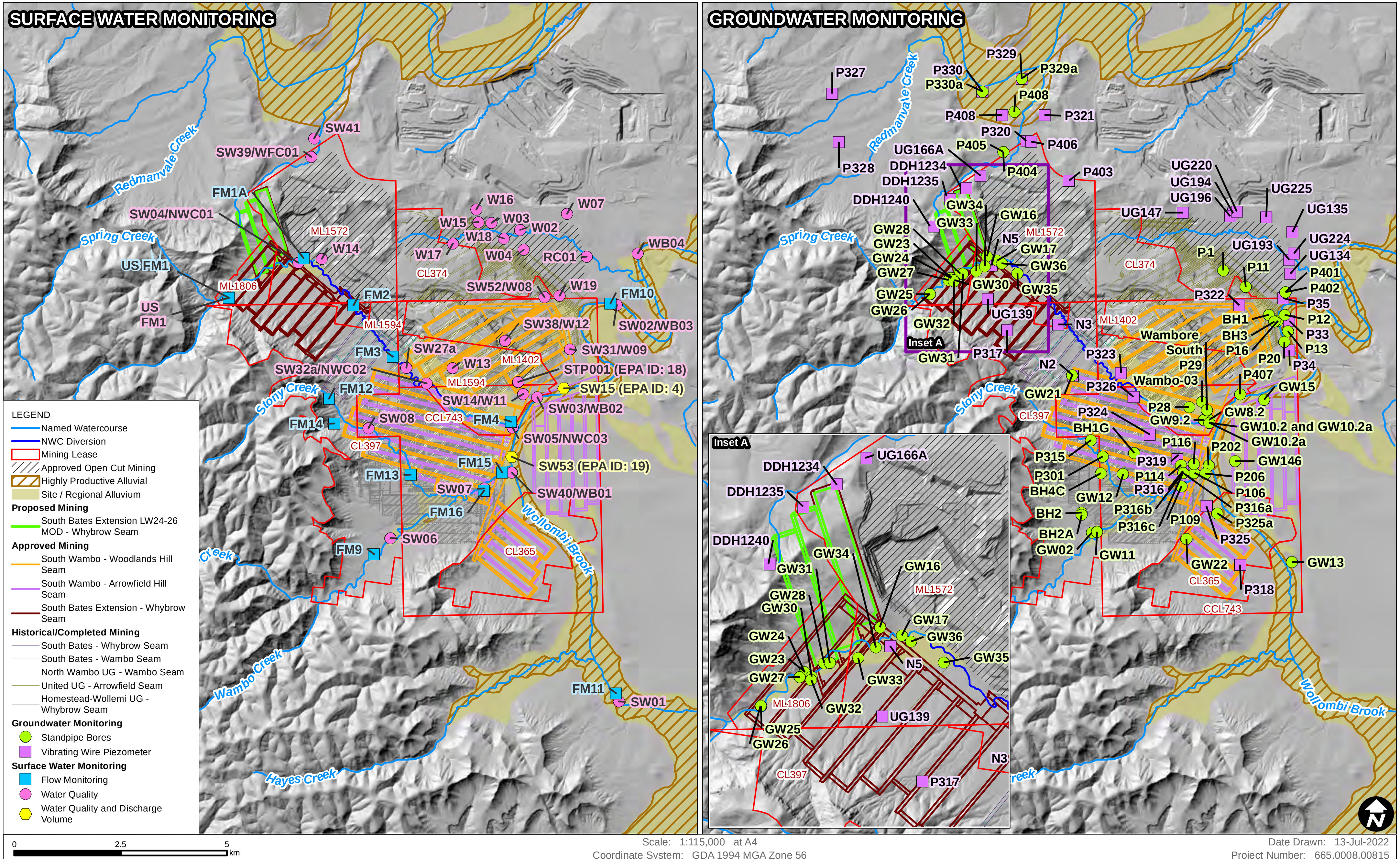
- Standpipe monitoring bores including:
    - Alluvial monitoring bores screened within alluvium associated with the Hunter River, Wollombi Brook, North Wambo Creek, Wambo Creek, Redbank Creek or Stony Creek.
    - Permian Coal Measures monitoring bores screened within the Permian coal measures within and adjacent to active and historical areas of mining.
- VWP locations with sensors screened within the Permian Coal Measures surrounding areas of mining.

Table 6-1 Groundwater monitoring network near South Bates Extension Underground Mine

Bore ID	Type	Easting	Northing	Screened Interval/ Sensor Depth (mbgl)	Lithology
GW16	MB	306639	6396174	6.15 – 12.15	Alluvium, Regolith
GW17	MB	306886	6396096	11 – 14	Regolith
GW23	MB	305789	6395670	5.2 – 8.2	North Wambo Creek Alluvium
GW24	MB	305791	6395668	11.7 – 13.2	North Wambo Creek Weathered Rock
GW25	MB	305299	6395288	2.6 – 5.6	North Wambo Creek Alluvium
GW26	MB	305299	6395668	11.7 – 13.2	North Wambo Creek Weathered Rock
GW27	MB	305736	6395612	1.1 – 2.6	North Wambo Creek Alluvium (Channel)
GW28	MB	306011	6395772	2.85 – 5.85	North Wambo Creek Alluvium (Channel)
GW30	MB	306076	6395716	5.5 – 8.5	North Wambo Creek Alluvium
GW31	MB	305877	6395582	7 – 10	North Wambo Creek Alluvium
GW32	MB	306394	6395829	4 – 7	North Wambo Creek Alluvium
GW33	MB	306592	6395946	4 – 7	North Wambo Creek Alluvium
GW34	MB	307357	6395779	2.5 – 4	North Wambo Creek Alluvium
GW35	MB	306988	6396012	6 – 9	North Wambo Creek Alluvium
GW36a	MB	306248	6395901	5 – 8	North Wambo Creek Alluvium (Channel)
GW36b	MB	306247	6395907	14 – 17	North Wambo Creek Weathered Sandstone
N3	VWP	308314	6394575	30	Permian Overburden
				55	Permian Overburden
				75	Permian Overburden
				108.5	**Whybrow Seam**
				142	Interburden
				190	Wambo Seam
N5	VWP	306755	6395963	30	Permian Overburden
				73	**Whybrow Seam**
				89.5	Interburden
				133	Wambo Seam
P317	VWP	307115	6394439	35	Regolith
				100	Overburden
				174	**Whybrow Seam**
				213	Wambo Rider Seam
				248.5	Wambo Seam
P320	VWP	307573	6398890	92	Warkworth Seam

Bore ID	Type	Easting	Northing	Screened Interval/ Sensor Depth (mbgl)	Lithology
				191	Vaux Seam
				217.5	Bayswater Seam
				263	Pikes Gully Seam
				305	Lower Arties Seam
				344	Middle Barrett Seam
P321	VWP	307573	6398890	31.8	Arrowfield Seam
				72.1	Warkworth Seam
				161.15	Vaux Seam
				187.82	Bayswater Seam
P327	VWP	302941	6399995	65.25	Overburden
				228.25	**Whybrow Seam**
				301.05	Wambo Seam
				332.45	Whynot Seam
P328	VWP	303160	6398870	43	Overburden
				275	**Whybrow Seam**
				350	Wambo Seam
				388	Whynot Seam
P329	VWP	307454	6400351	67.6	Vaux Seam 1
				87.4	Vaux Seam 2/3
				117.5	Bayswater Seam
				150.5	Pikes Gully Seam
P329a	MB	307456	6400352	10 – 16	Hunter Alluvium
P330	VWP	306533	6400050	67	Vaux Seam 1
				137.25	Bayswater Seam
				201.5	Pike Gully Seam
P330a	MB	306533	6400052	10 – 13	Hunter Alluvium
P403	VWP	308565	6397958	TBC	Overburden & Coal Seams – Arrowfield, Warkworth & Vaux
P404	TBC	307023	6398634		Overburden
P405	TBC	307025	6398634		Arrowfield Seam
P406	VWP	307681	6398872	TBC	Overburden
P408	VWP	307000	6399500	138.75	Vaux Seam
				187	Bayswater Seam
				223.75	Pikes Gully Seam
P408 Standpipe	MB	307282	6399576	11.6 – 14.6	Hunter River Alluvium
SBX GW01	VWP	307010	6395886		Whybrow Seam Overburden
SBX GW02	VWP	306911	6395943	53.7	Whybrow Seam Overburden
				61.7	Whybrow Overburden

Bore ID	Type	Easting	Northing	Screened Interval/ Sensor Depth (mbgl)	Lithology
				65.8	**Whybrow Seam**
SBX20 GW02a	MB	306905	6395946	20	base of weathering
DDH1234_LW24	VWP	306153	6397780	22	Shallow overburden
				39	Near-seam overburden
				54	**Whybrow Seam**
DDH1235_LW25	VWP	305779	6397521	40	Shallow overburden
				80	Whybrow overburden
				114	**Whybrow Seam**
DDH1240_SBXX_20_ST07	VWP	305397	6396881	50	Narrabeen Group/ Overburden
				118	Overburden 1
				218.5	Overburden 2
				260.5	**Whybrow Seam**
UG139	VWP	306665	6395173	263	Unnamed D Seam
				281	Unnamed E Seam
				319	interburden Glen Munro – Unnamed E Seams
				329	Glen Munro Seam
				375	interburden Arrowfield – Glen Munro Seam
				382	Arrowfield Seam
				402	interburden Warkworth – Bowfield Seams
UG166A	VWP	306488	6398076	130	Unnamed D Seam
				153	Unnamed E Seam
				183	Blakefield Seam
				200	Glen Munro Seam
				238	Arrowfield Seam
				254	Bowfield Seam
				260	Bowfield Seam



Scale: 1:115,000 at A4
Coordinate System: GDA 1994 MGA Zone 56

Date Drawn: 13-Jul-2022
Project Number: 665.0008.00815

Data Source: Base data supplied by NSW SS

SLR

SOUTH BATES EXTENSION
LONGWALLS 24-26 MODIFICATION

Surface water and groundwater monitoring network

FIGURE 6-1

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_6_1_MonitoringNetwork_003.mxd

6.1.1 Data availability

As presented in **Table 3-1**, baseline groundwater levels at the site must be monitored for at least two years. The IESC's Information Guidelines also state that monitoring is required to be at a frequency sufficient to identify any seasonal and/or annual climatic related trends. Groundwater levels should also be monitored at an appropriate number of bores to inform groundwater gradients across the modified SBX Underground Mine area in the main hydrostratigraphic units that may be directly or indirectly impacted by the Modification.

Table 6-2 and **Table 6-3** provide a summary of the groundwater level monitoring records for the main hydrostratigraphic units in the vicinity of the modified SBX Underground Mine area, based on the information currently held by SLR.

Table 6-2 Standpipe groundwater level data availability summary

Screened Geological Unit	Catchment/ area	Bores with Manual Dip Data	Bores with Logger Data[1]	Bores – currently actively monitoring	Record date range	Historical Monitoring Frequency
North Wambo Creek Alluvium/ Regolith	North Wambo Creek/ SBX	12	2	12 (Manual) + 2 (Logger)	January 2010 to present (GW16, GW17) Other sites from ~2018/19 to present	At least bi-monthly
Waterfall Creek Alluvium/ Colluvium	Waterfall Creek	0	0	0	n/a	n/a
Hunter Alluvium	Hunter	3	0	2 (P408 unknown)	Nov 2020 to present	Bi-monthly
Permian Coal Measures	North Wambo Creek	4	2	4 (Manual) + 2 (Logger)	Feb 2019 onwards	At least bi-monthly
	Waterfall Creek	0	0	0	n/a	n/a
	Redmanvale Creek (~3-4 km north)	0	0	0	n/a	n/a
Total		**19**	**4**	**18**	-	-

[1]GW36a, GW36b, GW36 and SBX- GW02 have been monitored with dataloggers since mid-2020

Table 6-3 VWP groundwater level data availability summary

Screened Geological Unit	Catchment/ area	Bores	Active Bores	Strata targeted
Permian Coal Measures	North Wambo Creek/ SBX	N5, SBX20_GW02, SBX20_GW01, P317, UG139, N3 DDH1234, DDH1235, DDH1240[1]	N5, SBX20_GW02 DDH1234, DDH1235, DDH1240	Wambo Seam, Whybrow Seam, Overburden
	Waterfall Creek	UG166A, P321	UG166A, P320	Below Whynot Seam
	Redmanvale Creek (~3-4 km north)	P328a, P327	P328a, P327	Wambo Seam, Whybrow Whynot, Wambo and Whybrow Seams, Overburden
	Hunter River	P408, P329, P330	P408, P329, P330	Vaux to Pikes Gully Seams

[1]DDH1234, DDH1235 and DDH1240 have been installed in Q1/ Q2 2022. Data from these sites has not yet been reviewed.

6.2 Hydraulic properties

6.2.1 Hydraulic conductivity

Extensive hydraulic testing has historically been undertaken across the Hunter Valley using a variety of methods including packer testing, slug testing, pumping tests and laboratory core permeability testing. Much of this data was compiled in MER (2009) and has been used to inform previous Wambo and UWOCP groundwater assessments (HydroSimulations, 2017; AGE, 2016). Data from surrounding sites (AGE (2003, 2010, 2014, 2016)) has also been used to inform appropriate model parameters, with regional data collated and summarised in **Table 6-4**.

Table 6-4 Summary of hydraulic conductivity data

Unit	Kh (m/day)				Kv (m/day)			
	Average	Min	Max	Population	Average	Min	Max	Population
Alluvium – Hunter River	$4.0\times10^{+01}$	5.3×10^{-02}	$3.7\times10^{+02}$	56	$5.1\times10^{+00}$	2.3×10^{-01}	$1.0\times10^{+01}$	2
Alluvium – Wollombi Brook	$3.4\times10^{+00}$	2.0×10^{-01}	$1.0\times10^{+01}$	5	$1.0\times10^{+01}$	$1.0\times10^{+01}$	$1.0\times10^{+01}$	1
Regolith	8.2×10^{-02}	3.3×10^{-05}	$1.0\times10^{+00}$	37	4.0×10^{-05}	6.3×10^{-07}	8.0×10^{-05}	2
Warkworth Sands	3.0×10^{-01}	-	-	1	-	-	-	-
Overburden	8.3×10^{-06}	1.4×10^{-06}	2.1×10^{-05}	5	1.5×10^{-06}	2.9×10^{-07}	3.3×10^{-06}	5
Whybrow Seam	2.6×10^{-01}	3.5×10^{-04}	$2.6\times10^{+00}$	17	6.6×10^{-06}	6.6×10^{-06}	6.6×10^{-06}	1
Interburden	1.1×10^{-04}	1.1×10^{-06}	8.6×10^{-04}	10	2.6×10^{-06}	1.8×10^{-07}	1.2×10^{-05}	6
Redbank Creek Seam	2.8×10^{-01}	2.0×10^{-02}	9.0×10^{-01}	5	-	-	-	-
Interburden	1.2×10^{-04}	6.2×10^{-07}	5.1×10^{-04}	15	2.8×10^{-04}	2.2×10^{-07}	2.5×10^{-03}	9

Unit	Kh (m/day)				Kv (m/day)			
	Average	Min	Max	Population	Average	Min	Max	Population
Wambo Seam	$4.0x10^{-01}$	$9.0x10^{-03}$	$2.3x10^{+00}$	6	-	-	-	-
Interburden	$2.9x10^{-06}$	$2.6x10^{-07}$	$1.3x10^{-05}$	7	$8.3x10^{-07}$	$1.3x10^{-07}$	$3.1x10^{-06}$	5
Whynot Seam	$2.2x10^{-02}$	$9.0x10^{-04}$	$4.4x10^{-02}$	3	-	-	-	-
Interburden	$6.0x10^{-04}$	$9.8x10^{-07}$	$1.0x10^{-03}$	4	-	-	-	-
Blakefield Seam	$6.6x10^{-01}$	$3.9x10^{-05}$	$1.2x10^{+01}$	19	$8.3x10^{-07}$	$8.3x10^{-07}$	$8.3x10^{-07}$	1
Interburden	$5.7x10^{-05}$	$6.4x10^{-07}$	$2.3x10^{-04}$	7	$5.2x10^{-06}$	$3.4x10^{-07}$	$1.1x10^{-05}$	4
Glen Munro Seam	$1.7x10^{-02}$	$1.4x10^{-05}$	$8.9x10^{-02}$	21	$5.8x10^{-05}$	$5.9x10^{-06}$	$1.1x10^{-04}$	2
Interburden	$2.0x10^{-05}$	$0.0x10^{+00}$	$1.4x10^{-04}$	16	$7.4x10^{-07}$	$1.5x10^{-07}$	$2.0x10^{-06}$	9
Woodlands Hill Seam	$1.8x10^{-02}$	$7.3x10^{-04}$	$1.0x10^{-01}$	25	$1.9x10^{-04}$	$2.0x10^{-06}$	$1.0x10^{-03}$	8
Interburden	$4.1x10^{-04}$	$2.2x10^{-07}$	$5.3x10^{-03}$	13	$4.4x10^{-06}$	$1.5x10^{-07}$	$2.8x10^{-05}$	7
Arrowfield Seam	$3.4x10^{-02}$	$1.3x10^{-03}$	$1.4x10^{-01}$	11	$3.4x10^{-05}$	$3.8x10^{-07}$	$1.0x10^{-04}$	3
Interburden	$2.8x10^{-04}$	$6.1x10^{-06}$	$1.0x10^{-03}$	5	$3.5x10^{-07}$	$3.5x10^{-07}$	$3.5x10^{-07}$	1
Bowfield Seam	$9.3x10^{-01}$	$4.0x10^{-03}$	$5.3x10^{+00}$	24	$2.0x10^{-04}$	$6.1x10^{-07}$	$2.4x10^{-03}$	13
Interburden	$1.5x10^{-03}$	$6.5x10^{-07}$	$1.1x10^{-02}$	8	$1.1x10^{-03}$	$1.0x10^{-07}$	$4.4x10^{-03}$	4
Warkworth Seam	$4.8x10^{-02}$	$6.4x10^{-06}$	$2.5x10^{-01}$	6	$1.6x10^{-04}$	$1.6x10^{-04}$	$1.6x10^{-04}$	1
Interburden	$7.5x10^{-02}$	$6.6x10^{-07}$	$4.5x10^{-01}$	6	$9.7x10^{-07}$	$4.2x10^{-07}$	$2.1x10^{-06}$	6
Mt. Arthur Seam	$7.3x10^{-02}$	$2.4x10^{-06}$	$1.0x10^{+00}$	38	$1.3x10^{-03}$	3.3x10-07	$5.0x10^{-03}$	8
Interburden	$6.2x10^{-02}$	$3.9x10^{-07}$	$2.4x10^{-01}$	4	$2.7x10^{-07}$	$2.7x10^{-07}$	$2.7x10^{-07}$	1
Piercefield Seam	$2.8x10^{-02}$	$1.1x10^{-05}$	$1.4x10^{-01}$	10	$2.1x10^{-06}$	$4.0x10^{-07}$	$3.7x10^{-06}$	3
Edderton Seam	$8.0x10^{-02}$	-	-	1	-	-	-	-
Interburden	$6.5x10^{-04}$	$4.8x10^{-07}$	$2.6x10^{-03}$	4	$1.1x10^{-06}$	$3.0x10^{-07}$	$1.9x10^{-06}$	2
Vaux Seam	$7.3x10^{-02}$	$1.6x10^{-06}$	$2.3x10^{-01}$	8	$2.0x10^{-05}$	$2.0x10^{-05}$	$2.0x10^{-05}$	1
Interburden	$1.4x10^{-03}$	$8.3x10^{-07}$	$8.1x10^{-03}$	15	$3.3x10^{-02}$	$1.2x10^{-06}$	$1.6x10^{-01}$	5
Broonie Seam	$6.9x10^{-02}$	$1.1x10^{-03}$	$2.7x10^{-01}$	5	$7.4x10^{-05}$	$8.3x10^{-07}$	$2.0x10^{-04}$	3
Interburden	$2.9x10^{-03}$	$1.0x10^{-04}$	$6.2x10^{-03}$	7	$6.5x10^{-05}$	$8.0x10^{-07}$	$1.6x10^{-04}$	6
Bayswater Seam	$3.0x10^{-02}$	$6.4x10^{-06}$	$3.6x10^{-01}$	49	$4.7x10^{-04}$	$3.4x10^{-07}$	$2.3x10^{-03}$	5
Wynn Seam	$8.0x10^{-02}$	-	-	1	-	-	-	-
Bengalla Seam	$8.0x10^{-02}$	-	-	1	-	-	-	-
Interburden	$1.6x10^{-06}$	$8.3x10^{-07}$	$1.5x10^{-05}$	5	-	-	-	-
Ramrod Creek Seam	$6.5x10^{-01}$	-	-	1	-	-	-	-
Greta Coal Measures – Coal	1.1	$7.9x10^{-1}$	2.0	6	-	-	-	-
Spoil	$1.1x10^{+00}$	$7.0x10^{-01}$	$1.6x10^{+00}$	4	$5.0x10^{-01}$	$5.6x10^{-07}$	$1.0x10^{+00}$	2

Highest hydraulic conductivities are observed in the unconsolidated sediments. Hydraulic conductivities within the Permian strata are on average two orders of magnitude lower than the alluvium. The various sedimentary units have a low hydraulic conductivity due to their fine grain size and in some cases high clay content. The coal seams are the most permeable horizons within the coal measures and have hydraulic conductivities which are on average one to three times higher than the consolidated sediments (HydroSimulations, 2017).

There is a decrease in hydraulic conductivity with depth consistent with data reported by Mackie (2009) and AGE (2016). **Figure 6-2** and **Figure 6-3** present the distribution of horizontal hydraulic conductivity with depth for interburden strata and coal seams. Both graphs show a decrease in hydraulic conductivity with depth, which is due to increasing overburden pressure reducing the aperture of secondary porosity features. The decrease in hydraulic conductivity with depth is also related to reduced width and occurrence of joint and fracture opening due to increased overburden pressure with depth of burial (HydroSimulations, 2017).

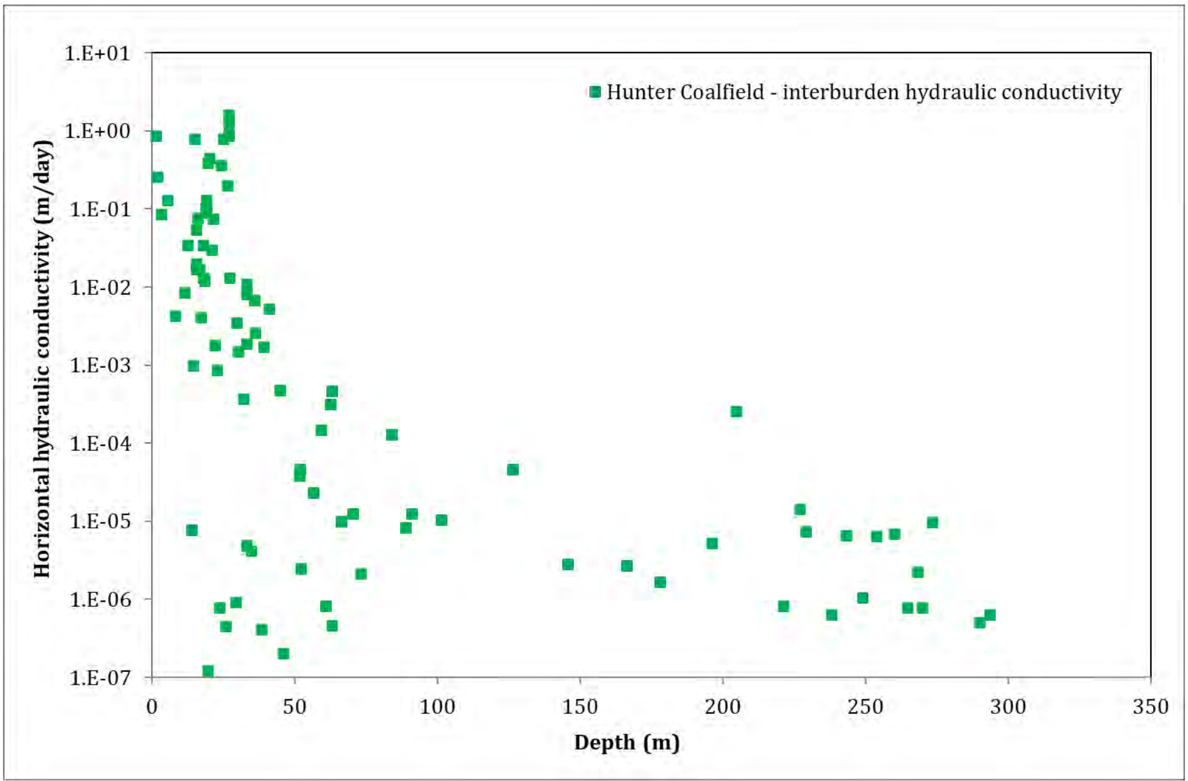


Figure 6-2 Hydraulic conductivity vs. depth – Permian interburden

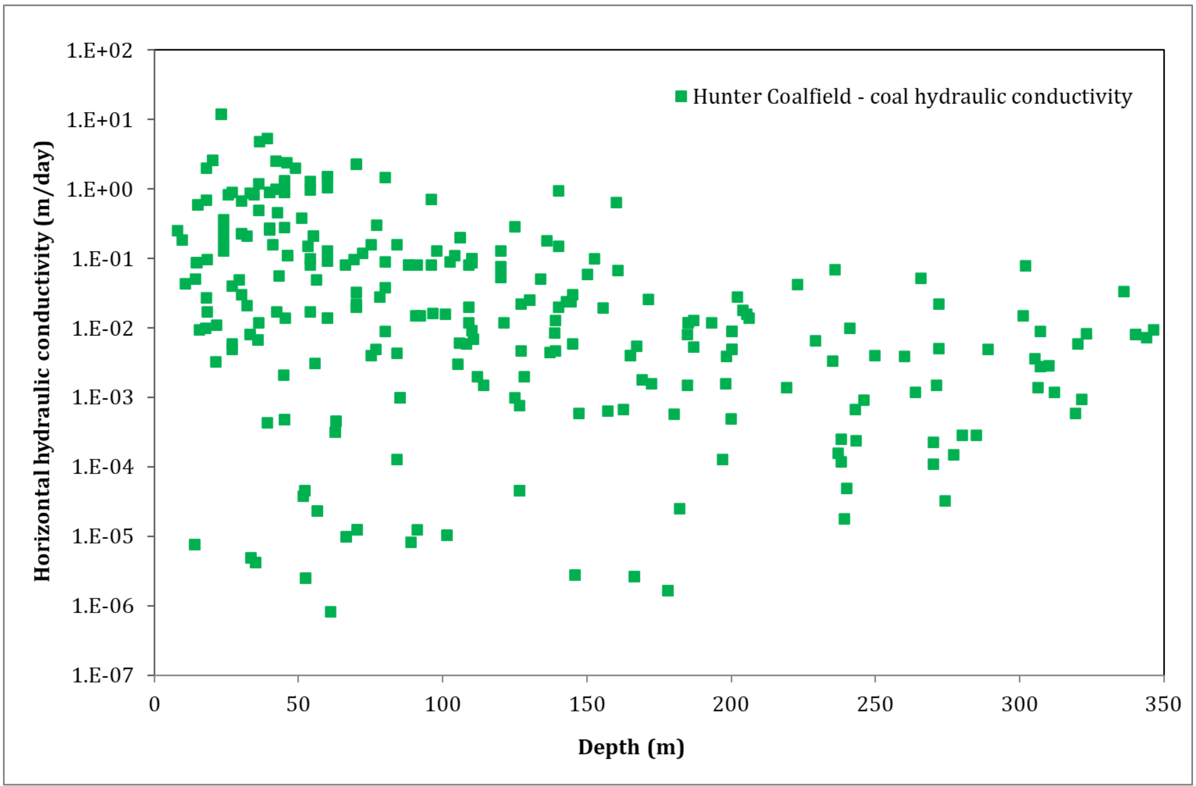


Figure 6-3 Hydraulic conductivity vs. depth – Permian coal seams

6.2.2 Storage properties

MER (2009) conducted an extensive review of available data on the hydraulic properties of consolidated coal measure strata and alluvial deposits in the Hunter region. While noting that specific yield (Sy, drainable porosity) was infrequently tested, MER (2009) provided the following values for Sy:

- < 1% in dull weakly cleated coal to > 3% in bright strongly cleated coal.
- < 0.0001% (claystones) to < 2% to 3% (sandstones) in unweathered interburden.
- 5% to > 30% for alluvium, about 20% considered representative for sandy silty unconsolidated sediment.

It is understood that there is no site-specific data on storage properties. Specific storage values as described in HydroSimulations (2017) can be estimated from Young's Modulus, Poisson's Ratio, and porosity. For coal, Ss generally lies in the range 5 x 10^{-6} m^{-1} to 5 × 10^{-5} m^{-1}, and interburden could be slightly higher due to higher porosity (MER, 2009). **Table 6-5** provides a summary of the storage data utilised in HydroSimulations (2017) and AGE (2016).

Table 6-5 Summary of storage properties from HydroSimulations (2017) and AGE 2016

Geological Unit	South Wambo Groundwater Modelling Parameters (HydroSimulations 2017)		United Wambo Groundwater Assessment (AGE 2016)	
	Specific Yield (Sy)	Storage Coefficient^	Specific Yield (Sy)	Specific Storage (Ss) (m^{-1})
Alluvium	1.00×10^{-1}	N/A	$3.00 \times 10^{-2} - 7.00 \times 10^{-2}$	$3.00 \times 10^{-3} - 2.78 \times 10^{-4}$
Colluvium	1.00×10^{-2}	5.00×10^{-4}	$3.00 \times 10^{-2} - 6.00 \times 10^{-2}$	$3.00 \times 10^{-3} - 3.10 \times 10^{-4}$
Permian interburden	1.00×10^{-3}	1.00×10^{-4}	$5.05 \times 10^{-3} - 8.99 \times 10^{-3}$	$3.40 \times 10^{-5} - 1.00 \times 10^{-4}$
Permian coal seams	5.00×10^{-3}	5.00×10^{-4}	$1.00 \times 10^{-3} - 1.00 \times 10^{-2}$	$2.45 \times 10^{-5} - 3.12 \times 10^{-4}$

^Ss times thickness

6.3 Groundwater levels, distribution, flow, recharge, and discharge

Hydrogeological characteristics of aquifer units near Wambo, including the nature of aquifer material, recharge and discharge mechanisms are presented in the following sections. Groundwater level trends, and responses to climatic and anthropogenic influences are also discussed for aquifer units near the modified SBX Underground Mine.

6.3.1 North Wambo Creek alluvium

6.3.1.1 Distribution and flow

Geological information from recent drilling and installation of monitoring bores conducted by SLR (2020) shows the alluvium along the upper reaches of North Wambo Creek is around 4 to 10 m thick. The alluvium generally comprises sand, silt, and gravel, overlying weathered sandstones (regolith). The current extent of alluvium along North Wambo Creek to the northeast of the SBX Underground Mine is limited by the footprint of Montrose Pit. Underlying and to the southwest of North Wambo Creek, 0.75 km^2 of alluvium is mapped to underlie the approved SBX Underground Mine footprint, while 0.6 km^2 is mapped to underlie the modified Longwalls 24 to 26 footprint. Outside of high rainfall and flow events, alluvial bores in this area are observed to be unsaturated with saturation and flow occurring mainly within the underlying regolith (SLR, 2020). Recharge to the alluvium is observed in response to rainfall events of sufficient magnitude to induce flow on the alluvial flats of North Wambo Creek, with alluvial saturation nearing ground surface and indicating the potential for baseflow to North Wambo Creek.

6.3.1.2 Recharge and discharge

Recharge to the North Wambo Creek alluvium occurs via diffuse infiltration from rainfall events of sufficient intensity where suitable lithology exists (i.e. porous, minimal clay). North Wambo Creek is ephemeral with flows influenced by rainfall trends. The creek is characterised as dominantly having losing conditions, with limited baseflow, consequently acting as a recharge mechanism for the North Wambo Creek alluvium in periods of flow (SLR, 2020). The alluvium does not remain saturated for long periods of time following rainfall/ flow events, with water percolating laterally or through to the underlying regolith.

6.3.1.3 Groundwater level trends

Upstream of the North Wambo Creek Diversion, historical groundwater level data within the alluvium has been collected since alluvial bores were installed over the period 2017 to mid-2020. Data loggers were installed in two alluvial bores (GW35 and GW36b), upstream of the North Wambo Creek Diversion to assist in the assessment of groundwater levels.

Most of the monitoring bores installed in the upstream reaches of the North Wambo Creek alluvium from 2017 to early 2020 were dry. This has been attributed to a lack of rainfall and flow in North Wambo Creek associated with drought conditions. Since the start of 2020, above average rainfall has resulted in several flow events in North Wambo Creek with recharge to the alluvium occurring due to creek flow losses and direct infiltration. The hydrographs in the upstream North Wambo Creek monitoring area show a range of responses described below.

On the uppermost reach of the North Wambo Creek alluvium (GW23, GW25, GW27) the hydrographs in **Figure 6-4** generally show a similar trend with increasing groundwater levels at the start of 2020 following the end of the three-year drought period with higher-than-average rainfall through 2020. Since the increase in groundwater levels at the start of 2020, levels then fluctuate between 1 to 3 m in response to rainfall events to the end of 2021. Despite the continued higher than average rainfall during this period there is generally not an overall increasing trend, and it is likely that the highest groundwater levels recorded over this period reflect close to maximum levels at these locations, with creek discharge being a control.

In the central area of the upper North Wambo Creek closer to the North Wambo Creek Diversion or Montrose Open Cut (GW28, GW30, GW31, GW32, GW33, GW34, GW35 and GW36b), some alluvial bores (**Figure 6-4**) show large rises and falls in the range of 4 to 7 m in response to the high rainfall events during 2020 and 2021. The rapid groundwater level response to high rainfall events appears closely linked to flow and flow recession in North Wambo Creek (refer to **Section 6.3.7**).

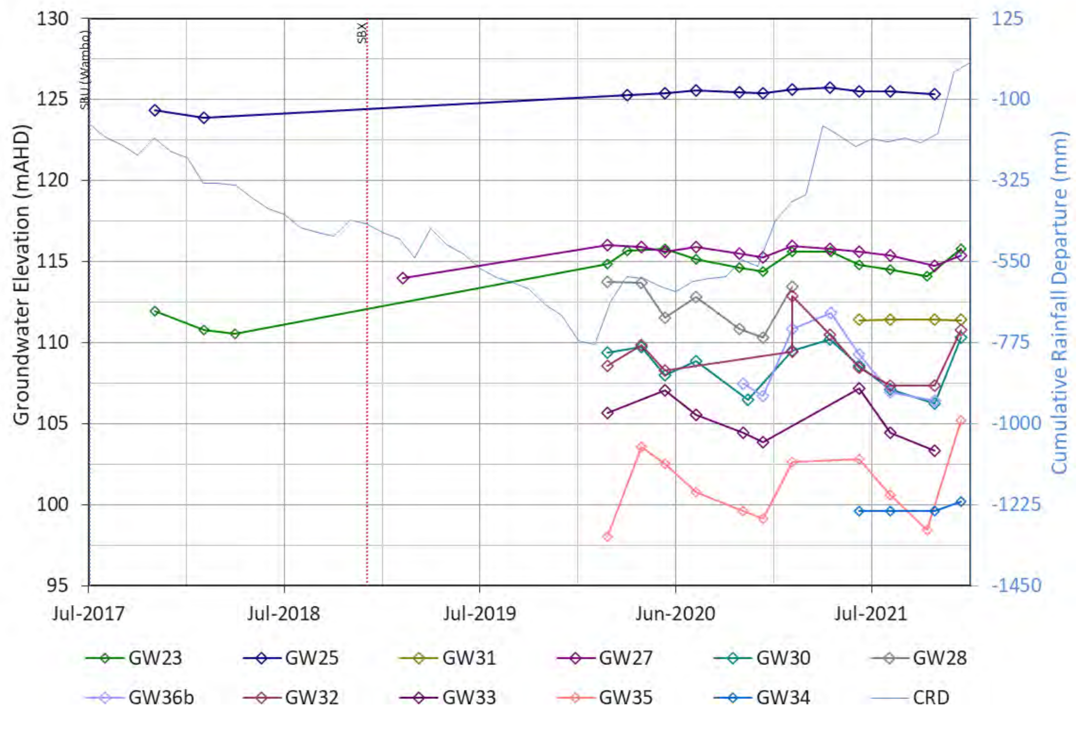


Figure 6-4 North Wambo Creek alluvium hydrographs

6.3.2 Hunter River alluvium

6.3.2.1 Distribution and flow

The Hunter River alluvium comprises surficial silts and clays overlying basal sands and gravels. The main aquifer has been found to occur within the basal gravel sequence (MER, 2009). The hydraulic properties of the alluvium vary due to the variable lithologic composition, with field tests indicating horizontal hydraulic conductivity can range between 5.3 x 10^{-2} m/day and 3.7 x 10^{2} m/day along the Hunter River (AGE, 2016). The Hunter River alluvium is considered unconfined, and flow direction typically mimics topography in areas away from mining.

6.3.2.2 Recharge and discharge

Recharge to the Hunter River alluvium occurs via two primary mechanisms, diffuse recharge, and focussed recharge. Diffuse recharge occurs via rainfall infiltration where there are no substantial clay barriers in the shallow sub-surface. Focussed recharge, interpreted to be the primary mechanism (AGE, 2016), occurs via stream losses from regulated streamflow or flooding. The Hunter River alluvium also gains water from the underlying Permian coal measures, particularly downstream of Foy Brook (AGE, 2016).

Where mining has resulted in depressurisation of the Permian coal measures, the Hunter River alluvium will discharge to the coal measures (AGE, 2016). In some areas, groundwater levels compared to stream gauge levels indicate the Hunter River is receiving baseflow from the alluvium providing another pathway for groundwater discharge.

6.3.2.3 Groundwater level trends

Groundwater level data for Hunter River alluvium monitoring bores P329a and P330a is presented in **Figure 6-5**. For the monitoring data available since 2020, fluctuations in groundwater levels up to 1 m have been observed in response to rainfall events generally in accordance with CRD.

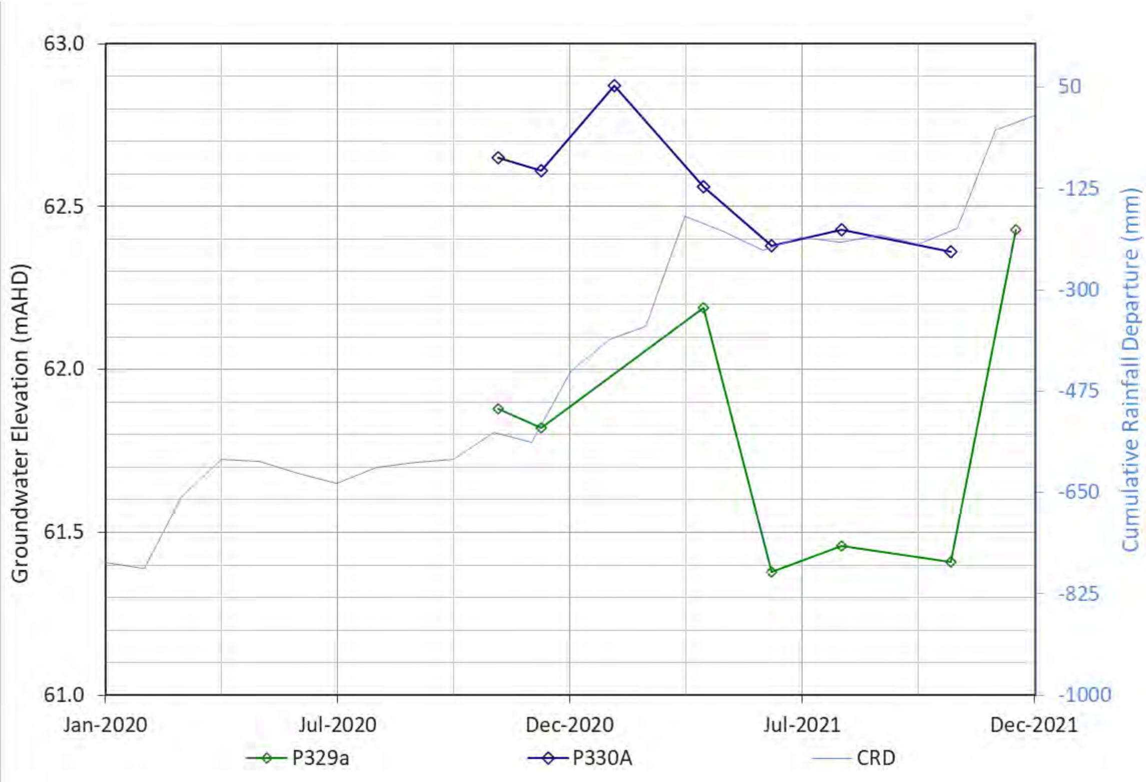


Figure 6-5 Hunter River alluvium hydrographs

6.3.3 Wollombi Brook alluvium

6.3.3.1 Distribution and flow

Wollombi Brook comprises up to 10 to 20 m of unconsolidated sediments including gravel, sand, silt, and clay (MER, 2009). The Wollombi Brook alluvium has both highly productive and less productive zones; the main aquifer has been found to occur within the basal sands and gravels (AGE, 2016). The hydraulic properties of the alluvium vary due to the variable lithologic composition. Groundwater flow in the Wollombi Brook alluvium is in a north to north-easterly direction towards the Hunter River.

6.3.3.2 Recharge and discharge

The nature of recharge and discharge to the Wollombi Brook alluvium are similar to Hunter River alluvial sediments, receiving both diffuse and focussed recharge.

Groundwater levels within the alluvium associated with the Wollombi Brook around active mining areas are generally below stream levels. This indicates a losing stream recharging the alluvium. Conversely, on the eastern bank of Wollombi Brook, further from active mining, alluvial groundwater levels are higher than stream levels indicating groundwater discharge via baseflow.

6.3.4 Wambo Creek alluvium

6.3.4.1 Distribution and flow

The understanding of the alluvium along Wambo creek is consistent with SLR (2020); along the creek alluvium is approximately 4 to 7 m thick and comprises clayey to sandy, brown silt with areas of localised fine to medium grained sand (HLA-Envirosciences, 1999). There are also indications that the alluvial aquifer of Wambo Creek is discontinuous, probably due to bedrock highs (HLA-Envirosciences, 1999).

6.3.4.2 Recharge and discharge

As with the other local ephemeral watercourses, recharge to the Wambo Creek alluvium is via diffuse rainfall recharge and losses from Wambo Creek during flow events. The alluvium does not maintain saturation and discharge via leakage to the underlying strata is apparent.

6.3.5 Shallow weathered bedrock / residual sediment (regolith)

6.3.5.1 Distribution and flow

The regolith is generally saturated, with groundwater occurring between 4 to 12 m below ground surface. The regolith thickness map developed by CSIRO (2015) indicates the regolith in the vicinity of Wambo is variable in thickness ranging from less than 1 m up to 11 m outside the mapped alluvium extents. At higher elevation, the regolith was found to be thin and is generally thicker in areas of lower elevation. Field tests indicate the horizontal hydraulic conductivity of the regolith can range between 3.3×10^{-5} m/day and 1 m/day and the vertical hydraulic conductivity between 6.3×10^{-7} m/day and 8.0×10^{-5} m/day (**Table 6-4**) (MER, 2009).

6.3.5.2 Recharge and discharge

A transient short-term perched groundwater system is thought to form within the regolith in periods of significant rainfall when recharge rates exceed the ability of the underlying rock to receive the overlying recharge. The regolith, covering much of the region, is the conduit for the main source of recharge to the underlying hard rock. The regolith contains localised areas of increased recharge associated with its weathered and fractured nature. Coal seams that weather to the finer material will have limited ability to transmit groundwater, while the sandier units offer increased potential for groundwater recharge.

6.3.5.3 Groundwater level trends

Groundwater levels in the shallow Permian near North Wambo Creek are monitored upstream of the North Wambo Creek diversion at bores GW24, GW26, GW36a, GW16, GW17 and SBX-GW02 (**Figure 6-6**). Data loggers were installed in two of these regolith bores (SBX-GW02 and GW36a).

Despite relatively shallow construction depths (less than 20 m), nearby mining and the drought conditions from 2017 to 2020, the bores upstream of the North Wambo Creek Diversion maintained saturation and provide useful baseline data prior to undermining in the future.

Groundwater levels illustrated in **Figure 6-6** indicate large fluctuations in groundwater levels up to 8 m in response to rainfall events. The rapid groundwater level response to high rainfall events appears similar to the North Wambo Creek alluvium and is closely linked to flow and flow recession in North Wambo Creek (refer to **Section 6.3.7**).

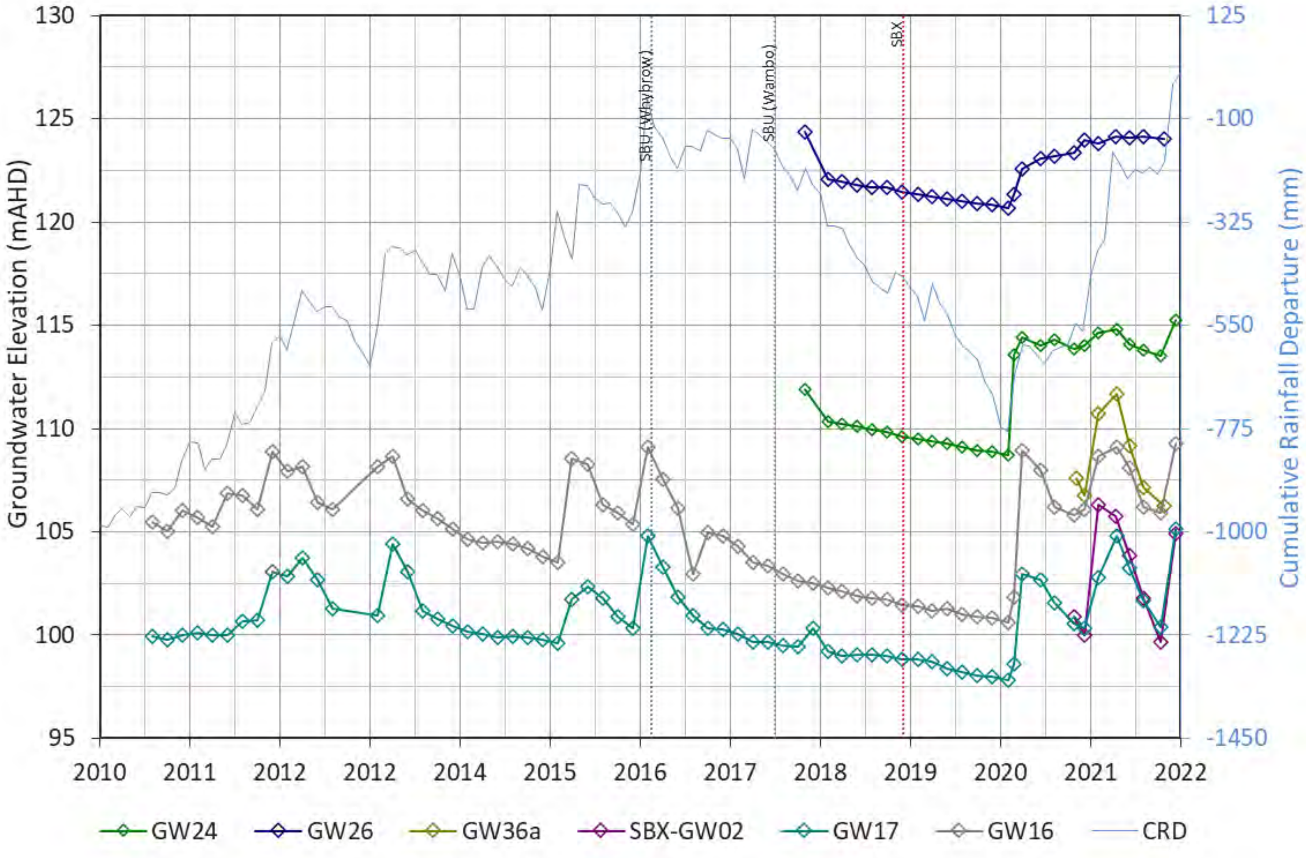


Figure 6-6 North Wambo Creek shallow Permian hydrographs

6.3.6 Permian coal measures

6.3.6.1 Distribution and flow

The Permian coal measures comprise stratified sequences of sandstone, siltstone, and claystone (interburden) and coal. The coal seams are identified as the groundwater bearing units, with the low permeability interburden generally confining the individual seams.

The Permian coal measures have a low vertical hydraulic conductivity which is likely to be a contributing factor for the lack of connectivity with surface water features and limited groundwater recharge (HydroSimulations, 2017).

Hydraulic conductivity of the coal decreases slightly with depth due to increasing overburden pressure reducing the aperture of fractures. Vertical movement of groundwater (including recharge) is limited by the confining interburden layers, meaning that groundwater flow is primarily horizontal through the seams with recharge primarily occurring at sub-crop.

Groundwater within the Permian coal measures is confined to semi-confined with the coal measures occurring at outcrop. Groundwater flow largely follows the regional topography, flowing in a north-easterly direction and is likely host to the water table in elevated areas away from incised drainage lines and watercourses. Localised drawdown nearby active mining is apparent.

6.3.6.2 Recharge and discharge

The Permian coal measures are recharged from rainfall primarily occurring at sub-crops, from downward seepage and site water storage. Where mining is occurring, the actively mined coal seams are depressurised, and groundwater levels are significantly lower than groundwater levels in the alluvium resulting in no upward leakage to the overlying sediments.

Groundwater elevation (hydraulic head) contours indicate downward leakage from the overlying Narrabeen Group, as well as recharge via outcrops. It is likely that localised downward leakage (losing conditions) occurs from the Quaternary alluvium, particularly where the more permeable coal seams sub-crop beneath the alluvium where active mining is present (AGE, 2016).

Groundwater discharge occurs as discharge to active mining and abstraction bores (**Section 6.5**), and in localised areas outside the extent of mining influence, potential upward seepage to the Quaternary alluvium where hydraulic gradients enable this (AGE, 2016).

6.3.6.3 Groundwater level trends

Extensive historical open cut and underground mining in the district has generated a regional zone of depressurisation within the Permian coal sequences.

Groundwater levels in the in Permian strata near approved and proposed mining at SBX (**Figure 6-1**) are monitored at Wambo multi-sensor VWPs N2, N5, SBX_GW02, P317 and UWOCP multi sensor VWPs UG139 and UG166a. Hydrographs at these sites are displayed in **Appendix C**.

VWP sensors in the overburden above the Whybrow seam generally show heads near the top of the unit, with a downward gradient from overlying weathered strata and alluvium (SBX-GW02), before mining, and are frequently observed to go dry following undermining (N2, P317, N5). Similar trends are observed within sensors in the Whybrow seam. Upward gradients from Whybrow-Wambo seam interburden, and Wambo seam sensors to the Whybrow seam are also observed at some locations (N5, P317).

VWP UG166a targeting strata deeper than the Whynot seam, the target of seam of historical Wambo open cut operations, shows some impact associated with open cut operations in 2011 and 2012 that remained until the last available observation in 2018. UG139 shows some evidence of an upward gradient towards Wambo underground and open cut mining operations but may also have some sensors influenced by more distant historical mining such as United Underground.

6.3.7 Groundwater interaction with watercourses

Surface water associated with larger drainage features is likely to be connected with any associated alluvium, and groundwater within the alluvium will discharge to the stream channels in some areas (HydroSimulations, 2017). This relationship is supported by the baseflow estimates undertaken for the Hunter River and Wollombi Brook (AGE, 2016) (see **Section 4.2**) which identifies groundwater may contribute 231 ML/day and 70 ML/day respectively to surface water flow.

A comparison of stream stage height with nearby groundwater elevations in both alluvial and shallow Permian aquifers has enabled an assessment of surface water-groundwater interaction for North Wambo Creek near the approved and modified SBX Underground Mine (**Figure 6-7**)

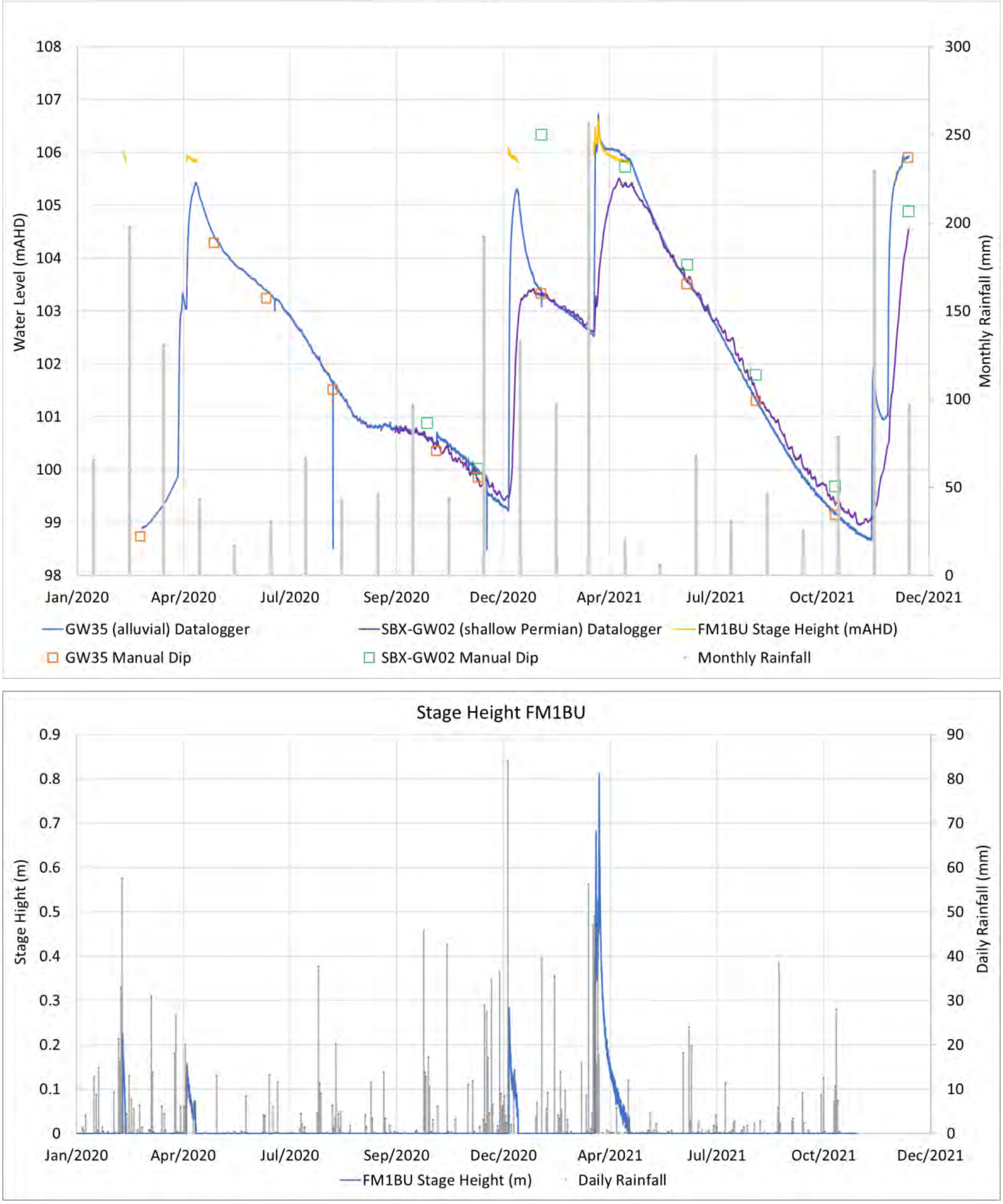


Figure 6-7 GW35 (Alluvial) and SBX-GW02_Standpipe (shallow Permian) comparison with FM1BU

Figure 6-7 shows logger data from alluvial monitoring bore GW35 with North Wambo Creek flow events at the backup FM1 monitoring site (approximately 125 m northeast of GW35), monthly rainfall, and shallow Permian groundwater levels in nearby SBX_GW02_Standpipe (approximately 100 m southwest of GW35). These surface and groundwater monitoring sites are located near the confluence of North Wambo Creek and the North Wambo Creek Diversion (**Figure 6-1**).

Rapid increases in groundwater level (up to 6 m) at GW35 are observed to correlate with periods of high rainfall and flow at the North Wambo Creek FM1BU surface water monitoring site. Following high rainfall events, levels in GW35 (screened to the base of the alluvium – AGE, 2019) declines by up to 6 to 7 m during the dry winter months, i.e. from April to December 2020 and from April to November 2021.

Similar trends are observed in underlying Permian strata (SBX_GW02 Standpipe), with peak groundwater levels around 1 m lower and occurring approximately 2 to 3 weeks after peak levels are observed in the alluvium. This is consistent with delayed infiltration into the lower conductivity weathered coal measures from the North Wambo Creek alluvium.

A reference elevation for FM1BU has been inferred using available LiDAR data, enabling a preliminary assessment of periods when baseflow or leakage is occurring. Flow events at FM1BU in April 2020 and January 2021 appear to be leakage only, with observed groundwater levels not reaching the inferred North Wambo Creek stage height, while there is likely a period of baseflow following the April 2021 flow event, inferred from the longer duration of flow, and the observed groundwater elevation at GW35 above the inferred FM1BU elevation.

The relationship between surface water and alluvial groundwater at this reach of North Wambo Creek is consistent with the HydroSimulations (2017) conceptualisation, with **Figure 6-7** also indicating that high rainfall events resulting in flow in North Wambo Creek are likely to be an important recharge mechanism for its alluvium and underlying weathered strata.

6.4 Groundwater quality

This section discusses the chemical characteristics and possible beneficial uses of groundwater within the various geological units across the wider Wambo area. Water quality results for surface water (North Wambo Creek) are also discussed below.

6.4.1 Salinity

Salinity is a key constraint to groundwater use and can be described by the EC of a water sample.

Figure 6-8 presents box and whisker plots of the EC data associated with waters screened in the various geological horizons for monitoring bores near the SBX Underground Mine, while **Figure 6-9** and **Figure 6-10** present available time-series EC data at the same sites against the rainfall trend. Surface water EC for North Wambo Creek and Waterfall Creek surface water monitoring sites is shown in **Figure 6-11**.

EC observations for surface water at Waterfall Creek are fresh (<200 microsiemens/cm [µS/cm]), but due to the highly ephemeral nature of Waterfall Creek, collection of water quality data is limited to periods shortly after a rain event sufficient to generate flow (**Figure 6-11**). As discussed previously, there are no groundwater monitoring sites near Waterfall Creek.

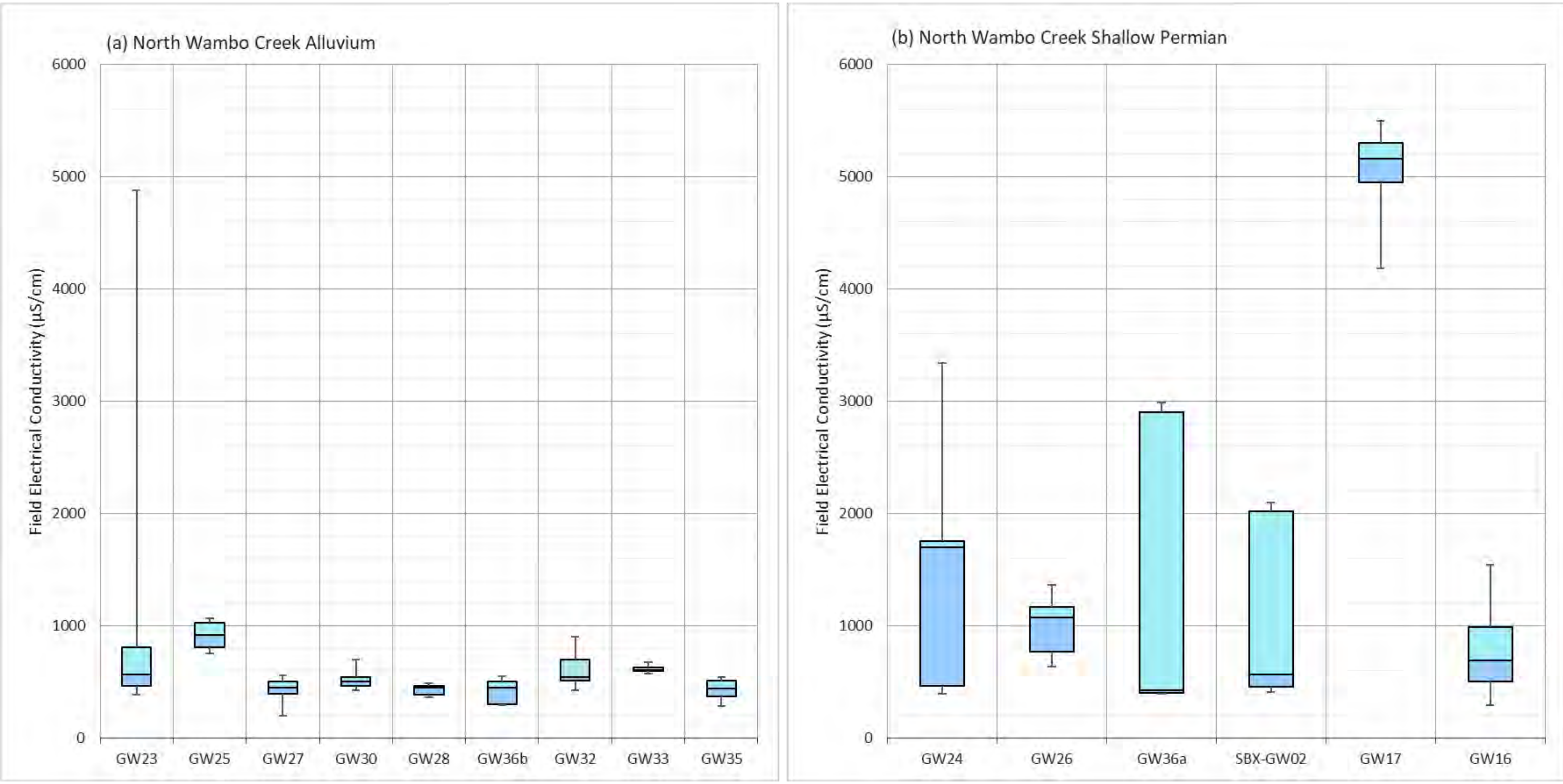


Figure 6-8 Box plots of groundwater salinity near North Wambo Creek

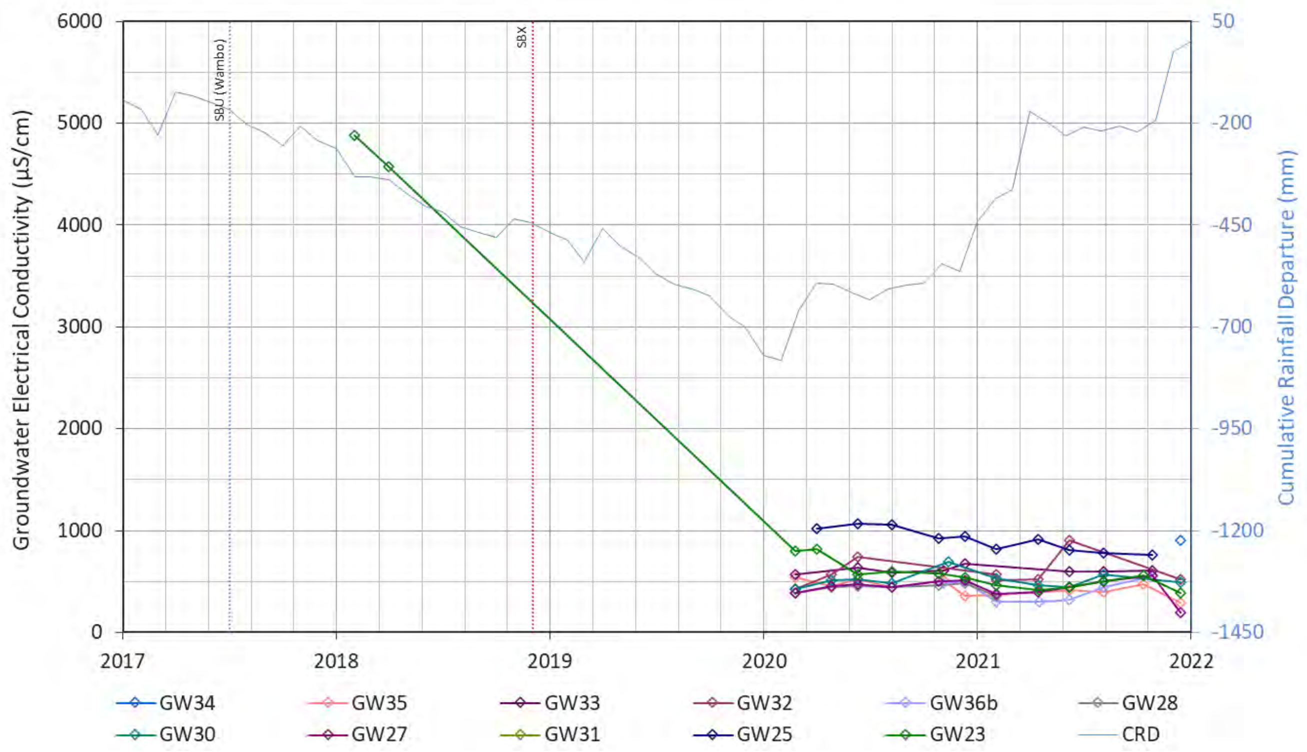


Figure 6-9 Time-series EC at North Wambo Creek alluvial bores

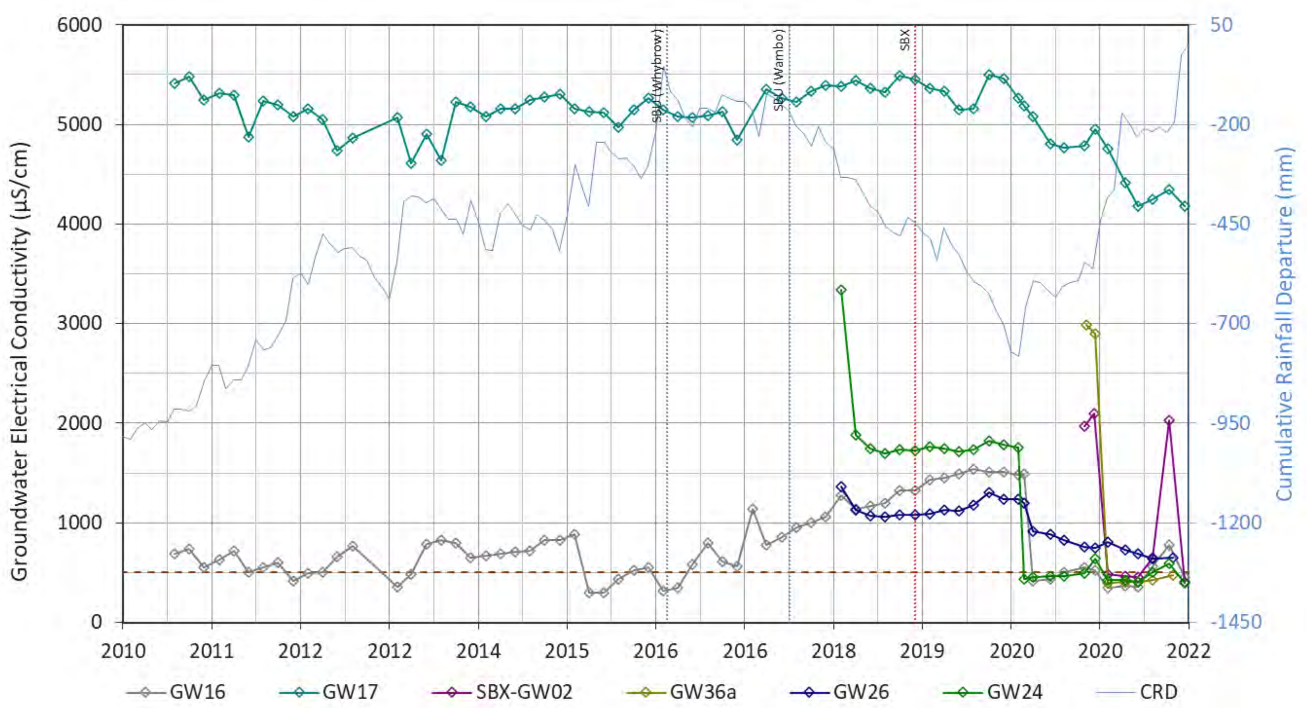


Figure 6-10 Time-series EC at shallow Permian (weathered) bores near North Wambo Creek

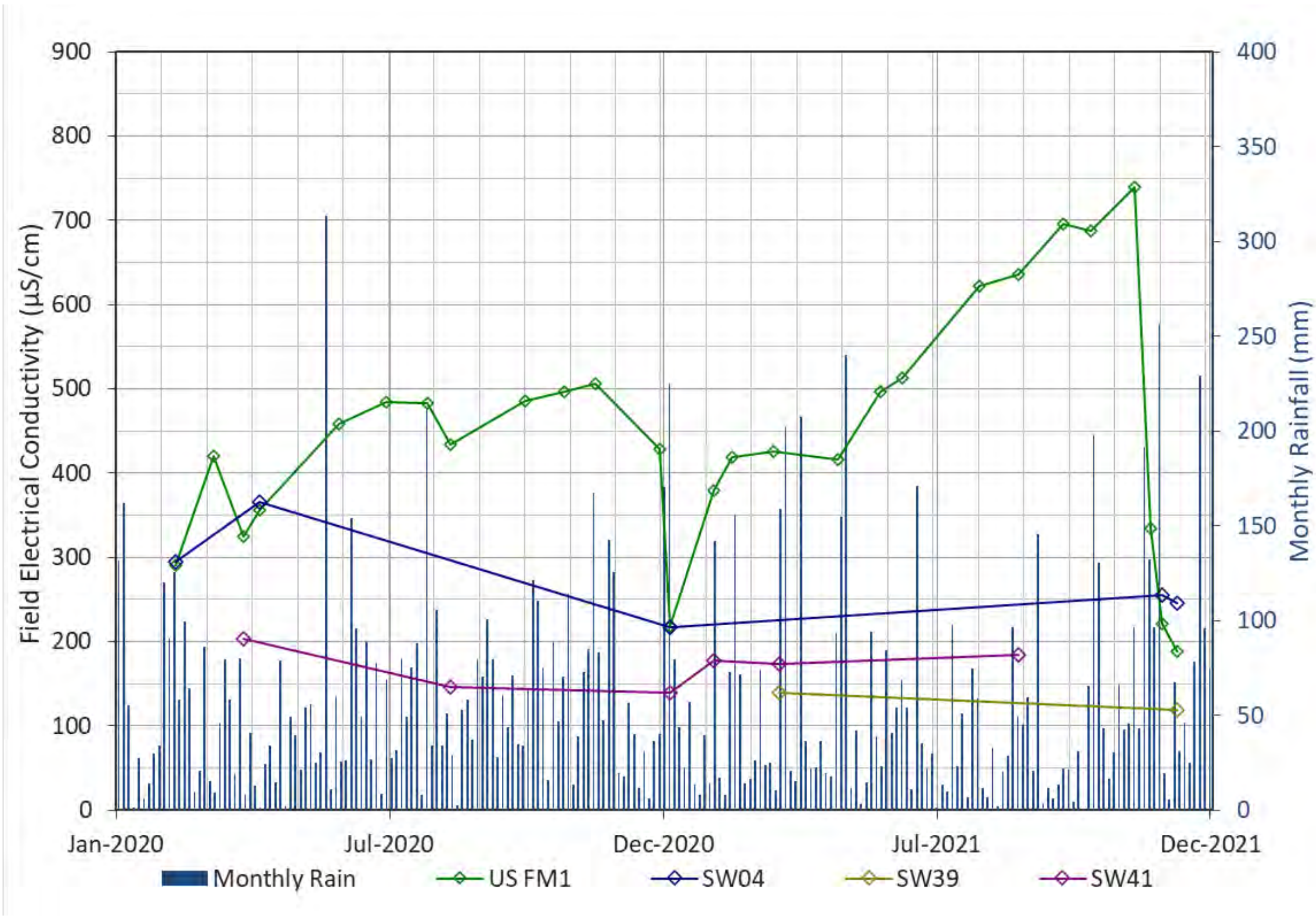


Figure 6-11 Surface water EC at North Wambo and Waterfall Creeks

The charts show that groundwater within the North Wambo Creek alluvium is fresh, with EC generally 350 to 1000 µS/cm (**Figure 6-8** and **Figure 6-9**). These alluvial EC observations are also generally consistent with surface water quality observations for North Wambo Creek. Higher surface water EC observed at surface water monitoring site, US FM1, which is within a more confined bedrock and boulder-lined channel upstream of the North Wambo Creek alluvial plain, may be indicative of groundwater discharge (baseflow) from Narrabeen Group or Newcastle Coal Measures aquifers. This appears to be the main source of flow at US FM1 outside of periods of high rainfall and runoff, and is likely influencing EC observations at GW25, the furthest upstream alluvial monitoring site.

The upper limits of EC observations at shallow Permian monitoring bores are generally more saline than overlying alluvial sites (**Figure 6-8** and **Figure 6-10**), with EC values prior to 2020 from 1000 to 3000 µS/cm at most sites, and approximately 5000 µS/cm at GW17. However, following above average rainfall conditions through 2020 and 2021, EC has declined at most shallow Permian sites to values consistent with those observed in the alluvium. This indicates downward leakage from the alluvium is a recharge source for shallow Permian strata during periods of above average rainfall and saturation within the alluvium. Outside of wet climatic periods, up-flow or lateral flow through Permian strata is the likely recharge mechanism at these sites. This is indicated by the higher EC observations prior to 2020, and the increase in EC observed at sites such as SBX-GW02 during average rainfall conditions in early 2022 (**Figure 6-10**).

6.5 Groundwater use – Anthropogenic

A search of the NSW Bore Database was undertaken by WCPL in 2020 to supplement bore census findings reported by HydroSimulations (2014) and AGE (2016). The search identified 122 bores within a 4 km radius of Wambo and the UWOCP.

A majority of the existing bores (41) are registered as monitoring/test bores and located within WCPL tenement boundaries (namely ML 1402, CL 743, and ML 1594). Fifteen bores were identified as mining/dewatering/exploration bores and 16 bores were of unknown use. Twenty-seven of the bores are registered for irrigation, domestic and/or stock use. The remainder of identified bores were noted as abandoned or destroyed (23). Bore details (including bore use and current status) are outlined in **Table 6-6** for all registered bores, excluding monitoring bores and bores that have been abandoned and destroyed (62 bores). The approximate locations of bores registered for irrigation, domestic and/or stock use, or have an unknown use are shown in **Figure 6-12**.

SLR and WCPL have also further investigated the NSW Bore Database locations of nine registered bores nearest the modified SBX Underground Mine. This investigation aimed to help confirm bore location, construction and whether the bores are in use. A summary of the investigation is provided in the points below, with comments also included in **Table 6-6**. The locations of these bores are also shown on **Figure 6-12.**

There are no metered records available for abstraction from these bores, although significant groundwater use is considered unlikely. AGE (2016) and WCPL (in 2021c, 2022) consultation with landholders indicates dated pumping hardware and generally infrequent use of private bores (**Table 6-6)**.

Of the registered bores presented in **Table 6-6** and presented on **Figure 6-12**, those identified to be located on private, non-mine owned land have been focussed on in additional detail for this assessment. The bores are GW043225, GW064382, GW078477, GW078574, GW078575, GW078576, and GW078577. Potential impacts to all nearby registered bores are considered and presented in *Groundwater Modelling Technical Report* (**Appendix D**).

Table 6-6 Registered groundwater bores

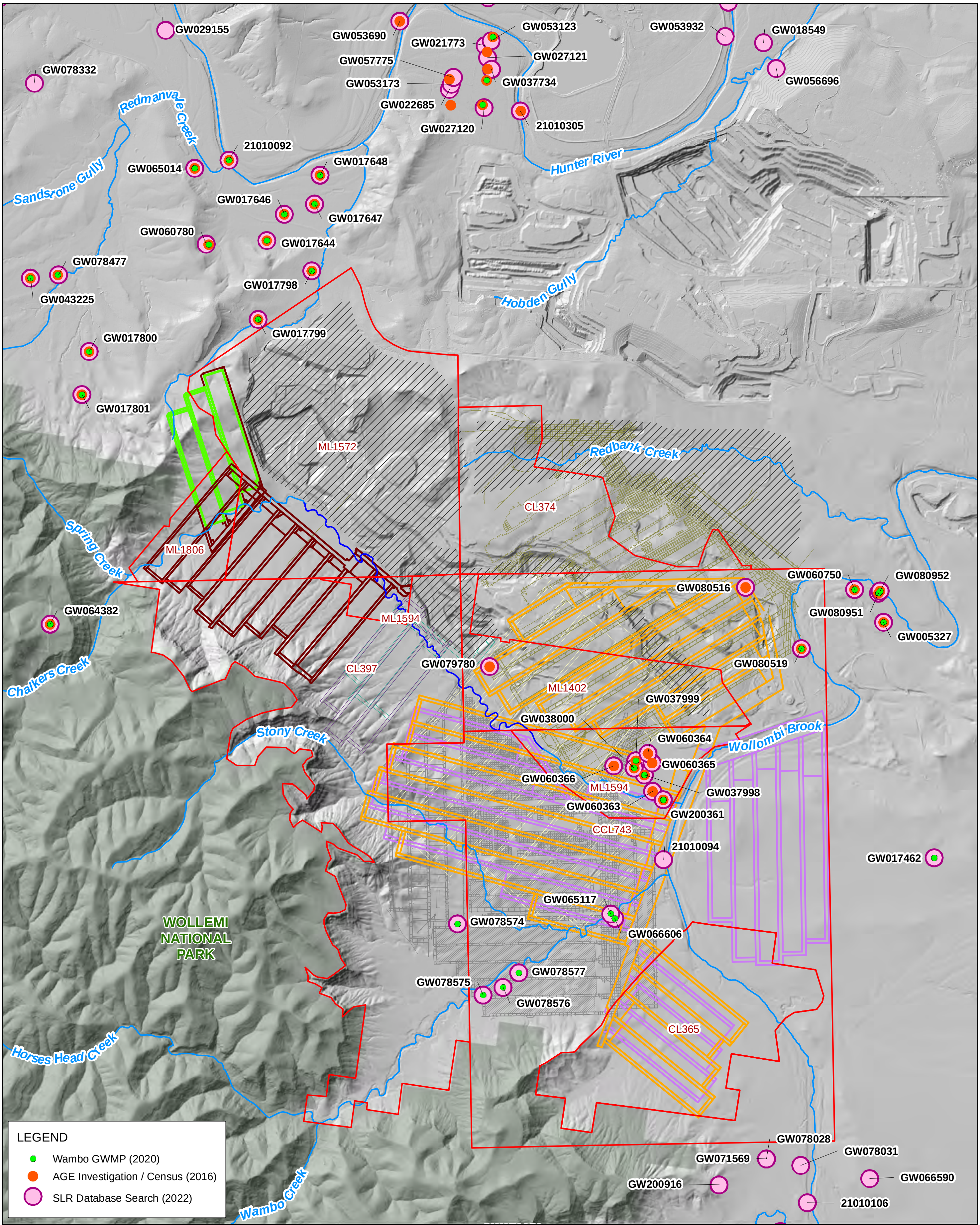
Bore No.	Location		Licence No.	Elevation (mAHD)	SWL (mbgl)	EC	Yield (L/s)	Bore Depth (mbgl)	Aquifer	Status	Bore Use	Comment (from AGE, 2016)
10010974	316585	6394626	-	67.89	-	-	-	-	Alluvium	Unknown/ AD	Unknown	HVO land – Lemington South
10011156	306219	6400469	-	66.03	-	-	-	-	Alluvium	Unknown	Unknown	Access restrictions, bore not assessed.
GW005327	314683	6394498	20BL009540	59.92	6.1*	Excellent	0.13*	10.4	Alluvium	EX	Stock	Located in township of Warkworth.
GW017462	315339	6391460	20BL008224	-	-	-	-	0	-	-	Farming	-
GW017644	306708	6399431	-	75.3	-	salty*	-	11.6*	Weathered Permian	EX	Irrigation	Inspected by SLR May 2022 – missing. Located on WCPL owned land
GW017646	306937	6399774	-	72.7	-	3,001-7,000*	-	11*	Alluvium	Unknown	Unknown	Located on WCPL owned land
GW017647	307326	6399905	-	72	-	7,001-10,000*	-	9.1*	Weathered Permian	EX	Unknown	Located on WCPL owned land
GW017648	307397	6400276	-	70.3	-	3,001-7,000*	25.26*	12.8*	Alluvium	Unknown	Irrigation	Located on WCPL owned land
GW017798	307290	6399042	-	86.6	-	1,001-3,000*	-	12.2*	Weathered Permian	EX	Unknown	Inspected by SLR April 2022 – missing. Located on WCPL owned land
GW017799	306598	6398412	-	108.7	-	Salty*	-	12.2*	Weathered Permian	EX	Unknown	Inspected by SLR April 2022 – missing. Located on WCPL owned land
GW017800	304413	6398000	-	133.2	-	-	-	27.4*	Triassic Narrabeen	Unknown	Unknown	Inspected by SLR May 2022 – dry/ blocked at 2.67 mbgl
GW017801	304320	6397443	-	149	-	-	-	42.7*	Triassic Narrabeen	EX	Stock	Inspected by SLR May 2022 – missing.
GW018045	302941	6398556	-	0	-	-	-	27.4*	Newcastle CM	Unknown	Unknown	Inspected by SLR May 2022 – missing, possibly damaged due to farming
GW018046	303013	6398866	-	0	-	-	-	18.3*	Newcastle CM	Unknown	Unknown	Inspected by SLR May 2022 – missing, possibly damaged due to farming
GW018047	302620	6398920	-	145.31	26.08	-	-	32	Newcastle CM	PRP	Unknown	Inspected by SLR May 2022
GW022685	309088	6401184	-	75	10.67	1022	Continuous use	14.6	Alluvium	EX	Stock	Concrete well with pump infrastructure in place. Continuously used for stock and domestic supply. Water quality sample taken.
GW027120	309501	6401185	-	77	10.75	822	25.26*	13.4	Alluvium	AU	Irrigation	Concrete well at surface with metal lid. Currently disused.
GW030731	316680	6397640	-	63	13.33	2460	No Pump	17.02	Alluvium	AU	-	Steel bore with marker post, disused. Water quality sample taken.
GW037184	309685	6393911	-	0	-	-	-	21*	Sandstone	-	Exploration	Located on WCPL owned land
GW037734	309553	6401502	-	83	11.36	1022	15.16*	13.4	Alluvium	AU	Irrigation	Concrete well structure in paddock. No pump infrastructure present, appears disused.
GW037998	311589	6392530	-	62.38	-	-	-	10.9*	Alluvium	-	Irrigation	Located on WCPL owned land
GW037999	311482	6392713	-	64.01	-	-	-	13.7*	Shale	-	Irrigation	Located on WCPL owned land
GW038000	311457	6392620	-	63.59	-	-	-	9.4*	Shale	-	Irrigation	Located on WCPL owned land
GW038579	309738	6393882	-	0	-	-	-	20.9*	Weathered Permian	-	Exploration	Located on WCPL owned land

Bore No.	Location		Licence No.	Elevation (mAHD)	SWL (mbgl)	EC	Yield (L/s)	Bore Depth (mbgl)	Aquifer	Status	Bore Use	Comment (from AGE, 2016)
GW042364	316824	6397645	-	63	12.77	1077	-	13.3	Alluvium	AU	Unknown	Steel bore with marker post, was used for irrigation but hasn't been used for some time.
GW043225	303653	6398949	-	116	15.08	-	-	24.7	Sandstone	EX	Irrigation	Inspected by WCPL May 2022. Bore viable but not currently utilised. Water described as 'black and saline'.
GW043673	311486	6392467	-	63.11	-	-	-	9.4*	Shale	-	Exploration	Located on WCPL owned land
GW043674	311303	6392525	-	64.6	-	-	-	8.2*	Alluvium	-	Exploration	Located on WCPL owned land
GW043675	311433	6392527	-	63.73	-	-	-	8.5*	Alluvium	-	Exploration	Located on WCPL owned land
GW043676	311480	6392805	-	64.24	-	-	-	10.6*	Shale	-	Exploration	Located on WCPL owned land
GW053123	309631	6402062	-	78	12.55	993	-	13.1	Alluvium	AU	Irrigation	Concrete well structure, disused.
GW053173	309101	640317	-	76	13.38	967	10.1*	14.8	Alluvium	AU	Irrigation and stock	Concrete well with old pump infrastructure present but appears disused.
GW053292	317670	6398097	-	53.3	-	-	-	10*	Alluvium	EX	Irrigation	Bore not visited, located on east side of Hunter River.
GW060326	314104	6393348	-	-	6.7	-	-	9.8		-	Mining	-
GW060327	314181	6393442	-	-	6.7	0-500	-	9.8	-	-	Mining	-
GW060328	314205	6393534	-	-	7	-	-	10	-	-	Mining	-
GW060329	311904	6392474	-	-	-	-	-	6.4	-	-	Mining	-
GW060330	311727	6392163	-	-	3.8	0-500	-	6.2	-	-	Mining	-
GW060750	314310	6394923	20BL132130	59	-	-	-	24.4*	Weathered Permian	Unknown	Domestic	Bore not visited, located in township of Warkworth.
GW060780	305961	6399379	-	104.1	18.62	1552	No Pump	25.5	Weathered Permian	AU	Stock and domestic	Steep bore within vegetation. Uncapped and appears disused (no pump infrastructure present).
GW064382	303908	6394477	-	414.4	-	-	-	60*	Sandstone	-	Stock and domestic	Access restrictions, bore not assessed.
GW065014	305777	6400368	-	85	-	-	-	14.5*	Weathered Permian	Unknown	HUSE	Located on Wambo owned land
GW065117	311154	6390735	-	-	-	-	-	6	-	-	Irrigation	-
GW066606	311207	6390674	-	-	-	-	-	2.5	-	-	Domestic	-
GW078055	310105	6390490	-	-	-	1660	3-5 L/s	198.5		-	Test	-
GW078477	304007	6398988	-	109.8	11.05	3630*	-	102.5*	Sandstone	EX	Domestic	Private bore, bore in use with water licence 20BL167575. 150 mm diameter PVC casing. Grundfos pump installed to 29 m depth, used approximately every 3 months, and yields 3 L/s.
GW078574	309174	6390605	20BL167170	-	-	-	-	12	-	-	Farming	-
GW078575	309505	6389687	20BL167171	-	-	-	-	12	-	-	Farming	-
GW078576	309764	6389784	20BL167172	-	-	-	-	7	Gravel, coal measures	-	Farming	-
GW078577	309969	6389973	20WA20855 9	-	-	-	-	10		-	Domestic	-
GW079060	314596	6394852	-	-	-	-	-	14.6		-	Unknown	-

Bore No.	Location		Licence No.	Elevation (mAHD)	SWL (mbgl)	EC	Yield (L/s)	Bore Depth (mbgl)	Aquifer	Status	Bore Use	Comment (from AGE, 2016)
GW080502	308897	6390160	20BL168017	-	105	-	-	250	Coarse Sand	-	Mining	-
GW080519	313622	6394161	20BL168885	57.98	7.42*	6490*	-	10.5*	Alluvium	-	Unknown	Located on WCPL owned land
GW080951	314619	6394878	-	55	-	-	-	3.14*	Alluvium	Unknown	-	Bore not visited, located in township of Warkworth.
GW080952	314643	6394904	-	54	-	-	-	1.59*	Alluvium (sandy clay)	EX	-	Bore not visited, located in township of Warkworth.
GW200361	311833	6392209	20BL170638	60.97	3.12	-	-	-	Alluvium	-	Test	Located on WCPL owned land
GW200624	310166	6392650	20BL168939	-	6	-	-	260		-	Dewatering	
GW200625	310901	6393375	20BL168940	-	-	-	-	270		-	Mining	-
GW200942	312325	6395750	20BL167947	-	32	-	-	37		-	Test	-
GW200943	312332	6395760	20BL167947	-	27	-	-	30		-	Test	-
GW203459	311820	6392560	-	0	-	-	-	55	Jerrys Plains SG	EX	Dewatering	
Unregistered bore (near GW029155)	305430	6401656	-	76	8.2	-	-	9.8	Alluvium	EX	Stock	Private bore, well at least 50 years old, 1 m concrete well, casing 0.6 m above surface. Windmill in place and pumps at rate of 2.4 L/minute. Used for stock water supply year-round.

Status: AU – Abandoned but useable AD – Abandoned EX – Existing

* - value derived from NSW Bore Database/ Pinneena



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0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:65,000 at A4
Project Number:	665.0008.00815
Date:	13-Jul-2022
Drawn by:	ANP

SLR

- Named Watercourse
- NWC Diversion
- Mining Lease
- Approved Open Cut Mining
- NPWS Reserve

Proposed Mining

- South Bates Extension LW24-26 MOD - Whybrow Seam

Approved Mining

- South Wambo - Woodlands Hill Seam
- South Wambo - Arrowfield Hill Seam
- South Bates Extension - Whybrow Seam

Historical/Completed Mining

- South Bates - Whybrow Seam
- South Bates - Wambo Seam
- North Wambo UG - Wambo Seam
- United UG - Arrowfield Seam
- Homestead-Wollemi UG - Whybrow Seam

Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION

Registered Bores

FIGURE 6-12

6.6 Groundwater use – Environmental

6.6.1 Groundwater Dependent Ecosystems

A GDE can be a plant (vegetation) and/or animal community (i.e. stygofauna) that is dependent on the availability of groundwater to maintain its structure and function. A review of relevant data sources was undertaken as part of this groundwater assessment with details on the occurrence of potential GDEs in the vicinity of modified SBX Underground Mine is provided below.

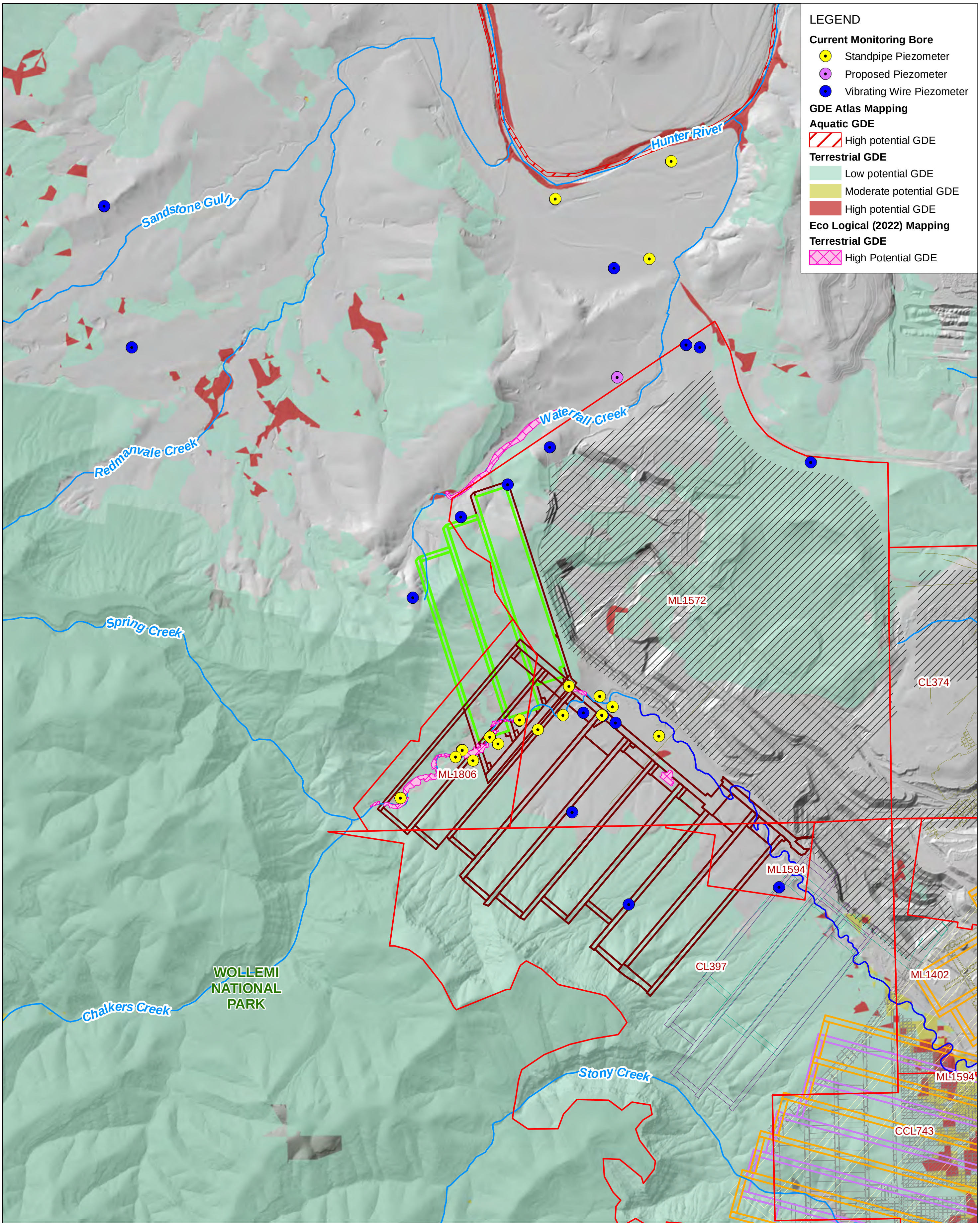
6.6.1.1 GDE Atlas

The Groundwater Dependent Ecosystems Atlas (BoM, 2021) was developed as a national dataset of Australian GDEs to inform groundwater planning and management. The GDE Atlas uses the following categories for mapping the likelihood of terrestrial GDEs:

- High potential for groundwater interaction.
- Moderate potential for groundwater interaction.
- Low potential for groundwater interaction.

The term 'potential' is used to reflect the uncertainty inherent in identifying ecosystems as groundwater-dependent using desktop methods.

Figure 6-13 shows GDE Atlas mapping of the modified SBX Underground Mine area. The figure shows that large parts of the modified SBX Underground Mine area are mapped as low potential Terrestrial GDEs. Areas mapped as high potential terrestrial GDEs include areas mapped around Redmanvale Creek and the Hunter River (located northwest and north of modified Longwalls 24 to 26), and small areas around Waterfall Creek and North Wambo Creek (located northeast and southeast of modified Longwalls 24 to 26). The mapping also identifies the Hunter River (located north of modified Longwalls 24 to 26) as a high potential Aquatic GDE.



0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:40,000 at A4
Project Number:	665.0008.00815
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SLR

- Named Watercourse
- NWC Diversion
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- Approved Open Cut Mining
- NPWS Reserve

Proposed Mining

- South Bates Extension LW24-26 MOD - Whybrow Seam

Approved Mining

- South Wambo - Woodlands Hill Seam
- South Wambo - Arrowfield Hill Seam
- South Bates Extension - Whybrow Seam

Historical/Completed Mining

- South Bates - Whybrow Seam
- South Bates - Wambo Seam
- North Wambo UG - Wambo Seam
- United UG - Arrowfield Seam
- Homestead-Wollemi UG - Whybrow Seam

Data Source: NSW SS 2020
Groundwater Dependent Ecosystems Atlas

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION

Potential Groundwater Dependent Ecosystems (GDEs)

FIGURE 6-13

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6.6.1.2 Vegetation

HydroSimulations (2019) completed a GDE Study for the approved SBX Underground Mine. This was informed by an ecological study (Hunter Eco, 2019) which identified a vegetation community along North Wambo Creek as the most likely to be groundwater dependant within this area. The following points provide a summary of the work completed for the GDE study and in subsequent investigations:

- SLR (2018, 2020), AGE (2019a, 2019b) installed 15 alluvial and shallow Permian monitoring bores within the North Wambo Creek alluvium. These sites aim to understand the groundwater conditions within the North Wambo Creek alluvium, and whether there is likely to be interaction between groundwater and the vegetation community identified by Hunter Eco (2019) as likely to be groundwater dependent.
- Modelling undertaken by HydroSimulations (2019) included revision of the alluvial geometry within the model near North Wambo Creek to reflect the SLR (2018) and AGE (2019) drill programs, alongside updated vegetation mapping and revised rooting depth to improve the ET simulation. The model results were consistent with observed data at the time (drought conditions) and simulated unsaturated conditions in the alluvium near the vegetation community identified by Hunter Eco (2019) as likely to be groundwater dependent.
- Groundwater observation data from March 2020 to present indicate areas of the North Wambo Creek alluvium saturate to near ground level. This is observed following high magnitude rainfall events that resulted in flow in North Wambo Creek. Groundwater levels are observed to decline rapidly following these events.
- Modelling undertaken to assess the Modification simulates flow events in North Wambo Creek based on a rainfall event – stream flow relationship (**Section 4.2.1**). Model results using this relationship were consistent with observed data. This relationship will be utilised in this Groundwater Assessment.

Based on groundwater level observations within the approved SBX Underground Mine area, the high potential GDE vegetation community identified by Hunter Eco (2019) is likely to have periodic access to groundwater. This periodic saturation of the alluvium is associated with high rainfall and flow events in North Wambo Creek and is captured within contemporary groundwater modelling. The monitoring network near this vegetation community is sufficient to observe changes in groundwater behaviour associated with the SBX Underground Mine.

Ecological (2022) prepared a Biodiversity Review for the Modification and noted that a high potential GDE occurs north of the modified SBX Underground Mine area along Waterfall Creek. The ephemeral drainage lines located above the modified SBX Underground Mine area that flow into Waterfall Creek do not contain any likely associated GDE.

6.7 Conceptual model

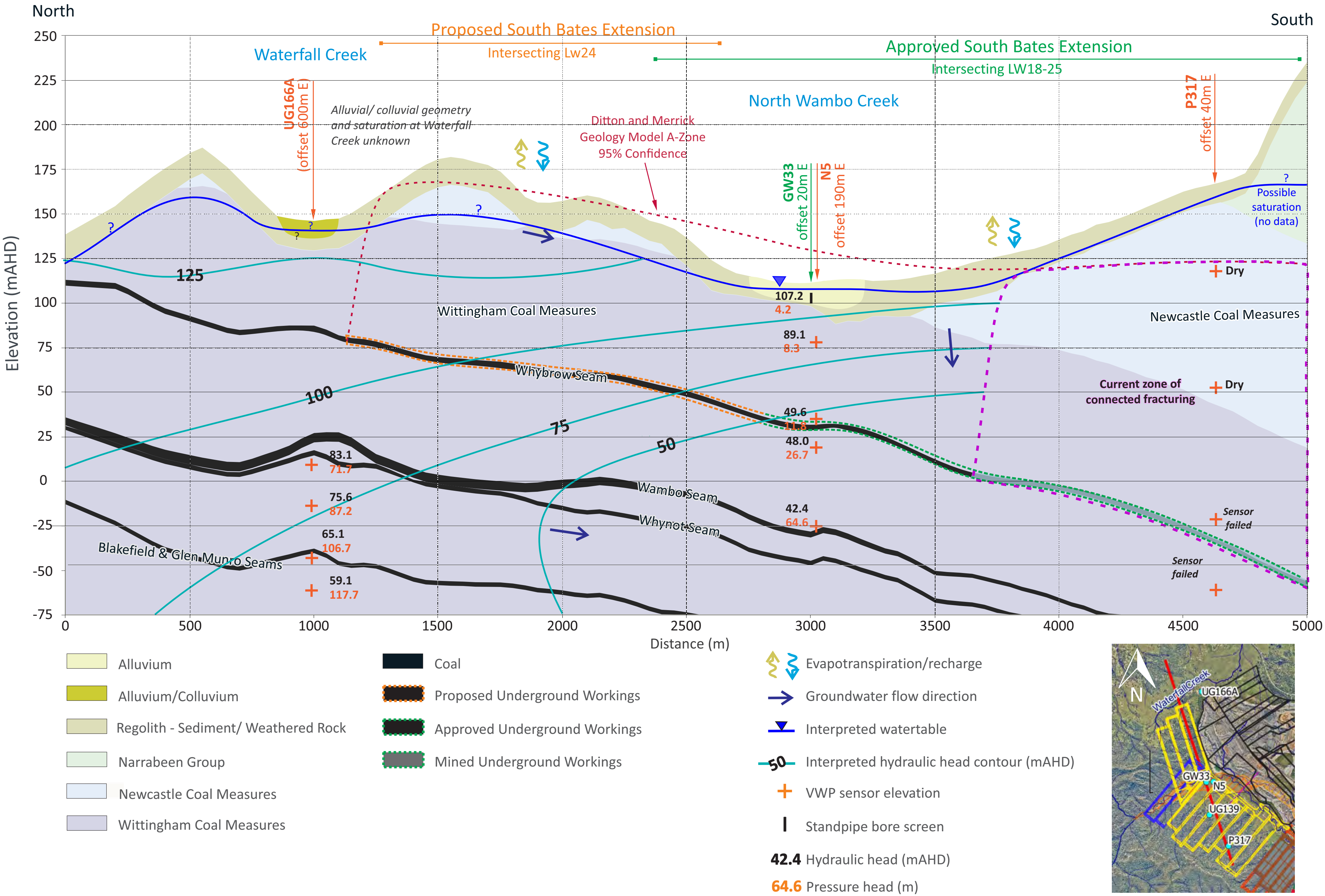
The primary groundwater aquifer units in the Wambo area are the deposits of Quaternary Alluvium and less productive coal seams of the Permian Coal Measures. The composition of regolith and shallow weathered strata is variable but can have significant permeability in places. A summary of these units is provided below.

- Alluvial sediments of the ephemeral watercourses, North Wambo Creek and Wambo Creek – the alluvium associated with these ephemeral creeks is typically unsaturated and will receive recharge via losses from the watercourse during periods of flow. However, following flow events and periods of saturation, groundwater drains laterally or to the underlying strata.

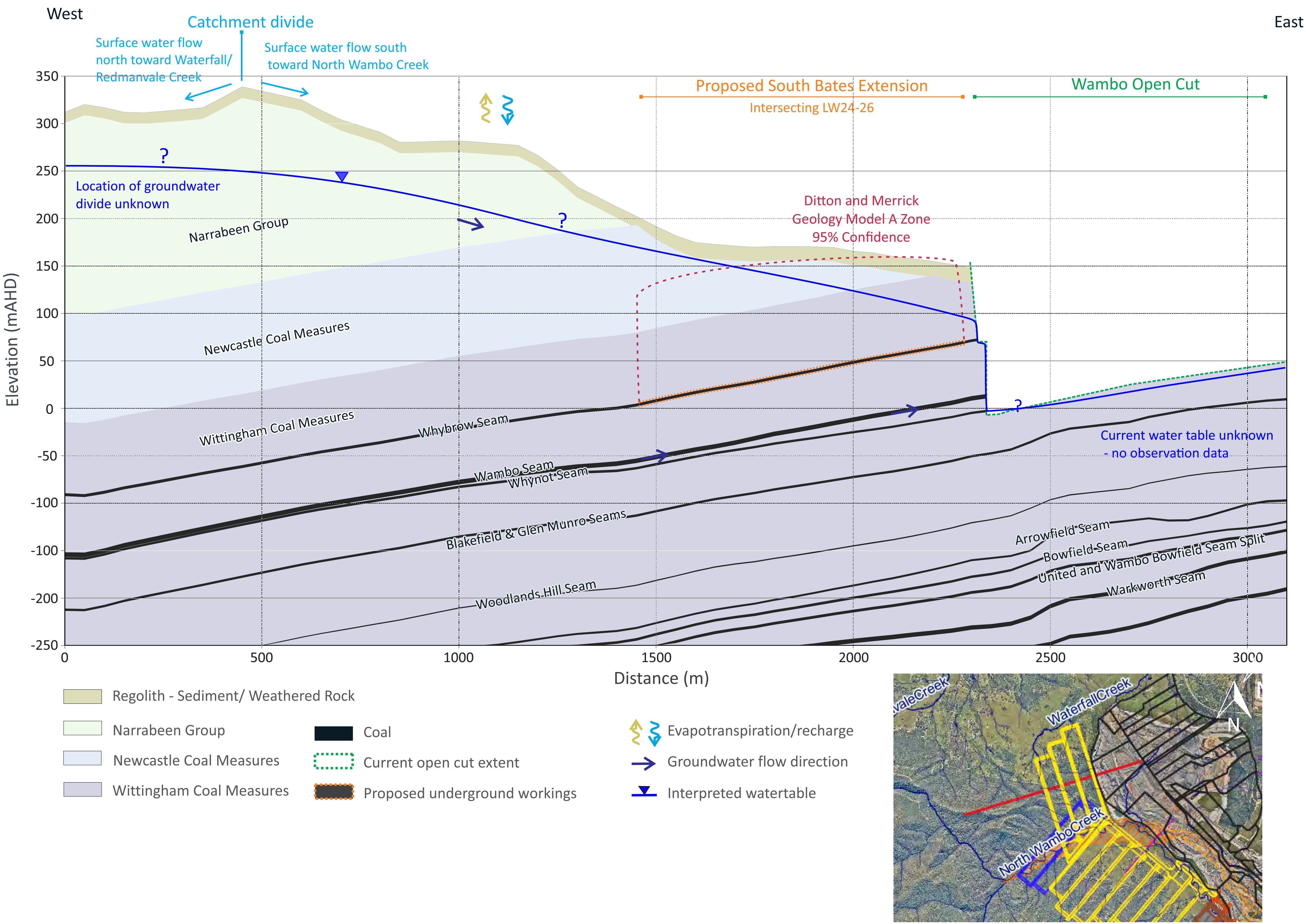
- Due to the small catchment size of Waterfall Creek compared with other ephemeral watercourses in the Wambo area (e.g. North Wambo Creek, Wambo Creek), and the relatively confined valley it is in, it is likely that any alluvial material will be limited in extent. Alluvial groundwater at Waterfall Creek will likely be sourced from upward or lateral flow from Permian coal measures, or downward infiltration following rainfall and flow in Waterfall Creek, as is observed at other ephemeral creeks at Wambo.
- Wollombi Brook Alluvium – unconfined saturated alluvial sediments, typically 10 to 20 m thick with both highly productive and less productive zones. On the western bank finer alluvial sediments are influenced by the nearby mining, with water levels generally below stream levels, whilst the eastern banks of the stream typically contain coarser alluvial sediments and do not indicate mining impacts.
- Hunter River Alluvium – unconfined saturated alluvial sediments. The alluvium receives both direct recharge and recharge from the river during periods of high flow. Alluvium recharge and discharge is highly dependent on flow conditions in the Hunter River and alluvium groundwater conditions.
- Shallow bedrock (regolith) – typically saturated, with groundwater occurring between 4 to 12 m below surface.
- Permian Coal Measures – comprised of a stratified sequences of sandstone, siltstone, and claystone (interburden) and coal, with the coal seams acting as the primary water bearing units whilst the low permeability interburden generally confines the individual seams. Mining activities locally influence the recharge and discharge mechanisms of the Permian Coal Measures. Recharge typically occurs via rainfall, downward seepage, and site water storage losses. Groundwater discharge is via mining, private abstraction and in localised areas outside of the extent of mine influence, potential upward seepage where gradients enable this.

Overall, the hydrogeological system can be considered a connected system with zones of interaction between hydrogeological units present in the form of upward and downward leakage (recharge and discharge between aquifers). It is not a wholly connected system with interburden and overburden and variability in permeability acting as confining layers. Relationships with surface water vary, dependent on impacts of mining and level of flow in the water courses.

North- south (**Figure 6-14)** and west east (**Figure 6-15**) hydrogeological cross sections collate available geological, groundwater level, environmental and mining operation information to visualise the groundwater system relevant to the SBE Modification. These conceptual figures represent the groundwater flow at the end of 2021.



North
South
Proposed South Bates Extension
Intersecting Lw24
Approved South Bates Extension
Intersecting LW18-25
Waterfall Creek
North Wambo Creek
UG166A (offset 600m E)
Alluvial/ colluvial geometry and saturation at Waterfall Creek unknown
Ditton and Merrick Geology Model A-Zone 95% Confidence
GW33 offset 20m E
N5 offset 190m E
P317 offset 40m E
Possible saturation (no data)
Wittingham Coal Measures
Newcastle Coal Measures
Whybrow Seam
Wambo Seam
Whynot Seam
Blakefield & Glen Munro Seams
Current zone of connected fracturing
Dry
Sensor failed
107.2
4.2
89.1
8.3
49.6
11.8
48.0
26.7
42.4
64.6
83.1
71.7
75.6
87.2
65.1
106.7
59.1
117.7
125
100
75
50
Elevation (mAHD)
Distance (m)
Alluvium
Alluvium/Colluvium
Regolith - Sediment/ Weathered Rock
Narrabeen Group
Newcastle Coal Measures
Wittingham Coal Measures
Coal
Proposed Underground Workings
Approved Underground Workings
Mined Underground Workings
Evapotranspiration/recharge
Groundwater flow direction
Interpreted watertable
Interpreted hydraulic head contour (mAHD)
VWP sensor elevation
Standpipe bore screen
42.4 Hydraulic head (mAHD)
64.6 Pressure head (m)
Waterfall Creek
UG166A
GW33
N5
UG139
P317
N


West
East
Catchment divide
Surface water flow north toward Waterfall/ Redmanvale Creek
Surface water flow south toward North Wambo Creek
Proposed South Bates Extension
Intersecting LW24-26
Wambo Open Cut
Location of groundwater divide unknown
Narrabeen Group
Ditton and Merrick Geology Model A Zone 95% Confidence
Newcastle Coal Measures
Wittingham Coal Measures
Whybrow Seam
Wambo Seam
Whynot Seam
Blakefield & Glen Munro Seams
Woodlands Hill Seam
Arrowfield Seam
Bowfield Seam
United and Wambo Bowfield Seam Split
Warkworth Seam
Current water table unknown - no observation data
Elevation (mAHD)
Distance (m)
350
300
250
200
150
100
50
0
-50
-100
-100
-200
-250
0
500
1000
1500
2000
2500
3000
Regolith - Sediment/ Weathered Rock
Narrabeen Group
Newcastle Coal Measures
Wittingham Coal Measures
Coal
Current open cut extent
Proposed underground workings
Evapotranspiration/recharge
Groundwater flow direction
Interpreted watertable
WaterfallCreek
North WamboCreek
N

7 Groundwater Simulation Model

7.1 Model Details

This section provides a summary of the design and development of the numerical groundwater model used to support this groundwater assessment. Full details of the numerical groundwater model are included within the *Wambo Coal Mine Longwalls 24-26 Modification Groundwater Modelling Technical Report* (**Appendix D**).

7.1.1 Model objectives

Numerical modelling was undertaken in support of the groundwater assessment for the Modification to evaluate the potential incremental impacts of the Modification on the local groundwater regime. The objectives of the predictive modelling were to:

- Assess the groundwater inflow to the mine workings as a function of mine position and timing.
- Simulate and predict the extent and area of influence of dewatering, and the level and rate of drawdown at specific locations and in specific strata.
- Identify areas of potential risk, where groundwater impact mitigation/control measures may be necessary.
- Estimate direct and indirect water take.
- Estimate post-mining recovery conditions.

7.1.2 Model design

The numerical groundwater model was developed based on the conceptual groundwater model, presented within **Section 6.7**. Conceptualisation of the groundwater regime and the calibration of the model against observed data are key to achieving a reliable numerical model. Conceptualisation is a simplified overview of the groundwater regime (i.e. the distribution and flow of groundwater) based on available data and experience. Consistency between numerical model results and the conceptual understanding of the groundwater regime increases the credibility of the numerical model predictions.

The numerical model was developed using a GIS in conjunction with MODFLOW-USG, which is distributed by the United States Geological Survey (USGS). MODFLOW-USG is a relatively new version of the popular MODFLOW code (McDonald and Harbaugh, 1988) developed by the USGS. MODFLOW is the most widely used code for groundwater modelling and has long been considered an industry standard.

The numerical groundwater model for Wambo has been rebuilt for this Groundwater Assessment based on the existing numerical models for Wambo (SLR, 2020) and the UWOCP (AGE, 2016), and updated using site and regional geological models. The updates to the model design from previous numerical modelling (SLR, 2020 and AGE, 2016) include:

- Model extent and grid – utilise *Algomesh* software to generate an unstructured model grid that includes grid refinement around the modified SBX Underground Mine.
- Timing – refine timing to capture revised mine progression.

- Model layers – updated layers to provide greater discretisation above the uppermost target seam (Whybrow Seam) at Wambo, capture stratification of alluvium and update model layers to match Wambo geological model surfaces and update LiDAR data.
- Boundary Conditions – update relevant model boundary conditions with revised grid geometry and regional flows.

7.1.3 Model calibration

The numerical model includes a transient calibration (2003 to 2020). Both the steady-state and transient calibrations capture historical mining at Wambo and adjacent MTW, and HVO (North and South) mines. Mining was represented in the model using the MODFLOW drain package, with the drain cells set to the base of the target coal seam for open cut pits, and within the target coal seam for underground mines. Calibration of the model was carried out with the objective being to replicate the groundwater levels measured in the Wambo, UWOCP, MTW and HVO monitoring networks and available privately-owned bores, in accordance with Australian Groundwater Modelling Guidelines (Barnett *et al*., 2012).

Observations from recently installed Wambo site bores have been included in the transient calibration statistics. Wambo site bore residuals (used in the calculation of calibration statistics) were calculated as the difference between the observed water level and simulated water level for the corresponding time-period in the calibration model. Transient calibration for the model achieved a 6.7% scaled root mean square (SRMS) error, which is within the acceptable limits (i.e. 10%) recommended by the Australian groundwater modelling guidelines (Barnett *et al*., 2012). A detailed description of the calibration procedure is provided in **Appendix D**.

7.1.4 Model performance and limitations

The groundwater modelling was conducted in accordance with the Australian Groundwater Modelling Guidelines (Barnett *et al.* 2012), the Murray – Darling Basin Commission (MDBC) Groundwater Flow Modelling Guideline (MDBC, 2001) and the IESC Explanatory Note for Uncertainty Analysis (Middlemis and Peeters, 2018). These are generic guides and do not include specific guidelines on special applications, such as underground coal mine modelling.

The Australian Groundwater Modelling Guidelines (Barnett *et al*, 2012) has replaced the model complexity classification of the previous guideline by a "model confidence level" (Class 1, Class 2, or Class 3 in order of increasing confidence) typically depending on:

- Available data (and the accuracy of that data) for the conceptualisation, design, and construction.
- Calibration procedures that are undertaken during model development.
- Consistency between the calibration and predictive analysis.
- Level of stresses applied in predictive models.

It is generally expected that a model confidence level of Class 2 is required for mining environmental assessment. **Table 7-1** (based on Table 2.1, Barnett *et al,* 2012) provides summary responses to the classification criteria and shows a scoring system allowing model classification. Based on **Table 7-1**, the groundwater model developed for this Groundwater Assessment may be classified as primarily Class 2 (effectively "medium confidence") with some items meeting Class 3 criteria, which is considered an appropriate level for this Modification.

Table 7-1 Groundwater Model Classification Table

Class	Data	Calibration	Prediction	Indicators	Total
1	Not much. Sparse. **No metered usage.** Remote climate data.	Not Possible. Large error statistics. Inadequate data spread. Targets incompatible with model purpose.	Timeframe>>calibration. Long stress periods. Transient prediction but steady state calibration. Bad verification.	Timeframe>10x. Stresses>5x. Mass balance>1% (or single 5%). Properties<>Field. Bad discretisation. No review.	
Count	1	0	0	0	**1**
2	**Some.** **Poor coverage**. Some usage info. Baseflow estimates.	**Partial performance.** Long-term trends wrong. Short time record. Weak seasonal replication. No use of targets compatible with model purpose.	Timeframe>calibration. Long stress periods. New stresses not in calibration. Poor verification.	**Timeframe=3-10x.** **Stresses=2-5x.** **Mass balance<1%.** **Properties<>Field measurements.** Some key coarse discretisation. **Reviewed by hydrogeologist.**	
Count	2	1	0	5	**8**
3	Lots. Good aquifer geometry. Good usage info. **Local climate info.** **K measurements** **Hi –res DEM.**	Good performance stats. Long-term trends replicated. **Seasonal fluctuations OK.** **Present day data targets.** **Head and flux targets.**	**Timeframe~ calibration.** Similar stress periods. **Similar stresses to those in calibration.** Steady state prediction consistent with steady state calibration. Good verification.	Timeframe<3x. Stresses<2x. **Mass balance<0.5%** Properties ~Field measurements. **No key coarse discretisation.** **Reviewed by modeller.**	
Count	3	3	2	3	**10**

7.2 Model predictions

Transient predictive modelling was undertaken to simulate both the mining at Wambo and surrounding mines from January 2021 to December 2041. The model timing used quarterly stress period durations as mining progressed into the future. Four numerical model scenarios were run:

1. **Null Run** – No Wambo/United Collieries/UWOCP mining after 2003 (i.e. when Development Consent (DA305-7-2003) was issued). This scenario does include mining at other approved mining operations outside of the Wambo/United Collieries/UWOCP mining complex.
2. **No Wambo Underground Mining** – No underground mining at Wambo after 2003 (i.e. when Development Consent (DA305-7-2003) was issued). This scenario does include mining at other approved mining operations around Wambo.
3. **Approved** – Approved mining at Wambo (i.e. in accordance with Development Consent (DA305-7-2003) and mining at other approved mining operations around Wambo.
4. **Modification** – Approved mining at Wambo (i.e. in accordance with Development Consent [DA305-7-2003]) plus the Modification and mining at other approved mining operations around Wambo.

The following differential comparisons were made on groundwater level and groundwater flux outputs to evaluate incremental impacts due to the Modification, and cumulative impacts due to Wambo including the Modification:

- *Modification Scenario* compared to the *Approved Scenario* – to **evaluate the incremental impacts** of the Modification compared with the approved Wambo.
- *Modification Scenario* compared to the *No Wambo Underground Mining Scenario* – to evaluate the **overall impacts of underground mining** of modified Wambo (i.e. including the modified Longwalls 24 to 26).
- *Modification Scenario* compared to the *Null Run* – **to evaluate cumulative impacts** due to modified Wambo (i.e. including the modified Longwalls 24 to 26) and the United Collieries/UWOCP operations.

7.2.1 Environmental assumptions

Table 7-2 provides an overview of how environmental inputs were simulated during the quarterly stress periods of the predictive modelling, and the annual, decadal and century length stress periods of the recovery modelling.

Table 7-2 Summary of environmental assumptions during predictive modelling

Environmental Process	Reach/ Zone	Predictive assumption	Recovery assumptions
Stream stage	Hunter River	Seasonality simulated using long-term average stage height per quarter.	No seasonality – Long-term annual average stage height.
	Wollombi Brook	Seasonality simulated using long-term average stage height per quarter.	No seasonality – Long-term annual average stage height.
	Ephemeral watercourses	Timing of recharge episodes not predictable. No stage height simulated for ephemeral steams in the predictive modelling (e.g. Wambo Creek, North Wambo Creek, Stony Creek)	No stage height simulated for ephemeral steams in the recovery modelling.
Rainfall Recharge	Recharge zones as per calibration including a time variant zone for spoil/ backfill	No seasonality. Long-term annual average rate applied after modification with calibrated multipliers.	No seasonality. Long-term annual average rate applied after modification with calibrated multipliers.
Evapotranspiration	ET zones as per calibration including a time variant zone for spoil and final voids	Seasonality simulated using long-term average rate per quarter.	No seasonality. Long-term annual average rate applied.

7.3 Predicted groundwater interception

The predicted groundwater inflows for the approved and modified underground mines at Wambo, and the total underground mine inflows are presented in **Figure 7-1**.

No change to maximum inflows are predicted for the SBX Underground Mine between the approved and modified scenarios, with both predicted to reach a maximum annual inflow of 480.45 ML (1.32 ML/day) in 2021. The predicted groundwater inflows for the approved and modified SBX Underground Mine are within the same order of magnitude as HydroSimulations (2017) which predicted a maximum mine inflow of approximately 365 ML/year (1 ML/day).

While there is no increase in maximum predicted groundwater inflow for the SBX Underground Mine due to the Modification, the extended SBX Underground Mine life for the Modification compared with the approved SBX Underground Mine scenario results in an extension of the period of groundwater inflows.

The maximum predicted inflows for the Woodlands Hill Seam and Arrowfield Seam at the South Wambo Underground Mine are 567 ML/year (1.55 ML/day) and 290 ML/year (0.79 ML/day), respectively. These predicted inflows are generally consistent with HydroSimulations (2017) predictions for the approved South Wambo Underground Mine.

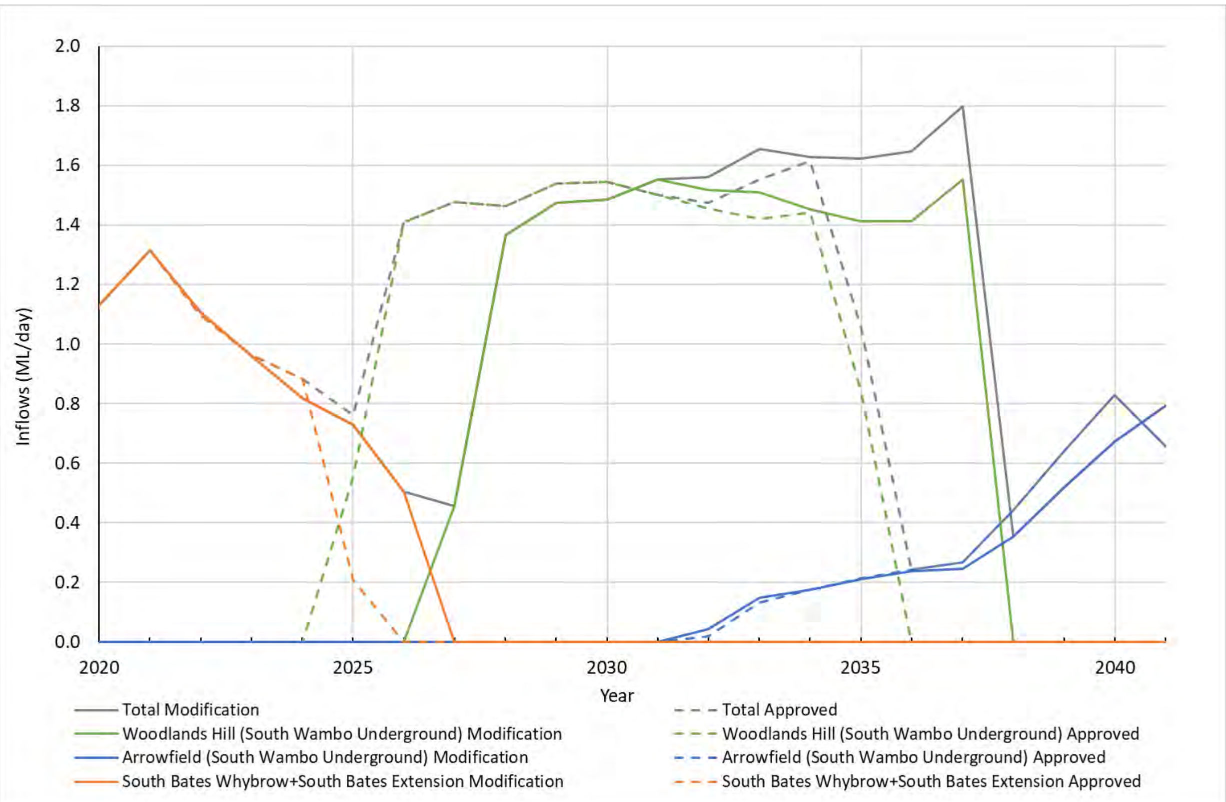


Figure 7-1 Predicted Wambo underground mine groundwater inflows

Table 7-3 presents the predicted average and maximum groundwater inflow rates for Wambo underground mines for the approved and modified scenarios. A small increase in average underground mine groundwater inflow is predicted for the Modification (0.06 ML/day).

Table 7-3 Summary of predicted total Wambo underground mine groundwater inflow.

Scenario	Avg mine groundwater inflow (ML/day)	Max mine groundwater inflow (ML/day)	Year of maximum
Approved	1.08	1.62	2034
Modification	1.14	1.80	2037

The increase in maximum underground mine groundwater inflow is associated with the increase in the period that longwall mining would occur concurrently in the Woodlands Hill Seam and Arrowfield Seam at the South Wambo Underground Mine to allow underground mining operations to finish within the approved mine life of Wambo. Notwithstanding the above, previous assessments of the approved South Wambo Underground Mine (HydroSimulations 2016, 2017) predicted higher maximum underground mine groundwater inflows of approximately 1,100 ML/year (3 ML/day). These predictions (HydroSimulations 2016, 2017) simulated near-concurrent start dates for extraction from both Woodlands Hill and Arrowfield Seam workings, so the maximum inflow was likely influenced by peak inflow in each seam occurring at a similar time. As is shown in **Figure 7-1**, mining in the Arrowfield seam begins approximately five-years later than mining in the Woodlands Hill seam in this assessment.

7.4 Predicted maximum drawdowns

The process of mining reduces water levels in surrounding groundwater units due to the interception of groundwater in the mined geology. The extent of the zone affected is dependent on the properties of the aquifers/aquitards and is referred to as the zone of drawdown. Aquifer drawdown is greatest at the working coal-face, and generally, gradually decreases with distance from the mining operations.

Incremental drawdown due to the Modification is obtained by comparing the difference in groundwater levels for different aquifers between the Modified and Approved Scenarios. The maximum drawdown is a combination of the maximum drawdown values recorded at each model cell at any time over the duration of the predictive model. Predicted drawdown figures (**Figure 7-2** to **Figure 7-6)** show where maximum incremental drawdown impacts are predicted to exceed 1 m in key hydrogeological units.

Several higher resolution versions of key spatial figures have also been developed to help identify the location and magnitude of predicted incremental drawdowns. The inset extent, where relevant, is displayed on the full extent figure.[2]

Maximum incremental drawdown to the water table is shown in **Figure 7-2** and **Figure 7-2 a**. Incremental drawdown to the water table of approximately 20 m is predicted above the modified Longwalls 24 to 26, with the 1 m drawdown contour extending up to 1.6 km north of the modified Longwalls 24 to 26. Some drawdown impacts to the water table are predicted above the north-eastern ends of the modified SBX Underground Mine where there are shallower depths of cover above the longwalls, and fracture height calculations (Ditton and Merrick, 2014 – see **Section 4.3.1**) indicate surficial strata may be intersected by subsidence related fracturing.

[2] Note: Inset figure numbers are only referenced in the first instance. Relevant figures will display inset extent.

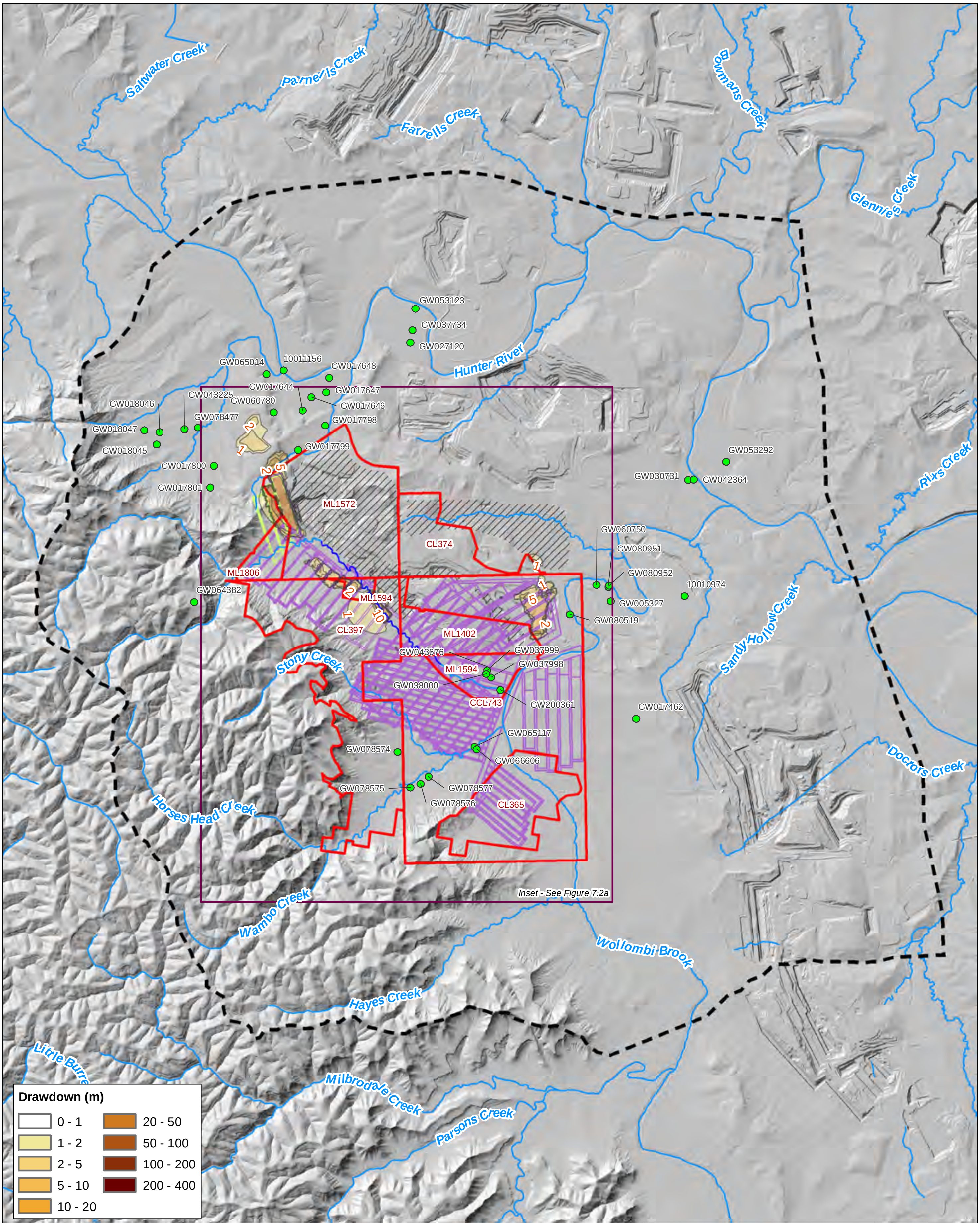
No incremental drawdown impacts are predicted for the alluvium as a result of the Modification (**Figure 7-3** and **Figure 7-3 a**). Conceptually, impacts to the North Wambo Creek alluvium are expected to be less than currently approved, with a smaller area of alluvium directly undermined by the modified SBX Underground Mine compared to the approved SBX Underground Mine. Other alluvial zones associated with larger watercourses (Wambo Creek, Wollombi Brook, Hunter River) are distant enough from the modified SBX Underground Mine that no incremental drawdowns are predicted. This prediction is consistent with HydroSimulations (2017) modelling.

The maximum predicted incremental drawdown associated with the Modification within the target Whybrow Seam is shown in **Figure 7-4** and **Figure 7-4 a**. The drawdown extent within the Whybrow Seam (Layer 7) is influenced by unit structure and is confined to unit extents, meaning that drawdown does not extend east, where the Whybrow Seam has outcropped. The 1 m drawdown influence is predicted to extend up to 3.4 km north-west of the Modification.

Incremental drawdown for the deepest target seams of the South Wambo Underground Mine (Arrowfield Seam – Layer 17) and the UWOCP (Vaux Seam – Layer 27) are displayed in **Figure 7-5 (and Figure 7-5 a**) and **Figure 7-6** respectively. There are no changes in mining extent for the South Wambo Underground Mine and the UWOCP associated with this Modification; only the timing of South Wambo Underground Mine longwall extraction is different.

The apparent incremental drawdown in the Arrowfield Seam (**Figure 7-5**) may be due to the commencement of Arrowfield Seam mining in the modified scenario prior to the approved scenario for the first three longwall panels (LW01E, LW02E, LW03E), before the timing of extraction for both scenarios become similar, or longwalls in the approved scenario are extracted earlier.

No incremental drawdown is predicted for the Vaux Seam (Layer 27) due to the Modification. The timing of UWOCP does not change as a result of the Modification.



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	13-Jul-2022
Drawn by:	ANP

SLR

- Wambo GWMP (2020)
- New Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

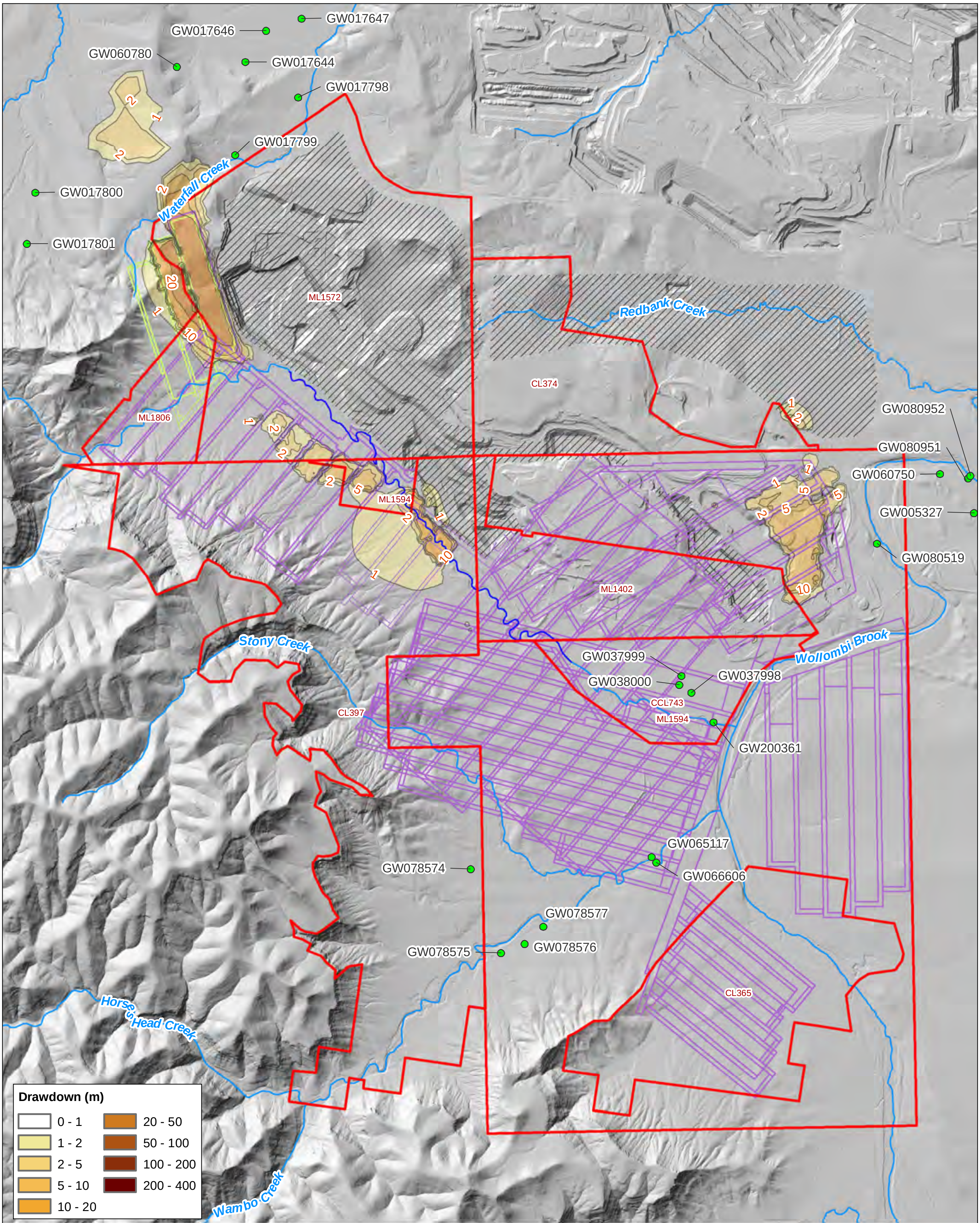
WAMBO LONGWALLS 24-26 MODIFICATION
GROUNDWATER MODELLING
IMPACT ASSESSMENT

Maximum incremental drawdown at the water table

Data Source: NSW SS 2020

FIGURE 7-2

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_2_Max_Incremental_DD_at_WT.mxd



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:55,000 at A4
Project Number:	665.0008.00815
Date:	13-Jul-2022
Drawn by:	ANP

SLR

Wambo GWMP (2020)

New Wambo Model Boundary

Named Watercourse

NWC Diversion

Mining Lease

Proposed LW24-26 Layout

Existing/Approved Underground Development

Approved Open Cut Mining

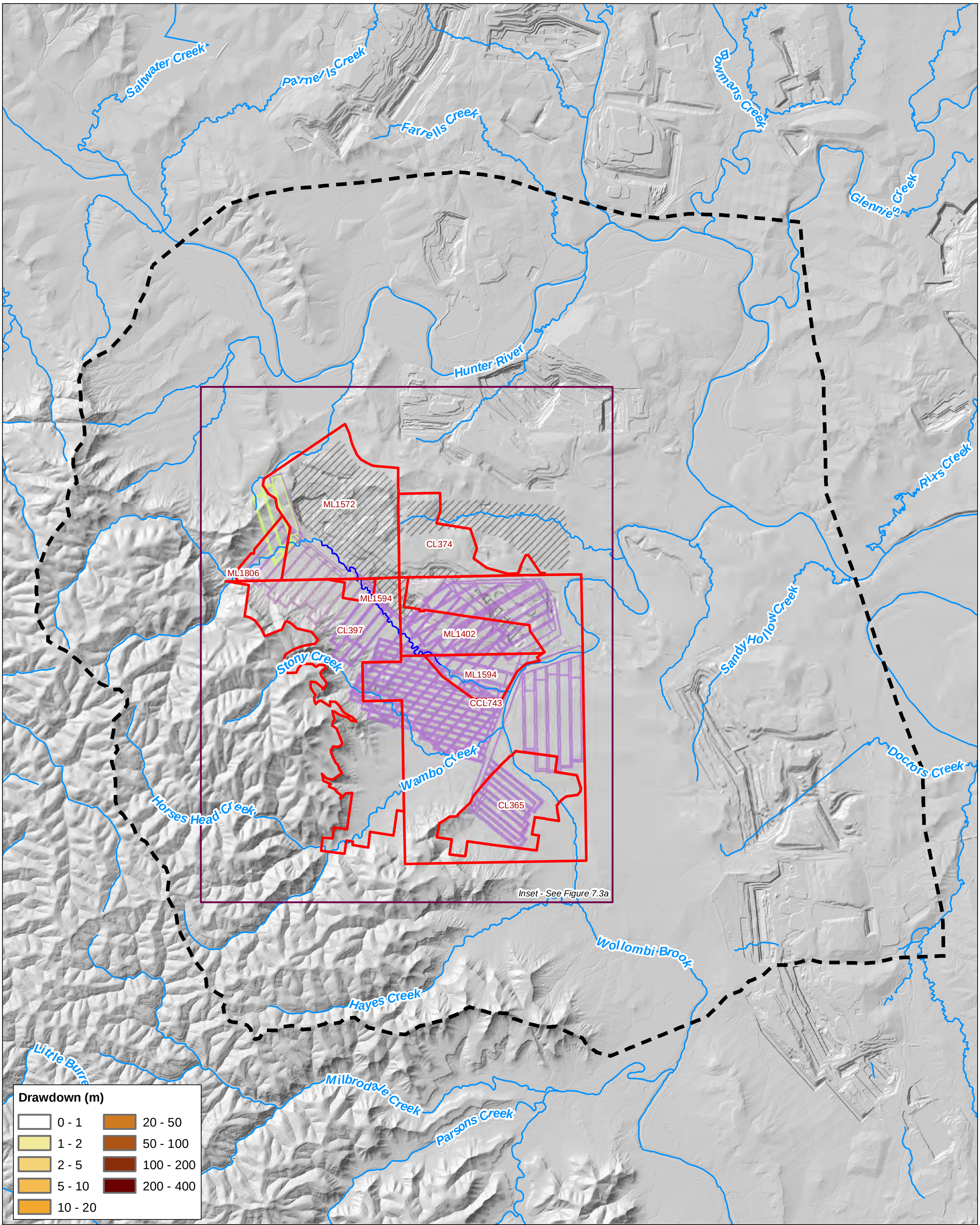
WAMBO LONGWALLS 24-26 MODIFICATION
GROUNDWATER MODELLING
IMPACT ASSESSMENT

Maximum incremental drawdown at the water table - Inset

Data Source: NSW SS 2020

FIGURE 7-2a

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_2a_Max_Incremental_DD_at_WT.mxd



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	10-Jul-2022
Drawn by:	ANP

New Wambo Model Boundary

Named Watercourse

NWC Diversion

Mining Lease

Proposed LW24-26 Layout

Existing/Approved Underground Development

Approved Open Cut Mining

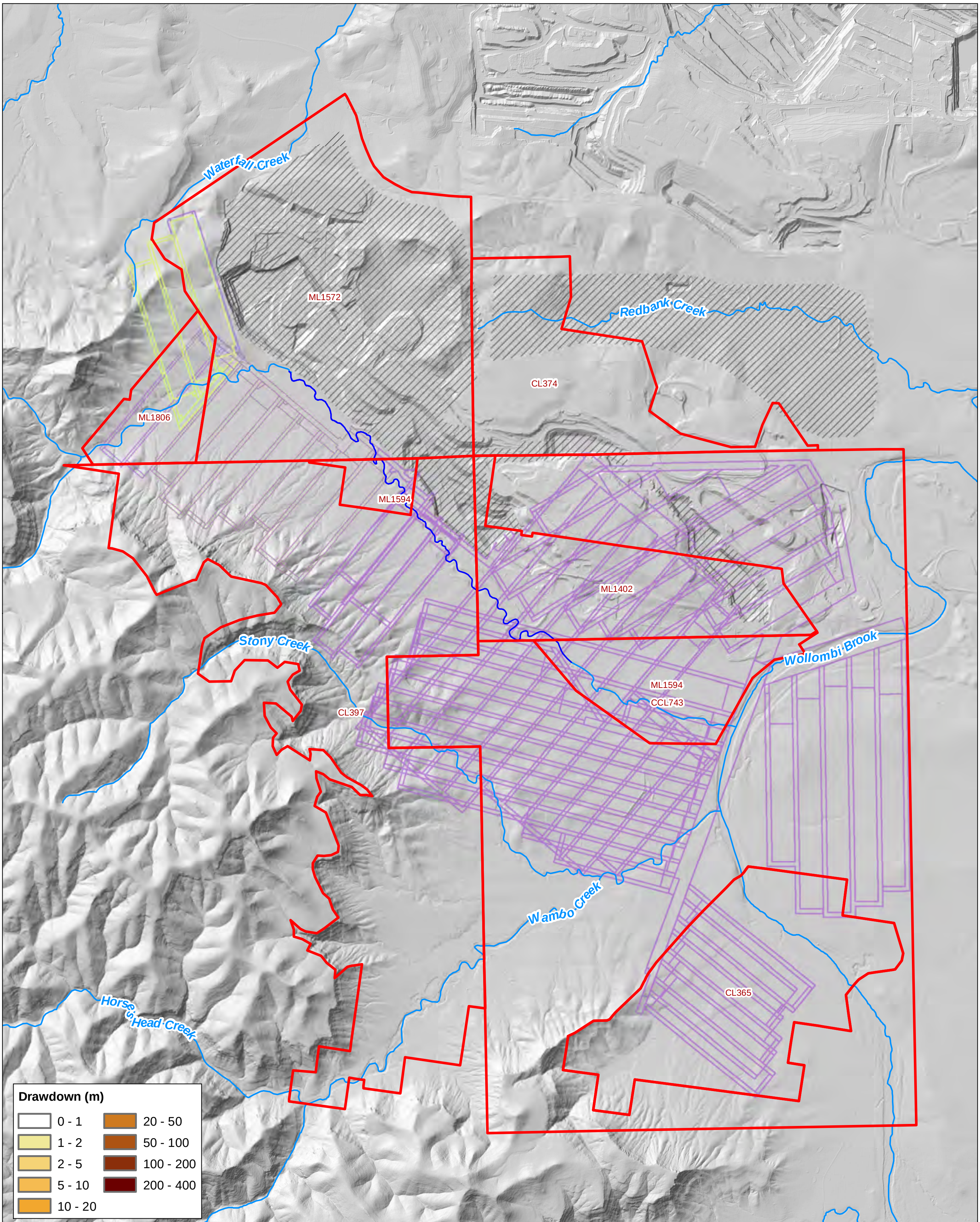
WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Maximum incremental drawdown in alluvium and regolith (layer 1)

Data Source: NSW SS 2020

FIGURE 7-3

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_3_Max_IncrementalDD_Layer_1_End2041.mxd



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:55,000 at A4
Project Number:	665.0008.00815
Date:	10-Jul-2022
Drawn by:	ANP

New Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

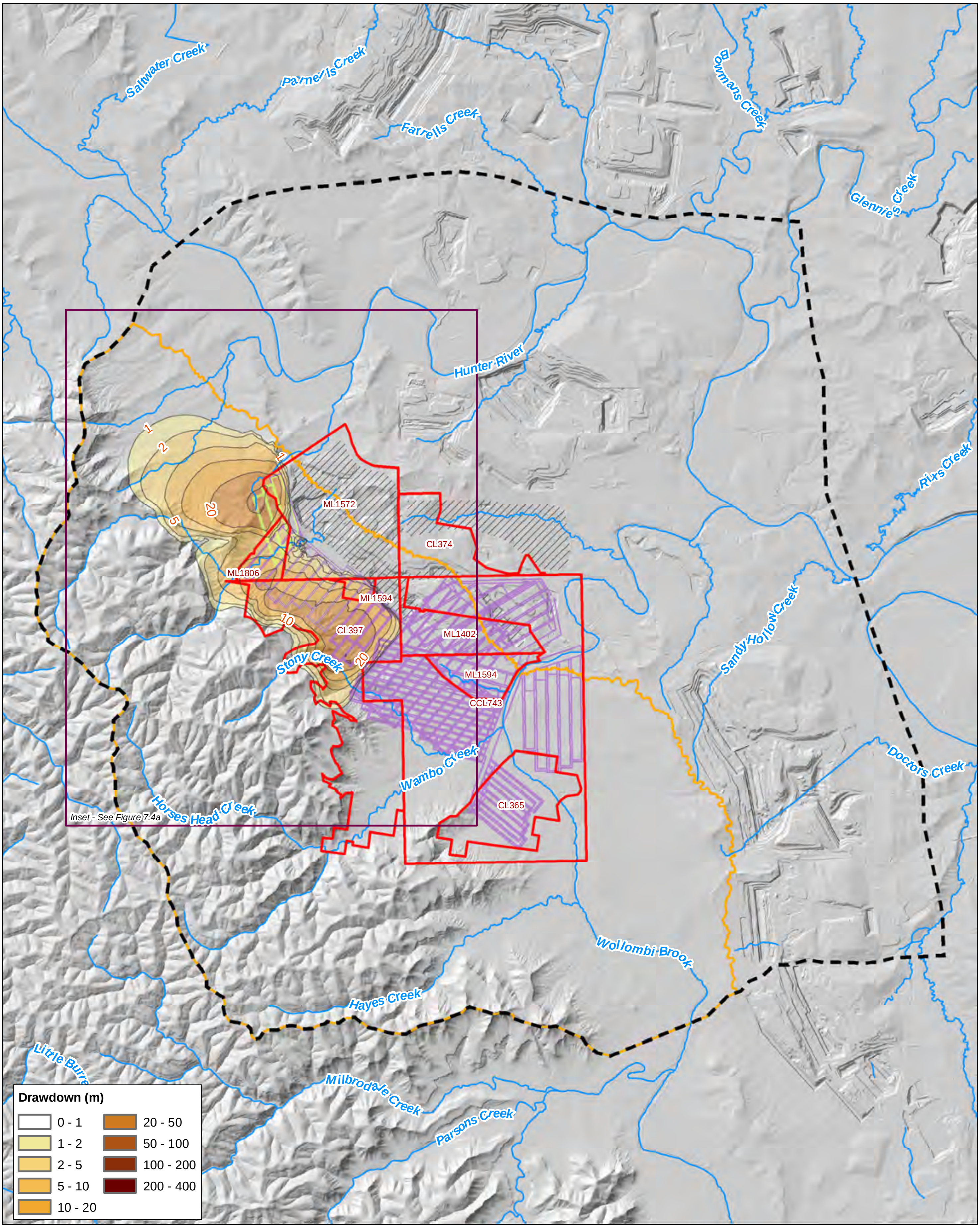
Maximum incremental drawdown in alluvium and regolith (layer 1) - Inset

SLR

Data Source: NSW SS 2020

FIGURE 7-3a

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_3a_Max_IncrementalDD_Layer_1_End2041.mxd



N
0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	10-Jul-2022
Drawn by:	ANP

SLR

- New Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Whybrow Seam Extent (Layer 7)
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

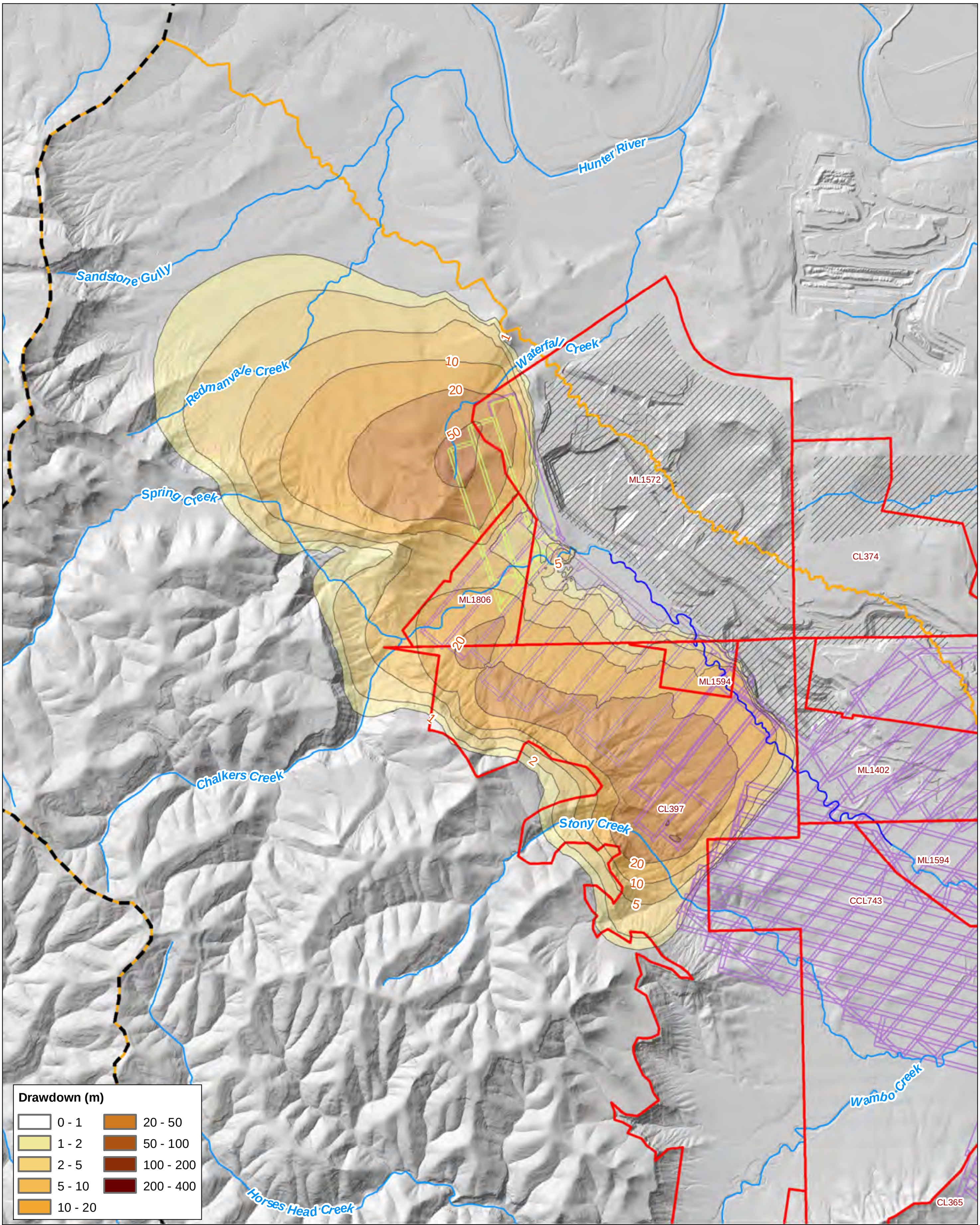
WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Maximum incremental drawdown in Whybrow Seam (layer 7)

Data Source: NSW SS 2020

FIGURE 7-4

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_4_Max_IncrementalDD_Layer_7_End2041.mxd



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:55,000 at A4
Project Number:	665.0008.00815
Date:	10-Jul-2022
Drawn by:	ANP

- New Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Whybrow Seam Extent (Layer 7)
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

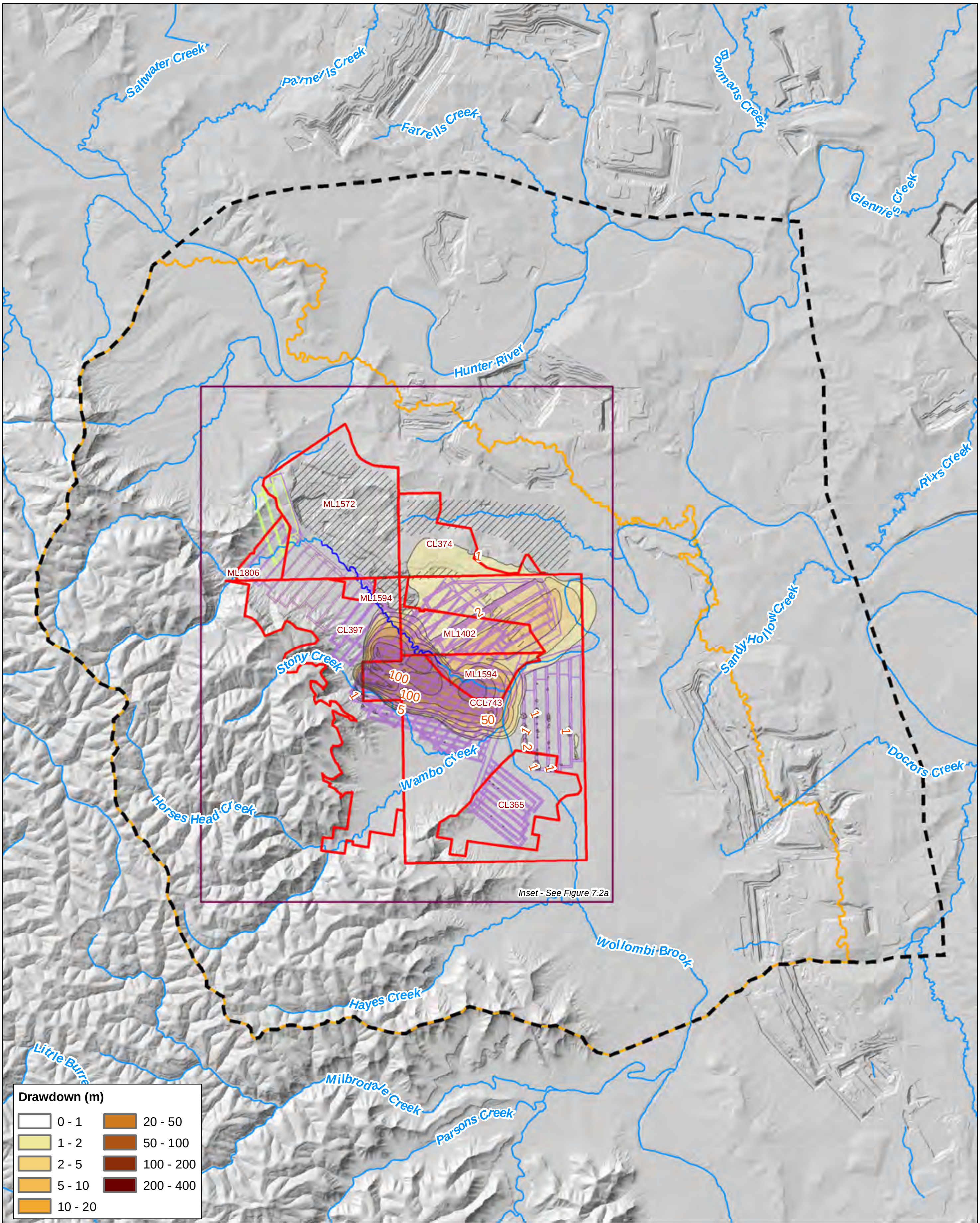
WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Maximum incremental drawdown in Whybrow Seam (layer 7)- Inset

Data Source: NSW SS 2020

FIGURE 7-4a

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_4a_Max_IncrementalDD_Layer_7_End2041.mxd



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	10-Jul-2022
Drawn by:	ANP

New Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Arrowfield Seam Extent (Layer 17)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

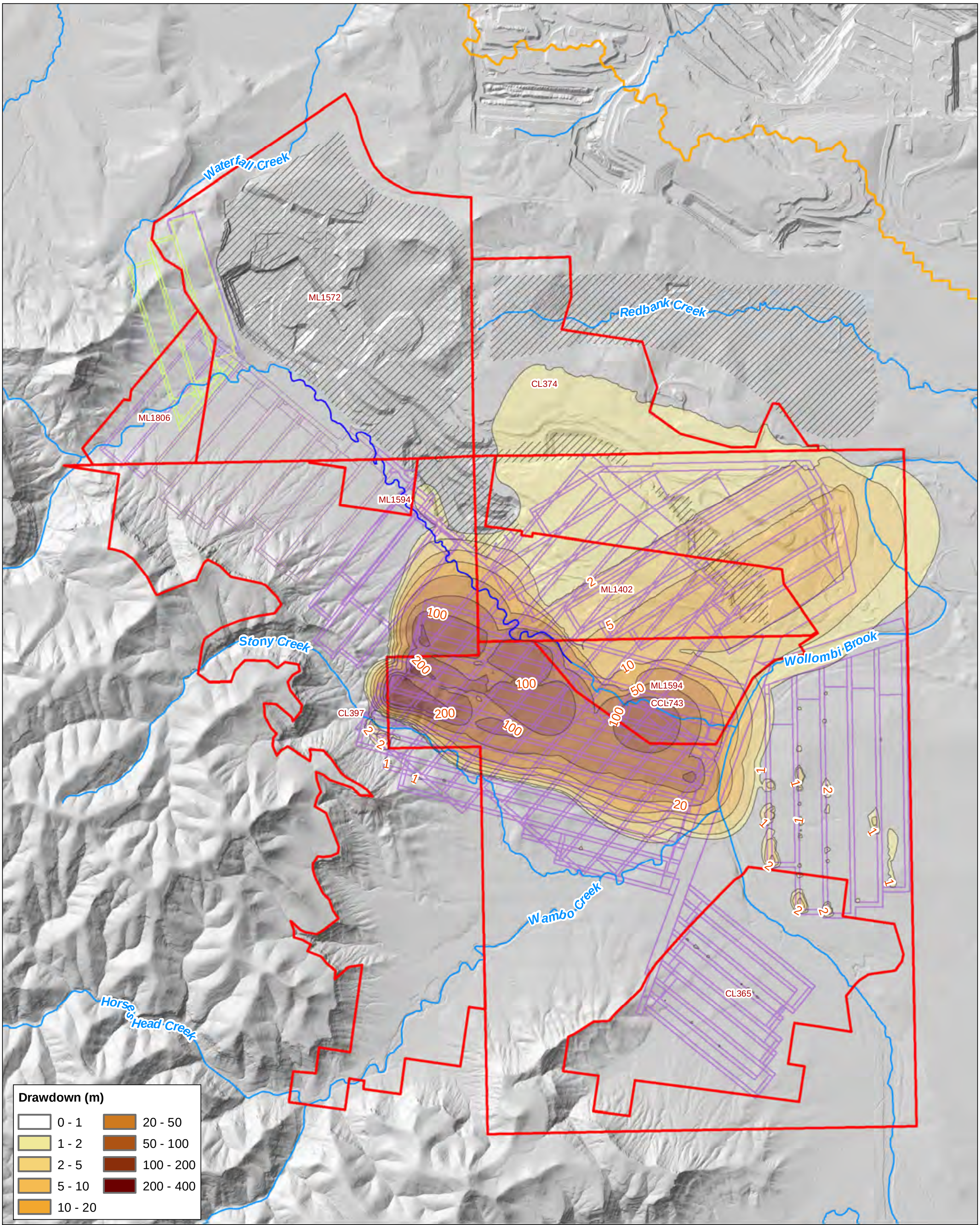
Maximum incemental drawdown in Arrowfield Seam (layer 17)

SLR

Data Source: NSW SS 2020

FIGURE 7-5

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_5_Max_IncrementalDD_Layer_17_End2041.mxd



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0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:55,000 at A4
Project Number:	665.0008.00815
Date:	10-Jul-2022
Drawn by:	ANP

New Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Arrowfield Seam Extent (Layer 17)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

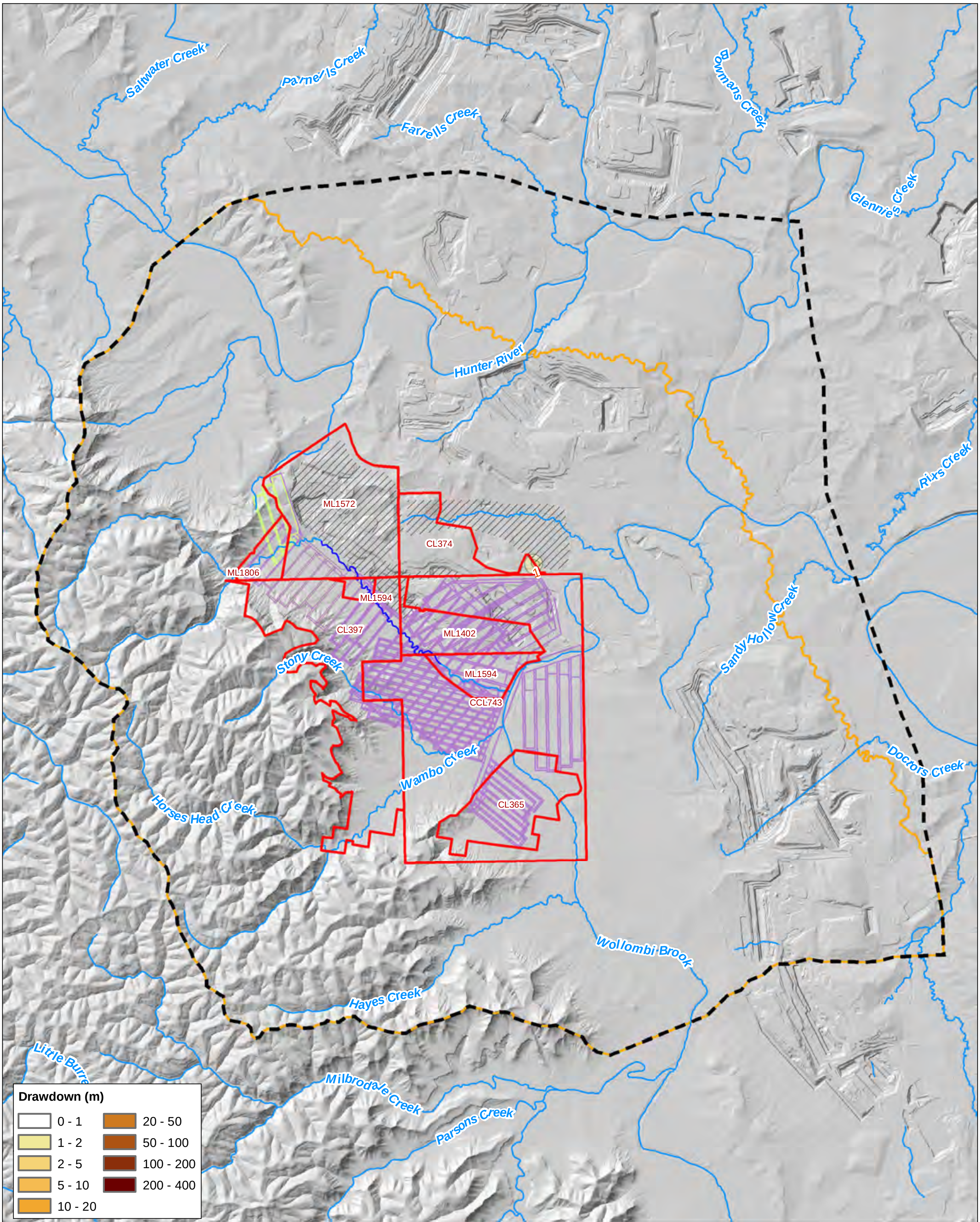
WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Maximum incemental drawdown in Arrowfield Seam (layer 17) - Inset

SLR

Data Source: NSW SS 2020

FIGURE 7-5a



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	ANP

New Wambo Model Boundary

Named Watercourse

NWC Diversion

Mining Lease

Vaux Seam Extent (Layer 27)

Proposed LW24-26 Layout

Existing/Approved Underground Development

Approved Open Cut Mining

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Maximum incremental drawdown in Vaux Seam (layer 27)

SLR

Data Source: NSW SS 2020

FIGURE 7-6

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_6_Max_IncrementalDD_Layer_27_End2041.mxd

7.5 Incidental water impacts

7.5.1 Influence on alluvium

There is no direct interception of the alluvium, including that associated with North Wambo Creek, by the approved or modified SBX Underground Mine operations. Any predicted interference of alluvial groundwater therefore largely relates to the depressurisation of the underlying Permian coal measures resulting in the potential for increased leakage from the alluvium to the Permian coal measures, or decreased flow from the Permian coal measures to the alluvium.

It is conceptualised for there to be a reduction in mining induced flux change in North Wambo Creek alluvium upstream of the creek diversion due to the Modification, with the modified SBX Underground Mine longwalls directly underlying a smaller area of North Wambo Creek alluvium than the approved SBX Underground Mine longwalls. North Wambo Creek downstream of the diversion, Wambo Creek and Wollombi Brook alluvium are conceptualised to show minor, temporary incremental differences between the approved and modification scenarios due to differences in South Wambo Underground Mine scheduling.

Over the extent of alluvium near Wambo, the model predicts a low magnitude, short-term decrease in leakage of water (less impact) from the North Wambo Creek, Wambo Creek and Wollombi Brook alluvium due to the Modification (from 2023, peaking 2029-2031), before this effect declines to the end of mining (**Figure 7-7**). There is negligible effect predicted for the Hunter River alluvium due to the Modification.

A maximum decrease of approximately 50 cubic metres per day (m^3/day) mining induced baseflow change is predicted in the Wollombi Brook alluvium due to the Modification relative to the approved Wambo, while maximum decreases of 21 m^3/day and 5 m^3/day are predicted for Wambo Creek alluvium and North Wambo Creek alluvium, respectively. It is noted that these reductions occur during the South Wambo Underground Mine operations, and not during SBX Underground Mine operations.

As the timing of longwall extraction is the only difference between the Approved and Modification scenario for the South Wambo Underground Mine, timing and the extended duration of concurrent mining is likely driving the apparent reduction in mining induced flux change.

There is no alluvium mapped at Waterfall Creek, and the model predicts Layer 1 representing alluvium and regolith to be unsaturated at Waterfall Creek near the modified Longwalls 24 to 26. No flux changes due to the Modification are therefore predicted for the surficial groundwater system at Waterfall Creek.

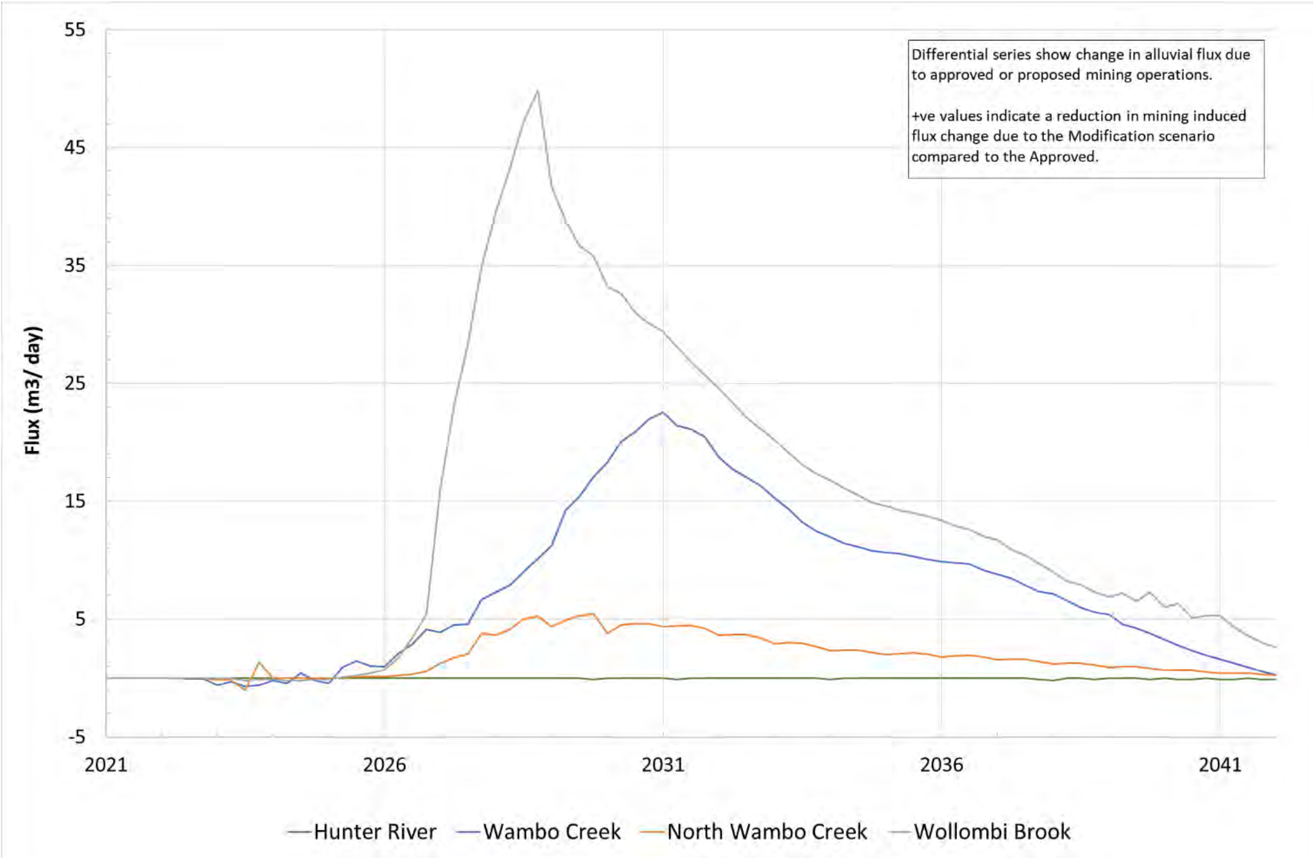


Figure 7-7 Incremental alluvial flux change between Modified and Approved Scenarios

7.5.2 Influence on baseflow

The predicted change in water levels induced by mining could increase the hydraulic gradient between surface water flow in nearby watercourses and the underlying alluvium. As outlined within the conceptual model (**Section 6.7**), ephemeral watercourses near Wambo (North Wambo Creek and Wambo Creek) may be losing systems during peak flow periods and gaining systems following these peak flow events when there is sufficient alluvial saturation. Semi-perennial (Wollombi Brook) and perennial (Hunter River) watercourse are predominantly gaining systems (receiving groundwater) (see **Section 4.2**), although there are also areas where the river recharges the underlying alluvium (losing environment), particularly in high flow events.

Infrequent periods of flow identified in recent surface water sampling events (2019 to 2021) at Waterfall Creek are not consistent with ongoing periods of groundwater discharge (baseflow) to Waterfall Creek (see **Section 4.2.1.2**). While some leakage from Waterfall Creek to underlying unconsolidated strata will occur during infrequent flow events, this is currently conceptualised to be a minor contribution to the groundwater system, and Waterfall Creek is set up in the model with a stage height of 0.0 m. This means it is simulated as a potentially gaining system only (i.e., negative net flow).

As described in **Section 7.2.1** the predictive modelling does not simulate episodic periods of flow in ephemeral watercourses and will only report gaining conditions. Wollombi Brook and the Hunter River utilise long-term quarterly average stage heights throughout the prediction period.

Figure 7-8 provides incremental flux change at watercourses near Wambo due to the Modification. This is calculated by taking the difference in net flux from the MODFLOW RIV package between the modified and approved scenarios. It is noted that the model predicts no interaction between the surface water and groundwater system at Waterfall Creek for any model scenario, and therefore has not been included in **Figure 7-8**. Similar to predictions for alluvial fluxes (see **Section 7.5.1**), the Modification is predicted to not decrease baseflow to, or increase leakage from watercourses near Wambo. Instead, an increase in net flux is predicted for Wambo Creek, Wollombi Brook and the Hunter River, with the increase predicted to be an increase in baseflow or reduction in leakage (less impact). As discussed in **Section 7.5.1** this temporary reduction in predicted impacts is likely driven by the earlier start of South Wambo Underground Mine in the approved scenario. No change in net flux is predicted for North Wambo Creek due to the Modification.

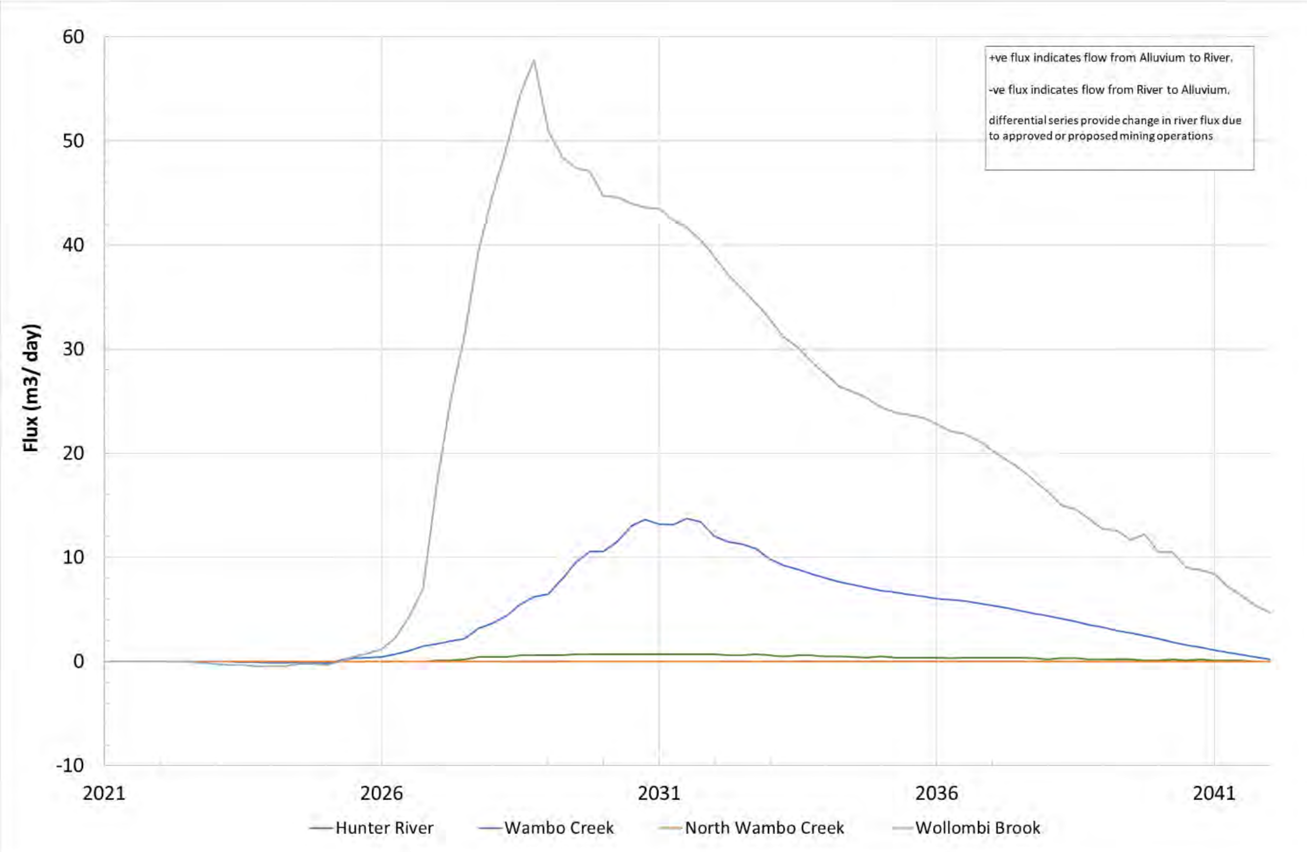


Figure 7-8 Incremental RIV flux change

7.6 Cumulative impacts

Cumulative impacts associated with Wambo (including the Modification) and approved and foreseeable open cut and underground coal mines in the Wambo area were modelled in accordance with IESC requirements (refer IESC, 2018a). The simulated cumulative drawdown predictions due to Wambo and UWOCP mining presented in this section show the impacts on different aquifers due to the existing approved works and entitlements within the model domain. As described in **Section 7.2**, cumulative impacts are evaluated by comparing the Modification and Null predictive modelling scenarios.

The simulated cumulative drawdown predictions also show whether the zone of impact from the approved Wambo is predicted to interact with the zone of impact from the Modification in the different aquifers. **Figure 7-9** to **Figure 7-13** show the maximum cumulative drawdown for key stratigraphic units, with cumulative drawdown determined by comparing the Modification model scenario with the Null scenario (i.e. no Wambo/Untied Collieries/UWOCP mining from 2003).

Several higher resolution versions of key spatial figures have also been developed to help identify the location and magnitude of predicted cumulative drawdowns. The inset extent, where relevant, is displayed on the full extent figure.[3]

Figure 7-9 shows predicted cumulative maximum water table drawdown. Depending on the depth to water table across the model domain, this drawdown may be experienced in surficial (layer 1) or shallow weathered strata (layer 2), or within the Permian coal measures in more elevated areas away from drainage lines. The largest water table drawdowns are experienced in areas of open cut mining, and where there are shallower depths of cover above the longwalls and fracture height calculations (Ditton and Merrick, 2014 – see **Section 4.3.1**) indicate surficial strata may be intersected by subsidence related fracturing (e.g. the north-eastern ends of the approved SBX Underground Mine longwalls).

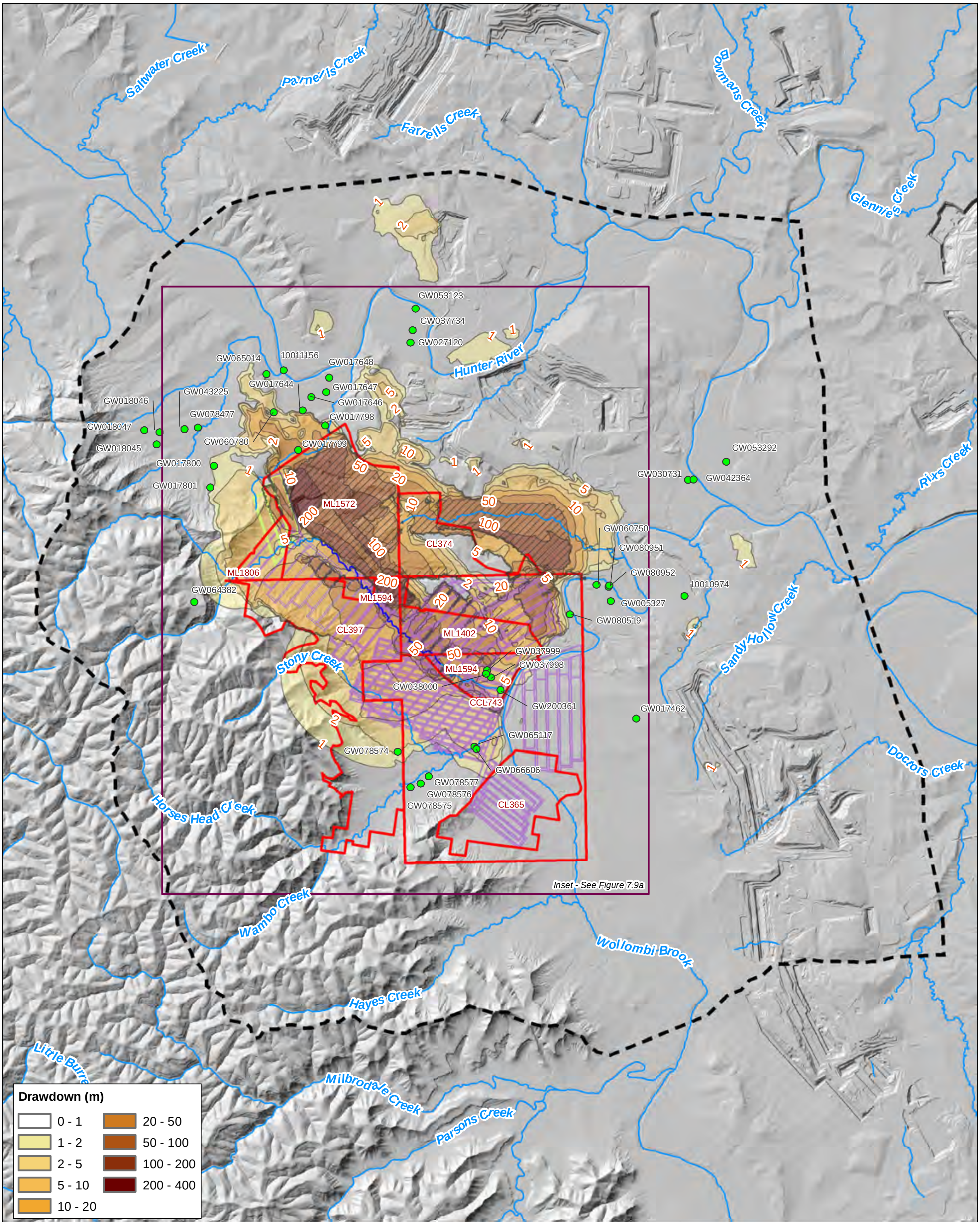
Figure 7-10 and **Figure 7-10 a** show that maximum cumulative drawdown within mapped Quaternary alluvium extends along Wollombi Brook, and ephemeral creeks near Wambo. The most significant areas of modelled drawdown are within North Wambo Creek where it has been mined-out by the Montrose open cut, and the confluence of North Wambo Creek and Wollombi Brook.

Figure 7-11 and **Figure 7-11 a** show maximum cumulative drawdown within the Whybrow Seam, the target seam of approved and modified SBX Underground Mine. As with drawdown due to the Project, cumulative drawdown extends northwest and southeast along the strike of the Whybrow Seam.

Figure 7-12 shows the maximum cumulative drawdown within the Arrowfield Seam, the deepest target seam of the South Wambo Underground Mine. Drawdown within this seam is largest at the mine footprint, extends 4 km northwest and 2.5 km southeast of Wambo.

Figure 7-13 shows the maximum cumulative drawdown within the Vaux Seam, the deepest target seam of the UWOCP. Drawdown within this seam is largest at the UWOCP, where the Vaux Seam is mined. Drawdown extends 2.3 km northwest and 4.4 km southeast of Wambo.

[3] Inset figure numbers are only referenced in the first instance. Relevant figures will display inset extent.



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	10-Jul-2022
Drawn by:	ANP

SLR

- Wambo GWMP (2020)
- New Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

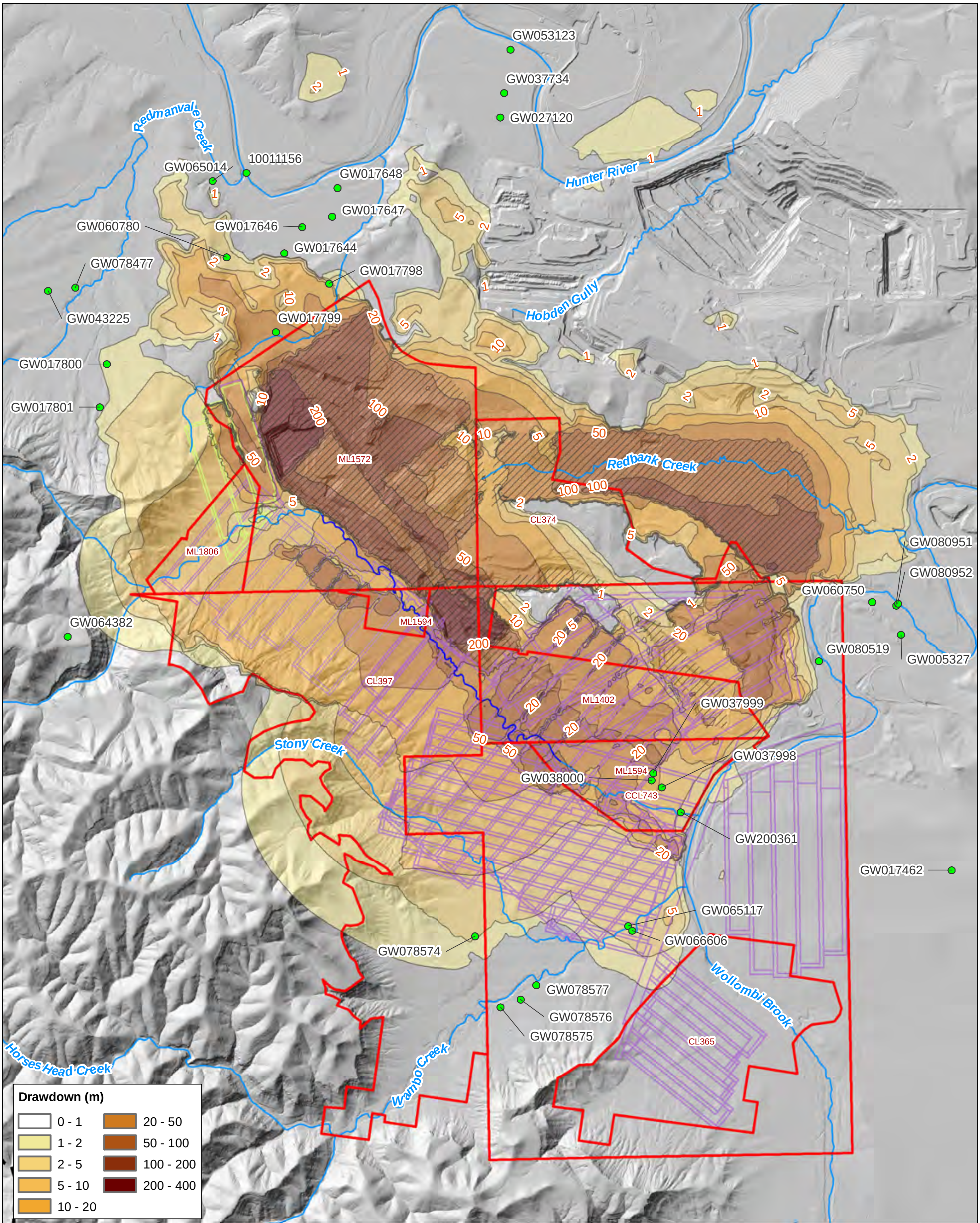
Data Source: NSW SS 2020

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Maximum cumulative drawdown at the water table

FIGURE 7-9

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_9_Max_Cumulative_DD_at_WT.mxd



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:65,000 at A4
Project Number:	665.0008.00815
Date:	13-Jul-2022
Drawn by:	ANP

SLR

- Wambo GWMP (2020)
- New Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

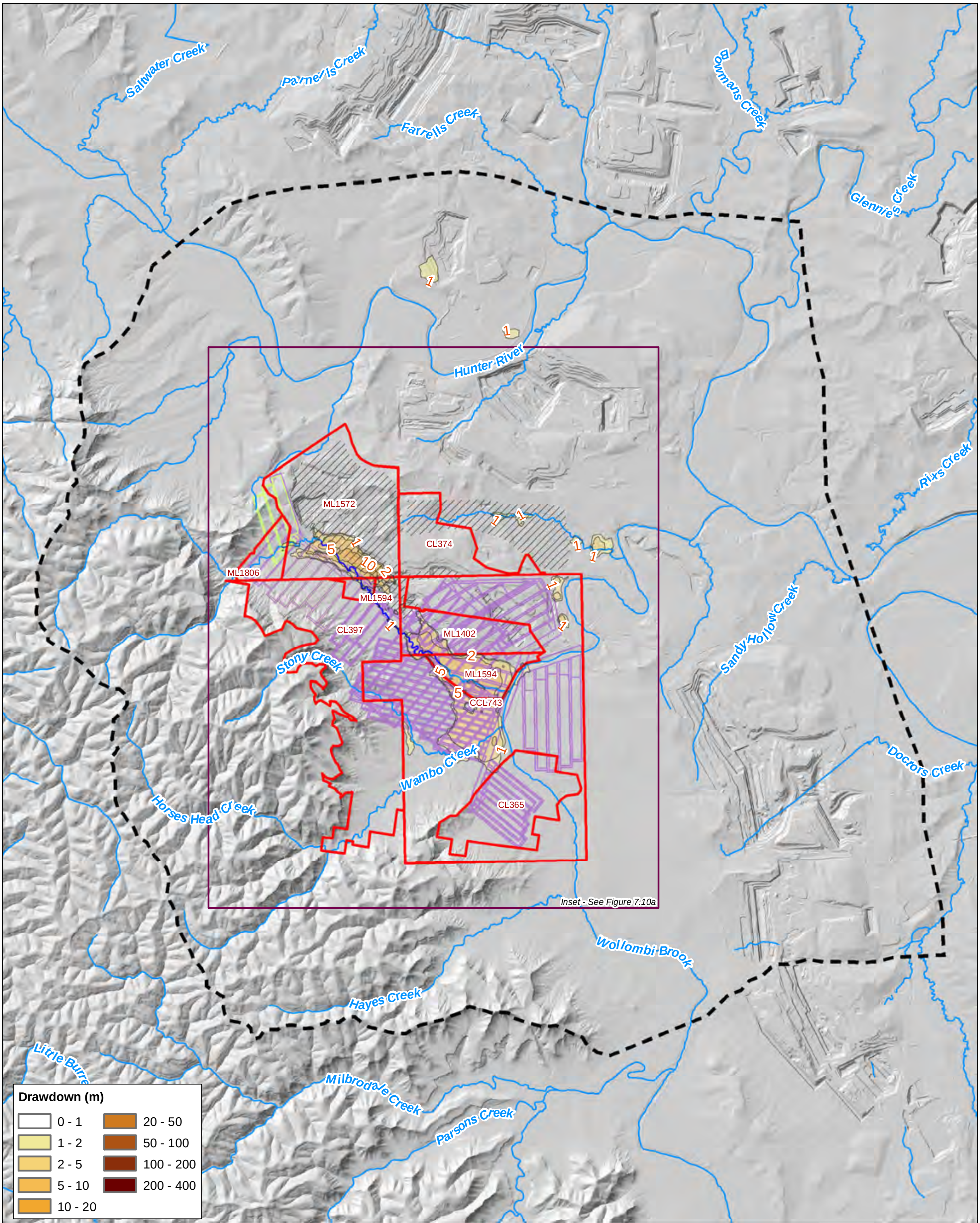
WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Maximum cumulative drawdown at the water table - Inset

Data Source: NSW SS 2020

FIGURE 7-9a

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_9a_Max_Cumulative_DD_at_WT.mxd



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	10-Jul-2022
Drawn by:	ANP

New Wambo Model Boundary

Named Watercourse

NWC Diversion

Mining Lease

Proposed LW24-26 Layout

Existing/Approved Underground Development

Approved Open Cut Mining

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

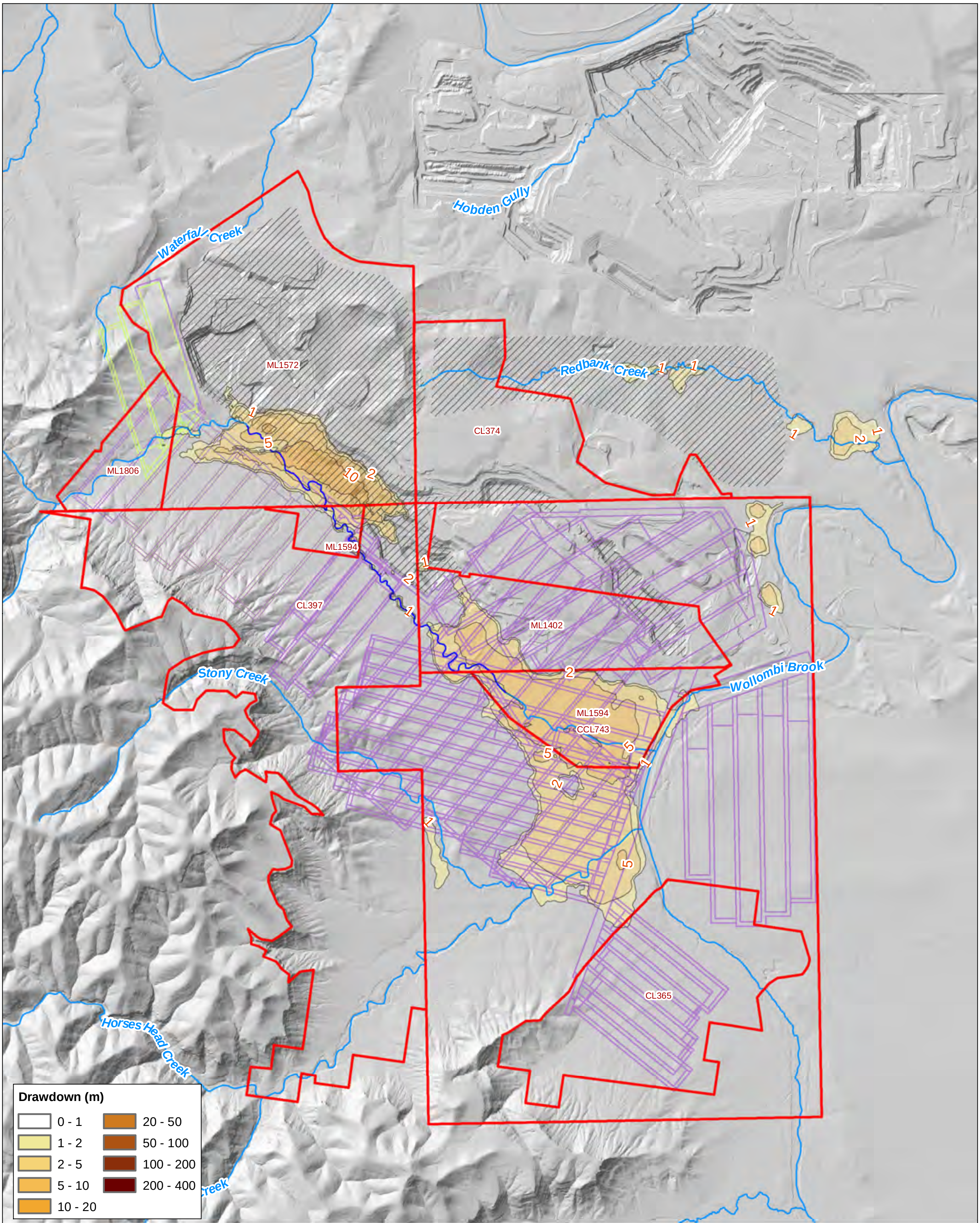
Maximum cumulative drawdown in alluvium and regolith (layer 1)

SLR

Data Source: NSW SS 2020

FIGURE 7-10

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_10_Max_CumulativeDD_Layer_1_End2041.mxd



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:60,000 at A4
Project Number:	665.0008.00815
Date:	10-Jul-2022
Drawn by:	ANP

New Wambo Model Boundary

Named Watercourse

NWC Diversion

Mining Lease

Proposed LW24-26 Layout

Existing/Approved Underground Development

Approved Open Cut Mining

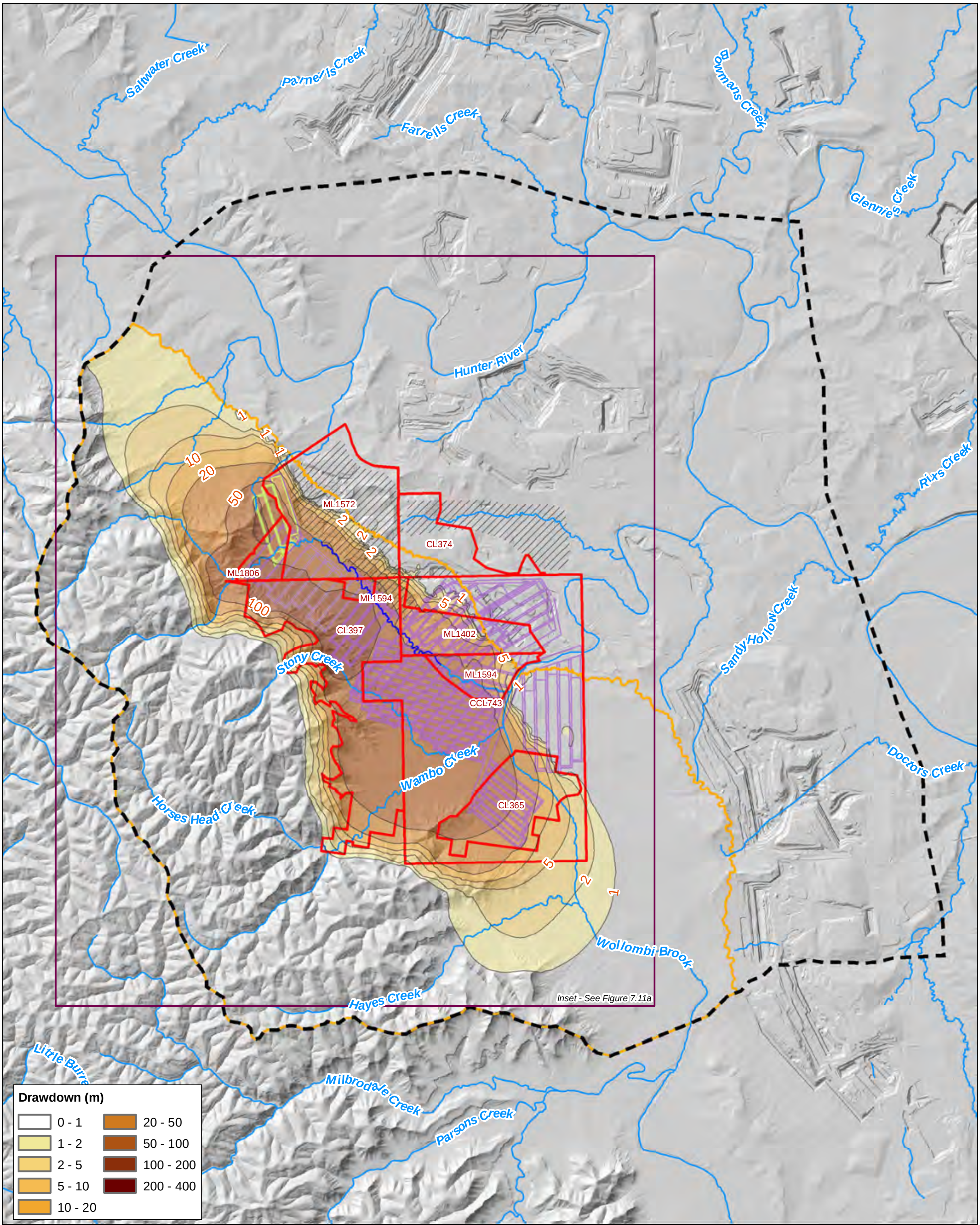
Data Source: NSW SS 2020

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Maximum cumulative drawdown in alluvium and regolith (layer 1) - Inset

FIGURE 7-10a

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_10a_Max_CumulativeDD_Layer_1_End2041.mxd



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	10-Jul-2022
Drawn by:	ANP

New Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Whybrow Seam Extent (Layer 7)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

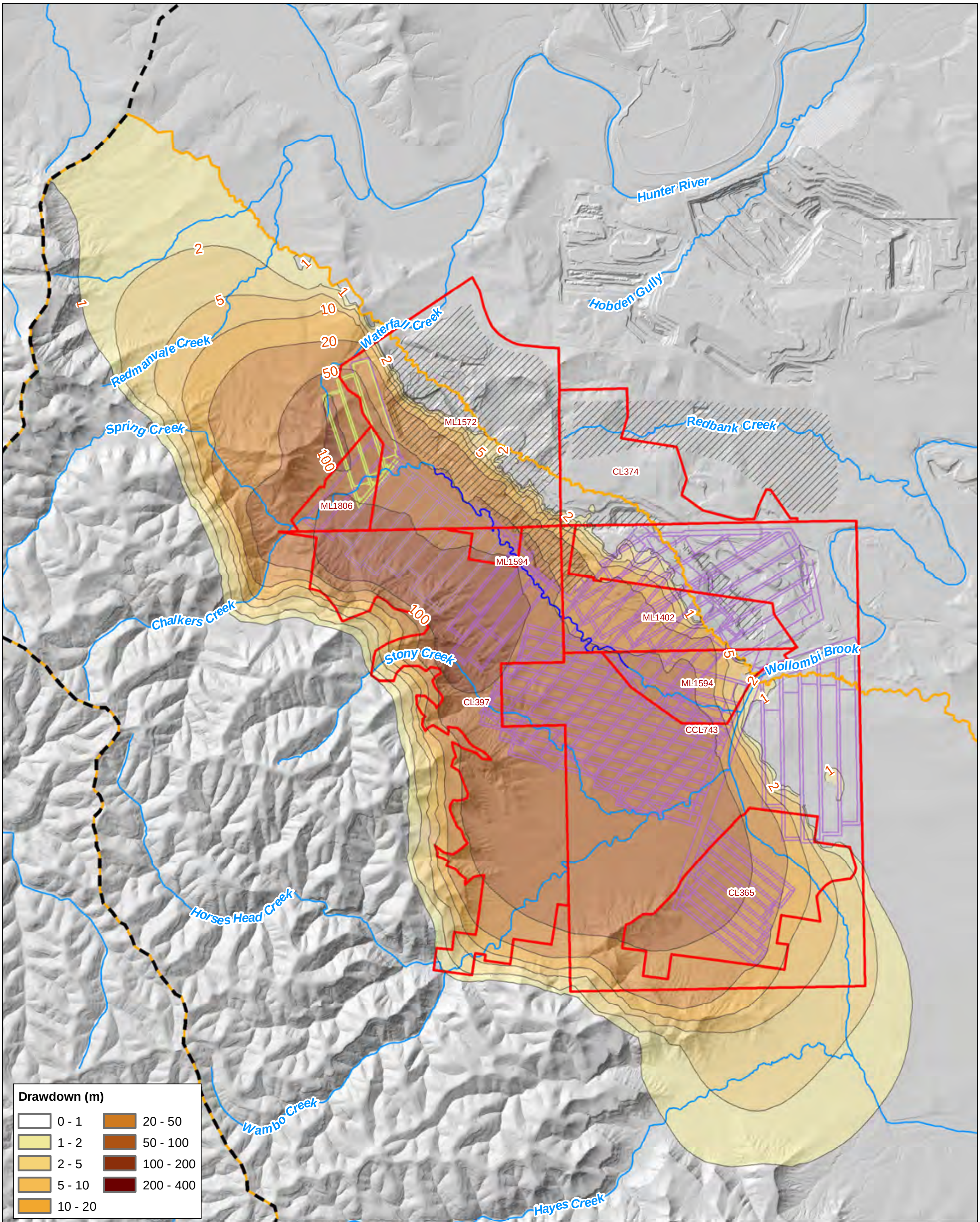
WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Maximum cumulative drawdown in Whybrow Seam (layer 7)

Data Source: NSW SS 2020

FIGURE 7-11

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_11_Max_CumulativeDD_Layer_7_End2041.mxd



0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:80,000 at A4
Project Number:	665.0008.00815
Date:	10-Jul-2022
Drawn by:	ANP

New Wambo Model Boundary

Named Watercourse

NWC Diversion

Mining Lease

Whybrow Seam Extent (Layer 7)

Proposed LW24-26 Layout

Existing/Approved Underground Development

Approved Open Cut Mining

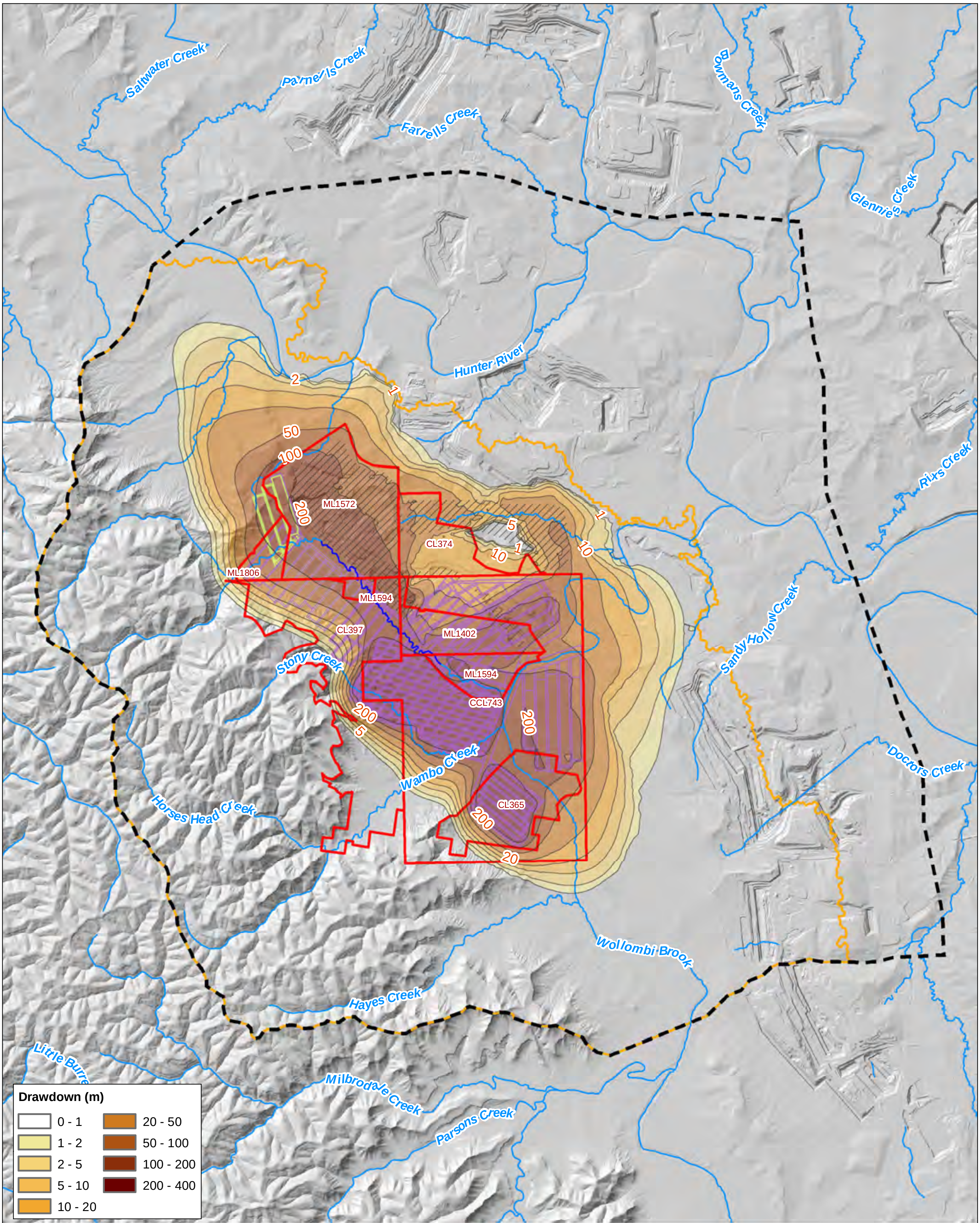
WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Maximum cumulative drawdown in Whybrow Seam (layer 7) - Inset

Data Source: NSW SS 2020

FIGURE 7-11a

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_11a_Max_CumulativeDD_Layer_7_End2041.mxd



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N

0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	ANP

- New Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Arrowfield Seam Extent (Layer 17)
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

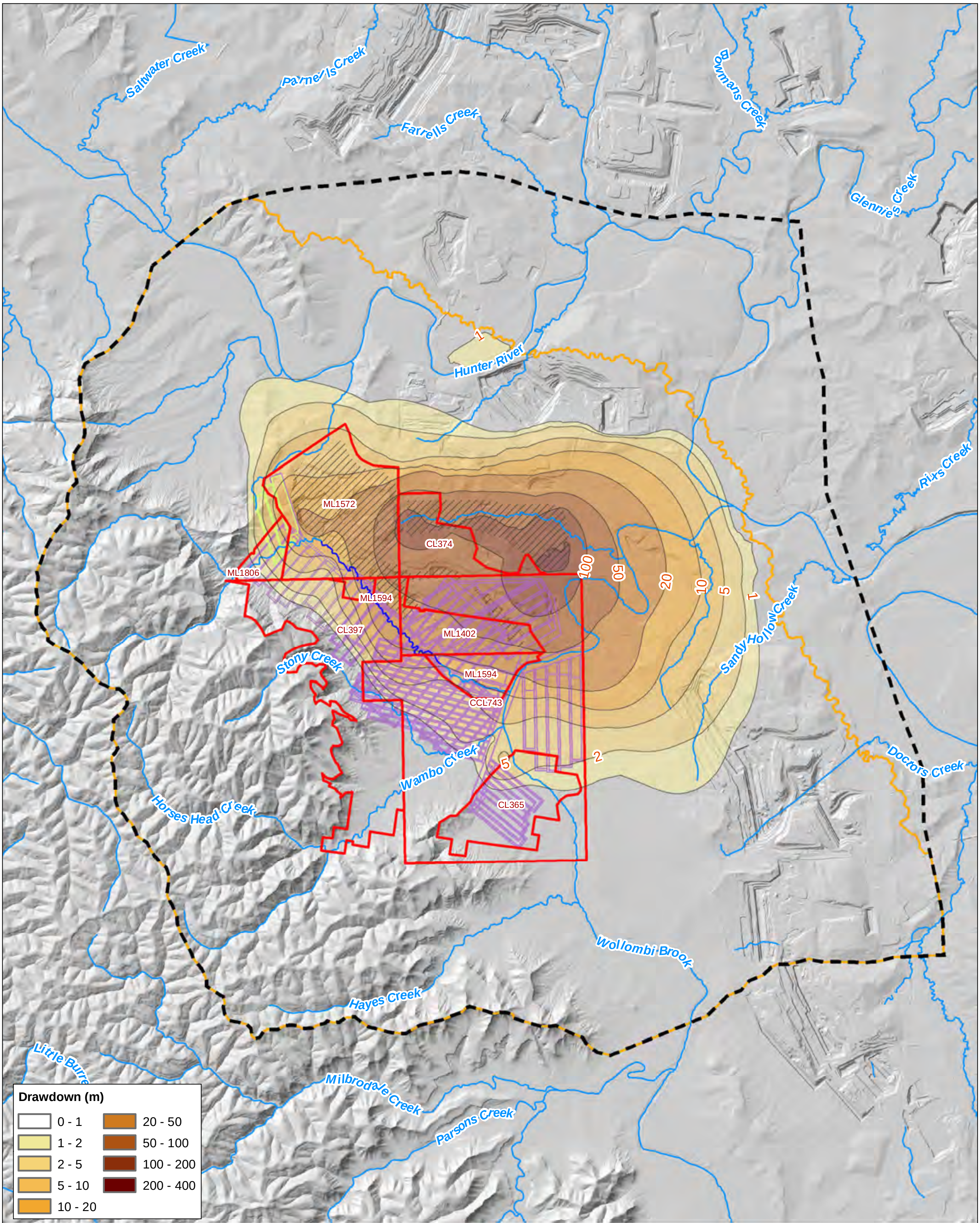
WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Maximum cumulative drawdown in Arrowfield Seam (layer 17)

SLR

Data Source: NSW SS 2020

FIGURE 7-12



N

0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	ANP

- New Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Vaux Seam Extent (Layer 27)
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Maximum cumulative drawdown in Vaux Seam (layer 27)

SLR

Data Source: NSW SS 2020

FIGURE 7-13

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_13_Max_CumulativeDD_Layer_27_End2041.mxd

7.6.1 Drawdown at privately owned registered bores

Locations of relevant privately owned registered bores in the vicinity of Wambo and the predicted incremental water table drawdown associated with the Modification are presented in **Figure 7-2** .

Figure 7-9 shows the cumulative water table drawdown associated with the Wambo (including the Modification) and relevant privately-owned registered bores.

Table 7-4 presents a summary of relevant privately-owned registered bores near Wambo including predicted cumulative and incremental drawdown associated with the Modification. Of the private bores near Wambo, none are predicted to exceed a drawdown of 2 m. Predicted incremental and cumulative impacts at all relevant registered bores near Wambo are presented in the *Groundwater Modelling Technical Report* (**Appendix D**).

Table 7-4 Predicted drawdown effects at privately owned registered bores

Work No. (bore ID)	Location (GDA94 z56)		Use	Measured Depth to Water (mbgl)	Depth (mbgl)	Predicted Drawdown (m)	
	mE	mN				Incremental[1]	Cumulative[2]
GW043225	303653	6398949	Irrigation	15.1 (2022)	24.7	0.0	0.0
GW064382	303908	6394477	Stock/ domestic		60	0.0	0.1
GW078477	304007	6398988	Domestic	11.05 (2015)	102.5	0.0	0.1
GW078574	309174	6390605	Farming		12	0.0	1.3
GW078575	309505	6389687	Farming		12	0.0	0.4
GW078576	309764	6389784	Farming		7	0.0	0.0
GW078577	309969	6389973	Domestic		10	0.0	0.3

[1] Incremental drawdown is evaluated by comparing the Modification and Approved predictive model scenarios (**Section 7.2**)
[2]Cumulative drawdown is evaluated by comparing the Modification and Null predictive model scenarios (**Section 7.2**)

7.7 Uncertainty analysis

A Type 3 Monte Carlo uncertainty analysis (IESC, 2018b) was undertaken to estimate the uncertainty in the future impacts predicted by the model. This method operates by generating numerous alternative sets of input parameters to the deterministic groundwater flow model (realisations), executing the model independently for each realisation, and then aggregating the results for statistical analysis.

The first step in Monte Carlo analysis is to define the parameter distribution and range. For this assessment, the parameters are assumed to be log-normally distributed around the optimum value derived from the calibration and the standard deviation attributed to the log (base 10) of parameter is 0.5. This means that 95% of selected parameter values will lie within one order of magnitude either side of the initially calibrated value. The distribution for each parameter were checked and constrained such that upper or lower ranges do not go beyond ranges in literature for physical constraints. Two thousand model realisations were generated, each having differing values of key parameters. The realisations were run, and calibration quality was assessed. In this case, models were considered to have an acceptable calibration if they achieved an SRMS less than 6.5% (i.e. about 10 % above calibration SRMS of 5.9%). Of the 2000 model runs, 113 model runs were found to meet the above criteria. These were used in all model scenarios (calibration, Modification, Approved, and Null) and statistically analysed for uncertainty.

7.7.1 Number of realisations

As discussed above, 113 realisations met the calibration criteria and were selected as calibrated realisations. The predictive model was run using the 113 parameters sets. The results from the predictive model were used to conduct statistical analyses to assess if additional realisations were likely to provide results that would significantly change the reported predictive results. The 95% confidence interval was calculated for the mine groundwater inflows and the maximum drawdown.

Figure 7-14 and **Figure 7-15** show the 95% confidence intervals of the median and maximum drawdown and predicted inflows, as well as the variance of the median and maximum drawdown and predicted inflows as more realisations are added to the uncertainty analysis. For example, the 95% confidence interval for the maximum drawdown is calculated by first estimating the maximum drawdown for each realisation and then calculating the 95% confidence interval of the maximum drawdowns as each realisation is added to the dataset. As shown in **Figure 7-14** and **Figure 7-15**, additional realisations are unlikely to significantly increase or decrease the confidence intervals of predictions of mine inflows and maximum drawdowns. Therefore, the results from the 113 realisations are considered representative and used for predicted drawdown and indirect water take (alluvium and surface water).

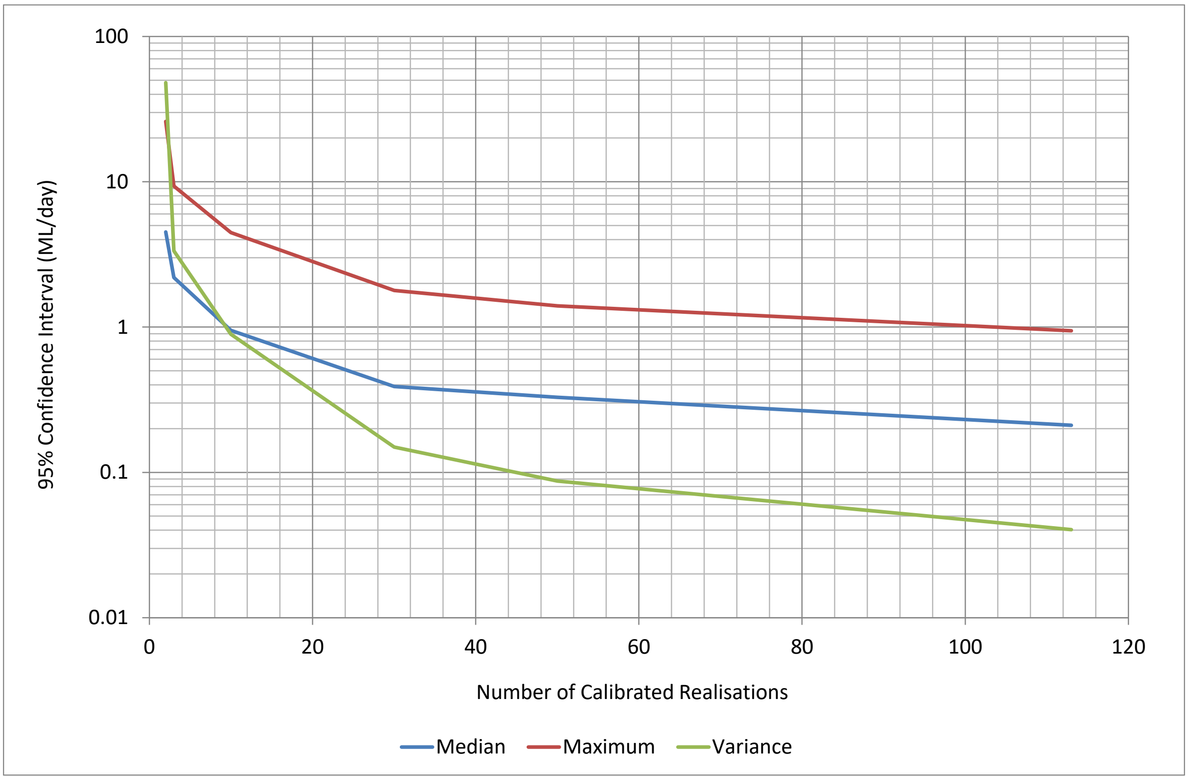


Figure 7-14 95% confidence interval for mine inflows

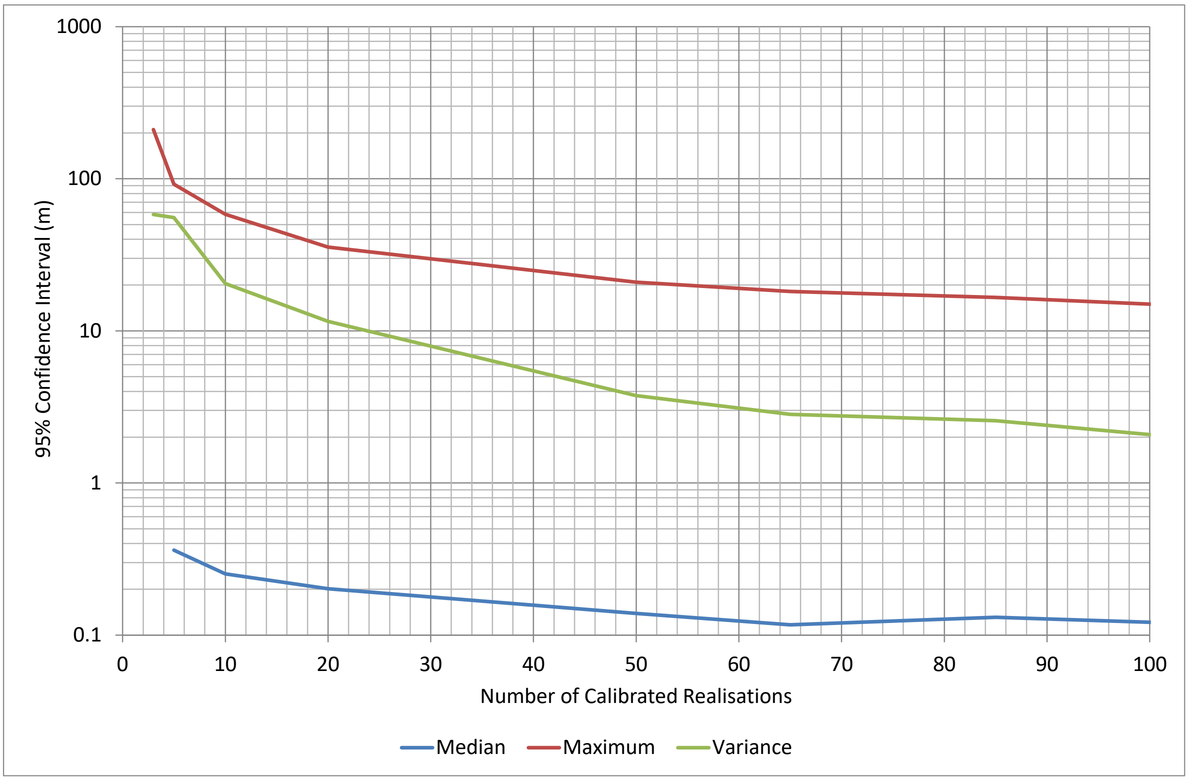


Figure 7-15 95% Confidence Interval for Maximum Drawdowns

7.7.2 Uncertainty of SBX Underground Mine groundwater inflows

Figure 7-16 presents the uncertainty of groundwater inflow into the modified SBX Underground Mine from over the modelling period. The figure shows the predicted groundwater inflows for the base case model and different percentiles including 5th,33rd, 50th, 67th and 95th prediction bounds. Based on the IESC's (2018a) Information Guidelines these represent:

- 5th percentile indicates it is very likely the outcome is larger than this value, the
- 5th – 33rd percentile indicates the outcome is expected to be larger than this value in normal conditions, the
- 33rd – 67th percentile indicates it is as likely as not that the outcome is larger or smaller than this value, the
- 67th – 95th percentile indicates the outcome is not expected to be larger than this value in normal conditions, and the
- 95th percentile indicates it is very unlikely the outcome is larger than this value.

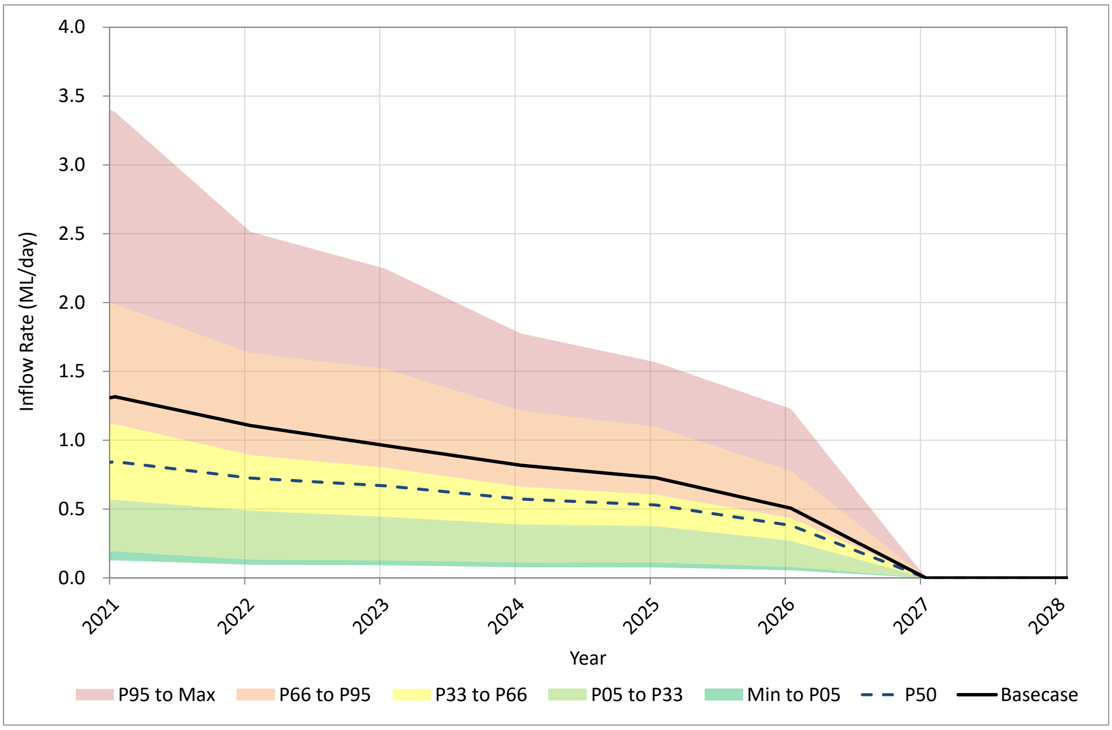


Figure 7-16 Predictive uncertainty of mine inflow – Modified SBX Underground Mine (Whybrow Seam)

The bounds in the figure demonstrate the uncertainty within the predicted modified SBX Underground Mine groundwater inflow rate. The bounds show that the calibrated base case model is above the 50th percentile. This means that the base case model is more conservative than what is most likely to occur (P50). **Figure 7-16** shows that, while the realisations created in uncertainty analysis provide a reasonable fit to calibration datasets, they generally predict lower modified SBX Underground Mine groundwater inflows than what is reported for the base case (See **Appendix D**). This can be seen in the figure by comparing the predicted groundwater inflow in the base case and the 50th percentile (P50) predicted groundwater inflow. The difference between the base case groundwater inflow and the 50th percentile may be due to coal seam specific yield values in the base case. The specific yield values in the calibrated model were generally within the normal parameter range for coal seams (0.8%) (0.1% to 3% from MER, 2009), and the higher end of the parameter range for interburden (0.5%) (0.0001% to 2 to 3% for claystones to sandstones from MER, 2009). While the value of approximately 0.5 to 1% for specific yield for coal seam and interburden is reasonable and consistent with the literature, measured groundwater inflow data was not available to constrain this parameter during the calibration. Therefore, the uncertainty analysis has tested the model with lower values for specific yield and this resulted in lower 50th percentile groundwater inflow comparing to the base case (See **Appendix D**).

As shown in **Figure 7-16**, the maximum groundwater inflow value considered as likely as not to occur for the modified SBX Underground Mine in the uncertainty analysis (the 67th Percentile) was 730.5 ML/year (2 ML/day) (unlikely outcome is larger than this value). The 5th to 95th percentile range in maximum mine groundwater inflows was 73 ML/year (0.2 ML/day) to 1,260 ML/year (3.45 ML/day).

7.7.3 Groundwater drawdowns

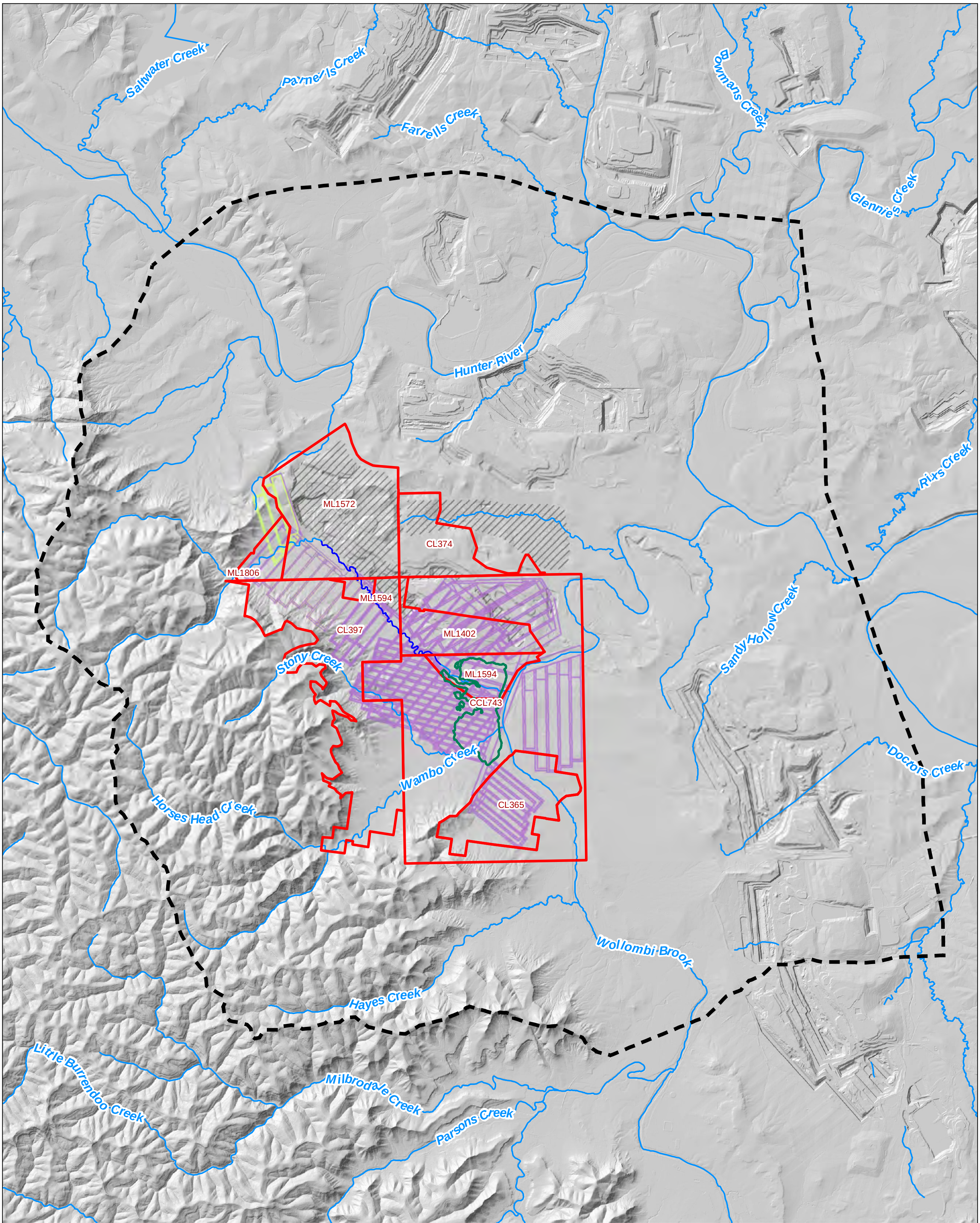
To illustrate the level of uncertainty in the extent of predicted drawdown, the base case maximum drawdown, the 50th percentile maximum drawdown extent was compared to the maximum drawdown extent for the 5th and 95th percentiles.

The uncertainty analysis results showed a small area of incremental drawdown impacts above 1 m for the Quaternary alluvium at the 95th percentile as a result of the Modification (**Figure 7-17**). These impacts are located at the downstream end of both Wambo Creek and North Wambo Creek, near their respective confluences with Wollombi Brook, over 5 km from the modified SBX Underground Mine. It is likely the incremental drawdown at the 95th percentile is related to the South Wambo Underground Mine timing difference between approved and modified mine schedules, and not related to the re-alignment of SBX Underground Mine longwall panels.

Predicted incremental drawdown in the Whybrow Seam from the uncertainty analysis (**Figure 7-18**), shows the extent of the 1 m drawdown contour at the 50th percentile is similar to the calibration model (**Figure 7-4**). At the 10th percentile, the 1 m drawdown extent is smaller, with the 1 m contour approximately 1.5 km closer to the modified SBX Underground Mine than the calibration (**Figure 7-4**). At the 90th percentile, the 1 m drawdown contour extends further north-west, to the model boundary, and an additional 8.3 km south-east compared to the calibration model and the 50th percentile. The 1 m contour at the 90th percentile also extends to the outcrop extent of the Whybrow Seam north of the modified SBX Underground Mine.

Predicted incremental drawdown in the Arrowfield Seam from the uncertainty analysis (**Figure 7-19**), shows the extent of the 1 m drawdown contour at the 50th percentile is similar to the calibration model **Figure 7-5**. At the 10th percentile, the 1 m drawdown extent is smaller, limited to the area of the larger incremental drawdown from the calibration model (**Figure 7-5**). At the 90th percentile, the 1 m drawdown contour extends an additional 4 km north-west, and 2 km south-east compared to the calibration model and the 50th percentile.

Only a small area of incremental drawdown is predicted at the 90th percentile in the Vaux Seam at the north-eastern end of the Woodlands Hill Seam operations of the South Wambo Underground Mine (**Figure 7-20**). No incremental drawdown due to the Modification is predicted at the 10th or 50th percentiles.



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	ANP

SLR

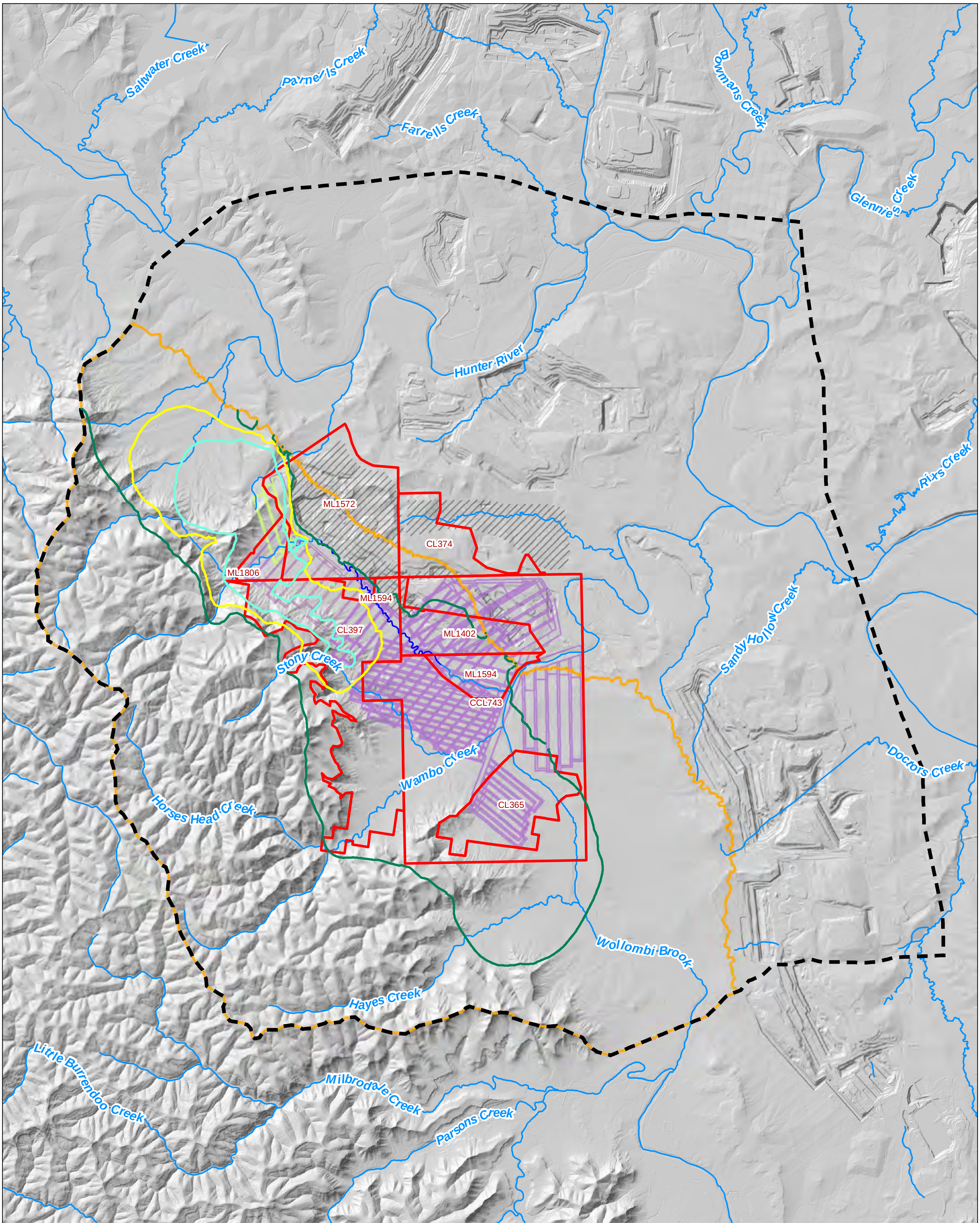
- New Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining
- Drawdown 1m (10th Percentile)
- Drawdown 1m (50th Percentile)
- Drawdown 1m (90th Percentile)

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Uncertainty in predicted 1m maximum incremental drawdown in alluvium and regolith (layer 1)

FIGURE 7-17

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_17_Uncertainty_Layer_1.mxd



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	ANP

SLR

- New Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Whybrow Seam Extent (Layer 7)
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining
- Drawdown 1m (10th Percentile)
- Drawdown 1m (50th Percentile)
- Drawdown 1m (90th Percentile)

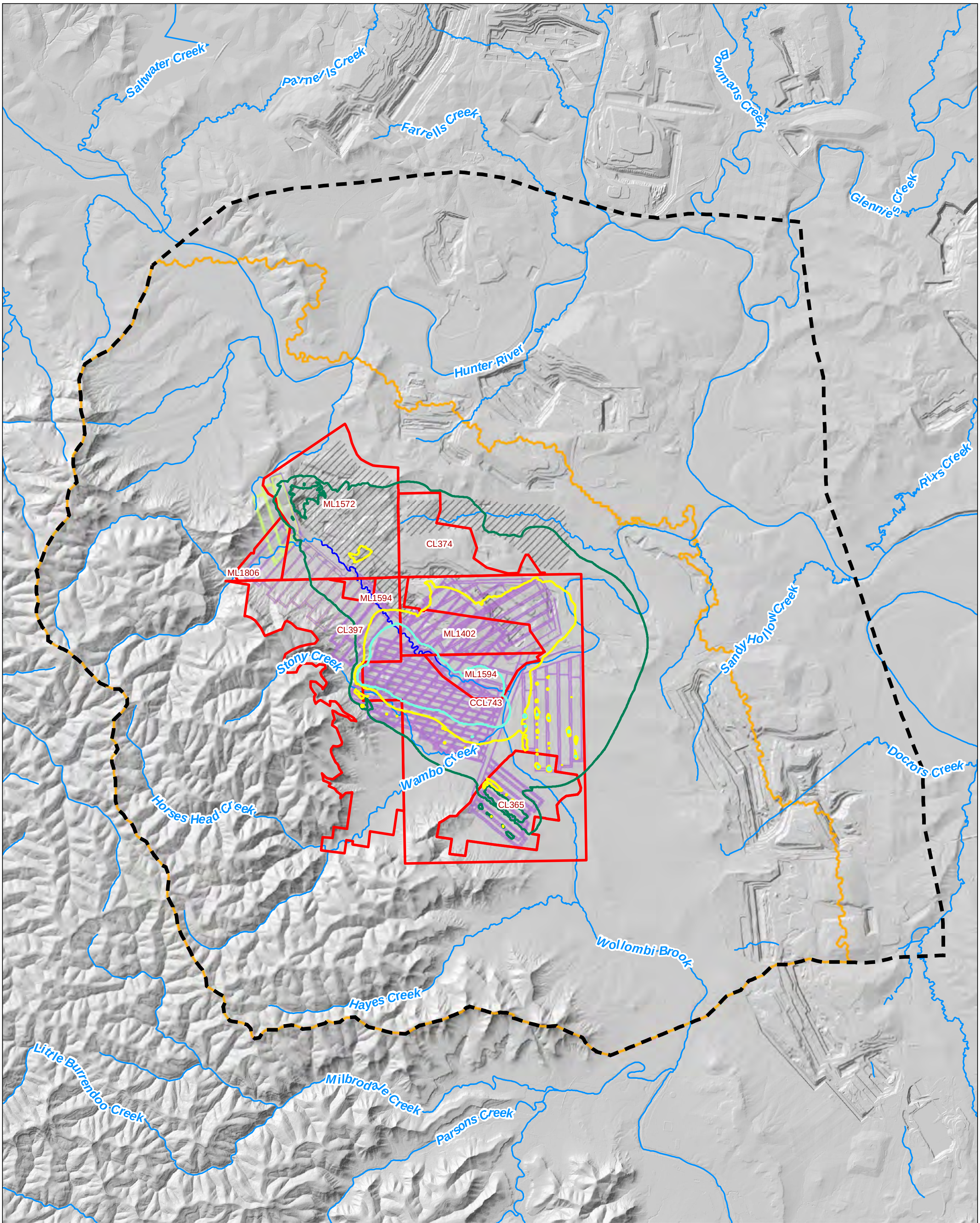
Data Source: NSW SS 2020

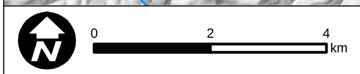
WAMBO LONGWALLS 24-26 MODIFICATION
GROUNDWATER MODELLING
IMPACT ASSESSMENT

Uncertainty in predicted 1m maximum incremental drawdown in Whybrow Seam (layer 7)

FIGURE 7-18

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_18_Uncertainty_Layer_7.mxd





Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	ANP

New Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Arrowfield Seam Extent (Layer 17)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining
Drawdown 1m (10th Percentile)
Drawdown 1m (50th Percentile)
Drawdown 1m (90th Percentile)

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Uncertainty in predicted 1m maximum incremental drawdown in Arrowfield Seam (layer 17)

FIGURE 7-19

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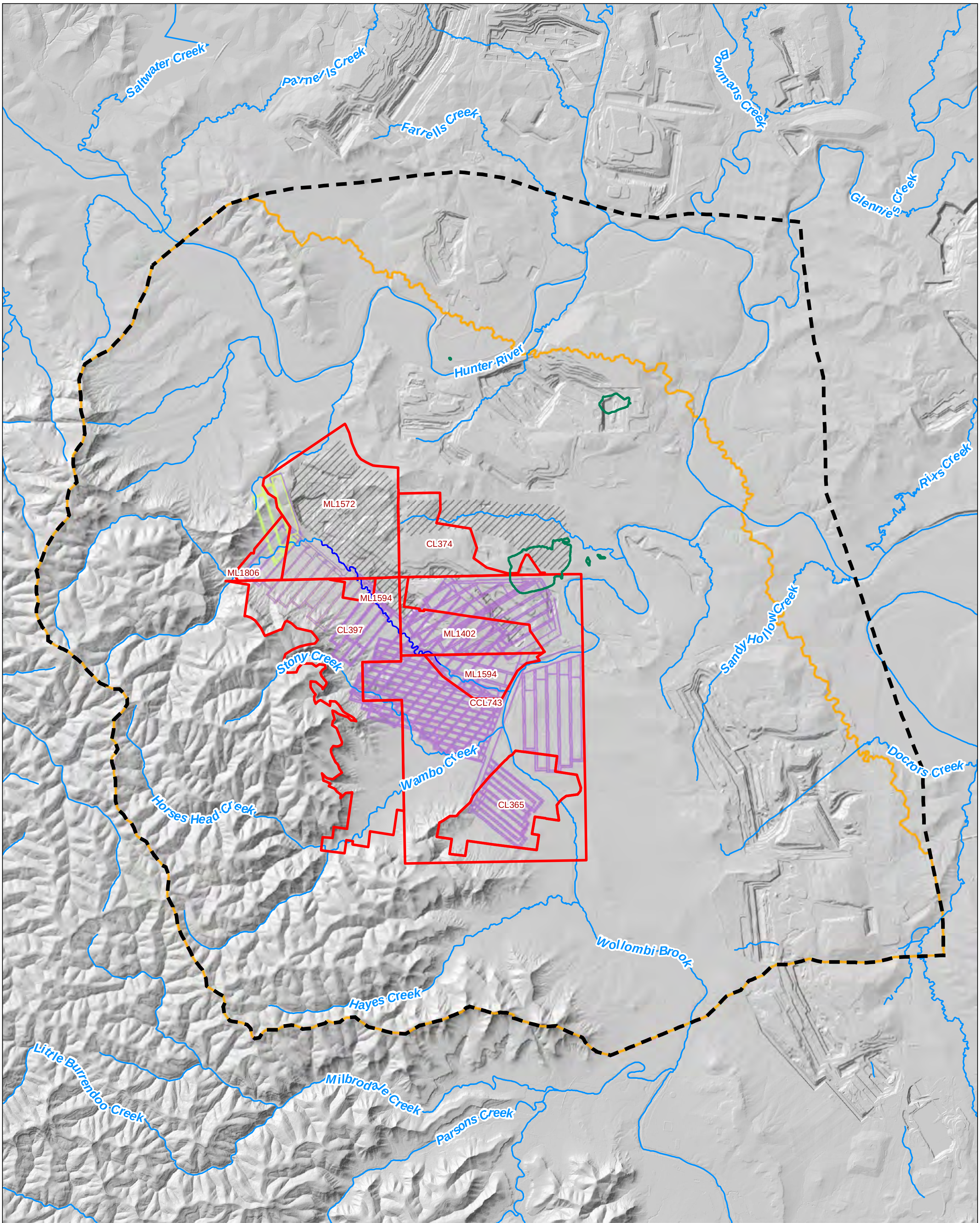


N

0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	ANP

SLR

New Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Vaux Seam Extent (Layer 27)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining
Drawdown 1m (10th Percentile)
Drawdown 1m (50th Percentile)
Drawdown 1m (90th Percentile)

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Uncertainty in predicted 1m maximum incremental drawdown in Vaux Seam (layer 27)

FIGURE 7-20

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_20_Uncertainty_Layer_27.mxd

7.7.4 Uncertainty of drawdown at private registered bores

Table 7-5 summarises the 95th percentile maximum drawdown at bores predicted to be impacted. The locations of the bores that may be impacted are shown in **Figure 6-12**. Bores in the southern area of Wambo are interpreted to be screened within alluvium/ regolith material associated with Stony Creek or Wambo Creek. Bores to the north of Wambo are likely screened in the Newcastle Coal Measures which overlie the Wittingham Coal Measures hosting the target coal seams at Wambo.

Predicted maximum incremental drawdown at these bores from the Modification remains below the relevant AIP minimal impact threshold of 2 m, at the 95th percentile. Predicted maximum cumulative drawdown, is above the AIP minimal impact threshold of 2 m at GW078574 at the 95th percentile.

Table 7-6 shows the predicted maximum cumulative drawdown at different uncertainty percentiles for GW078574, indicating predicted drawdown will fall below the 2 m impact threshold between the 67th and 90th percentile. As per the IESC's (2018b) Information Guidelines on uncertainty analysis, a result occurring above the 67th percentile is considered unlikely to occur.

The uncertainty results showed it is very unlikely that any privately owned registered bores are predicted to experience drawdowns greater than 1 m due to the modified Wambo.

Table 7-5 Predicted drawdown at private registered bores

Work No. (bore ID)	Location		Use	Depth (mbgl)	Aquifer/ Water Source	Maximum Drawdown (m) - 95th percentile	
	mE	mN				Incremental[1]	Cumulative[2]
GW043225	303653	6398949	Irrigation	24.5	Sandstone – Porous rock, less productive	0.1	0.5
GW064382	303908	6394477	Stock/ domestic	60		0.0	1.5
GW078477	304007	6398988	Domestic	102.5		0.2	1.0
GW078574	309174	6390605	Farming	12	Alluvium/ regolith* - alluvium, less productive	0.7	2.8
GW078575	309505	6389687	Farming	12		0.4	1.3
GW078576	309764	6389784	Farming	7		0.0	0.0
GW078577	309969	6389973	Domestic	10		0.3	1.6

Note: Coordinates in GDA94 Z56

*Geology at these sites unknown but has been inferred here inferred based on bore depth and proximity to Stony Creek and South Wambo Creek.

[1] Incremental drawdown is evaluated by comparing the Modification and Approved predictive model scenarios (see **Section 7.2**)

[2] Cumulative drawdown is evaluated by comparing the Modification and Null predictive model scenarios- (see **Section 7.2**)

Table 7-6 Predicted maximum cumulative drawdown for uncertainty percentiles at GW078574

Percentile	5th	10th	33rd	50th	67th	90th	95th	Base Case
Cumulative drawdown at GW078574 (m)	0	0.24	0.46	0.69	1.15	2.29	2.75	1.3

Further discussion of predicted impacts at GW078574 compared to the MOD17 – South Bates Extension Underground Mine groundwater assessment (Hydrosimulations, 2017) is included in **Section 8.4**.

7.7.5 Uncertainty of influence on alluvium and surface water flow

Table 7-7 shows the 5th and 95th percentiles for the incremental net flow change associated with the Modification at the times which the net flow change is maximum. It is noted that positive numbers in **Table 7-7** indicate that an increase in net flow to alluvium or a watercourse when compared to the approved scenario, while negative numbers indicate that a greater reduction in net flow than the approved scenario. The base case model predicts an increase or no change in net flow to alluvium or surface water due to the Modification, while at the outer bounds of the uncertainty analysis (95th and 5th percentiles), net flow change is predicted to either increase or decrease due to the Modification.

North Wambo Creek and its associated alluvium is nearest to the Modification, and is predicted by the uncertainty analysis to have a possible variation in flow due to the Modification of:

- Between 5.1 m^3/day additional loss, and 14.4 m^3/day additional gain to surface water.
- Between 43.9 m^3/day additional loss, and 43.2 m^3/day additional gain to alluvial groundwater.

The largest magnitude changes to surface water and alluvial flux occur at Wollombi Brook, which predicts an increase in net flow 4-5 times higher than the base case at the 95th percentile, and an incremental loss of a similar magnitude at the 5th percentile. Following the IESC's (2018b) Information Guidelines explanatory note on uncertainty analysis, it is very unlikely net flow change to alluvium or surface water will be of larger magnitude than predicted at these upper ranges.

Table 7-7 Maximum Net River and Alluvial Flow Change 5th and 95th percentile

Watercourse	River flux change (m^3/day)			Alluvium flux change (m^3/day)		
	5th Percentile	Base Case	95th Percentile	5th Percentile	Base Case	95th Percentile
Wollombi Brook	-176.5	49.2	215.2	-76.6	42	144.6
Hunter River	-13	0.7	4.3	-3.8	0	12.7
Wambo Creek	-56.9	12	59.4	-57.5	20.9	115.1
Wambo North Creek	-5.1	0	14.4	-43.9	5.4	43.2

7.8 Post mining recovery

Post-mining impacts were investigated with a recovery period following the transient predictive numerical model. The recovery period commences from the end of mining at Wambo, and simulations were run for 358 years (from 2042 to 2400). Simulation of final voids and recovered water levels utilises final void geometry and water level recovery assumptions presented in the UWOCP EIS (AGE, 2016). This assessment utilised pit lake recovery rates from a high-resolution surface water model and is considered the best available data source for this groundwater assessment.

Based on AGE (2016), the Wambo open cut (the more western open cut - **Figure 1-1**) final void will be largely rehabilitated with a minimum final void elevation of 40 mAHD, while the United open cut (the more eastern open cut - **Figure 1-1**) final void will be deeper, with a depth down to -150 mAHD. The final voids are predicted to reach a final void water level of approximately 55 mAHD in the Wambo open cut and 20 mAHD in the United open cut with predicted recovery levels per stress period shown in **Figure 7-21**. The graph shows that the void water level recovery is a slow process with the recovery rate declining as it reaches equilibrium conditions.

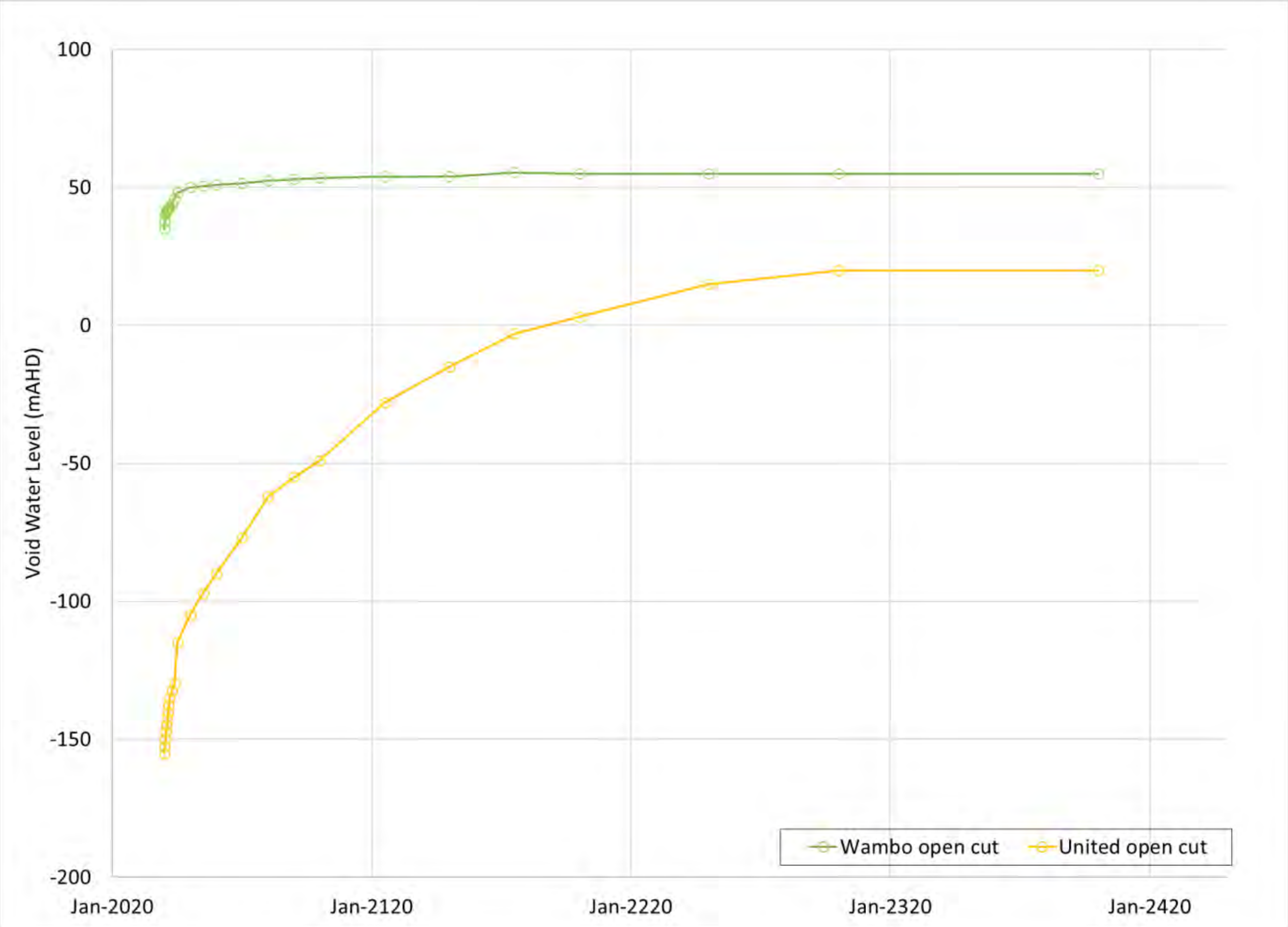


Figure 7-21 Final void recovery level over time

Table 7-8 describes changes made to key model input files to represent post-mining conditions including the recovery of water in the final voids.

Table 7-8 Post mining setup of model packages

MODFLOW package	Post mining setup
Drain (DRN)	Drain cells simulating mining/ dewatering in the Wambo area removed at the end of the prediction periods to allow groundwater levels to recover/ equilibrate.
Time-Variant Materials (TVM)	At the end of mining, the properties of the final void cells within the UWOCP open cuts were converted to values representative of void values.
Constant Head (CHD)	Pit lake recovery rates are incorporated into the groundwater model using a series of constant heads over time (following Figure 7-19 from AGE, 2016)
Recharge (RCH)	Recharge package updated so that no recharge applied to final void lakes represented by constant head cells.
Evapotranspiration (EVT)	Evapotranspiration package updated so that no evapotranspiration taken from final void lakes represented by constant head cells.

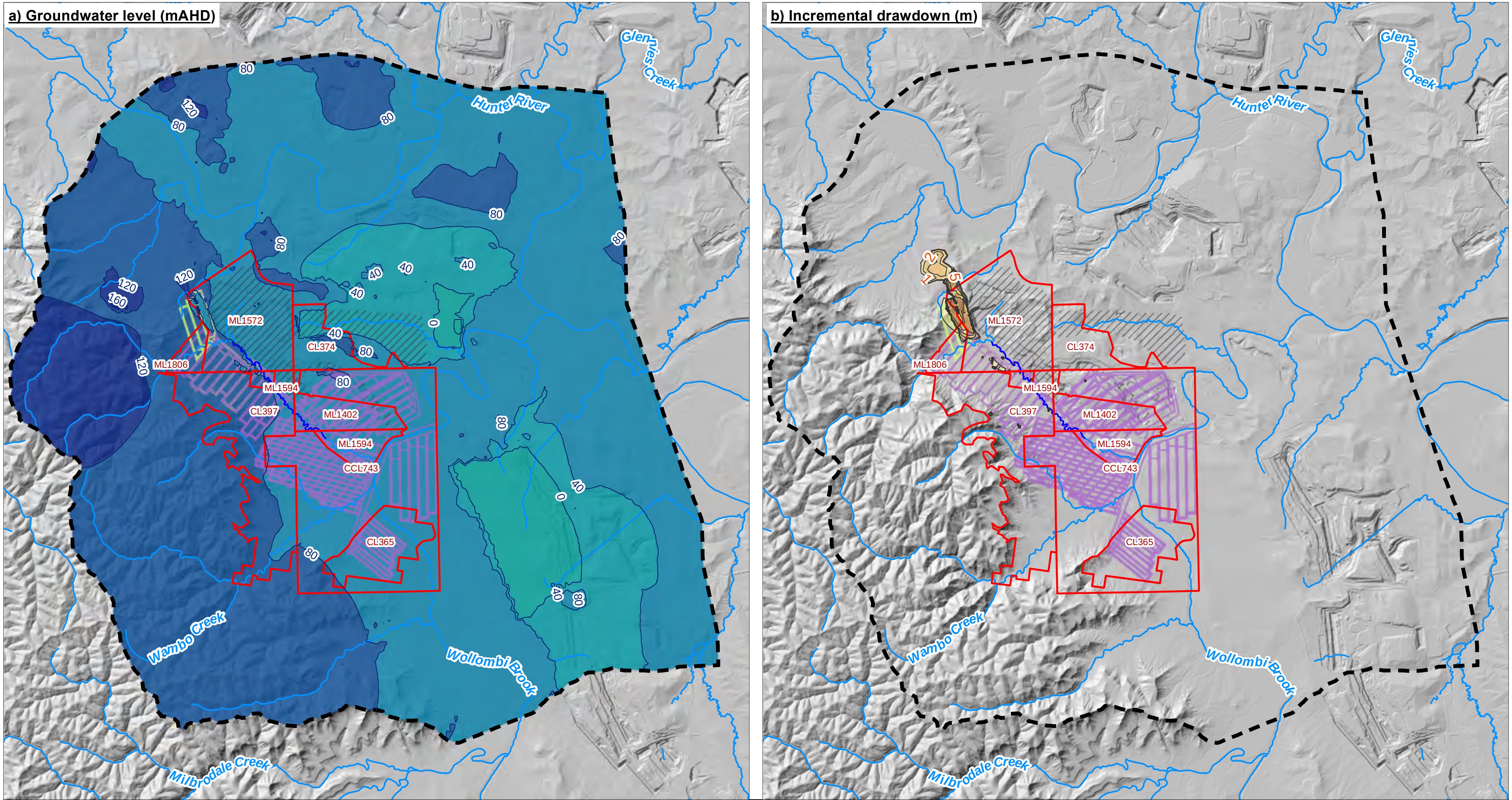
7.8.1 Post mining groundwater recovery

The predicted post mining water levels and incremental drawdowns (at 260 years after mining) for the water table, alluvium, and regolith (Layer 1), the Whybrow Seam (Layer 7), Arrowfield Seam (Layer 17), and the Vaux Seam (Layer 27) are shown in **Figure 7-22** through to **Figure 7-26**.

Groundwater levels around the UWOCP final voids range from approximately 105 mAHD at the water table to 50 m within the Vaux Seam. This range is above the predicted lake water levels in the void of 20 mAHD in the United open cut final void, indicating that the void is predicted to behave as a groundwater sink with an inwards hydraulic gradient from all surrounding aquifers, and therefore unlikely to impact on water quality within the surrounding strata.

There is no long-term incremental drawdown predicted for the alluvium and regolith (**Figure 7-23**), Arrowfield Seam (**Figure 7-25**) and Vaux Seam (**Figure 7-26**). Long term incremental drawdown is predicted at the water table overlying and north of modified Longwalls 24 to 26 (**Figure 7-22**). Predicted drawdown peaks at 70 m above Longwall 24 and 1-2 m drawdown extends approximately 1.4 km north of the mine footprint.

The maximum predicted incremental drawdown associated with the Modification within the target Whybrow Seam is shown in (**Figure 7-24**). The drawdown extent within the Whybrow Seam (Layer 7) is influenced by unit structure and is confined to unit extents, meaning that drawdown does not extend east, where the Whybrow Seam has outcropped or been mined-out. The 1 m drawdown influence predicted to extend up to 4.2 km north-west of the modified Longwalls 24 to 26.



Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:175,000 at A4
Project Number: 665.0008.00815
Date: 20-Jul-2022
Drawn by: NT

0 2.5 5 km

New Wambo Model Boundary
NWC Diversion
Named Watercourse
Mining Lease
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

Water Table (mAHD)

-240 - -200
-200 - -160
-160 - -120
-120 - -80
-80 - -40
-40 - 0
0 - 40
40 - 80
80 - 120
120 - 160
160 - 200

Drawdown (m)

0 - 1
1 - 2
2 - 5
5 - 10
10 - 20
20 - 50
50 - 100
100 - 200
200 - 400

WAMBO LONGWALLS 24-26 MODIFICATION
GROUNDWATER MODELLING
IMPACT ASSESSMENT

Predicted water table groundwater level (a) and incremental drawdown (b) – post mining recovery

FIGURE 7-22

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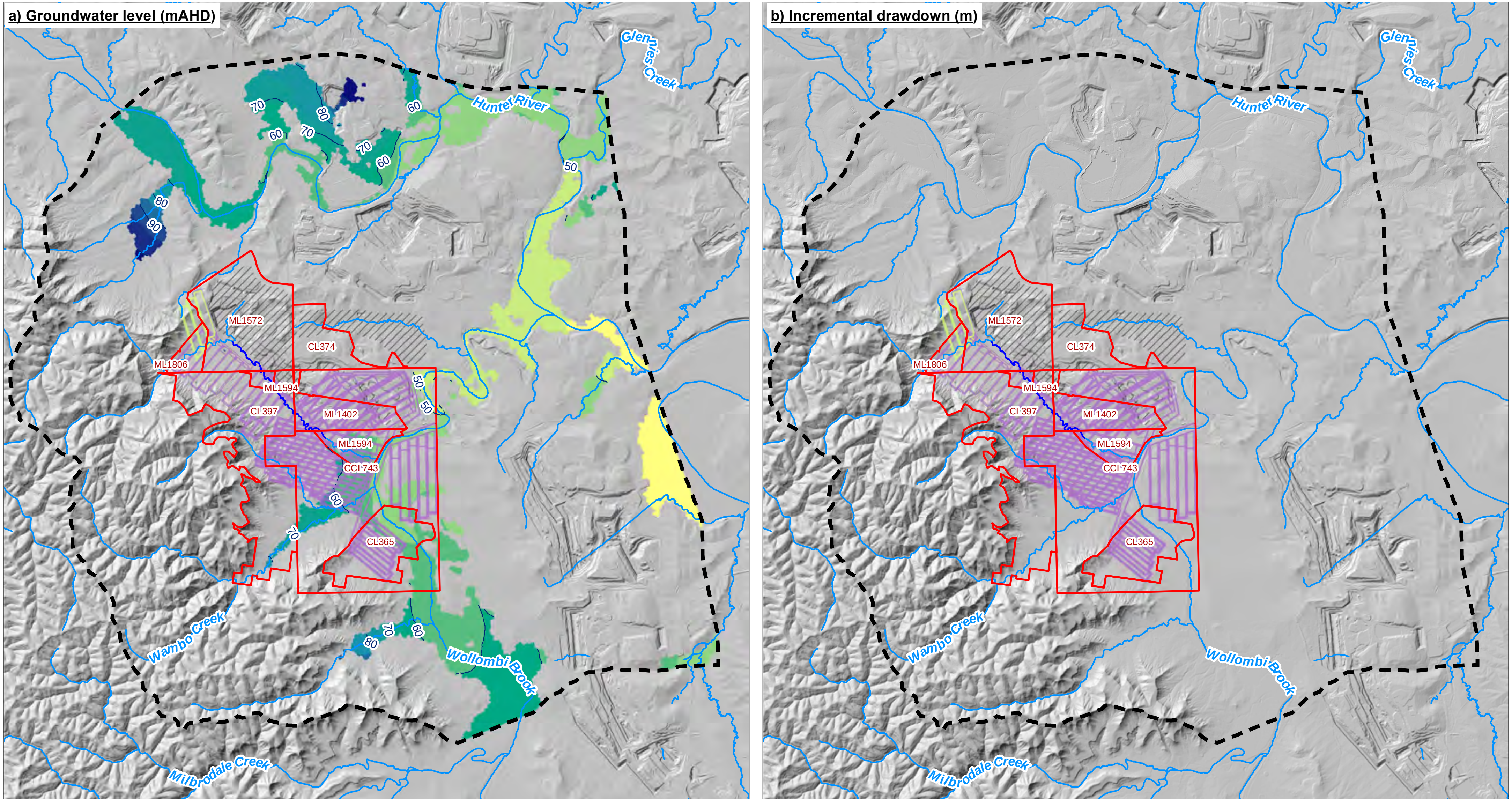

0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:175,000 at A4
Project Number:	665.0008.00815
Date:	20-Jul-2022
Drawn by:	NT

SLR

- New Wambo Model Boundary
- NWC Diversion
- Named Watercourse
- Mining Lease
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

Groundwater Level (mAHD)

- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 75 - 80
- 80 - 85
- 85 - 90
- 90 - 95
- 95 - 100
- 100 - 105

Drawdown (m)

- 0 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 400

WAMBO LONGWALLS 24-26 MODIFICATION
GROUNDWATER MODELLING
IMPACT ASSESSMENT

Predicted alluvium and regolith (layer 1) groundwater level (a) and incremental drawdown (b) – post mining recovery

FIGURE 7-23

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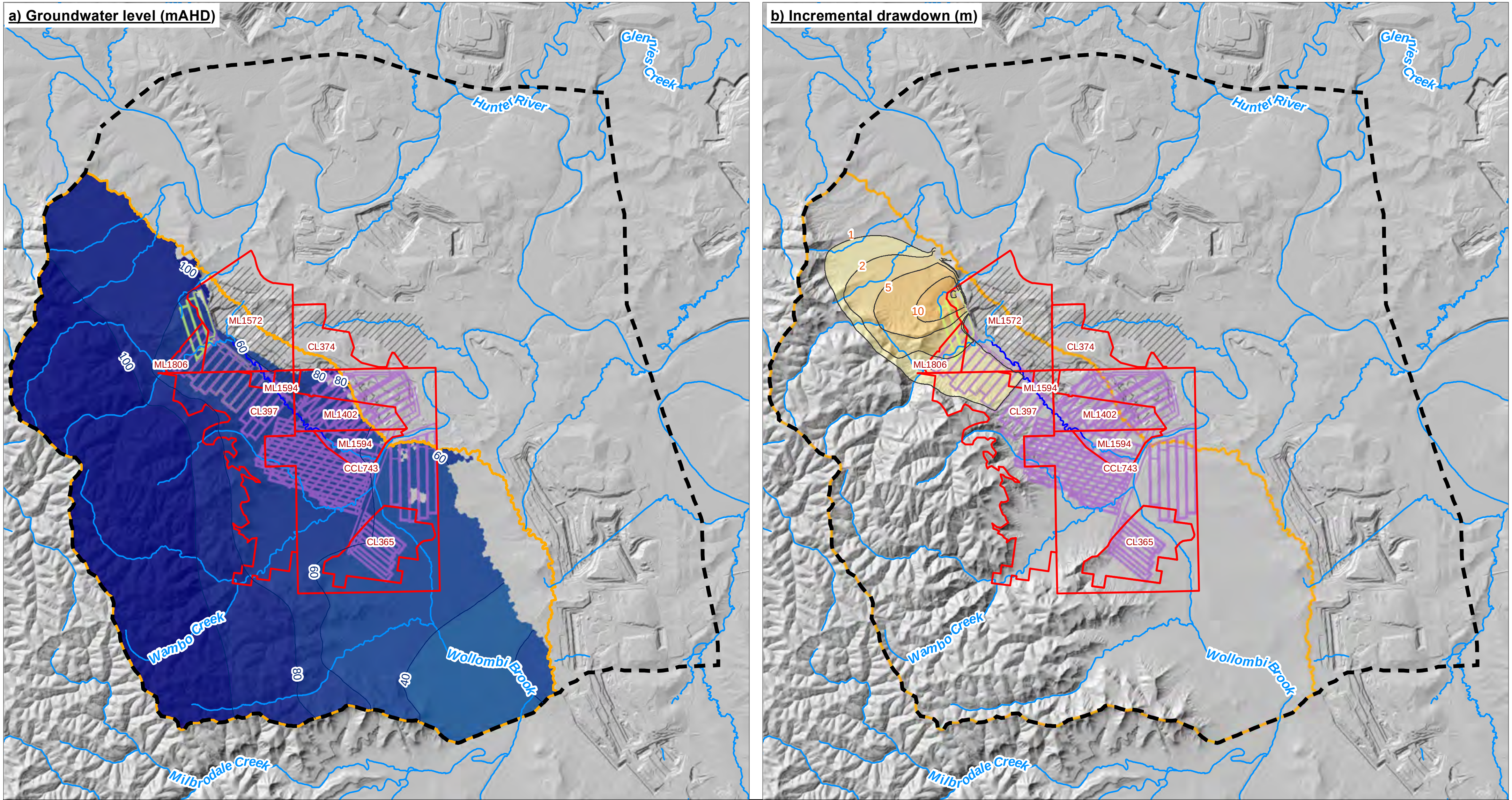


0 2.5 5 km

Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:175,000 at A4
Project Number: 665.0008.00815
Date: 20-Jul-2022
Drawn by: NT

New Wambo Model Boundary
NWC Diversion
Named Watercourse
Mining Lease
Whybrow Seam Extent (Layer 7)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

Groundwater Level (mAHD)

300 - -280
-280 - -260
-260 - -240
-240 - -220
-220 - -200
-200 - -180
-180 - -160
-160- -140
-140 - -120
-120 - -100
-100 - -80
-80 - -60
-60 - -40
-40 - -20
-20 - 0
0 - 20
20 - 40
40 - 60
60 - 80
80 - 100
100 - 120

Drawdown (m)

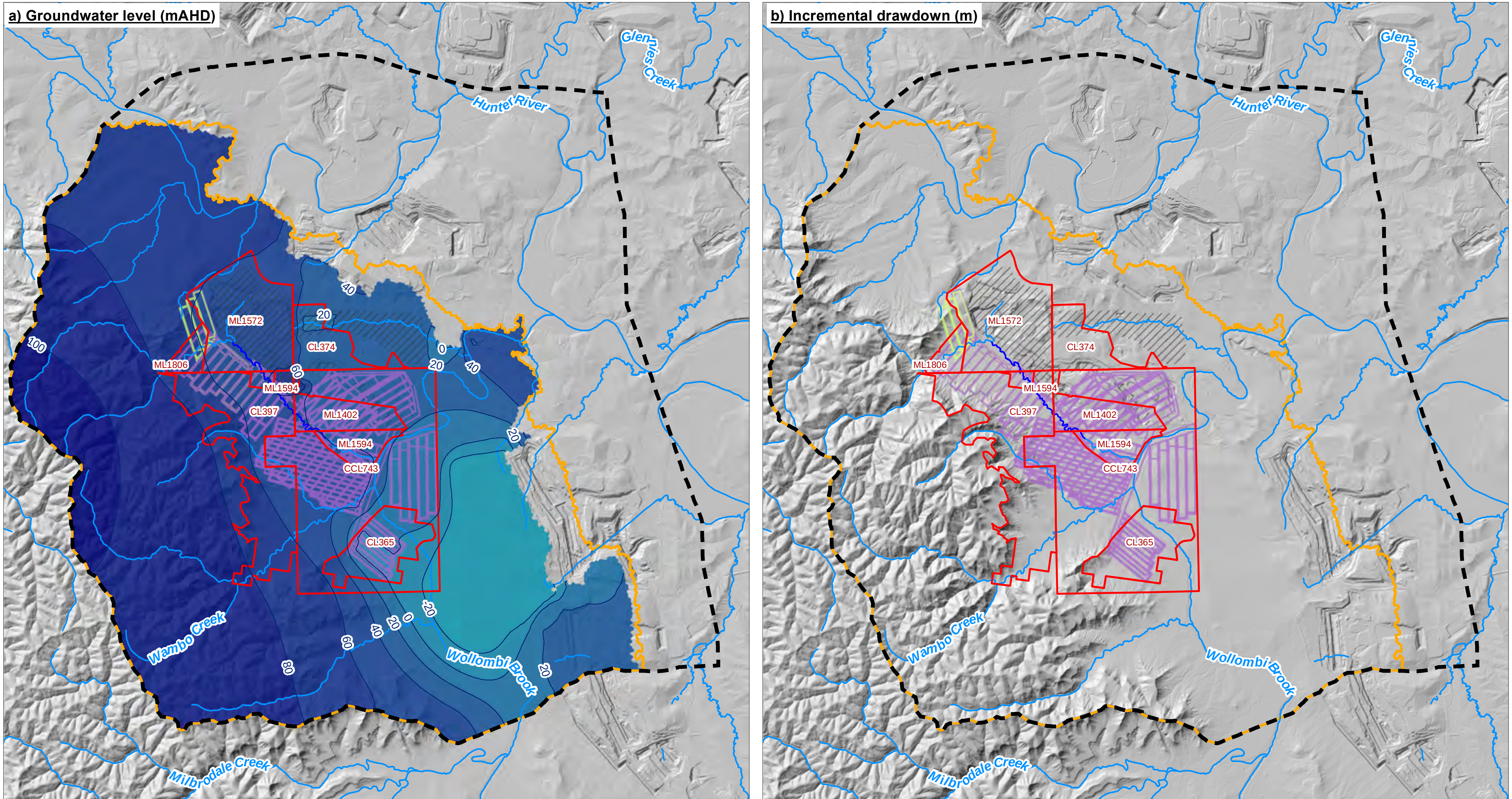
0 - 1
1 - 2
2 - 5
5 - 10
10 - 20
20 - 50
50 - 100
100 - 200
200 - 400

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Predicted Whybrow Seam (layer 7) groundwater level (a) and incremental drawdown (b) – post mining recovery

FIGURE 7-24

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_24_Pred_Layer_7_GWL_IncDDN_End2400_revA.mxd



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:175,000 at A4
Project Number:	665.0008.00815
Date:	20-Jul-2022
Drawn by:	NT

SLR

- New Wambo Model Boundary
- NWC Diversion
- Named Watercourse
- Mining Lease
- Arrowfield Seam Extent (Layer 17)
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

Groundwater Level (mAHD)

300 - -280	-160- -140	-20 - 0
-280 - -260	-140 - -120	0 - 20
-260 - -240	-120 - -100	20 - 40
-240 - -220	-100 - -80	40 - 60
-220 - -200	-80 - -60	60 - 80
-200 - -180	-60 - -40	80 - 100
-180 - -160	-40 - -20	100 - 120

Drawdown (m)

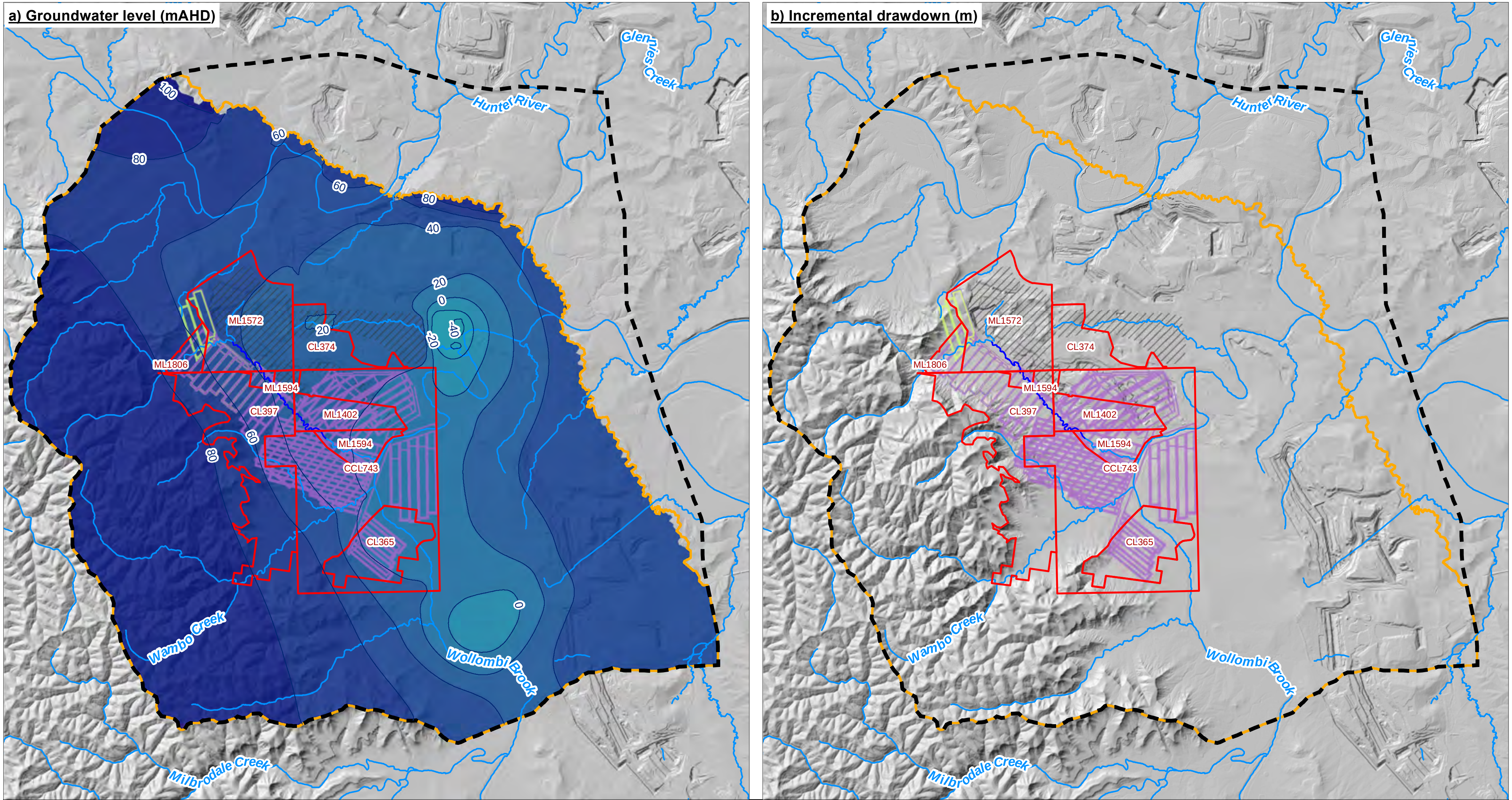
0 - 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 400
10 - 20	

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Predicted Arrowfield Seam (layer 17) groundwater level (a) and incremental drawdown (b) – post mining recovery

FIGURE 7-25

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_25_Pred_Layer_17_GWL_IncDDN_End2400_revA.mxd



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:175,000 at A4
Project Number:	665.0008.00815
Date:	20-Jul-2022
Drawn by:	NT

SLR

New Wambo Model Boundary
NWC Diversion
Named Watercourse
Mining Lease
Vaux Seam Extent (Layer 27)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

Groundwater Level (mAHD)

300 - -280	-160- -140	-20 - 0
-280 - -260	-140 - -120	0 - 20
-260 - -240	-120 - -100	20 - 40
-240 - -220	-100 - -80	40 - 60
-220 - -200	-80 - -60	60 - 80
-200 - -180	-60 - -40	80 - 100
-180 - -160	-40 - -20	100 - 120

Drawdown (m)

0 - 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 400
10 - 20	

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING IMPACT ASSESSMENT

Predicted Vaux Seam (layer 27) groundwater level (a) and incremental drawdown (b) – post mining recovery

FIGURE 7-26

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWIA_7_26_Pred_Layer_27_GWL_IncDDN_End2400_revA.mxd

7.8.2 Post mining influence on alluvium

Over the extent of alluvium near Wambo during the prediction period, the model predicts a low magnitude, short-term decrease in leakage of water from the North Wambo Creek, Wambo Creek and Wollombi Brook alluvium due to the Modification (from 2023, peaking 2029-2031), before this effect declines to the end of mining (**Section 7.5.1**). There is negligible effect predicted for the Hunter River alluvium due to the Modification.

Post mining, there is no long-term predicted effect on alluvial flux due to the Modification compared to Approved Scenario (**Figure 7-27**). Temporary increases in mining induced alluvial flux (more impact) change are predicted to occur in North Wambo Creek, Wambo Creek, Hunter River and Wollombi Brook alluvium. These changes are predicted to peak approximately 20-30 years post mining and are likely related to a slight delay in the timing of recovery above South Wambo Underground Mine longwalls in the Modification Scenario compared to the approved. Woodlands Hill and Arrowfield Seam workings are scheduled to finish two-years earlier and five months earlier respectively in the Approved Scenario.

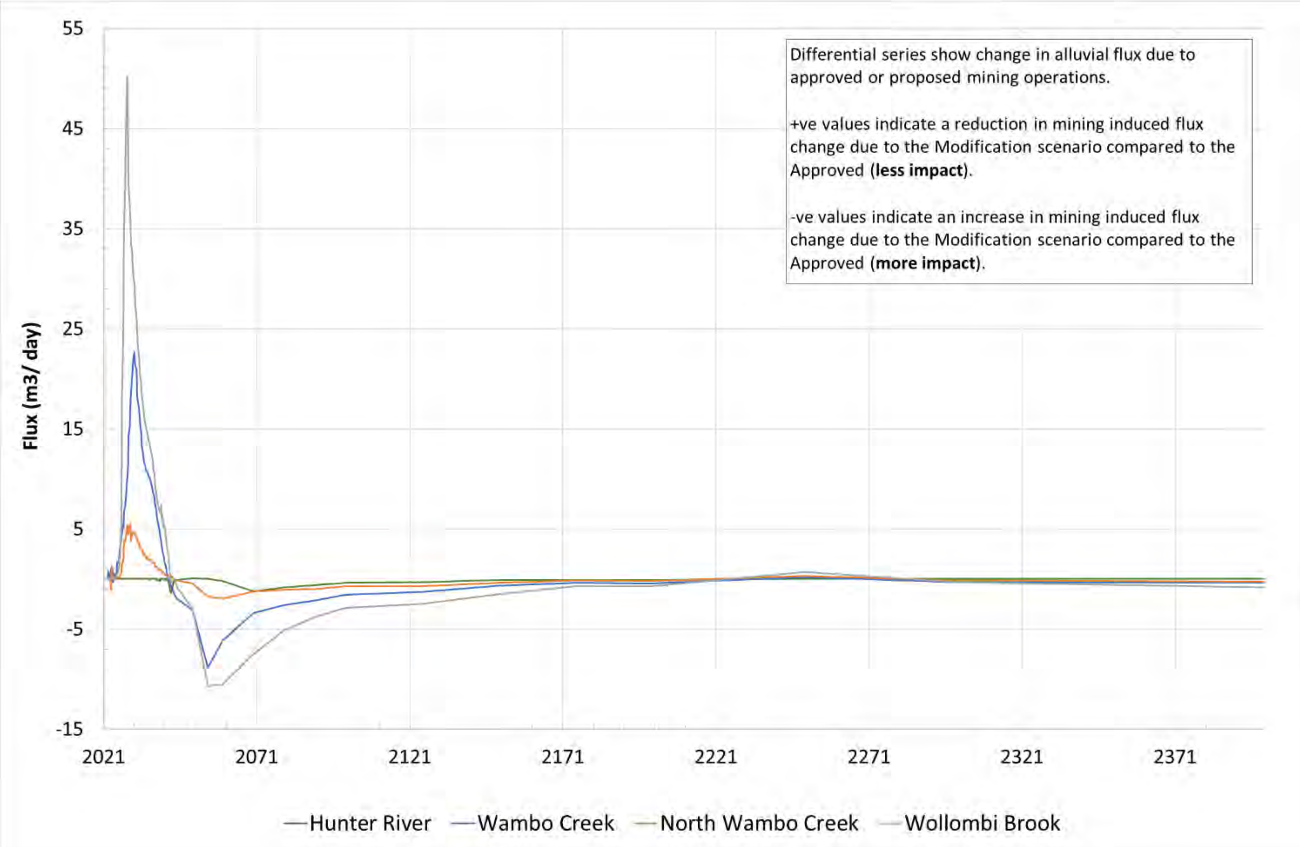


Figure 7-27 Post mining incremental alluvial flux change between Modified and Approved Scenarios

7.8.3 Post mining influence on surface water

Similar to post mining predictions for alluvial fluxes (see **Section 7.8.2**), the Modification is predicted to not cause any long-term decrease of baseflow to or increase in leakage from watercourses near Wambo (**Figure 7-28**). A temporary decrease in net flux post mining (more predicted impact) is predicted for Wambo Creek and Wollombi Brook and the Hunter River, which is likely related to recovery above South Wambo Project mine occurring slightly later in the modification scenario due to scheduling.

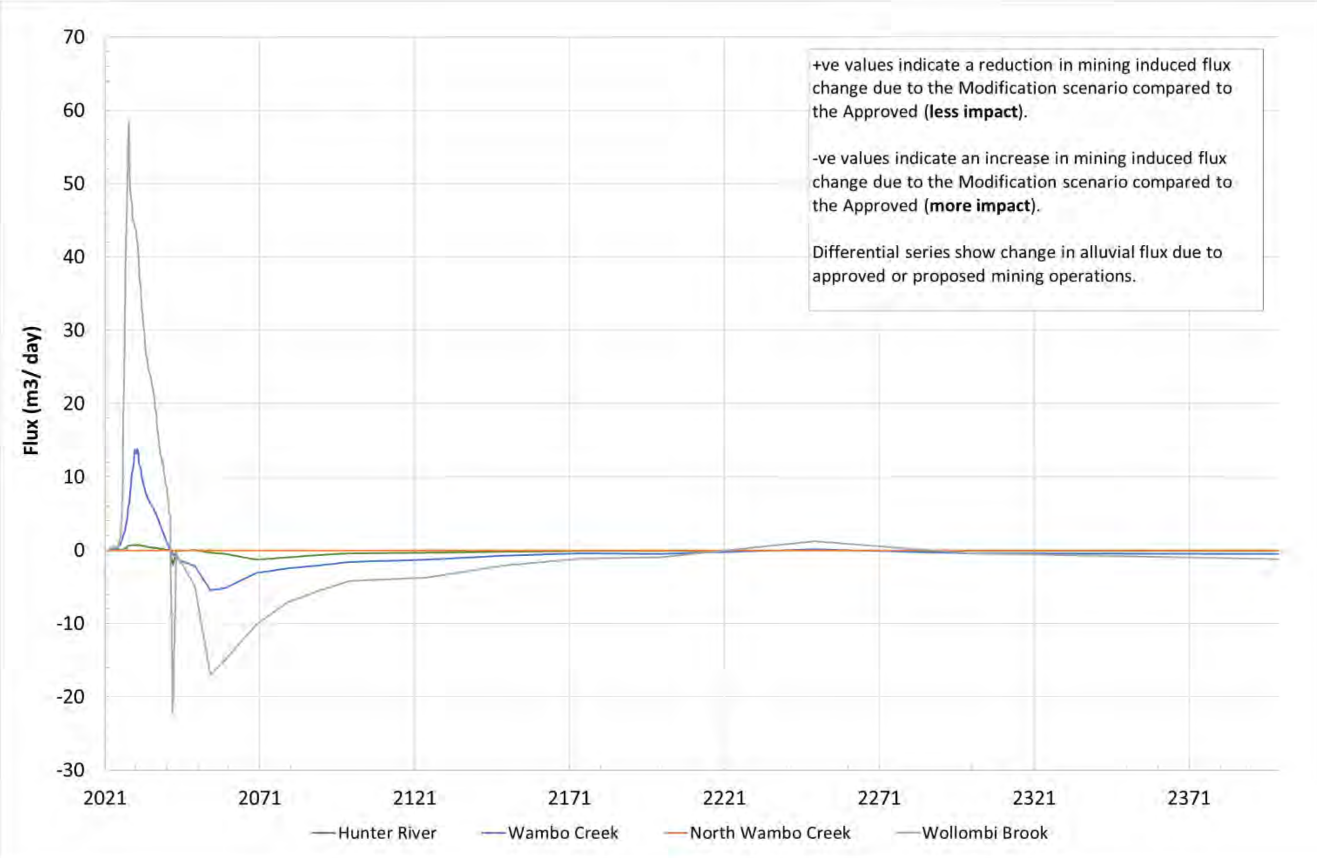


Figure 7-28 Post mining incremental RIV flux change

8 Impacts on groundwater resources

The proposed underground mining at the modified SBX Underground Mine may take water from both alluvial and underlying rock groundwater sources associated with the following water sources in the Wambo area (**Section 2.2.2**):

- Sydney Basin North Coast Groundwater Source (associated with the Permian bedrock strata in the vicinity of the modified SBX Underground Mine) within the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016*.
- Lower Wollombi Brook Alluvial Water Source within the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*.
- Upstream Glennies Creek Management Zone of the Hunter Regulated River Alluvial Water Source and Unnamed Alluvium within Jerrys Water Source (associated with the alluvial deposits to the north of the modified SBX Underground Mine) within the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*.

This section considers impacts to relevant individual catchments within each water source, as well as anthropogenic and environmental groundwater receptors that may be impacted by the Modification. Requirements for groundwater and surface water licensing due to Wambo are also presented, and predicted impacts are assessed against Minimal Impact Considerations of the AIP.

8.1 Sydney Basin North Coast Groundwater Source

The approved South Bates Extension Underground Mine will cause depressurisation of the Permian strata in the Sydney Basin North Coast Groundwater Source within the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016*. Due to the Modification there may be some additional drawdown in the Whybrow Seam and overlying, and the spatial distribution of drawdown may change.

8.1.1 Groundwater levels

Groundwater level drawdowns within the Sydney Basin North Coast Groundwater Source due the Modification for the water table, the target seam of SBX Underground Mine (Whybrow Seam – Layer 7), the deepest target seams of the South Wambo Underground Mine (Arrowfield Seam – Layer 17) and the UWOCP (Vaux Seam – Layer 27) are presented in **Section 7.4**.

Outside of areas of alluvium, the water table in the Wambo area is likely to be located within Permian strata (geology background – see **Section 5.2.5**), with drawdown to the water table in these areas considered to be impacts to the Permian rock groundwater source. Incremental drawdown to the water table of approximately 20 m is predicted above the modified Longwalls 24 to 26, with the 1 m drawdown contour extending up to 1.6 km north of the modified Longwalls 24 to 26 (**Figure 7-2**). Some drawdown impacts to the water table are predicted above the north-eastern ends of SBX Underground Mine where there are shallower depths of cover above the longwalls and fracture height calculations (Ditton and Merrick, 2014 – see **Section 4.3.1**) indicate surficial strata may be intersected by subsidence related fracturing.

These incremental impacts may be due to differences in timing between approved and modified mine scheduling at SBX Underground Mine. Approved SBX Underground Mine operations finish earlier than the modified SBX Underground Mine, with dewatering continuing in the modified scenario while recovery commences at the water table in the approved scenario.

In the Whybrow Seam (Layer 7), a maximum incremental drawdown of 50 m is predicted to occur at the north-western corner of the modified Longwall 26, with the incremental 1 m drawdown influence predicted to extend up to 3.4 km north-west of the modified SBX Underground Mine (**Figure 7-4**). Incremental drawdown within the Whybrow Seam in the location of the SBX Underground Mine longwalls is expected, and the largest drawdown occurring over modified Longwall 26 is likely due to this panel being extracted after the completion of approved SBX Underground Mine, which is likely starting to recover at the time of the modified Longwall 26 extraction.

Drawdown observed on the western ends of South Bates and SBX longwall panels are also likely related to differences in mine schedule between approved and modified operations. Following completion in December 2024, recovery would begin in the approved scenario, while dewatering and mining is scheduled to continue until June 2026 in the Modification. Drawdown extending to the north-west follows the strike of the Whybrow seam and is generally limited in areas east and north of the Wollemi National Park escarpment. The use of depth dependent hydraulic conductivity within the model means that drawdown will preferentially extend along the northwest to southeast strike, where strata depths are shallow, and hydraulic conductivities are higher.

Incremental drawdown for the deepest target seams of the South Wambo Underground Mine (Arrowfield Seam – Layer 17) and the UWOCP (Vaux Seam – Layer 27) are displayed in **Figure 7-5** and **Figure 7-6,** respectively. There are no changes in mining extent for the South Wambo Underground Mine and the UWOCP associated with the Modification, only the timing of South Wambo longwall extraction is different.

The apparent incremental drawdown in the Arrowfield Seam (**Figure 7-5**) may be due to the commencement of Arrowfield Seam mining in the Modification scenario prior to the approved scenario for the first three longwall panels (LW01E, LW02E, LW03E), before the timing of extraction for both scenarios becomes similar, or longwalls in the approved scenario are extracted earlier.

No incremental drawdown is predicted for the Vaux Seam (Layer 27) due to the Modification. The timing of UWOCP does not change between the approved and modified scenarios and this result is expected.

Cumulative drawdown due to Wambo (including the Modification) and approved and foreseeable open cut and underground coal mines in the Wambo area within the Sydney Basin North Coast Groundwater Source are displayed for key coal seams in **Figure 7-11** to **Figure 7-13** and discussed in **Section 7.6**.

8.1.2 Groundwater flux

Groundwater flux changes within the Sydney Basin North Coast Groundwater Source due the Modification are captured in the DRN package, which simulates dewatering from active mine workings. Predicted mine groundwater inflow for the modified Wambo is presented in **Figure 8-1**, which shows a minor increase in Wambo groundwater inflow due to the timing of South Wambo Underground Mine (see **Section 7.2**).

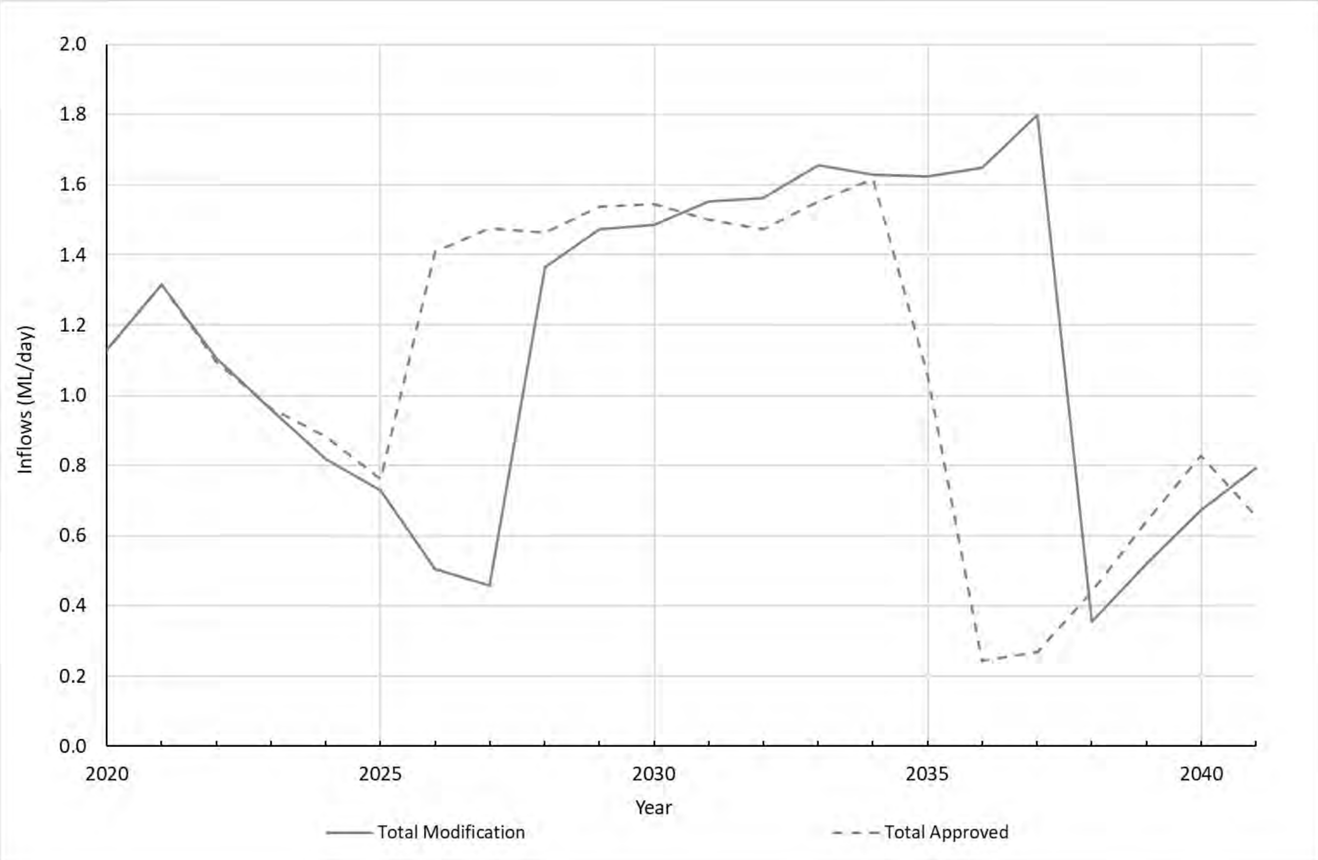


Figure 8-1 Predicted mine inflow to Wambo underground

8.2 Lower Wollombi Brook Alluvial Water Source

Approved and modified mining at Wambo underlies, or is located near to watercourses and associated alluvium, which are part of the Lower Wollombi Brook Alluvial Water Source within the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*. Predicted changes in groundwater level and groundwater flux to these areas of alluvium due to the Modification are presented in the following sections.

8.2.1 North Wambo Creek alluvium

The realignment of SBX Underground Mine longwalls for the Modification would result in a smaller area of North Wambo Creek alluvium directly overlying the SBX Underground Mine compared to the approved SBX Underground Mine. Therefore, it is conceptualised that impacts associated with the Modification would be less than for the approved SBX Underground Mine.

8.2.1.1 Groundwater levels

No incremental drawdown is predicted for the alluvium as a result of the Modification (**Figure 7-3**). Conceptually, impacts to the North Wambo Creek alluvium are expected to be less than currently approved, with a smaller area of alluvium directly undermined by SBX Underground Mine longwalls.

This prediction is consistent with HydroSimulations (2017) modelling. However, it is noted that the model simulates the North Wambo Creek alluvium, upstream of the North Wambo Creek diversion to be dry for the approved and modified scenarios under average climatic conditions in the prediction period of the model. There are no periods of flow within ephemeral creeks during this period. Saturated North Wambo Creek alluvium is located downstream of the North Wambo Creek diversion near the confluence of North Wambo Creek and Wollombi Brook during these model scenarios (**Appendix D**).

8.2.1.2 Alluvial flux

Net flux to or from the North Wambo Creek alluvium for the Approved, Modified, No Wambo Underground Mining and Null Scenarios are presented in **Figure 8-2**. As is indicated on **Figure 8-2**, flux with a negative magnitude indicates net leakage from alluvium, and flux with a positive magnitude indicates flow from underlying Permian strata to alluvium. The initial spike in net flux for all model scenarios has likely resulted from a high rainfall event that generated flow in ephemeral watercourses in early 2020, prior to the prediction period.

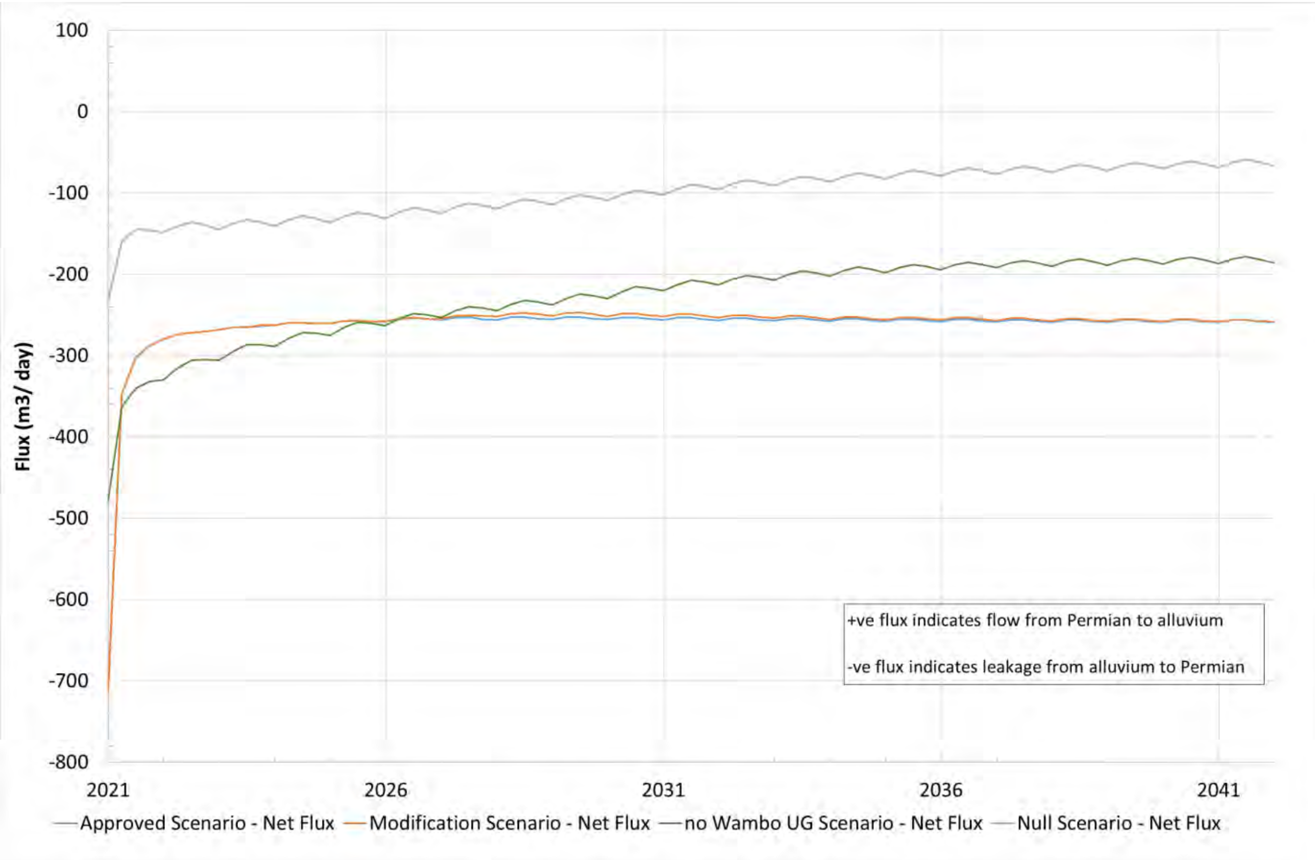


Figure 8-2 Predicted net alluvial flux for North Wambo Creek

Evaluation of incremental impacts for the Modification shows a minor net increase in flow from the North Wambo Creek alluvium compared with approved mining, with a maximum additional rate of 1.8 ML/year (5 m^3/day) in 2029 due to the Modification. It is noted that this minor increase occurs during South Wambo Underground Mine, and not during approved or modified SBX Underground Mine. As the timing of longwall extraction is the only difference between the approved and Modified scenarios for the South Wambo Underground Mine, timing is likely driving the apparent reduction in mining induced flux change.

Evaluation of cumulative impacts for the Modification (compared to the Null Scenario) predicts a net loss of water from the North Wambo Creek alluvium that peaks during the prediction period at 72 ML/year (197 m^3/day).

Evaluation of impacts to the North Wambo Creek alluvium from all Wambo Underground mining including the modification indicates a net loss of water that peaks at 28 ML/year (77 m^3/day). **Figure 8-3** shows this loss is an increase in leakage of alluvial sourced water to the surrounding system, with this volume considered appropriate for evaluation against licences held by Wambo for the *Lower Wollombi Brook Alluvial Water Source*.

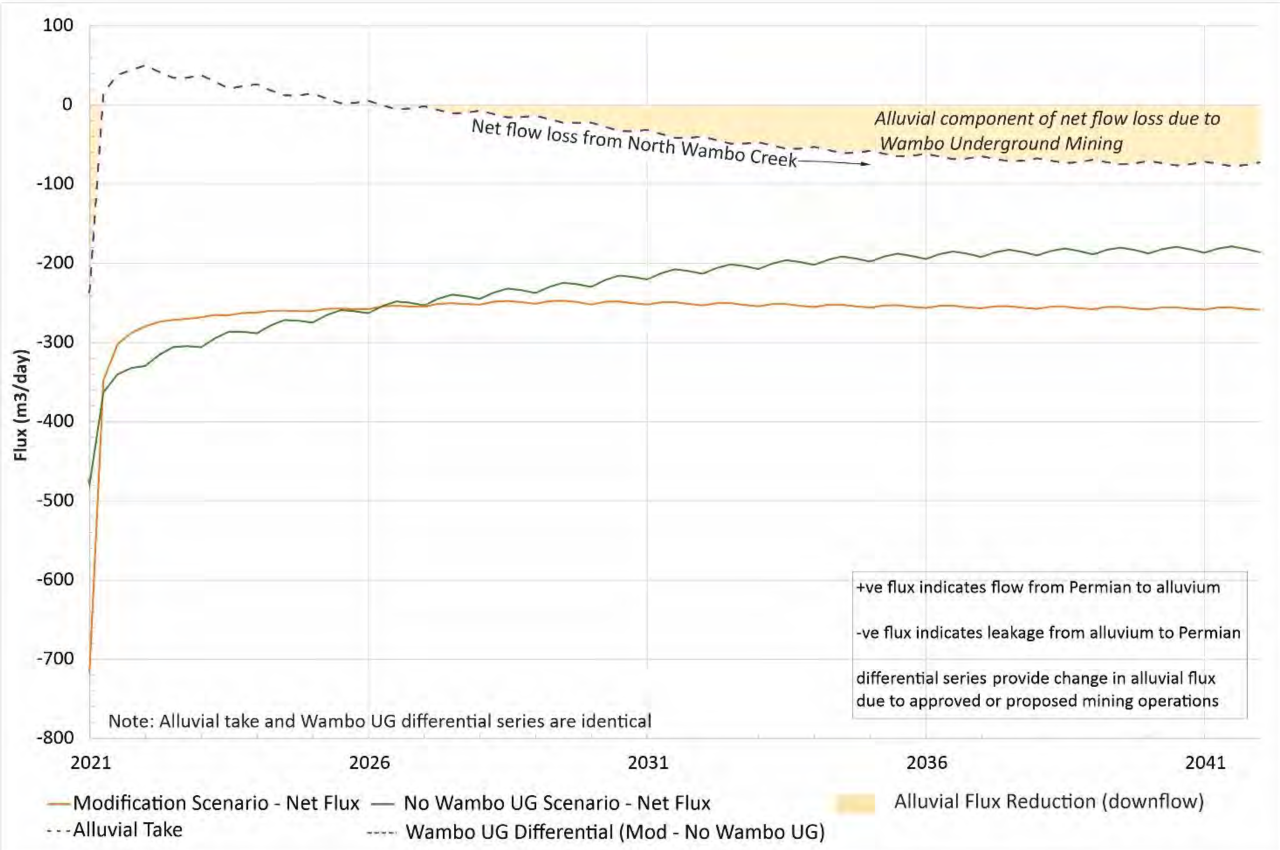


Figure 8-3 Components of predicted net alluvial flux for North Wambo Creek

8.2.2 Wambo Creek alluvium

The Wambo Creek alluvium within the Lower Wollombi Brook Alluvial Water Source is over 6 km from the modified SBX Underground Mine but will be undermined by the approved South Wambo Underground Mine.

8.2.2.1 Groundwater levels

No incremental drawdown impacts are predicted for the alluvium as a result of the Modification (**Figure 7-3**). Conceptually, incremental impacts to the Wambo Creek alluvium are unlikely due to the distance from the modified SBX Underground Mine to Wambo Creek.

This prediction is consistent with HydroSimulations (2017) modelling, with no drawdown in the Wambo Creek alluvium predicted to be caused by the approved SBX Underground Mine operations.

8.2.2.2 Alluvial flux

Net flux to or from the South Wambo Creek alluvium for the Approved, Modified, No Wambo Underground Mining and Null modelling scenarios are presented in **Figure 8-4.**

As is indicated on **Figure 8-4**, flux with a negative magnitude indicates net leakage from alluvium, and flux with a positive magnitude indicates flow from underlying Permian strata to alluvium.

Evaluation of incremental impacts for the Modification show a minor net increase in flow from the Permian to the Wambo Creek alluvium from 2026 to 2041 compared with approved mining, with a maximum additional rate of 7.6 ML/year (21 m^3/day) in 2031 due to the Modification. It is noted that this minor increase occurs during the South Wambo Underground Mine, and not during the approved or modified SBX mining. As the timing of longwall extraction is the only difference between the approved and modified scenarios for the South Wambo Underground Mine, timing is likely driving the apparent reduction in mining induced flux change.

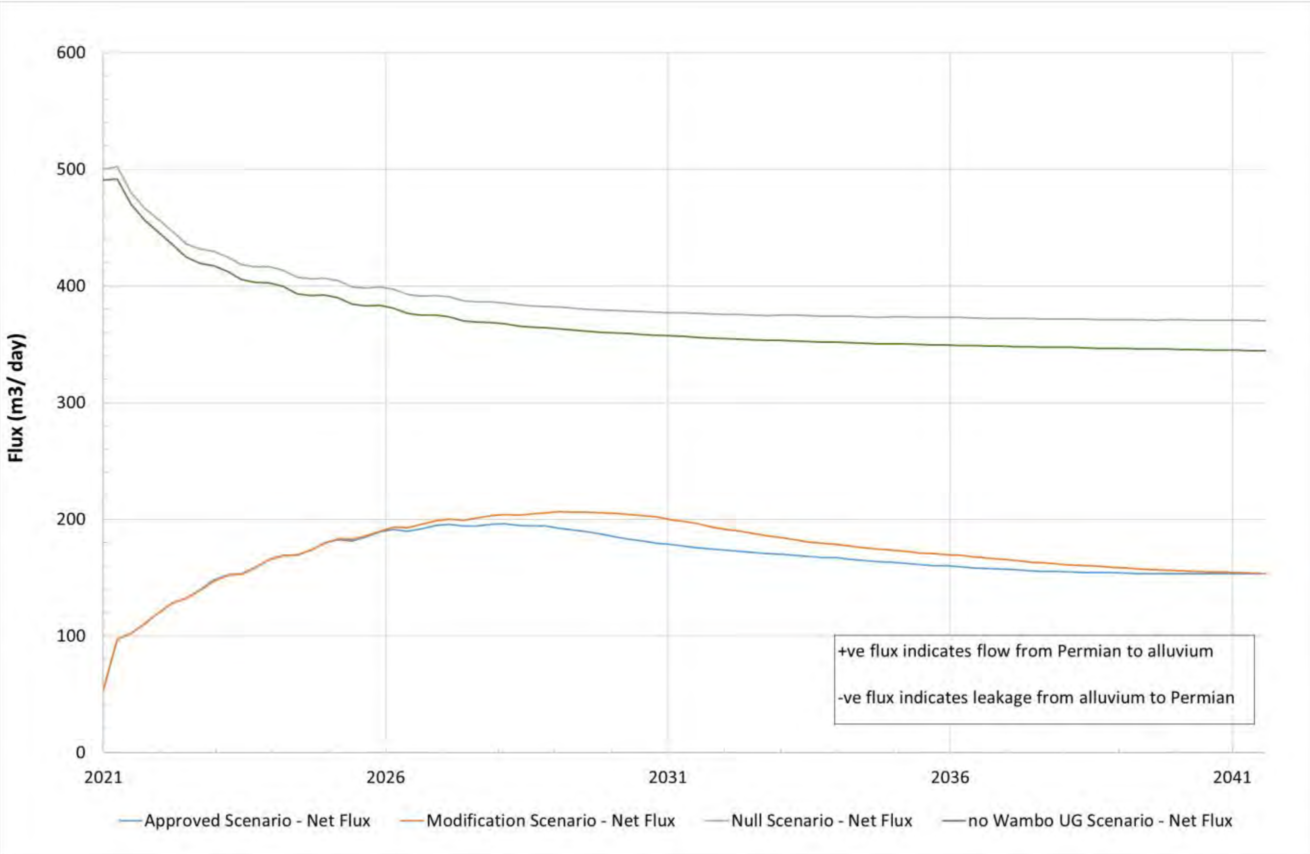


Figure 8-4 Predicted net alluvial flux for Wambo Creek

Evaluation of cumulative impacts for the Modification predict a net loss of water from the South Wambo Creek alluvium during the prediction period that peaks at 178 ML/year (488 m^3/day).

Evaluation of impacts to the Wambo Creek alluvium from Wambo Underground mining including the modification indicates a net loss of water that peaks at 144 ML/year (395 m^3/day). **Figure 8-5** shows this loss is a reduction in flow to the alluvium from Permian-sourced groundwater for the entire prediction period, with no loss of alluvial sourced groundwater (alluvial leakage) predicted for South Wambo Creek. This predicted loss of Permian flow is not considered for evaluation against licences held by Wambo for the Lower Wollombi Brook Alluvial Water Source. The loss is accounted for as part take from the Sydney Basin North Coast Groundwater Source (See **Section 8.6**).

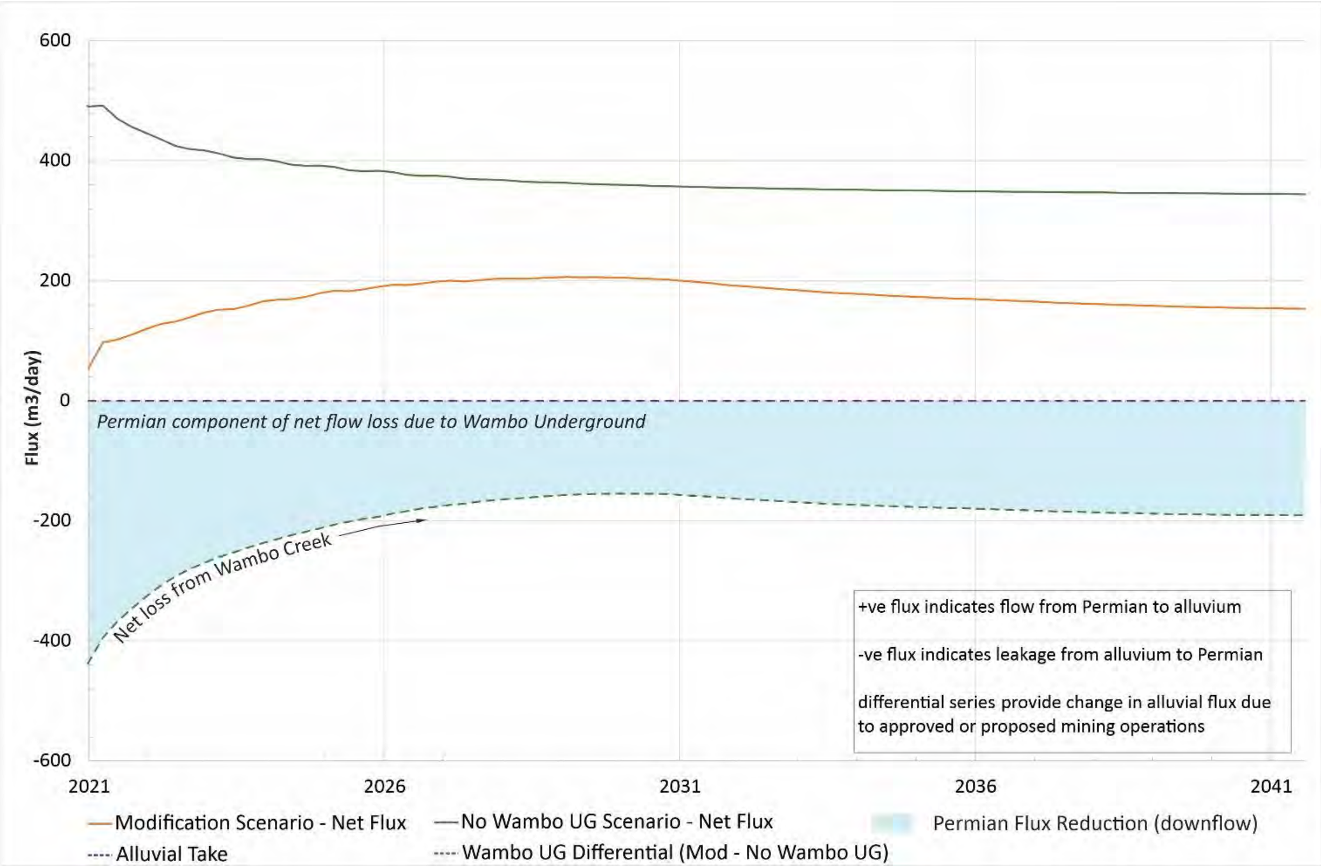


Figure 8-5 Components of predicted net alluvial flux for Wambo Creek

8.2.3 Wollombi Brook Alluvium

The alluvium associated with Wollombi Brook within the Lower Wollombi Brook Alluvial Water Source is over 6.5 km from the modified SBX Underground Mine. While mains, roadways and other non-collapsing workings will underlie the Wollombi Brook alluvium, approved South Wambo Underground Mine longwalls will not directly underlie the alluvium.

8.2.3.1 Groundwater Levels

No incremental drawdown impacts are predicted for the Wollombi Brook alluvium as a result of the Modification (**Figure 7-3**). Conceptually, incremental impacts to the Wollombi Brook alluvium are unlikely due to the distance from the modified SBX Underground Mine to the Wollombi Brook.

This prediction is consistent with HydroSimulations (2017) modelling, with no drawdown in Wollombi Brook alluvium predicted to be caused by the approved SBX Underground Mine operations.

8.2.3.2 Alluvial flux

Net flux to or from the Wollombi Brook alluvium for the Approved, Modified, No Wambo Underground Mining and Null modelling scenarios are presented in **Figure 8-6.**

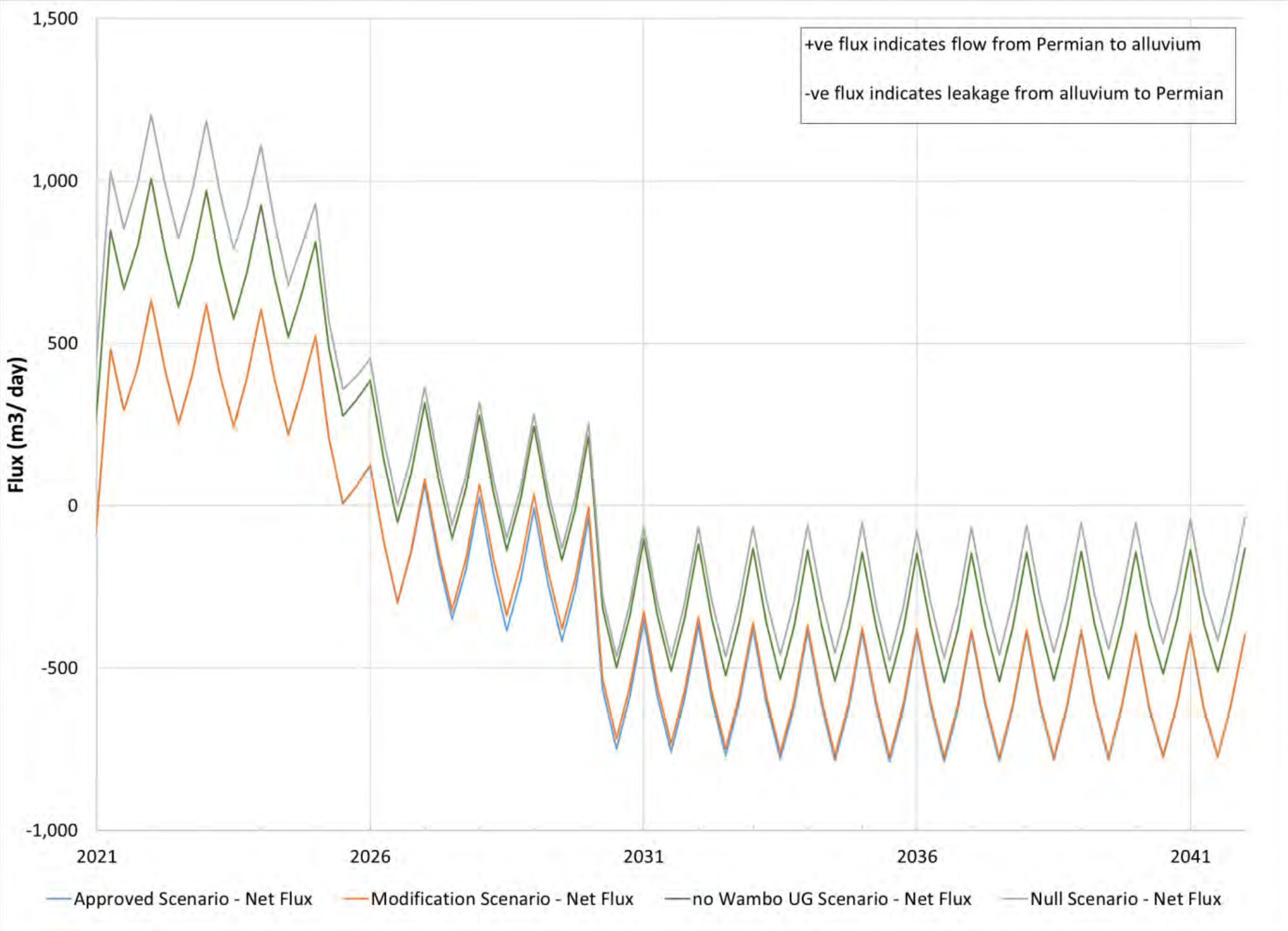


Figure 8-6 Predicted net alluvial flux for Wollombi Brook

As is indicated on **Figure 8-6**, flux with a negative magnitude indicates net leakage from alluvium, and flux with a positive magnitude indicates flow from underlying Permian strata to alluvium. Note that the result for the Null Scenario may be influenced by non-Wambo district mining.

Evaluation of incremental impacts for the Modification show a minor net decrease in flow from the Wollombi Brook alluvium from 2026 to 2041 compared with approved mining, with a maximum additional rate reduction of 15.3 ML/year (42 m^3/day) in 2028 due to the Modification. It is noted that this occurs during the South Wambo Underground Mine, and not during approved or modified SBX Underground Mine. As the timing of longwall extraction is the only difference between the approved and modified scenarios for the South Wambo Underground Mine, timing is likely driving the apparent reduction in mining induced flux change.

Evaluation of cumulative impacts for the Modification (compared with the Null Scenario) predicts a net loss of water from the Wollombi Brook alluvium during the prediction period that peaks at 209 ML/year (571 m^3/day) in 2022.

Evaluation of impacts to the Wollombi Brook alluvium from all Wambo Underground mining including the modification indicates a net loss of water that peaks at 137 ML/year (375 m^3/day). **Figure 8-7** shows this peak loss is a reduction in inflow to the alluvium from Permian-sourced groundwater. Peak loss of alluvial-sourced water from the Wollombi Brook alluvium is predicted to be 97 ML/yr. (266 m^3/day) at the end of mining in 2041 (**Figure 8-7**). This volume of alluvial sourced water (alluvial leakage) is considered appropriate for evaluation against licences held by Wambo for the *Lower Wollombi Brook Alluvial Water Source*.

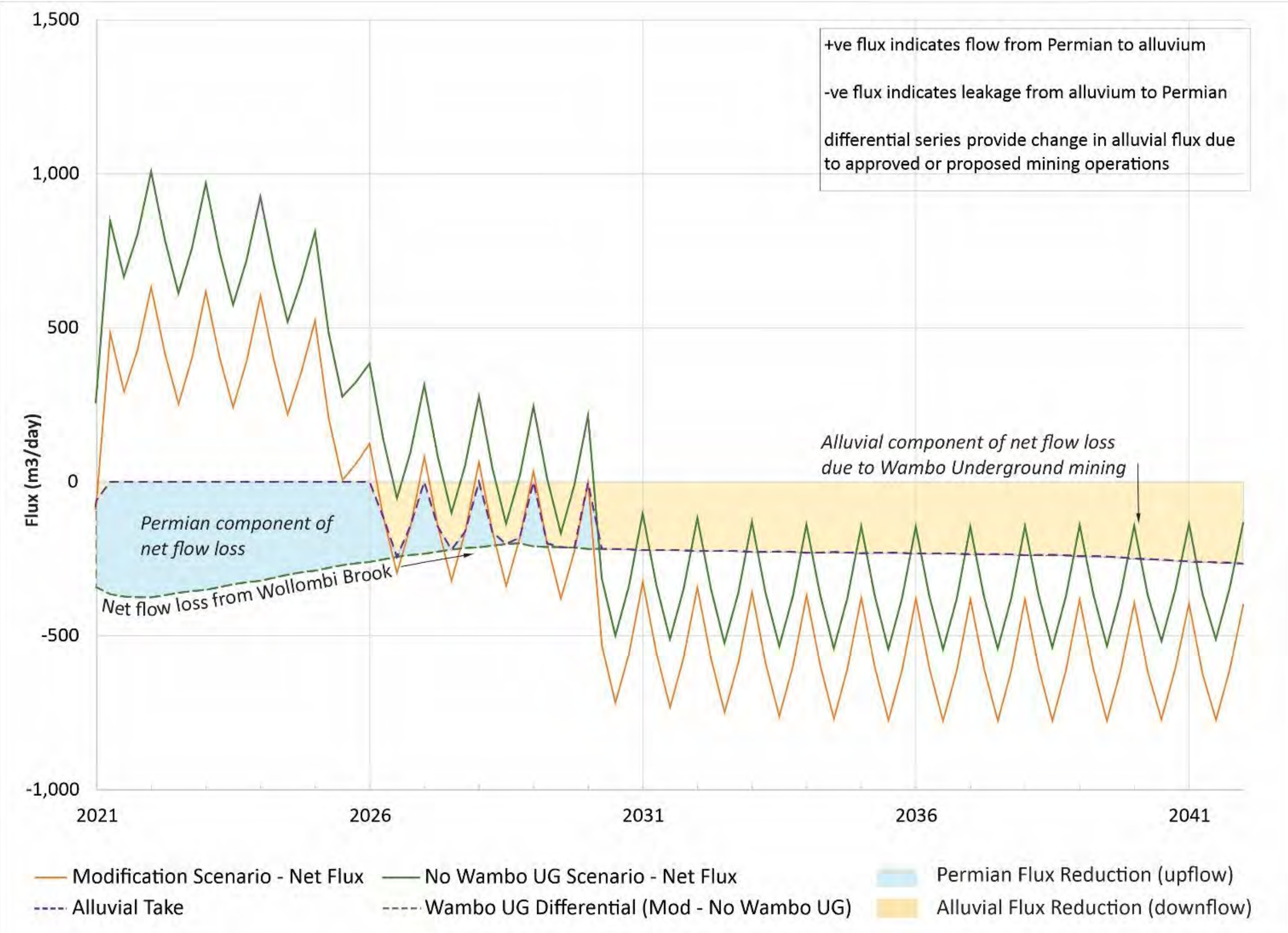


Figure 8-7 Components of predicted net alluvial flux for Wollombi Brook

8.3 Hunter River Unregulated and Alluvial Water Source

Approved and modified underground mining at Wambo underlies, or is located near to watercourses and alluvium, which are within the *Jerrys Water Source* of the *Upstream Glennies Creek Management Zone*. Predicted changes in groundwater level and groundwater flux to these areas of alluvium due to the Modification are presented in the following sections.

8.3.1 Hunter River

The modified mine plan for the SBX Underground Mine is 1.3 km closer to Hunter River alluvium than the approved SBX Underground Mine layout (1.5 km compared with 2.8 km). The target Whybrow Seam (model layer 7) outcrops between the modified SBX Underground Mine and the Hunter River, with no direct flow pathway between the Hunter Alluvium and the SBX Underground Mine.

8.3.1.1 Groundwater levels

No incremental drawdown impacts are predicted for the Hunter River alluvium as a result of the Modification (**Figure 7-3**). Conceptually, incremental impacts to the Hunter River alluvium are considered unlikely. Although the distance of proposed mining from the SBX Underground Mine to the Hunter alluvium has decreased, migration of drawdown due to the Modification would be limited by the geometry of the Whybrow Seam, which outcrops between the SBX Underground Mine and the mapped alluvial extent.

8.3.1.2 Alluvial flux

Net flux to or from the Hunter River alluvium for the Approved, Modified, No Wambo Underground Mining and Null modelling scenarios are presented in **Figure 8-8.** It is noted that Approved Scenario, Modification Scenario, and no Wambo UG Scenario net flux series are coincident.

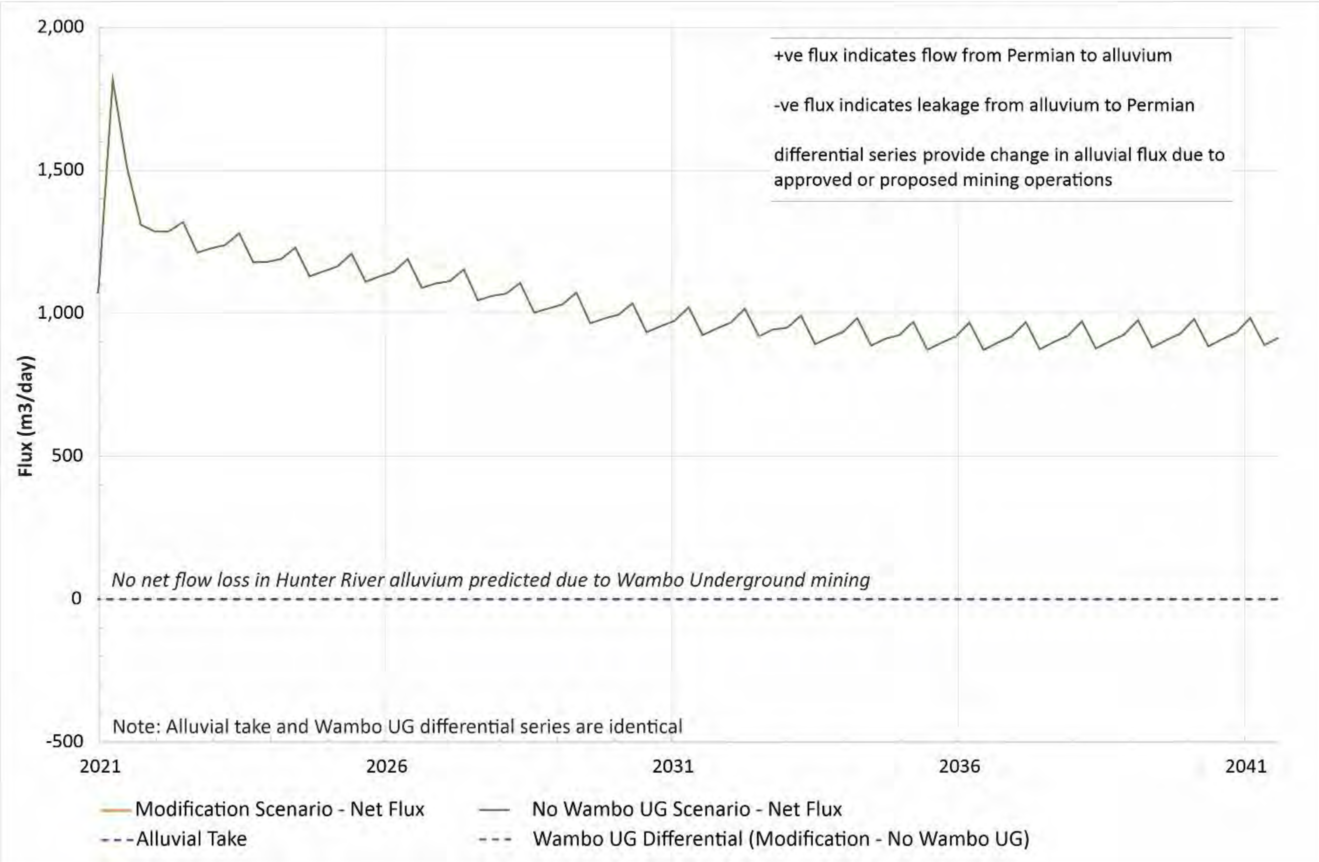


Figure 8-8 Predicted net alluvial flux for the Hunter River

As is indicated on **Figure 8-8**, flux with a negative magnitude indicates net leakage from alluvium, and flux with a positive magnitude indicates flow from underlying Permian strata to alluvium.

Evaluation of incremental impacts for the Modification shows no change in flow to the Hunter Alluvium due to the Modification. Other alluvial zones where a change in alluvial flux due to the Modification (North Wambo Creek, Wambo Creek, Wollombi Brook) has been predicted are closer to the South Wambo Underground Mine. This distance of the Hunter River alluvium from the South Wambo Underground Mine (5 km east and 5.5 km north) is likely the reason no incremental flux changes are observed.

Evaluation of cumulative impacts for the modified Wambo indicates a net loss of water from the Hunter River alluvium that peaks at 39 ML/year (107 m^3/day) in 2034. This is around half the maximum cumulative annual inflow volume from the UWOCP EIS (AGE, 2016).

Evaluation of impacts to the Hunter River alluvium from Wambo Underground mining indicates no impacts are predicted due to Wambo underground mining including the modification. **Figure 8-9** shows no change to net flux between the modification and no Wambo UG model scenarios. The predictions are consistent with a conceptualised lack of impact to the Hunter River as Wambo underground mining is some distance away, with target seams generally outcropping to the east.

This predicted lack of impact has been accounted for when considering licensable take as part Hunter River Unregulated and Alluvial Water Source (See **Section 8.6**).

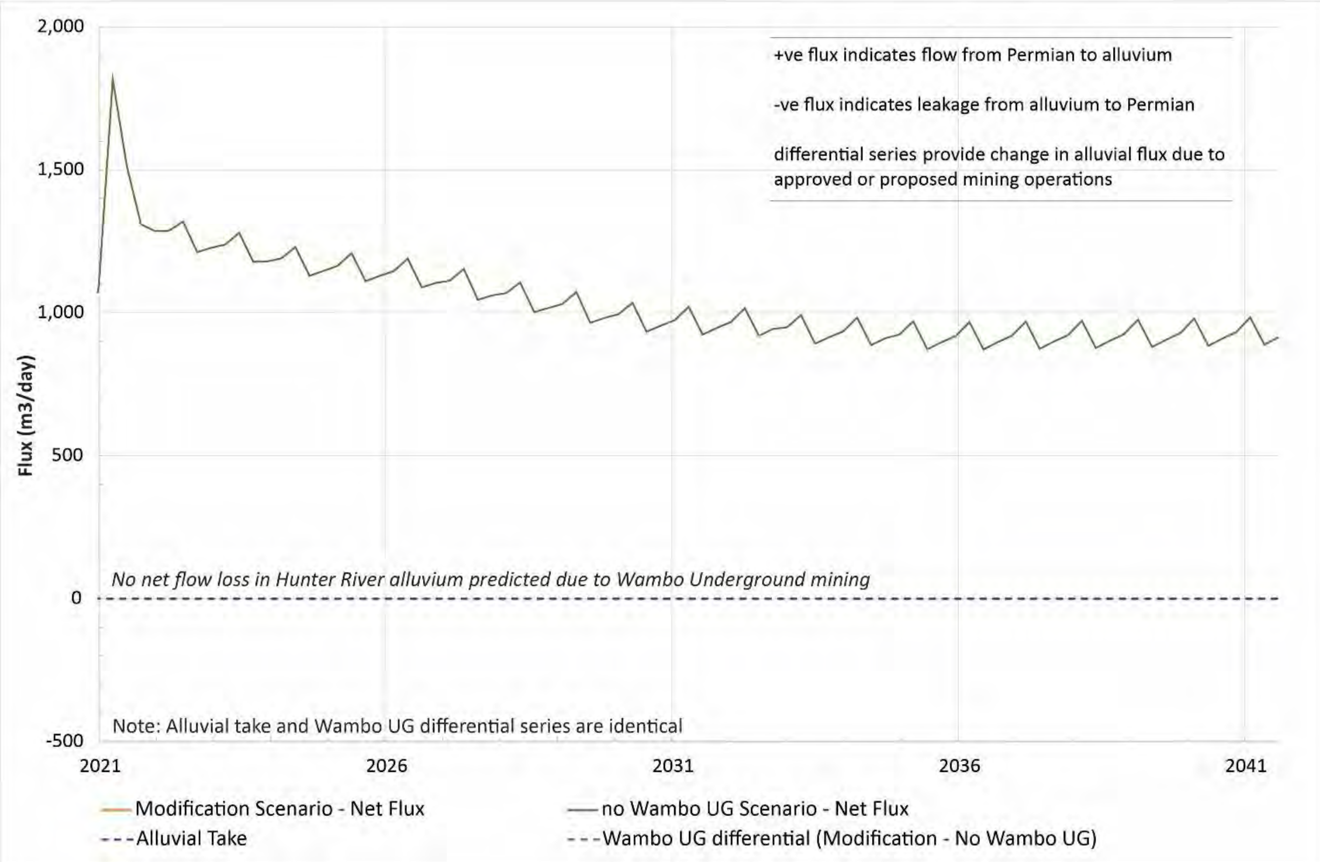


Figure 8-9 Components of predicted net alluvial flux for the Hunter River

8.3.2 Waterfall Creek

The Waterfall Creek catchment is located to the north of North Wambo Creek, with the northern end of modified Longwalls 24 and 25 extending to within 100 to 300 m of the creek, while Longwall 26 underlies the first and second order drainage lines that form the headwaters of Waterfall Creek. There is no mapped alluvium or available information showing the presence of alluvium along Waterfall Creek.

8.3.2.1 Groundwater levels

Alluvium is not mapped or defined along Waterfall Creek and has not been included in the model. No drawdown is predicted within the regolith/ colluvium (layer 1) near Waterfall Creek (**Figure 7-3**).

8.3.2.2 Alluvial flux

Alluvium is not mapped or defined along Waterfall Creek and has not been included in the model. As discussed in **Section 7.5.2** the model also predicts no interaction between surface water and groundwater along Waterfall Creek for the approved, modified and no Wambo scenarios. There are therefore no predicted losses to surface water or alluvium due to the Modification.

8.4 Privately owned registered bores

An overview of predicted incremental and cumulative impacts at privately owned registered bores for the base case numerical modelling and the uncertainty analysis are provided in **Section 7.6.1** and **Section 7.7.4 respectively.** The following section considers these predicted impacts against the AIP minimal harm criterion.

Due to the cumulative effects of all open cut and underground mining in the Wambo area, some drawdowns greater than 2 m are to be expected, and there are a number of registered bores that are predicted to have a maximum cumulative drawdown greater than 2 m (**Figure 7-9**). However, most of these bores are either owned by WCPL or have a listed use for mining or monitoring, and therefore the AIP minimal harm criterion is not relevant. Bore attributes were derived from the Wambo GWMP (WCPL, 2021a), site inspections undertaken by SLR in early 2022, and a review of the NSW Government bore database in 2022.

Table 8-1 presents a summary of privately owned registered bores near Wambo including predicted total and incremental drawdown associated with the Modification. Of the private bores near Wambo, none exceeds a drawdown of 2 m due to the approved and modified Wambo operations.

Drawdown above the 2 m threshold for minimal impact considerations is predicted for model realisations above the 95th percentile at one private registered bore (GW078574) from the uncertainty analysis (see **Section 7.7.4**). Further investigation of results from the uncertainty analysis found the 67th percentile result is below the 2 m threshold for minimal impact considerations at GW078574 (1.15 m drawdown predicted due to all Wambo operations from 2003). As per the IESC's (2018b) Information Guidelines on uncertainty analysis, at the 67th percentile, it is considered a larger magnitude outcome is not expected to occur in normal conditions, and at the 95th percentile the result is considered unlikely to occur even in extreme conditions. While a number of realisations predict drawdown impacts at this location >2 m, it is considered unlikely impacts would be above 1.15 m drawdown, and very unlikely that impacts will reach the 2.8 m predicted at the 95th percentile.

Numerical modelling for MOD17 - South Bates Extension Underground Mine predicted a maximum cumulative drawdown of 18 m at GW078574 (HydroSimulations, 2017) when the bore was simulated to be screened in the HydroSimulations (2017) model layer 2 (Permian Overburden). Layer 2 was the only model layer above the Whybrow Seam in HydroSimulations (2017), which was targeted by the historical Homestead-Wollemi underground mine under GW078574. Subsidence induced changes to hydraulic parameters from historical longwall mining would have been applied to the full thickness of layer 2 (>150m thick in this location) and may have resulted in some over-prediction of likely impacts.

Table 8-1 Predicted drawdown effects at privately owned registered bores

Work No. (bore ID)	Licence/ Approval Number	Location (GDA94 z56)		Use	Measured Depth to Water (mbgl)	Depth (mbgl)	Water Source	Status/ Comment	Predicted Drawdown (m)	
		mE	mN						Incremental[1]	Cumulative[2]
GW043225		303653	6398949	Irrigation	15.1 (2022)	24.7	Sydney Basin North Coast Fractured and Porous Rock	150 mm diameter PVC bore, viable but not currently used (in 2022). WQ described by owner as black and saline.	0.0	0.0
GW078477	20BL167575/ 20WA216092	304007	6398988	Domestic	11.05 (2015)	102.5		Bore in use with 150 mm diameter PVC casing. Pump installed to 29 m depth, used approx. quarterly and yields 3 L/s (from 2015).	0.0	0.1
GW064382		303908	6394477	HUSE		60		Access restrictions, bore not assessed. Bore in Wollemi National Park.	0.0	0.1
GW078574	20BL167170/ 20WA215998	309174	6390605	Farming		12	Lower Wollombi Brook Alluvial Water Source – less productive	Well	0.0	1.3
GW078575	20BL167171/ 20WA215999	309505	6389687	Farming		12		Well	0.0	0.4
GW078576	20BL167172/ 20WA216000	309764	6389784	Farming		7		Well	0.0	0.0
GW078577	20WA208559	309969	6389973	Domestic		10		Well	0.0	0.3

[1] Incremental drawdown is evaluated by comparing the Modification and Approved predictive model scenarios (**Section 7.2**)

[2] Cumulative drawdown is evaluated by comparing the Modification and Null predictive model scenario (**Section 7.2**)

Additional discretisation of the weathered zone and overburden strata in the numerical modelling undertaken for this assessment simulates four model layers between the Whybrow Seam (layer 7) and the shallow weathered strata the bore is predicted to intersect at a depth of 12 m (layer 2). The migration of subsidence induced changes to hydraulic parameters would be more realistically represented in the current modelling.

8.5 Ecological sites

A review of relevant data sources was undertaken as part of this Groundwater Assessment with details on the occurrence of potential GDEs or other environmental groundwater receptors in the vicinity of the modified Longwalls 24-26 is provided in **Section 6.6.1**.

8.5.1 Waterfall Creek GDE

The high potential GDE along Waterfall Creek has been reviewed against predicted alluvium/ regolith (Layer 1), and water table impacts due to the Modification (incremental impacts) and the modified Wambo (cumulative impacts).

No incremental drawdown is predicted in alluvium/ regolith (layer 1) at the high potential GDE at Waterfall Creek due to the Modification (incremental impact - **Figure 7-3)**. Up to 18 m of incremental drawdown at the water table is predicted at the high potential GDE north of modified Longwall 24 due to the Modification (incremental impact -**Figure 7-2**). The water table elevation at this location is predicted to be 53 mbgl in the Modification scenario and 35 mbgl in the Approved scenario and likely not accessible by vegetation.

No drawdown is predicted in alluvium/ regolith (layer 1) at the high potential GDE at Waterfall Creek due to Wambo area underground and open cut operations (cumulative impact - **Figure 7-10)**. Up to 26 m drawdown at the water table is predicted at the high potential GDE north of Modification LW24 due to the Wambo area underground and open cut operations (cumulative impact -**Figure 7-9**). The water table elevation at this location is predicted to be 53 mbgl in the Modification scenario and 27 mbgl in the Null scenario and likely not accessible by vegetation.

8.5.2 North Wambo Creek GDEs

The high potential GDE characterised in the biodiversity review for the Modification (Eco Logical, 2022). is mapped to cover a 1.5 km reach along North Wambo Creek (**Figure 6-13**). The full reach (1.5 km) of North Wambo Creek containing the high potential GDE is underlain by approved Longwalls 24 and 25; 0.5 km of the reach is underlain by the Modification footprint, with 0.2 km of the reach directly overlying the southern end of Longwall 26.

MSEC (2017) predicted up to 1.95 m of subsidence above the SBX Underground Mine, potentially causing increased ponding and scouring of North Wambo Creek. HydroSimulations (2019) concluded that fracturing to the surface above longwalls, or temporary connection between surface cracks and subsurface fracturing may lead to periods of water transfer out of North Wambo Creek. However, it was also concluded that this occurrence is likely to be temporary and is unlikely to reduce the long-term ability for the high potential GDE to temporarily access groundwater. The reduced surface area of high potential GDE subject to subsidence with the Modification mine plan will reduce likelihood of this facultative GDE being impacted by the SBX Underground Mine.

Key outputs from the groundwater modelling relating to the North Wambo Creek high potential GDE due to the Modification and Wambo include:

- No incremental drawdown is predicted for the North Wambo Creek alluvium due to the Modification (**Figure 7-3)** where the high potential GDE is located.
- The water table under a small area of the mapped high potential GDE (<50 m long near the southern end of Modification Longwall 24) is predicted to experience approximately 2 m of incremental drawdown due to the Modification (**Figure 7-2**).
- No other mapped areas of the high potential GDE along North Wambo Creek overlie areas of predicted water table drawdown due to the Modification.
- 1 m drawdown within the North Wambo Creek alluvium is predicted for the eastern-most extent (a 120 m reach) of the high potential GDE along North Wambo Creek due to Wambo area underground and open cut operations Cumulative impact (**Figure 7-10**). Approximately 5 – 7.5 m drawdown is predicted for the water table underlying the entire vegetation community identified by Hunter Eco (2019) as likely to be groundwater dependent and the broader SBX Underground Mine area (**Figure 7-9**).

An additional vegetation community is identified as a high potential GDE (Eco Logical, 2022) and is located at the north-eastern end of the approved Longwall 20. This area is outside of mapped alluvium associated with North Wambo Creek and is 300 m from the nearest shallow standpipe piezometer (GW34). Eco Logical (2022) described the location of this additional high potential GDE as isolated and having impeded drainage, with recent aerial photography showing the high potential GDE located next to a minor drainage line with a series of dams.

No incremental drawdown is predicted for the North Wambo Creek alluvium or water table due to the Modification (**Figure 7-3** and **Figure 7-2**) where the high potential GDE overlying the approved Longwall 20 is located.

1 m drawdown within the alluvium/ regolith of model layer 1 is predicted for the north-eastern 20% (approximately 0.15 Ha) of the additional high potential GDE due to Wambo since 2003 (Cumulative impact - **Figure 7-10**). Approximately 10 – 30 m drawdown is predicted for the water table underlying the entire additional high potential GDE due to Wambo area underground and open cut operations. This is likely due to nearby open cut and underground mining (Cumulative impact **Figure 7-9**).

8.5.3 GDE Atlas high-potential GDEs

Areas mapped as high potential terrestrial GDEs from the BoM GDE Atlas (**Figure 6-13**), including areas mapped around Redmanvale Creek and the Hunter River (located northwest and north of LW24 – 26), and small areas around Waterfall Creek and North Wambo Creek (located northeast and southeast of LW24 – LW26) have been reviewed against predicted alluvium/ regolith (Layer 1 and Layer 2), and water table impacts due to the Modification and Wambo.

- There are no incremental drawdown impacts predicted due to the Modification in alluvium/ regolith (Layer 1) or the water table (**Figure 7-3** and **Figure 7-2**) at any mapped vegetation identified in the BoM GDE Atlas as a high potential terrestrial or aquatic GDE.
- There are no drawdown impacts predicted due to Wambo area underground and open cut operations in alluvium/ regolith (Layer 1) (**Figure 7-10**) at any mapped vegetation identified in the BoM GDE Atlas as a high potential terrestrial or aquatic GDE.

- Approximately 3 m of cumulative drawdown is predicted at the water table (**Figure 7-9**) over the south-western fifth of a mapped high potential terrestrial GDE on Waterfall Creek, 250 m north of the modified Longwall 25. The water table elevation at this location is predicted to be 42 metres below ground level (mbgl) and likely not accessible by vegetation.
- Approximately 1 m of cumulative drawdown is predicted at a small number of mapped high potential terrestrial GDEs near Redmanvale Creek. The water table elevation at this location is predicted to be 15 to25 mbgl and likely not accessible by vegetation.

8.6 Groundwater licensing

For the mapped extent of alluvium (alluvial mapping nearby Wambo is shown in **Figure 5-1**), outputs from the model have been assessed to evaluate the effect of Wambo operations on the groundwater flow between the alluvium and the underlying Permian rock. The component of flow between alluvium and underlying rock to be considered for alluvial groundwater licensing is an increased leakage from alluvium to Permian induced by Wambo. Reduction in groundwater flow from Permian strata to alluvium has not been considered a component of alluvial licensing, as this reduction in Permian flow is considered licensable take from the North Coast Fractured and Porous Rock Groundwater Sources and is accounted for in predicted groundwater inflow to Wambo mining operations.

Table 8-2 shows the predicted annual groundwater volumes required to be licensed for Wambo, for both alluvial and porous/fractured rock groundwater sources for the Approved and Modified Scenarios. The predictions for the approved Wambo licencing volumes from HydroSimulations (2017) are also included. It is acknowledged that maximum impacts may occur following the completion of mining. The predicted groundwater volumes required for licencing from this assessment have therefore considered the post-mining/ recovery period (to 2400). The average values in **Table 8-2** are indicative and only consider the predictive mining period (2021-2041).

For the duration of Wambo mining operations, including the modified SBX Underground Mine, there is predicted to be a net average loss of alluvial groundwater to the underlying rock of 71 ML/year during mining and a maximum of 128 ML/year for the *Lower Wollombi Brook Alluvial Water Source* that is predicted to occur post mining (in 2049). This maximum is the same as predicted for the Approved Scenario, while the net average loss during mining is a small reduction from the Approved Scenario (see **Table 8-2**). No loss of alluvial groundwater to underlying Permian rock is predicted for the *Jerrys Water Source* of the *Upstream Glennies Creek Management Zone*; net flow change for this water source is predicted to be a reduction in Permian flow to the alluvium (**Section 8.3**).

Table 8-2 Groundwater licensing summary

Water Sharing Plan	Management Zone/ Groundwater Source	Licensed Entitlement (ML/ year)	Predicted Annual Groundwater Inflow Volumes requiring Licensing (ML/year)		
			Approved Wambo		Modified Wambo
			HydroSimulations (2017)	SLR	
Hunter Unregulated and Alluvial Water Sources Water Sharing Plan 2009	**Lower Wollombi Brook Water Source**	420*	Max. 69	Av. 77 Max. 128	Av. 71 Max. 128
	Jerrys Water Source	-	0	0	0
North Coast Fractured and Porous Rock Groundwater Sources ^^	**Porous Rock**	1,647**	Max. 1,072	Av. 395 Max: 590	Av. 417 Max. 657

^^ Porous Rock is the Sydney Basin - North Coast Groundwater Source, as defined in the *WSP for the North Coast Fractured and Porous Rock Groundwater Sources*, released 1 July 2016.

*Licence No. WAL23897 and WAL18437

**Licence No. WAL42373, WAL41532

The maximum take from the porous/fractured rock groundwater sources from the hard rock water source due to Wambo mining is estimated to be 657 ML/year.

WCPL currently has licence entitlements of 420 ML/year for the Lower Wollombi Brook Water Source and 1,647 ML/year for groundwater derived from the Porous Rock source (WCPL, 2021a). The current groundwater licence for the *Lower Wollombi Brook Water Source* is therefore sufficient to cover the predicted water extraction from alluvium shown in **Table 8-2** for both the approved and modified mine plans, while sufficient licence is currently available for the *North Coast Fractured and Porous Rock Groundwater Sources*.

8.7 Surface water licensing

For watercourses within the model domain, model outputs have been assessed to evaluate the effect of Wambo operations on the groundwater-surface water flow between the watercourses and their underlying alluvium/ regolith. The component of flow between watercourses and their alluvium to be considered for surface water licensing is an increased leakage from surface water to underlying alluvium/ regolith induced by Wambo. Reduction in groundwater flow to watercourses (baseflow) has not been considered a component of surface water licensing.

There is no licensable surface water take predicted for the approved or Modification model scenarios. Any change in net flux to/from watercourses due to Wambo is predicted to be a baseflow reduction, and licensable as extraction from an alluvial water source. **Section 8.6** provides licensable take estimates for the Lower Wollombi Brook Water Source, while **Section 8.2** and **Section 8.3** provide detail on how these are derived from net flow changes to areas of alluvium near Wambo.

WCPL currently has licence entitlements of 2,194 ML/year for the Hunter Regulated River Water Source under high security, general security, and supplementary licence categories. WCPL currently has licence entitlements of 350 ML/year for the Lower Wollombi Brook Water Source in the unregulated river licence category (WCPL, 2020b).

8.8 Groundwater quality

Consistent with HydroSimulations (2017), there are no anticipated risks of reduced beneficial use of the highly productive alluvium associated with Wollombi Brook and the Hunter River as a result of the Modification. The Modification is predicted to have no discernible long-term effect on stream baseflow or natural river leakage for Wollombi Brook, beyond the effects of approved mining (see **Section 7.8.2** and **Section 7.8.3**). Therefore, the Modification would have negligible effect on the long-term salinity of Wollombi Brook or Hunter River.

The Modification is predicted to have negligible long-term effect on stream baseflow or natural river leakage for Wambo Creek, North Wambo Creek, or Waterfall Creek stream systems, beyond the effects of approved mining (see **Section 7.8.2** and **Section 7.8.3**). It is anticipated that the Modification would not increase the long-term salinity of Wambo Creek, North Wambo Creek, or Waterfall Creek.

8.9 Climate change and groundwater

The effects of climate change on groundwater are projected to be negative in some places on earth, but positive in other places. Overall predicted changes remain controversial with respect to magnitude and timing.

The NSW Climate Impact Profile – The Impacts of Climate Change on the Biophysical Environment of New South Wales (Department of Environment, Climate Change and Water, 2010) indicates changes to the climate of the Hunter Region may include:

- Increase in maximum and minimum temperatures;
- Increase in summer rainfall;
- Increase in evaporation; and
- Increase in the intensity of flood producing rainfall events.

Annual rainfall is expected to change by -10 to +5% by 2030 (Pittock, 2003) in parts of south-eastern Australia. In addition, annual average temperatures are projected to increase by 0.4 to 2.0 degrees Celsius (°C) (relative to 1990) at that time.

In consideration of the above, there are potential cumulative effects to the groundwater system associated with the Modification and climate change. However, as the Modification is predicted to not have significant effects beyond the effects of approved mining, no additional groundwater effects associated with the Modification would be expected when considered cumulatively with potential effects associated with climate change.

8.10 Assessment against the Minimal Impact Considerations

The AIP establishes minimal impact considerations for highly productive and less productive groundwater. DPE Water mapping of highly productive groundwater in the vicinity of Wambo indicates that an area of highly productive alluvial aquifer exists along Wollombi Brook and a small portion on Wambo Creek (but not into the other tributary channels).

It follows that the remaining alluvial and porous rock groundwater systems in the vicinity of the Wambo mine are less productive.

Table 8-3 to **Table 8-4** provide an assessment of the Modification against the minimal impact considerations in the AIP and include consideration of cumulative impacts where appropriate.

Table 8-3 Highly Productive Alluvial Aquifer – Minimal Impact Considerations

Aquifer	Unnamed Upriver Alluvium* in the Lower Wollombi Brook Water Source (part of the Hunter Unregulated and Alluvial Water Sources 2009)
Type	Alluvial Aquifer
Category	Highly Productive
Level 1 Minimal Impact Consideration	**Assessment**
<u>Water Table</u> Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: high priority groundwater dependent ecosystem; or high priority culturally significant site; listed in the schedule of the relevant water sharing plan. OR A maximum of a 2 m water table decline cumulatively at any water supply work.	**Level 1 - Acceptable** There are no High Priority Groundwater Dependent Ecosystems identified in the Water Sharing Plan for the Lower Wollombi Brook Water Source. There are no High Priority Culturally Significant Sites listed in the Hunter Unregulated and Alluvial Water Sources Water Sharing Plan. Wambo mining would not result in cumulative drawdown of more than 2 m at any privately owned water supply work in a 'highly productive' alluvial aquifer over the duration of SBX Underground Mine.
<u>Water pressure</u> A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.	**Level 1 - Acceptable** Wambo mining would not result in cumulative drawdown of more than 40% of the pressure head at any privately owned water supply work in a 'highly productive' alluvial aquifer.

Aquifer	Unnamed Upriver Alluvium* in the Lower Wollombi Brook Water Source (part of the Hunter Unregulated and Alluvial Water Sources 2009)
Type	Alluvial Aquifer
Category	Highly Productive
Level 1 Minimal Impact Consideration	**Assessment**
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a “reliable water supply”. Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining activities beyond 200 m laterally from the top of high bank and 100 m vertically beneath a highly connected surface water source that is defined as a “reliable water supply”.	**Level 1 - Acceptable** There are no simulated risks of reduced beneficial uses of the highly productive alluvium as a result of the Modification. The Modification would have no discernible effect on stream baseflow or natural river leakage for Wollombi Brook, beyond the effects of approved mining. Therefore, the Modification would have negligible effect on the long-term salinity of Wollombi Brook. Wollombi Brook is a “reliable water supply” associated with Highly Productive groundwater. The Modification will not extract alluvial material associated with the Highly Productive alluvial groundwater system.

* Online shapefile name

Table 8-4 Less Productive Alluvial Aquifer – Minimal Impact Considerations

Aquifer	Alluvium outside the boundary of the 'Highly Productive' Hunter Alluvial Water Source (part of the Hunter Unregulated and Alluvial Water Sources 2009)
Type	Alluvium
Category	Less Productive
Level 1 Minimal Impact Consideration	**Assessment**
Water Table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: high priority groundwater dependent ecosystem; or high priority culturally significant site; listed in the schedule of the relevant water sharing plan. OR A maximum of a 2 m water table decline cumulatively at any water supply work.	**Level 1 - Acceptable** There are no High Priority Groundwater Dependent Ecosystems identified in the Water Sharing Plan for the Lower Wollombi Brook Water Source. There are no high priority culturally significant sites listed in the Hunter Unregulated and Alluvial Water Sources Water Sharing Plan. There are vegetation communities identified through BoM GDE Atlas mapping and the Biodiversity Review (EcoLogical, 2022) that are considered 'high potential GDEs' near North Wambo Creek and Waterfall Creek (**Section 8.5**). • No incremental drawdown is predicted in alluvium/ regolith due to the Modification at the 'high potential GDEs' near North Wambo Creek and Waterfall Creek. • A maximum incremental drawdown of approximately 2 m is predicted for the water table below an isolated patch of the riparian high potential GDE near North Wambo Creek (approximately 3% of the community). This effect is not predicted to occur following recovery. No incremental drawdown is predicted for the rest of the riparian community • The predicted depth to water at the Waterfall Creek 'high potential' GDE at the end of currently approved mining is 35 mbgl. At this depth, groundwater is likely not accessible by the 'high potential' GDE and the predicted maximum incremental drawdown of 18 m due to the Modification will not change the potential for interaction between the 'high potential' GDE and groundwater. The paired groundwater monitoring site recommended near Waterfall Creek (**Section 9**) would monitor shallow groundwater conditions near the 'high potential' GDE and could be used to verify the potential for groundwater interaction. Under normal conditions Wambo mining is predicted to not result in cumulative drawdown of more than 2 m at any privately owned water supply work in a 'less productive' alluvial aquifer over the duration of Wambo Underground mining. WCPL would continue to implement the Surface and Groundwater Response Plan (WCPL, 2015b) in the event a complaint is received in relation to loss of groundwater supply.

Aquifer	Alluvium outside the boundary of the 'Highly Productive' Hunter Alluvial Water Source (part of the Hunter Unregulated and Alluvial Water Sources 2009)	
Type	Alluvium	
Category	Less Productive	
Level 1 Minimal Impact Consideration		**Assessment**
<u>Water pressure</u> A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.		**Level 1 - Acceptable** Wambo mining would not result in cumulative drawdown of more than 40% of the pressure head at any privately owned water supply work in a 'less productive' alluvial aquifer.
<u>Water quality</u> Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply".		**Level 1 - Acceptable** There are no simulated risks of reduced beneficial uses of the alluvium as a result of the Modification. The Modification would have no discernible effect or negligible effect on stream baseflow or natural river leakage for Wambo Creek, North Wambo Creek, or Waterfall Creek stream systems, beyond the effects of approved mining. It is anticipated that the Modification would not increase the long-term salinity of North Wambo Creek, Waterfall Creek or Wambo Creek. Extraction will occur within the three dimensional extent of the alluvial water source associated with North Wambo Creek. There are no bores along the North Wambo Creek alluvium for irrigation, domestic or stock use. North Wambo Creek is not considered a "reliable water supply" due to the limited ability of the alluvium to remain saturated outside of high magnitude rainfall events.

Table 8-5 Less Productive Porous Rock Aquifer – Minimal Impact Considerations

Aquifer	Sydney Sandstone Central Coast* (part of the North Coast Fractured and Porous Rock Groundwater Sources WSP)
Type	Porous Rock Aquifer
Category	Less Productive

Level 1 Minimal Impact Consideration	Assessment
Water Table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: high priority groundwater dependent ecosystem; or high priority culturally significant site; listed in the schedule of the relevant water sharing plan. OR A maximum of a 2 m water table decline cumulatively at any water supply work.	**Level 2** The only high priority groundwater dependent ecosystem near Wambo is Parnell Spring. Parnell Spring likely flows from the Triassic-age Narrabeen Formation and is located 9 km south-southwest of the Modification longwall panels (Section 2.2). Wambo mining would result in negligible drawdown at Parnell Spring. A cumulative drawdown of more than 2 m is not predicted at any privately owned water supply work in the porous rock water source.
Water pressure A cumulative pressure head decline of not more than a 2 m decline, at any water supply work.	**Level 2** The Modification would not result in cumulative drawdown of more than 2 m at any privately owned water supply work in a 'less productive' porous rock aquifer over the duration of South Bates Underground mining. WCPL would continue to implement the Surface and Groundwater Response Plan (WCPL, 2015b) in the event a complaint is received in relation to loss of groundwater supply.
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.	**Within Level 1** There is not expected to be a migration of groundwater away from the Wambo areas in the Permian system either during mining or following completion of mining activities. On this basis, Wambo would not lower the beneficial use category of the groundwater within the Permian system.

* http://www.legislation.nsw.gov.au/#/view/regulation/2016/375

9 Conclusions

The assessment for this Modification considers the following changes to the SBX Underground Mine:

- Reorientation of Longwalls 24 and 25, and the addition of Longwall 26 in the Whybrow Seam to the north of the nine approved Whybrow Seam longwalls at South Bates Underground.
- Change in timing of mining at South Wambo Underground in the Woodlands Hill and Arrowfield Seams. Mining in the Woodlands Hill Seam would occur from Feb-2027 to Oct-2037 (currently approved for Jan-2025 to May-2035). Mining in the Arrowfield Seam would occur from Apr-2032 to Nov-2041 (currently approved for Jun-2032 to Jun-2041).

This Groundwater Assessment for the Modification has been conducted with reference to the work done for five earlier modifications: Heritage Computing (2012) for North Wambo Underground Longwalls 9 and 10; HydroSimulations (2014) for North Wambo Underground Longwall 10A; HydroSimulations (2015) for South Bates (Wambo Seam) Underground Mine; HydroSimulations (2016) for South Wambo Underground Mine; and HydroSimulations (2017) for South Bates Extension Underground Mine. Data gathered since that time has been analysed (**Section 4**), most notably, alluvial geometry and groundwater behaviour (**Section 6.3**) and surface water-groundwater interaction (**Section 6.3.7**).

The groundwater modelling carried out for the Modification was based on that used for South Bates Extension Underground Mine reporting (HydroSimulations, 2017), and the UWOCP (AGE, 2016) using MODFLOW-USG Beta software.

The incremental effects of the Modification have been considered as changes between the approved and modified scenarios. Cumulative effects of Wambo mining since the approval of Development Consent (DA 305-7-2003) have also been considered.

The key findings of this assessment are:

- The maximum groundwater inflows to the modified SBX Underground Mine are predicted not to change from the approved mine plan.
- The maximum total groundwater inflows for all Wambo underground mining are predicted to increase from 1.6 ML/day to 1.8 ML/day. This peak occurs during the South Wambo Underground Mine operations.
- The Modification would result in additional drawdown at the water table and within the Whybrow Seam above and to the north of the modified Longwalls 24 to 26. This additional drawdown is predicted to not impact any registered bores, alluvium, surface water, or GDEs identified in this study.
- The Modification would not have a significant impact on water levels in the Permian coal measures from a regional perspective due to the regional zone of depressurisation within the Permian coal measures created by historical and ongoing open cut and underground mining.
- There is expected to be negligible impact on the highly productive alluvium associated with Wollombi Brook and the Hunter River as a result of the Modification.
- The Modification would not lower the beneficial use category of the groundwater within the Permian aquifers, as there would be no migration of groundwater away from the underground mining areas in the Permian aquifers either during mining or following completion of mining activities.

- The Modification would not result in reduced beneficial uses of the alluvium (from a water quality perspective).
- The change in timing in mining at South Wambo Underground Mine is predicted to result in a slight decrease in groundwater levels in the Arrowfield Seam relative to the approved scenario.
- The alluvium adjacent to the SBX Underground Mine footprint at North Wambo Creek has been affected by open cut mining activities. The Modification longwalls underlie a smaller area of North Wambo Creek than approved mining and are unlikely to cause additional impacts.
- There are no bores above the SBX footprint that are used for irrigation, domestic or stock use.
- WCPL hold sufficient entitlements under the WM Act for the predicted groundwater take associated with the approved and modified Wambo operations.

An additional groundwater monitoring location is recommended to be installed at Waterfall Creek, north of the modified Longwalls 24 to 26. This paired monitoring bore would target shallow unconsolidated and weathered strata and would aim to improve the understanding of the nature and saturation level of unconsolidated material, and any potential interaction with the underlying groundwater system. Data collected at the recently installed VWPs north and west of the modified Longwalls 24 to 26 should continue to be monitored to validate conceptual model assumptions and numerical model predictions.

No additional groundwater impact mitigation measures are proposed for the Modification. Groundwater levels and quality should continue to be monitored at Wambo in accordance with the GWMP approved under the Development Consent.

Consistent with the currently approved GWMP (WCPL, 2021), in the event that a groundwater quality or water level trigger level specified in the GWMP is exceeded, an investigation should be conducted in accordance with the Groundwater Management Plan. Consistent with the AIP, management measures that may be implemented as a result of the investigation described above could include a “make good” commitment or relinquishment of an equivalent portion of water access licences as a direct offset for potential groundwater inflows into the underground.

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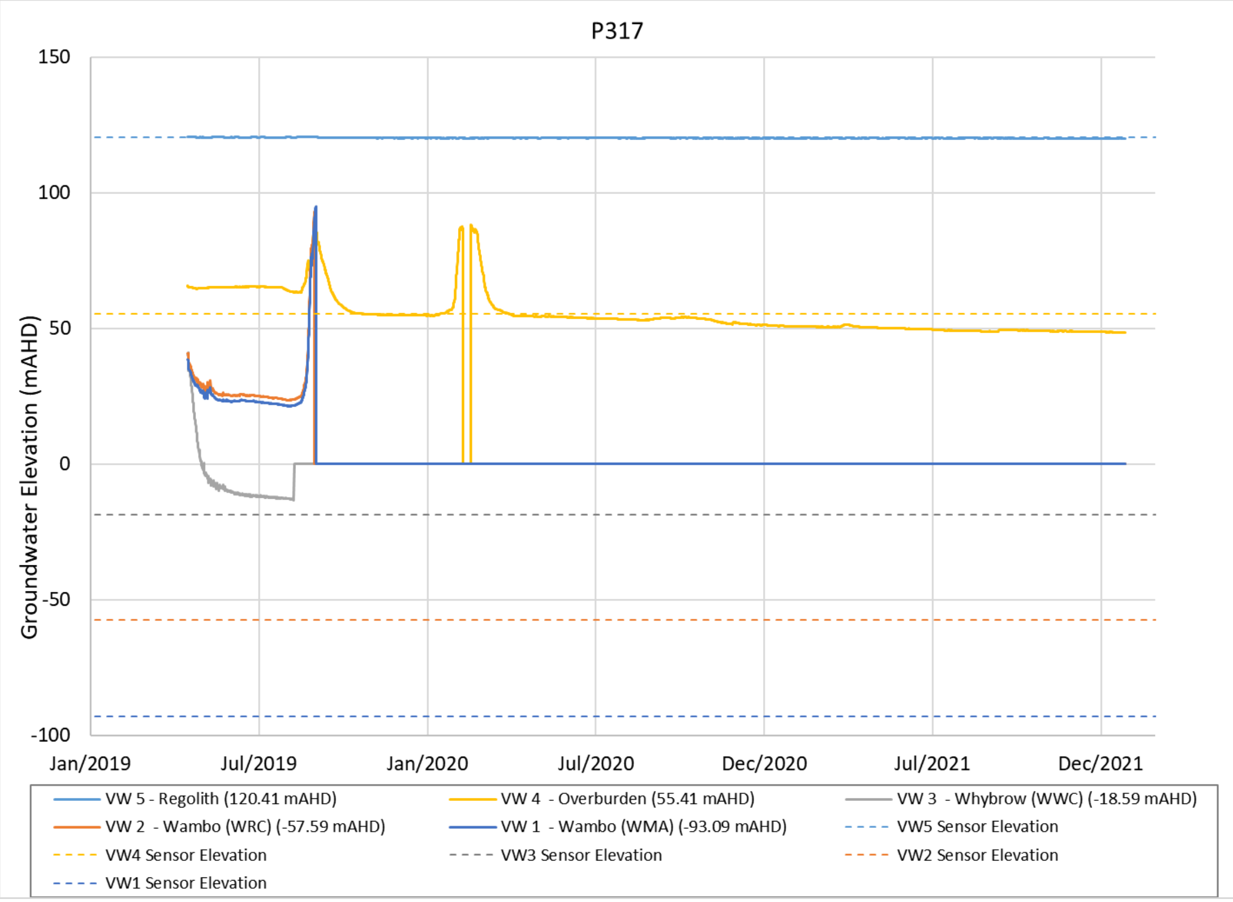
Wambo Coal Pty Ltd, 2021b. *United Wambo Open Cut and Wambo Water Monitoring Program.*

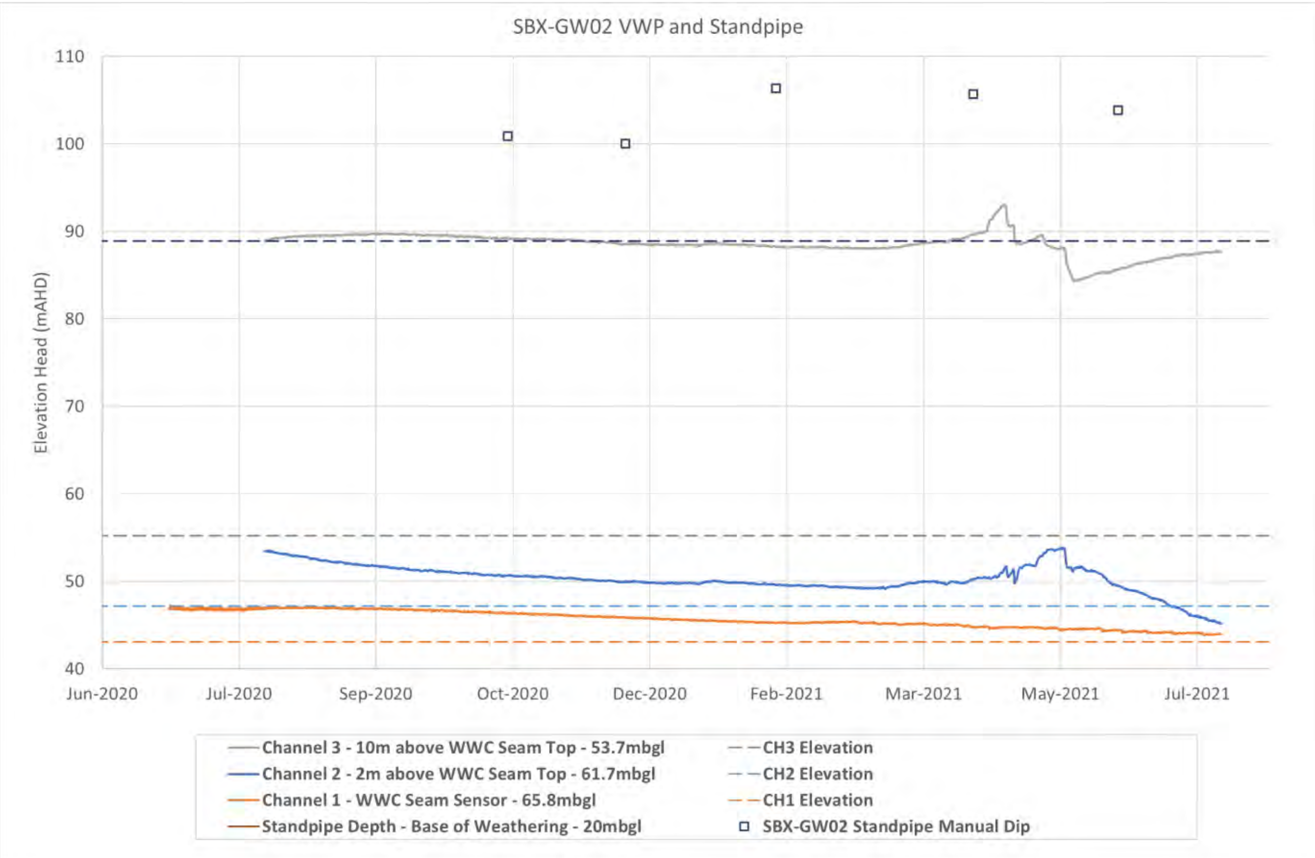
Wambo Coal Pty Ltd, 2021c. *Wambo Coal Pty Ltd – 2020 Annual Review.*

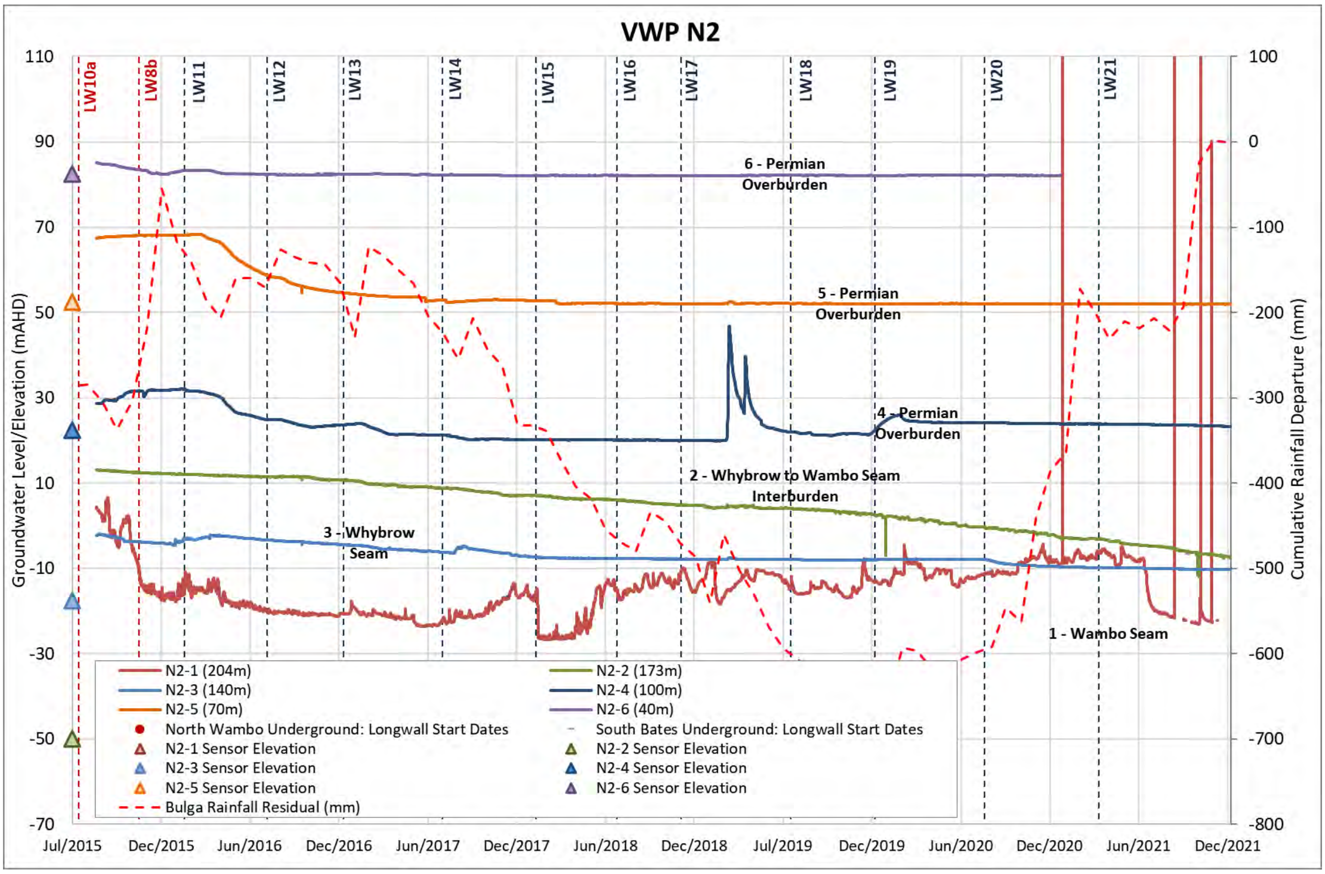
Wambo Coal Pty Ltd, 2022. *Wambo Coal Pty Ltd – 2021 Annual Review.*

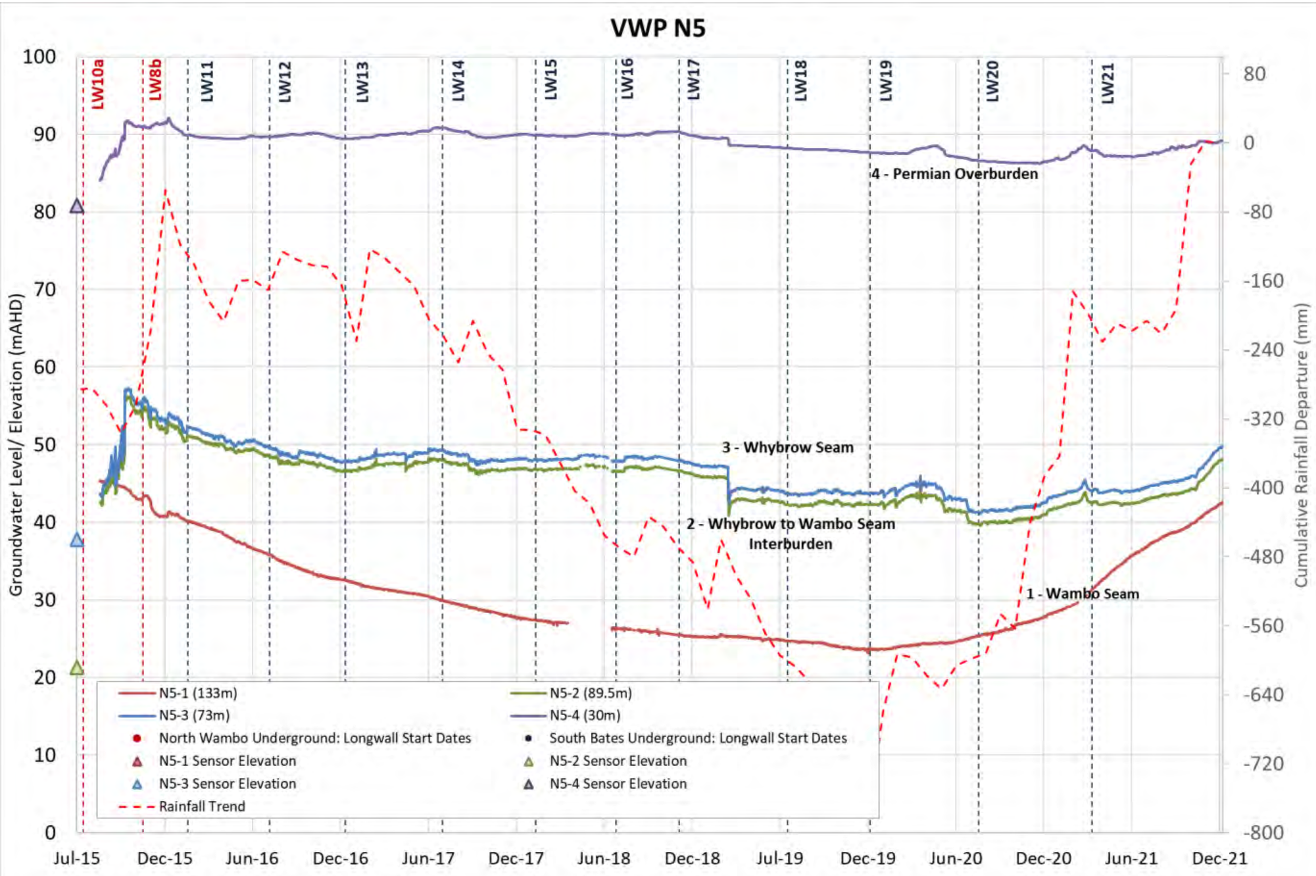
Appendix A:

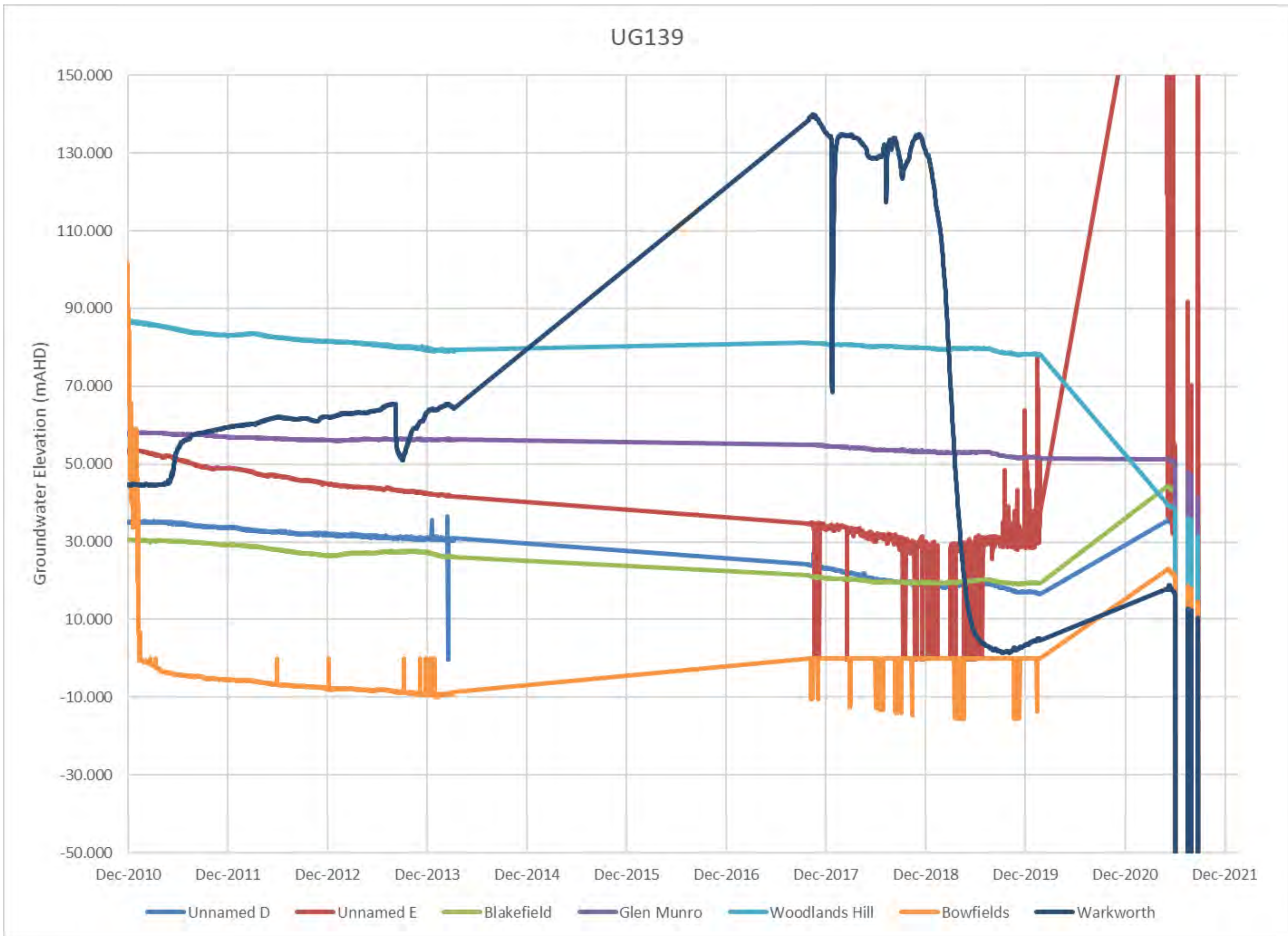
Additional VWP Hydrographs


P317
150
100
50
0
-50
-100
Groundwater Elevation (mAHD)
Jan/2019
Jul/2019
Jan/2020
Jul/2020
Dec/2020
Jul/2021
Dec/2021
VW 5 - Regolith (120.41 mAHD)
VW 4 - Overburden (55.41 mAHD)
VW 3 - Whybrow (WWC) (-18.59 mAHD)
VW 2 - Wambo (WRC) (-57.59 mAHD)
VW 1 - Wambo (WMA) (-93.09 mAHD)
VW5 Sensor Elevation
VW4 Sensor Elevation
VW3 Sensor Elevation
VW2 Sensor Elevation
VW1 Sensor Elevation


SBX-GW02 VWP and Standpipe
110
100
90
80
70
60
50
40
Elevation Head (mAHD)
Jun-2020
Jul-2020
Sep-2020
Oct-2020
Dec-2020
Feb-2021
Mar-2021
May-2021
Jul-2021
Channel 3 - 10m above WWC Seam Top - 53.7mbgl
CH3 Elevation
Channel 2 - 2m above WWC Seam Top - 61.7mbgl
CH2 Elevation
Channel 1 - WWC Seam Sensor - 65.8mbgl
CH1 Elevation
Standpipe Depth - Base of Weathering - 20mbgl
SBX-GW02 Standpipe Manual Dip


VWP N2
LW10a
LW8b
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW20
LW21
6 - Permian Overburden
5 - Permian Overburden
4 - Permian Overburden
2 - Whybrow to Wambo Seam Interburden
3 - Whybrow Seam
1 - Wambo Seam
Groundwater Level/Elevation (mAHD)
Cumulative Rainfall Departure (mm)
N2-1 (204m)
N2-2 (173m)
N2-3 (140m)
N2-4 (100m)
N2-5 (70m)
N2-6 (40m)
North Wambo Underground: Longwall Start Dates
South Bates Underground: Longwall Start Dates
N2-1 Sensor Elevation
N2-2 Sensor Elevation
N2-3 Sensor Elevation
N2-4 Sensor Elevation
N2-5 Sensor Elevation
N2-6 Sensor Elevation
Bulga Rainfall Residual (mm)
Jul/2015
Dec/2015
Jun/2016
Dec/2016
Jun/2017
Dec/2017
Jun/2018
Dec/2018
Jul/2019
Dec/2019
Jun/2020
Dec/2020
Jun/2021
Dec/2021


VWP N5
LW10a
LW8b
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW20
LW21
4 - Permian Overburden
3 - Whybrow Seam
2 - Whybrow to Wambo Seam Interburden
1 - Wambo Seam
Groundwater Level/ Elevation (mAHD)
Cumulative Rainfall Departure (mm)
N5-1 (133m)
N5-2 (89.5m)
N5-3 (73m)
N5-4 (30m)
North Wambo Underground: Longwall Start Dates
South Bates Underground: Longwall Start Dates
N5-1 Sensor Elevation
N5-2 Sensor Elevation
N5-3 Sensor Elevation
N5-4 Sensor Elevation
Rainfall Trend
Jul-15
Dec-15
Jun-16
Dec-16
Jun-17
Dec-17
Jun-18
Dec-18
Jul-19
Dec-19
Jun-20
Dec-20
Jun-21
Dec-21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130.000
110.000
90.000
70.000
50.000
30.000
10.000
-10.000
-30.000
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Groundwater Elevation (mAHD)
Dec-2010
Dec-2011
Dec-2012
Dec-2013
Dec-2014
Dec-2015
Dec-2016
Dec-2017
Dec-2018
Dec-2019
Dec-2020
Dec-2021
Unnamed D
Unnamed E
Blakefield
Glen Munro
Woodlands Hill
Bowfields
Warkworth

Appendix B:

IESC Information Checklist

Assessment Item - Groundwater		
IESC Checklist		**SLR Response**
1	**Context and conceptualisation**	
a	Describe and map geology at an appropriate level of horizontal and vertical resolution including: – definition of the geological sequence(s) in the area, with names and descriptions of the formations and accompanying surface geology, cross-sections, and any relevant field data. – geological maps appropriately annotated with symbols that denote fault type, throw and the parts of sequences the faults intersect or displace.	See **Section 5** which includes detail on the geological sequence and structure. Outcrop geology and structure is displayed in **Figure 5-1**.
b	Provide data to demonstrate the varying depths to the hydrogeological units and associated standing water levels or potentiometric heads, including direction of groundwater flow, contour maps, and hydrographs. All boreholes used to provide this data should have been surveyed.	See **Section 6**, which provides detail on hydrogeological units key to this groundwater assessment. Groundwater monitoring locations, groundwater level, response to climate/ stresses over time are presented. **Table 6-1** provides detail on bore depth and intersected geology.
c	Define and describe or characterise significant geological structures (e.g. faults, folds, intrusives) and associated fracturing in the area and their influence on groundwater – particularly groundwater flow, discharge, or recharge. – Site-specific studies (e.g. geophysical, coring/wireline logging etc.) should consider characterising and detailing the local stress regime and fault structure (e.g. damage zone size, pen/closed along fault plane, presence of clay/shale smear, fault jogs or splays). – Discussion on how this fits into the fault's potential influence on regional-scale groundwater conditions should also be included.	Overview of structural geology presented in **Section 5.3**. Limited site specific data characterising the influence of faults, fold and intrusives on groundwater.
d	Provide hydrochemical (e.g. acidity/alkalinity, electrical conductivity, metals, and major ions) and environmental tracer (e.g. stable isotopes of water, tritium, helium, strontium isotopes, etc.) characterisation to identify sources of water, recharge rates, transit times in aquifers, connectivity between geological units and groundwater discharge locations.	Groundwater electrical conductivity for alluvial and Permian aquifers near the modification presented in **Section 6.4.1.** Shallow groundwater sourced from surface water flow or rainfall recharge generally fresh, while groundwater from Permian coal measures is brackish to saline.
e	Provide site-specific values for hydraulic parameters (e.g. vertical and horizontal hydraulic conductivity and specific yield or specific storage characteristics including the data from which these parameters were derived) for each relevant hydrogeological unit. In situ observations of these parameters should be sufficient to characterise the heterogeneity of these properties for modelling.	**Section 6.2** provides hydraulic parameters for different hydrogeological units. Heterogeneity of these properties captured in the depth dependant relationship for hydraulic conductivity.

Assessment Item - Groundwater		
IESC Checklist		**SLR Response**
f	Describe the likely recharge, discharge, and flow pathways for all hydrogeological units likely to be impacted by the proposed development.	See **Section 6.3**
g	Provide time series level and water quality data representative of seasonal and climatic cycles.	See **Section 6.3** for groundwater level hydrographs in key hydrogeological units. **Section 6.4** provides time-series electrical conductivity data.
h	Assess the frequency (and time lags if any), location, volume, and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.	Interaction and flow direction between surface water and groundwater (baseflow and leakage) and inter-aquifer (alluvium, weathered strata, and Permian Coal Measures) is presented in **Section 6.3**
2	**Analytical and numerical modelling**	
a	Provide a detailed description of all analytical and/or numerical models used, and any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	**Section 7.1** provides an overview of the numerical model used in this assessment. Detailed description is provided in the *Groundwater Modelling Technical Report* – **Appendix D**
b	Provide an explanation of the model conceptualisation of the hydrogeological system or systems, including multiple conceptual models if appropriate. Key assumptions and model limitations and any consequences should also be described.	Hydrogeological conceptualisation presented in **Section 6.7**while key assumptions and model limitations are discussed in **Section 7.1.4**
c	Undertaken groundwater modelling in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), including independent peer review.	Independent peer review undertaken by Dr Noel Merrick (**Appendix E**). Modelling undertaken in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012). Model classification (following Barnett et al. 2012) and performance presented in **Section 7.1.4**.
d	Consider a variety of boundary conditions across the model domain, including constant head or general head boundaries, river cells and drains, to enable a comparison of groundwater model outputs to seasonal field observations.	Boundary conditions used in the model domain are presented in the *Groundwater Modelling Technical Report* – **Appendix D**. Field observations were used to inform which boundary conditions were appropriate for simulating identified environmental processes.
e	Calibrate models with adequate monitoring data, ideally with calibration targets related to model prediction (e.g. use baseflow calibration targets where predicting changes to baseflow).	Calibration quality presented in **Section 7.1.4** and described in more detail in the *Groundwater Modelling Technical Report* – **Appendix D**.
f	Undertake sensitivity analysis and uncertainty analysis of boundary conditions and hydraulic and storage parameters, and justify the conditions applied in the final groundwater model (see Middlemis and Peeters 2018).	Key results from the uncertainty analysis presented in **Section 7.7**. Median results from uncertainty analysis generally close to base case model results and justify conditions applied in the final groundwater model.
g	Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and linkages between units, if any.	Hydrogeological units including their thickness are provided in **Section 2.3** of the *Groundwater* Modelling Technical Report (**Appendix D**), Calibrated hydraulic parameters (storage and hydraulic characteristics) are in **Section 3.4** of the same report. Unit linkages and interaction is discussed in **Section 6** of this report.

Assessment Item - Groundwater		
IESC Checklist		**SLR Response**
h	Provide an assessment of the quality of, and risks and uncertainty inherent in, the data used to establish baseline conditions and in modelling, particularly with respect to predicted potential impact scenarios.	Based on the legislation and guidance outlined in **Section 2**, a summary of baseline groundwater information required to prepare the Groundwater Assessment is presented in **Section 3**. These information requirements informed a data review and gap analysis which was undertaken during the conceptualisation phase of this groundwater assessment. Data considered reliable and relevant to this assessment has been presented and discussed in **Sections 4** to **6.** Uncertainty in baseline conditions and hydraulic parameters is considered in tested in the numerical modelling uncertainty analysis (**Section 7.7**).
i	Describe the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the proposed Project.	Recharge/ discharge pathways for each of the units is discussed in **Section 6**. Changes predicted to occur are conceptualised in **Section 6.7** and evaluated by the numerical model in **Section 7** and **Section 7.8.2**.
j	Undertake an uncertainty analysis of model construction, data, conceptualisation, and predictions (see Middlemis and Peeters 2018).	Uncertainty analysis undertaken presented in **Section 7.7**, with additional detail included in the *Groundwater Modelling Technical Report* **Section 5**.
k	Describe the various stages of the proposed Project (construction, operation, and rehabilitation) and their incorporation into the groundwater model. Provide predictions of water level and/or pressure declines and recovery in each hydrogeological unit for the life of the Project and beyond, including surface contour maps for all hydrogeological units.	Numerical model detail, predictive scenarios tested, and model predictions presented and discussed in **Section 7** and **Section 7.8.2** of this report. Surface contour maps in key hydrogeological units are presented in these sections.
l	Provide a program for review and update of models as more data and information become available, including reporting requirements.	The WCPL GWMP (Peabody, 2021) describes a program for periodic recalibration of the model based on observed piezometric heads and groundwater inflow data. An independent review of the model is committed to every 3-years in accordance with Condition B66(d)(v) of DA305-7-2003.
m	Identify the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	**Section 7.3**, **Section 7.5,** and **Section 7.8.2** identify volumes of water predicted to be taken annually
n	Provide information on the magnitude and time for maximum drawdown and post-development drawdown equilibrium to be reached.	See recovery modelling presented in **Section 7.8**
o	Undertake model verification with past and/or existing site monitoring data.	Model calibrated to past and existing site data. See **Section 7.1.3** of this report and **Section 3** of the *Groundwater Modelling Technical Report* (**Appendix D**)

Assessment Item - Groundwater		
IESC Checklist		**SLR Response**
3	**Impacts to water resources and water-dependant assets**	
a	Provide an assessment of the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts. Consider and describe: – any hydrogeological units that will be directly or indirectly dewatered or depressurised, including the extent of impact on hydrological interactions between water resources, surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water. – the effects of dewatering and depressurisation (including lateral effects) on water resources, water-dependent assets, groundwater, flow direction and surface topography, including resultant impacts on the groundwater balance. – the potential impacts on hydraulic and storage properties of hydrogeological units, including changes in storage, potential for physical transmission of water within and between units, and estimates of likelihood of leakage of contaminants through hydrogeological units. – the possible fracturing of and other damage to confining layers. – For each relevant hydrogeological unit, the proportional increase in groundwater use and impacts as a consequence of the proposed Project, including an assessment of any consequential increase in demand for groundwater from towns or other industries resulting from associated population or economic growth due to the proposal.	See **Section 7** for predicted impacts due to the Modification and **Section 7.8.2** for how these impacts are predicted to influence water sources and both anthropogenic and environmental water users.
b	Describe the water resources and water-dependent assets that will be directly impacted by mining or CSG operations, including hydrogeological units that will be exposed/partially removed by open cut mining and/or underground mining.	See **Section 6**
c	For each potentially impacted water resource, provide a clear description of the impact to the resource, the resultant impact to any water-dependent assets dependent on the resource, and the consequence or significance of the impact.	See **Section 7.8.2**
d	Describe existing water quality guidelines, environmental flow objectives and other requirements (e.g. water planning rules) for the groundwater basin(s) within which the development proposal is based.	Described in the WCPL GWMP (Peabody, 2021)

Assessment Item - Groundwater		
IESC Checklist		**SLR Response**
e	Provide an assessment of the cumulative impact of the proposal on groundwater when all developments (past, present and/or reasonably foreseeable) are considered in combination.	Cumulative impacts assessed (see **Section 7** and **Section 7.6**). Detail on the cumulative scenario described in **Section 7.2**.
f	Describe proposed mitigation and management actions for each significant impact identified, including any proposed mitigation or offset measures for long-term impacts post mining	No significant impacts have been identified due to the Modification compared with Approved operations. Mitigation and management actions have therefore not been developed.
g	Provide a description and assessment the adequacy of proposed measures prevent/minimise impacts on water and water-dependent assets.	As above
4	**Data and monitoring**	
a	Provide sufficient data on physical aquifer parameters and hydrogeochemistry to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes.	**Section 6** provides detail on aquifer properties, hydrogeochemistry and time-series groundwater level for key hydrostratigraphic units.
b	Provide long-term groundwater monitoring data, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.	Long-term water level and quality monitoring data for relevant sites presented **Section 6**.
c	Develop and describe a robust groundwater monitoring program using dedicated groundwater monitoring wells – including nested arrays where there may be connectivity between hydrogeological units – and targeting specific aquifers, providing an understanding of the groundwater regime, recharge, and discharge processes, and identifying changes over time.	Monitoring network and data availability presented in **Section 6.1**. This includes detail on 3 new VWPs installed near the Modification mine footprint in Q1/Q2 2022
d	Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZG 2018) and relevant legislated state protocols.	Water quality monitoring methodology provided in the UWOCP and Wambo Water Monitoring Program (Peabody, 2021)
e	Develop and describe proposed targeted field programs to address key areas of uncertainty, such as the hydraulic connectivity between geological formations, the sources of groundwater sustaining GDEs, the hydraulic properties of significant faults, fracture networks and aquitards in the impacted system, etc., where appropriate.	A data gap analysis undertaken in the early stages of this groundwater assessment has informed recommendations for targeted field programs provided in **Section 9**

Appendix C:

Structure of groundwater modelling report – following *Groundwater assessment toolbox for major projects in NSW* DPE (2022)

The *Groundwater assessment toolbox for major projects in NSW - Overview document* (DPE, 2022) requires a stand-alone groundwater modelling report in addition to the main groundwater assessment report and provides a recommended report structure (Table 4, Page 18 – DPE, 2022).

A stand-alone groundwater modelling report has been completed in addition to the main groundwater assessment report and is included in **Appendix D**. The table below provides reference to where the recommended sections are located withing the groundwater modelling (GM) report (**Appendix D**) or the main groundwater assessment (GA) report (this report).

Recommended Section		Where addressed
1	Report title	Cover page
2	Executive Summary	Included at beginning of GA Report
3	Introduction and model objectives	GA Report Section 1 and Section 7.1.1. GM Report Section 1
4	Conceptualisation	GA Report Sections 4 to 6
5	Model design	GA Report Section 7.1.2. GM Report Section 2
6	Model calibration	GA Report Section 7.1.3. GM Report Section 3
7	Predictive modelling	GA Report Sections 7.2 to 7.4. GM Report Section 4
8	Uncertainty analysis	GA Report Section 7.7 – GM Report Section 5
9	Model limitations	GA Report Section 7.1.4. GM Report Section 7
10	Conclusions and recommendations	GA Report Section 9. GM Report Section 8
11	References	GA Report Section 10. GM Report Section 9
12	Appendices	Appendices A to D – Appendix D is the *Groundwater Modelling Technical Report* Attachments A to D are included with the *Groundwater Modelling Technical Report*

Appendix D:

Numerical Modelling Technical Report

WAMBO COAL MINE

Longwalls 24-26 Modification
Groundwater Modelling Technical Report

Prepared for:

Wambo Coal Pty Ltd
PMB1
Singleton NSW, 2330

SLR Ref: 665.10008.00815-R02
Version No: -v4.0
July 2022

PREPARED BY

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BASIS OF REPORT

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
665.10008.00815-R02-v4.0-20220728.docx	28 July 2022	Vahid Shapoori and Adam Skorulis	Brian Rask	Brian Rask
665.10008.00815-R02-v3.0-20220722.docx	22 July 2022	Vahid Shapoori and Adam Skorulis	Brian Rask	Brian Rask
665.10008.00815-R02-v2.0-20220526.docx	26 May 2022	Vahid Shapoori and Adam Skorulis	Brian Rask	Brian Rask

CONTENTS

DOCUMENT REFERENCES

TABLES

FIGURES

ATTACHMENTS

1 Introduction

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Wambo Coal Pty Limited (WCPL) to prepare a Groundwater Assessment in support of an application to modify the Development Consent (DA 305-7-2003) for the Wambo Coal Mine (Wambo). The Modification would include the reorientation of approved Longwalls 24 and 25, and the addition of Longwall 26, at the approved South Bates Extension (SBX) Underground Mine (**Figure 1-1**).

As a part of the Groundwater Assessment, numerical groundwater modelling was undertaken to predict impacts of the modified Wambo on the local groundwater regime. The overall objectives of the modelling are to:

- assess the groundwater inflow to the mine workings as a function of mine position and timing;
- simulate and predict the extent of dewatering due to the Project and the level and rate of drawdown at specific locations;
- identify areas of potential risk, where groundwater impact mitigation/control measures may be necessary;
- estimate direct and indirect water take; and
- estimate post-mining recovery conditions.

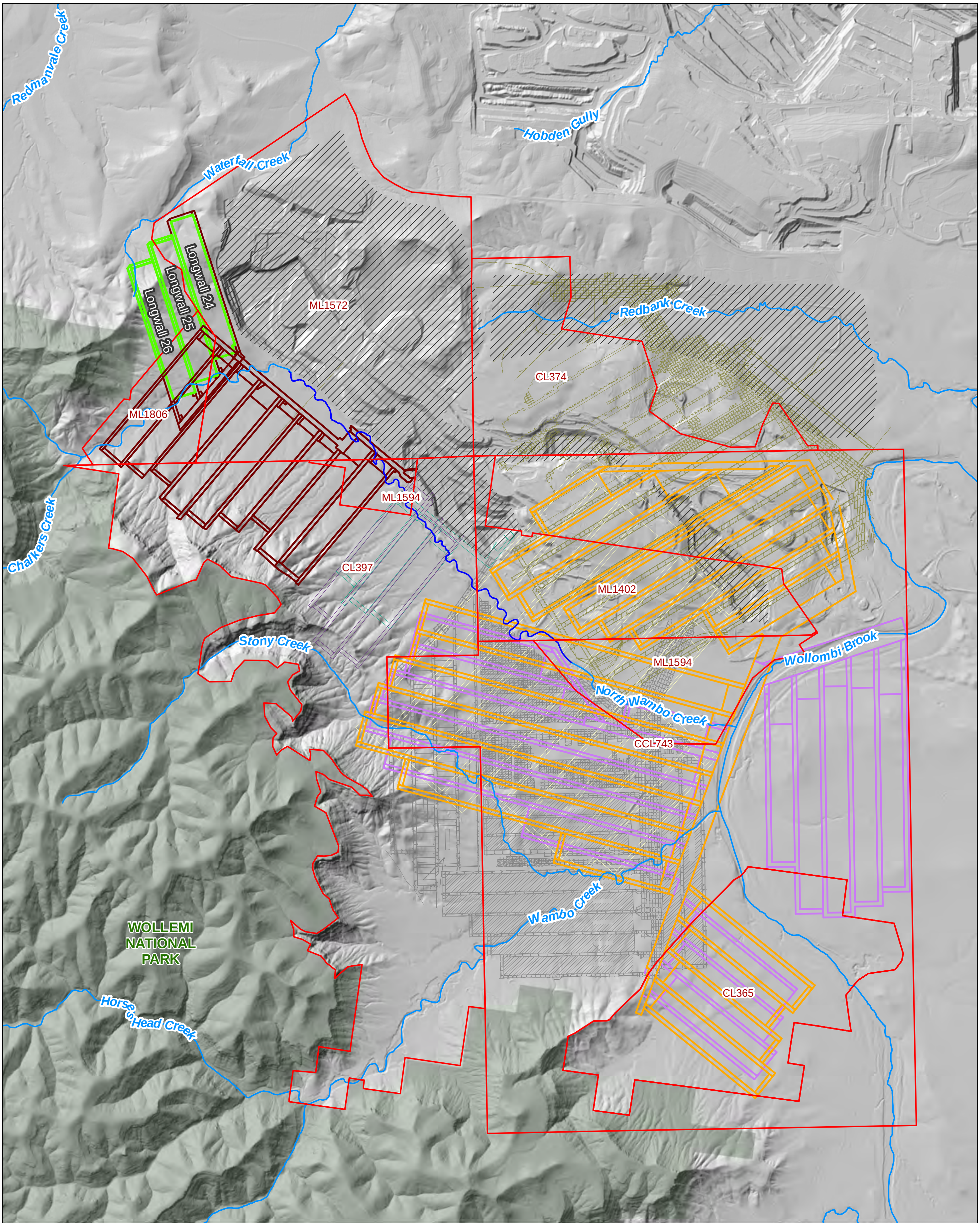
Conceptualisation of the groundwater regime and the calibration of the model against observed data are key to achieving a reliable numerical model. Conceptualisation is a simplified overview of the groundwater regime (i.e. the distribution and flow of groundwater) based on available data and experience. Consistency between numerical model results and the conceptual understanding of the groundwater regime increases the credibility of the numerical model predictions. The conceptualisation of the groundwater regime was carried out by SLR in 2022 and is reported in the *Wambo Coal Mine Longwalls 24-26 Modification Groundwater Assessment* (SLR, 2022) of which this groundwater modelling technical report forms an appendix.

Confidence in the numerical model is increased by calibration of numerical model results against observed data. A well calibrated model has demonstrated the ability to simulate groundwater levels that approximate observed levels at specific locations.

The numerical groundwater model for Wambo has been rebuilt for the *Wambo Coal Mine Longwalls 24-26 Modification Groundwater Assessment* based on the existing numerical models for Wambo (SLR, 2020) and the United-Wambo Open Cut Project (UWOCP) (AGE, 2016), and updated using site and regional geological models. The updates to the model design from previous numerical modelling include:

- Model extent and grid – utilise *Algomesh* software to generate an unstructured model grid that includes grid refinement around Longwalls 24-26.
- Timing – refine timing to capture revised mine progression.
- Boundary Conditions – update relevant model boundary conditions with revised grid geometry.

Further details on the setup are discussed in **Section 2**. **Section 2** of this modelling report presents how the conceptualisation has been developed as a numerical groundwater model, and **Section 3** presents how well the model replicates observed data (calibration). Details on how the model represents the Project and other future approved and foreseeable activities within the region is outlined within **Section 4**.



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:55,000 at A4
Project Number:	665.0008.00815
Date:	26-Jul-2022
Drawn by:	ANP

Named Watercourse
NWC Diversion
Mining Lease
Approved Open Cut Mining
NPWS Reserve

Proposed Mining

South Bates Extension LW24-26 MOD - Whybrow Seam

Approved Mining

South Wambo - Woodlands Hill Seam
South Wambo - Arrowfield Hill Seam
South Bates Extension - Whybrow Seam

Historical/Completed Mining

South Bates - Whybrow Seam
South Bates - Wambo Seam
North Wambo UG - Wambo Seam
United UG - Arrowfield Seam
Homestead-Wollemi UG - Whybrow Seam

Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION

Plan of Wambo mining and surrounds

FIGURE 1-1

2 Model construction and development

2.1 Model code

MODFLOW-USG Transport was used as the model code (Panday *et al.*, 2013). MODFLOW-USG is a recent version of industry standard MODFLOW code and was assumed to be the most suitable modelling code for accomplishing the model objectives. MODFLOW-USG optimises the model grid and increases numerical stability by using unstructured, variably sized cells. These cells take any polygonal shape, with variable size constraints allowing for refinement in areas of interest (i.e. geological or mining features).

Where previous MODFLOW versions restricted interlayer flow to vertical connectivity, MODFLOW-USG offers lateral connectivity between model layers. Lateral connectivity enables more accurate representations of hydrostratigraphic units, particularly those that pinch out, outcrop, or cross geological faults.

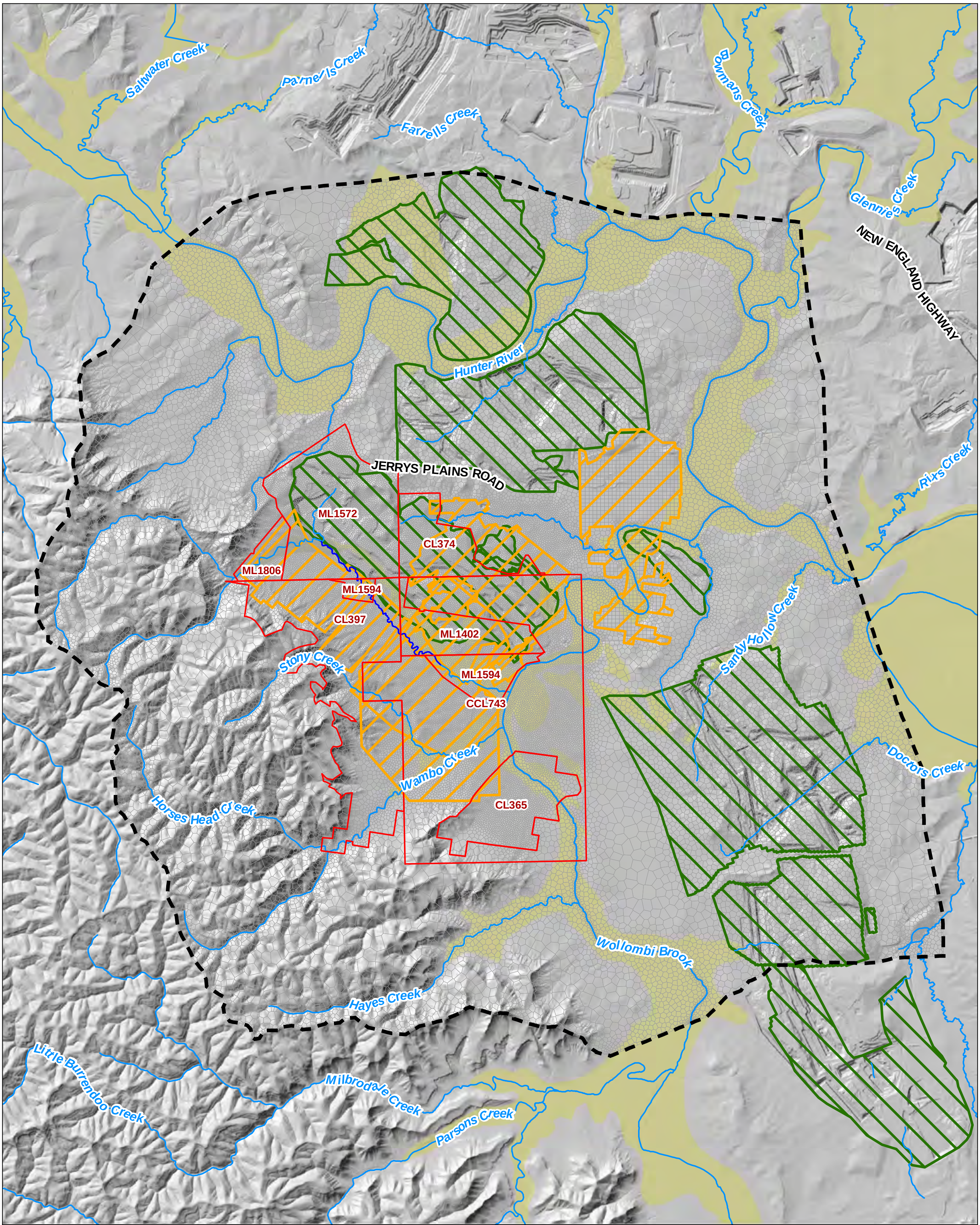
MODFLOW-USG is also able to simulate unsaturated conditions, allowing progressive mine dewatering and post closure rewetting to be represented by the model. For the Wambo model, vadose zone properties have been excluded, and the unsaturated zone was simulated using the upstream-weighting method.

Fortran code and a MODFLOW-USG edition of the Groundwater Data Utilities (Watermark Numerical Computing) were used to construct the MODFLOW-USG input files.

2.2 Model extent and mesh design

The model extent is shown in **Figure 2-1**. The model extent was designed to be large enough to incorporate surrounding mines and to prevent boundary influence on modelled mining drawdowns.

The model domain was designed large enough to allow the adjacent mines/projects (Mt Thorley Warkworth (MTW), Hunter Valley Operations (HVO) North and HVO South mines) to be assessed for potential cumulative impacts. To the west where the coal seam units dip below the overlying Triassic Narrabeen Group, the model extends more than 5 km from Wambo and generally follows the catchment divide of watercourses draining through the model domain. To the east, the model extends beyond the subcrop line of the deepest coal seam (i.e. Bayswater) that is likely to be mined at Wambo, United and/or surrounding mines in the future. To the north, the model covers HVO South and follows the outcrop of Jerry's Plan subgroup and alluvium. To the South, the model extent cuts off MTW, not including Bulga, mine and also follows the northern boundary of the Parsons Creek catchment divide.



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Date:	06-Apr-2022
Drawn by:	ANP

SLR

Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Numerical model extent and mesh refinement

FIGURE 2-1

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_G10_ModelMeshRefinement_002.mxd

To allow stable numerical modelling of the large spatial area of the model domain, an unstructured grid with varying Voronoi cell sizes was designed using Algomesh (Merrick & Merrick, 2015). Varying Voronoi cell sizes allowed refinement around areas of interest, while a coarser resolution elsewhere reduces the total cell count to a manageable size. The model domain was vertically discretised into 30 layers, each layer comprising a cell count of up to 48,472. The total number of cells in the model is 1,072,347, after pinching out areas in Layer 3 to 30 where a layer is not present based on the structural geology.

In developing the model grid in Algomesh, specific areas were identified where refinements to the grid cell geometry were required (see **Figure 2-1**), this included:

- 25 metres (m) to 100 m irregular shaped Voronoi cells were used for North Wambo Creek, Wambo creek, Wollombi Brook, Hunter River, and other minor watercourses.
- 25 m Voronoi cells were used for alluvium within North Wambo Creek. 100 m to 250 m hexagonal Voronoi cells were used for the rest of alluvium within the model area.
- 75 m Voronoi cells were used for the Wambo and United open cut workings.
- 150 m Voronoi cells were used for all other existing open cut and future mine areas within the model extent.
- 50 m square cells were used for underground workings for Wambo and United.
- 100 m square cells were used for all other underground Workings.

2.3 Model layers

The model was developed with 30 layers to represent the regional stratigraphy and capture key coal seams mined at site and surrounding operations. The model layers are presented in **Table 2-1** and include the average thickness and comments on the relevance of the layer for the Project.

The top of layer 1 was developed based on LiDAR data for the key watercourses and mine areas. Outside of these areas the Digital Elevation Model from NSW Government Data was used. The extent of alluvium across the model domain was based on regional geological mapping that included refinements in key areas based on previous investigations and site geological data. The depth of alluvium was based on site drill data near the Wambo and UWOCP areas, and utilised existing layer geometries across the broader model extent. Alluvium associated with the Hunter River was subdivided into two layers consistent with observed finer material overlying coarser basal sands and gravels. In locations where the Hunter River alluvium thickness exceeds 10 m, the thickness of layer 1 was limited to 10 m and the remaining thicknesses were assigned to layer 2. Outside the alluvium extent, the CSIRO (2015) depth of regolith mapping was used for the base of layer 1. The base of weathering defined in the WCPL's geology model was used for the base of layer 2 and beyond the extent of WCPL's geology model, the base of Layer 2 was assumed to be 10 m below the base of layer 1.

The layering for the Permian coal measures was based on WCPL's geological models, the regional Hunter Coalfield Geology model (NSW Department of Mining, Exploration and Geoscience) as well as existing layers from the current Wambo (HydroSimulations, 2017 and SLR, 2020) and UWOCP (AGE, 2016) numerical groundwater models. Due to the structural geology, pinched out layers were used from Layer 3 to Layer 30. The extent/outcrop of the coal seam layers was based on the site geological model and drill data.

Table 2-1 Model layers

Layer	Lithology	Average Thickness (m)	Comments
1	Alluvium (less and highly productive), Regolith	6.4	Align with site drill data, where available.
2	Alluvium (less and highly productive), weathered zone	8.7	Align with site drill data, where available.
3	Narrabeen Group	247.4	
4	Newcastle Coal Measures	86.7	
5	Overburden 1 (Sandstone / siltstone / shale)	33.7	
6	Overburden 2 (Sandstone / siltstone / shale)	34.9	
7	Whybrow seam	2.9	Wambo (South Bates Underground [Whybrow], South Bates Extension (Underground) and Wollemi – Homestead
8	Sandstone / siltstone / shale	50.6	
9	Wambo seam	3.2	Wambo (North Wambo Underground), South Bates Underground [Wambo]
10	Sandstone / siltstone / shale	17.0	
11	Whynot Seam	2.4	
12	Sandstone / siltstone / shale	39.5	
13	Blakefield, Glen Munro	2.5	
14	Sandstone / siltstone / shale	72.7	
15	Woodlands Hill Seams	1.1	Wambo (South Wambo Underground)
16	Sandstone / siltstone / shale	36.0	
17	Arrowfield Seam	2.1	Wambo (South Wambo Underground) and United Underground
18	Sandstone / siltstone / shale	10.6	
19	Bowfield Seam	3.3	
20	Siltstone / shale (interburden)	4.9	
21	United and Wambo Bowfield seam split	2.3	
22	Siltstone / shale (interburden)	14.5	
23	Warkworth Seam	4.0	UWOCP
24	Siltstone / shale (interburden)	34.9	
25	Mt Arthur Seam	4.1	Lemington Underground
26	Siltstone / shale (interburden)	35.4	
27	Piercefield and Vaux Seams	5.4	Last mined seam at UWOCP
28	Siltstone / shale (interburden)	132.3	
29	Broonie and Bayswater Seams	9.0	Bayswater last mined seam at HVO South and MTW
30	Basement	5.8	Wambo Coal Mine (South Bates Underground, South Bates Extension Underground) and Homestead

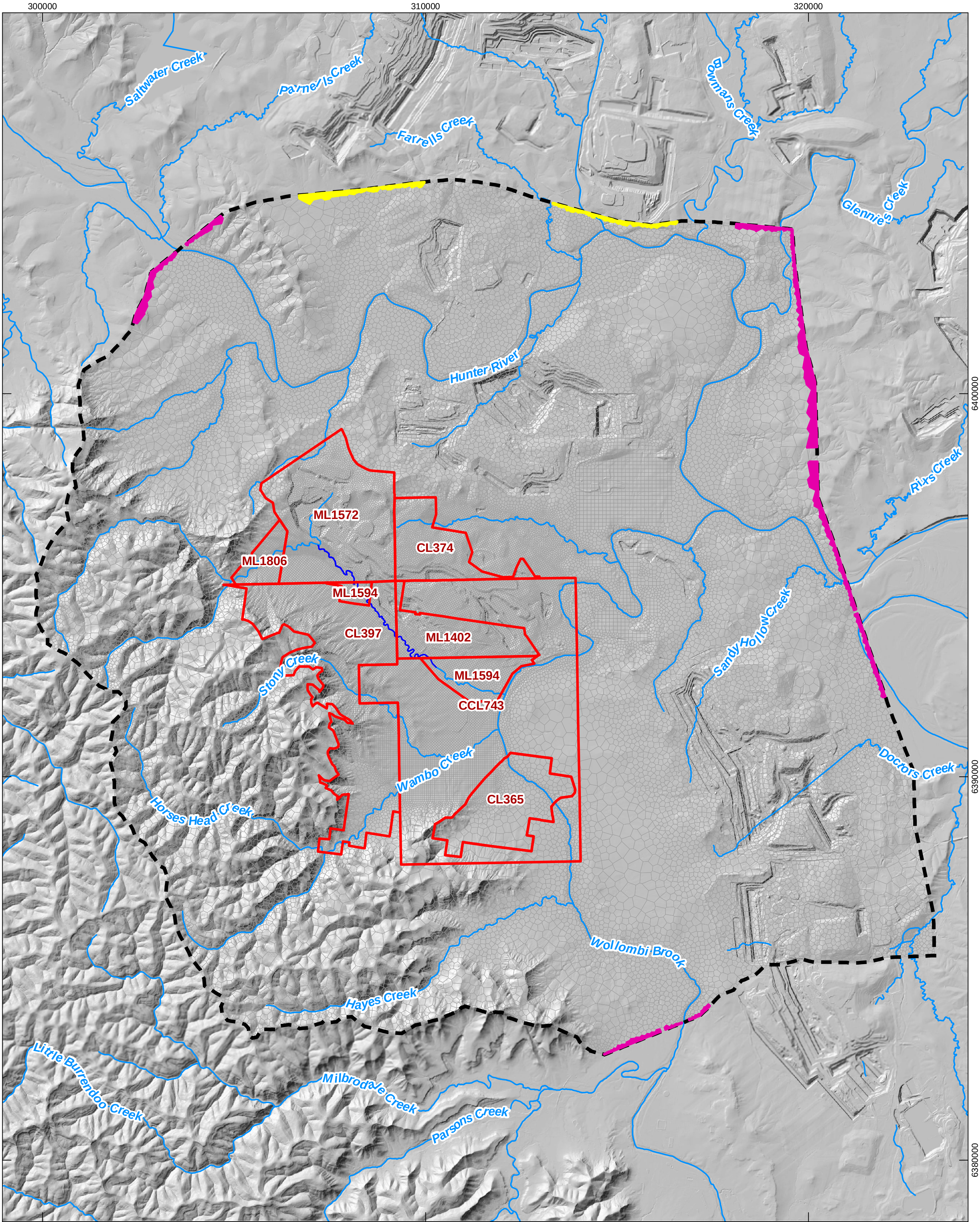
2.4 Model stresses and boundary conditions

2.4.1 Regional groundwater flow

Groundwater conditions at the model boundary are controlled using MODFLOW boundary condition packages. These govern flow in and out of the model and allow for the simulation of stresses external to model area that may be influencing groundwater conditions within the model domain.

The General Head Boundary (GHB) conditions were used to represent the regional flow into and out of the model area. Groundwater enters the model where the head set in the GHB is higher than the modelled head in the adjacent cell and leaves the model when the water level is lower in the GHB. The GHB heads were assigned based on average water levels at monitoring bores near the model boundary. GHB's were set within areas of the Hunter River alluvium to the north and east of the model, and also along the Wollombi Creek alluvium along the south of the model to enable inflow and outflow of groundwater through the alluvium.

The Drain (DRN) boundary condition was used to represent groundwater impacts from regional mining activity that were not included within the active model domain. DRN cells were used on the southern and northern model boundary to simulate impacts from Bulga and HVO mining operations respectively. The model boundary conditions are presented in **Figure 2-2**.



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	03-Dec-2021
Drawn by:	ANP

Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Model Grid

Boundary Conditions
Drain Boundary Condition (DRN)
General Head Boundary (GHB)

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Model boundary conditions

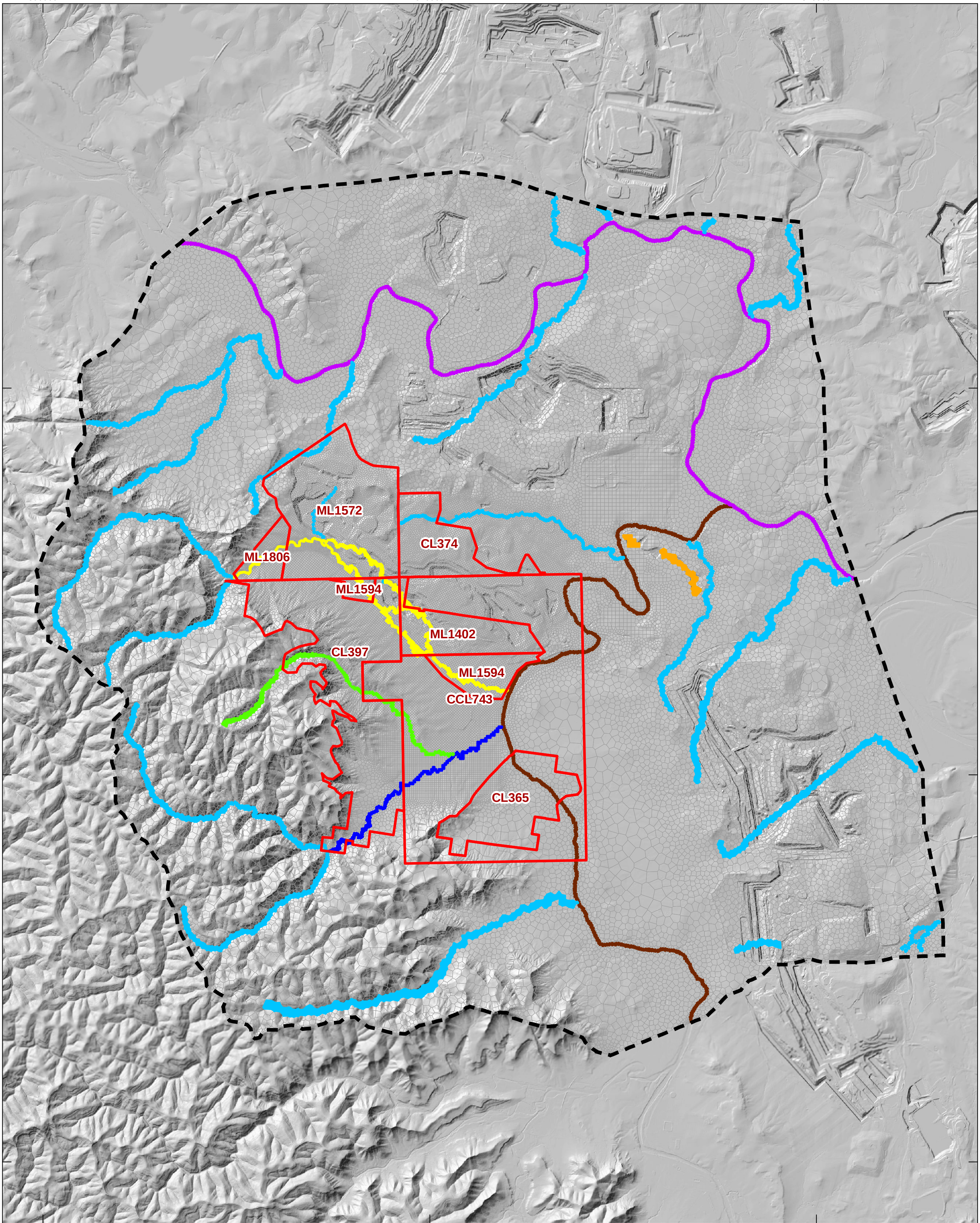
H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_G11_ModelBoundaryConditions_001.mxd

Data Source: NSW SS 2020

FIGURE 2-2

2.4.2 Watercourses

River cells in the model are shown in **Figure 2-3**. The major water courses include the Hunter River and Wollombi Brook, as well as the more minor Wambo Creek and North Wambo Creek (east and south-east of Wambo). Creeks and rivers throughout the model domain were simulated using MODFLOW's River (RIV) package. The rivers included in the RIV package are presented in **Table 2-2**. River and creek widths and conductances were adopted from the Wambo and United models. The river widths were assumed to be fixed for each river in the model. The river widths were estimated using aerial photography and aligned with assumptions within previous groundwater models for Wambo (HydroSimulations, 2014), UWOCP (AGE, 2016), and HVO (AGE, 2017). The river conductance was calculated using river width, river length, riverbed thickness, and the vertical hydraulic conductivity of riverbed material (Kz). Therefore, the river conductance is variable due to the non-constant spatial discretisation in each of the model river cells.



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	03-Dec-2021
Drawn by:	ANP

Wambo Model Boundary
Mining Lease
Model Grid

River Zones
- Hunter River
- Lemington Water Storage
- Minor Watercourse
- North Wambo Creek
- Stony Creek
- Wambo Creek
- Wollombi Brook

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Modelled watercourses

Data Source: NSW SS 2020

FIGURE 2-3

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_G12_ModelWatercourse_001.mxd

Table 2-2 River and surface water features in the groundwater model

Boundary	Width (m)	Conductance (m^2/ day)	River Bed Kz (m/day)
Hunter River	15.5	47.1 - 65.3	5.0×10^{-1}
Wollombi Brook	9.7	22.3 - 83.9	1.0×10^{0}
Wambo Creek	6	108.1 - 252.5	1.0×10^{0}
Wambo North Creek	3	52.7 - 584.7	1.0×10^{0}
Lemington Water Storage	50	2.5	1.0×10^{-3}
Other Minor Creeks	2	39.0 - 365.5	1.0×10^{0}

With regards to major water courses (i.e. Hunter River and Wollombi Brook), the development of transient stage heights were based on publicly available gauging station data from WaterNSW (**Table 2-3**). Simulated stage heights were developed based on stress period length, with long-term average levels used in the warm-up period, a rolling quarterly average stage height during the transient calibration, and long-term quarterly averages used during the transient prediction.

Table 2-3 Gauging station

Watercourse	Gauging Station
Wollombi Brook	210135 – Wollombi Brook D/S Brickmans Bridge
	210004 – Wollombi Brook at Warkworth
	210028 – Wollombi Brook at Bulga
Hunter River	210083 – Hunter River at Liddell
	210126 – Hunter River at U/S Foybrook
	210127 – Hunter River at Glennies Creek
	210128 – Hunter River at Mason Dieu

With regards to key ephemeral water courses near Wambo and UWOCP mining operations, a complete dataset is not available for the transient calibration period. However, as described in the conceptual model (SLR 2022), there was sufficient data for the surface water consultant, Alluvium, to develop a rainfall-flow relationship using an Antecedent Precipitation Index (API) (Alluvium Consulting, Pers Comm 2020). A rainfall event that had an API of greater than 100 millimetres (mm) was determined as likely to result in flow within the upstream reaches of North Wambo Creek. This relationship was similarly applied to Wambo and Stony Creeks, with stage heights scaled based on the number of days per quarter where API was greater than 100 mm and controlled to observed stage heights. The flow events, their stage heights and observational data used to control stage heights is shown in **Figure 2-4**. The development of this relationship enabled the simulation of inferred flow events in ephemeral creeks which are conceptualised as potentially being key sources of recharge to alluvium near Wambo and UWOCP mining operations.

The incorporation of this rainfall-stage relationship aims to simulate the level, duration, and extent of saturation within alluvium associated with these ephemeral watercourses more accurately, enabling more robust estimates of alluvial take associated with Wambo and UWOCP mining operations to be made.

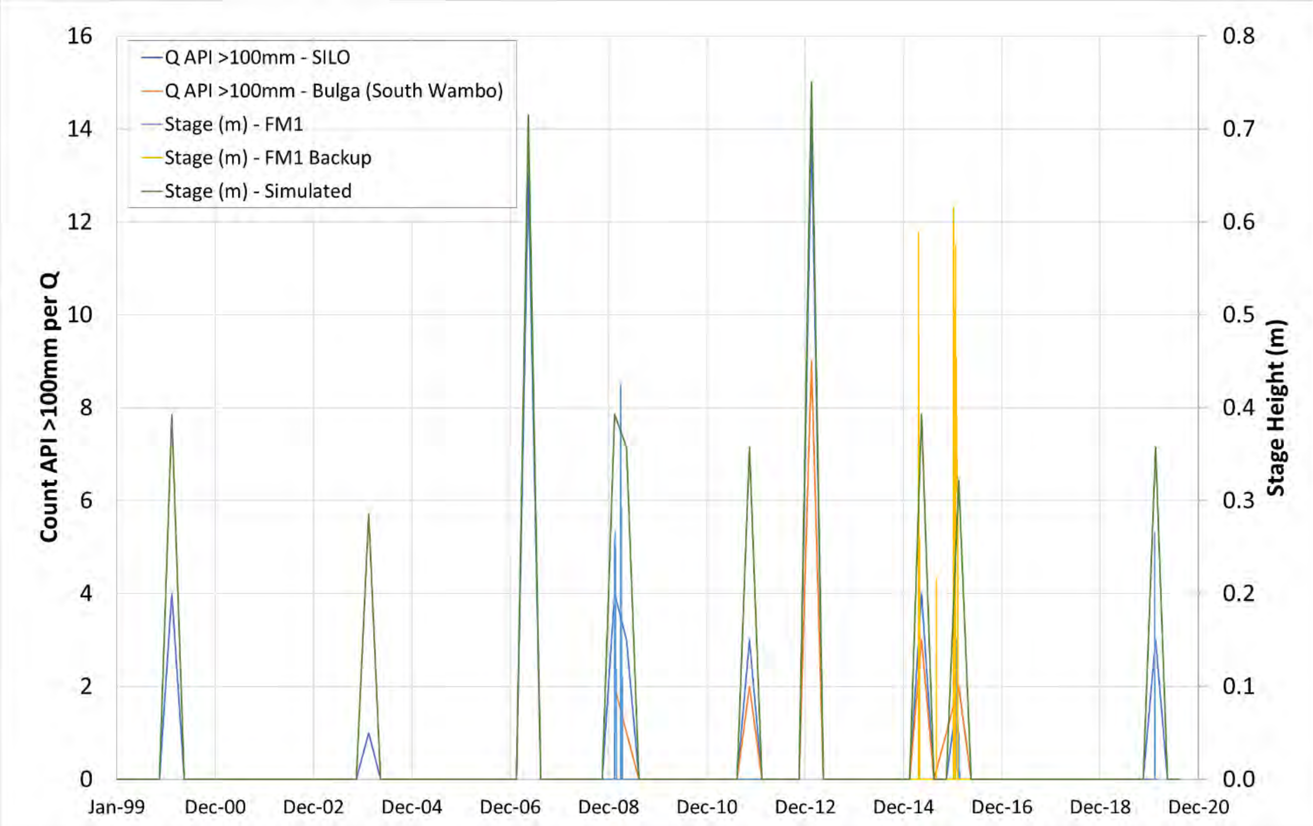


Figure 2-4 Simulated flow events and stage heights at ephemeral creeks

The river stage height in the minor tributaries or drainage lines was set to 0 m (i.e. river stage elevation was equal to river bottom elevation). Therefore, the minor tributaries or drainage lines act as drains to the groundwater system and do not recharge the aquifer.

Water stored within the historical Lemington open cut is simulated using the RIV package. The storage level has been inferred from Wambo regional and publicly available LiDAR data, with a bed conductance value based on likely hydraulic conductivity of the Permian Coal Measures at the base of the void (**Table 2-2**).

The representation of river stage heights for incorporation in prediction and recovery modelling are presented in **Section 4.1.1**

2.4.3 Rainfall recharge

The dominant mechanism for recharge to the regional 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).

The time-series recharge rate utilised in the model was derived from the Australian Landscape Water Balance model (AWRA-L) deep drainage estimate for the project area (Frost, Ramchurn and Smith, 2018).

The AWRA-L model provides estimates of water fluxes and stores in the Australian landscape and is based on a model that simulates the flow of water through the landscape, through vegetation and soil, and then out again as evapotranspiration, runoff, and deep drainage to groundwater. The outputs from the model consist of soil moisture, runoff, evapotranspiration, deep drainage, and precipitation at the spatial resolution of 5 km^2. For this project, the deep drainage component was derived for the location of project and used as the initial estimate of recharge to the aquifer. **Figure 2-5** presents the local transient deep drainage estimate from the AWRA-L model in comparison with observed groundwater levels at shallow bores (P106, GW15). **Figure 2-5** indicate that the deep drainage estimate recharge follows a similar trend as observed groundwater levels through time. That is, periods of greater estimated deep drainage correlate with increased groundwater levels, while periods of lower estimate deep drainage correlate with lower groundwater levels in shallow strata. This correlation indicates the time series estimate for deep drainage in the Wambo and United-Wambo area is an appropriate starting point for simulating diffuse rainfall recharge to the model (RCH).

To simulate spatial variability in recharge, three zones were assigned to the upper layer of the model based on surficial geology (coarse grained alluvium (higher recharge rate), finer grained alluvium (lower recharge rate) and Regolith). **Figure 2-6** shows the recharge zones within the model. The recharge rate from AWRA-L model was assumed as the initial estimate, and a multiplier was used for each zone to estimate the final recharge rate at each zone. The multipliers were calibrated to provide the best fit to groundwater level observations. The long-term average deep drainage rate from AWRA-L was used for the steady-state model, with the prediction model using quarterly averages of the deep drainage estimates after modification with calibrated multipliers.

The representation of rainfall recharge for incorporation in prediction and recovery modelling are presented in **Section 4.1.1**

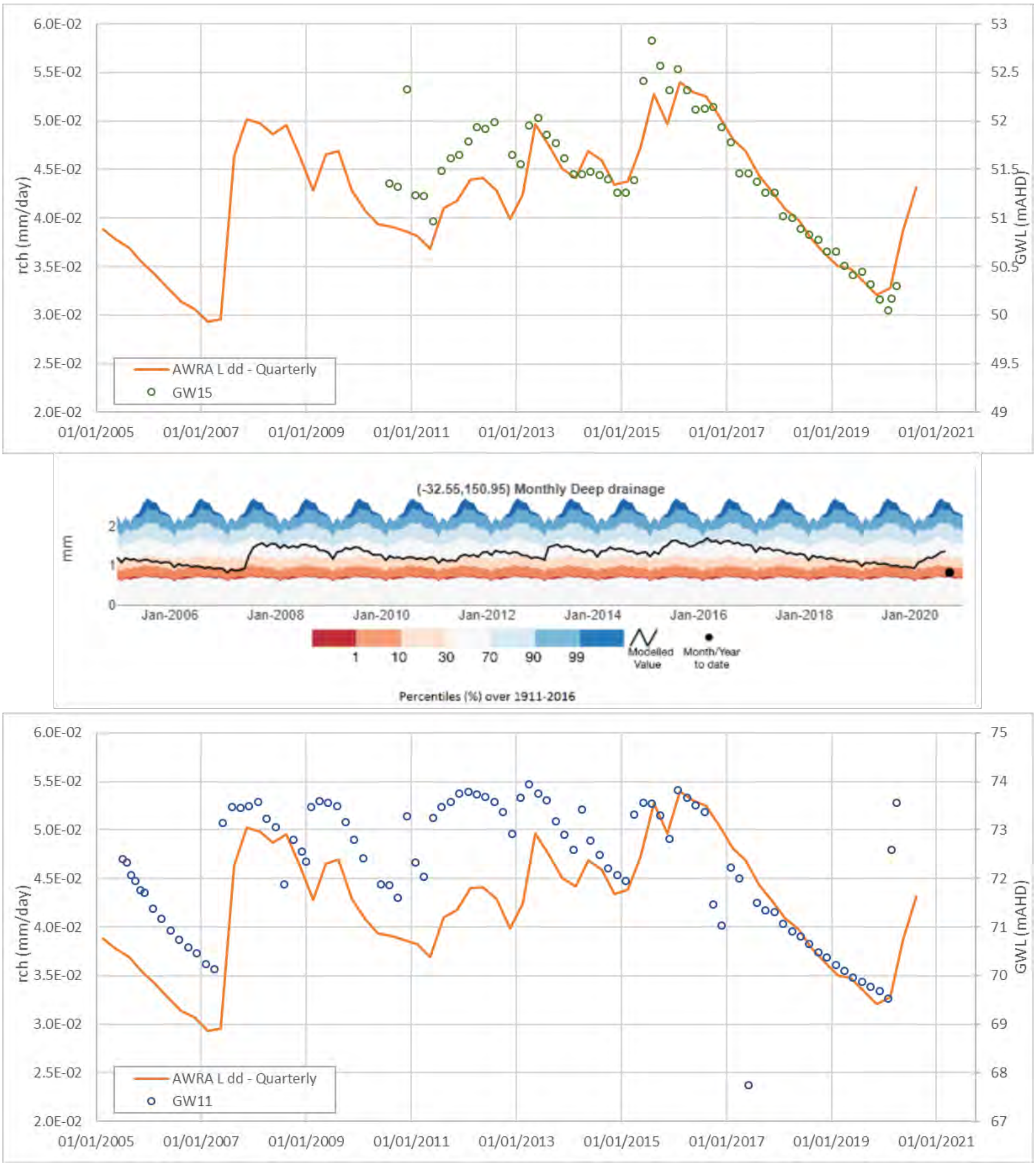
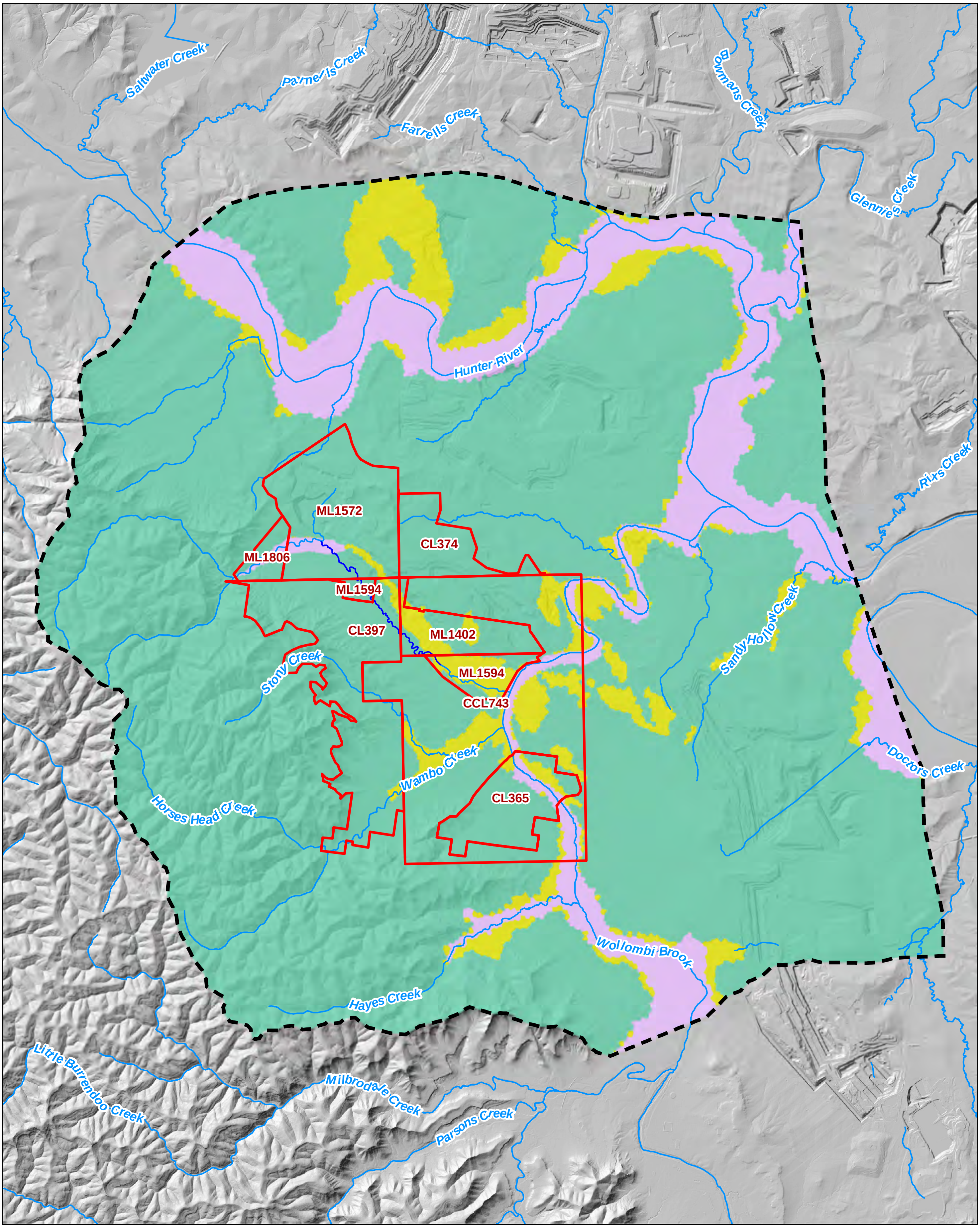


Figure 2-5 Recharge rate and water levels in observation bores



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	03-Dec-2021
Drawn by:	ANP

Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease

Recharge Zone
Highly Productive Alluvium
Less Productive Alluvium
Regolith

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Modelled rainfall recharge zones

Data Source: NSW SS 2020

FIGURE 2-6

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_G13_ModelRainfallRechargeZones_001.mxd

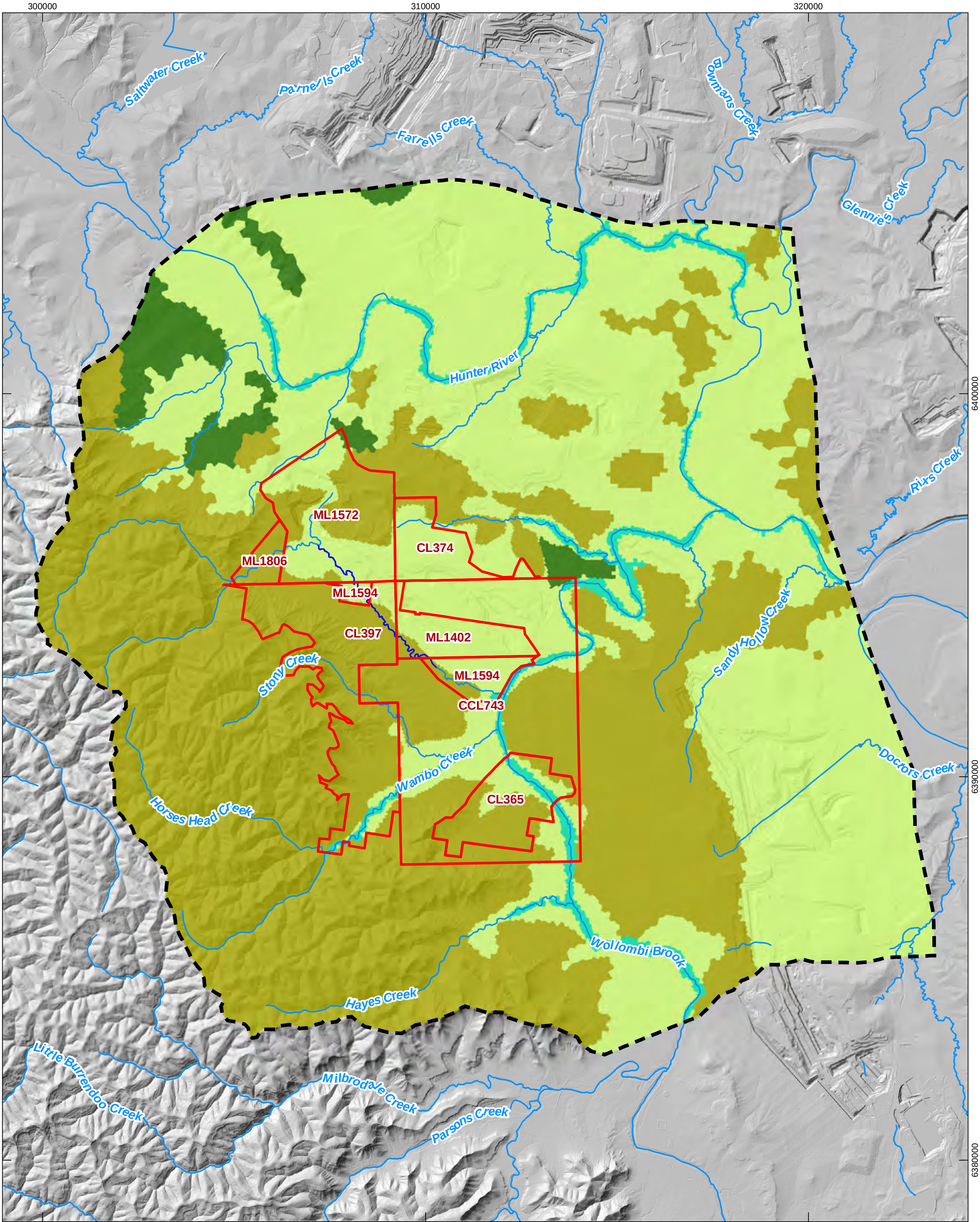
2.4.4 Evapotranspiration

Evapotranspiration from the shallow water table was simulated using the evapotranspiration package (EVT). Evapotranspiration was represented in the upper most cells of the model domain, with the extinction depth varied spatially based on the estimated rooting depths of regionally mapped vegetation, following Canadell et al. (1996). **Table 2-4** shows the vegetation type and the simulated rooting depth used in the model. With regards to evapotranspiration, a variable maximum rate of evapotranspiration was generated from the SILO Grid Point series and averaged quarterly for the site. The average evapotranspiration used for steady state is 915 millimetres per year (mm/year). **Figure 2-7** shows the extent of evapotranspiration zones.

The representation of evapotranspiration for incorporation in prediction and recovery modelling are presented in **Section 4.1.1**

Table 2-4 Vegetation type within model domain and simulated rooting depth

Zones	Vegetation Type	Estimated Rooting Depth/ ET Extinction Depth (m)
1	Woodland	2
2	Forest	2.5
3	Riparian	2.5
4	Rest of model	1



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	03-Dec-2021
Drawn by:	ANP

SLR

Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Modelled evapotranspiration zones

FIGURE 2-7

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_G14_ModelEvapotranspirationZones_001.mxd

2.4.5 Mining

The DRN package was used to simulate mine dewatering in the model for Wambo, UWOCP and surrounding mines. Drain boundary conditions allow a one-way flow of water out of the model, with invert elevations set near the base of the target seam model layer. In both the calibration and prediction model, mining at Wambo and UWOCP was simulated based on the historical and future mine plans for each mine area provided Glencore and Peabody. Foreseeable mining was also incorporated, with the operations at HVO and MTW simulated based on publicly available information.

The simulation of open cut mining involves the use of drain cells in the model layer representing the lowest target geology, and in all overlying model layers. This allows for the model to simulate dewatering/ mine inflow from the strata intersected during active mining, as well as continued seepage to the void. Underground mining was represented by using DRN nodes in the layer representing the target seam, and also uses the Time-Variant Materials (TVM) package to vary hydraulic properties of the model cells to replicate the goaf and fractured zone above each longwall panel (further detailed in **Table 2-5**).

Table 2-5 MODFLOW simulation of mining

Mining Methodology	Simulation During Mining	Simulation Post Mining
Open Cut	Drain cells in deepest mined seam layer and all layers overlying to represent groundwater take from the whole void area.	TVM used to convert open cut void areas (mined seam plus layers above) from their host properties to those of spoil/ backfill.
Bord and Pillar (first workings) Underground	Drain cells in layer representing mined seam to represent dewatering.	TVM used in target seam to convert host parameters to those estimating an open underground void.
Longwall Underground	Drain cells in layer representing mined seam and TVM in overlying layers to represent dewatering and subsidence induced fracturing.	TVM used in target seam and overlying layers to convert host parameters to those estimating the hydraulic impacts associated with longwall induced subsidence.

2.4.5.1 Variation in hydraulic properties - open cut mining

Backfilling of open cut mine areas with spoil was also modelled using the TVM package. The model cell properties were updated to spoil properties guided by operational mine plans. A horizontal hydraulic conductivity of 0.3 m/day and vertical hydraulic conductivity of 0.1 m/day was applied to the spoil. The storage parameters used for the spoil were specific yield of 0.1, storage coefficient of 1.0×10^{-5} m^{-1}.

2.4.5.2 Variation in hydraulic properties - longwall mining

As discussed above, the longwall method of underground mining was represented using the DRN nodes and TVM packages. In doing so, the model applied drains within the panels as the mine progresses (to simulate active dewatering) and simulates changes to aquifer properties in response to mining within the overlying strata and fracture zone above the longwall panel using the TVM package. Multipliers were used to enhance hydraulic conductivities within the fracture zone overlying coal extraction areas, with multipliers generally following a ramp function, so that the multipliers with highest values are applied to the units closest to the mined seam and then gradually decay as the units become close to the maximum height of connective fracturing. The average hydraulic conductivity multipliers for the fractured zone are presented in **Table 2-6.**

Table 2-6 Fracture zone multipliers

Layer	Unit	Average Kx Multipliers	Average Kz Multipliers	Longwall Mining Operation
2	Weathered zone	2	3	
3	Narrabeen Group	2	3	
4	Newcastle Coal Measures	2	16	
5	Overburden 1	2	48	
6	Overburden 2	2	74	
7	Whybrow seam	2	71	Wambo (South Bates Underground [Whybrow], South Bates Extension Underground) and Wollemi – Homestead
8	Interburden	2	84	
9	Wambo seam	2	3	Wambo (North Wambo Underground, South Bates Underground [Wambo])
10	Interburden	2	3	
11	Whynot Seam	2	7	
12	Interburden	2	9	
13	Blakefield, Glen Munro	2	21	
14	Interburden	2	47	
15	Woodlands Hill Seams	2	73	Wambo (South Wambo Underground)
16	Interburden	2	87	
17	Arrowfield Seam			Wambo (South Wambo Underground) and United Underground

2.4.5.3 Height of connective fracturing

The height of connective fracturing was estimated using the Ditton/Merrick geology model equation (Ditton and Merrick, 2014) for the A Zone, which includes the key fracture height driving parameters of panel width (W), cover depth (H), mining height (T) and the local geology factor (t') where t' is the effective thickness of bridging stratum where the A Zone height occurs (typically 15-20 m in the Hunter Coalfield (Ditton and Merrick, 2014). The formula for the A Zone height for single seam mining is:

Geology Model: $A = 1.52\ W'^{0.4}\ H^{0.535}\ T^{0.464}\ t'^{-0.4}\ \ +/-\ aW'$

Where W' is the minimum of the panel width (W) and the critical panel width (1.4H).

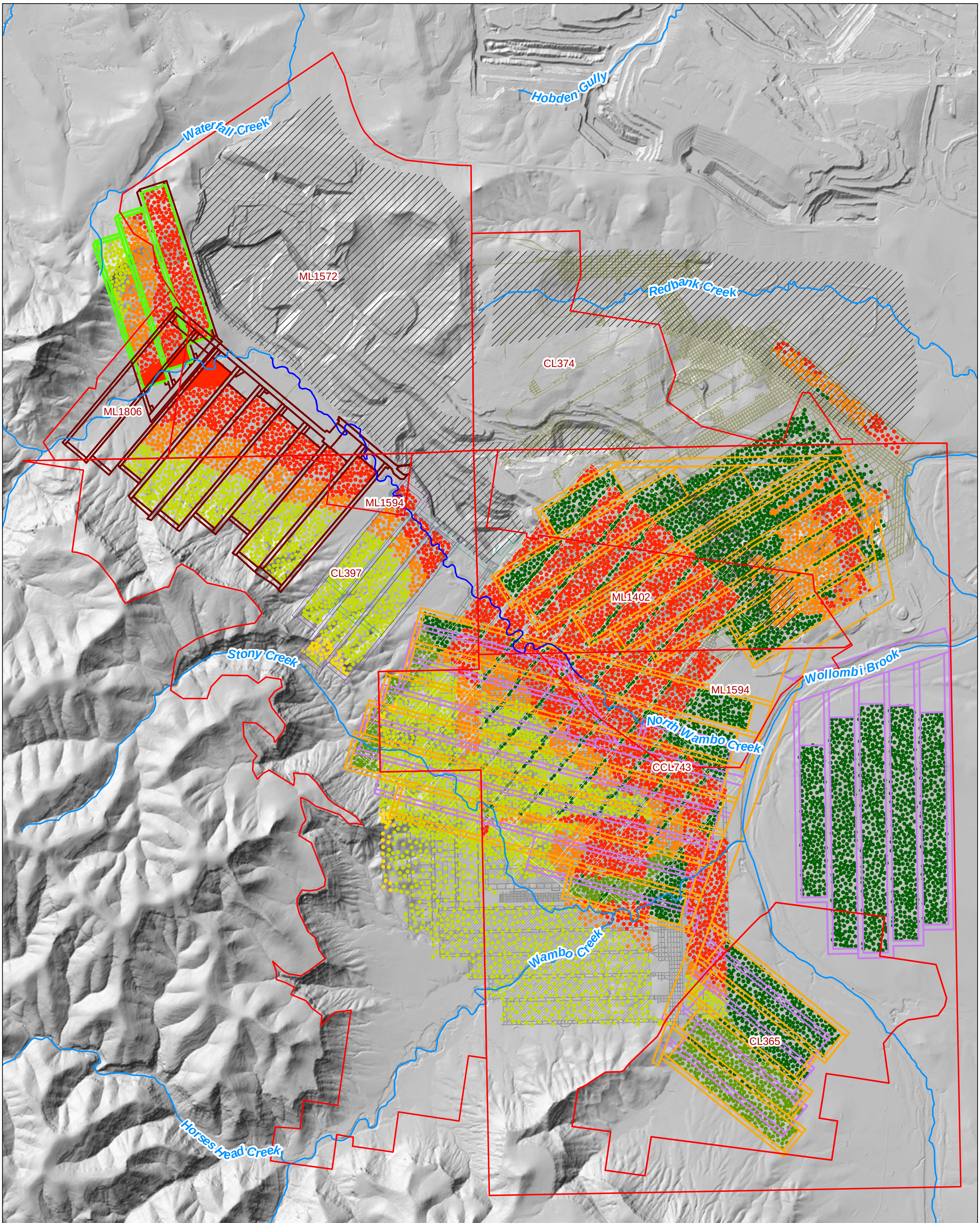
The 95th percentile (maximum) A-heights are estimated by adding aW' to the calculated A Zone height, where *a* varies from 0.1 for supercritical panels to 0.15 for subcritical panels.

For multi-seam mining, the mining height (T) in the above formula is replaced by an effective mining height (T') for the upper mined seam that accounts for additional subsidence caused by mining other seams that may increase the extent of fracturing above the upper mined seam. The effective mining height for multi-seam mining has been informed by a local investigation (Ditton, 2014 pers. Comm.) for NWU (Wambo Seam) and Homestead (Whybrow Seam) mining.

The multi-seam correction for calculating the A Zone height adjusts the effective thickness (T') of the uppermost mined seam to be the thickness of the uppermost seam, plus 70% of the sum of the stacked thickness of any underlying mined seam.

The extent of adopted fracturing in the groundwater model is consistent with previous groundwater assessments (See Figure D1 and Figure 21 of HydroSimulations, 2017), and is considered conservative as fracturing is often predicted to land surface (**Figure 2-8**). This is simulated to occur where depths of cover above longwall mining is low, such as the north-eastern ends of South Bates Extension longwalls, or where there are multiple seams of overlapping longwall mining e.g. where South Wambo Underground Mine longwalls overlap in the Woodlands Hill and Arrowfield Seams, and in turn are overlain by historical North Wambo Underground and Homestead-Wollemi mines.

Fracturing to the surface is simulated to occur over the eastern 60% of the Modification Longwalls 24-26 footprint. Fracturing to the surface (Layer 1) or to weathered strata (Layer 2) is simulated to occur over the eastern 85% of the Modification Longwalls 24-26 footprint.



0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:50,000 at A4
Project Number:	665.0008.00815
Date:	27-Jul-2022
Drawn by:	ANP

Source: NSW SS 2020

Named Watercourse
NWC Diversion
Mining Lease
Approved Open Cut Mining

Proposed Mining
South Bates Extension LW24-26 MOD - Whybrow Seam

Approved Mining
South Wambo - Woodlands Hill Seam
South Wambo - Arrowfield Hill
South Bates Extension - Whybrow Seam

Historical/Completed Mining
South Bates - Whybrow Seam
South Bates - Wambo Seam
North Wambo UG - Wambo Seam
United UG - Arrowfield
Homestead-Wollemi UG - Whybrow Seam

Layer Intersected by Subsidence Fracturing
1, 2, 3, 4, 5 - 7, 8 - 13

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION

Shallowest layer intersected by subsidence fracturing

FIGURE 2-8

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_2_8_HoF_001.mxd

2.5 Timing

A transient calibration model incorporates changes and stresses to the groundwater system consistent with historical climatic observations and mining activity. The calibration model developed for this work includes a combined transient warm-up and transient calibration model with the following timings:

- Steady state model for pre-mining conditions within the Hunter Coalfield
- Transient warm-up model for pre-2003 conditions to simulate influence of regional historical mining prior to the transient calibration. Warm-up model run from January 1970 to December 2002 with approximately decadal stress periods.
- Transient calibration model from January 2003 to Dec 2020 with quarterly time intervals.
- Transient prediction model from January 2021 to December 2041 with quarterly time intervals; and
- Transient recovery model from 2040 to December 2399 with progressively increasing annual, 5, 10, 25, 50, and 100 yearly stress periods.

The transient warm-up model was built to incorporate pre-2003 mining activities and their impacts on groundwater levels around the Project Area. The transient warm-up model covered from 1970 to January 2003 and included three time slices with the length of 10 years for the first and second time slices and 12 years for the third time slice. The warm-up model was used to change model cell properties from un-mined Permian Coal Measures to spoil/ backfill where open cut mining was conducted (i.e. Historical Wambo, United Collieries, HVO, and MTW) or goaf and fractured properties, if necessary, where underground mining occurred (Homestead-Wollemi, United Collieries, Wambo and Lemington Underground). These warm-up periods aimed to provide appropriate starting conditions for the calibration model (i.e. starting heads and hydraulic properties).

The quarterly time intervals for the transient calibration model allowed for the incorporation of observed climatic and environmental data (rainfall, observed levels in watercourses), and detailed open cut and underground mine progression, with aquifer parameter changes made to replicate spoil/ backfill progression and fracturing associated with longwall mining.

Following the calibration period, a transient predictive model is run with quarterly time intervals (from January 2021 to December 2041) and includes the simulation of planned open cut and underground mine progression. The following scenarios (**Table 2-7**) have been developed to ascertain the incremental impacts of the modification, impacts of Wambo underground operations since approval of the initial Development Consent (DA 305-7-2003), and cumulative impacts of all Wambo area operations since approval of the initial Development Consent (DA 305-7-2003).

Table 2-7 Numerical model scenarios

Model Scenario	Simulated Mining
Null scenario – No Wambo mining	All approved and foreseeable regional mining. Historical Wambo Complex mining to 2003 only.
No Wambo underground scenario	• All approved and foreseeable regional mining. • Historical Wambo Complex mining to 2003 only. • Historical Wambo Complex open cut mining and United Underground mining. • Approved future mining including: • UWOCP
Approved mining scenario	All approved and foreseeable regional mining. Historical Wambo Complex mining to 2003. Historical Wambo Complex mining from 2003 to December 2020. Approved future mining including: • South Bates Extension (SBX) LW21-25 (April 2021 – Dec 2024); • South Wambo - Woodlands Hill (Jan 2025 – May 2035) and Arrowfield (Jun 2032 – Jun 2041); and • UWOCP.
Proposed mining scenario	All approved and foreseeable regional mining. Historical Wambo Complex mining to 2003. Historical Wambo Complex mining from 2003 to December 2020. Approved future mining including: • South Bates Extension (SBX) LW21 -23 (April 2021 – Aug 2023); • South Wambo - Woodlands Hill (Feb 2027 – Oct 2037) and Arrowfield (Apr 2032 – Nov 2041); and • UWOCP Proposed future mining: • South Bates Extension (SBX) LW24-26 (December 2032 – June 2026) see **Figure 1-1.**

3 Model calibration

Automated calibration utility PEST ++ (Doherty, 2010) and manual calibration were used to match the available transient water level data. The groundwater levels for the transient calibration recorded between January 2003 and December 2020 were used for the model calibration. Historical groundwater levels during the steady state and transient warm-up periods were not used in calibration. In all, 16,138 heads targets (groundwater level observations) were established from 464 groundwater monitoring points from the following sites:

- UWOCP standpipes and VWPs: 98 groundwater level observation points;
- Wambo standpipes and VWPs: 109 groundwater level observation points;
- HVO standpipes and VWPs: 154 groundwater level observation points; and
- MTW standpipes and VWPs: 58 groundwater level observation points.

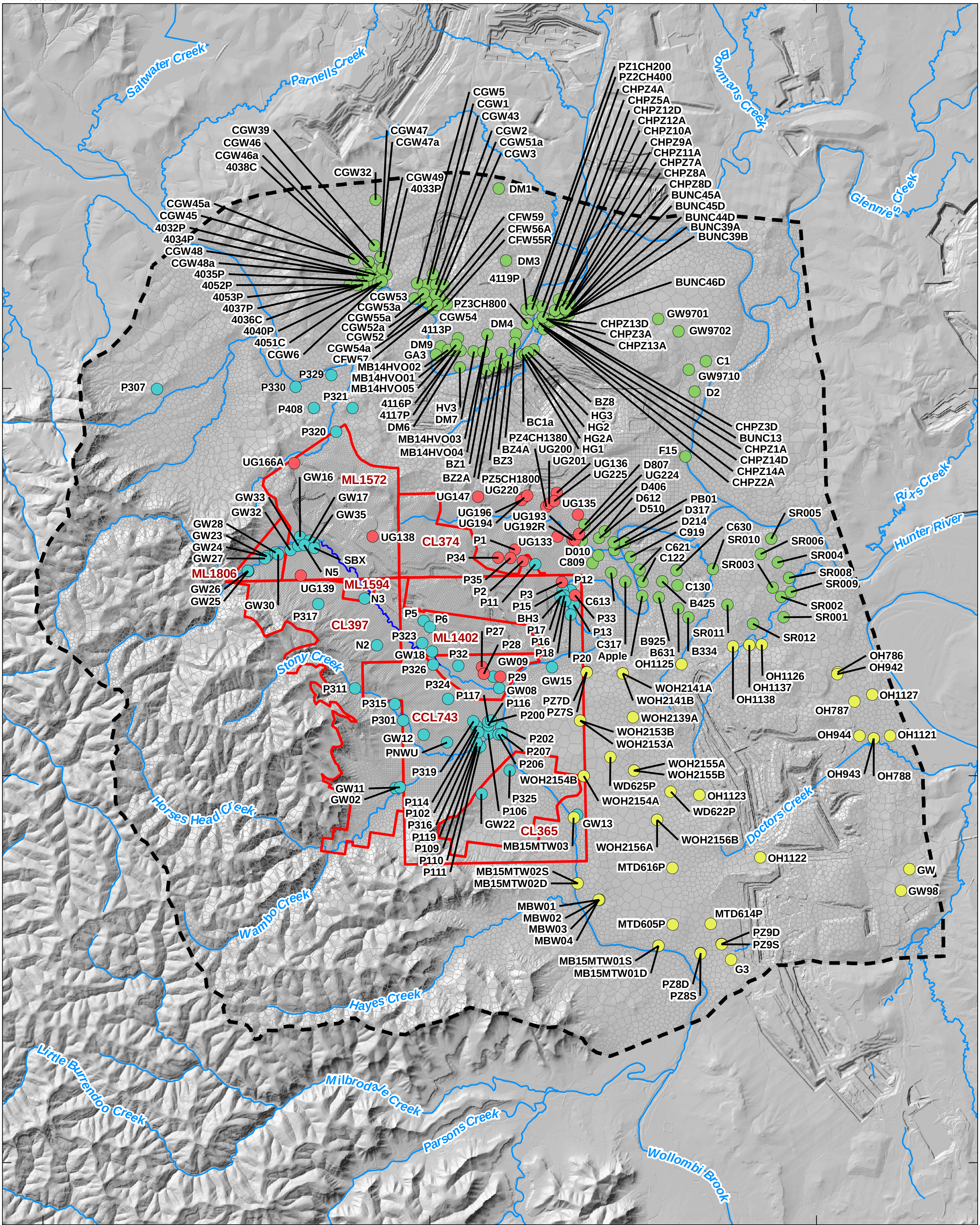
Groundwater targets were selected where:

- Data appeared reliable and consistent with surrounding observations targeting the same units; and/or
- Valid information on bore construction or geology information was available for the site.

Data at groundwater monitoring sites that were assessed to be reliable were used for the calibration, with each site given a weighting of 1. The locations of these bores are shown in **Figure 3-1**.

The hydraulic properties (i.e., horizontal, vertical conductivity, specific yield, and specific storage) and recharge rates were adjusted during the calibration to provide best match between the measurements and model simulated heads.

Pilot points have been used during the calibration to allow for spatially variable parameters. That is, spatially variable hydraulic conductivity within the Alluvium and Regolith, and spatially variable parameters with depth across coal and interburden units. This was achieved using PLPROC and PEST++ utilities. The location of the pilot points is shown in **Figure 3-2**. Overall, the pilot points are generally set in higher density areas near observation bores, while more uniform spacing of pilot points is used across the rest of the model domain. PEST++ interpolates between the pilot point values and creates a surface across the model domain for a targeted model parameter. This surface of model parameter values in then interrogated for values at the model cell centres to provide a value at each model cell. A total of 6,080 pilot points were used to assign the hydraulic parameters to layers 1 to 30 of the model.



Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Model Grid

Calibration Data Points (Owner)
HVO
MTW
United
Wambo

0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	02-Dec-2021
Drawn by:	ANP

SLR

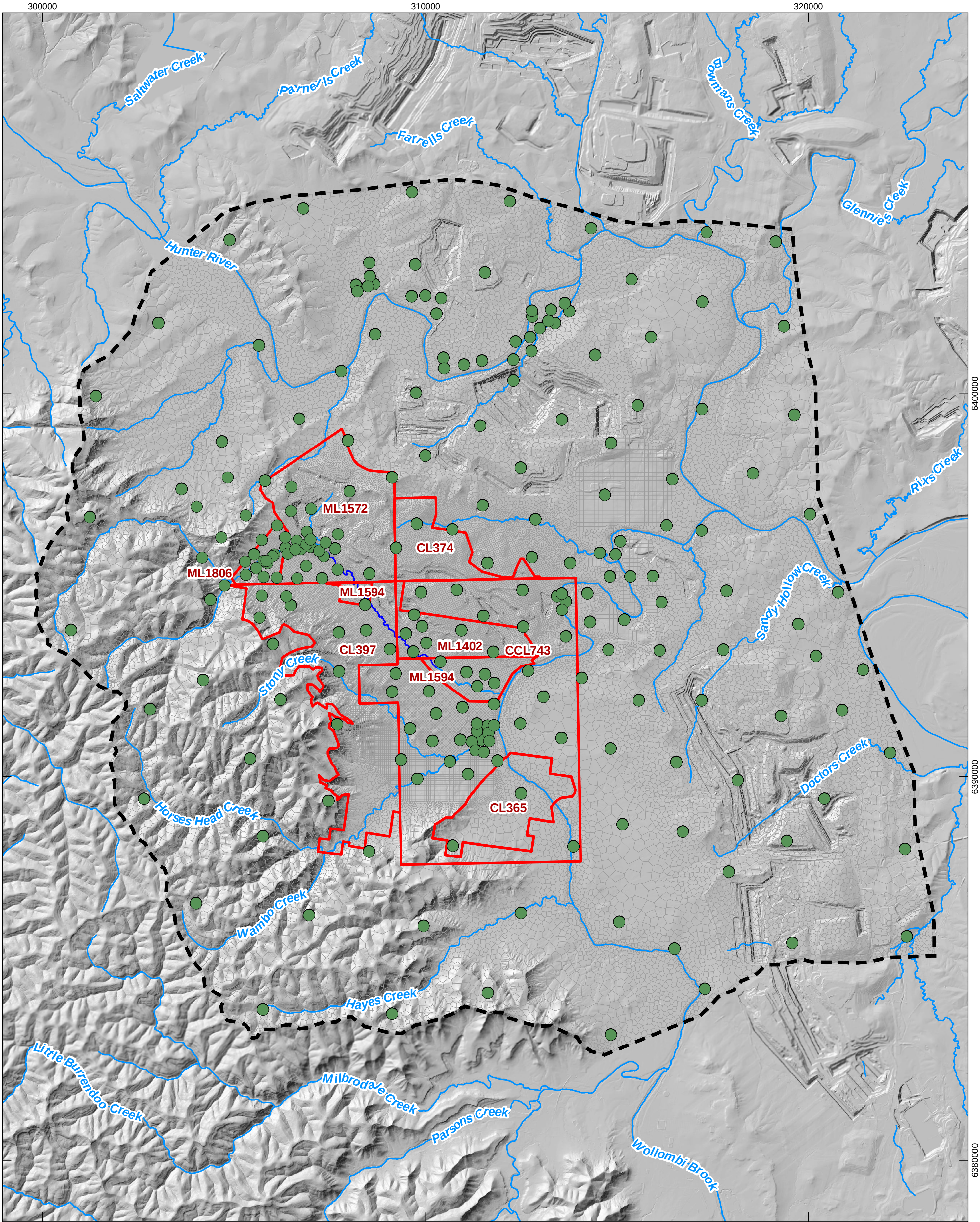
Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Calibration data points

FIGURE 3-1

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_G15_CalibrationDataPoints_001.mxd



0 2 4 km

Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:130,000 at A4
Project Number: 665.0008.00815
Date: 02-Dec-2021
Drawn by: ANP

Wambo Model Boundary
Pilot Point Location
Named Watercourse
NWC Diversion
Mining Lease
Model Grid

Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Pilot point locations

FIGURE 3-2

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_G16_PilotPoints_001.mxd

3.1 Calibration statistics

One of the industry standard methods to evaluate the calibration of the model is to examine the statistical parameters associated with the calibration. This is done by assessing the error between the modelled and observed (measured) water levels in terms of the root mean square (RMS). RMS is expressed as:

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

where: n = number of measurements

h_0 = observed water level

h_m = simulated water level

RMS is considered to be a good measure of error if errors are normally distributed. The RMS error calculated for the calibrated model is 13.07 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 total measured head change across the model domain is 219 m; therefore, the ratio of RMS to the total head loss (SMRS) is 6.0%. While there is no recommended universal SRMS error, the Australian Guidelines suggests that setting Scaled RMS targets such as 5 or 10% may be appropriate in some circumstances (Barnett et al., 2012).

Figure 3-3 presents the observed and simulated groundwater levels graphically as a scattergram for the initial and historic transient calibration (2003 to 2020). The overall transient calibration statistics are presented in **Table 3-1**. 91% (14784/16218 calibration targets) are within ±20 m of the observed measurements. This provides an indication of reasonable fit for the large regional dataset; however, further discussion on the fit between modelled and observed trends is included in **Section 3.2**.

The spatial distribution of average residuals for each bore from the transient calibration is shown in **Figure 3-4**, while minimum, maximum and average residuals at each calibration site are included in **Attachment A**. The residual is the difference between the measured and the modelled water level at each bore. A negative residual represents an over estimation of water levels, while a positive residual represents an underestimate. The size of the bore symbol in **Figure 3-4** is proportional to the residual (i.e. larger residual has a larger symbol size). **Figure 3-4** shows regionally there is a good match between the observed and simulated groundwater levels, noting that the model appears to be well calibrated in shallow/alluvial sites near the proposed SBX LW24-26 panels.

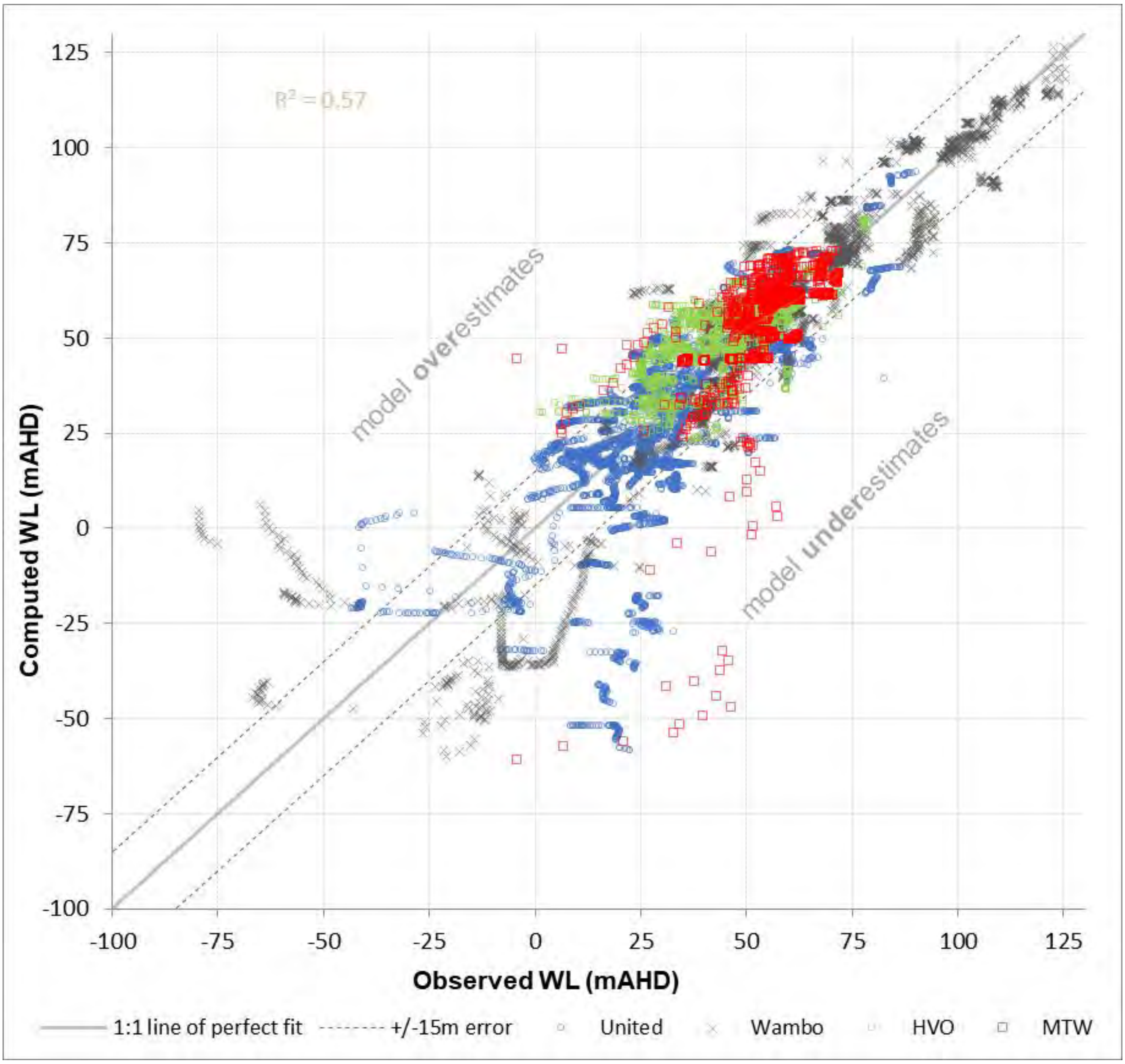
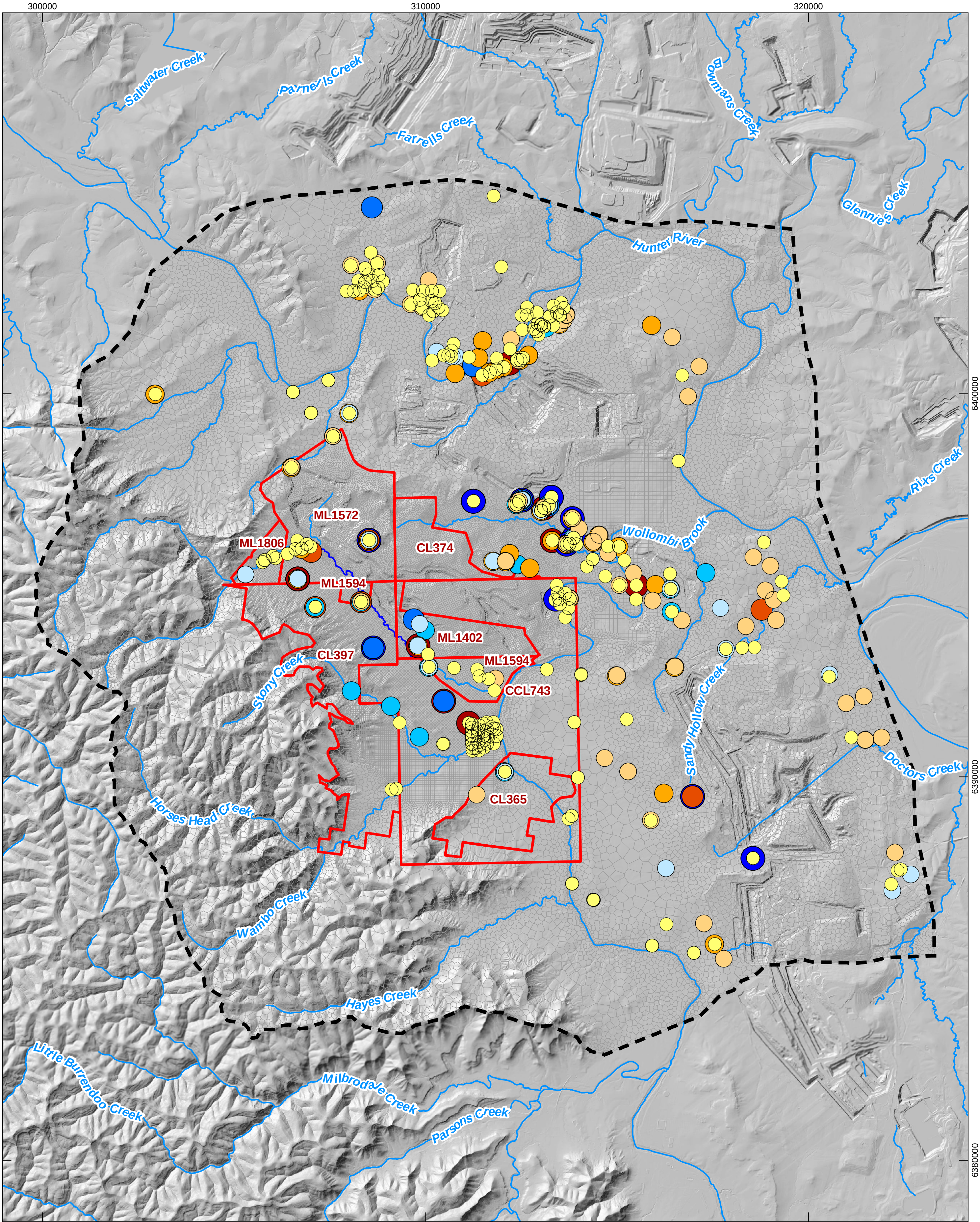


Figure 3-3 Calibration scattergram– modelled vs observed groundwater levels

Table 3-1 Transient calibration statistics

Statistic	Value
Residual Mean (m)	-0.62
Absolute Residual Mean (m)	8.09
Residual Std. Deviation (m)	13.06
Sum of Squares (m2)	2772549
RMS Error (m)	13.07
SRMS (%)	6.0%
Targets within ±2m	5064
Targets within ±5m	3040
Targets within ±20	6680
Targets greater than ±20	1434



Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:130,000 at A4
Project Number: 665.0008.00815
Date: 02-Dec-2021
Drawn by: ANP

SLR

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Average head residuals from transient calibration

FIGURE 3-4

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_G17_AverageResiduals_001.mxd

3.2 Calibration fit

This section provides discussion on how the model replicates observed groundwater level trends (calibration hydrographs) for key bores and aquifer units across the model domain. Calibration hydrographs for the full calibration dataset is presented as **Attachment B**.

3.2.1 North Wambo Creek

Discussion surrounding quality of fit between observed and modelled data at North Wambo Creek is divided into observation sites upstream and downstream of the North Wambo Creek Diversion (NWCD).

3.2.1.1 Upstream of the NWCD

Figure 3-5 shows that the model does a reasonable job of simulating the observed groundwater fluctuation of 3-5 m for many bores in the North Wambo Creek alluvium. It also shows that the model is able to simulate the observed peaky response to rainfall events (GW23 and GW30 in 2020). Sites within the shallow weathered sandstone (GW24) similarly show simulated groundwater level fluctuation in the order of 3-5 m, as well as more persistent saturation than the overlying alluvium. This is consistent with observed data and the conceptualisation of the groundwater system at North Wambo Creek (SLR, 2022).

It does however appear that the model is not able to simulate fully the fluctuation due to the recharge events at sites closer to the UWOCP (Montrose Open Cut) (GW35, GW16, GW17). To improve the heads at these sites, significant time was spent in effort to better calibrate the model parameters in the area, and the run presented here was the best simulation which was able to be achieved. Difficulty in calibrating these locations is likely related to model structure and layer assignment of GW16 and GW17, as bore logs indicate these are screened across alluvium/regolith as well as in underlying weathered Permian (Parsons Brinkerhoff, 2009).

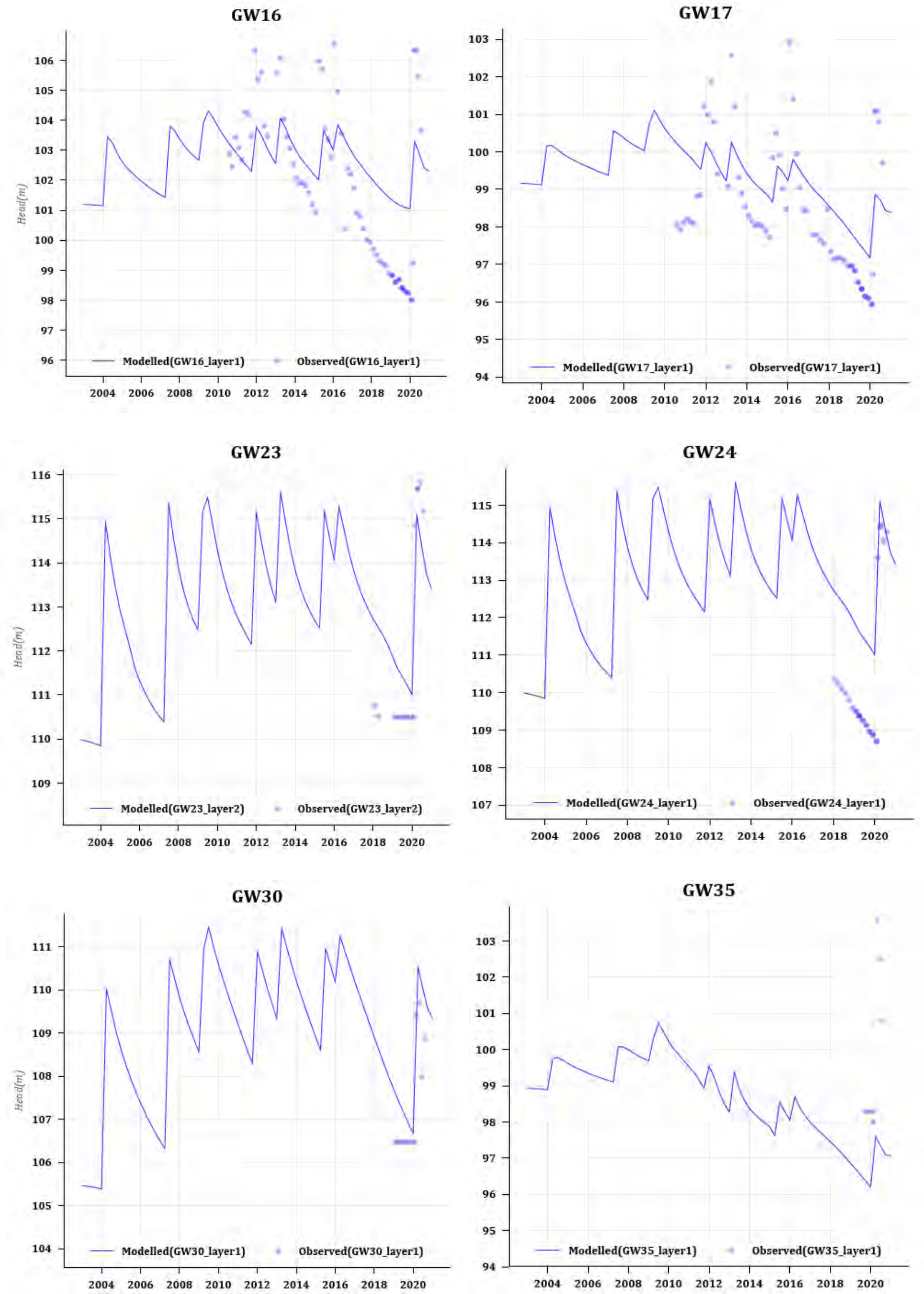


Figure 3-5 Hydrographs from key monitoring sites within the North Wambo Creek alluvium

3.2.1.2 Downstream of the NWCD

General trends in simulated water levels within the alluvium and shallow Permian groundwater system downstream of the NWCD are well matched to observed data (**Figure 3-6**). The timing and magnitude of groundwater level responses to mining impacts at sites such as GW08, GW09 and P27 within the North Wambo Creek alluvium, including periods where the alluvium is observed to go dry, are well represented by the model. However, seasonal fluctuations and response to flow events in North Wambo Creek are of a greater magnitude than observed. Further review of the downstream flow monitoring station (FM4) and subsequent adjustment of flow events at the reach of North Wambo Creek downstream of the diversion may help adjust the rainfall-flow relationship locally and improve the quality of the calibration. Simulated groundwater conditions at the start of the transient calibration period are also slightly underestimated (approximately 3.5 m). This appears to be related to an overprediction of the impacts associated with Homestead-Wollemi underground mining in the warm-up stress periods and is likely caused by the simulation of the complete underground operation in a single, 10-year stress period.

A similar relationship between observed and modelled data exists for P28, located in the shallow Permian strata downstream of the NWCD, with the magnitude and timing of a mining effect well matched, but a slight overestimation of response to flow events.

P29, within model layer 6 (overlying the Whybrow Seam), does not show a good match to mining related drawdown associated with North Wambo Underground longwall mining. Further investigation of how the model is representing dewatering from historical underground workings (Wambo No1 and Homestead-Wollemi) may improve the calibration at this location.

3.2.2 Wambo and Stony Creek alluvium

Upstream of historical underground operations (Homestead-Wollemi and North Wambo Underground) at sites GW02 and GW11, simulated and observed groundwater levels show a good match in terms of both the timing and magnitude of responses to recharge events (rainfall and creek flow) (**Figure 3-7**).

Further downstream, above historical underground workings, simulated water levels in the alluvium are reasonably represented, with the residual for sites within alluvium and underlying weathered Permian strata generally less than 5 m. As with sites downstream of the NWCD (**Section 3.2.1.2**), groundwater levels near Wambo Creek (P114, P116 and P109) are often underestimated at the beginning of the transient calibration period. This is likely related to a greater than observed mining impact from Homestead-Wollemi underground mine due to the simulation of the entire workings within a single warm-up stress period. P-NWU-08 also shows a good match between vertical hydraulic gradients in the alluvium and shallow underlying weathered Permian.

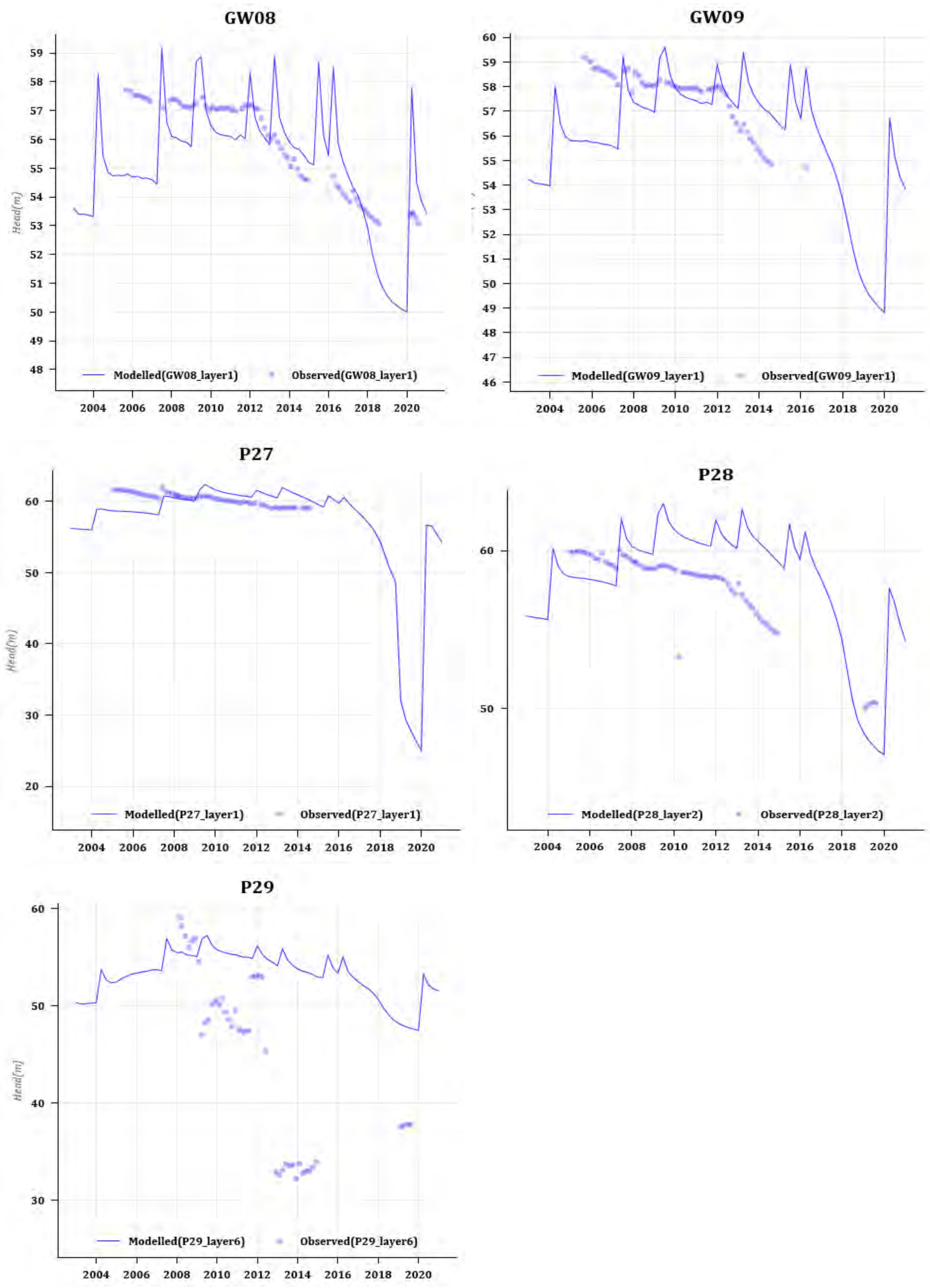


Figure 3-6 Hydrographs from key monitoring bores at downstream North Wambo Creek

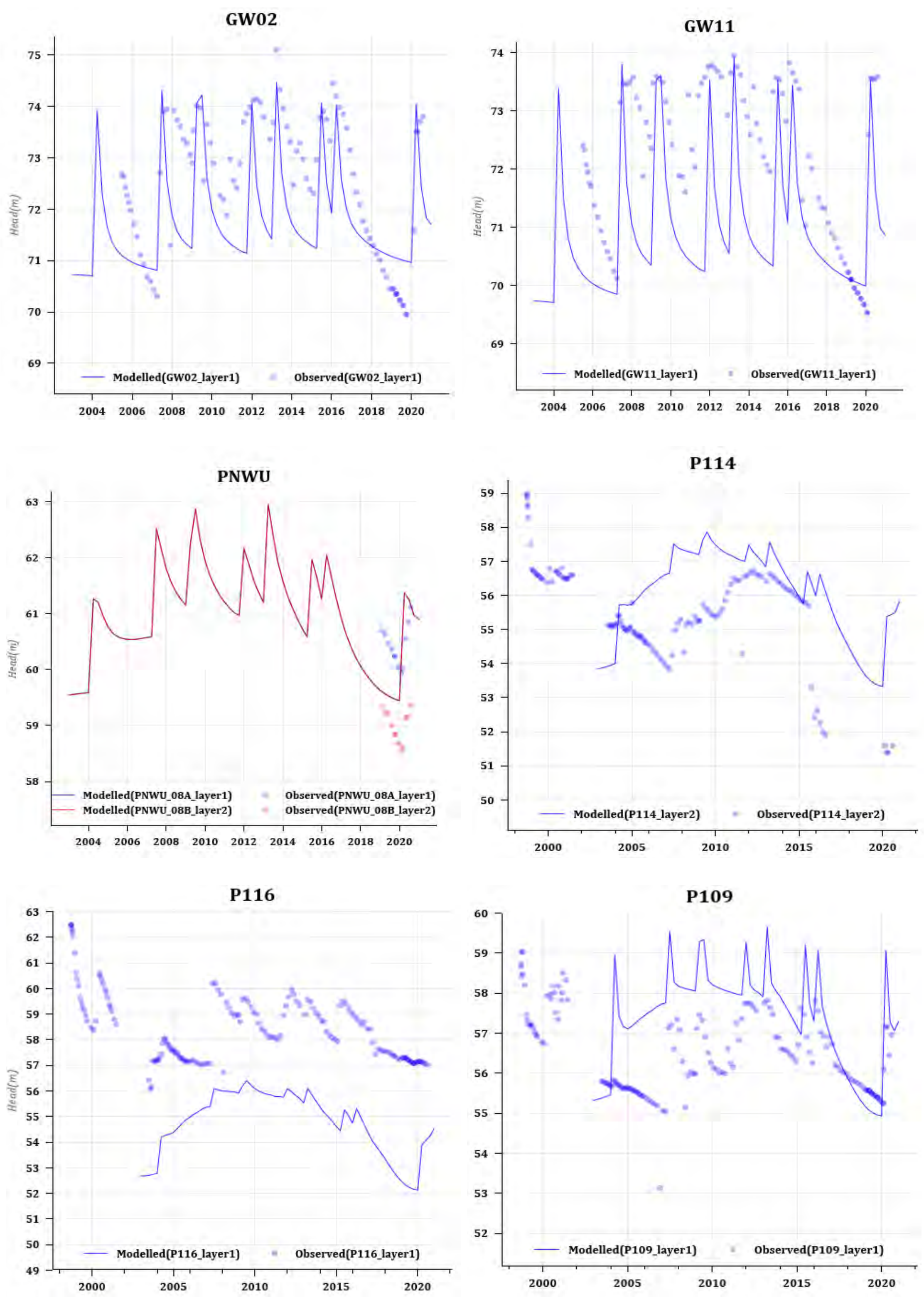


Figure 3-7 Hydrographs from key monitoring bores at Wambo and Stony Creek alluvium

3.2.3 Wollombi Brook alluvium

The elevation and magnitude of groundwater level fluctuation at Wollombi Brook monitoring sites is well matched by the groundwater model. Sites to the east of Wollombi Brook, within the sandier alluvium have groundwater levels over-estimated by approximately 1 m (P12, P13 and GW15) (**Figure 3-8**), while sites within the west-Wollombi Brook colluvium generally simulate water levels within 1 m of observations (P16 and P18) (**Figure 3-9**). The relationship between observed and modelled groundwater levels further downstream, near the confluence of Redbank Creek and Wollombi Brook, is similarly well matched as seen in sites upstream. Seasonality in groundwater levels is generally well captured by the modelling with modelled levels within 1 m of observations.

A slight over-estimation of mining impacts is simulated at P15, and P17, likely related to United Underground and North Wambo Underground mining from 2008 to 2016, while minor impacts associated with Glen Munro Pit can be seen in simulated water levels at P16 and P20 **Attachment B**.

Groundwater levels at Wollombi Brook sites are all seen to recover in response to rainfall and flow events in early 2020. This is not replicated at the same rate in observed data at some locations (e.g. GW15). Further investigation into recharge mechanisms at these sites, and review of contemporary observation data following above average rainfall through 2021 may help improve calibration at these sites in future model updates.

3.2.4 Hunter River alluvium

Groundwater monitoring sites within the Hunter River Alluvium with data available for this assessment are owned by either HVO or MTW and were not a key area of focus for this updated groundwater modelling. Simulated groundwater levels within the Hunter River Alluvium, however, are well matched to observed data (within 1-2 m) and generally capture fluctuations caused by groundwater recharge events (flow and rainfall) (**Attachment B**).

Ongoing observations at Hunter River Alluvium standpipe bores owned by United-Wambo (P408) and Wambo (Hunter 1 and Hunter 2) will validate the quality of simulated groundwater levels at alluvial monitoring sites closer to United-Wambo and Wambo mining operations.

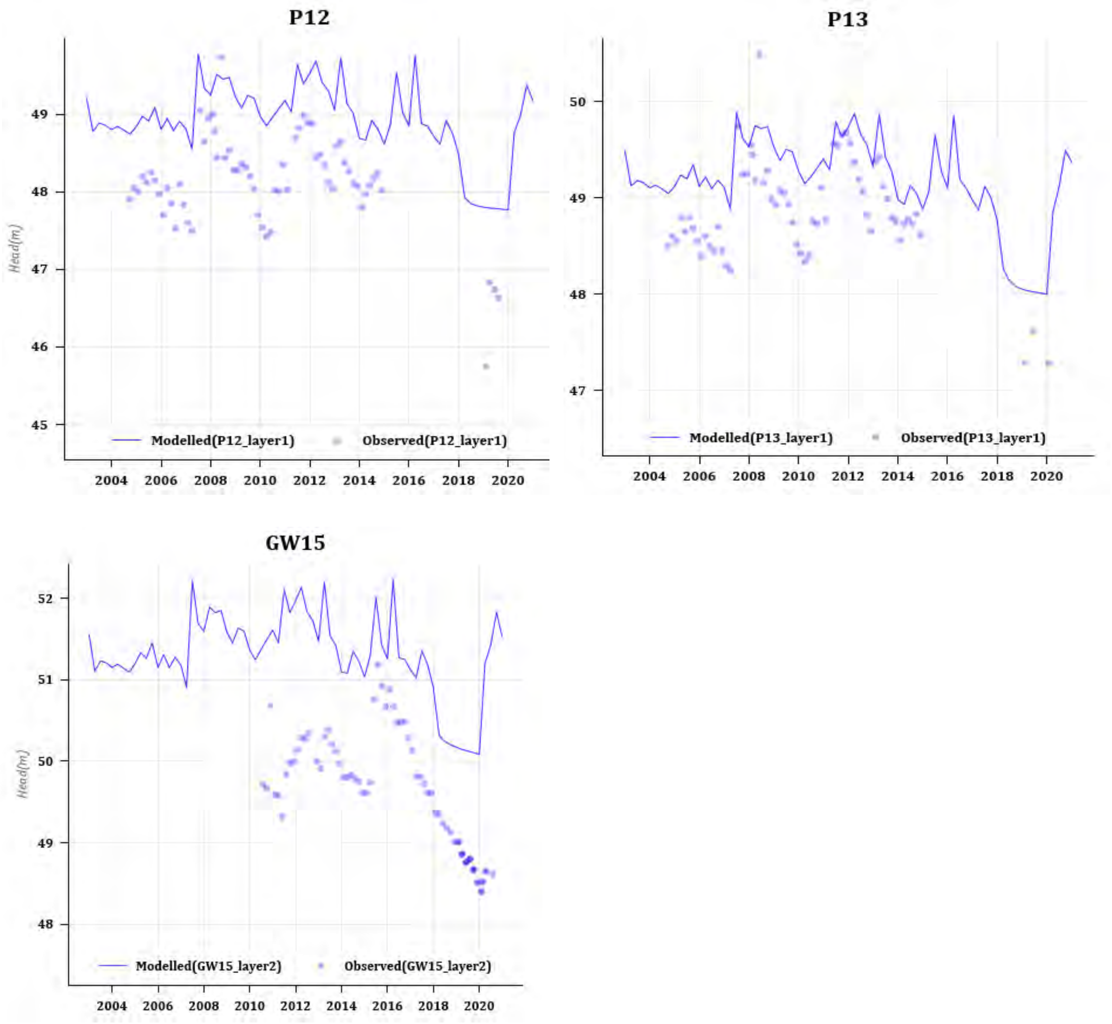


Figure 3-8 Hydrographs from key monitoring bores at east Wollombi Brook Alluvium

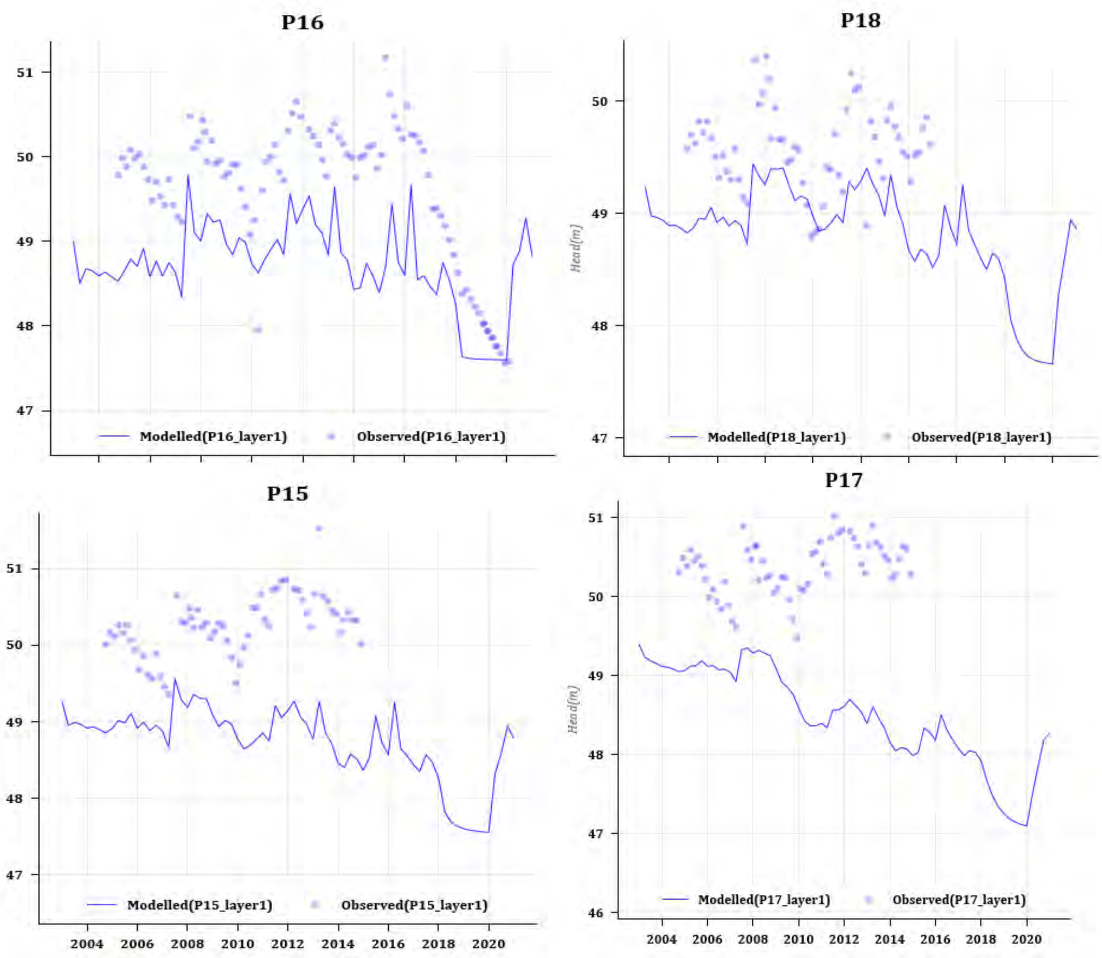


Figure 3-9 Hydrographs from key monitoring bores at west Wollombi Brook alluvium

3.2.5 Permian coal measures

The quality of fit of modelled groundwater levels to observed within Permian Coal Measures has been subdivided by mine area. A focus is placed on response to mining operations at Wambo and United-Wambo, but comment is also made on calibration quality of regional mines HVO South and MTW.

3.2.5.1 UWOCP

Groundwater monitoring of the Permian Coal Measures at United-Wambo is largely undertaken by VWP arrays, most of which monitor groundwater conditions to the east of historical United Underground, or to the north, between United Underground and HVO South, but also spread around the complex. **Figure 3-10** and **Figure 3-11** show the calibration fit at United-Wambo monitoring locations within Permian Coal Measures. Overall, hydraulic gradients and groundwater level trends are reasonably well matched between observed and simulated data, particularly at sites P33, P34 and P35 near to Wollombi Brook. It is noted that simulated heads for Layer 2 (P33_5) and Layer 12 (P33_4) are very similar, masking Layer 12 predicted heads. Due their sensor depths, P33_2 and P33_3 are also both in Layer 14, with modelled heads for P33_2 masked in the figure.

Standpipes P1, P2 and P3, interpreted as being within interburden between the Whynot and Woodlands Hill seams, show a generally good match to observed groundwater level trends with residuals usually <20 m. Other sites (e.g. UG136 and UG 147) show a good match at some sensors, but others appear to be outliers. As with P33, some of the modelled heads are masked by similar heads in other layers, or two sensors being compared against simulated heads in the same model layer.

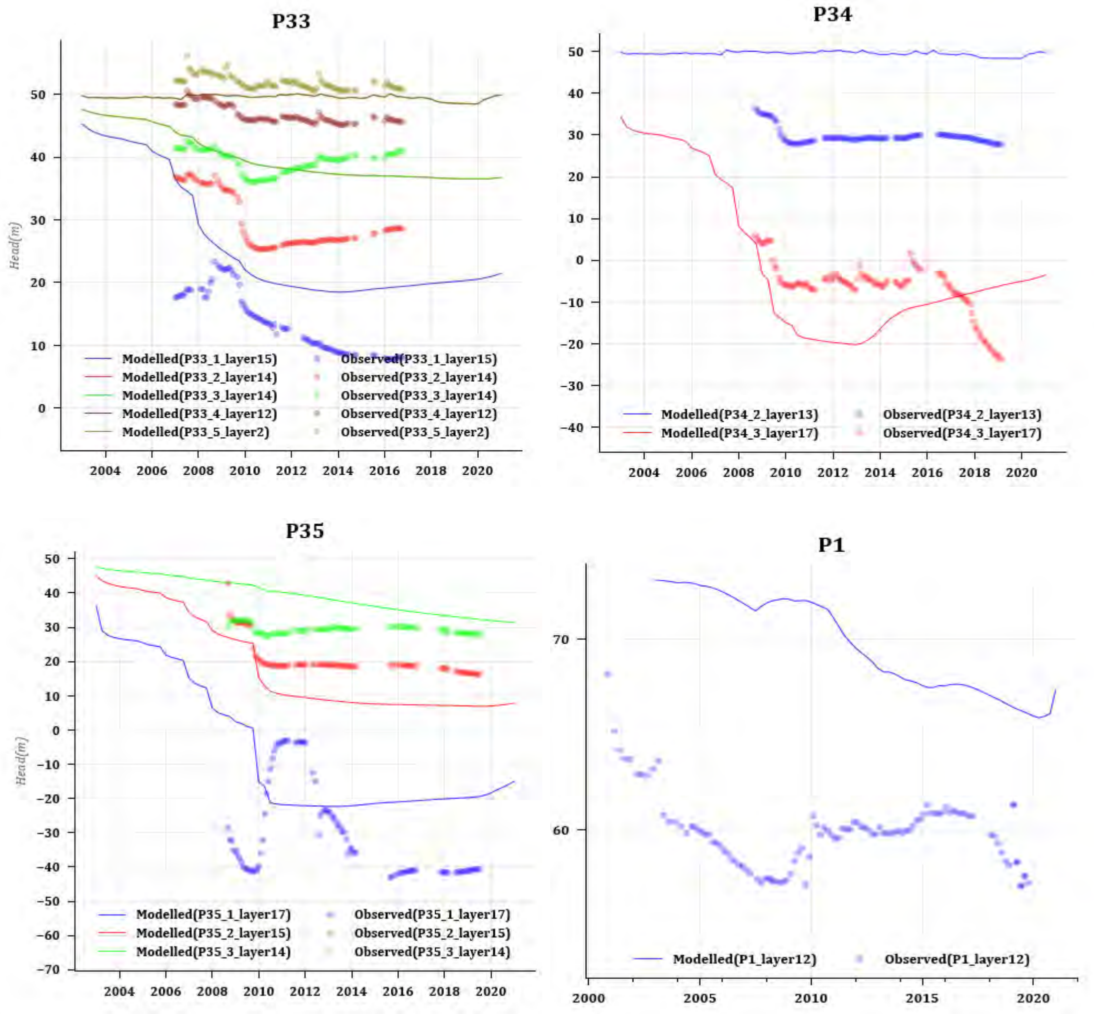


Figure 3-10 Hydrographs from key monitoring UWOCP bores in Permian coal measures (a)

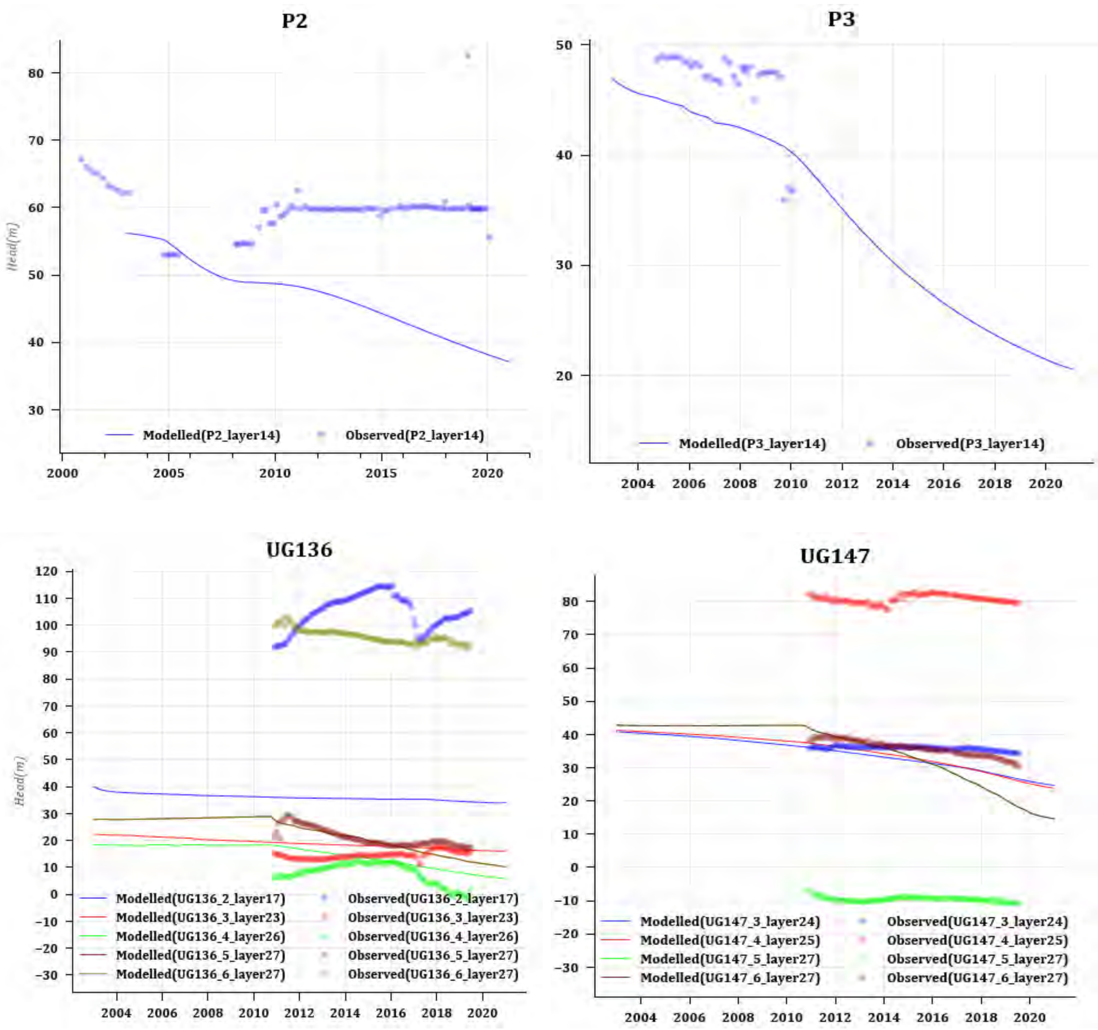


Figure 3-11 Hydrographs from key monitoring UWOCP bores in Permian coal measures (b)

3.2.5.2 North Wambo Underground and Homestead - Wollemi

Figure 3-12 and **Figure 3-13** show the calibration fit at weathered Permian and shallow overburden sites near North Wambo Underground and Homestead-Wollemi Underground. Overall, the timing and magnitude of mining related drawdown within Permian Coal Measures near historical underground mining at Homestead-Wollemi (Whybrow Seam) and North Wambo Underground (Wambo Seam) is generally well captured by the groundwater model. Standpipe monitoring sites GW22, P202 and P206 show some influence of a mining effect and subsequent recovery, as well as some seasonality due to rainfall. VWP monitoring sites P316, P323, P324, P325, P326 show reasonable matches to observed groundwater levels in strata overlying the deepest mined seam (Wambo seam), but occasionally struggle to replicate water levels in lower strata, which are likely to be impacted by adjacent open cut and regional mining operations.

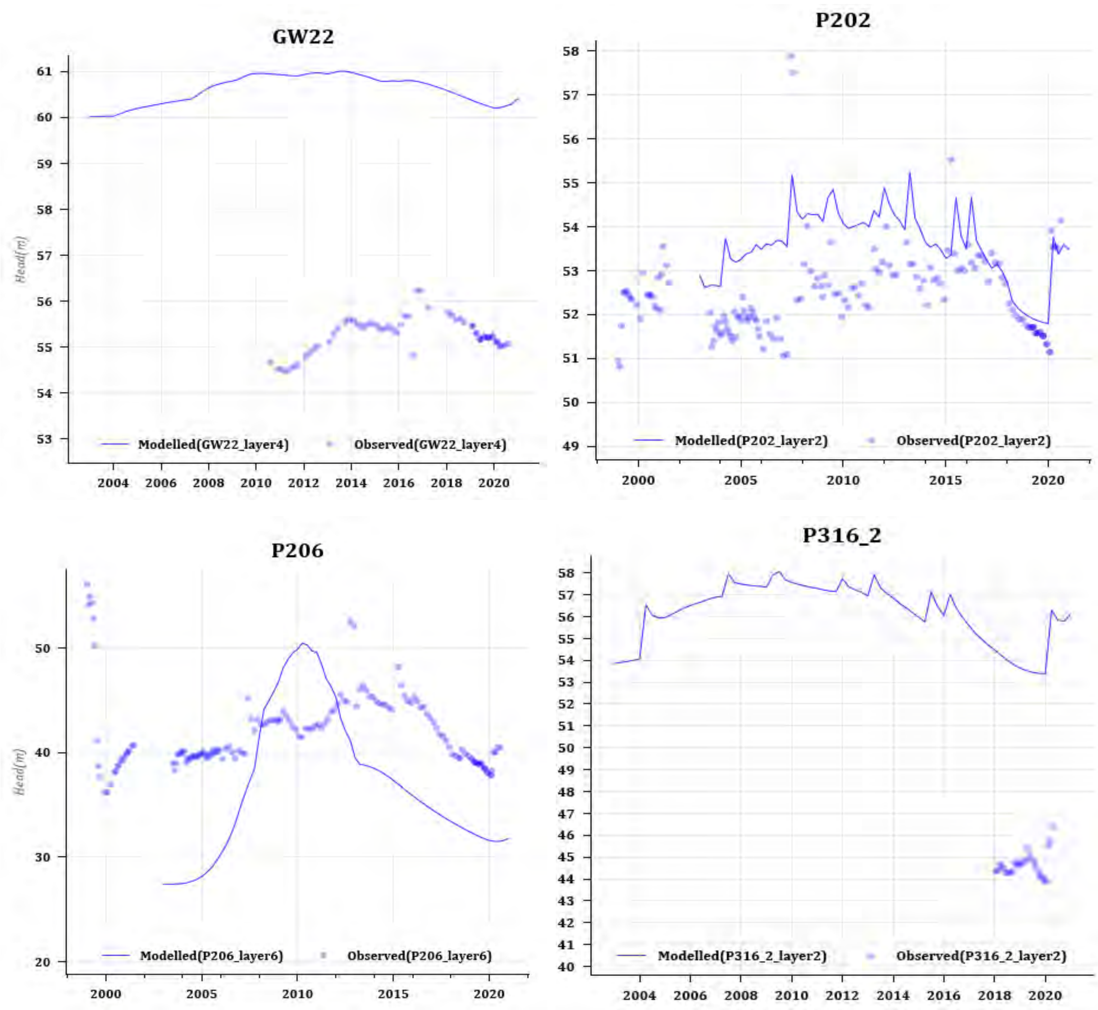


Figure 3-12 Hydrographs from key North Wambo Underground and Homestead-Wollemi monitoring bores (a)

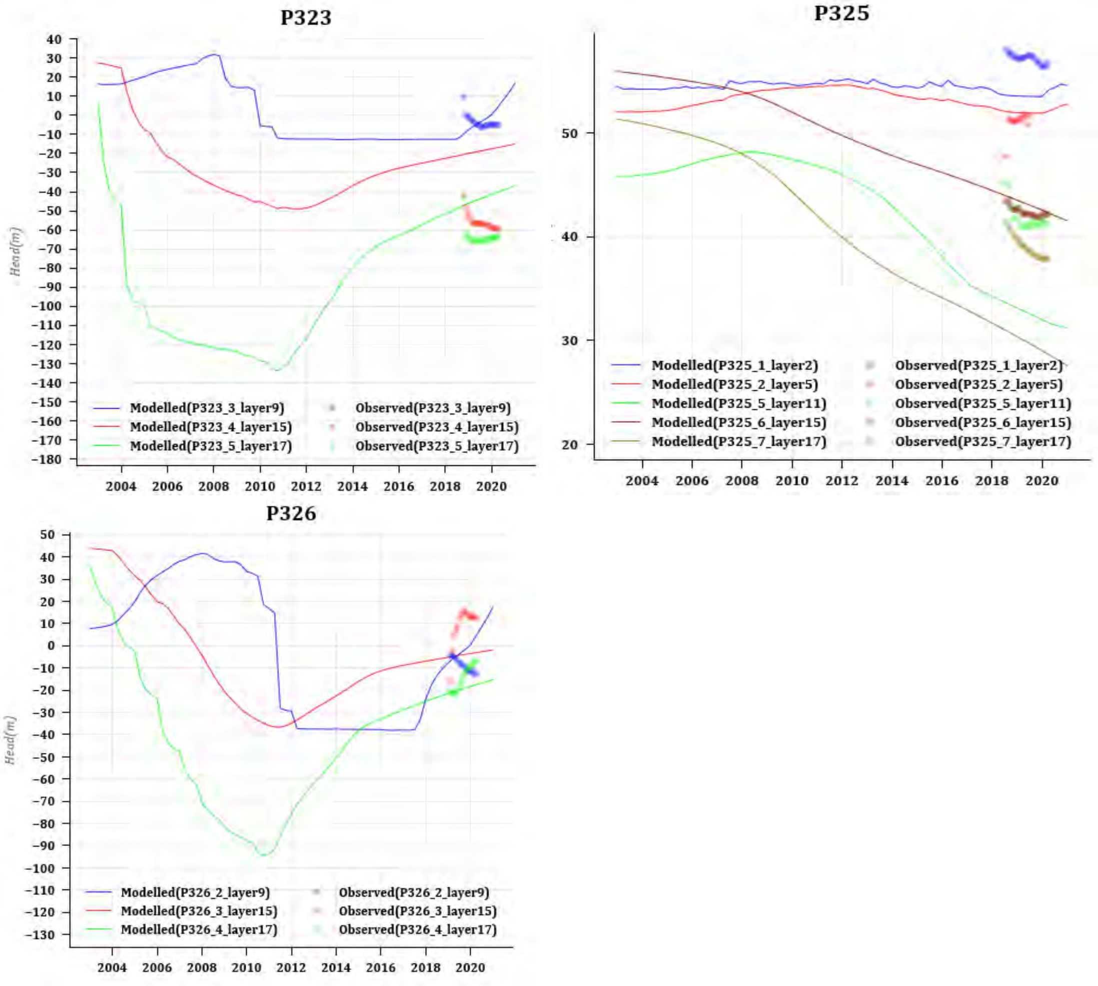


Figure 3-13 Hydrographs from key North Wambo Underground and Homestead-Wollemi monitoring bores (b)

3.2.5.3 South Bates Underground and South Bates Extension

Figure 3-14 shows calibration fit at South Bates Underground and South Bate Extension Underground monitoring locations. N2, N3 and N5 (above and adjacent to South Bates and South Bates Extension Undergrounds) show an improvement in calibration fit compared with previous groundwater modelling (SLR, 2020), with a better absolute match to observed levels and improved representation of hydraulic gradients. P317 (see **Attachment B**) similarly shows a good match to data observed prior to sensor failure.

Some over-estimation of groundwater levels is observed in the upper, overburden sensors in these VWP arrays, while impacts appear to be over-estimated in the lower sensors at N2. Some protection from South Bates drawdown may be provided by a fault in-between NWU and South Bates workings, which could be considered for more specific inclusion in future model revisions. A review of layer geometry and layer assignment may help also improve calibration to observed data in the upper sensors.

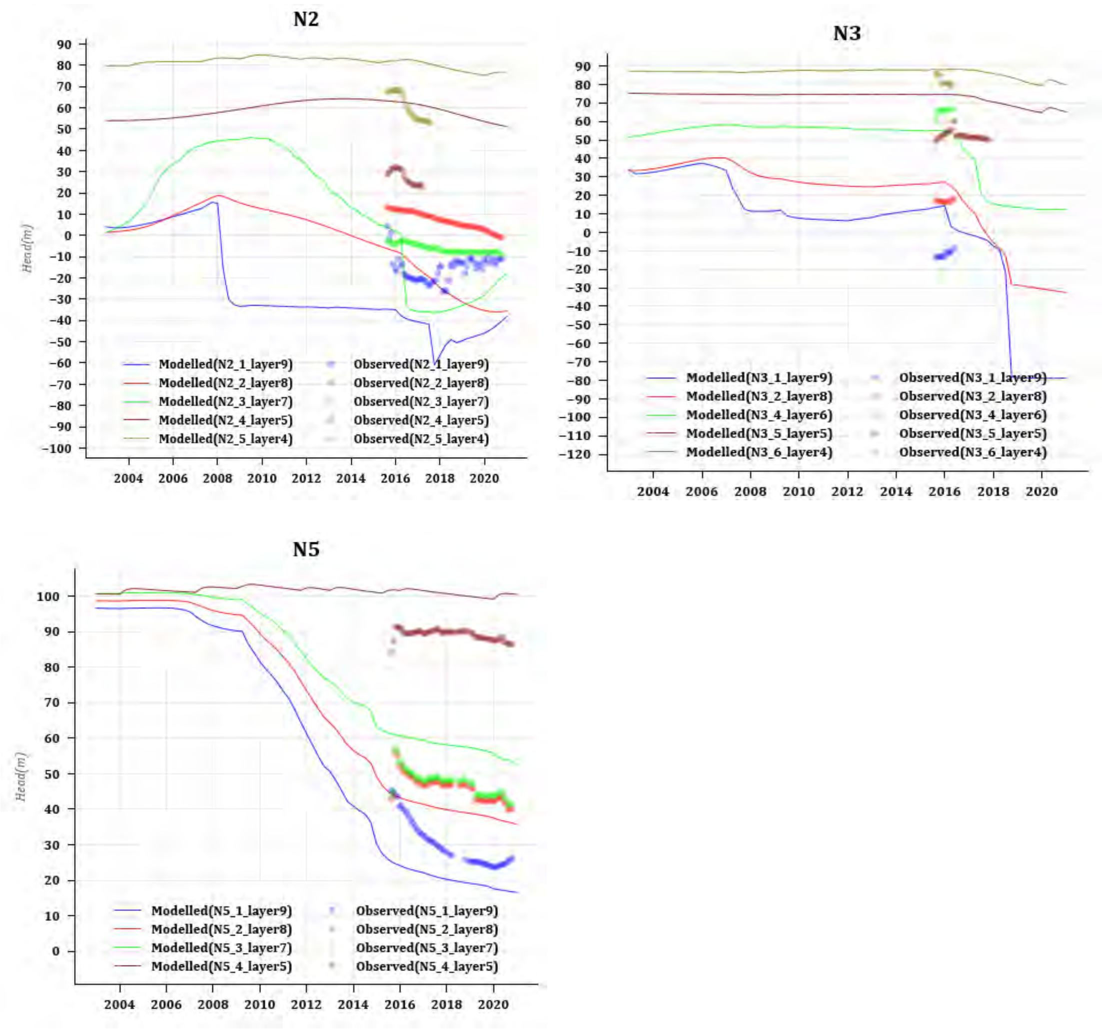


Figure 3-14 Hydrographs from key South Bates Underground and South Bates Extension monitoring bores

3.2.5.4 Wambo open cut operations

The observation of groundwater response to open cut operations at Wambo is undertaken at sites that often monitor impacts from nearby underground operations (**Figure 3-15**). The deepest target seam of Wambo open cut operations is the Whynot Seam (model layer 11), which is monitored at P325 and P307. Simulated groundwater levels over-predict drawdown within the Whynot seam at P325 by ~10 m, which may be due to water storages within the mine footprint not being simulated in this model, or an overprediction of impacts from the MTW open cut which is also nearby. P307 is north of current operations and is over-predicting heads within the Whynot Seam. Further refinement of the geological layering at this location, or revision of the boundary condition elevations in the north-west of the model domain may improve calibration at this site.

Shallow monitoring bores near Wambo open cut operations generally replicate observed groundwater levels well. GW16 and GW17 (see **Figure 3-5**) adjacent to West Montrose pit continue to replicate observed fluctuations associated with climate, while P16 and P20, near Glen Munro pit are significantly responsive to Wollombi Creek water level dynamics and simulate a minor mining effect that can been seen in observed data.

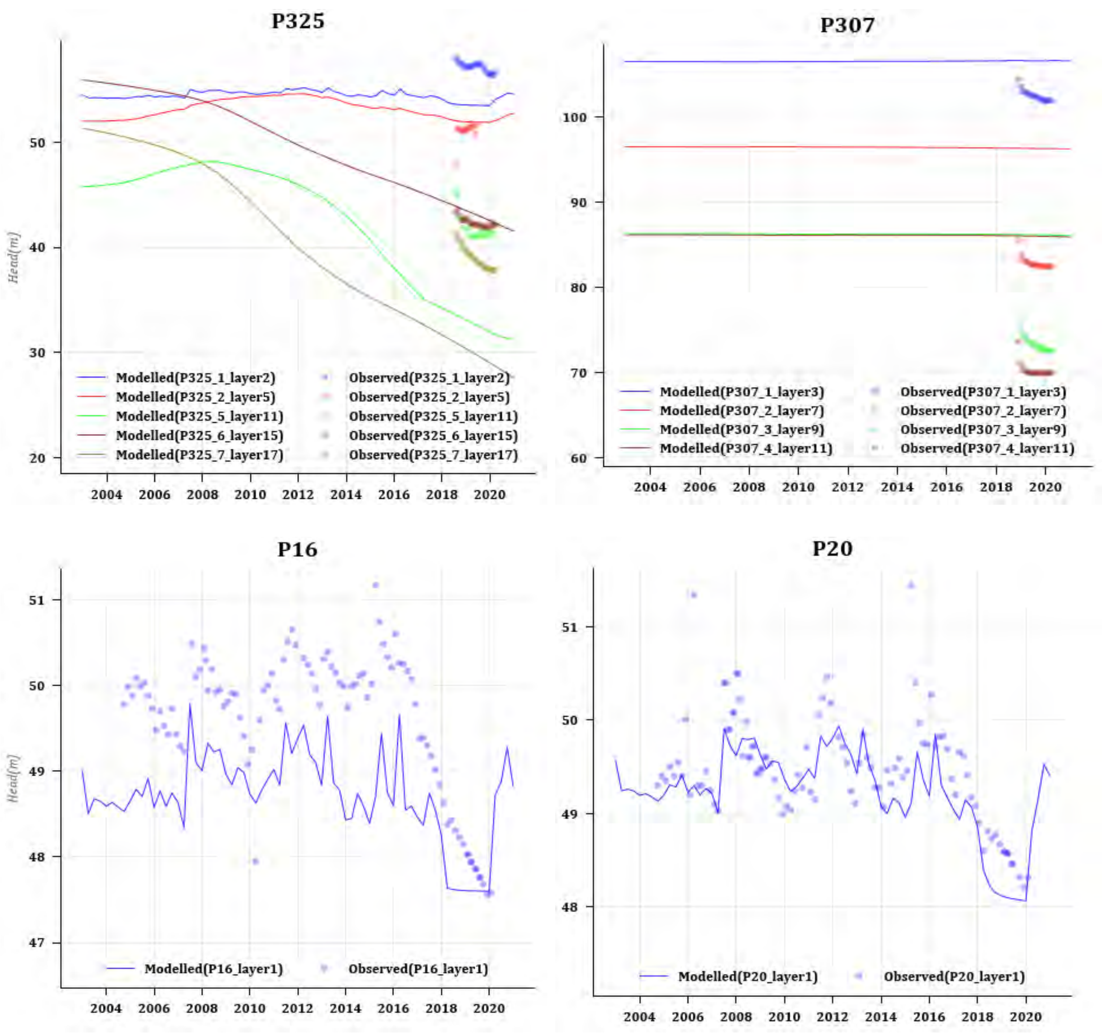


Figure 3-15 Hydrographs from key Wambo open cut operations monitoring bores

3.2.5.5 MTW

Calibration hydrographs for MTW monitoring sites used in the calibration are provided in **Attachment B**. Simulated groundwater levels at shallow MTW monitoring sites within or adjacent to Wollombi Brook Alluvium generally show a very good match to observed groundwater levels (within 5 m). Mining related drawdown within Permian Coal Measures is generally well matched between simulated and observed data in terms of timing, rate, and magnitude of decline.

Some sites closer to the southern model boundary, where impacts from Bulga operations are likely contributing to groundwater level observations, are less well matched by the model.

3.2.5.6 HVO

Calibration hydrographs for HVO monitoring sites used in the calibration are provided in **Attachment B**. As discussed previously, simulated groundwater levels at shallow HVO South monitoring sites within or adjacent to Wollombi Brook Alluvium (**Section 3.2.3**) or Hunter River Alluvium (**Section 3.2.4**) generally show a good match to observed groundwater levels (within 5 m). The calibration fit of groundwater level and mining related drawdown within Permian Coal Measures is variable for HVO monitoring sites dependent on bore location and target geology. A brief overview of these variable trends is provided below:

- Monitoring bores screened within the Bowfield Seam (Layer 19) near Lemington underground and Lemington pit observe a groundwater level decline from 2015 through to 2019. This is thought to be associated with groundwater extraction from the Lemington Underground (LUG) supply bore. Extraction from this bore is simulated within the target seam of Lemington Underground mining (Mt Arthur Seam - Layer 25) and does not appear to be impacting groundwater levels in the overlying Bowfield seam (Layer 19).
- Coal measures bores in the north of the model domain have a poorer calibration fit than other locations within the model; this is attributed to the following influences:
    - Geological detail within the model not as well defined in the north of the model. Wambo and United geology models do not extend that far.
    - Mining progression and rehabilitation not as well understood for HVO.
    - Stress from HVO North only represented in conditions applied at the model boundary.

3.3 Water balance

3.3.1 Steady state calibration

The water balance for the steady state model calibration is shown in **Table 3-2**. The water balance for the steady-state model indicates that recharge was the largest net inflow contributor to the model (11.7 megalitres per day [ML/d]). Regional groundwater inflow and outflow are 1.2 and 0.20 ML/day respectively, indicating that groundwater enters the model domain through this boundary.

A net outflow of 12.5 ML/d from the model occurs due to baseflow seepage to the main watercourses (i.e. surface water and groundwater interaction in the Hunter River, Wollombi Brook, and local ephemeral watercourses). This is the largest component of outflow from the model during steady state calibration. The other factor that contributes to outflow from the groundwater system is evapotranspiration (0.7 ML/d outflow). The mass balance error for the steady state calibration is 0.00%, within the error threshold recommended by the Australian Groundwater Modelling Guidelines (Barnett et al., 2012), and indicating the model is stable and achieves an accurate numerical solution.

Table 3-2 Steady-state model water balance

Component	Inflow (ML/d)	Percent of Total Inflows (%)	Outflow (ML/d)	Percent of total outflows (%)
Recharge (RCH)	11.7	91.2	0.0	0.0
Evapotranspiration (ET)	0.0	0.0	0.6	4.6
SW-GW Interaction (RIV)	0.6	4.8	12.2	95.4
Regional GW Flow (GHB)	0.5	4.0	0.0	0.0
Mines (DRN)	0.0	0.0	0.0	0.0
Well (WEL)	0.0	0.0	0.0	0.0
Storage	0.0	0.0	0.0	0.0
Total	**12.8**	**100.0**	**12.8**	**100.0**

3.3.2 Transient calibration

The water balance for the transient simulation is presented in **Table 3-3**, which provides daily average rates from January 2003 to December 2020. The mass balance error, that is, the difference between calculated model inflows and outflows at the completion of the transient calibration was 0.0%. This value indicates that the model is stable and achieves an accurate numerical solution.

The water balance indicates that recharge to the groundwater system within the model averages 12.7 ML/day. Approximately 9.5 ML/day is discharged via surface drainage (baseflow), and 0.6 ML/day lost to evapotranspiration in areas where the water table is within the rooting depth of various vegetation types across the model domain.

No changes can be seen for in/out fluxes from the GHB component. This indicates that the mining activities do not have any impact on the flux changes occurring between the model and groundwater system surrounding the model. About 9.2 ML/day is removed from the model by Drain boundary condition that represents mining in the model (for all mines) during the calibration period.

Table 3-3 Transient model water balance

Component	Inflow (ML/d)	Percent of Total Inflows (%)	Outflow (ML/d)	Percent of total outflows (%)
Recharge	12.6	54.7	0.0	0.0
Evapotranspiration (ET)	0.0	0.0	0.6	2.5
SW/GW Interaction (RIV)	5.6	24.4	9.5	41.4
Regional GW flow (GHB)	0.5	2.2	0.0	0.1
Drains (Mine inflows)	0.0	0.0	9.2	40.1
Well	0.0	0.0	0.0	0.1
Storage	4.3	18.7	3.7	15.9
Total	**23.0**	**100.0**	**23.0**	**100.0**

3.3.3 Calibration inflows

The model calculates the volume of water removed by mining based on hydraulic properties and gradients, not by direct user input. It was important to constrain the model such that the magnitude of water being removed is comparable to what is observed to have been removed. **Figure 3-16** shows the calibrated simulated inflows at Wambo and United workings.

During the operation of the historical mines, North Wambo Underground has two peaks in inflows in years 2013 and 2015. On average, North Wambo Underground provides a simulated inflow of approximately 2.0 ML/day between 2007 and 2017. The result is comparable with the previous modelling for the underground workings by AGE (2016) and HydroSimulations (2014). In summary, AGE (2016) predicted an average inflow of less than 1 ML/day with the peak short-term inflow of 5 ML/day from the Wambo seam for the North Wambo Underground. HydroSimulations also predicted inflows of about 1 ML/day from the Wambo seam for the North Wambo Underground.

With regards to Open cut mining, West Montrose provides an average simulated inflow of 0.9 ML/day between 2003 and 2020. AGE (2016) predicted an average inflow of less than 1 ML/day for the open cut workings which is consistent with the estimates provided here.

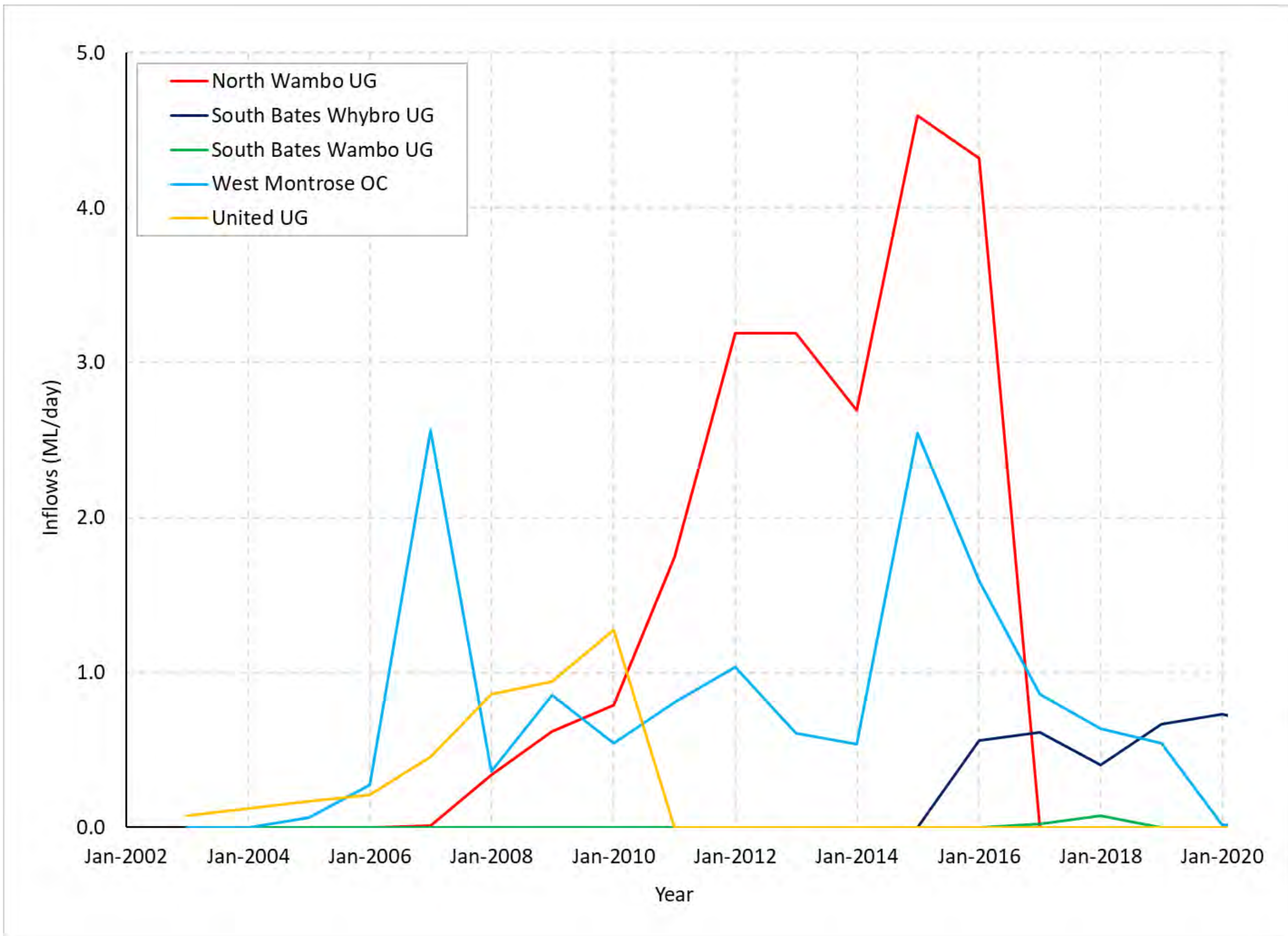


Figure 3-16 Estimated inflows during calibration period

3.4 Calibrated hydraulic parameters

Table 3-4 summarises the calibrated values for horizontal hydraulic conductivity (Kx) and horizontal to vertical hydraulic conductivity ratio (Kx/Kz), Specific Storage (SS) and Specific Yield (SY). The hydraulic conductivity of the Permian coal and interburden material in the model reduces with depth in order to reflect field observations. Therefore, the average horizontal and vertical hydraulic conductivity in Permian coal and interburden unit is presented in **Table 3-4**.

Table 3-4 Calibrated hydraulic parameters

Layer	Geological Unit	Average Kx (m/day)	Average Kz (m/day)	Average SY (-)	SS (1/m)
L01	Highly productive alluvium	2.6E+00	4.6E-01	8.0E-03	1.2E-05
	Less productive alluvium	7.9E+00	4.2E-01	7.3E-02	1.3E-05
	Regolith	1.3E+00	8.6E-03	1.3E-02	2.2E-06
L02	Highly productive alluvium	8.3E+01	2.8E+00	1.3E-02	1.6E-05
	Less productive alluvium	5.9E+00	1.7E-01	1.8E-02	1.4E-05
	Weathered coal measures	1.1E+00	1.0E-01	6.4E-02	1.3E-05
L03	Narrabeen Group	5.0E-02	2.2E-04	3.2E-02	1.7E-06
L04	Newcastle Coal Measures*	6.9E-02	1.6E-02	3.5E-03	2.3E-06
L05	Overburden 1 (Sandstone / siltstone / shale)*	2.0E-03	8.6E-05	1.0E-02	7.3E-06
L06	Overburden 2 (Sandstone / siltstone / shale)*	6.8E-04	3.4E-05	1.3E-02	3.5E-06
L07	Whybrow seam*	6.4E-02	2.0E-02	6.9E-03	1.2E-06
L08	Sandstone / siltstone / shale*	8.1E-04	1.4E-04	4.2E-03	8.1E-07
L09	Wambo seam*	4.1E-02	1.8E-04	3.0E-03	6.4E-06
L10	Sandstone / siltstone / shale*	5.6E-04	1.2E-05	3.0E-03	2.7E-06
L11	Whynot Seam*	5.4E-02	2.6E-02	4.8E-03	2.1E-06
L12	Sandstone / siltstone / shale*	5.6E-04	9.3E-05	4.2E-03	8.5E-07
L13	Blakefield, Glen Munro*	4.6E-02	3.6E-03	2.9E-02	6.4E-06
L14	Sandstone / siltstone / shale*	4.2E-04	5.1E-05	7.8E-03	2.5E-06
L15	Woodlands Hill Seams*	2.4E-02	8.2E-05	3.5E-03	3.2E-06
L16	Sandstone / siltstone / shale*	1.1E-04	1.4E-05	4.7E-03	2.3E-06
L17	Arrowfield Seam*	2.5E-02	1.6E-02	6.9E-03	9.6E-07
L18	Sandstone / siltstone / shale*	7.7E-05	1.2E-05	4.2E-03	7.4E-07
L19	Bowfield Seam*	2.1E-02	2.1E-04	1.4E-02	9.8E-07
L20	Siltstone / shale (interburden) *	3.2E-04	3.2E-05	6.6E-03	1.1E-06
L21	United and Wambo Bowfield seam split*	1.8E-02	1.6E-02	2.4E-03	9.5E-07
L22	Siltstone / shale (interburden) *	2.9E-04	1.5E-05	3.6E-03	2.6E-06
L23	Warkworth Seam*	1.9E-02	1.4E-04	2.3E-02	1.4E-06
L24	Siltstone / shale (interburden) *	4.0E-04	8.5E-05	4.0E-03	6.0E-06
L25	Mt Arthur Seam*	1.1E-02	8.7E-05	9.7E-03	1.2E-06
L26	Siltstone / shale (interburden) *	3.1E-04	2.0E-05	4.0E-03	2.9E-06

Layer	Geological Unit	Average Kx (m/day)	Average Kz (m/day)	Average SY (-)	SS (1/m)
L27	Piercefield and Vaux Seams*	1.7E-02	3.8E-03	5.5E-03	1.1E-06
L28	Siltstone / shale (interburden) *	1.4E-04	3.8E-05	4.3E-03	8.0E-07
L29	Broonie and Bayswater Seams*	1.4E-02	7.9E-04	2.4E-02	2.5E-06
L30	Basement*	4.3E-04	9.5E-05	1.9E-02	6.0E-06

*depth dependence equation was applied.

The hydraulic conductivity of the interburden/overburden and coal seam layers decreases with depth according to Equations 1 and 2:

- Coal: $HC = HC_{01} \times \exp^{(Slope1 \times depth)}$ (Eq. 1)
- Interburden: $HC = HC_{02}\ ^{(Slope2 \times depth))}$ (Eq.2)

Where:

- HC is horizontal hydraulic conductivity at specific depth;
- HC_0 is horizontal hydraulic conductivity at depth of 0 m (intercept of the curve);
- depth is depth of the floor of the layer (thickness of the cover material);
- slope is a term representing slope of the formula (steepness of the curve).

HC_0 was estimated in the calibration. It varies for the coal seams and for the interburden and overburden units in the model. It should be mentioned that only HC_0 was estimated in the calibration and the slope was assumed to be fixed during the calibration. **Figure 3-17** and **Figure 3-18** present the horizontal conductivity against depth relationships for coal and Interburden estimated during the calibration. It should be mentioned that the HC_0 used to show the depth relationships in **Figure 3-17** and **Figure 3-18** are the average of calibrated HC_0 for coal seams and interburden accordingly. The figures also present the Wambo and United site data and conductivity measurements from the surrounding mines.

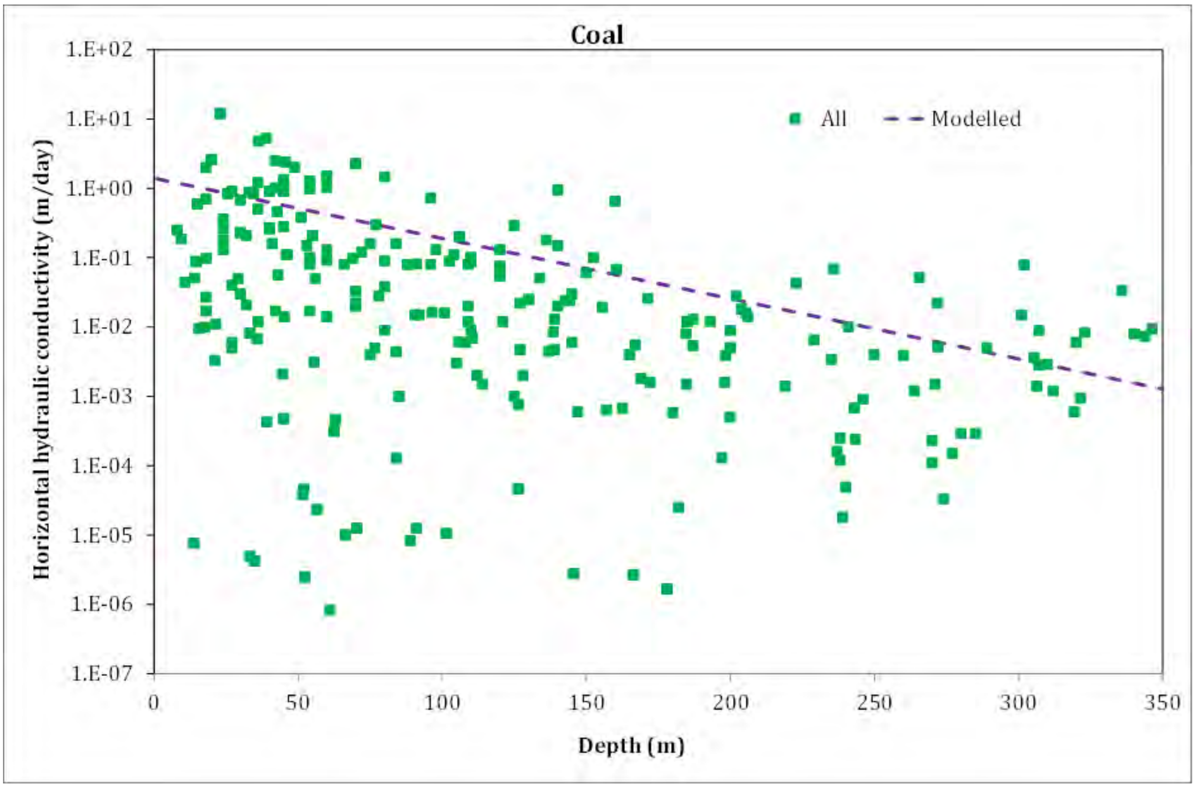


Figure 3-17 Hydraulic conductivity versus depth – Coal

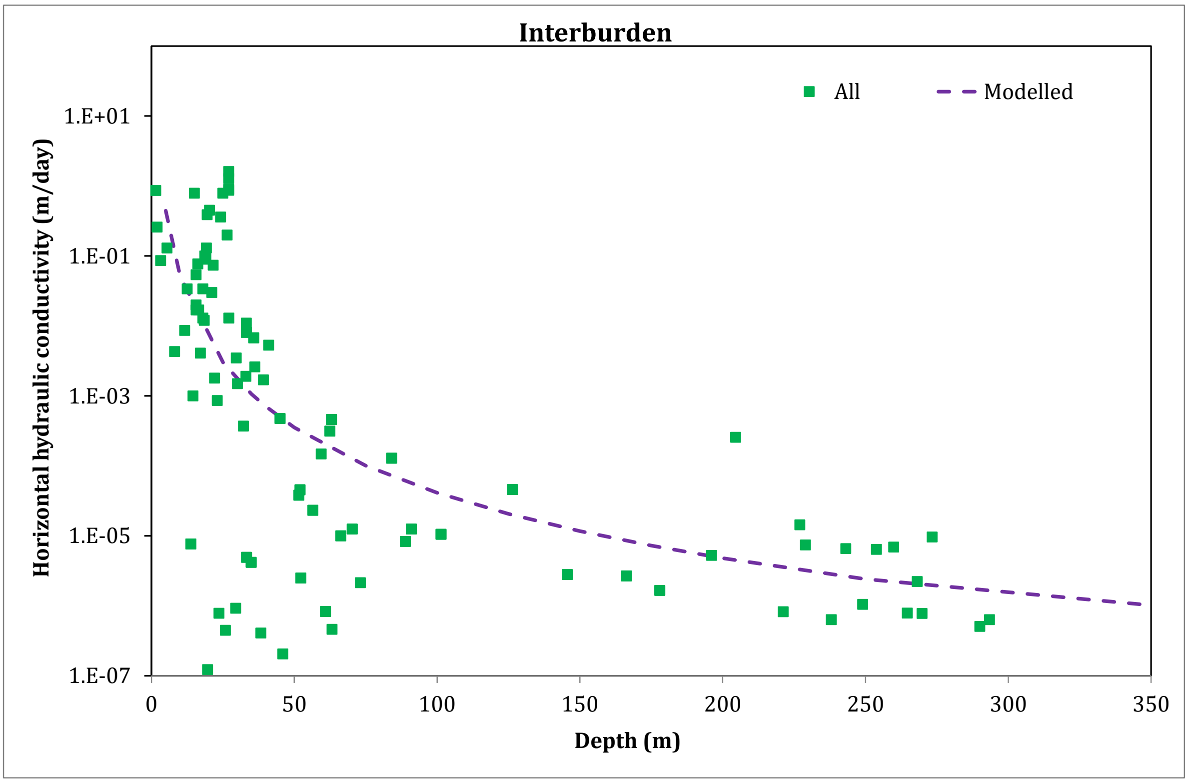


Figure 3-18 Hydraulic conductivity versus depth – Interburden

3.5 Calibrated recharge

Table 3-5 presents the calibrated recharge rates for each geological unit in the model. It should be noted that the average recharge is calculated based on the transient recharge estimated from the method described in **Section 2.4.3**. To show the recharge as the percentage of annual rainfall, the average recharge for each zone is divided by the annual rainfall (i.e. 653.3 mm/year) and shows as the percentage in the third column of **Table 3-5**. These calibrated recharge rates have been adopted into the predictive model. The recharge zones in the model layers are presented in **Figure 2-6**.

Table 3-5 Calibrated rainfall recharge

Model Geology Zone	Average recharge (mm/year)	% of average rainfall
Alluvium highly productive	43.8	6.7
Alluvium less productive	37.7	5.8
Regolith	3.0	0.5

4 Predictive modelling

4.1 Timing and mining

Transient predictive modelling was used to simulate short-term proposed mining at the United-Wambo and Wambo mining operations as well as mining at other approved and foreseeable mines within the model domain. The predictive model comprises quarterly stress periods, starting from December 2020 until Dec 2041. Mining cells progress quarterly, following the quarterly stress period duration.

Transient predictive models have been developed for four model scenarios:

- **Null Run** – No Wambo Complex mining after 2003 (i.e. when Development Consent (DA305-7-2003) was issued). This scenario does include mining at other approved mining operations around Wambo.
- **No Wambo Underground** – No Wambo underground mining after 2003 (i.e. when Development Consent (DA305-7-2003) was issued). This scenario does include mining at other approved mining operations around Wambo, does include Wambo and UWOCP open cut mining, and does include United Underground mining.
- **Approved** – Approved mining at Wambo (i.e. in accordance with Development Consent (DA305-7-2003) and mining at other approved mining operations around Wambo.
- **Modification** – Approved mining at Wambo (i.e. in accordance with Development Consent [DA305-7-2003]) plus the Modification and mining at other approved mining operations around Wambo.

As in the calibration, model cells representing active mining were progressed in line with the quarterly stress periods, with drain cells applied to the target seam for underground mining or projected down to the base of the lower most target coal seam for open cut mining.

Table 4-1 presents the simulated timings of mining in the Modification and Approved scenarios. All mines included in the model were simulated using the MODFLOW Drain (DRN) package. A nominally high drain conductance of 100 square metres per day (m^2/day) was applied to drain cells to simulate rapid removal of water from the system. Drain cells are kept active for four years (16 quarterly stress periods) post mining for open cut operations, while drains cells representing dewatering from underground mining are kept active for 0.25 years (1 stress period).

The following differential comparisons were made on groundwater level and groundwater flux outputs to evaluate incremental impacts due to the Modification, and cumulative impacts due to Wambo including the Modification:

- *Modification Scenario* compared to the *Null Run* – **to evaluate cumulative impacts** due to Wambo including the Modification.
- *Modification Scenario* compared to the *Approved Scenario* – to **evaluate the incremental impacts** of the Modification compared with the approved Wambo.
- *Modification Scenario* compared to the *No Wambo Underground Scenario* – to evaluate the **impacts of underground mining** including the LW24-26 Modification at Wambo

Table 4-1 Predictive model stress period setup and mining

Interval	Stress Period	Date (from)	Date (to)	Wambo Whybrow (UG)		Wambo Woodland (UG)		Wambo Arrowfield (UG)		Wambo (OC)		HVO (OC)		MTW(OC)	
				Mod	App	Mod	App	Mod	App	Mod	App	Mod	App	Mod	App
Quarterly	77	31/12/2020	01/04/2021	x	x					x	x	x	x	x	x
Quarterly	78	01/04/2021	02/07/2021	x	x					x	x	x	x	x	x
Quarterly	79	02/07/2021	01/10/2021	x	x					x	x	x	x	x	x
Quarterly	80	01/10/2021	31/12/2021	x	x					x	x	x	x	x	x
Quarterly	81	31/12/2021	02/04/2022	x	x					x	x	x	x	x	x
Quarterly	82	02/04/2022	02/07/2022	x	x					x	x	x	x	x	x
Quarterly	83	02/07/2022	01/10/2022	x	x					x	x	x	x	x	x
Quarterly	84	01/10/2022	01/01/2023	x	x					x	x	x	x	x	x
Quarterly	85	01/01/2023	02/04/2023	x	x					x	x	x	x	x	x
Quarterly	86	02/04/2023	02/07/2023	x	x					x	x	x	x	x	x
Quarterly	87	02/07/2023	01/10/2023	x	x					x	x	x	x	x	x
Quarterly	88	01/10/2023	01/01/2024	x	x		x			x	x	x	x	x	x
Quarterly	89	01/01/2024	01/04/2024	x	x		x			x	x	x	x	x	x
Quarterly	90	01/04/2024	01/07/2024	x	x		x			x	x	x	x	x	x
Quarterly	91	01/07/2024	01/10/2024	x	x		x			x	x	x	x	x	x
Quarterly	92	01/10/2024	31/12/2024	x	x		x			x	x	x	x	x	x
Quarterly	93	31/12/2024	01/04/2025	x	x		x			x	x	x	x	x	x
Quarterly	94	01/04/2025	02/07/2025	x	x		x			x	x	x	x	x	x
Quarterly	95	02/07/2025	01/10/2025	x	x		x			x	x	x	x	x	x
Quarterly	96	01/10/2025	31/12/2025	x	x		x			x	x	x	x	x	x
Quarterly	97	31/12/2025	02/04/2026	x		x	x			x	x	x	x	x	x

Interval	Stress Period	Date (from)	Date (to)	Wambo Whybrow (UG)		Wambo Woodland (UG)		Wambo Arrowfield (UG)		Wambo (OC)		HVO (OC)		MTW(OC)	
				Mod	App	Mod	App	Mod	App	Mod	App	Mod	App	Mod	App
Quarterly	98	02/04/2026	02/07/2026	x		x	x			x	x	x	x	x	x
Quarterly	99	02/07/2026	01/10/2026	x		x	x			x	x	x	x	x	x
Quarterly	100	01/10/2026	01/01/2027	x		x	x			x	x	x	x	x	x
Quarterly	101	01/01/2027	02/04/2027			x	x			x	x	x	x	x	x
Quarterly	102	02/04/2027	02/07/2027			x	x			x	x	x	x	x	x
Quarterly	103	02/07/2027	01/10/2027			x	x			x	x	x	x	x	x
Quarterly	104	01/10/2027	01/01/2028			x	x			x	x	x	x	x	x
Quarterly	105	01/01/2028	01/04/2028			x	x			x	x	x	x	x	x
Quarterly	106	01/04/2028	01/07/2028			x	x			x	x	x	x	x	x
Quarterly	107	01/07/2028	01/10/2028			x	x			x	x	x	x	x	x
Quarterly	108	01/10/2028	31/12/2028			x	x			x	x	x	x	x	x
Quarterly	109	31/12/2028	01/04/2029			x	x			x	x	x	x	x	x
Quarterly	110	01/04/2029	02/07/2029			x	x			x	x	x	x	x	x
Quarterly	111	02/07/2029	01/10/2029			x	x			x	x	x	x	x	x
Quarterly	112	01/10/2029	31/12/2029			x	x			x	x	x	x	x	x
Quarterly	113	31/12/2029	02/04/2030			x	x			x	x	x	x	x	x
Quarterly	114	02/04/2030	02/07/2030			x	x			x	x	x	x	x	x
Quarterly	115	02/07/2030	01/10/2030			x	x			x	x	x	x	x	x
Quarterly	116	01/10/2030	01/01/2031			x	x			x	x	x	x	x	x
Quarterly	117	01/01/2031	02/04/2031			x	x	x	x	x	x			x	x
Quarterly	118	02/04/2031	02/07/2031			x	x	x	x	x	x			x	x
Quarterly	119	02/07/2031	01/10/2031			x	x	x	x	x	x			x	x
Quarterly	120	01/10/2031	01/01/2032			x	x	x	x	x	x			x	x

Interval	Stress Period	Date (from)	Date (to)	Wambo Whybrow (UG)		Wambo Woodland (UG)		Wambo Arrowfield (UG)		Wambo (OC)		HVO (OC)		MTW(OC)	
				Mod	App	Mod	App	Mod	App	Mod	App	Mod	App	Mod	App
Quarterly	121	01/01/2032	01/04/2032			x	x	x	x	x	x			x	x
Quarterly	122	01/04/2032	01/07/2032			x	x	x	x	x	x			x	x
Quarterly	123	01/07/2032	01/10/2032			x	x	x	x	x	x			x	x
Quarterly	124	01/10/2032	31/12/2032			x	x	x	x	x	x			x	x
Quarterly	125	31/12/2032	01/04/2033			x	x	x	x	x	x			x	x
Quarterly	126	01/04/2033	02/07/2033			x	x	x	x	x	x			x	x
Quarterly	127	02/07/2033	01/10/2033			x	x	x	x	x	x			x	x
Quarterly	128	01/10/2033	31/12/2033			x	x	x	x	x	x			x	x
Quarterly	129	31/12/2033	02/04/2034			x	x	x	x	x	x			x	x
Quarterly	130	02/04/2034	02/07/2034			x	x	x	x	x	x			x	x
Quarterly	131	02/07/2034	01/10/2034			x	x	x	x	x	x			x	x
Quarterly	132	01/10/2034	01/01/2035			x	x	x	x	x	x			x	x
Quarterly	133	01/01/2035	02/04/2035			x	x	x	x	x	x			x	x
Quarterly	134	02/04/2035	02/07/2035			x	x	x	x	x	x			x	x
Quarterly	135	02/07/2035	01/10/2035			x	x	x	x	x	x			x	x
Quarterly	136	01/10/2035	01/01/2036			x	x	x	x	x	x				
Quarterly	137	01/01/2036	01/04/2036			x		x	x	x	x				
Quarterly	138	01/04/2036	01/07/2036			x		x	x	x	x				
Quarterly	139	01/07/2036	01/10/2036			x		x	x	x	x				
Quarterly	140	01/10/2036	31/12/2036			x		x	x	x	x				
Quarterly	141	31/12/2036	01/04/2037			x		x	x	x	x				
Quarterly	142	01/04/2037	02/07/2037			x		x	x	x	x				
Quarterly	143	02/07/2037	01/10/2037			x		x	x	x	x				

Interval	Stress Period	Date (from)	Date (to)	Wambo Whybrow (UG)		Wambo Woodland (UG)		Wambo Arrowfield (UG)		Wambo (OC)		HVO (OC)		MTW(OC)	
				Mod	App	Mod	App	Mod	App	Mod	App	Mod	App	Mod	App
Quarterly	144	01/10/2037	31/12/2037			x		x	x	x	x				
Quarterly	145	31/12/2037	02/04/2038			x		x	x	x	x				
Quarterly	146	02/04/2038	02/07/2038			x		x	x	x	x				
Quarterly	147	02/07/2038	01/10/2038			x		x	x	x	x				
Quarterly	148	01/10/2038	01/01/2039			x		x	x	x	x				
Quarterly	149	01/01/2039	02/04/2039					x	x	x	x				
Quarterly	150	02/04/2039	02/07/2039					x	x	x	x				
Quarterly	151	02/07/2039	01/10/2039					x	x	x	x				
Quarterly	152	01/10/2039	01/01/2040					x	x	x	x				
Quarterly	153	01/01/2040	01/04/2040					x	x	x	x				
Quarterly	154	01/04/2040	01/07/2040					x	x	x	x				
Quarterly	155	01/07/2040	01/10/2040					x	x	x	x				
Quarterly	156	01/10/2040	01/01/2041					x	x	x	x				
Quarterly	157	01/01/2041	01/04/2041					x	x	x	x				
Quarterly	158	02/04/2041	30/06/2041					x	x	x	x				
Quarterly	159	01/07/2041	30/09/2041					x	x	x	x				
Quarterly	160	01/10/2041	31/12/2041					x	x	x	x				

4.1.1 Environmental assumptions

Table 4-2 provides an overview of how environmental inputs were simulated during the quarterly stress periods of the predictive modelling.

Table 4-2 Summary of environmental assumptions during predictive modelling

Environmental Process	Reach/ Zone	Predictive assumption	Recovery assumptions
Stream stage	Hunter River	Seasonality simulated using long-term average stage height per quarter.	No seasonality - Long-term annual average stage height.
	Wollombi Brook	Seasonality simulated using long-term average stage height per quarter.	No seasonality - Long-term annual average stage height.
	Ephemeral watercourses	Timing of recharge episodes not predictable. No stage height simulated for ephemeral steams in the predictive modelling (e.g. Wambo Creek, North Wambo Creek, Stony Creek)	No stage height simulated for ephemeral steams in the recovery modelling.
Rainfall Recharge	Recharge zones as per calibration including a time variant zone for spoil/ backfill	No seasonality. Long-term annual average rate applied after modification with calibrated multipliers.	No seasonality. Long-term annual average rate applied after modification with calibrated multipliers.
Evapotranspiration	Evapotranspiration zones as per calibration including a time variant zone for spoil and final voids	Seasonality simulated using long-term average rate per quarter.	No seasonality. Long-term annual average rate applied.

4.2 Water balance

Table 4-3 details average flow rates for water transfer into and out of the predictive model period (March 2020 until December 2041) for the three predictive scenarios. The mass balance error for all three scenarios was 0.0% indicating that the model was stable and achieved an accurate numerical solution.

The tables show that simulated recharge increased from 13.2 ML/d in the no mine scenario to 14.1 ML/day in the modification and approved scenarios compared to the null run. The increase in recharge is due to the presence of open cut mining at Wambo complex and the consequent enhanced recharge through the spoil to the groundwater system in the modification and approved scenarios.

Table 4-3 shows a net volume of 0.68 ML/day entering the model through the regional groundwater flow (GHB) in all the scenarios, independent of regional mining activity. Like regional groundwater flow (GHB), evapotranspiration for all three scenarios appears to be similar and around 0.45 ML/day.

With regards to the rivers, the results indicate that in all the scenarios the net river flux is positive, which indicates that overall, the rivers are gaining water from the groundwater system. However, it appears that there is a slight reduction in net river (RIV) flux for modification and approved scenarios when compared to the no Wambo underground and null scenarios. This is likely due to the influence from mining activities, resulting in lower groundwater levels and a reduction of groundwater contribution to river baseflow. It is expected that the reduction of groundwater contribution to baseflow would be less for the no Wambo underground scenario compared to the Approved and Modification scenarios.

Table 4-3 Average simulated water balance over the prediction period

Component	Modification		Approved		No Wambo UG		Null	
	Inflow (ML/d)	Outflow (ML/d)	Inflow (ML/d)	Outflow (ML/d)	Inflow (ML/d)	Outflow (ML/d)	Inflow (ML/d)	Outflow (ML/d)
Recharge RCH)	14.07	0.00	14.07	-	14.07	0.00	13.21	-
Evapotranspiration (ET)	0.00	0.45	-	0.45	0.00	0.45	-	0.46
SW/GW Interaction (RIV)	2.16	9.22	2.16	9.21	2.09	9.92	2.08	10.31
Regional GW flow (GHB)	0.72	0.04	0.72	0.04	0.72	0.04	0.72	0.04
Drains (Mine inflows)	0.00	6.87	-	6.78	0.00	5.89	-	3.81
Wells (WELL)	0.00	0.48	-	0.48	0.00	0.48	-	0.50
Storage	7.59	7.46	7.50	7.49	6.73	6.82	4.92	5.81
Total	24.53	24.53	24.45	24.45	23.60	23.60	20.93	20.93
Error (%)	0.0		0.0		0.0		0.0	

4.3 Predicted groundwater levels

Predicted groundwater levels at the end of Wambo area mining (2041) for the Modified and Approved scenarios are presented in **Figure 4-1** to **Figure 4-5**.

The gaps in the water level grids represent unsaturated areas (i.e. where the simulated water level elevation is below the base of cell).

Figure 4-1 shows the water table at the end of 2041 for Modified and Approved scenarios, with very little difference observable between the scenarios. Lower heads are observed above the Modification longwalls compared with the Approved scenario, consistent with conceptualised impacts.

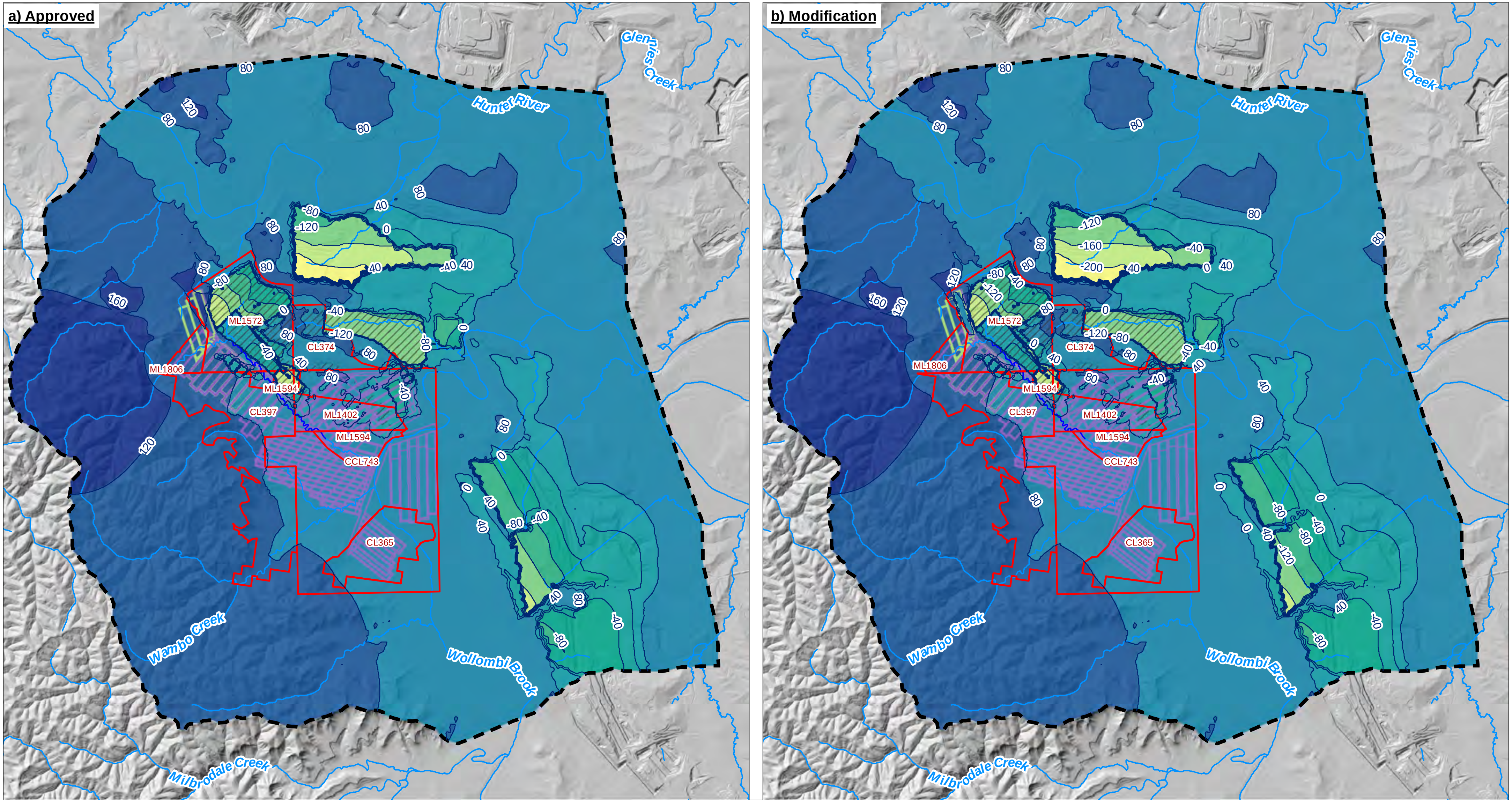
Figure 4-2 shows the predicted groundwater levels within alluvium and regolith (layer 1) at the end of mining. There is no observable difference in this unit due to the Modification.

The groundwater levels in the target or deepest seams of Wambo and UWOCP operations are also shown.

The predicted end of mining groundwater levels for the Whybrow Seam (**Figure 4-3**) show differences are controlled by the changed layout of SBX longwalls.

The predicted end of mining groundwater levels for the Arrowfield Seam (**Figure 4-4**) are very similar between Modification and Approved scenarios, with both simulating the same extent of longwall mining.

The predicted end of mining groundwater levels for the Vaux Seam (**Figure 4-5**) show very little difference. There is no change to the timing or extent of open cut mining targeting this seam between Modification and Approved scenarios.



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:175,000 at A4
Project Number:	665.0008.00815
Date:	17-May-2022
Drawn by:	NT

0 2.5 5 km

Wambo Model Boundary

NWC Diversion

Named Watercourse

Mining Lease

Proposed LW24-26 Layout

Existing/Approved Underground Development

Approved Open Cut Mining

Water Table (mAHD)

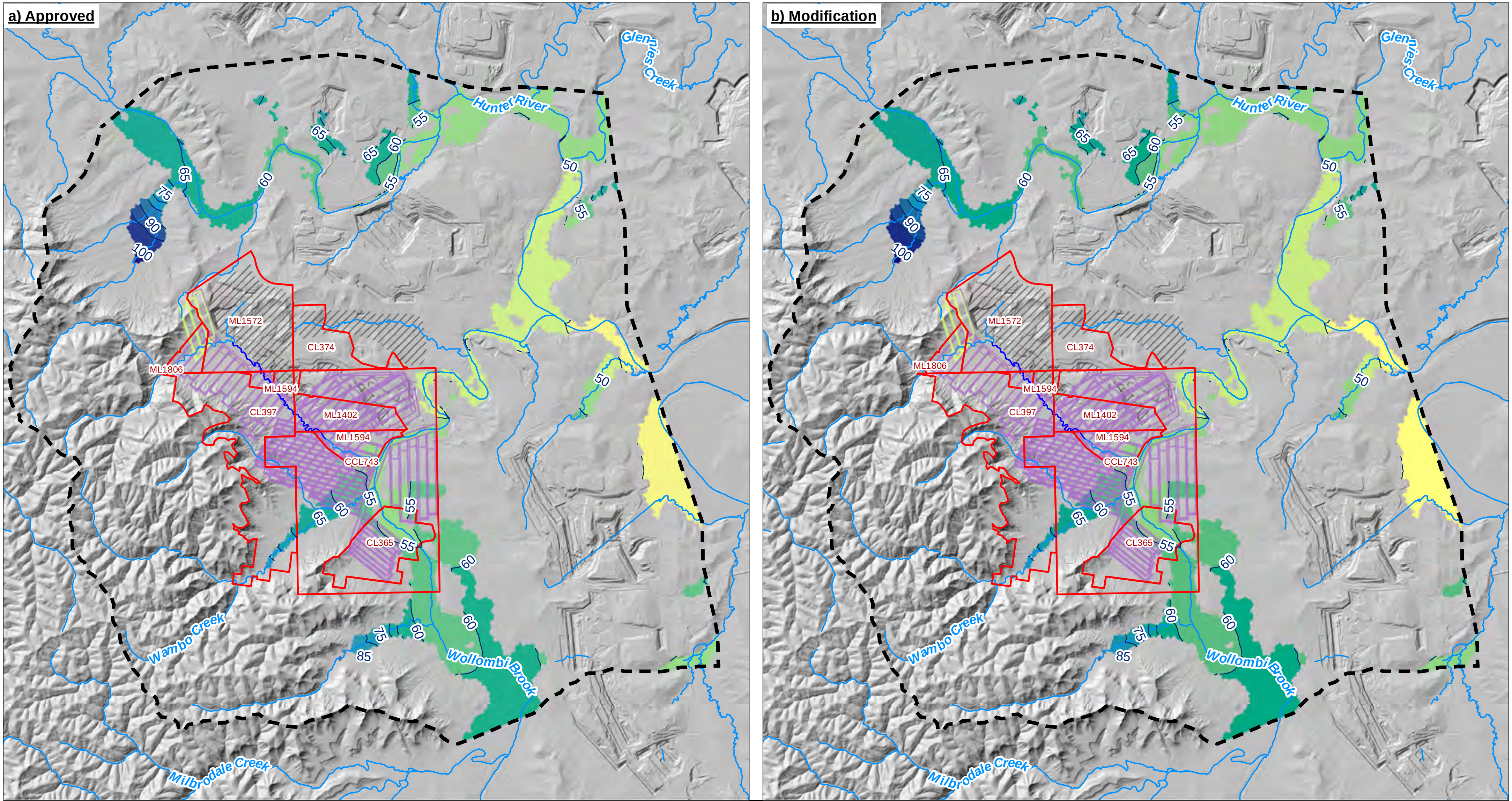
- -240 - -200
- -200 - -160
- -160 - -120
- -120 - -80
- -80 - -40
- -40 - 0
- 0 - 40
- 40 - 80
- 80 - 120
- 120 - 160
- 160 - 200

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Predicted water table at the end of 2041

FIGURE 4-1

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_3_Pred_WT_End2041revA.mxd



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:175,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	NT

Wambo Model Boundary
NWC Diversion
Named Watercourse
Mining Lease
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

Groundwater Level (mAHD)

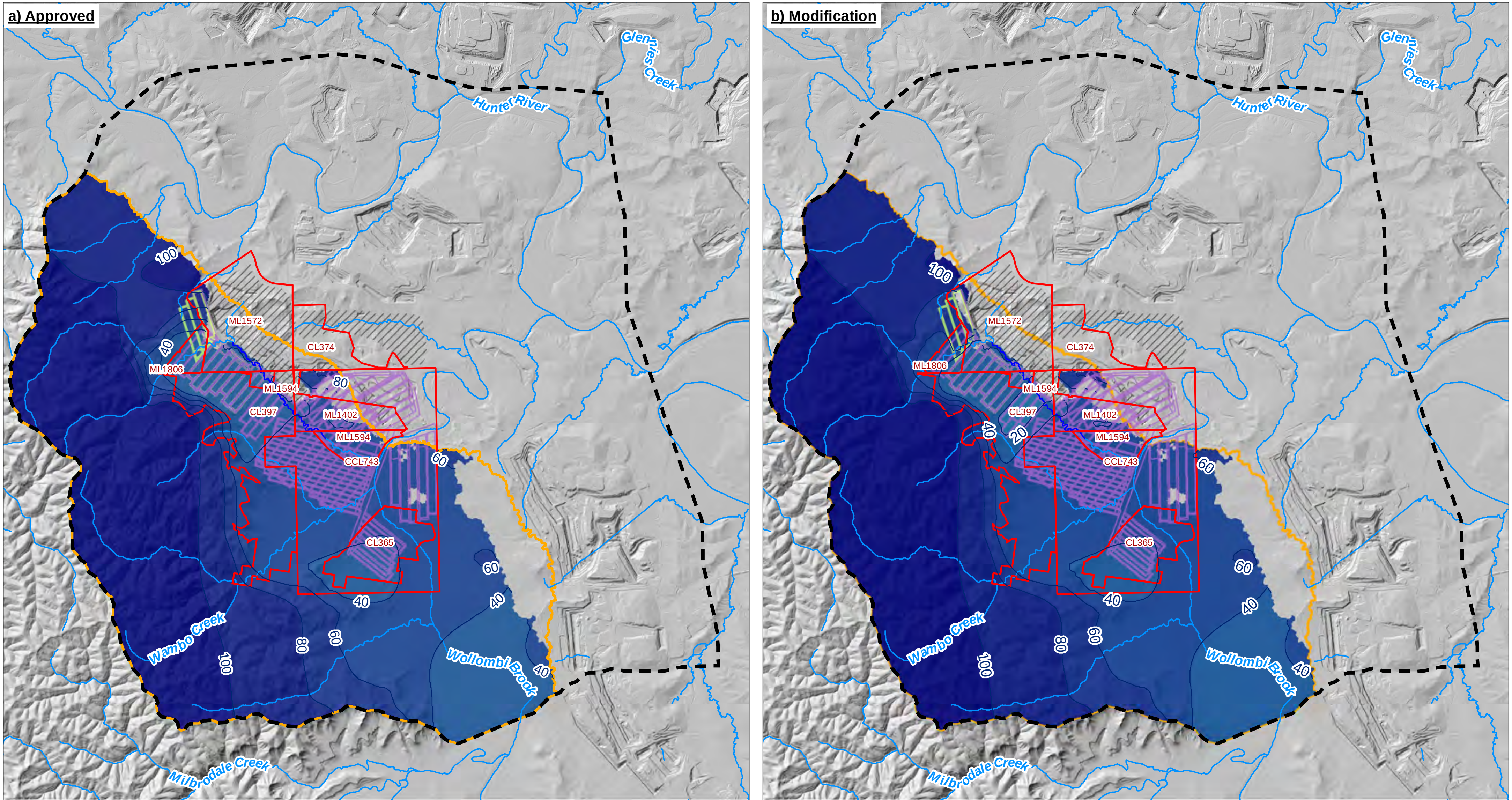
40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
65 - 70
70 - 75
75 - 80
80 - 85
85 - 90
90 - 95
95 - 100
100 - 105

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Predicted groundwater level in alluvium and regolith (layer 1) at the end of 2041

FIGURE 4-2

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_4_Pred_GWL_Layer_1_End2041_RevA.mxd



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:175,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	NT

SLR

- Wambo Model Boundary
- NWC Diversion
- Named Watercourse
- Mining Lease
- Whybrow Seam Extent (Layer 7)
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

Groundwater Level (mAHD)

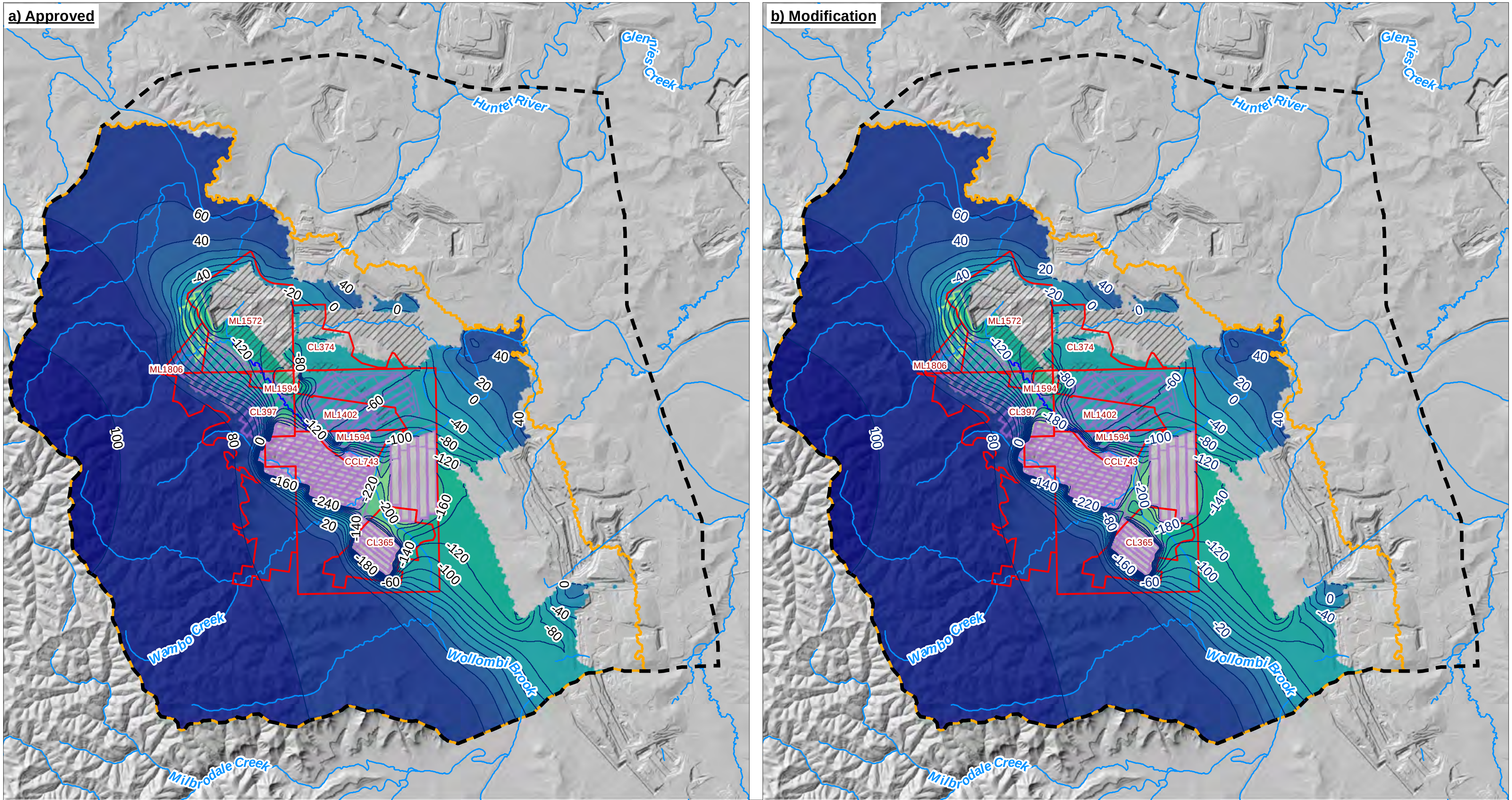
- 300 - -280
- -280 - -260
- -260 - -240
- -240 - -220
- -220 - -200
- -200 - -180
- -180 - -160
- -160- -140
- -140 - -120
- -120 - -100
- -100 - -80
- -80 - -60
- -60 - -40
- -40 - -20
- -20 - 0
- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Predicted groundwater level in Whybrow Seam (layer 7) at the end of 2041

FIGURE 4-3

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_5_Pred_GWL_Layer_7_End2041_RevA.mxd



Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:175,000 at A4
Project Number: 665.0008.00815
Date: 24-May-2022
Drawn by: NT

Wambo Model Boundary
NWC Diversion
Named Watercourse
Mining Lease
Arrowfield Seam Extent (Layer 17)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

Groundwater Level (mAHD)

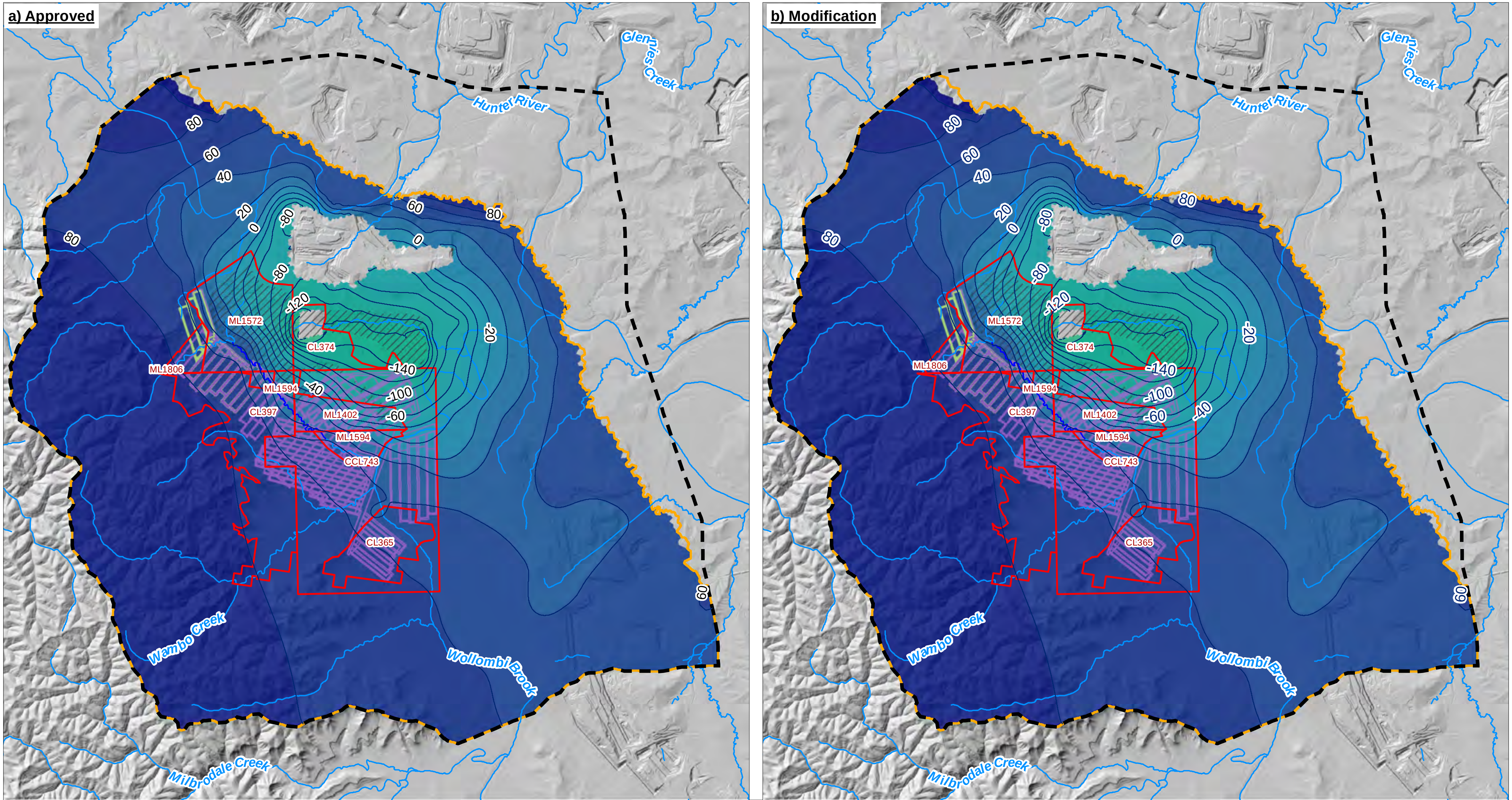
300 - -280	-160- -140	-20 - 0
-280 - -260	-140 - -120	0 - 20
-260 - -240	-120 - -100	20 - 40
-240 - -220	-100 - -80	40 - 60
-220 - -200	-80 - -60	60 - 80
-200 - -180	-60 - -40	80 - 100
-180 - -160	-40 - -20	100 - 120

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Predicted groundwater level in Arrowfield Seam (layer 17) at the end of 2041

FIGURE 4-4

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_6_Pred_GWL_Layer_17_End2041_RevA.mxd



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:175,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	NT

- Wambo Model Boundary
- NWC Diversion
- Named Watercourse
- Mining Lease
- Vaux Seam Extent (Layer 27)
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

Groundwater Level (mAHD)

300 - -280	-160- -140	-20 - 0
-280 - -260	-140 - -120	0 - 20
-260 - -240	-120 - -100	20 - 40
-240 - -220	-100 - -80	40 - 60
-220 - -200	-80 - -60	60 - 80
-200 - -180	-60 - -40	80 - 100
-180 - -160	-40 - -20	100 - 120

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Predicted groundwater level in Vaux Seam (layer 27) at the end of 2041

FIGURE 4-5

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_7_Pred_GWL_Layer_27_End2041_RevA.mxd

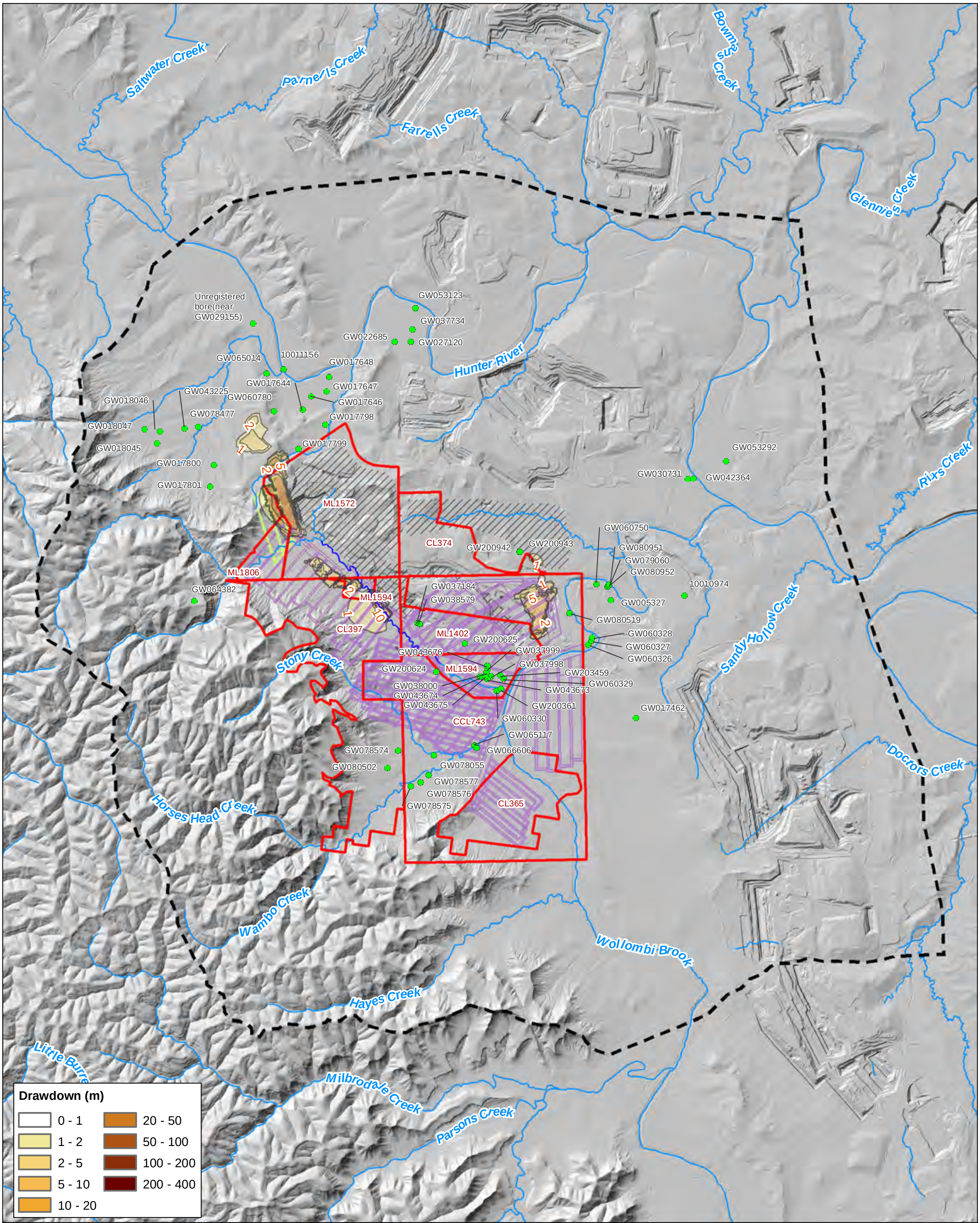
4.4 Maximum predicted drawdowns

The process of mining reduces water levels in surrounding groundwater units. The extent of the zone affected is dependent on the hydraulic properties of the geological units in the adjacent groundwater system. This is referred to as the zone of depressurisation in a confined aquifer and zone of drawdown within the water table. Depressurisation/drawdown is greatest close to active mining operations and dewatering, and gradually reduces with distance from the mine. The predicted incremental drawdown due to the proposed Modification and cumulative drawdown due to the Wambo Underground and United-Wambo mining operations since 2003 are discussed in the following sections.

4.4.1 Incremental drawdowns

The incremental drawdown refers to the drawdown impact associated with the modification of the SBX layout, which has been simulated in the Modification scenario and is obtained by comparing the difference in predicted aquifer groundwater levels for the Approved model scenario and the Modification model scenario at matching times. The maximum drawdown represents the maximum drawdown values recorded at each model cell at any time over the model duration. **Figure 4-6** to **Figure 4-10**[1] show the predicated maximum drawdown in the water table, alluvium, and regolith (layer 1), Whybrow (layer 7), Arrowfield (layer 17), and Vaux (layer 27) seams respectively. **Figure 4-6** shows that the modification creates some drawdown at the water table particularly overlying and to the north of the proposed SBX LW24-26 layout. **Figure 4-7** shows there is no incremental drawdown predicted for the alluvium or regolith due to the modification. **Figure 4-8** and **Figure 4-9** show that the maximum incremental drawdown within the target seams of Wambo underground mining occur where there is a difference in layout (Whybrow Seam – SBX) or timing of extraction (Arrowfield Seam – South Wambo Project). With regards to the deeper Vaux Seam (Layer 27), there is no difference in layout or timing of UWOCP mining and there is no significant drawdown (**Figure 4-10)**.

[1] Larger scale inset maps of incremental drawdown in key hydrogeological units are presented in the main Groundwater Assessment report.



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	17-May-2022
Drawn by:	ANP

- Wambo GWMP (2020)
- Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

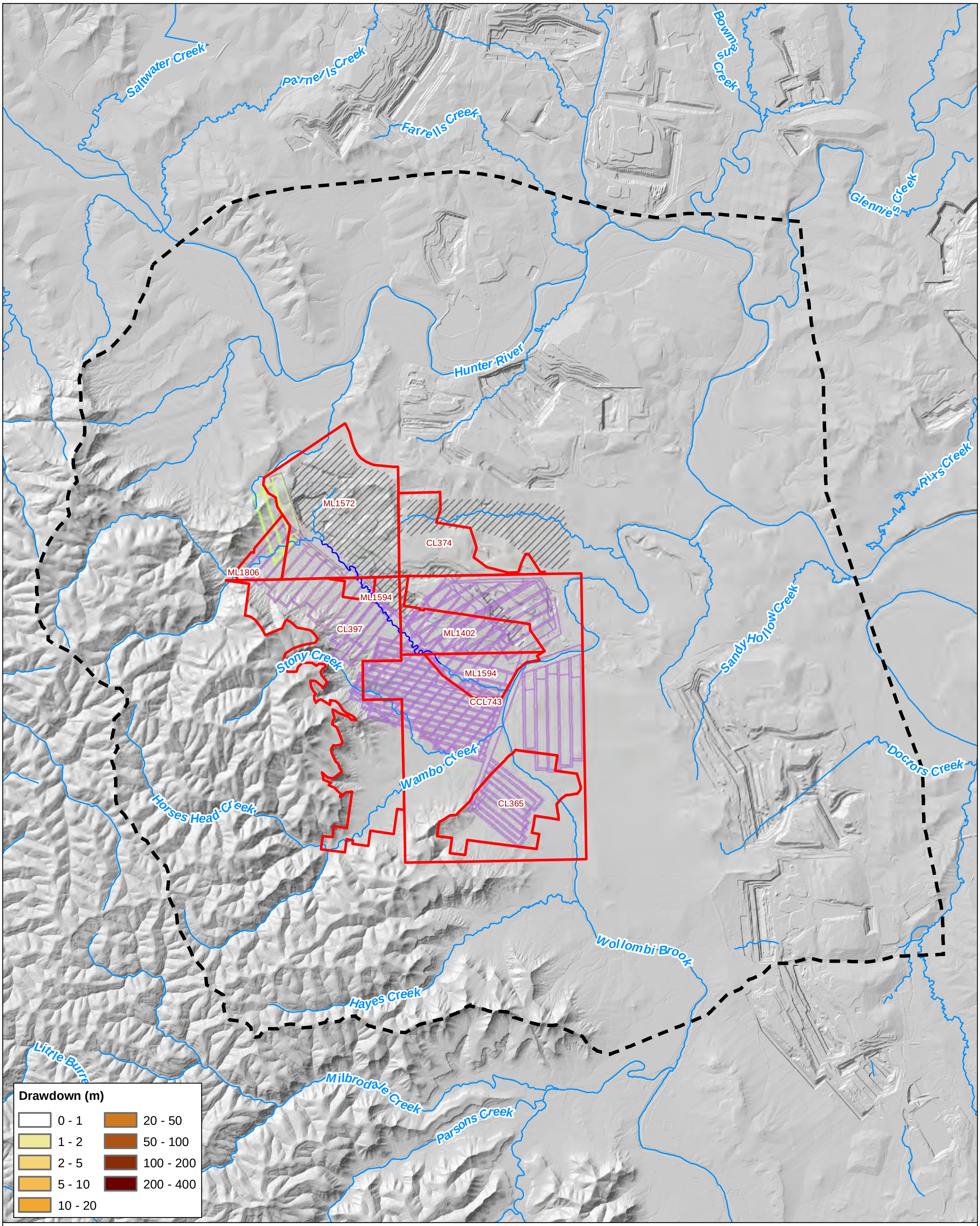
SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Maximum incremental drawdown at the water table

Data Source: NSW SS 2020

FIGURE 4-6

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_8_Max_Incremental_DD_at_WT.mxd



N

0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	17-May-2022
Drawn by:	ANP

SLR

Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

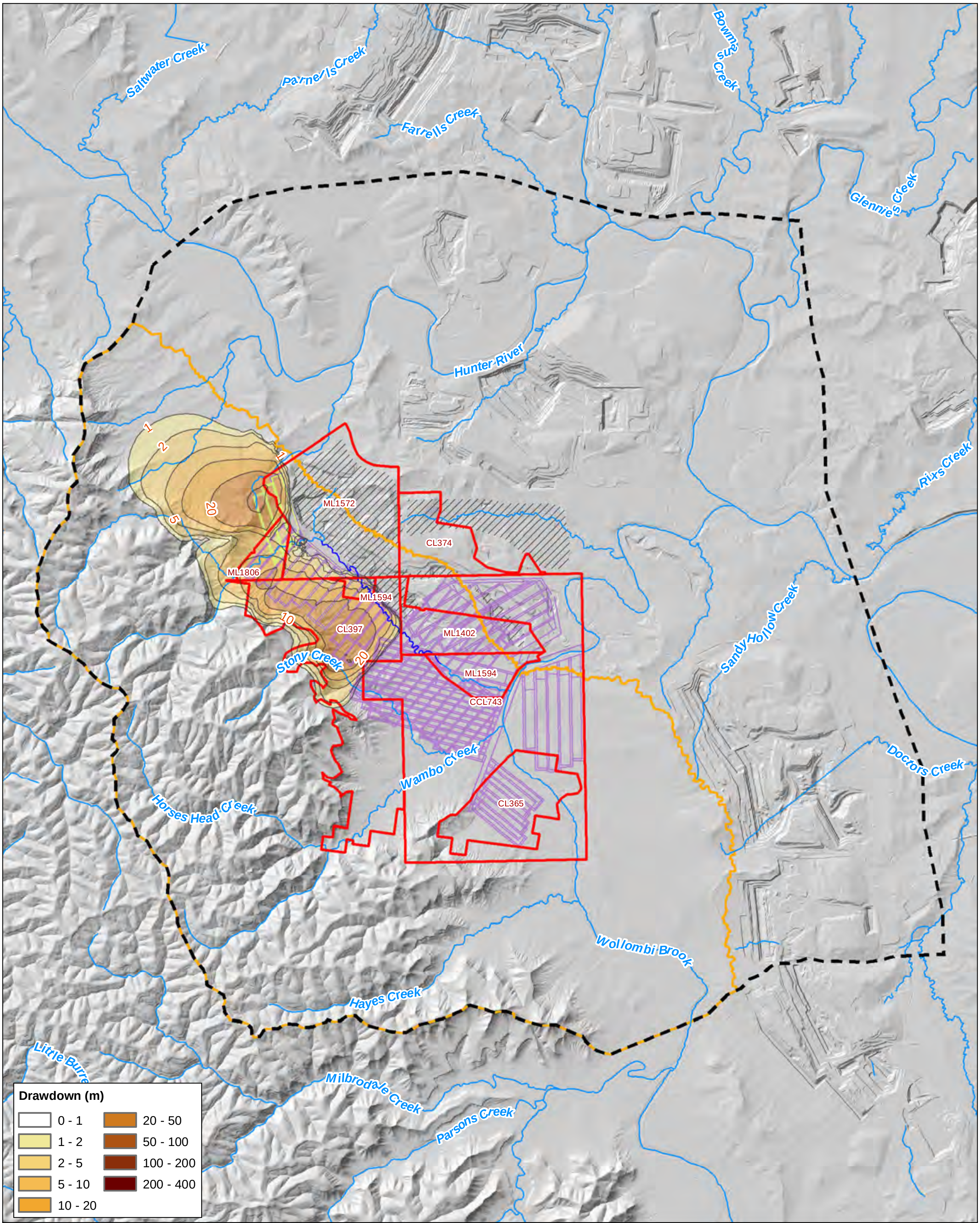
Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Maximum incremental drawdown in alluvium and regolith (layer 1)

FIGURE 4-7

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_9_Max_IncrementalDD_Layer_1_End2041.mxd



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Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	ANP

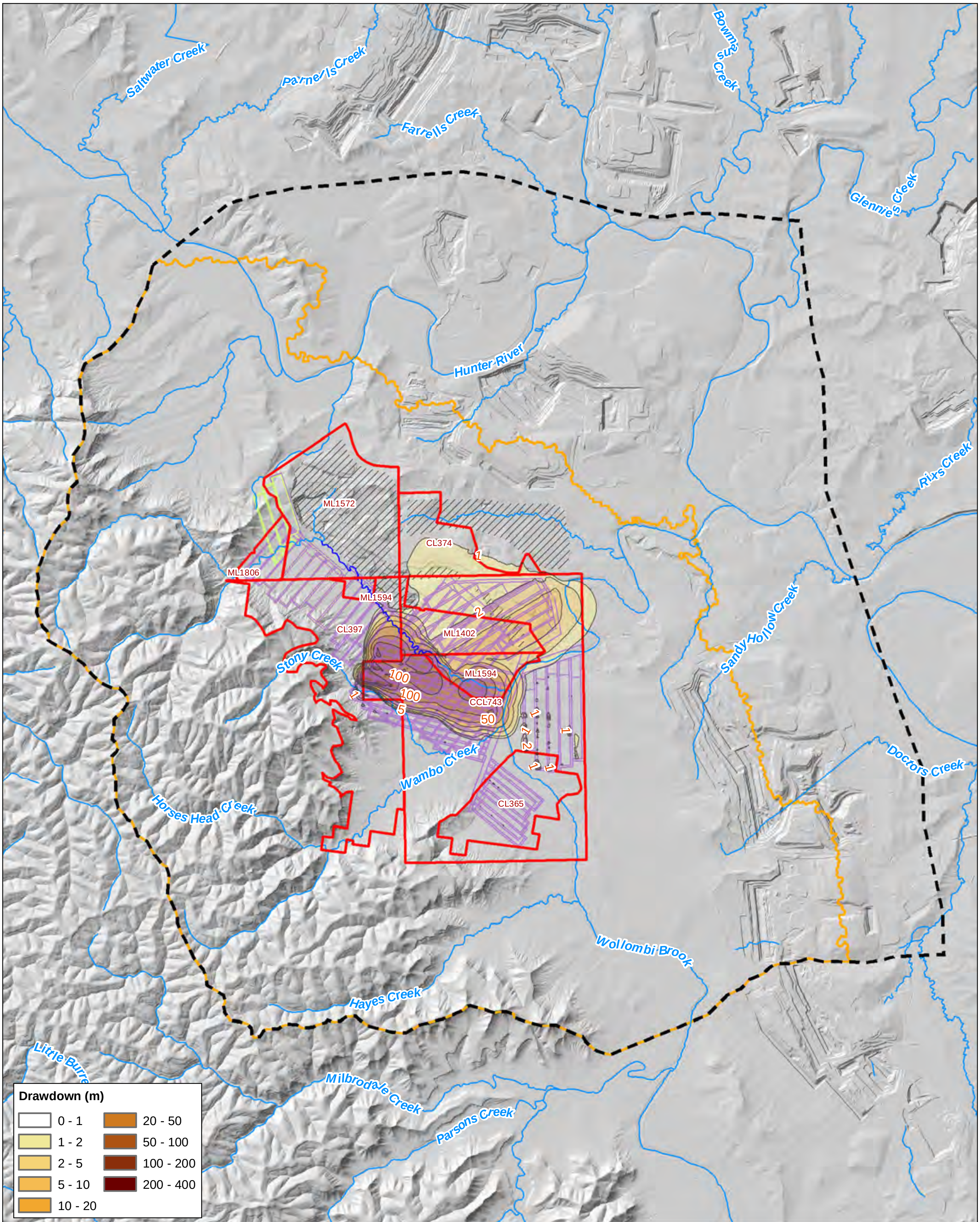
Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Whybrow Seam Extent (Layer 7)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Maximum incremental drawdown in Whybrow Seam (layer 7)

Data Source: NSW SS 2020

FIGURE 4-8



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0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	ANP

Wambo Model Boundary

Named Watercourse

NWC Diversion

Mining Lease

Arrowfield Seam Extent (Layer 17)

Proposed LW24-26 Layout

Existing/Approved Underground Development

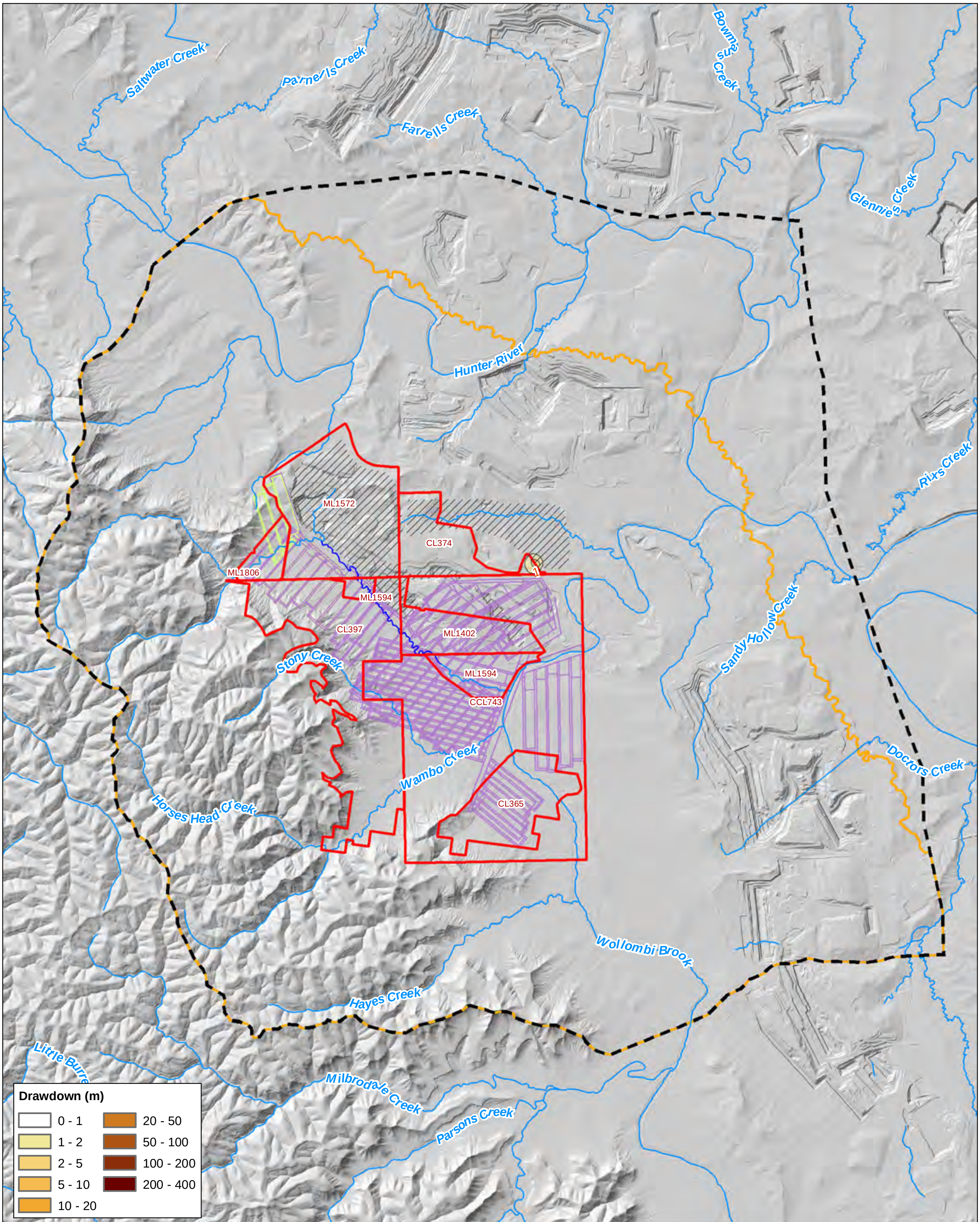
Approved Open Cut Mining

Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Maximum incemental drawdown in Arrowfield Seam (layer 17)

FIGURE 4-9



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	ANP

Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Vaux Seam Extent (Layer 27)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

SLR

Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Maximum incremental drawdown in Vaux Seam (layer 27)

FIGURE 4-10

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_12_Max_IncrementalDD_Layer_27_End2041.mxd

4.4.2 Cumulative drawdown

The maximum drawdowns are obtained by calculating the maximum difference in heads between the Modified and null scenarios at each cell at any time, from start of the transient calibration model (2003) to the end of the mining at the Wambo complex (December 2041). **Figure 4-11** to **Figure 4-15**[2] show the predicted maximum cumulative drawdown due to the Wambo complex since 2003 for the water table, alluvium, and regolith (layer 1) and the major target seams (i.e. Whybrow (layer 7), Arrowfield (layer 17) and Vaux (layer 27) seams). **Figure 4-11** indicates that water table drawdown is predicted to be focussed within areas of historical, approved and proposed open cut and underground mining at the Wambo Complex.

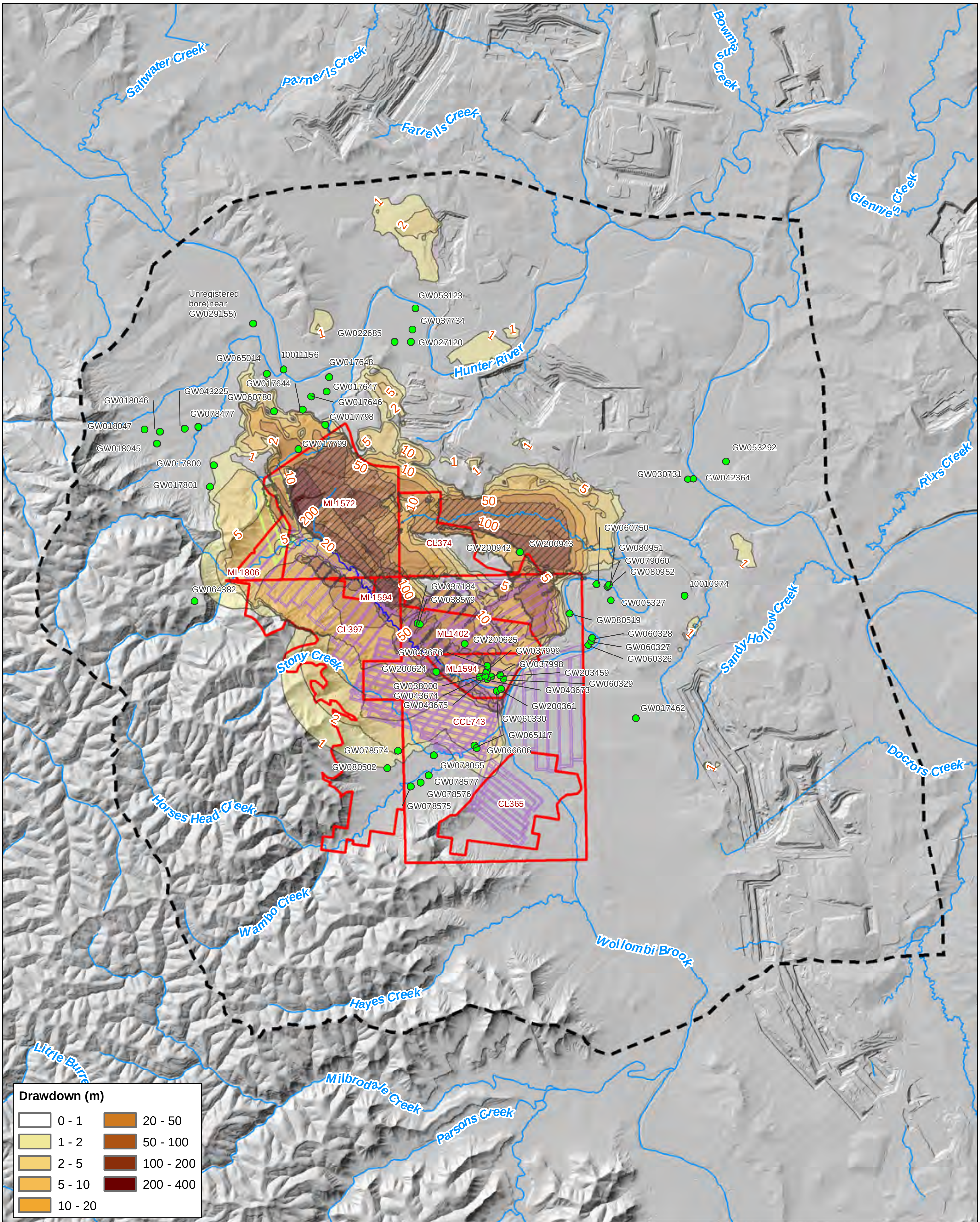
Figure 4-12 shows that maximum cumulative drawdown within mapped Quaternary alluvium and regolith extends along Wollombi Brook, and ephemeral creeks near Wambo Complex mining.

Figure 4-13 shows the predicted extent of maximum cumulative drawdown in the Whybrow Seam. It shows that the drawdowns are limited to the east due to the structural geology (i.e. coal seam subcrop/ outcrop) and extends up to 6 km to the southeast and northwest of the Wambo complex.

Similar patterns in maximum cumulative drawdown are predicted in the Arrowfield Seam, the deepest target seam of the South Wambo Project as shown in **Figure 4-14**. Drawdown within this seam is largest at the mine footprint, extends 4 km northwest and 2.5 km southeast of Wambo Complex mining.

Figure 4-15 shows maximum cumulative drawdown in the Vaux Seam, the deepest target seam of the UWOCP. Predicted drawdown is generally centred around Wambo open cut workings and extends up to 2.3 km northwest and 4.4 km southeast of Wambo Complex mining.

[2] Larger scale inset maps of incremental drawdown in key hydrogeological units are presented in the main Groundwater Assessment report.



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	17-May-2022
Drawn by:	ANP

SLR

- Wambo GWMP (2020)
- Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

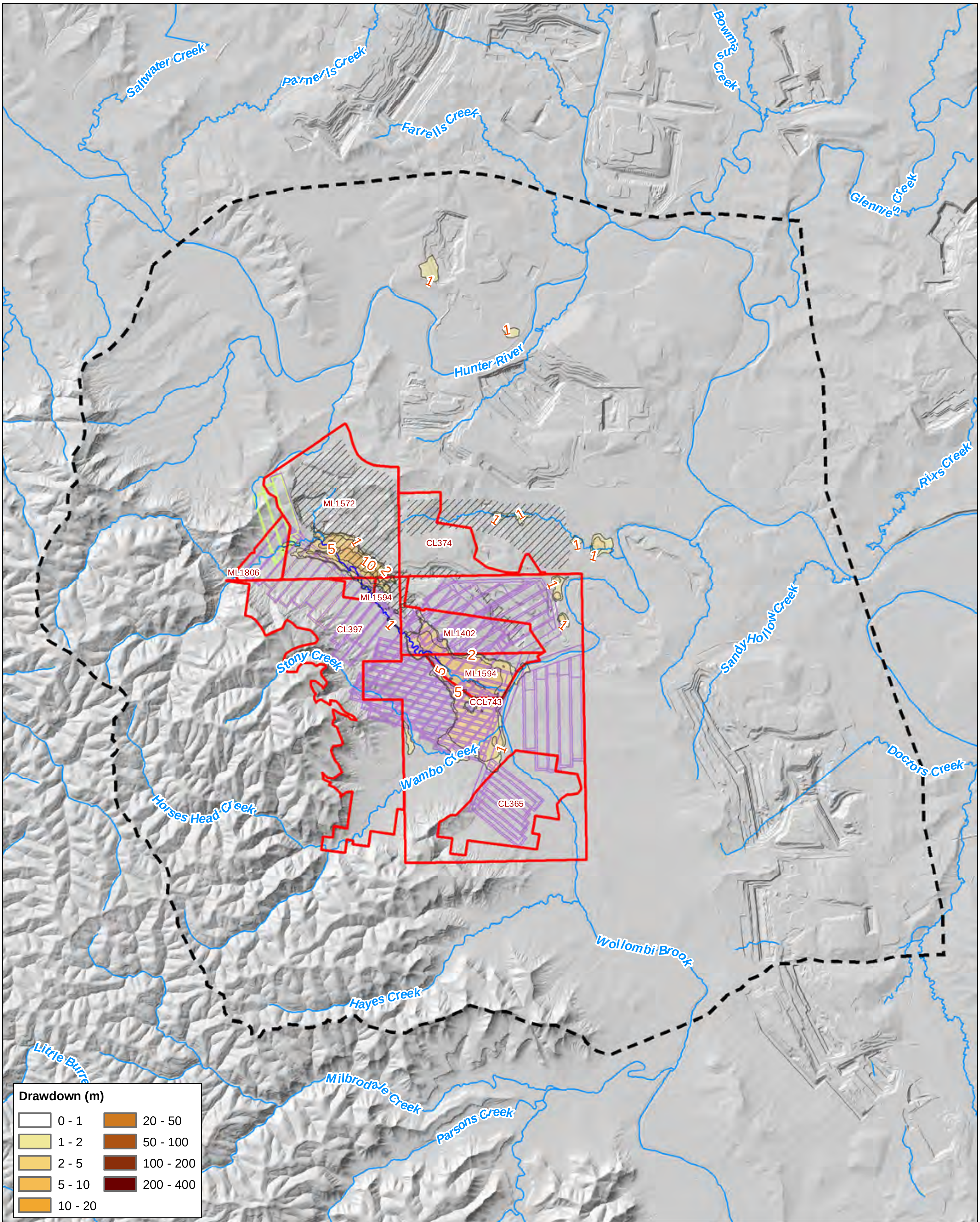
Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Maximum cumulative drawdown at the water table

FIGURE 4-11

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_13_Max_Cumulative_DD_at_WT.mxd



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	17-May-2022
Drawn by:	ANP

Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

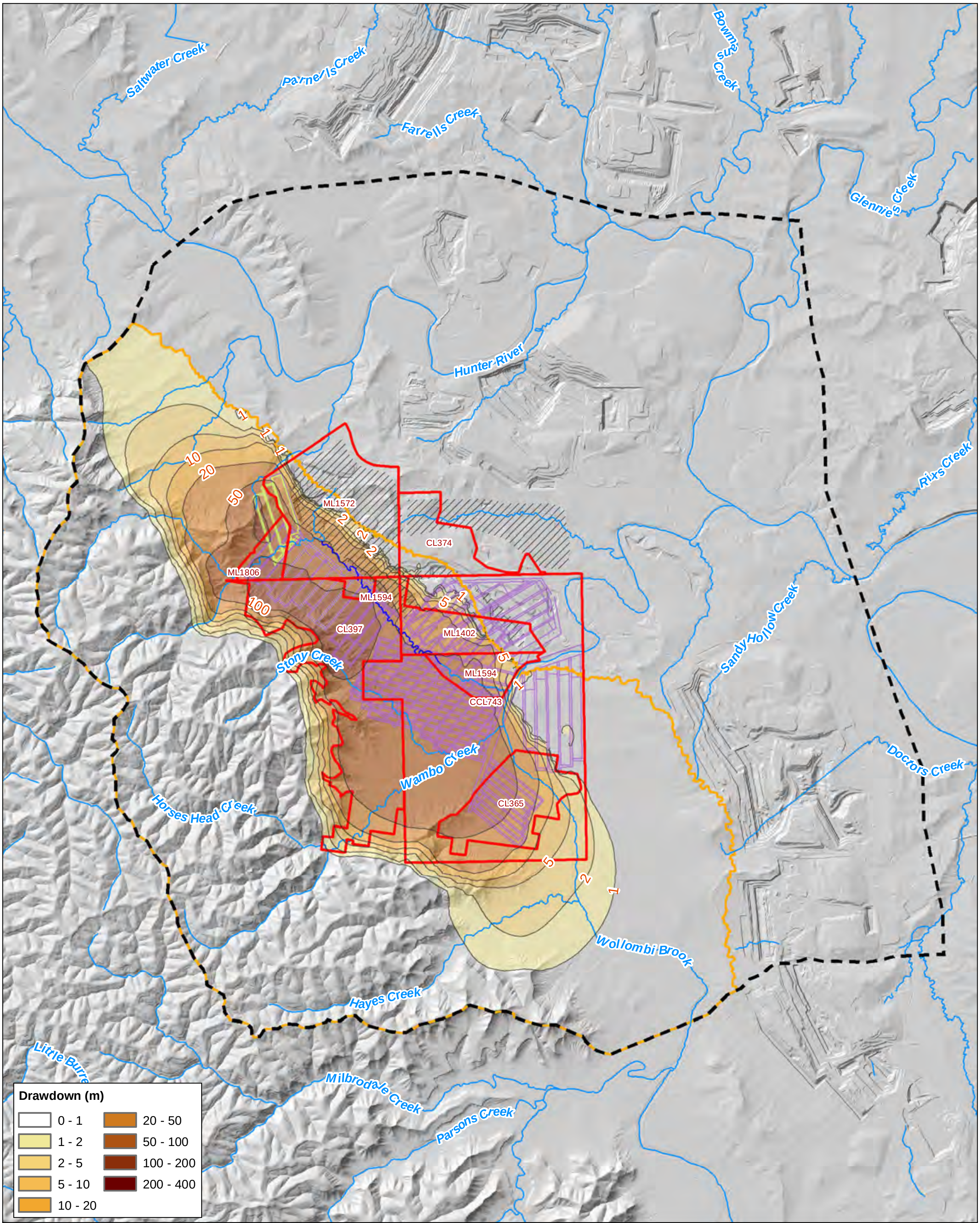
SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Maximum cumulative drawdown in alluvium and regolith (layer 1)

Data Source: NSW SS 2020

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_14_Max_CumulativeDD_Layer_1_End2041.mxd

FIGURE 4-12



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	17-May-2022
Drawn by:	ANP

Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Whybrow Seam Extent (Layer 7)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

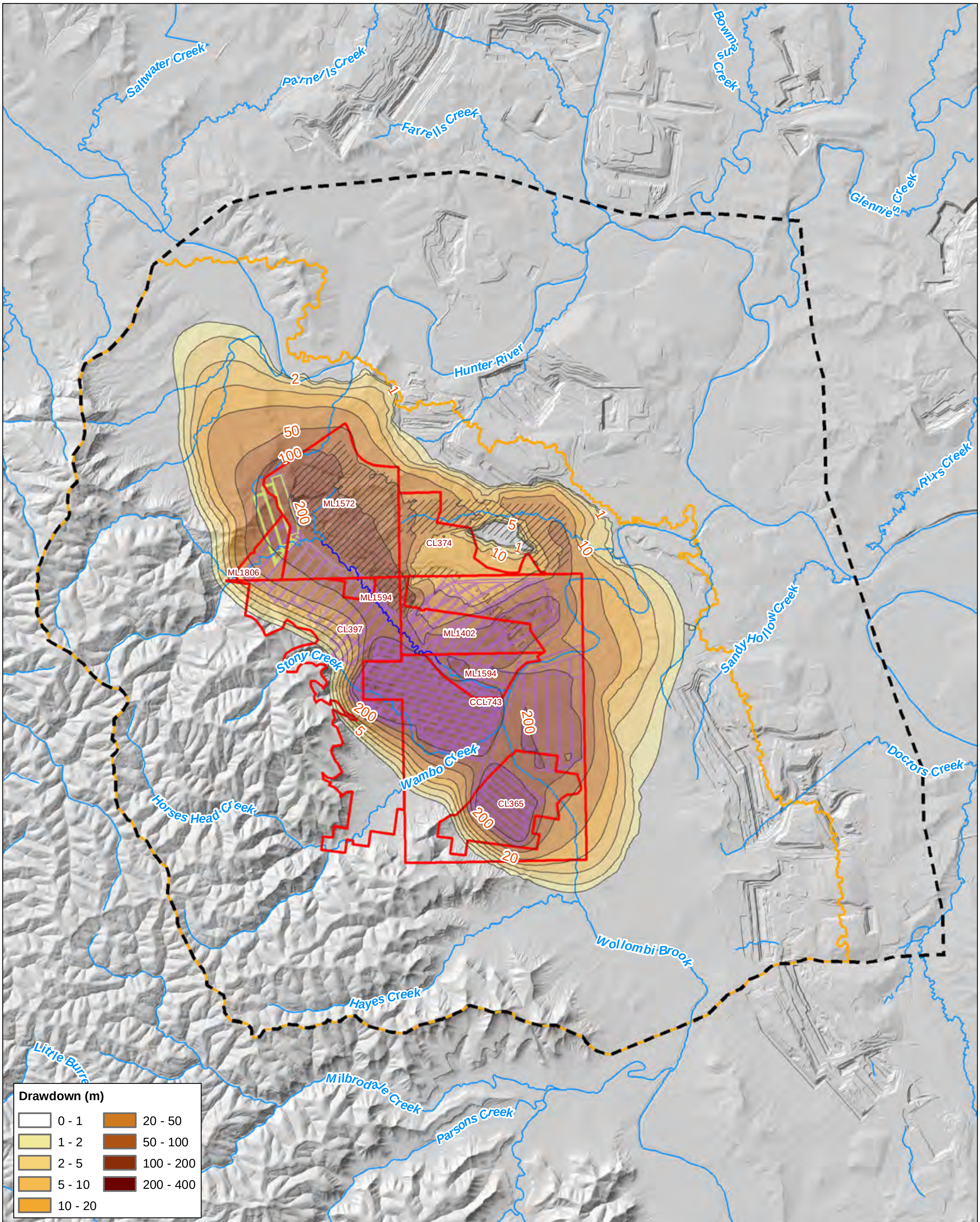
SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Maximum cumulative drawdown in Whybrow Seam (layer 7)

Data Source: NSW SS 2020

FIGURE 4-13

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_15_Max_CumulativeDD_Layer_7_End2041.mxd



0 2 4 km

Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:130,000 at A4
Project Number: 665.0008.00815
Date: 17-May-2022
Drawn by: ANP

Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Arrowfield Seam Extent (Layer 17)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

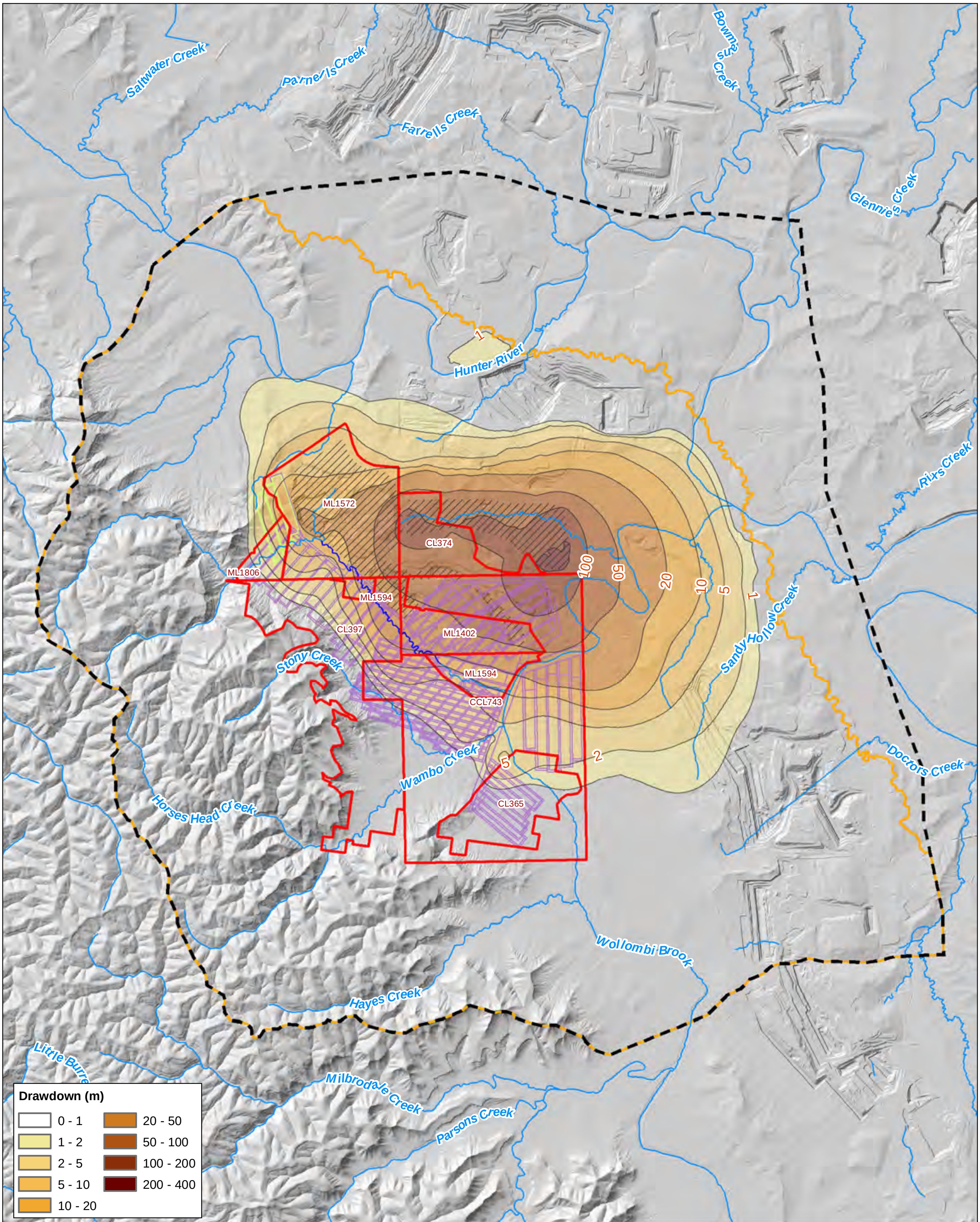
SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Maximum cumulative drawdown in Arrowfield Seam (layer 17)

Data Source: NSW SS 2020

FIGURE 4-14

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_16_Max_CumulativeDD_Layer_17_End2041.mxd



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	17-May-2022
Drawn by:	ANP

Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Vaux Seam Extent (Layer 27)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

SLR

Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Maximum cumulative drawdown in Vaux Seam (layer 27)

FIGURE 4-15

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_4_17_Max_CumulativeDD_Layer_27_End2041.mxd

4.5 Predicted groundwater interception

4.5.1 Wambo underground inflows

Predicted groundwater inflows to the Wambo underground workings have been estimated for the Modified and Approved scenarios. The predicted inflows for the three future areas of Wambo underground mining are presented in **Figure 4-16**. The inflows peaks at 1.3 ML/day in SBX for both Modified and Approved scenarios with the inflows reducing to zero at the faster rate in the Approved scenario than for the Modification scenario. This is expected, as the additional longwall (LW26) in the proposed SBX layout will extend the period of SBX mining. Timing differences for mining are observed between the Modification and Approved scenarios in the Woodlands Hill Seam workings of the South Wambo Project. Inflow to the Woodlands Hill seam is predicted to peak at around 1.5 ML/day. Predicted inflows in the Arrowfield Seam are comparable between Modified and Approved scenarios, and peak at 0.8 ML/day in 2040.

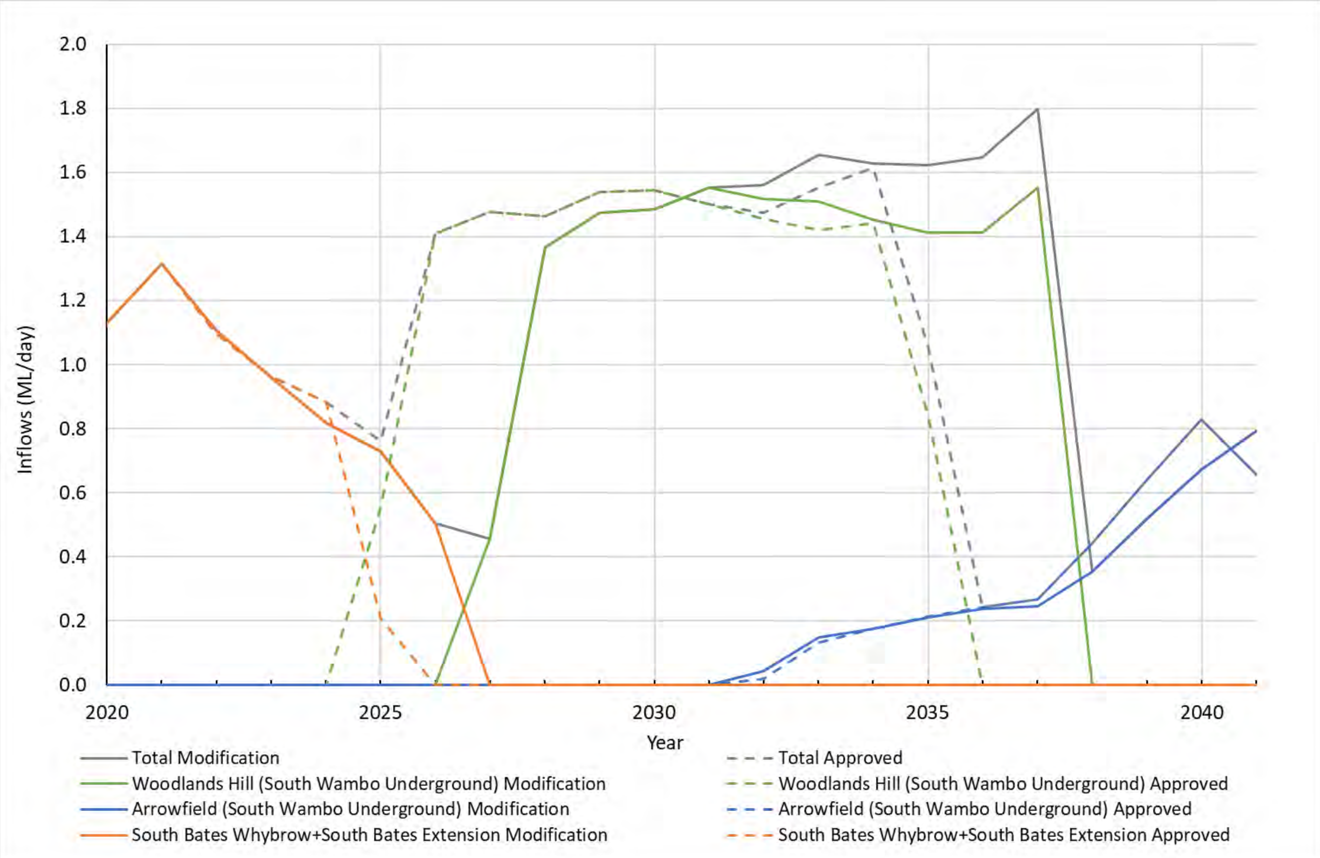


Figure 4-16 Wambo underground inflows (Approved and Modification scenarios)

4.6 Incidental water impacts

4.6.1 Alluvium net flow change

The change in alluvial water resources was estimated by comparing water budgets for alluvial zones using the Modification, Approved and Null scenarios of the predictive model. **Figure 4-17** to **Figure 4-20** show the net alluvial flux in Modification, Approved and Null scenarios for four key alluvial zones near the Wambo Complex (i.e. Wollombi Brook, North Wambo Creek, Wambo Creek and the Hunter River respectively). The dashed lines in **Figure 4-17** to **Figure 4-20** are showing differential net flow changes for incremental and cumulative impacts. The dashed blue line indicates incremental flux change due to the proposed LW24-26 layout (i.e. Modification – Approved scenarios. The yellow dashed line indicates flux change due to approved and proposed mining in the Wambo complex since 2003 (i.e. Modification – Null scenarios). The purple dashed line indicated flux change due to approved mining in the Wambo complex since 2003 only (Approved – Null scenarios).

Wollombi Brook alluvial flux (**Figure 4-17**) indicates that the overall direction of flow is from Permian to Alluvium between 2021 and 2026, which changes gradually from Alluvium to Permian leakage during 2027 to 2041. It is noted that the Null run includes regional mining near to Wollombi Brook (MTW) which is likely driving the change from upflow to downflow (positive to negative magnitude net flux) after 2030.

Figure 4-18 shows that the overall flow is leakage from Alluvium to Permian at North Wambo Creek, including alluvial zones both upstream and downstream of the north Wambo Creek Diversion. The initial spike in alluvial leakage is likely related to the simulated period of above average rainfall and simulated flow in ephemeral creeks that occurred near the end of the calibration period.

Figure 4-19 shows that the flow is upflow from Permian to Alluvium in Wambo Creek for the duration of the predictive model.

Figure 4-20 shows that the flow direction is generally from Permian to Alluvium in Hunter River Alluvium.

With regard to the incremental net flux changes, **Figure 4-17** to **Figure 4-20** show that the net flow changes due to the proposed LW24-26 layout (Modification scenario - i.e. Blue dash line) are a small component of net alluvial flow, generally is close to zero, and become slightly positive from 2026 and 2036 for Wollombi Brook, North Wambo Creek and Wambo Creek alluvium. This indicates that the modification predicts similar or slightly reduced net flow impacts on alluvial groundwater when compared to the approved scenario. Overall, it is predicted that the proposed LW24-26 layout and the mining timing changes made in the modification run will not cause significant change to the alluvium flow net.

With regard to net flux changes due to Wambo Complex mining since 2003 (cumulative impacts), **Figure 4-17** shows that Wollombi Brook net alluvial flux is reduced by a maximum of 560 m^3/day during 2021 and 2023. **Figure 4-18** shows that the reduction in net alluvial flux due to Wambo Complex mining since 2003 at North Wambo Creek (i.e. dashed yellow line) increases throughout the prediction period to a maximum of 200 m^3/day. **Figure 4-19** shows that net flow change due to Wambo Complex mining since 2003 in Wambo Creek peaks at 450 m^3/day in 2021 and gradually reduces to around 200 m^3/day at the end of mining. **Figure 4-20** shows that the net flow changes due to Wambo Complex mining since 2003 at the Hunter River are predicted to peak at 95 m^3/day in 2034.

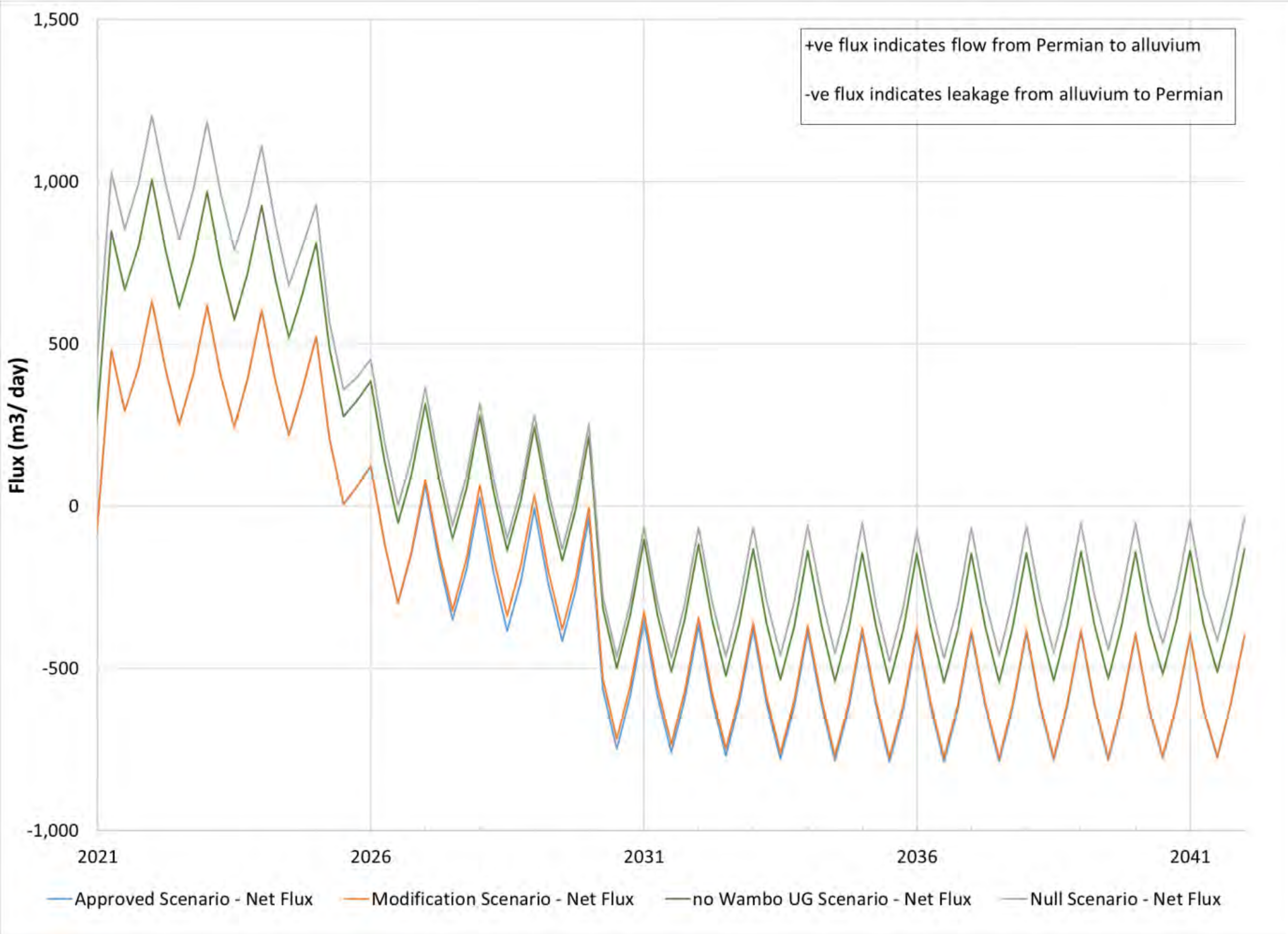


Figure 4-17 Alluvium net flow for Wollombi Brook – Modification, Approved, no Wambo UG, and Null scenarios.

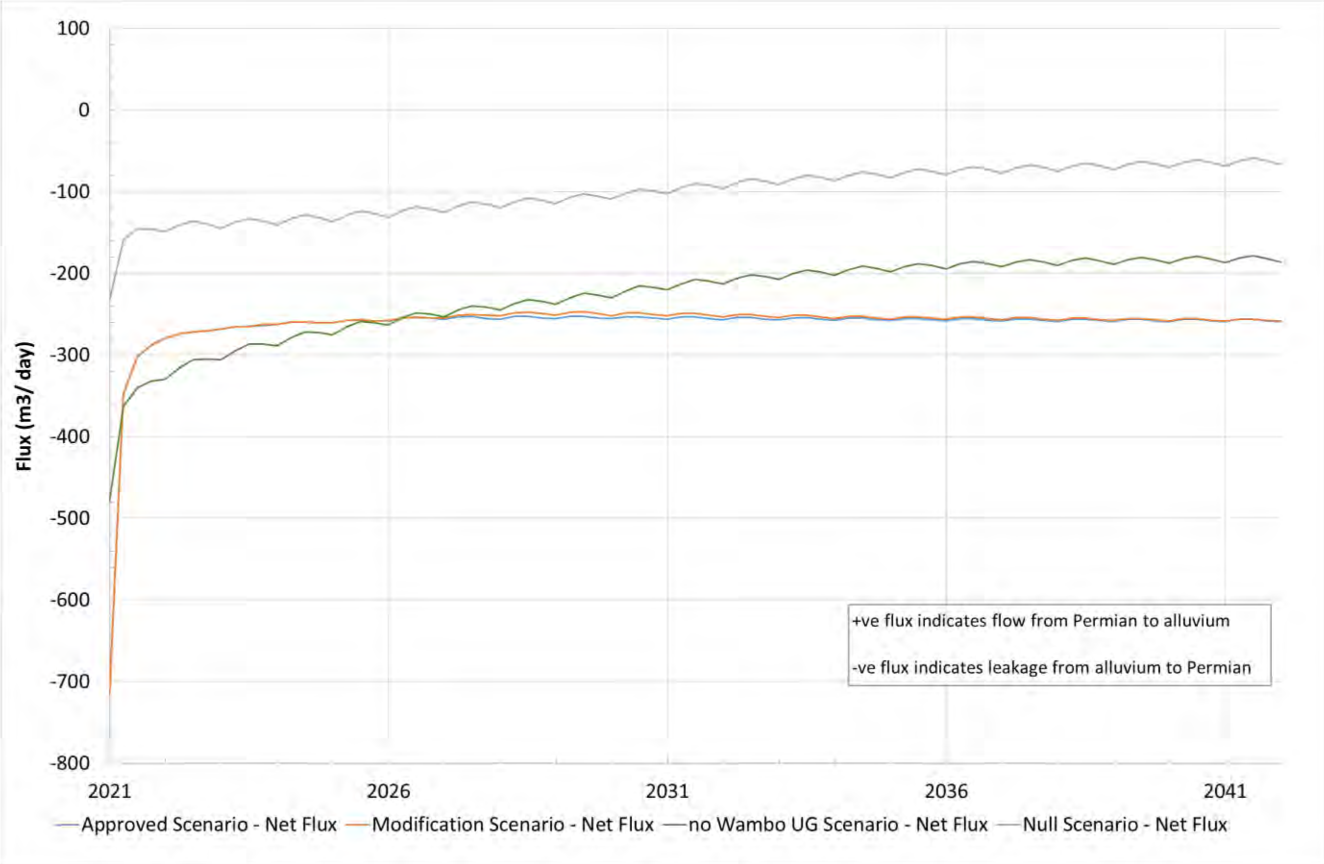


Figure 4-18 Alluvium net flow for North Wambo Creek – Modification, Approved, no Wambo UG, and Null scenarios.

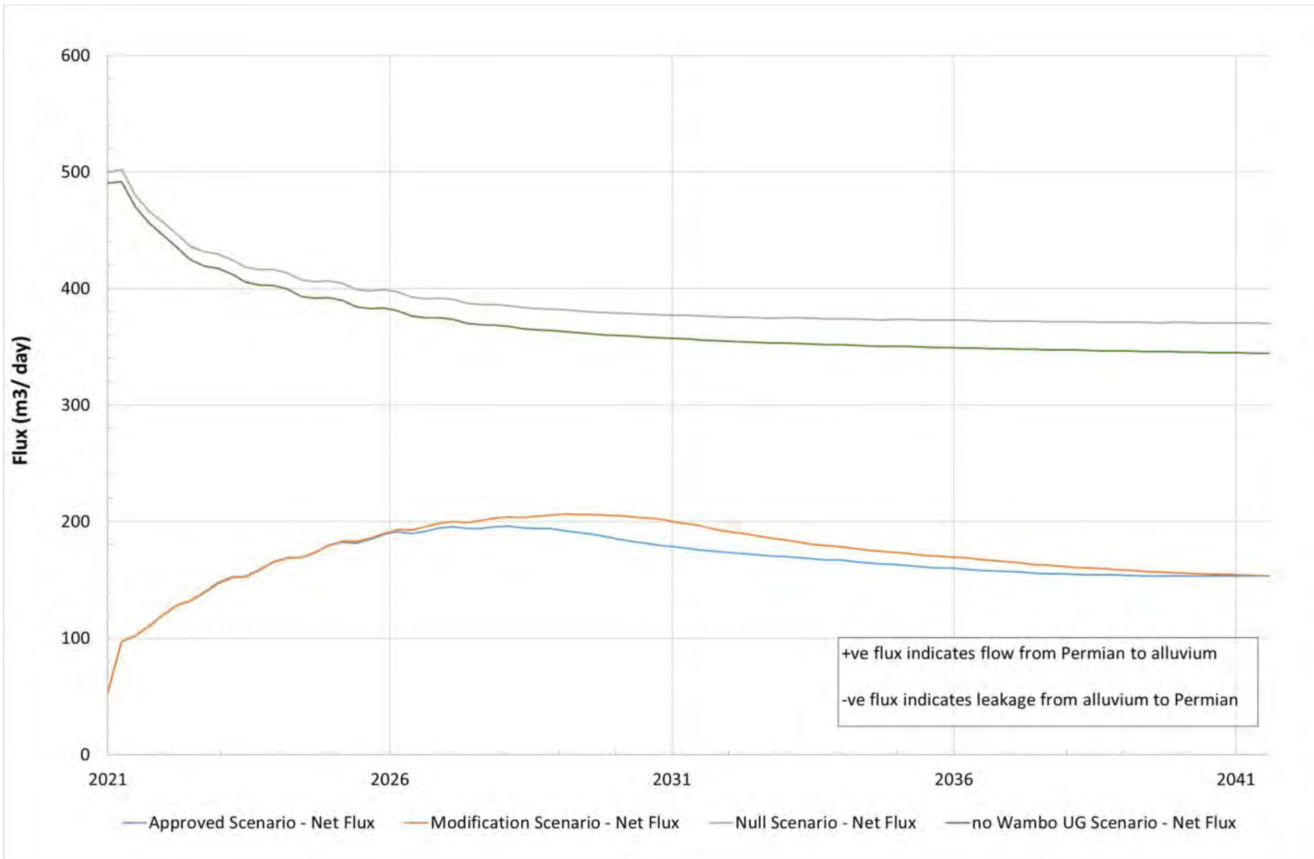


Figure 4-19 Alluvium net flow for Wambo Creek – Modification, Approved, no Wambo UG, and Null scenarios.

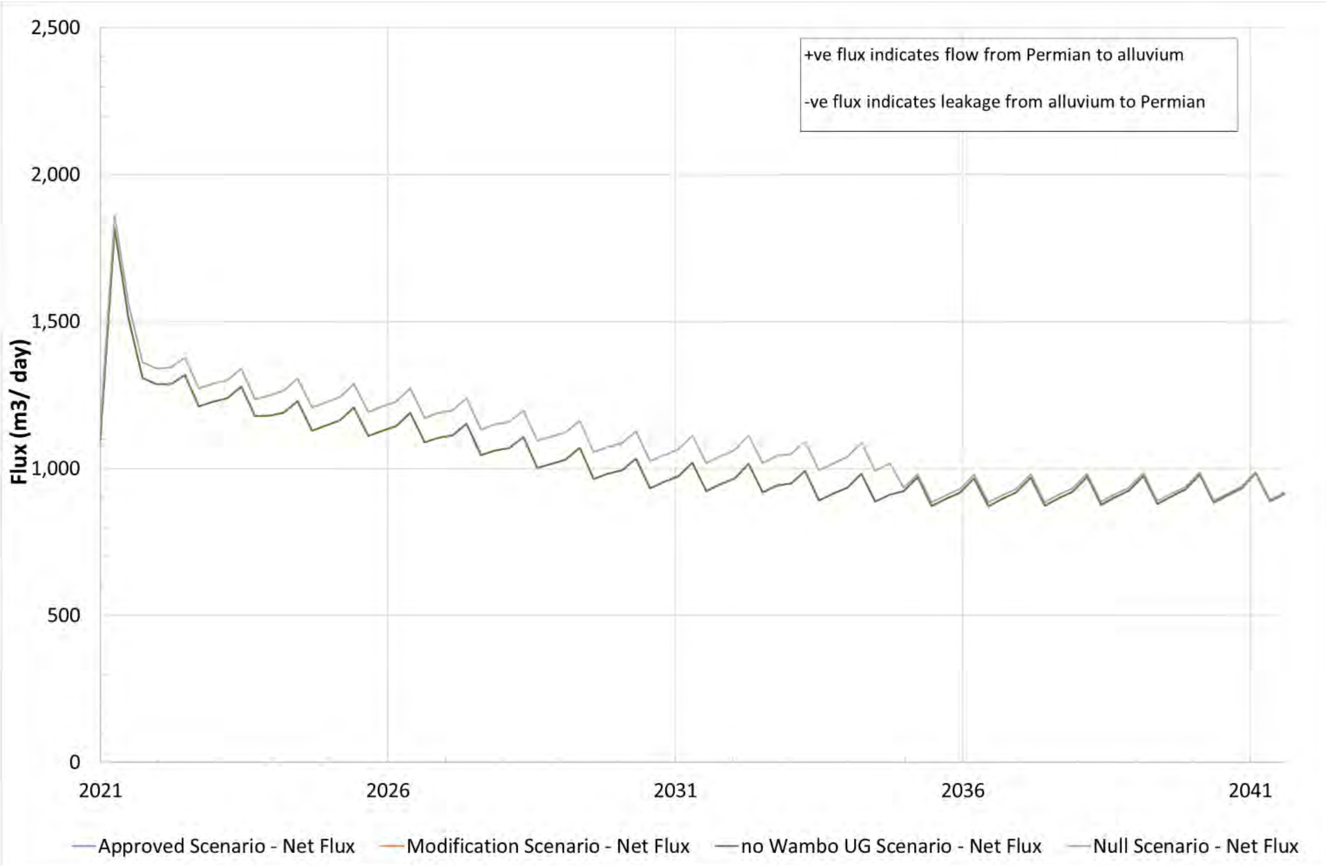


Figure 4-20 Alluvium net flow for Hunter River – Modification, Approved, no Wambo UG, and Null scenarios.

4.7 Groundwater – surface water interaction

4.7.1 River net flow change

Predicted change in surface water resources was estimated by comparing water budgets for river (RIV) zones using the Modification, Approved and Null scenarios of the predictive model. **Figure 4-21** to **Figure 4-24** show net river flux in Modification, Approved and Null scenarios for four key watercourses near the Wambo Complex (i.e. Wollombi Brook, North Wambo Creek, Wambo Creek and the Hunter River). The dashed lines in **Figure 4-21** to **Figure 4-24** are showing the differential net flow changes due to: the Modification mine plan only (i.e. the dashed blue line is Modification – Approved scenario), Wambo complex mining since 2003 including the Modification (i.e. dash yellow line is Modification – Null scenario) and approved Wambo complex mining since 2003 only (i.e. dash purple line is Approved – Null Scenario). Similar to the review of alluvial flow change (**Section 4.6.1)**, the results indicate that the Modification is predicted to not change or reduce net flow to surface water when compared to the Approved scenario.

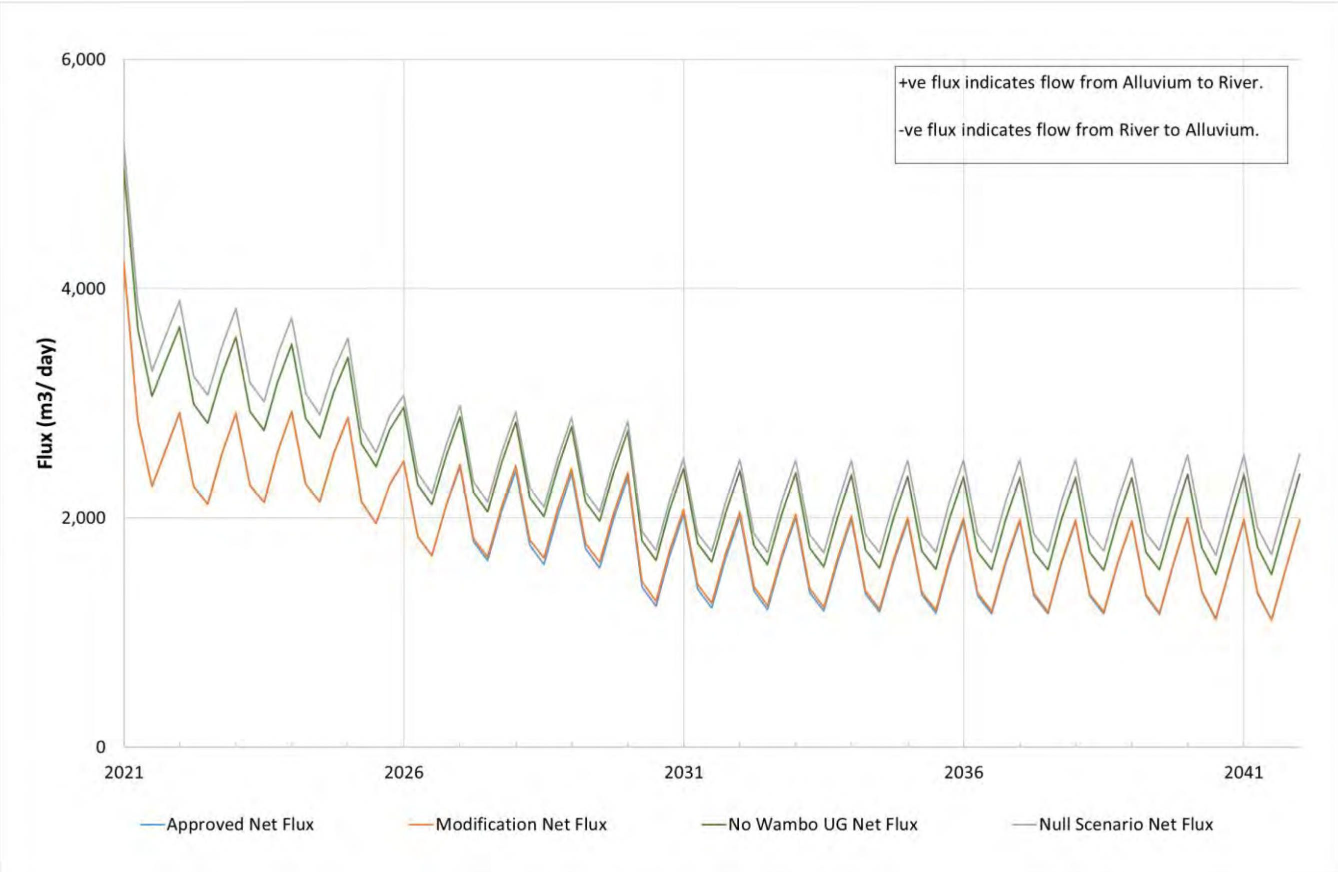


Figure 4-21 River net flow for Wollombi Brook – Modification, Approved, no Wambo UG and Null scenarios.

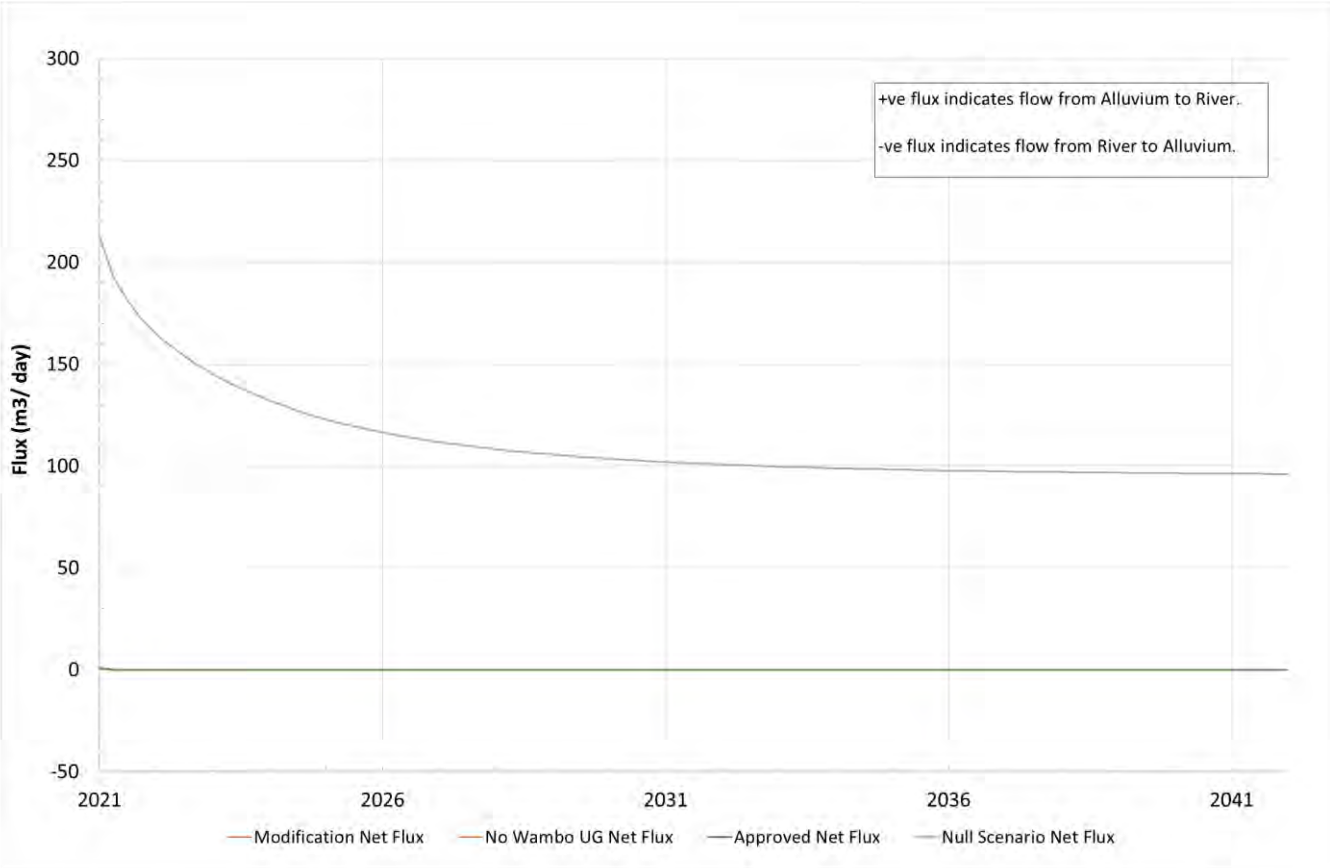


Figure 4-22 River net flow for North Wambo Creek – Modification, Approved, no Wambo UG, and Null scenarios.

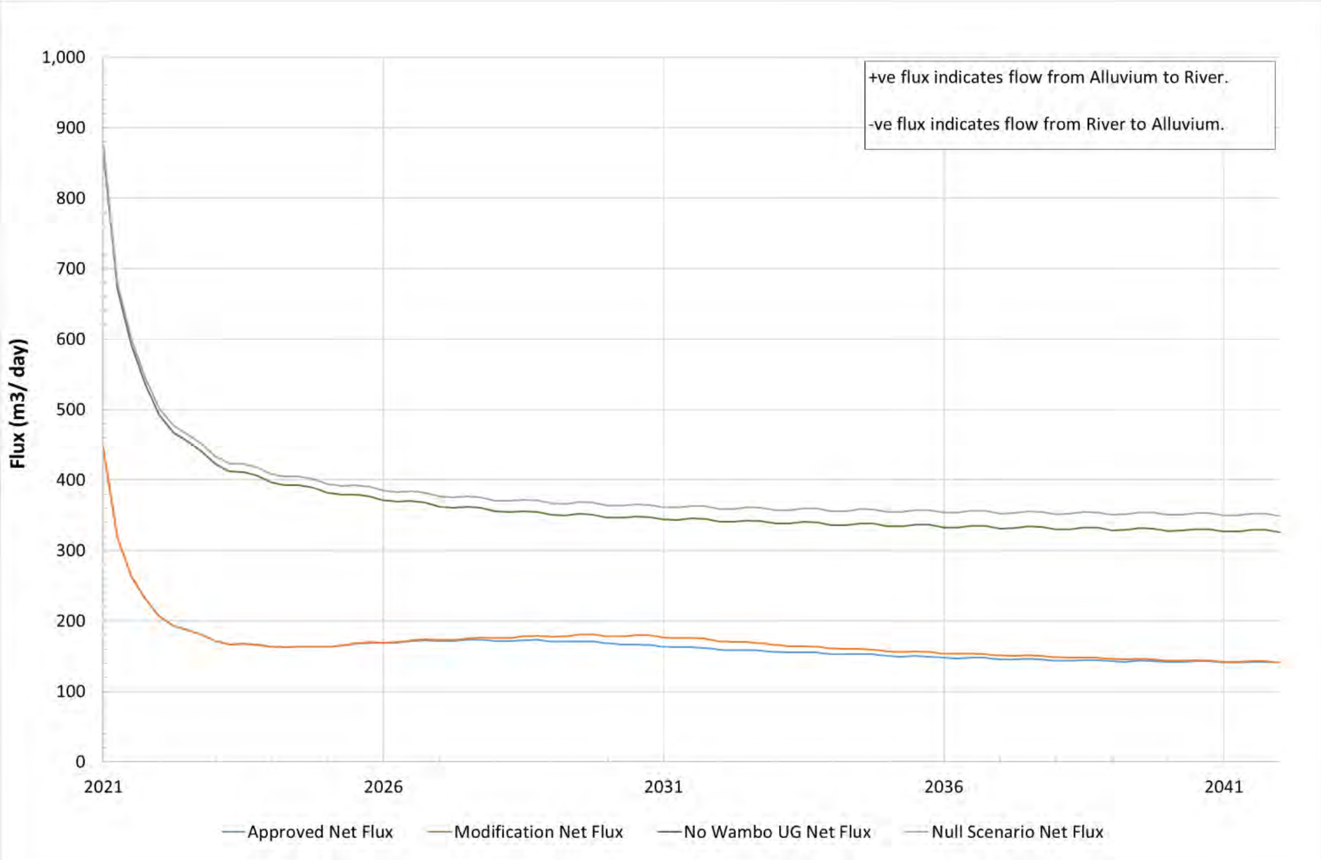


Figure 4-23 River net flow for Wambo Creek – Modification, Approved, no Wambo UG, and Null scenarios.

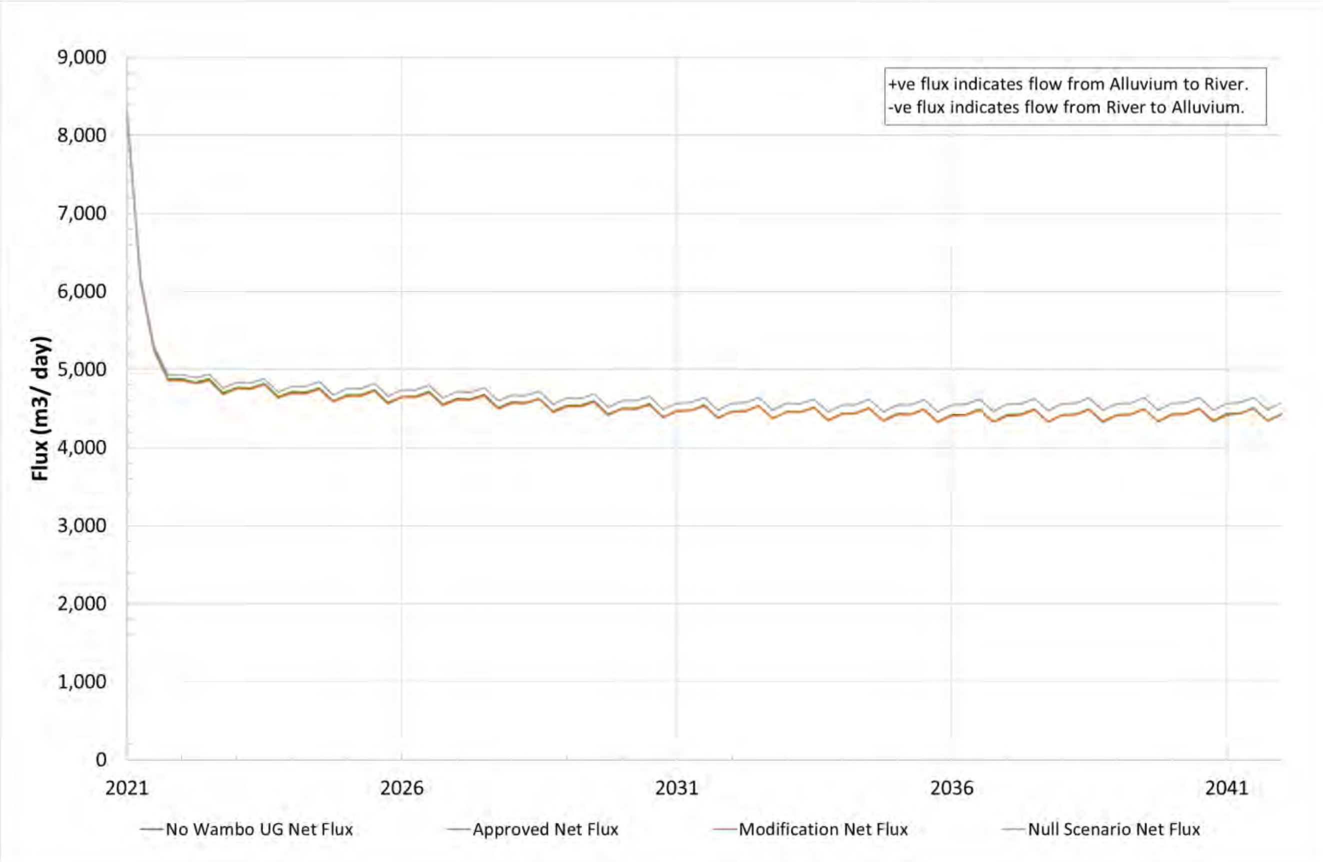


Figure 4-24 River net flow for Hunter River – Modification, Approved, no Wambo UG, and Null scenarios.

4.8 Impact on landholder bores

Table 4-4 presents a summary of predicted impacts to privately owned (not located on mine-owned land) registered bores near the Wambo Complex, including predicted incremental and Wambo Complex drawdown. Of the private bores near Wambo, none exceeds a drawdown of 2 m due to the Modification or Wambo operations after 2003.

The incremental and cumulative drawdown were also calculated for all registered bores within the model domain and the results are provided in **Attachment D**. Additional detail on the bores assessed in **Table 4-4** and **Attachment D** is provided in the main *Groundwater Assessment Report* (Section 6.5).

Table 4-4 Predicted drawdown effects at privately owned registered bores

Work No. (bore ID)	Location (GDA94 z56)		Use	Depth (mbgl)	Aquifer	Predicted Drawdown (m)	
	mE	mN				Incremental	Cumulative
GW043225	303653	6398949	Irrigation	24.7	Sandstone	0.0	0.0
GW064832	303908	6394477	Stock/ domestic	60		0.0	0.1
GW078477	304007	6398988	Domestic	102.5		0.0	0.1
GW078574	309174	6390605	Farming	12	alluvium/ regolith	0.0	1.3
GW078575	309505	6389687	Farming	12		0.0	0.4
GW078576	309764	6389784	Farming	7		0.0	0.0
GW078577	309969	6389973	Domestic	10		0.0	0.3

5 Uncertainty analysis

A Type 3 Monte Carlo uncertainty analysis (Middlemis and Peeters, 2018) was undertaken to estimate the uncertainty in the future impacts predicted by the model. This method operates by generating numerous alternative sets of input parameters to the deterministic groundwater flow model (realisations), executing the model independently for each realisation, and then aggregating the results for statistical analysis.

The first step in Monte Carlo analysis is to define the parameter distribution and range. For this project, the parameters are assumed to be log-normally distributed around the optimum value derived from the calibration and the standard deviation attributed to the log (base 10) of parameter is 0.5. This means that 95% of selected parameter values will lie within one order of magnitude either side of the initially calibrated value. The distributions for each parameter were checked and constrained such that upper or lower ranges do not go beyond ranges in literature for physical constraints. 2000 model realisations were generated, each having differing values of key parameters. The realisations were run, and calibration quality was assessed. In this case, models were considered to have an acceptable calibration if they achieved an SRMS less than 6.5% (i.e. about 10 percent above calibration SRMS of 6.0%). Of the 2000 model runs, 113 model runs were found to meet the above criteria. These were used in all model scenarios (calibration, Cumulative Mining, Approved Mining, and No Mining) and statistically analysed for uncertainty.

5.1 Parameter distributions

Table 5-1 to **Table 5-7** provide the parameter ranges explored during the sensitivity and uncertainty analysis simulations. Parameters were assumed to possess a log-Normal distribution with the mean for each parameter distribution displayed and constraints on parameters presented in **Table 5-1** to **Table 5-7**. The standard deviation for each distribution is a half order of magnitude from the mean.

Instead of simple random sampling, the Latin Hypercube Sampling (LHS) method was used to create random realisations from a parameter distribution. LHS aims to spread the sample points evenly across all possible values. In doing so, it divides parameter space into N intervals of equal probability and chooses one sample from each interval. The generated random numbers derived from LHS approach are distributed sufficiently across the parameter space even at the small sample size. The main advantage of LHS over simple random sampling is that a lower number of realisations are needed to obtain a reasonable convergence of the uncertainty results. The parameter distributions are provided as **Attachment C**, with prior distributions taken from the 2000 model realisations generated using LHS, and posterior distributions taken from the 113 model runs that met acceptable calibration criteria.

Table 5-1 Uncertainty parameter range for horizontal hydraulic conductivity

Layer	Layer- Unit	Horizontal Hydraulic Conductivity (m/day)	
		Mean (Log10)	Constraint
L01	Highly productive alluvium	0.40	No constraint
	Less productive alluvium	0.89	No constraint
	Regolith	0.11	< Kx_Alluvium Highly Productive, Kx_Less Productive
L02	Highly productive alluvium	1.92	No constraint
	Less productive alluvium	0.77	No constraint
	Weathered coal measures	0.04	< Kx_Alluvium Highly Productive, Kx_Less Productive
L03	Narrabeen Group	-1.30	< Kx_Alluvium Highly Productive, Kx_Less Productive
L04	Newcastle Coal Measures	-1.19	No constraint
L05	Overburden 1 (Sandstone / siltstone / shale)	-2.74	No constraint
L06	Overburden 2 (Sandstone / siltstone / shale)	-3.18	No constraint
L07	Whybrow seam	-1.23	No constraint
L08	Sandstone / siltstone / shale	-3.14	No constraint
L09	Wambo seam	-1.44	No constraint
L10	Sandstone / siltstone / shale	-3.21	No constraint
L11	Whynot Seam	-1.31	No constraint
L12	Sandstone / siltstone / shale	-3.14	No constraint
L13	Blakefield, Glen Munro	-1.37	No constraint
L14	Sandstone / siltstone / shale	-3.30	No constraint
L15	Woodlands Hill Seams	-1.59	No constraint
L16	Sandstone / siltstone / shale	-3.24	No constraint
L17	Arrowfield Seam	-1.55	No constraint
L18	Sandstone / siltstone / shale	-4.06	No constraint
L19	Bowfield Seam	-1.62	No constraint
L20	Siltstone / shale (interburden)	-3.42	No constraint
L21	United and Wambo Bowfield seam split	-1.70	No constraint
L22	Siltstone / shale (interburden)	-3.48	No constraint
L23	Warkworth Seam	-1.68	No constraint
L24	Siltstone / shale (interburden)	-3.34	No constraint
L25	Mt Arthur Seam	-1.89	No constraint
L26	Siltstone / shale (interburden)	-3.44	No constraint
L27	Piercefield and Vaux Seams	-1.72	No constraint
L28	Siltstone / shale (interburden)	-3.80	No constraint
L29	Broonie and Bayswater Seams	-1.80	No constraint
L30	Basement	-3.32	No constraint

Standard deviation = 0.5 order of magnitude for all units.

Table 5-2 Uncertainty parameter range for anisotropy (Kz/Kx)

Layer	Layer- Unit	Anisotropy (Kv/Kx)	
		Mean (Log10)	Constraint
L01	Highly productive alluvium	-1.0	< 1
	Less productive alluvium	-1.4	< 1
	Regolith	-2.3	< 1
L02	Highly productive alluvium	-1.6	< 1
	Less productive alluvium	-1.8	< 1
	Weathered coal measures	-1.3	< 1
L03	Narrabeen Group	-3.0	< 1
L04	Newcastle Coal Measures	-1.5	< 1
L05	Overburden 1 (Sandstone / siltstone / shale)	-1.5	< 1
L06	Overburden 2 (Sandstone / siltstone / shale)	-1.5	< 1
L07	Whybrow seam	-1.2	< 1
L08	Sandstone / siltstone / shale	-0.6	< 1
L09	Wambo seam	-2.9	< 1
L10	Sandstone / siltstone / shale	-1.9	< 1
L11	Whynot Seam	-0.8	< 1
L12	Sandstone / siltstone / shale	-0.8	< 1
L13	Blakefield, Glen Munro	-1.7	< 1
L14	Sandstone / siltstone / shale	-1.0	< 1
L15	Woodlands Hill Seams	-3.0	< 1
L16	Sandstone / siltstone / shale	-1.2	< 1
L17	Arrowfield Seam	-0.4	< 1
L18	Sandstone / siltstone / shale	-0.9	< 1
L19	Bowfield Seam	-2.7	< 1
L20	Siltstone / shale (interburden)	-1.1	< 1
L21	United and Wambo Bowfield seam split	0.0	< 1
L22	Siltstone / shale (interburden)	-1.2	< 1
L23	Warkworth Seam	-2.9	< 1
L24	Siltstone / shale (interburden)	-0.5	< 1
L25	Mt Arthur Seam	-3.0	< 1
L26	Siltstone / shale (interburden)	-1.4	< 1
L27	Piercefield and Vaux Seams	-1.3	< 1
L28	Siltstone / shale (interburden)	-0.3	< 1
L29	Broonie and Bayswater Seams	-1.8	< 1
L30	Basement	-1.0	< 1

Standard deviation = 0.5 order of magnitude for all units.

Table 5-3 Uncertainty parameter range for specific yield

Layer	Layer- Unit	Specific Yield (-)	
		Mean (Log10)	Constraint
L01	Highly productive alluvium	-2.3	<0.2
	Less productive alluvium	-1.3	<0.05
	Regolith	-2.0	<0.05
L02	Highly productive alluvium	-2.0	<0.2
	Less productive alluvium	-1.8	<0.05
	Weathered coal measures	-1.3	<0.05
L03	Narrabeen Group	-1.3	<0.05
L04	Newcastle Coal Measures	-2.5	<0.02
L05	Overburden 1 (Sandstone / siltstone / shale)	-2.0	<0.02
L06	Overburden 2 (Sandstone / siltstone / shale)	-2.0	<0.02
L07	Whybrow seam	-2.3	<0.02
L08	Sandstone / siltstone / shale	-2.5	<Whybrow seam, <0.02
L09	Wambo seam	-2.5	<0.02
L10	Sandstone / siltstone / shale	-2.6	<Wambo seam, <0.02
L11	Whynot Seam	-2.4	<0.02
L12	Sandstone / siltstone / shale	-2.5	<Whynot Seam, <0.02
L13	Blakefield, Glen Munro Seams	-1.7	<0.02
L14	Sandstone / siltstone / shale	-2.3	< Blakefield, Glen Munro Seams, <0.02
L15	Woodlands Hill Seams	-2.5	<0.02
L16	Sandstone / siltstone / shale	-2.6	< Woodlands Hill Seams, <0.02
L17	Arrowfield Seam	-2.2	<0.02
L18	Sandstone / siltstone / shale	-2.5	<Arrowfield Seam, <0.02
L19	Bowfield Seam	-2.0	<0.02
L20	Siltstone / shale (interburden)	-2.3	<Bowfield Seam, <0.02
L21	United and Wambo Bowfield seam	-2.7	<0.02
L22	Siltstone / shale (interburden)	-2.6	< United and Wambo Bowfield seam, <0.02
L23	Warkworth Seam	-1.7	<0.02
L24	Siltstone / shale (interburden)	-2.4	<Warkworth Seam, <0.02
L25	Mt Arthur Seam	-2.1	<0.02
L26	Siltstone / shale (interburden)	-2.5	<Mt Arthur Seam, <0.02
L27	Piercefield and Vaux Seams	-2.4	<0.02
L28	Siltstone / shale (interburden)	-2.5	<Piercefield Seam, <0.02
L29	Broonie and Bayswater Seams	-1.7	<0.02
L30	Basement	-2.3	<0.02

Standard deviation = 0.5 order of magnitude for all units.

Table 5-4 Uncertainty parameter range for specific storage (1/m)

Layer	Layer- Unit	Specific Storage (1/m)	
		Mean (Log10)	Constraint
L01	Highly productive alluvium	-5.00	<1 x 10^{-5}
	Less productive alluvium	-5.00	<1 x 10^{-5}
	Regolith	-5.76	<1 x 10^{-5}
L02	Highly productive alluvium	-5.05	<1 x 10^{-5}
	Less productive alluvium	-5.00	<1 x 10^{-5}
	Weathered coal measures	-5.00	<1 x 10^{-5}
L03	Narrabeen Group	-5.96	<1 x 10^{-5}
L04	Newcastle Coal Measures	-5.84	<1 x 10^{-5}
L05	Overburden 1 (Sandstone / siltstone / shale)	-5.30	<1 x 10^{-5}
L06	Overburden 2 (Sandstone / siltstone / shale)	-5.60	<1 x 10^{-5}
L07	Whybrow seam	-6.12	<1 x 10^{-5}
L08	Sandstone / siltstone / shale	-6.47	<1 x 10^{-5}
L09	Wambo seam	-5.46	<1 x 10^{-5}
L10	Sandstone / siltstone / shale	-5.68	<1 x 10^{-5}
L11	Whynot Seam	-5.75	<1 x 10^{-5}
L12	Sandstone / siltstone / shale	-6.33	<1 x 10^{-5}
L13	Blakefield, Glen Munro Seams	-5.30	<1 x 10^{-5}
L14	Sandstone / siltstone / shale	-5.74	<1 x 10^{-5}
L15	Woodlands Hill Seams	-5.66	<1 x 10^{-5}
L16	Sandstone / siltstone / shale	-5.80	<1 x 10^{-5}
L17	Arrowfield Seam	-6.40	<1 x 10^{-5}
L18	Sandstone / siltstone / shale	-6.56	<1 x 10^{-5}
L19	Bowfield Seam	-6.37	<1 x 10^{-5}
L20	Siltstone / shale (interburden)	-6.15	<1 x 10^{-5}
L21	United and Wambo Bowfield seam	-6.42	<1 x 10^{-5}
L22	Siltstone / shale (interburden)	-5.69	<1 x 10^{-5}
L23	Warkworth Seam	-5.96	<1 x 10^{-5}
L24	Siltstone / shale (interburden)	-5.30	<1 x 10^{-5}
L25	Mt Arthur Seam	-6.09	<1 x 10^{-5}
L26	Siltstone / shale (interburden)	-5.68	<1 x 10^{-5}
L27	Piercefield and Vaux Seams	-6.16	<1 x 10^{-5}
L28	Siltstone / shale (interburden)	-6.33	<1 x 10^{-5}
L29	Broonie and Bayswater Seams	-5.68	<1 x 10^{-5}
L30	Basement	-5.40	<1 x 10^{-5}

Standard deviation = 0.5 order of magnitude for all units.

Table 5-5 Uncertainty parameter range for the recharge rate

Zone	Unit	Mean % of rainfall	Constraints
1	Alluvium highly productive	6.7	No Constraint
2	Alluvium less productive	5.8	No Constraint
3	Regolith	0.5	< Alluvium Highly Productive, <Alluvium less productive

Standard deviation = 0.5 order of magnitude for all units.

Table 5-6 Uncertainty parameter for spoil properties

Num	Unit	Value	Constraints
1	Spoil Horizontal Hydraulic Conductivity (m/day)	0.3	No Constraint
2	Spoil Vertical Hydraulic Conductivity (m/day)	0.1	No Constraint
3	Spoil Specific Yield	0.1	< 0.3
4	Spoil Specific storage	1E-5	No Constraint

Standard deviation = 0.5 order of magnitude for all units.

Table 5-7 Uncertainty parameter for river bed vertical hydraulic conductivity

Num	Unit	Mean(log10)	Constraints
1	Hunter River	-0.3	No Constraint
2	Wollombi Brook	0	No Constraint
3	Wambo Creek	0	No Constraint
4	Wambo North Creek	0	No Constraint
5	Lemington Water Storage	-3	No Constraint
6	Other Minor Creeks	0	No Constraint

Standard deviation = 0.5 order of magnitude for all units.

5.2 Number of realisations

As discussed in **Section 5.1**, 113 realisations met the calibration criteria and were selected as calibrated realisations. The predictive model was run using the 113 parameters sets. The results from the predictive model were used to conduct statistical analyses to assess if additional realisations were likely to provide results that would significantly change the reported predictive results. The 95% confidence interval was calculated for the mine inflows and the maximum drawdown.

Figure 5-1 and **Figure 5-2** show the 95% confidence intervals of the median and maximum drawdown and predicted inflows, as well as the variance of the median and maximum drawdown and predicted inflows as more realisations are added to the uncertainty analysis. For example, the 95% confidence interval for the maximum drawdown is calculated by first estimating the maximum drawdown for each realisation and then calculating the 95% confidence interval of the maximum drawdowns as each realisation is added to the dataset. As shown in **Figure 5-1** and **Figure 5-2**, additional realisations are unlikely to significantly increase or decrease the confidence intervals of predictions of mine inflows and maximum drawdowns. Therefore, the results from the 113 realisations can be considered representative and used for predicted drawdown and indirect water take (alluvium and surface water).

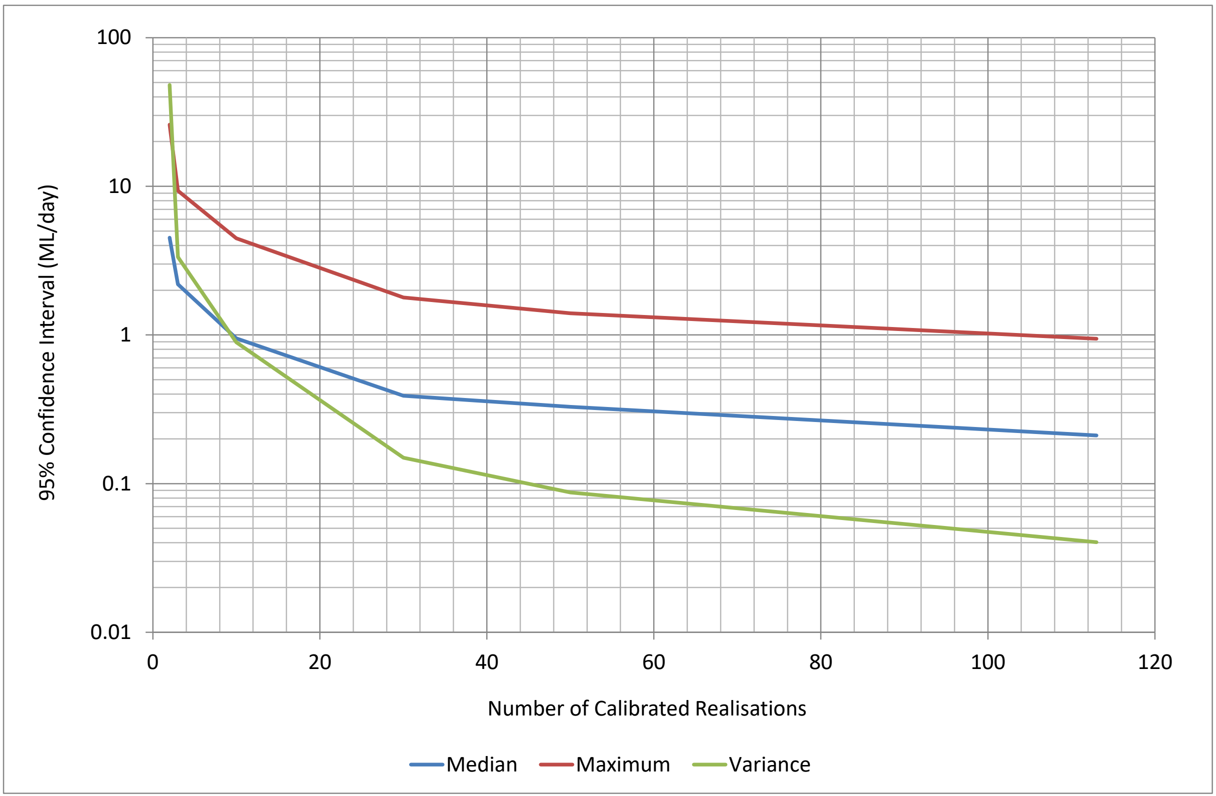


Figure 5-1 95% confidence interval for mine inflows

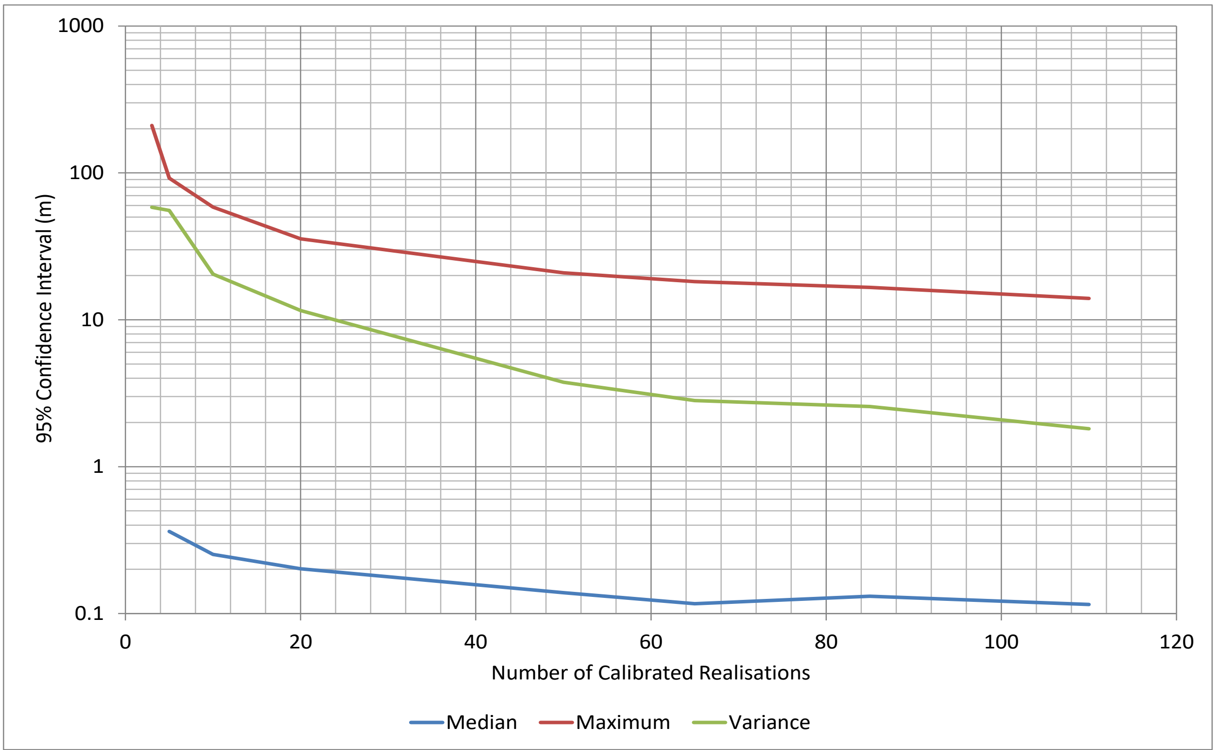


Figure 5-2 95% confidence interval for maximum drawdowns

5.3 Uncertainty results

5.3.1 Uncertainty of mine inflows

Figure 5-3 to **Figure 5-7** present the uncertainty of groundwater inflow into Wambo Complex mine areas from 2021 to the end of 2041 for the Modification scenario. The figures show the predicted inflows for different percentiles including 5th, 33rd, 50th, 67th and 95th prediction bounds. Based on the IESC (2018) guidelines these represent:

- Less than 10th percentile indicates it is very likely the outcome is larger than this value.
- 10th – 33rd indicates it is likely that the outcome is larger than this value.
- 33rd – 67th indicate it is as likely as not that the outcome is larger or smaller than this value.
- 67th – 90th indicates it is unlikely that the outcome is larger than this value.
- Greater than 90th percentile indicates it is very unlikely the outcome is larger than this value.

Figure 5-3 shows that the maximum mine inflow is very unlikely to exceed 3.4 ML/day for SBX mining in the Whybrow Seam. **Figure 5-4** shows that the inflows are predicted to be generally less than 6 ML/day for the South Wambo Project mining in the Woodlands Hill Seam between 2027 and 2037. **Figure 5-5** indicates that the inflows peak at the end of mining for the South Wambo Project mining in the Arrowfield Seam and are very unlikely to be higher than 3.5 ML/day. In each case, as the basecase model predicts more inflow than the 50th percentile, it can be regarded as a conservative indicator of likely future conditions.

With regards to the UWOCP, **Figure 5-6** shows that it is very unlikely that the inflows would be above 4 ML/day in 2022 and 3.2 ML/day between 2023 and 2041 in the United Pit (the eastern pit of the UWOCP). **Figure 5-7** shows two peaks in inflows are predicted to occur in 2022 and 2038 in the Montrose Pit (the western pit of the UWOCP), 95th percentile predictions indicate inflows are unlikely to be above 16 ML/day and 10 ML/day respectively and the inflows are generally expected to be lower than 4 ML/day during the mine operation. In each case, as the basecase model predicts similar inflow to the 50th percentile, it can be regarded as a good indicator of likely future conditions.

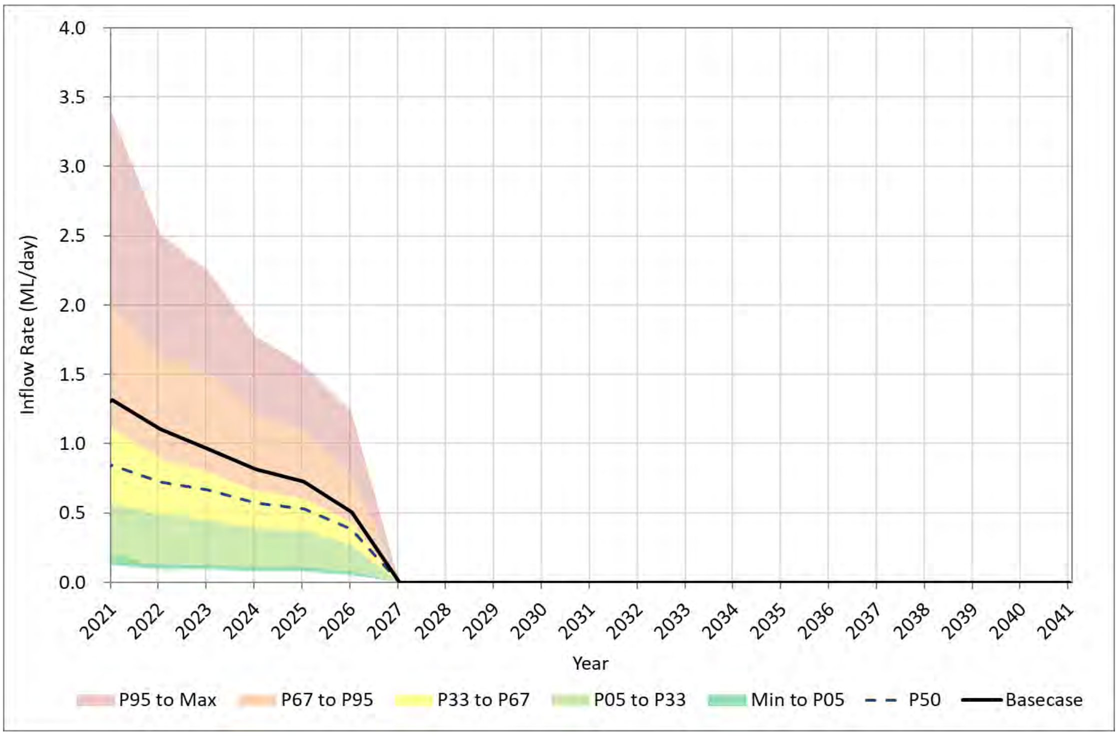


Figure 5-3 Predictive uncertainty of South Bates Extension mine inflow (Whybrow Seam) - Modification scenario

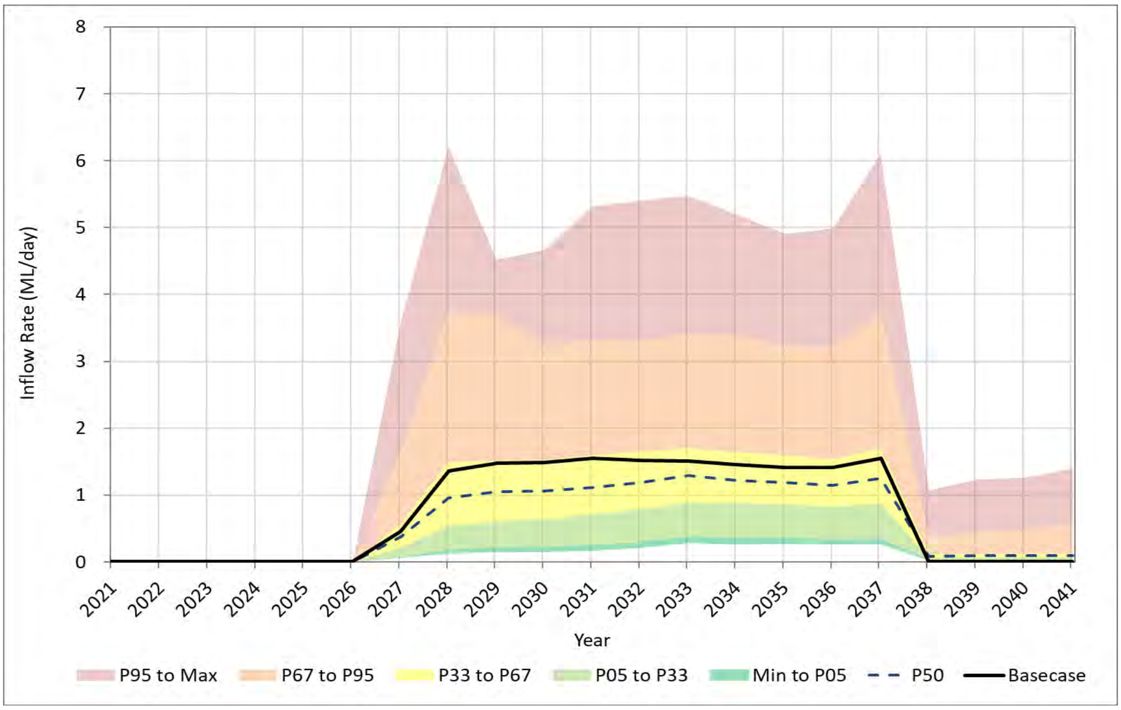


Figure 5-4 Predictive uncertainty of South Wambo Project mine inflow (Woodlands Hill Seam) - Modification scenario

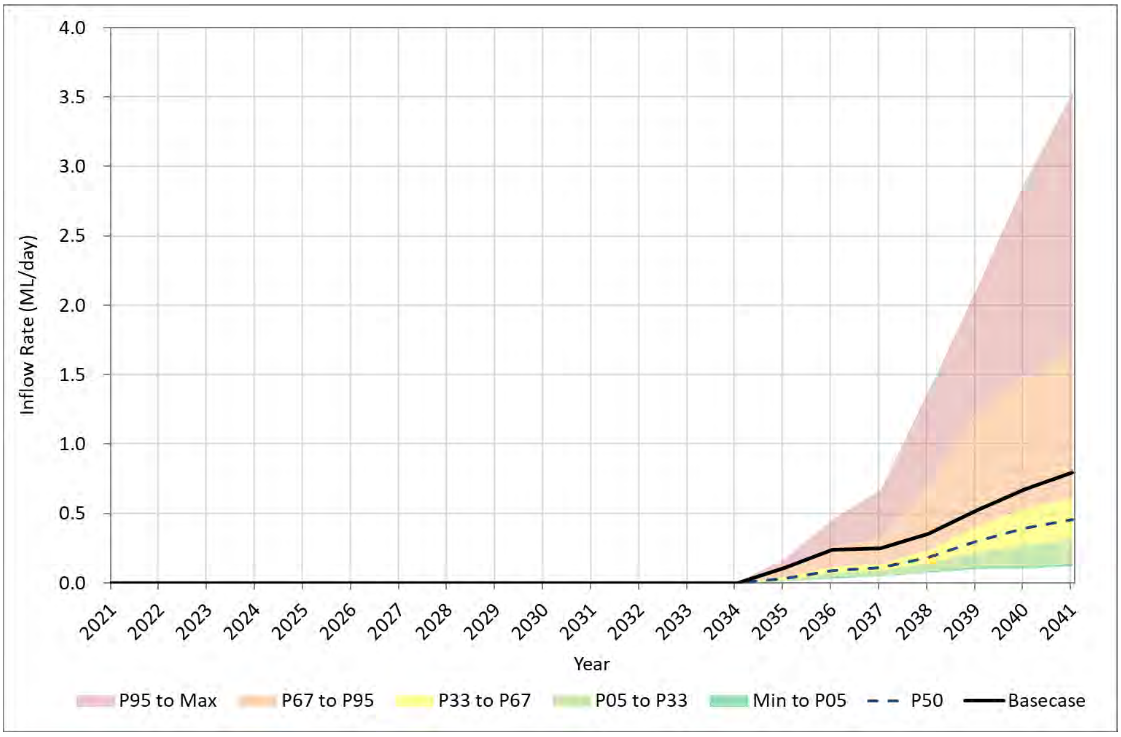


Figure 5-5 Predictive uncertainty of South Wambo Project mine inflow (Arrowfield Seam) - Modification scenario

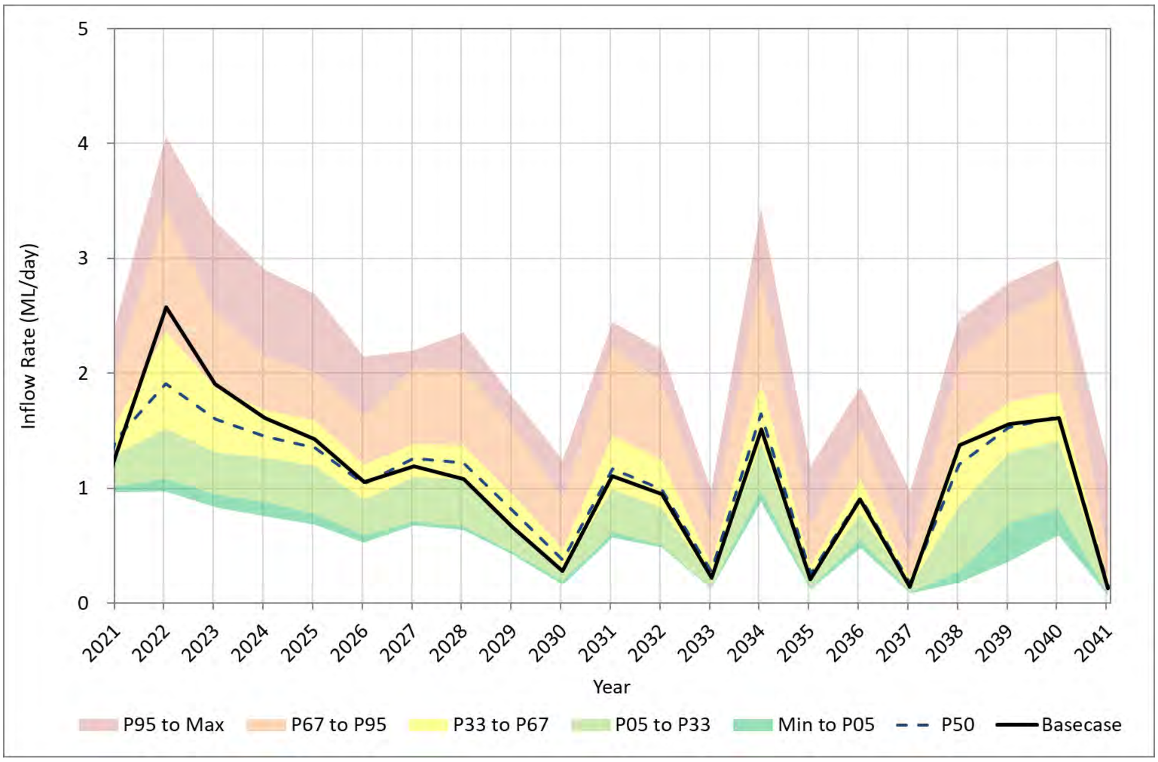


Figure 5-6 Predictive uncertainty of UWOCP mine inflow (United Pit) - Modification scenario

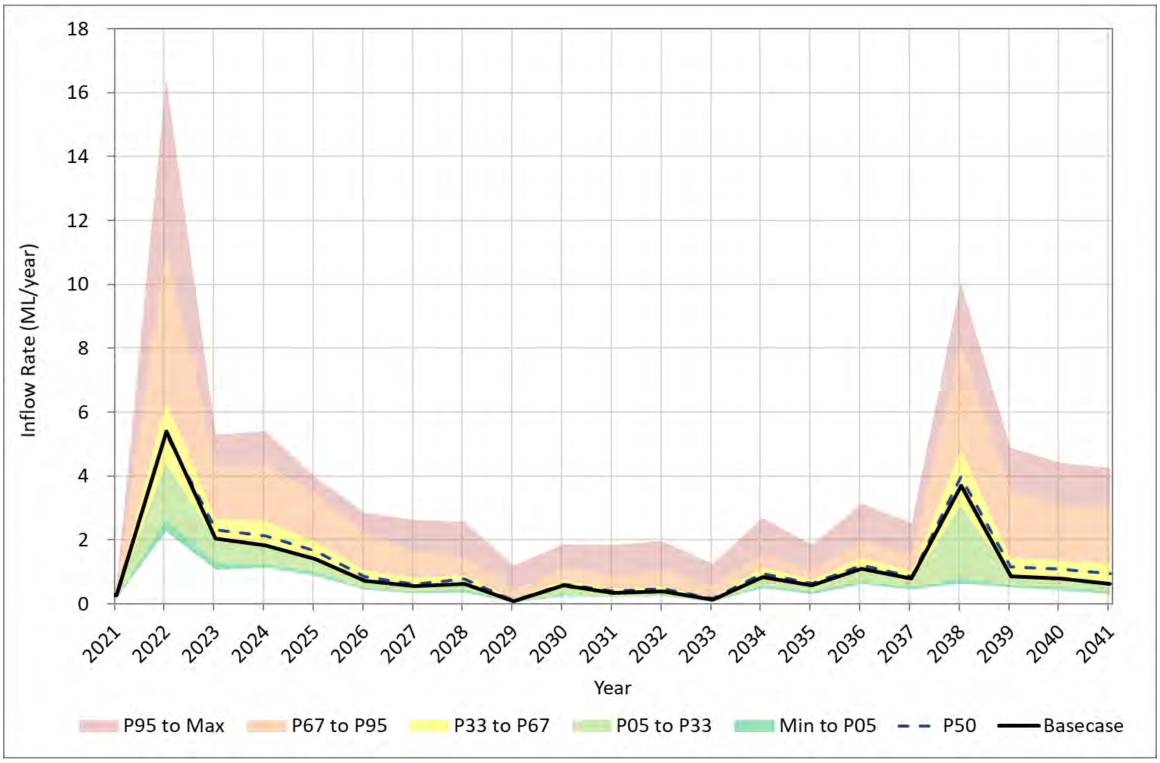
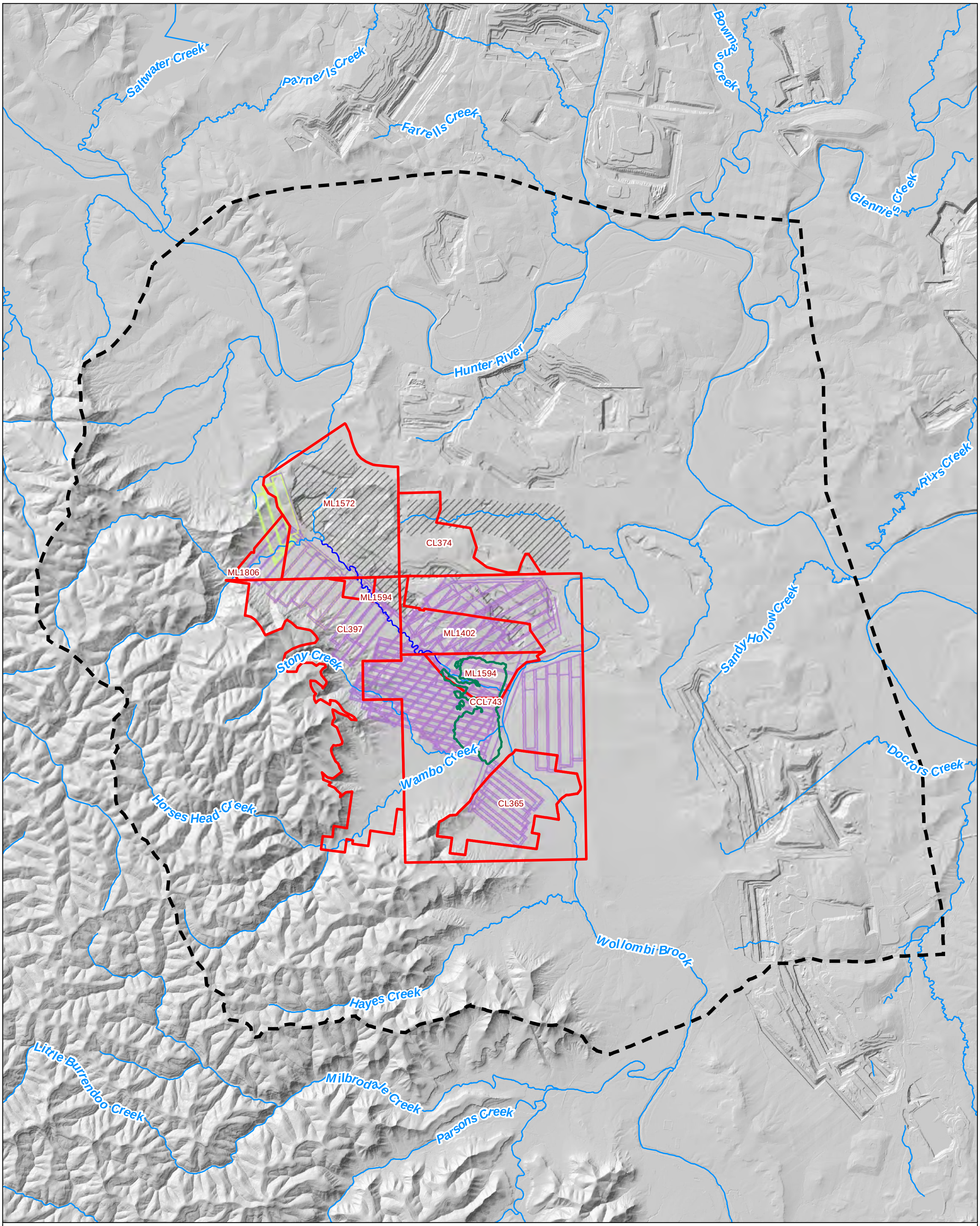


Figure 5-7 Predictive uncertainty of UWOCP mine inflow (Montrose Pit) - Modification scenario

5.3.2 Groundwater drawdowns

To illustrate the level of uncertainty in the drawdown, the 10th, 50th and 90th percentile maximum incremental drawdown was calculated (i.e. Modification – Approved scenario). **Figure 5-8** to **Figure 5-11** show the uncertainty in the extent of predicted 1 m maximum incremental drawdown in the alluvium and regolith (layer 1), Whybrow (layer 7), Arrowfield (layer 17) and Vaux (layer 27) seams respectively.

Figure 5-8 shows that there is no drawdown predicted in alluvium and regolith at the 10th and 50th percentiles but at the 90th percentile, drawdown is predicted near the confluences of North Wambo Creek and Wambo Creek with Wollombi Brook. This area of drawdown overlies up to four seams of historical and approved longwall mining, and drawdown of a greater extent is considered very unlikely to occur. **Figure 5-9** shows that the drawdown in Whybrow Seam is focussed mainly around the proposed LW24-26 layout at SBX underground mine extension for the 10th and 50th percentiles and extends up to a maximum of 8 km to the Southeast for the 90th percentile. **Figure 5-10** shows that the predicted incremental drawdown in the Arrowfield Seam is mainly around the first three longwalls scheduled for mining in the Arrowfield Seam in the Modification scenario at the 10th, 50th and 90th percentile 1 m drawdown contour. **Figure 5-11** shows that there is limited incremental drawdown in the Vaux Seam at the 90th percentile near the north-eastern side of the Woodlands Hill seam layout and the eastern edge of the United Pit of the UWOCP.



N

0 2 4 km

Coordinate System: GDA 1994 MGA Zone 56
Scale: 1:130,000 at A4
Project Number: 665.0008.00815
Date: 13-May-2022
Drawn by: ANP

Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining
Drawdown 1m (10th Percentile)
Drawdown 1m (50th Percentile)
Drawdown 1m (90th Percentile)

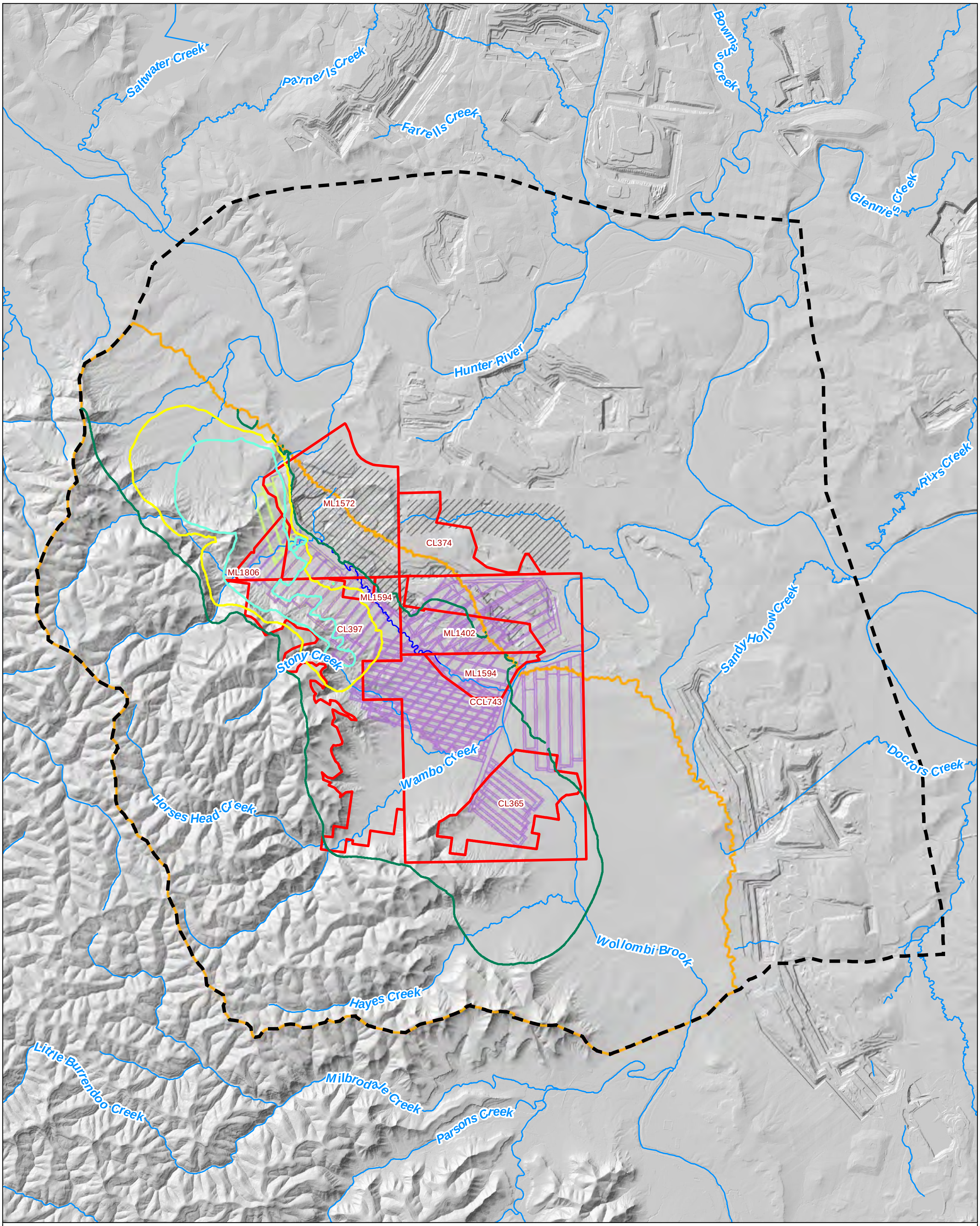
SLR

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Uncertainty in predicted 1m maximum incremental drawdown in alluvium and regolith (layer 1)

FIGURE 5-8

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_5_8_Uncertainty_Layer_1.mxd



0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	24-May-2022
Drawn by:	ANP

SLR

- Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Whybrow Seam Extent (Layer 7)
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining
- Drawdown 1m (10th Percentile)
- Drawdown 1m (50th Percentile)
- Drawdown 1m (90th Percentile)

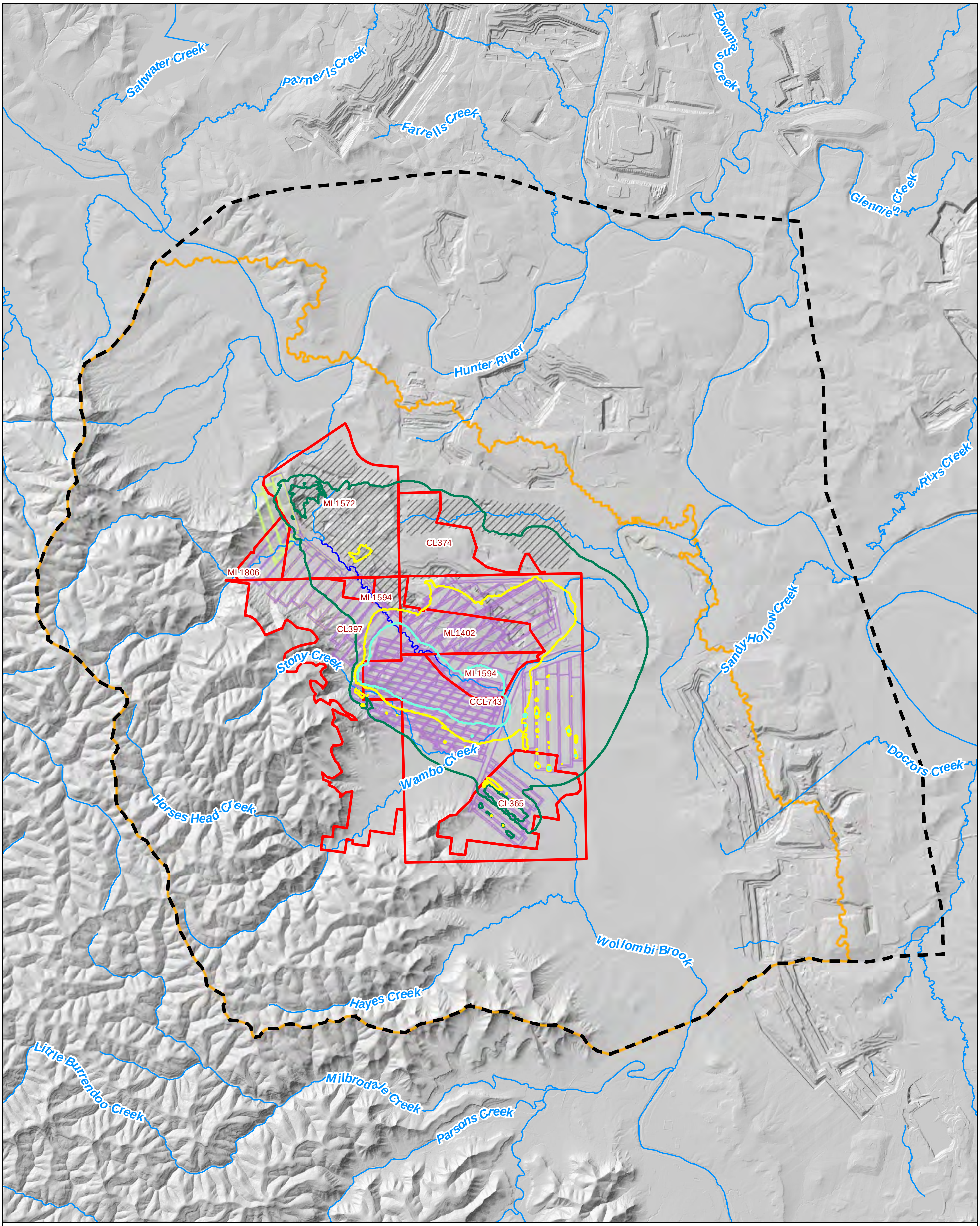
Data Source: NSW SS 2020

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Uncertainty in predicted 1m maximum incremental drawdown in Whybrow Seam (layer 7)

FIGURE 5-9

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_5_9_Uncertainty_Layer_7.mxd



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	13-May-2022
Drawn by:	ANP

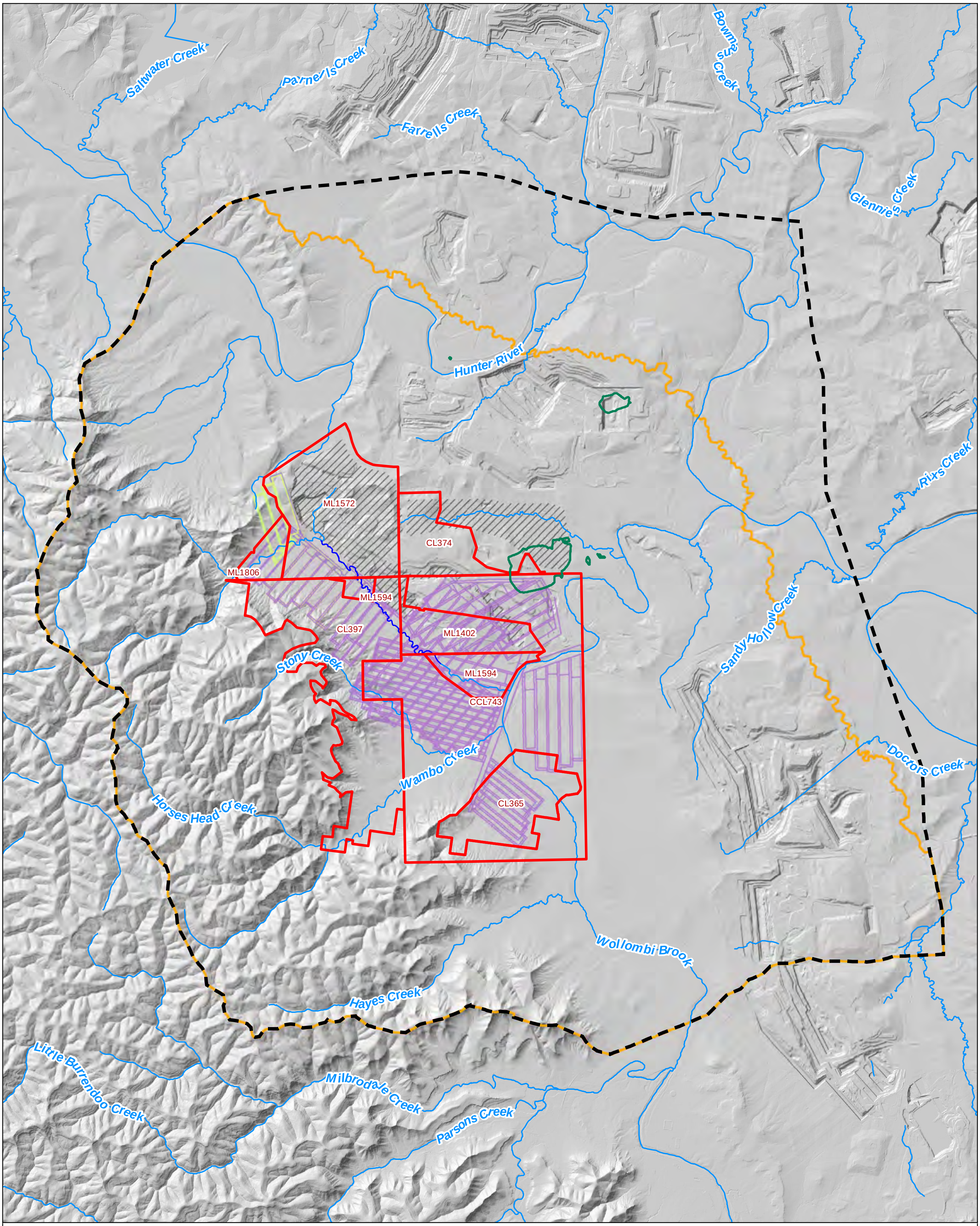
- Wambo Model Boundary
- Named Watercourse
- NWC Diversion
- Mining Lease
- Arrowfield Seam Extent (Layer 17)
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining
- Drawdown 1m (10th Percentile)
- Drawdown 1m (50th Percentile)
- Drawdown 1m (90th Percentile)

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Uncertainty in predicted 1m maximum incremental drawdown in Arrowfield Seam (layer 17)

FIGURE 5-10

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_5_10_Uncertainty_Layer_17.mxd



N

0 2 4 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:130,000 at A4
Project Number:	665.0008.00815
Date:	13-May-2022
Drawn by:	ANP

SLR

Wambo Model Boundary
Named Watercourse
NWC Diversion
Mining Lease
Vaux Seam Extent (Layer 27)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining
Drawdown 1m (10th Percentile)
Drawdown 1m (50th Percentile)
Drawdown 1m (90th Percentile)

SOUTH BATES EXTENSION LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Uncertainty in predicted 1m maximum incremental drawdown in Vaux Seam (layer 27)

FIGURE 5-11

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_5_11_Uncertainty_Layer_27.mxd

5.3.3 Uncertainty of drawdown at landholder bores

Table 5-8 summarises the 95th percentile predicted maximum incremental and cumulative drawdown at privately owned registered bores near Wambo Complex mining. The 95th percentile prediction is chosen to provide a conservative estimate of the upper range of likely impacts to these bores, noting that the impacts above those predicted at the 95th percentile are considered to be very unlikely. The uncertainty results indicate the 2 m drawdown threshold is predicted to be not exceeded at any private registered bore due to the proposed LW24-26 layout (the Modification). Cumulative drawdown due to Wambo Complex mining since 2003 (Null scenario), predicts GW078574 to be impacted by greater than the 2 m drawdown threshold at the 95th percentile.

Table 5-8 Maximum drawdown impact on privately owned bores (uncertainty analysis 95th percentile)

Work No. (bore ID)	Location (GDA94 z56)		Use	Depth (mbgl)	Aquifer	Maximum Drawdown (m) - 95th percentile	
	mE	mN				Wambo Complex (after 2003)	Incremental
GW043225	303653	6398949	Irrigation	22.5	Sandstone	0.5	0.1
GW078477	304007	6398988	Domestic	102.5	Sandstone	1.0	0.2
GW078574	309174	6390605	Farming	12		2.8	0.7
GW078575	309505	6389687	Farming	12		1.3	0.4
GW078576	309764	6389784	Farming	7	Unconsolidated/ regolith	0.0	0.0
GW078577	309969	6389973	Domestic	10		1.6	0.3

5.3.4 Uncertainty of influence on alluvium and surface water flow

Table 5-9 shows the 5th and 95th percentiles for the maximum incremental net flow change (i.e. due to the Modification) for alluvium and surface water. It is noted that the positive numbers in **Table 5-9** indicate that the Modification scenario decreases the magnitude of net flow change (less water loss) induced by Wambo Complex mining when compared to the Approved scenario, while negative numbers indicate that Modification scenario causes an increase in net flow change compared to the Approved scenario (more water loss). The basecase model predicts an increase or no change in net flow to alluvium or surface water due to the Project (Modification scenario), while at the outer bounds of the uncertainty analysis (95th and 5th percentiles), net flow change is predicted to either increase or decrease due to the Project.

North Wambo Creek and its associated alluvium is nearest to the Project, and is predicted by the uncertainty analysis to have a possible variation in flow due to the project of:

- Between 5.1 m^3/day additional loss, and 14.4 m^3/day additional gain to surface water; and
- Between 43.9 m^3/day additional loss, and 43.2 m^3/day additional gain to alluvial groundwater

The largest magnitude changes to surface water and alluvial flux occur at Wollombi Brook, which predicts an increase in net flow 4-5 times higher than the base case at the 95th percentile, and an incremental loss of a similar magnitude at the 5th percentile. Following the IESC (2018) explanatory note on uncertainty analysis, it is very unlikely net flow change to alluvium or surface water will be of larger magnitude than predicted at these upper ranges.

Table 5-9 Maximum net river flow change 5th and 95th percentile

Watercourse	River flux change (m^3/day)			Alluvium flux change (m^3/day)		
	5th Percentile	Base case	95th Percentile	5th Percentile	Base case	95th Percentile
Wollombi Brook	-176.5	49.2	215.2	-76.6	42	144.6
Hunter River	-13	0.7	4.3	-3.8	0	12.7
Wambo Creek	-56.9	12	59.4	-57.5	20.9	115.1
Wambo North Creek	-5.1	0	14.4	-43.9	5.4	43.2

6 Post mining recovery

Post-mining impacts were investigated with a recovery period following the transient predictive numerical model. The recovery period commences from the end of mining at Wambo, and simulations were run for 358 years (from 2042 to 2400). Simulation of final voids and recovered water levels utilises final void geometry and water level recovery assumptions presented in the UWOCP EIS (AGE, 2016). This assessment utilised pit lake recovery rates from a high-resolution surface water model and is considered the best available data source for this groundwater assessment.

Based on AGE (2016) the Wambo open cut (the more western open cut - **Figure 1-1**) final void will be largely rehabilitated with a minimum final void elevation of 40 mAHD, while the United open cut (the more eastern open cut - **Figure 1-1**) final void will be deeper, with a depth down to -150 mAHD. The final voids are predicted to reach a final void water level of approximately 55 mAHD in the Wambo open cut and 20 mAHD in the United open cut with predicted recovery levels per stress period shown in **Figure 6-1**. The graph shows that the void water level recovery is a slow process with the recovery rate declining as it reaches equilibrium conditions.

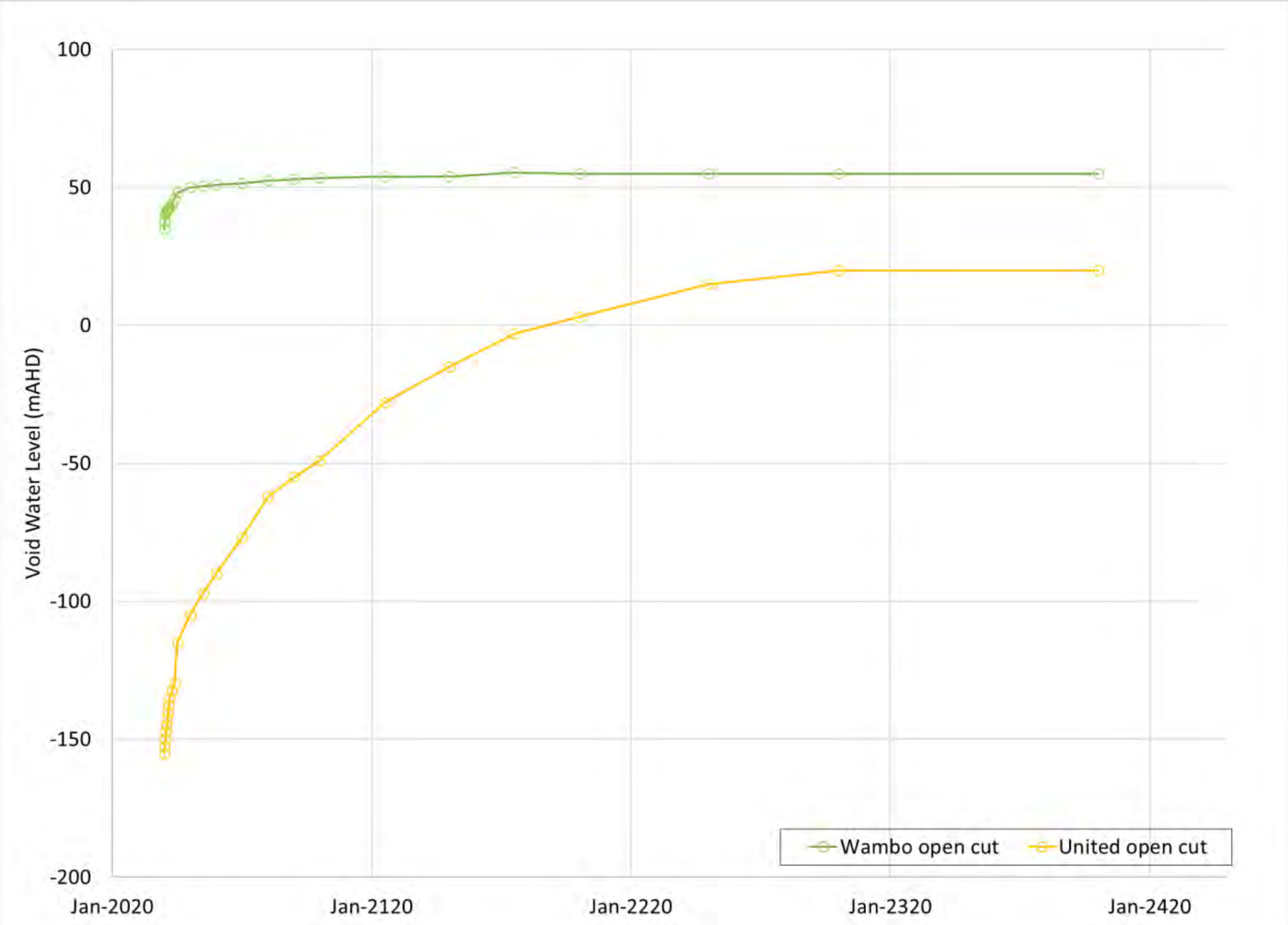


Figure 6-1 Final void recovery level over time

Table 6-1 describes changes made to key model input files to represent post-mining conditions including the recovery of water in the final voids.

Table 6-1 Post mining setup of model packages

MODFLOW package	Post mining setup
Drain (DRN)	Drain cells simulating mining/ dewatering in the Wambo area removed at the end of the prediction periods to allow groundwater levels to recover/ equilibrate.
Time-Variant Materials (TVM)	At the end of mining, the properties of the final void cells within the UWOCP open cuts were converted to values representative of void values.
Constant Head (CHD)	Pit lake recovery rates are incorporated into the groundwater model using a series of constant heads over time (following Figure 7-19 from AGE, 2016)
Recharge (RCH)	Recharge package updated so that no recharge applied to final void lakes represented by constant head cells.
Evapotranspiration (EVT)	Evapotranspiration package updated so that no evapotranspiration taken from final void lakes represented by constant head cells.

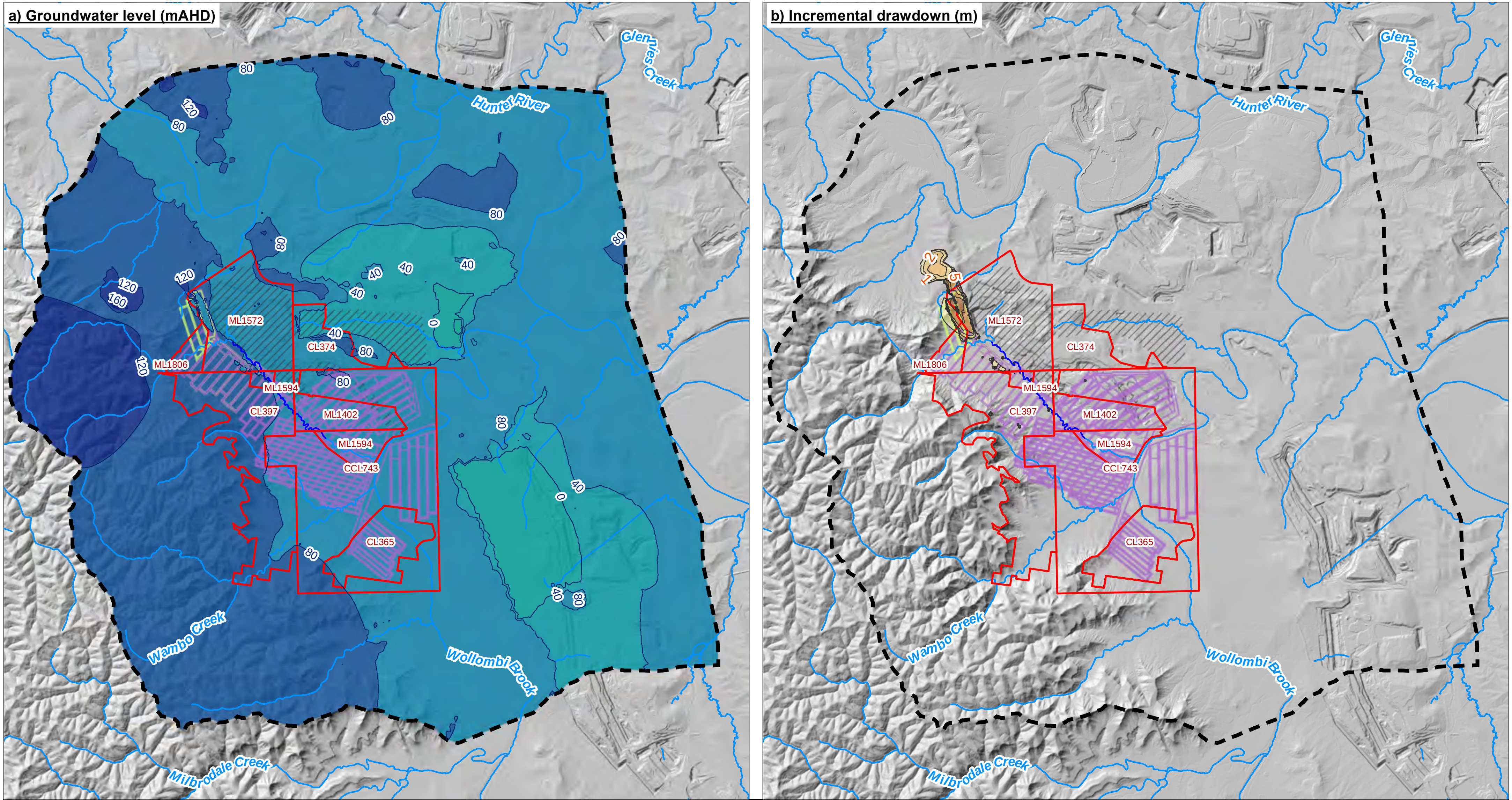
6.1.1 Post mining groundwater recovery

The predicted post mining water levels and incremental drawdowns (at 260 years after mining) for the water table, alluvium and regolith (Layer 1), the Whybrow Seam (Layer 7), Arrowfield Seam (Layer 17), and the Vaux Seam (Layer 27) are shown in **Figure 6-2** through to **Figure 6-6**.

Groundwater levels around the UWOCP final voids range from approximately 105 mAHD at the water table to 50 m within the Vaux Seam. This range is above the predicted lake water levels in the void of 20 mAHD in the United open cut final void, indicating that the void is predicted to behave as a groundwater sink with an inwards hydraulic gradient from all surrounding aquifers, and therefore unlikely to impact on water quality within the surrounding strata.

There is no long-term incremental drawdown predicted for the alluvium and regolith (**Figure 6-3**), Arrowfield Seam (**Figure 6-5**) and Vaux Seam (**Figure 6-6**). Long term incremental drawdown is predicted at the water table overlying and north of modification Longwalls 24 to 26 (**Figure 6-2**). Predicted drawdown peaks at 70 m above Longwall 24 and 1-2 m drawdown extends approximately 1.4 km north of the mine footprint.

The maximum predicted incremental drawdown associated with the Modification within the target Whybrow Seam is shown in **Figure 6-4**. The drawdown extent within the Whybrow Seam (Layer 7) is influenced by unit structure and is confined to unit extents, meaning that drawdown does not extend east, where the Whybrow Seam has outcropped or been mined-out. The 1 m drawdown influence is predicted to extend up to 4.2 km north-west of the Modification.



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:175,000 at A4
Project Number:	665.0008.00815
Date:	20-Jul-2022
Drawn by:	NT

SLR

New Wambo Model Boundary

NWC Diversion

Named Watercourse

Mining Lease

Proposed LW24-26 Layout

Existing/Approved Underground Development

Approved Open Cut Mining

Water Table (mAHD)

- -240 - -200
- -200 - -160
- -160 - -120
- -120 - -80
- -80 - -40
- -40 - 0
- 0 - 40
- 40 - 80
- 80 - 120
- 120 - 160
- 160 - 200

Drawdown (m)

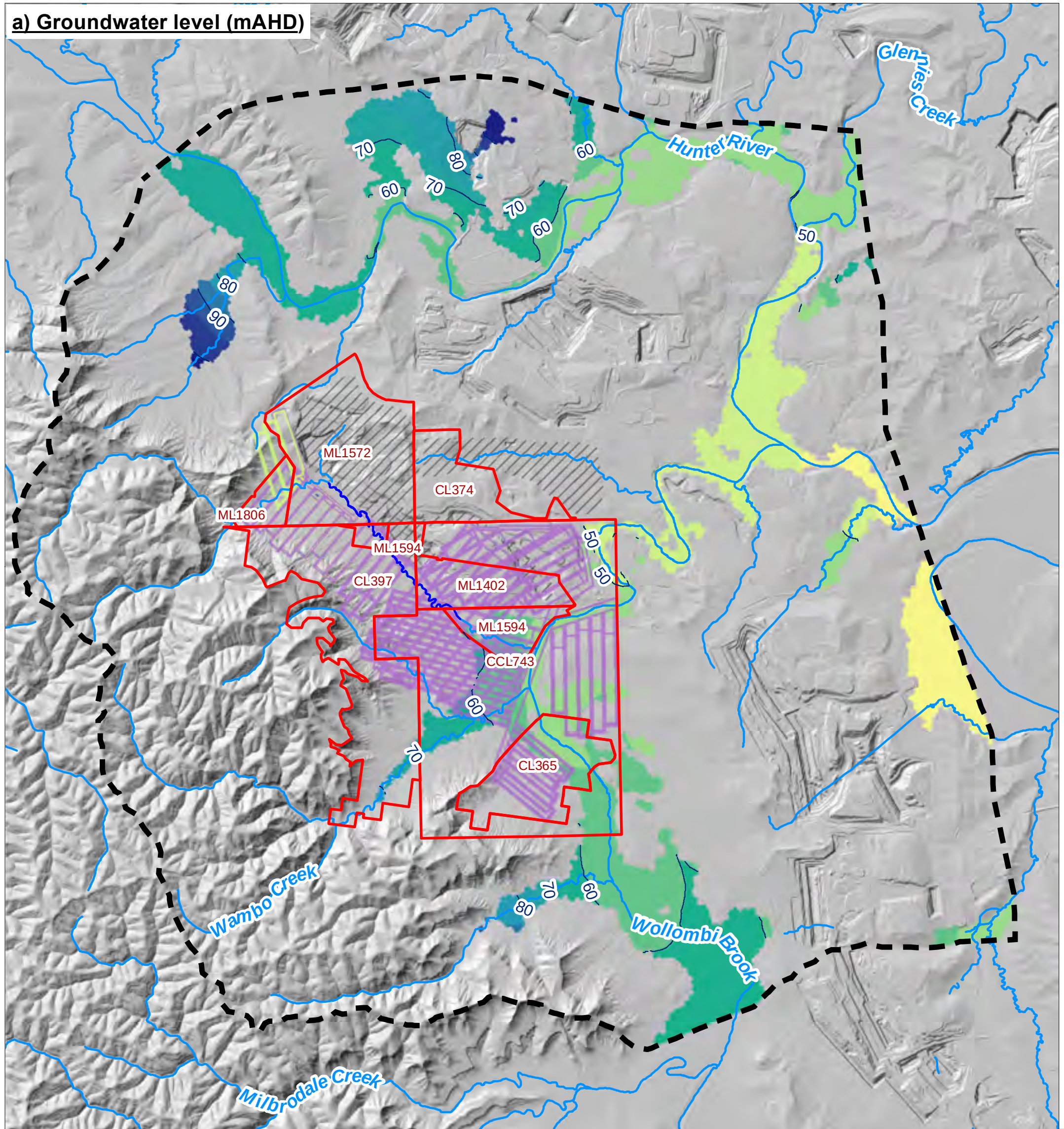
- 0 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 400

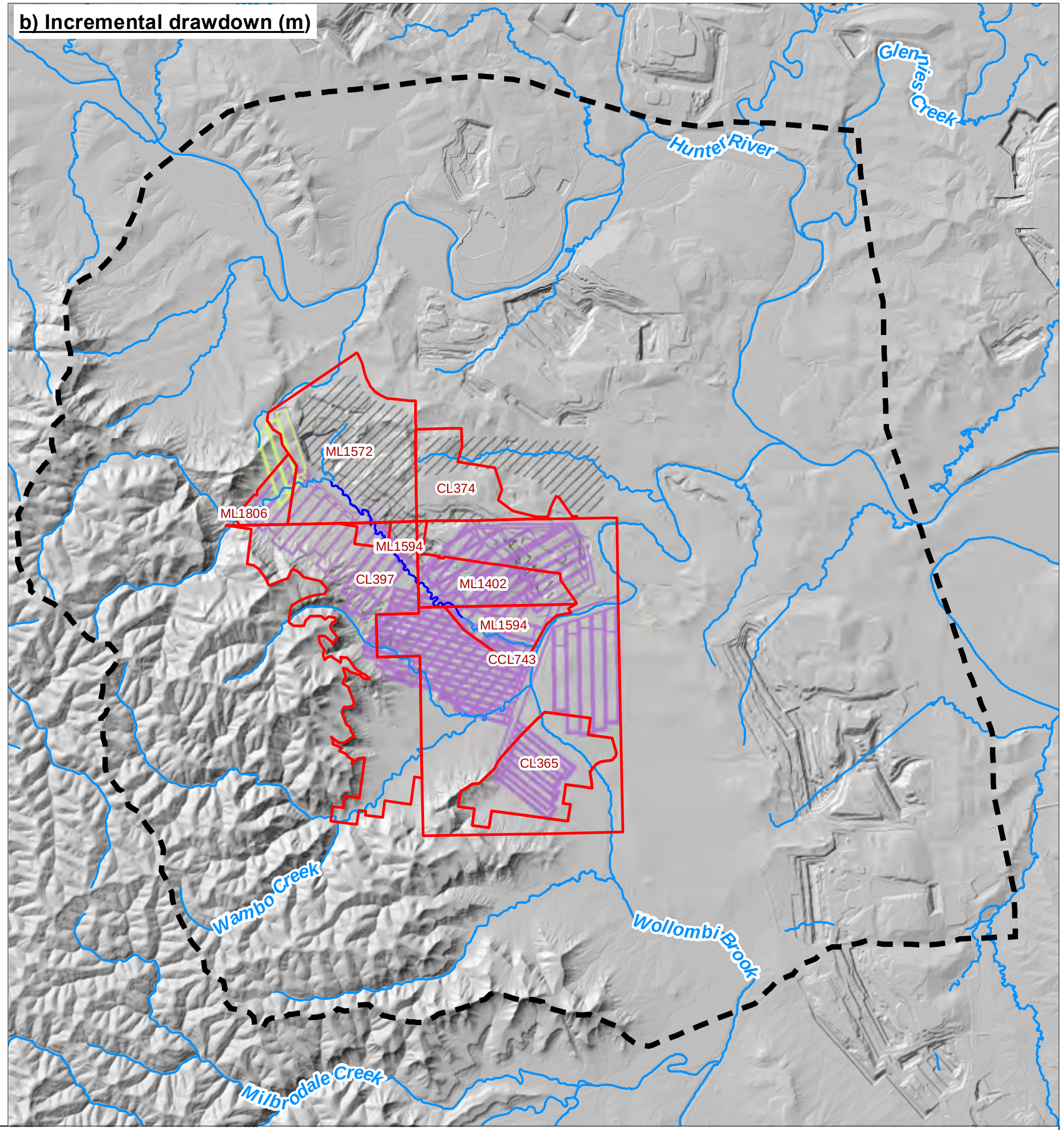
WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Predicted water table groundwater level (a) and incremental drawdown (b) – post mining recovery

FIGURE 6-2

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_6_2_Pred_WT_GWL_IncDDN_End2400_revA.mxd





0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:175,000 at A4
Project Number:	665.0008.00815
Date:	20-Jul-2022
Drawn by:	NT

New Wambo Model Boundary
NWC Diversion
Named Watercourse
Mining Lease
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

Groundwater Level (mAHD)
40 - 45; 45 - 50; 50 - 55; 55 - 60; 60 - 65; 65 - 70; 70 - 75; 75 - 80; 80 - 85; 85 - 90; 90 - 95; 95 - 100; 100 - 105

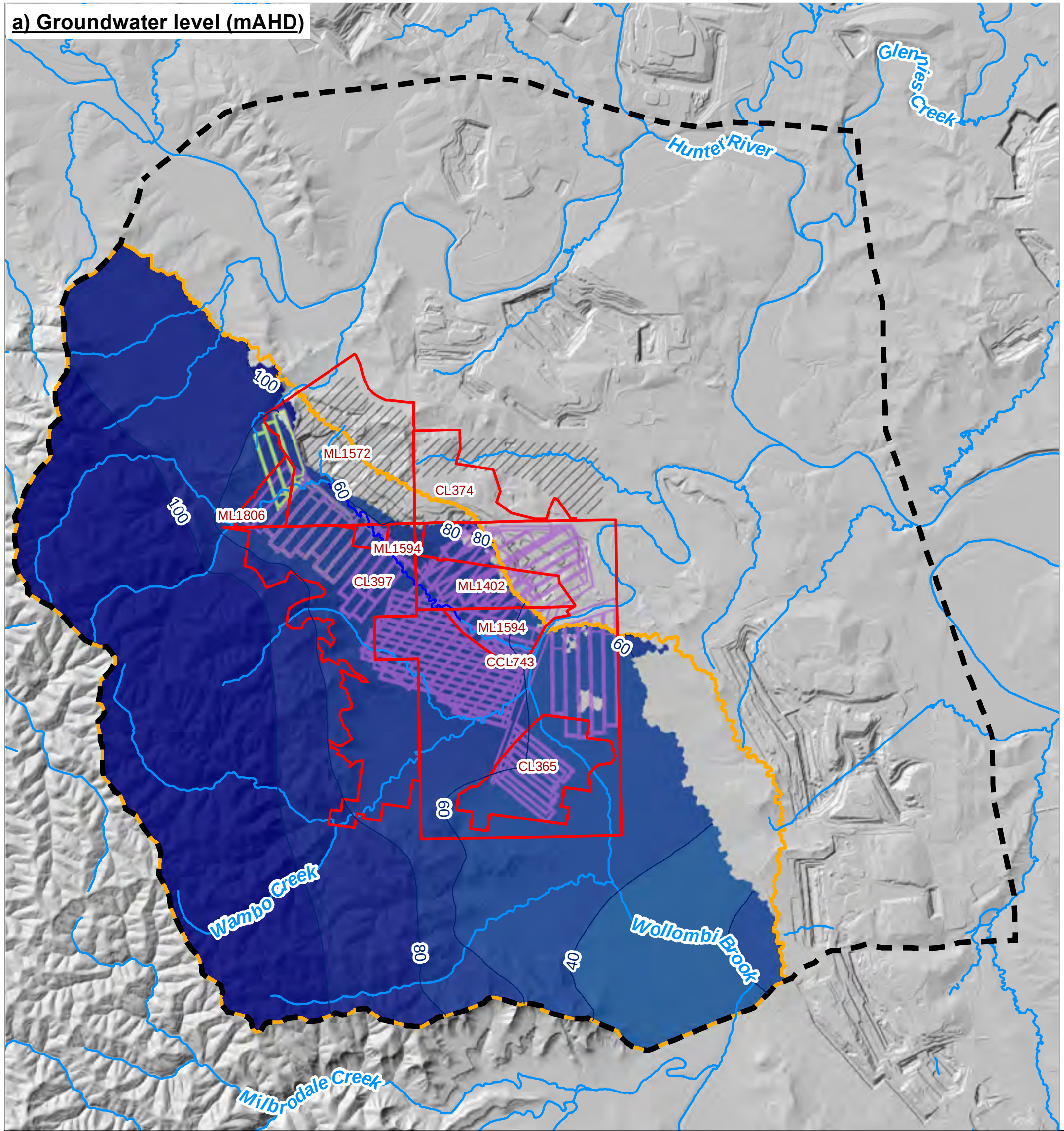
Drawdown (m)
0 - 1; 1 - 2; 2 - 5; 5 - 10; 10 - 20; 20 - 50; 50 - 100; 100 - 200; 200 - 400

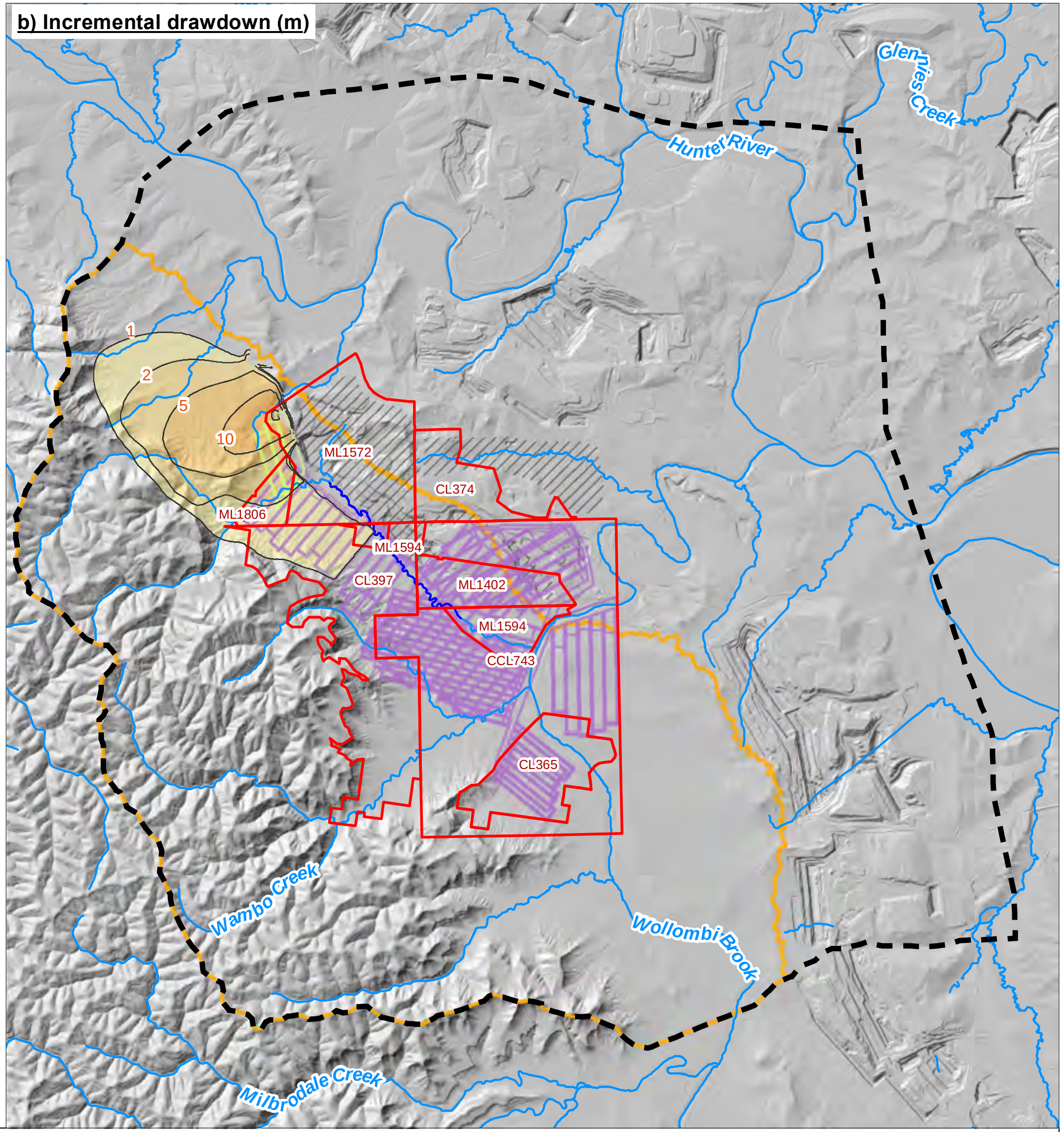
WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Predicted alluvium and regolith (layer 1) groundwater level (a) and incremental drawdown (b) – post mining recovery

FIGURE 6-3

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_6_3_Pred_Layer_1_GWL_IncDDN_End2400_revA.mxd





0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:175,000 at A4
Project Number:	665.0008.00815
Date:	20-Jul-2022
Drawn by:	NT

- New Wambo Model Boundary
- NWC Diversion
- Named Watercourse
- Mining Lease
- Whybrow Seam Extent (Layer 7)
- Proposed LW24-26 Layout
- Existing/Approved Underground Development
- Approved Open Cut Mining

Groundwater Level (mAHD)

300 - -280	-160- -140	-20 - 0
-280 - -260	-140 - -120	0 - 20
-260 - -240	-120 - -100	20 - 40
-240 - -220	-100 - -80	40 - 60
-220 - -200	-80 - -60	60 - 80
-200 - -180	-60 - -40	80 - 100
-180 - -160	-40 - -20	100 - 120

Drawdown (m)

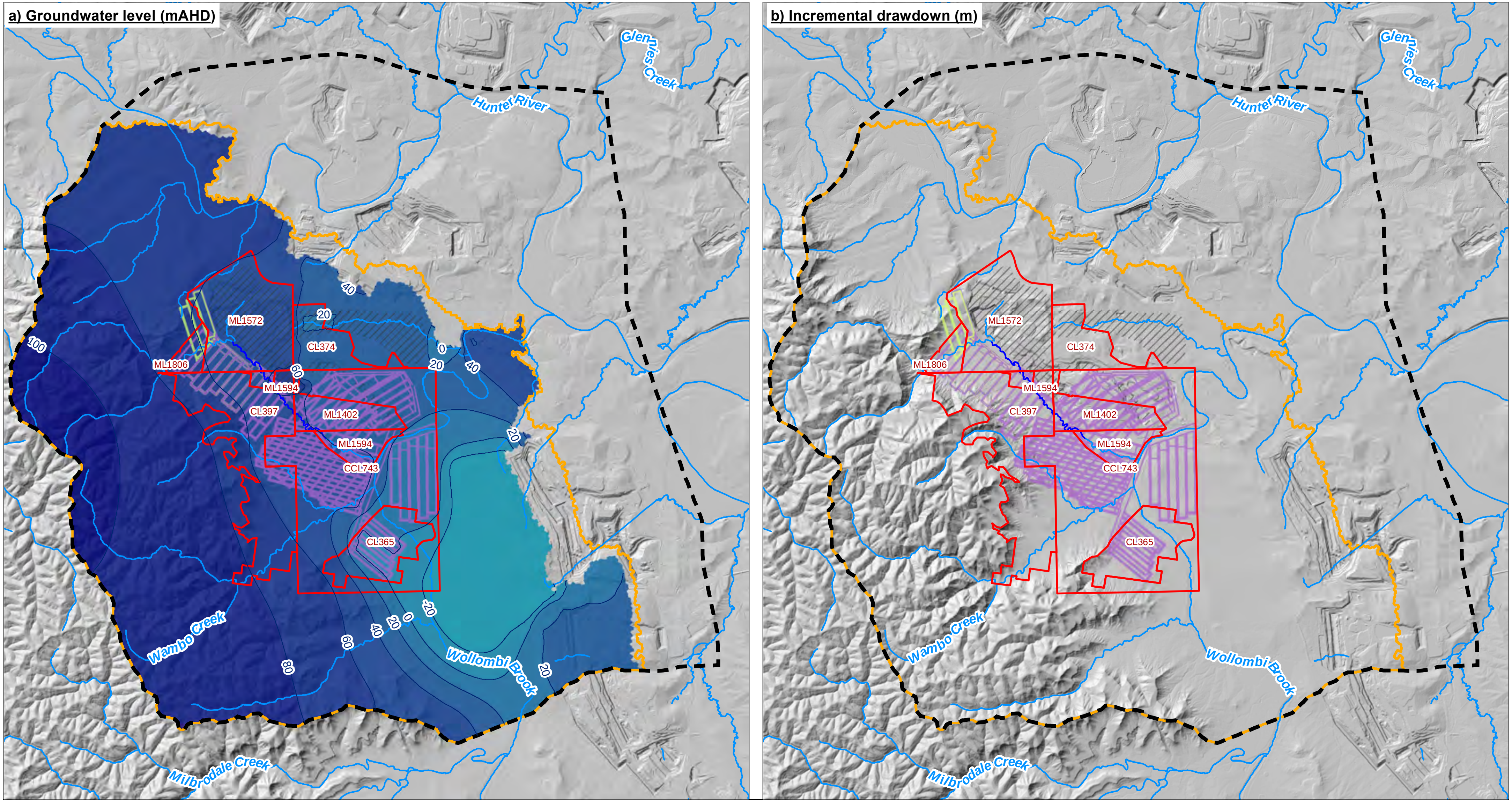
0 - 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 400
10 - 20	

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Predicted Whybrow Seam (layer 7) groundwater level (a) and incremental drawdown (b) – post mining recovery

FIGURE 6-4

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_6_4_Pred_Layer_7_GWL_IncDDN_End2400_revA.mxd



0 2.5 5 km

Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:175,000 at A4
Project Number:	665.0008.00815
Date:	19-Jul-2022
Drawn by:	NT

SLR

New Wambo Model Boundary
NWC Diversion
Named Watercourse
Mining Lease
Arrowfield Seam Extent (Layer 17)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

Groundwater Level (mAHD)

300 - -280	-160- -140	-20 - 0
-280 - -260	-140 - -120	0 - 20
-260 - -240	-120 - -100	20 - 40
-240 - -220	-100 - -80	40 - 60
-220 - -200	-80 - -60	60 - 80
-200 - -180	-60 - -40	80 - 100
-180 - -160	-40 - -20	100 - 120

Drawdown (m)

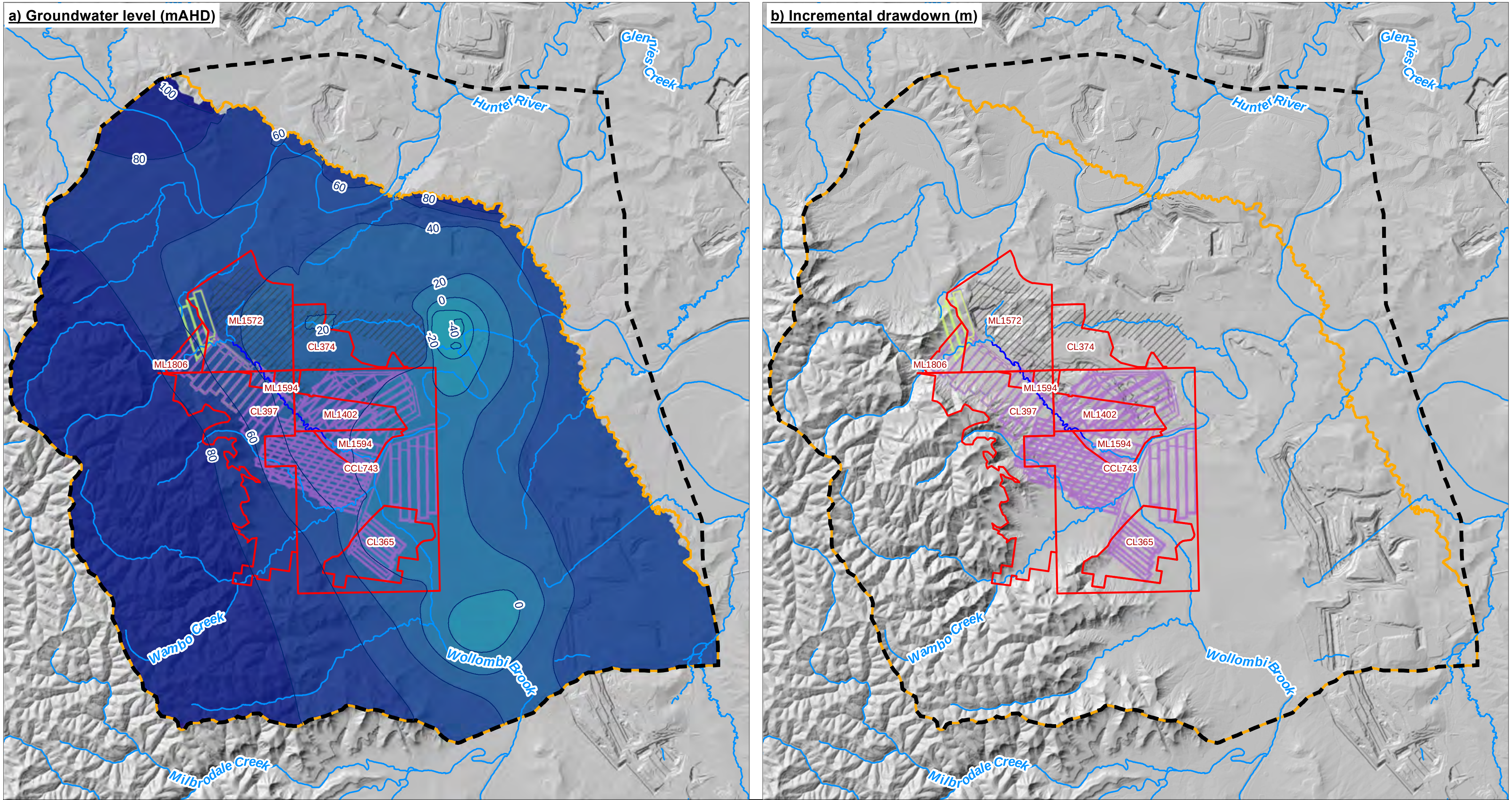
0 - 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 400
10 - 20	

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Predicted Arrowfield Seam (layer 17) groundwater level (a) and incremental drawdown (b) – post mining recovery

FIGURE 6-5

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_6_5_Pred_Layer_17_GWL_IncDDN_End2400_revA.mxd



Coordinate System:	GDA 1994 MGA Zone 56
Scale:	1:175,000 at A4
Project Number:	665.0008.00815
Date:	20-Jul-2022
Drawn by:	NT

0 2.5 5 km

SLR

New Wambo Model Boundary
NWC Diversion
Named Watercourse
Mining Lease
Vaux Seam Extent (Layer 27)
Proposed LW24-26 Layout
Existing/Approved Underground Development
Approved Open Cut Mining

Groundwater Level (mAHD)

300 - -280	-160- -140	-20 - 0
-280 - -260	-140 - -120	0 - 20
-260 - -240	-120 - -100	20 - 40
-240 - -220	-100 - -80	40 - 60
-220 - -200	-80 - -60	60 - 80
-200 - -180	-60 - -40	80 - 100
-180 - -160	-40 - -20	100 - 120

Drawdown (m)

0 - 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 400
10 - 20	

WAMBO LONGWALLS 24-26 MODIFICATION GROUNDWATER MODELLING TECHNICAL REPORT

Predicted Vaux Seam (layer 27) groundwater level (a) and incremental drawdown (b) – post mining recovery

FIGURE 6-6

H:\Projects-SLR\660-SrvWOL\660-WOL\665.10008 Wambo Groundwater Study\06 SLR Data\01 CADGIS\ArcGIS\SLR66510008_GWMT_6_6_Pred_Layer_27_GWL_IncDDN_End2400_revA.mxd

6.1.2 Post mining influence on alluvium

Over the extent of alluvium near Wambo during the prediction period (2020-2041), the model predicts a low magnitude, short-term decrease in leakage of water from the North Wambo Creek, Wambo Creek and Wollombi Brook alluvium due to the Modification (from 2023, peaking 2029-2031), before this effect declines to the end of mining (**Section 4.6.1**). There is negligible effect predicted for the Hunter River alluvium due to the Modification.

Post mining, there is no long-term predicted effect on alluvial flux due to the modification compared to approved mining (**Figure 6-7**). Temporary increases in mining induced alluvial flux (more impact) change are predicted to occur in North Wambo Creek, Wambo Creek, Hunter River and Wollombi Brook alluvium. These changes are predicted to peak approximately 20-30 years post mining and are likely related to a slight delay in the timing of recovery above South Wambo Project longwalls in the modification scenario compared to the approved. Woodlands Hill and Arrowfield Seam workings are scheduled to finish two years earlier and five months earlier respectively in the approved scenario.

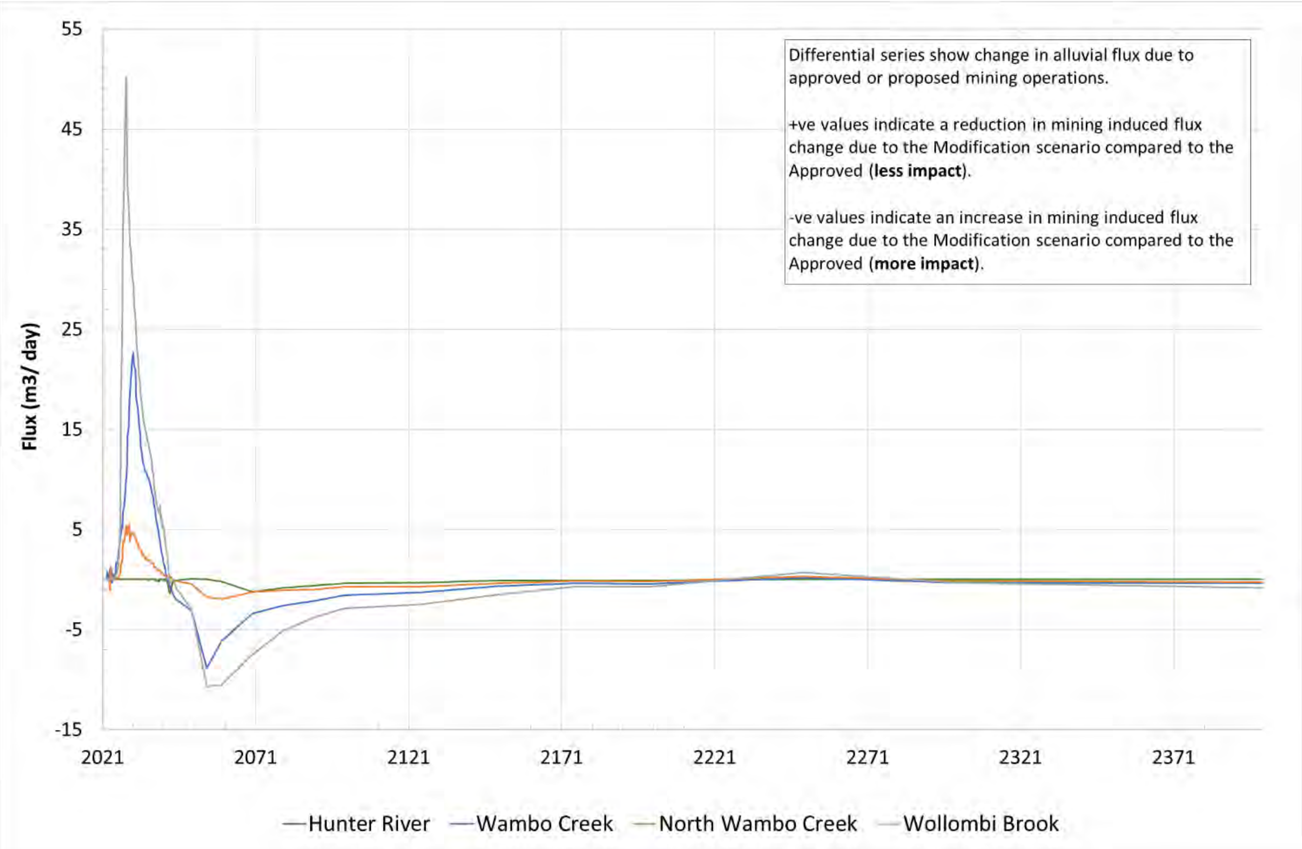


Figure 6-7 Post mining incremental alluvial flux change between Modified and Approved scenarios

6.1.3 Post mining influence on surface water

Similar to post mining predictions for alluvial fluxes (see **Section 6.1.2**), the Modification is not predicted to cause any long-term decrease of baseflow to or increase in leakage from watercourses near Wambo (**Figure 6-8**). A temporary decrease in net flux post mining (more predicted impact) is predicted for Wambo Creek and Wollombi Brook and the Hunter River, which is likely related to recovery above South Wambo Project mine occurring slightly later in the modification scenario due to scheduling.

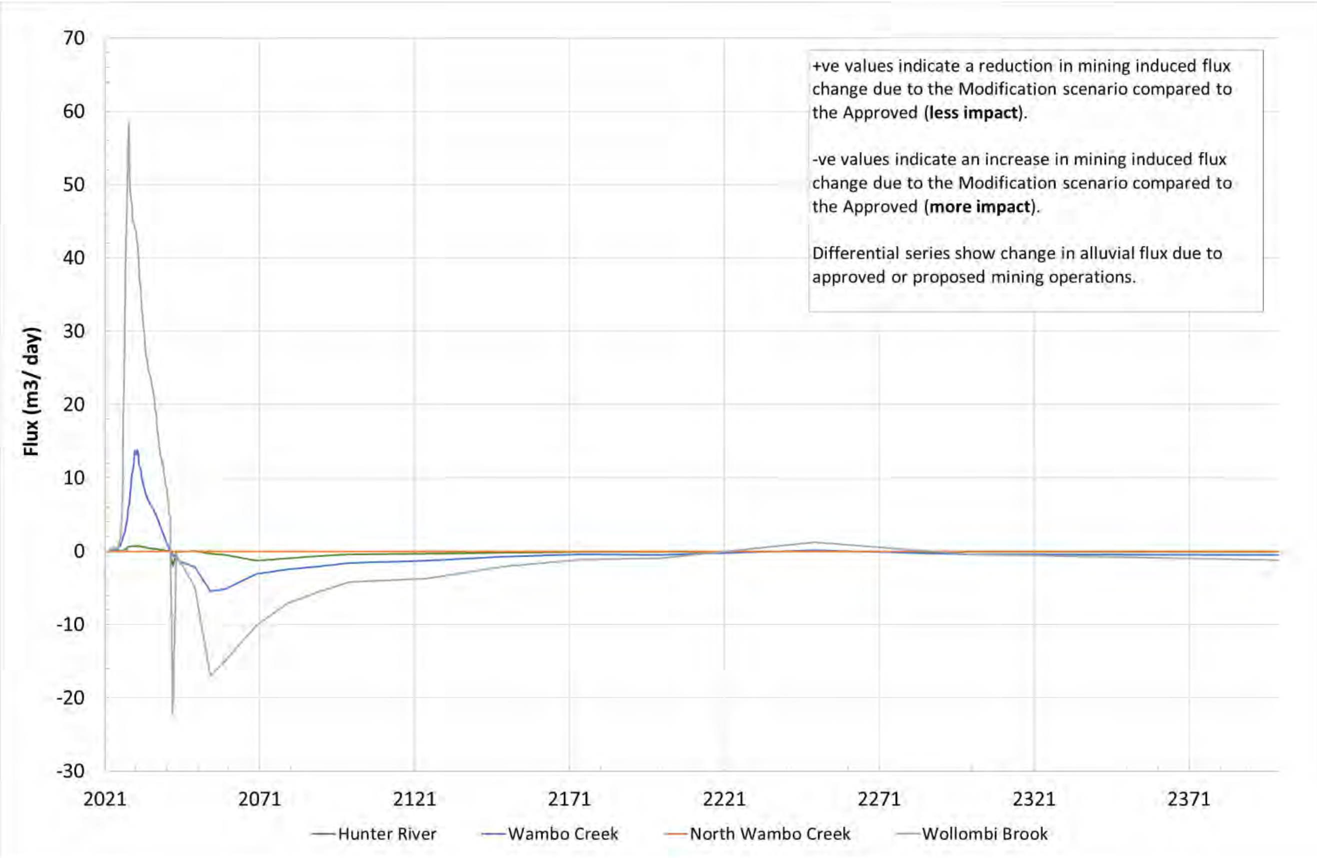


Figure 6-8 Post mining incremental RIV flux change between Modified and Approved scenarios

7 Model confidence level classification

The groundwater modelling was conducted in accordance with the Australian Groundwater Modelling Guidelines (Barnett *et al*., 2012), the MDBC Groundwater Flow Modelling Guideline (MDBC, 2001) and the released IESC Explanatory Note for Uncertainty Analysis (Middlemis and Peeters, 2018). These are mostly generic guides and do not include specific guidelines on special applications, such as underground coal mine modelling.

The Australian Groundwater Modelling Guidelines has replaced the model complexity classification of the previous MDBC Groundwater Flow Modelling Guideline by a "model confidence level" (Class 1, Class 2, or Class 3 in order of increasing confidence) typically depending on:

- Available data (and the accuracy of that data) for the conceptualisation, design, and construction.
- Calibration procedures that are undertaken during model development.
- Consistency between the calibration and predictive analysis.
- Level of stresses applied in predictive models.

It is generally expected that a model confidence level of Class 2 is required for mining environmental impact assessment. **Table 7-1** (based on Table 2.1, Barnett *et al*., 2012) summarises the classification criteria and shows a scoring system allowing model classification. The groundwater model developed for this Groundwater Assessment may be classified as primarily Class 2 (effectively “medium confidence”) with some items meeting the higher Class 3 criteria, and therefore the model is considered fit for purpose for this Project context.

Table 7-1 Groundwater model classification table

Class	Data	Calibration	Prediction	Indicators	Total
1	Not much. Spares. **Not metered usage.** Remote climate data.	Not Possible. Large error statistics. Inadequate data spread. Targets incompatible with model purpose.	Timeframe>>calibration. Long stress periods. Transient prediction but steady state calibration. Bad verification.	Timeframe>10x. Stresses>5x. Mass balance>1% (or single 5%). Properties<>Field. Bad discretisation. No review.	
Count	1	0	0	0	**1**
2	**Some.** **Poor coverage**. Some usage info. Baseflow estimates.	**Partial performance.** Long-term trends wrong. Short time record. Weak seasonal replication. No use of targets compatible with model purpose.	Timeframe>calibration. Long stress periods. New stresses not in calibration. Poor verification.	**Timeframe=3-10x.** **Stresses=2-5x.** **Mass balance<1%.** **Properties<>Field measurements.** Some key coarse discretisation. **Reviewed by hydrogeologist.**	
Count	2	1	0	5	**8**
3	Lots. Good aquifer geometry. Good usage info. **Local climate info.** **K measurements** **Hi –res DEM.**	Good performance stats. Long-term trends replicated. **Seasonal fluctuations OK.** **Present day data targets.** **Head and flux targets.**	**Timeframe ~calibration.** Similar stress periods. **Similar stresses to those in calibration.** Steady state prediction consistent with steady state calibration. Good verification.	Timeframe<3x. Stresses<2x. **Mass balance<0.5%** Properties ~Field measurements. **No key coarse discretisation.** **Reviewed by modeller.**	
Count	3	3	2	3	**10**

8 Groundwater model and data limitations

The IESC Uncertainty analysis – *Guidance for groundwater modelling within a risk management framework* (2018) also identifies four key sources of scientific uncertainty affecting groundwater model simulations:

- Structural / conceptual.
- Parameterisation.
- Measurement error.
- Scenario uncertainties.

These four sources of scientific uncertainty have been qualitatively assessed with regards key aspects of the groundwater model, as presented in **Table 8-1**.

Overall, the model captures depressurisation due to active mining. The model is numerically stable with no mass balance error. The model shows a good fit between observed and modelled groundwater levels (see **Section 3.2**). A depth dependence function was used for hydraulic conductivity, with the calibrated values showing a good fit to observed data as presented in **Section 3.4**. Overall, the model is considered fit for purpose to achieve the objectives outlined in **Section 1** based on the data provided and the project timeframe.

In case of future use of the model, updates could be conducted to further refine the model if it was deemed that an increase in model confidence level was required, but the applicability of this would be dependent on the purpose of the future modelling and availability of data to inform future changes. As it stands, the current model is deemed fit for purpose for the Project impact assessment.

Table 8-1 Groundwater model and data limitations

Type	Part	Status	Comment
Structural/ Conceptual	Grid and Model Extent	Fit for purpose	The model has an unstructured Voronoi grid that includes detailed cell refinement around site, neighbouring mines and along drainage features.
	Layers	Fit for purpose	Top of layer 1 incorporates site LiDAR data
		Fit for purpose	Representation of alluvium/ regolith based on CSIRO (2015) Regolith mapping and refined based on site drill data.
	Conceptualisation – Geological Structure	Fit for purpose	The local structure of the geology is based on detailed data at site (Wambo and United geology model), and regional model geometry (outside of site) interpolated based on neighbouring mines geology models (HVO and MTW) and geological mapping. Geophysical and geological surveys across the Project Area have identified some faulting in the Wambo and United areas. However, there is no clear evidence in observed water levels near the faults to suggest that those faults exist and/or act as barrier or conduit to flow near the proposed SBX LW24-26 layout. Therefore, no faults have been included within the Project area in the model other than through layer displacements from the site geological model.
	Conceptualisation – GDEs	Fit for purpose, future improvements possible if new data collected	The Groundwater Dependent Ecosystems Atlas (BOM) was used to inform groundwater planning and management. This data has supplemented previous work investigating known GDEs (location and interaction) at Wambo (Hunter Eco, 2019 and HydroSimulations, 2019), with both sources considered and incorporated in this assessment.
	Conceptualisation – Surface Water Groundwater Interactions	Fit for purpose	The Permian coal measures outcrop with a northwest to southeast strike along the site. The structure of the coal seams was checked to ensure it matches mapped and site modelled geology. The predictions of drawdown adjacent to mining was checked and the model shows a good fit between modelled and observed trends.

Type	Part	Status	Comment
	Conceptualisation – Saturated Extent of Alluvium and Regolith	Fit for purpose	The established monitoring network within identified alluvium was used to inform the saturated extent of alluvium locally at site and for calibration targets. The model slightly under or over-predicts groundwater levels in alluvium, but generally matches climatic trends and is predicted to be within 10 m of observed levels. For the extent alluvium in the vicinity of the Project Area (i.e., alluvium along Wambo and North Wambo Creek), regional geological mapping, site geophysics and the results of drilling investigations were used. Any additional data or study on alluvium extent and thickness at Wambo and United should be reviewed and captured (where relevant) in future updates of the model. Such improvements are not deemed required for the Project impact assessment however.
Parameterisation	Hydraulic Conductivity – Depth Dependence	Fit for purpose, future improvements possible	Field testing of hydraulic conductivity (horizontal and to a lesser extent vertical) has been conducted in the area. Hydraulic conductivity test results from the other sites within the model domain were also considered. The data shows a general decline in hydraulic conductivity with depth that is replicated in the model. Further conductivity tests and measurements of storage properties can improve model calibration and refine model predictions but are not deemed required for the Project impact assessment.
	Spoil Properties	Fit for purpose, future improvements possible	Limited site-specific data is available for the spoil. Spoil properties were adopted using the previous studies.
	Rivers	Fit for purpose, future improvements possible	Stage height in ephemeral creeks (North Wambo Creek, Wambo Creek and Stony Creek) is changed temporally in the historical calibration model based on observed levels, and a rainfall-flow relationship where flow observations were not available, while long term annual average stage height ('0' in ephemeral creeks) was used during the prediction model. Observed stage heights from government stream gauges were used to assign the stage heights at the Hunter River and Wollombi Brook. Other watercourses within and in the vicinity of the Project Area are considered minor ephemeral watercourses, only flow briefly after rainfall, and have limited flow observation data. Therefore, river stage height of zero was assigned to these watercourses in the model. Additional measurements of flow rates and stage height in the watercourses could help with improving the model calibration and refining the model predictions but are not deemed required for the Project impact assessment.

Type	Part	Status	Comment
	Recharge	Fit for purpose	Recharge zonation is based on mapped surface geology and calibrated recharge rates.
Measurement Error	Observation Data Quality	Fit for purpose	Bore logs and construction details available for most site bores, and long-term site water level data available for various units.
	Landholder Bore Data Quality	Fit for purpose	Impacts on registered landholder bores are influenced by the assumptions of the bore design, target geology and use.
	Temporal spread	Fit for purpose	Timeseries water level data from the site as well as the neighbouring mines (HVO and MTW) for the alluvium and Permian coal measures.
Scenario Uncertainties Future stresses/ conditions	Calibration	Fit for purpose	Transient warm-up (1970-2003) and transient (2003 to 2021) calibration model set up and a depth dependence function used and calibration to water levels conducted using automated (PEST) and manual methods.
	Predictive	Fit for purpose	Model captures approved and modified open cut mining at Wambo. The model also includes future mining at HVO and MTW mainly based on publicly available data. The actual future mine progression for these sites may vary.
	Sensitivity and uncertainty	Fit for purpose	Uncertainty analysis has been conducted by stochastic modelling using an adapted Monte Carlo method with modern software packages. The Latin Hypercube Sampling (LHS) method was used to create random realisations from parameter distributions and PEST++ was used to orchestrate the model runs. The uncertainty analysis quantified the variability in predictions with changes in maximum predicted drawdowns, mine inflows, impact on alluvium flow and impacts on surface water flow.

9 Conclusions

The numerical groundwater model developed for the Project successfully achieved the modelling objectives, as outlined in **Section 1**. Model calibration statistics are within suggested guidelines (MDBC, 2001) and mass balance errors remain low through the model calibration and predictive modelling. Model construction considers all available data, including the current site mine plan and site geological model for the Project Area.

The uncertainty analysis has demonstrated a low likelihood for the Project to impact on alluvial water levels, with drawdown to layers mostly contained within the Project Area. The model serves as a suitable representation of possible transient groundwater conditions within the Study Area, over the life of the Project; however, the uncertainty in predictions should be acknowledged.

The main outcome of this study is that there is negligible difference between the impacts predicted for the Approved mine plan and the Modification mine plan.

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ATTACHMENT A

Calibration Residuals

ID	Owner	Easting	Northing	Model Layer	Avg	Min	Max	Count
4032P	HVO	308609	6402945	1	-0.4	-1.6	0.0	28
4033P	HVO	308877	6402939	1	-1.9	-1.9	-1.9	1
4034P	HVO	308239	6402959	1	0.6	-1.2	1.1	29
4035P	HVO	308386	6402778	1	-1.3	-1.4	-1.2	7
4036C	HVO	308272	6402688	26	18.3	15.3	22.0	9
4037P	HVO	308277	6402702	1	-0.3	-1.3	0.2	28
4038C	HVO	308502	6403116	1	-1.4	-1.7	0.2	7
4040P	HVO	308675	6402724	1	-0.5	-1.8	-0.1	27
4051C	HVO	308664	6402721	26	8.6	5.2	11.8	16
4052P	HVO	307924	6402680	1	-1.0	-1.1	-0.9	5
4053P	HVO	308112	6402680	1	-1.0	-1.2	0.1	8
4113P	HVO	310729	6401304	24	3.0	-5.0	8.1	7
4116P	HVO	310681	6400978	24	-2.3	-6.6	-0.3	24
4117P	HVO	310670	6400980	24	8.5	-3.3	12.1	21
4119P	HVO	312501	6402048	28	1.5	-0.1	2.6	23
Apple	HVO	315491	6394639	1	-0.4	-1.8	0.7	68
B334_BF	HVO	316684	6394088	19	6.8	1.1	13.0	20
B425_WDH	HVO	316010	6395024	15	14.9	12.2	18.6	13
B631_BF	HVO	316425	6394319	19	-10.3	-17.7	5.7	19
B631_WDH	HVO	316424	6394319	15	-1.6	-2.5	-0.1	15
B925_BF	HVO	315921	6394604	19	8.0	-3.6	29.0	20
BC1a	HVO	312421	6400872	28	5.4	1.5	7.3	48
BH3	Wambo	313399	6394644	15	-32.9	-35.3	-28.5	3
BUNC13	HVO	313145	6401730	1	-16.0	-16.0	-16.0	1
BUNC39A	HVO	313500	6401823	28	6.6	6.2	6.9	8
BUNC39B	HVO	313500	6401823	1	10.8	10.1	12.2	7
BUNC44D	HVO	313601	6401922	28	4.7	3.5	5.4	12
BUNC45A	HVO	313667	6402055	1	8.1	6.2	9.5	35
BUNC45D	HVO	313677	6402060	28	8.8	6.2	10.2	36
BUNC46D	HVO	313328	6401782	28	1.4	-3.5	7.0	9
BZ1_1	HVO	311472	6400483	24	-6.5	-8.7	-4.2	47
BZ1_3	HVO	311472	6400483	25	10.4	-1.1	21.3	48
BZ2A_1	HVO	311671	6400561	27	14.4	-15.2	22.9	47
BZ2A_2	HVO	311671	6400561	26	3.5	2.2	11.0	12
BZ3_1	HVO	311840	6400640	26	-3.2	-4.9	13.4	50
BZ3_2	HVO	311840	6400640	2	-2.0	-4.3	2.5	24
BZ3_3	HVO	311840	6400640	27	15.5	-3.1	26.8	44
BZ4A_1	HVO	312029	6400705	26	4.9	4.0	5.7	10
BZ4A_2	HVO	312029	6400705	26	16.7	8.5	22.4	38

ID	Owner	Easting	Northing	Model Layer	Avg	Min	Max	Count
BZ8_2	HVO	312685	6401010	2	16.2	14.4	17.8	38
BZ8_3	HVO	312685	6401010	28	15.7	12.7	17.7	10
C1_WJ	HVO	317142	6400707	28	4.2	3.9	4.7	17
C122_WDH	HVO	315501	6395007	15	1.2	0.8	1.5	18
C130_AF	HVO	316400	6394916	17	-9.2	-12.8	-6.4	18
C130_AL	HVO	316400	6394916	2	-3.1	-4.7	-2.6	29
C130_BF	HVO	316400	6394916	19	5.1	-5.1	25.2	19
C130_WDH	HVO	316400	6394916	15	-3.7	-6.8	-2.8	17
C317_BF	HVO	315054	6395007	19	9.1	-0.2	28.0	18
C317_WDH	HVO	315054	6395007	15	2.5	0.8	21.7	19
C613_BF	HVO	314688	6395243	19	-2.1	-7.1	3.0	18
C621_BF	HVO	315421	6395321	19	11.6	3.1	25.3	20
C630_BF	HVO	316378	6395306	19	5.3	-6.0	17.7	18
C809	HVO	314207	6395493	15	-1.9	-2.8	-0.1	18
C919_AL	HVO	315192	6395655	1	0.0	-0.5	0.5	19
CFW55R	HVO	310439	6402180	1	1.3	0.3	2.6	95
CFW56A	HVO	310333	6402255	1	1.7	1.6	1.7	3
CFW57	HVO	310084	6402053	1	-0.6	-1.4	0.0	92
CFW59	HVO	310245	6402370	2	1.8	-0.2	3.2	46
CGW1	HVO	309930	6402690	1	2.1	1.1	3.6	54
CGW2	HVO	310156	6402685	1	2.9	2.2	3.8	41
CGW3	HVO	310360	6402679	1	4.2	3.6	4.8	18
CGW32	HVO	308598	6404872	28	-20.3	-22.9	-18.1	34
CGW39	HVO	308566	6403694	1	0.5	-2.5	2.1	42
CGW43	HVO	310074	6402959	1	8.6	3.7	19.7	5
CGW45	HVO	308042	6403349	2	-4.0	-10.7	9.0	14
CGW45a	HVO	308044	6403349	2	4.0	0.6	6.1	47
CGW46	HVO	308413	6403276	2	0.9	0.2	1.4	22
CGW46a	HVO	308415	6403276	2	-0.8	-2.9	1.0	69
CGW47	HVO	308729	6403406	2	-0.8	-2.4	1.5	69
CGW47a	HVO	308731	6403405	29	6.1	-9.9	20.9	43
CGW48	HVO	308418	6402919	27	8.2	-1.0	30.8	47
CGW48a	HVO	308418	6402919	1	-0.4	-1.3	0.6	39
CGW49	HVO	308778	6403098	2	-1.1	-2.5	0.2	91
CGW5	HVO	309666	6402712	1	1.2	-6.6	3.3	44
CGW51a	HVO	310149	6402419	2	2.3	1.0	4.6	104
CGW52	HVO	309906	6402255	28	8.2	-3.4	22.0	82
CGW52a	HVO	309902	6402249	1	-0.8	-3.1	0.0	112
CGW53	HVO	309606	6402333	28	8.2	-1.7	21.2	79
CGW53a	HVO	309606	6402333	1	-0.6	-1.5	0.2	94

ID	Owner	Easting	Northing	Model Layer	Avg	Min	Max	Count
CGW54	HVO	310196	6402159	27	5.1	4.3	6.9	27
CGW54a	HVO	310196	6402159	1	-0.2	-1.4	0.6	127
CGW55a	HVO	309840	6402457	1	0.4	-0.8	1.1	95
CGW6	HVO	308756	6402770	1	-1.3	-2.5	-0.2	81
CHPZ10A	HVO	313334	6402297	1	0.0	-0.8	0.6	35
CHPZ11A	HVO	313429	6402129	1	-0.4	-1.6	2.3	18
CHPZ12A	HVO	313238	6402013	1	0.2	-0.7	0.8	36
CHPZ12D	HVO	313236	6402019	2	0.3	-1.3	0.9	36
CHPZ13A	HVO	313009	6401801	1	-0.5	-2.0	-0.1	14
CHPZ13D	HVO	313014	6401801	28	1.4	0.1	1.8	14
CHPZ14A	HVO	312883	6401639	1	2.5	1.1	6.2	17
CHPZ14D	HVO	312891	6401639	28	3.2	1.1	4.7	17
CHPZ1A	HVO	312820	6401697	1	0.0	-0.9	0.5	35
CHPZ2A	HVO	312941	6401539	28	3.5	2.5	4.3	32
CHPZ3A	HVO	313086	6401756	1	0.4	-0.6	1.8	34
CHPZ3D	HVO	313094	6401756	28	3.2	2.1	4.0	34
CHPZ4A	HVO	312904	6402123	1	-0.1	-1.6	0.4	34
CHPZ5A	HVO	312926	6401838	1	-0.4	-0.8	-0.2	13
CHPZ7A	HVO	313600	6402238	1	-0.3	-0.7	0.5	11
CHPZ8A	HVO	313503	6402051	1	0.2	-0.7	0.8	19
CHPZ8D	HVO	313508	6402047	28	1.5	-0.1	2.6	34
CHPZ9A	HVO	313538	6402383	1	-0.5	-2.2	2.5	12
D010_BF	HVO	314355	6395687	19	0.8	-16.7	4.1	19
D010_GM	HVO	314355	6395687	14	-1.0	-2.6	16.7	19
D010_WDH	HVO	314355	6395687	15	-0.7	-1.3	-0.1	19
D2_WH	HVO	316847	6399926	28	8.2	8.0	8.5	6
D214_BF	HVO	314768	6395831	19	9.3	6.0	12.3	19
D317_AL	HVO	315044	6396018	1	-2.8	-3.6	-2.1	3
D317_BF	HVO	315043	6396019	19	15.2	11.8	18.6	18
D317_WDH	HVO	315044	6396018	16	1.0	-2.0	12.9	5
D406_AF	HVO	313931	6396074	17	3.8	1.0	6.6	16
D406_BF	HVO	313931	6396074	19	4.7	-0.6	8.1	20
D406_WDH	HVO	313931	6396074	16	4.3	4.3	4.3	2
D510_AF	HVO	314380	6396141	17	14.8	13.1	17.0	19
D510_BF	HVO	314380	6396141	19	8.8	6.1	16.0	18
D612_AF	HVO	314524	6396314	17	5.7	4.1	6.7	19
D612_BF	HVO	314524	6396314	19	10.1	8.1	11.0	19
D807_BF	HVO	314002	6396484	19	5.5	-1.8	9.5	17
DM1	HVO	311778	6405164	28	2.1	-0.4	3.2	23
DM3	HVO	311971	6403310	28	1.2	-9.0	3.1	64

ID	Owner	Easting	Northing	Model Layer	Avg	Min	Max	Count
DM4	HVO	312222	6401418	28	8.2	4.9	11.1	58
DM6_DB	HVO	310796	6400980	24	0.1	-6.5	11.5	3
DM7	HVO	311136	6400961	26	5.3	-2.6	9.4	10
DM9	HVO	310284	6401095	24	-2.1	-2.6	-1.9	3
F15	HVO	316607	6398247	27	-4.1	-4.7	-3.2	9
G3	MTW	317786	6385251	9	5.0	-30.0	24.4	24
GA3	HVO	310159	6400876	1	1.3	0.0	2.1	49
GW_9706	MTW	322404	6387589	1	-2.1	-2.9	-0.9	33
GW_9707	MTW	322319	6387569	1	0.0	-1.3	2.3	33
GW_9708	MTW	322158	6387209	2	0.4	-1.3	1.3	33
GW_9709	MTW	322251	6388026	2	8.0	6.2	9.3	32
GW02	Wambo	309109	6389680	1	-0.7	-2.7	1.2	99
GW08	Wambo	311793	6392266	1	-0.2	-3.0	4.3	70
GW09	Wambo	311643	6392563	1	-0.2	-3.4	4.0	52
GW11	Wambo	309228	6389699	1	-1.2	-3.3	1.8	102
GW12	Wambo	309841	6391056	2	-17.1	-20.9	-14.9	17
GW13	Wambo	313810	6388990	2	-5.0	-5.8	2.0	69
GW15	Wambo	313164	6392807	2	1.5	0.5	3.0	73
GW16	Wambo	306639	6396174	1	0.7	-3.9	3.9	69
GW17	Wambo	306885	6396081	1	0.5	-3.5	2.2	68
GW18	Wambo	310061	6393206	1	3.8	3.8	3.8	1
GW22	Wambo	311335	6389535	4	5.4	4.5	6.5	61
GW23	Wambo	305791	6395668	2	0.5	-1.4	2.1	14
GW24	Wambo	305789	6395670	1	2.0	-0.2	3.9	26
GW25	Wambo	305299	6395288	1	-6.3	-10.2	1.2	11
GW26	Wambo	305297	6395291	2	-5.4	-7.3	3.7	27
GW27	Wambo	305736	6395614	1	-1.9	-3.3	0.2	10
GW28	Wambo	306008	6395769	1	-1.3	-3.4	0.3	11
GW30	Wambo	306076	6395716	1	0.8	-0.5	2.2	11
GW32	Wambo	306393	6395828	1	-2.2	-3.2	-0.7	6
GW33	Wambo	306592	6395946	1	-2.2	-3.1	-0.6	6
GW35	Wambo	306988	6396012	1	-3.0	-6.0	-1.0	7
GW9701	HVO	315901	6401798	28	10.8	10.8	10.9	2
GW9702	HVO	316436	6401479	28	3.5	3.5	3.6	2
GW9710	HVO	316700	6400486	28	-3.7	-4.2	-3.2	2
GW98_1	MTW	322188	6387032	1	-5.3	-6.2	-4.1	33
GW98_2	MTW	322669	6387462	2	-7.9	-9.2	-7.3	33
HG1	HVO	312390	6400882	28	0.4	0.2	0.6	3
HG2	HVO	312469	6400886	26	0.7	0.3	0.9	25
HG2A	HVO	312469	6400886	26	13.8	13.5	14.6	25

ID	Owner	Easting	Northing	Model Layer	Avg	Min	Max	Count
HG3	HVO	312541	6400940	28	1.0	0.8	1.1	2
Hunter1_1	Wambo	307454	6400351	18	0.6	0.1	0.7	12
Hunter1_2	Wambo	307454	6400351	20	0.7	0.5	0.8	9
Hunter1_3	Wambo	307454	6400351	22	3.5	2.5	4.2	10
Hunter1_4	Wambo	307454	6400351	24	2.3	1.6	2.6	7
Hunter2_1	Wambo	306533	6400050	16	-1.0	-1.1	-0.7	15
Hunter2_2	Wambo	306533	6400050	22	-0.2	-0.6	-0.1	15
Hunter2_3	Wambo	306533	6400050	26	1.5	0.6	2.0	15
HV3	HVO	310776	6400546	1	11.3	5.3	18.4	5
MB14HVO01	HVO	310587	6401003	24	10.1	6.6	13.0	22
MB14HVO02	HVO	310469	6401001	24	10.4	6.8	13.3	22
MB14HVO03	HVO	311387	6400950	26	14.7	12.3	16.5	22
MB14HVO04	HVO	311491	6401392	26	15.4	13.6	16.8	22
MB14HVO05	HVO	310675	6401127	24	9.6	6.0	12.6	22
MB15MTW01D	MTW	315910	6385604	1	3.3	3.0	3.8	10
MB15MTW01S	MTW	315909	6385605	1	3.2	2.9	3.5	10
MB15MTW02D	MTW	313823	6387219	1	1.9	1.7	2.2	10
MB15MTW02S	MTW	313823	6387224	1	2.0	1.6	2.4	10
MB15MTW03	MTW	313722	6388917	1	0.2	-0.2	0.5	10
MBW01	MTW	314379	6386796	1	1.9	1.9	2.0	10
MBW02	MTW	314373	6386798	4	3.7	2.6	4.2	9
MBW03	MTW	314387	6386794	7	4.0	3.7	4.3	10
MBW04	MTW	314368	6386800	9	4.6	3.3	5.9	10
MTD605P	MTW	316279	6386156	5	-1.2	-1.7	-1.1	27
MTD614P	MTW	317259	6386175	6	7.9	7.1	9.4	26
MTD616P	MTW	316269	6387618	6	-5.6	-7.2	-4.9	27
N2_1	Wambo	308633	6393372	9	-29.5	-42.0	-18.2	63
N2_2	Wambo	308633	6393372	8	-30.8	-38.2	-19.4	63
N2_3	Wambo	308633	6393372	7	-20.7	-31.6	6.6	63
N2_4	Wambo	308633	6393372	5	35.0	31.0	38.6	20
N2_5	Wambo	308633	6393372	4	21.5	14.0	27.8	24
N3_1	Wambo	308313	6394574	9	21.7	10.2	27.4	10
N3_2	Wambo	308313	6394574	8	9.1	5.4	10.7	10
N3_4	Wambo	308313	6394574	6	-10.4	-13.2	-5.8	10
N3_5	Wambo	308313	6394574	5	21.5	14.7	25.3	27
N3_6	Wambo	308313	6394574	4	6.0	2.2	9.1	9
N5_1	Wambo	306753	6395960	9	-9.9	-20.0	-5.9	55

ID	Owner	Easting	Northing	Model Layer	Avg	Min	Max	Count
N5_2	Wambo	306753	6395960	8	-6.1	-12.2	1.8	59
N5_3	Wambo	306753	6395960	7	10.6	3.9	17.6	60
N5_4	Wambo	306753	6395960	5	11.6	9.7	17.6	61
OH1121	MTW	321902	6391030	30	8.6	8.3	8.8	33
OH1122_1	MTW	318545	6387886	13	-6.4	-7.9	-4.1	31
OH1122_2	MTW	318545	6387886	15	-0.1	-0.1	-0.1	1
OH1123_1	MTW	316967	6389501	15	-43.7	-54.5	-35.1	12
OH1123_2	MTW	316967	6389501	13	21.5	7.8	48.6	13
OH1123_3	MTW	316967	6389501	19	-79.2	-93.6	-56.7	13
OH1125_1	MTW	316511	6392875	13	12.6	8.4	19.0	33
OH1125_2	MTW	316511	6392875	13	10.1	10.1	10.1	1
OH1125_3	MTW	316511	6392875	16	-8.2	-14.7	1.3	33
OH1126	MTW	318586	6393387	27	4.0	2.5	7.1	33
OH1127	MTW	321444	6392097	29	8.5	7.7	8.8	33
OH1137	MTW	318266	6393377	27	-3.4	-4.8	-1.4	30
OH1138_1	MTW	317835	6393346	22	-11.1	-11.7	-10.5	47
OH1138_2	MTW	317835	6393346	24	-5.9	-6.6	-5.4	46
OH786	MTW	320542	6392674	1	-8.4	-10.7	-4.0	31
OH787	MTW	320982	6391921	1	8.3	8.2	8.4	33
OH788	MTW	321482	6390967	1	8.2	8.1	8.5	34
OH942	MTW	320536	6392622	1	-2.2	-2.6	-1.6	33
OH943	MTW	321476	6390963	1	8.1	8.0	8.4	28
OH944	MTW	321113	6391035	1	3.9	3.8	4.2	17
P1	United	312199	6395840	12	10.4	5.1	14.9	98
P102	Wambo	311207	6391187	1	-2.6	-2.6	-2.6	1
P106	Wambo	311515	6391083	1	2.7	-0.7	5.7	90
P109	Wambo	311215	6390764	1	1.1	-0.6	4.6	129
P11	Wambo	312728	6395462	12	13.4	7.5	17.4	45
P110	Wambo	311217	6390690	1	-1.1	-2.5	1.6	37
P111	Wambo	311300	6390760	1	1.9	-0.2	2.9	37
P114	Wambo	311205	6391286	2	1.3	-1.2	4.4	97
P116	Wambo	311509	6391293	1	-3.5	-5.0	-0.7	131
P117	Wambo	311508	6391394	1	1.6	0.3	3.0	11
P119	Wambo	311210	6390863	1	-1.8	-2.5	-0.3	14
P12	Wambo	313644	6394797	1	0.9	-0.3	2.0	65
P13	Wambo	313722	6394412	1	0.5	-0.8	1.0	64
P15	Wambo	313431	6394803	1	-1.3	-2.3	-0.7	61
P16	Wambo	313480	6394655	1	-0.9	-2.5	0.7	96
P17	Wambo	313376	6394631	1	-1.6	-2.6	-0.7	61
P18	Wambo	313503	6394512	1	-0.5	-1.2	0.5	61

ID	Owner	Easting	Northing	Model Layer	Avg	Min	Max	Count
P2	United	312403	6395552	14	-14.1	-43.3	2.3	82
P20	Wambo	313639	6394166	1	-0.2	-2.3	0.4	103
P200	Wambo	311586	6391431	2	11.5	10.8	12.7	13
P202	Wambo	311850	6391256	2	1.0	-3.3	2.6	129
P206	Wambo	311771	6391068	6	-5.8	-12.7	9.0	131
P207	Wambo	311851	6391069	5	0.4	0.1	1.2	14
P27	United	311344	6392810	1	0.0	-3.0	2.8	57
P28	United	311396	6392632	2	1.6	-2.9	7.8	65
P29	United	311820	6392560	6	9.7	-3.6	22.8	44
P3	United	313412	6395006	14	-3.9	-6.4	4.9	34
P301	Wambo	309311	6391425	1	0.0	-7.2	14.7	120
P307_1	Wambo	302941	6399995	3	4.0	2.2	4.7	17
P307_2	Wambo	302941	6399995	7	13.4	10.7	13.9	17
P307_3	Wambo	302941	6399995	9	12.5	8.2	13.6	17
P307_4	Wambo	302941	6399995	11	15.7	12.4	16.1	17
P311	Wambo	308064	6392255	3	-16.9	-20.0	-13.0	41
P315	Wambo	309091	6391852	1	-12.6	-21.5	-3.5	72
P316_2	Wambo	311252	6391128	2	9.3	8.1	10.1	28
P317_2	Wambo	307115	6394439	5	22.2	21.8	22.9	5
P317_3	Wambo	307115	6394439	7	-7.3	-30.4	15.7	2
P317_4	Wambo	307115	6394439	8	-6.1	-15.9	-2.9	5
P317_5	Wambo	307115	6394439	9	-17.9	-28.5	-14.7	5
P319_3	Wambo	311125	6391412	9	48.7	22.2	71.3	28
P319_4	Wambo	311125	6391412	14	-5.3	-5.7	-5.0	28
P32	Wambo	310735	6392842	1	1.2	-2.0	4.6	42
P320_1	Wambo	307573	6398890	23	-16.9	-18.8	-14.5	17
P320_2	Wambo	307573	6398890	27	-4.6	-5.1	-4.2	17
P320_3	Wambo	307573	6398890	29	6.5	5.2	7.0	17
P320_4	Wambo	307573	6398890	30	7.4	6.6	8.4	17
P320_5	Wambo	307573	6398890	30	8.0	6.8	9.0	17
P320_6	Wambo	307573	6398890	30	6.9	5.0	8.6	17
P321_2	Wambo	308000	6399499	23	-11.2	-13.3	-8.6	28
P321_3	Wambo	308000	6399499	27	1.6	0.1	3.8	28
P323_3	Wambo	309798	6393429	9	0.2	-19.4	9.7	19
P323_4	Wambo	309799	6393432	15	37.1	21.4	42.8	19
P323_5	Wambo	309799	6393432	17	19.9	-4.2	23.5	19
P324_3	Wambo	310471	6391984	9	78.2	71.1	84.1	10
P324_4	Wambo	310471	6391984	15	-25.1	-25.8	-23.9	13
P324_5	Wambo	310471	6391984	16	-24.7	-25.5	-23.7	13
P325_1	Wambo	312068	6390138	2	-3.6	-4.4	-2.6	21

ID	Owner	Easting	Northing	Model Layer	Avg	Min	Max	Count
P325_2	Wambo	312068	6390138	5	1.0	0.1	4.3	12
P325_5	Wambo	312068	6390138	11	-9.3	-11.7	-8.0	21
P325_6	Wambo	312068	6390138	15	0.7	0.1	1.1	21
P325_7	Wambo	312068	6390138	17	-9.2	-10.5	-8.8	21
P326_2	Wambo	310087	6392874	9	6.9	-2.3	17.0	15
P326_3	Wambo	310087	6392874	15	-13.2	-19.7	11.0	15
P326_4	Wambo	310087	6392874	17	-4.9	-10.8	1.1	15
P33_1	United	313757	6394659	15	8.6	2.0	18.8	89
P33_2	United	313757	6394659	14	9.5	3.9	13.4	99
P33_3	United	313757	6394659	14	-0.2	-4.1	3.0	99
P33_4	United	313757	6394659	12	3.0	-0.6	4.5	99
P33_5	United	313757	6394659	2	-2.2	-6.2	-0.9	99
P34_2	United	311768	6395634	13	19.8	13.6	21.6	111
P34_3	United	311768	6395634	17	-6.5	-18.9	17.6	111
P35_1	United	312086	6395627	17	12.8	-18.8	41.9	90
P35_2	United	312086	6395627	15	-8.9	-15.8	1.3	90
P35_3	United	312086	6395627	14	8.5	4.2	13.6	90
P408_1	Wambo	307000	6399500	21	-9.0	-9.5	-8.0	4
P408_2	Wambo	307000	6399500	24	0.4	-0.1	1.4	15
P408_3	Wambo	307000	6399500	26	3.9	2.4	4.7	15
P5	Wambo	309836	6394001	1	2.4	-1.7	6.4	25
P6	Wambo	309996	6393841	1	3.4	-13.4	10.5	94
PB01_AL	HVO	314754	6396026	1	0.1	-0.5	0.6	22
PNWU_08A	Wambo	310441	6390865	1	-0.3	-1.1	0.8	12
PNWU_08B	Wambo	310463	6390863	2	1.1	0.3	2.2	12
PZ1CH200	HVO	312646	6402256	1	-0.6	-2.1	-0.2	25
PZ2CH400	HVO	312635	6402051	1	-1.5	-7.1	0.4	26
PZ3CH800	HVO	312522	6401674	1	-0.4	-2.4	0.0	25
PZ4CH1380	HVO	312196	6401176	1	0.9	-0.6	1.3	25
PZ5CH1800	HVO	311852	6400928	1	-3.1	-4.7	0.3	25
PZ7D	MTW	314057	6392684	8	2.1	1.6	3.2	32
PZ7S	MTW	314055	6392671	1	1.8	1.3	2.3	32
PZ8D	MTW	317001	6385418	5	1.2	0.6	2.3	33
PZ8S	MTW	317002	6385411	1	0.7	0.4	1.0	33
PZ9D	MTW	317541	6385652	6	9.5	2.0	12.3	33
PZ9S	MTW	317542	6385642	1	0.6	0.1	1.3	30
SBX_GW01	Wambo	307010	6395886	5	25.5	22.8	28.3	2
SR001	HVO	319146	6394094	2	6.5	6.0	7.4	12
SR002	HVO	319079	6394620	29	8.3	6.6	9.3	12
SR003	HVO	318863	6394864	29	7.2	5.7	8.3	12

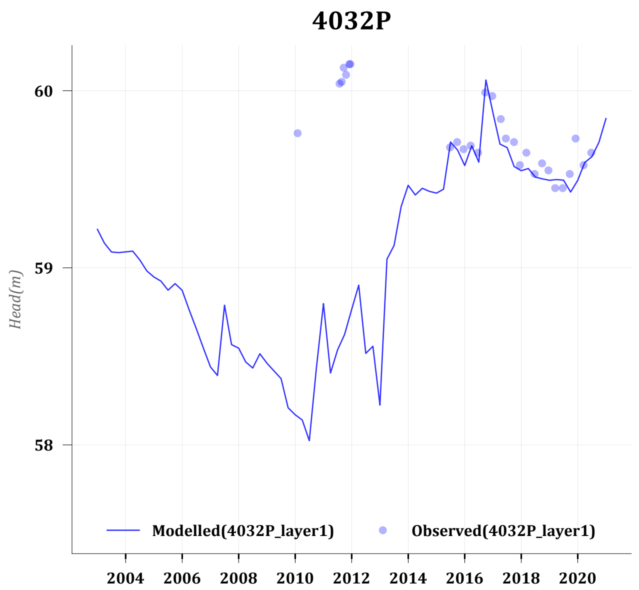
ID	Owner	Easting	Northing	Model Layer	Avg	Min	Max	Count
SR004	HVO	318994	6395506	29	8.2	6.6	9.3	12
SR005	HVO	318831	6396128	29	4.9	3.9	5.4	12
SR006	HVO	318555	6395732	29	6.0	5.1	6.5	12
SR008	HVO	319290	6395111	30	2.3	2.2	2.6	21
SR009	HVO	319338	6394746	30	1.6	1.4	1.9	21
SR010	HVO	317319	6395338	23	-12.1	-12.8	-11.3	21
SR011	HVO	317699	6394412	25	-7.4	-7.8	-6.9	21
SR012	HVO	318354	6393926	24	6.1	4.8	7.9	21
UG133_1	United	313297	6396177	14	-0.8	-2.0	-0.1	31
UG133_2	United	313297	6396177	17	19.6	14.8	21.2	92
UG133_4	United	313297	6396177	25	-23.2	-27.8	-20.7	91
UG133_5	United	313297	6396177	27	4.7	-0.1	8.7	92
UG133_6	United	313297	6396177	27	16.1	11.8	18.6	92
UG133_7	United	313297	6396177	29	18.6	12.8	24.2	92
UG135_1	United	313831	6396748	16	12.0	7.6	13.7	51
UG135_2	United	313831	6396748	23	-5.6	-6.4	-3.1	51
UG135_4	United	313831	6396748	27	10.8	8.3	14.2	51
UG135_5	United	313831	6396748	27	7.7	5.2	9.3	51
UG135_6	United	313831	6396748	29	10.2	8.8	11.9	51
UG136_3	United	313282	6397308	23	3.4	-0.9	6.3	104
UG136_4	United	313282	6397308	26	5.2	-0.3	11.9	104
UG136_5	United	313282	6397308	27	-1.6	-5.8	6.3	104
UG138_2	United	308517	6396181	14	18.1	12.9	23.0	34
UG138_4	United	308517	6396181	13	-3.4	-10.5	2.5	35
UG139_4	United	306665	6395173	16	11.1	9.6	12.0	68
UG139_5	United	306665	6395173	16	-14.9	-18.0	-11.7	68
UG139_7	United	306665	6395173	22	4.3	-2.8	18.7	40
UG147_3	United	311245	6397207	24	-4.0	-7.7	0.2	103
UG147_6	United	311245	6397207	27	-4.0	-12.6	3.5	102
UG166A_1	United	306488	6398076	13	6.5	3.4	8.6	38
UG166A_2	United	306488	6398076	14	5.0	2.4	5.9	38
UG166A_3	United	306488	6398076	15	5.5	1.4	6.5	38
UG166A_4	United	306488	6398076	16	1.4	-3.7	2.4	38
UG166A_5	United	306488	6398076	17	4.5	-3.4	6.2	38
UG166A_6	United	306488	6398076	18	10.9	5.9	11.8	38
UG166A_7	United	306488	6398076	19	6.6	5.1	7.0	38
UG192R_1	United	313683	6396084	29	4.9	-6.7	10.1	58
UG192R_2	United	313683	6396084	25	-59.7	-64.8	-56.3	37
UG192R_3	United	313683	6396084	22	0.6	-0.6	2.7	58
UG192R_4	United	313683	6396084	21	8.7	5.9	9.6	58

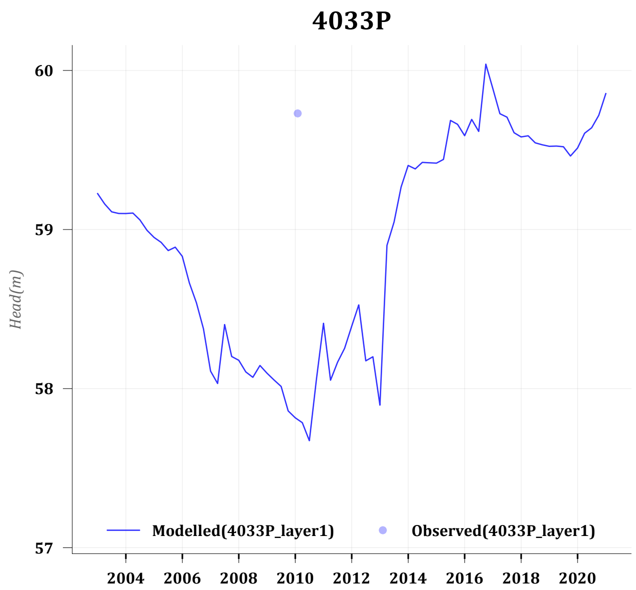
ID	Owner	Easting	Northing	Model Layer	Avg	Min	Max	Count
UG192R_5	United	313683	6396084	19	11.4	9.2	13.9	54
UG192R_6	United	313683	6396084	17	21.5	19.4	22.7	58
UG192R_7	United	313683	6396084	16	14.4	6.2	15.5	58
UG193_1	United	313757	6396090	29	-44.2	-47.0	-42.0	66
UG193_2	United	313757	6396090	27	-70.4	-80.9	-60.2	76
UG193_3	United	313757	6396090	23	-12.0	-18.8	-3.4	76
UG193_4	United	313757	6396090	19	-5.0	-10.7	0.6	70
UG193_5	United	313757	6396090	17	-0.1	-5.6	1.8	74
UG193_6	United	313757	6396090	16	6.5	2.1	8.2	74
UG194_1	United	312436	6397191	27	-9.3	-13.5	-4.0	30
UG194_2	United	312436	6397191	26	-2.8	-4.1	-2.4	30
UG194_3	United	312436	6397191	22	-19.5	-20.4	-18.0	42
UG194_4	United	312436	6397191	16	1.2	-1.7	2.5	40
UG194_5	United	312436	6397191	14	-8.1	-21.4	-2.6	42
UG194_6	United	312436	6397191	2	-17.3	-22.2	-14.6	36
UG196_1	United	312364	6397122	29	5.1	4.8	5.5	35
UG196_2	United	312364	6397122	25	-6.4	-11.1	-3.9	35
UG196_3	United	312364	6397122	24	-3.9	-6.3	-2.4	35
UG196_4	United	312364	6397122	22	-21.4	-23.2	-19.5	35
UG196_5	United	312364	6397122	17	-10.1	-15.9	-7.8	15
UG196_6	United	312364	6397122	14	-12.3	-21.6	-0.3	35
UG200_1	United	313009	6396950	29	-0.1	-1.0	6.1	88
UG200_2	United	313009	6396950	27	3.3	-5.5	5.9	58
UG200_3	United	313009	6396950	26	-9.5	-12.0	-7.0	88
UG200_4	United	313009	6396950	22	-10.7	-13.6	-9.4	88
UG200_5	United	313009	6396950	18	-4.4	-9.5	-1.7	88
UG200_6	United	313009	6396950	16	11.3	4.8	14.0	88
UG200_7	United	313009	6396950	14	-3.3	-7.0	-1.5	88
UG201_1	United	313087	6397025	29	6.3	3.0	8.9	78
UG201_2	United	313087	6397025	27	-4.3	-10.5	-0.7	78
UG201_3	United	313087	6397025	23	-7.8	-12.4	-5.9	78
UG201_5	United	313087	6397025	17	9.7	3.0	12.5	78
UG201_6	United	313087	6397025	14	-8.0	-10.6	-4.9	78
UG201_7	United	313087	6397025	2	-10.9	-14.2	-8.7	78
UG220_1	United	312522	6397233	27	-4.6	-8.9	-2.9	48
UG220_3	United	312522	6397233	23	-13.8	-20.7	-10.1	48
UG220_4	United	312522	6397233	22	-22.6	-24.2	-21.1	48
UG220_6	United	312522	6397233	17	-30.1	-33.2	-25.5	24
UG220_7	United	312522	6397233	16	-17.8	-21.9	-13.6	24
UG224_1	United	313860	6396243	27	-8.4	-14.6	-0.9	73

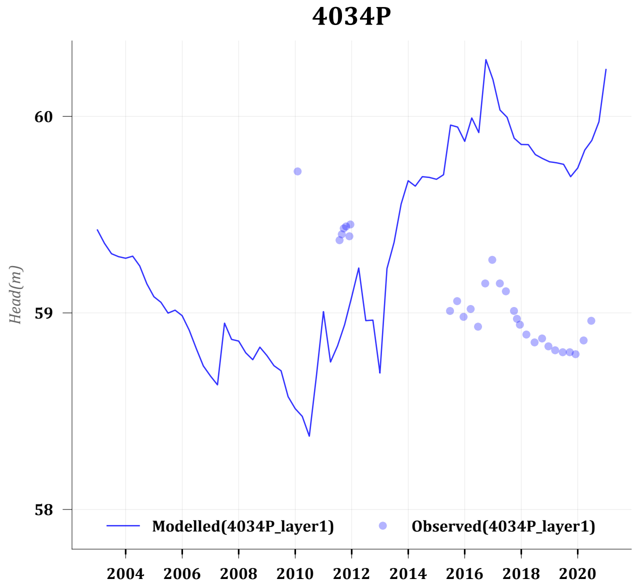
ID	Owner	Easting	Northing	Model Layer	Avg	Min	Max	Count
UG224_2	United	313860	6396243	26	-48.2	-60.0	-33.9	73
UG224_3	United	313860	6396243	24	-48.4	-60.5	-23.3	73
UG224_4	United	313860	6396243	22	-14.9	-17.5	-5.5	73
UG224_5	United	313860	6396243	20	-0.5	-21.9	11.8	73
UG224_6	United	313860	6396243	2	0.6	-9.8	7.2	40
UG225_1	United	313214	6397095	27	-7.2	-11.0	-4.4	115
UG225_2	United	313214	6397095	25	-23.6	-29.0	-18.4	115
UG225_3	United	313214	6397095	22	-15.5	-20.6	-10.8	115
UG225_4	United	313214	6397095	21	-15.7	-18.7	-9.5	115
UG225_5	United	313214	6397095	17	0.6	-6.3	13.2	115
WD622P	MTW	316229	6389585	9	10.8	1.5	17.9	27
WD625P	MTW	314669	6390487	7	5.9	3.9	10.6	27
WOH2139A	MTW	315249	6391511	13	-4.5	-10.9	5.9	38
WOH2141A	MTW	314989	6392647	11	6.3	1.9	10.7	32
WOH2141B	MTW	314989	6392647	13	10.7	6.9	15.6	16
WOH2153A	MTW	313881	6391429	8	3.4	-0.3	7.4	33
WOH2153B	MTW	313881	6391429	9	3.4	2.5	4.4	30
WOH2154A	MTW	313976	6389990	8	3.3	0.0	9.0	33
WOH2154B	MTW	313976	6389990	9	3.3	1.7	4.8	33
WOH2155A	MTW	315278	6390138	8	5.0	-2.7	14.3	33
WOH2155B	MTW	315278	6390138	9	6.5	5.1	7.8	33
WOH2156A	MTW	315874	6388866	8	8.1	1.6	16.7	33
WOH2156B	MTW	315874	6388866	9	0.1	-4.5	2.7	28

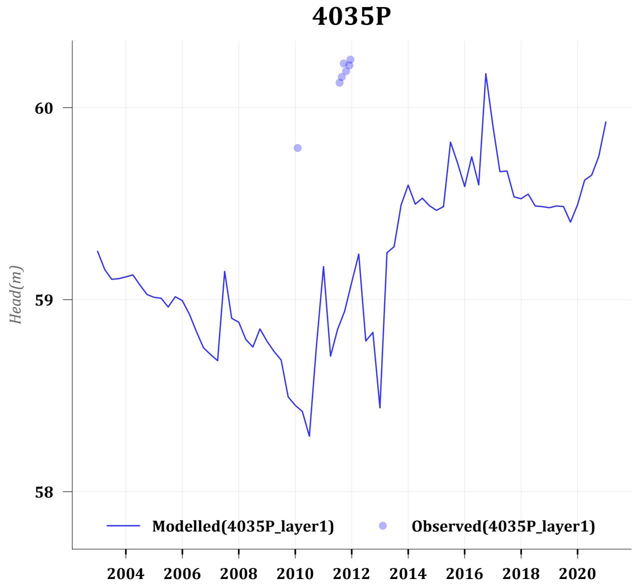
ATTACHMENT B

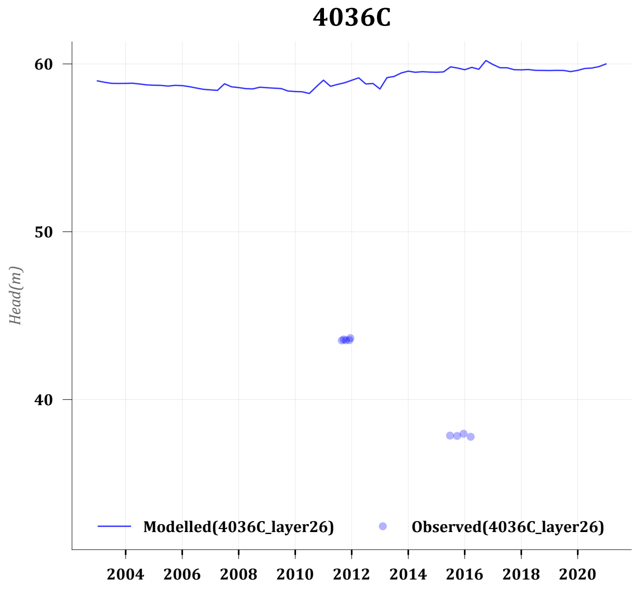
Calibration Hydrographs


4032P
Head(m)
60
59
58
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(4032P_layer1)
Observed(4032P_layer1)


4033P
Head(m)
60
59
58
57
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(4033P_layer1)
Observed(4033P_layer1)


4034P
Head(m)
60
59
58
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(4034P_layer1)
Observed(4034P_layer1)


4035P
Head(m)
60
59
58
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(4035P_layer1)
Observed(4035P_layer1)


4036C
Head(m)
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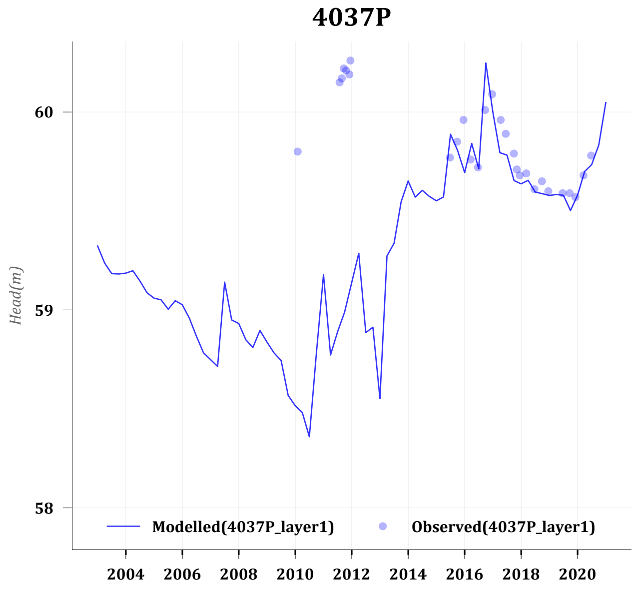
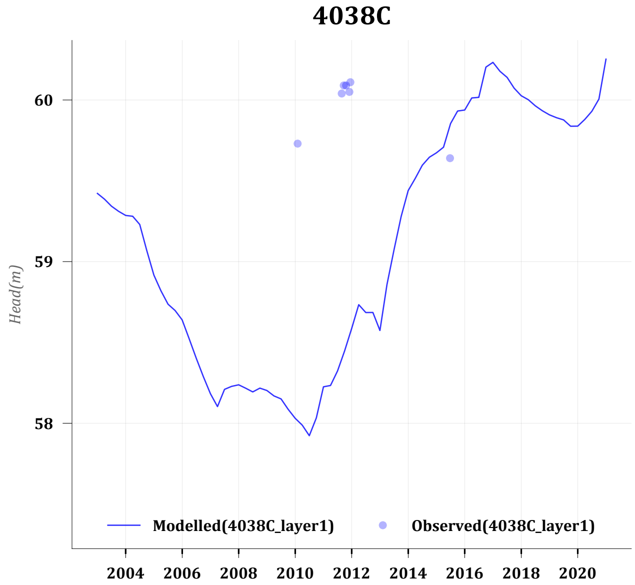
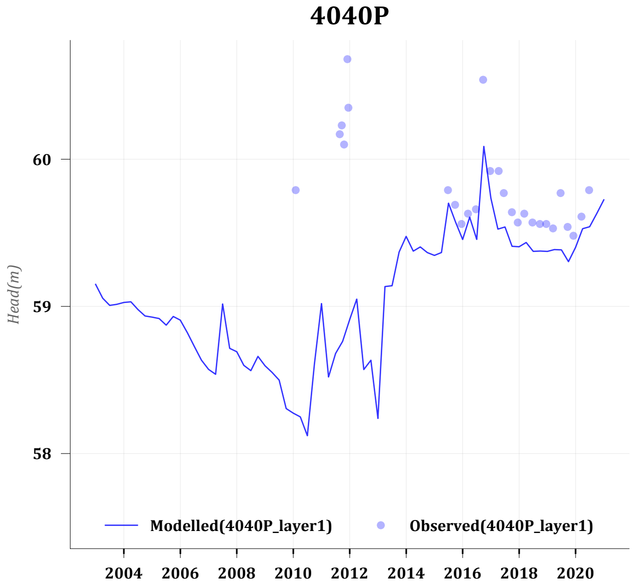
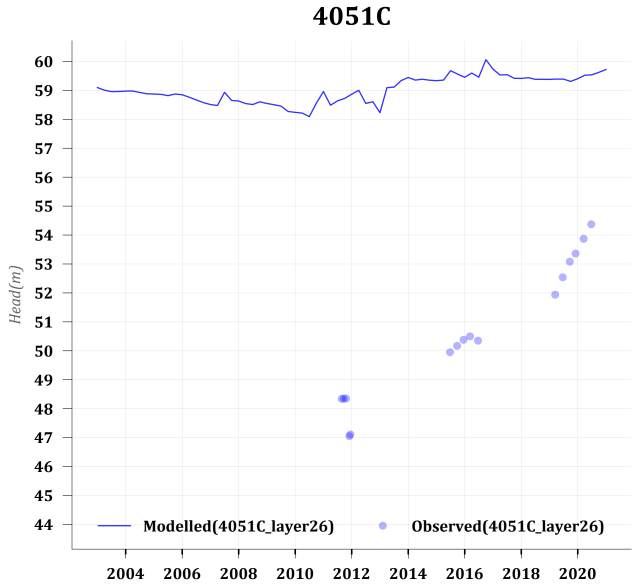
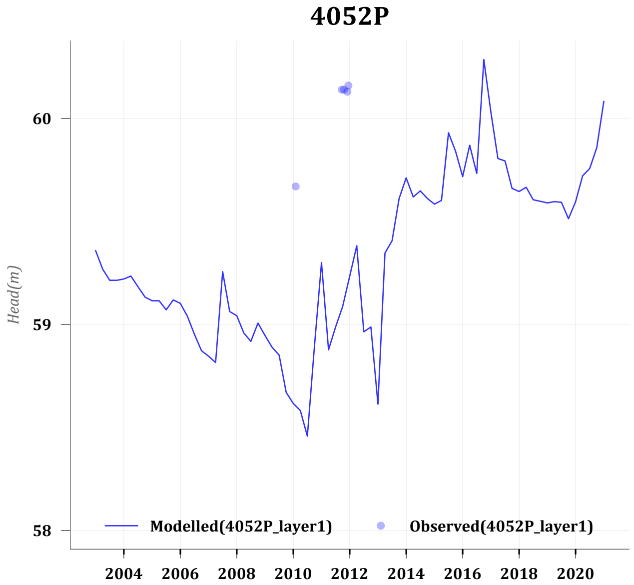
50
40
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(4036C_layer26)
Observed(4036C_layer26)

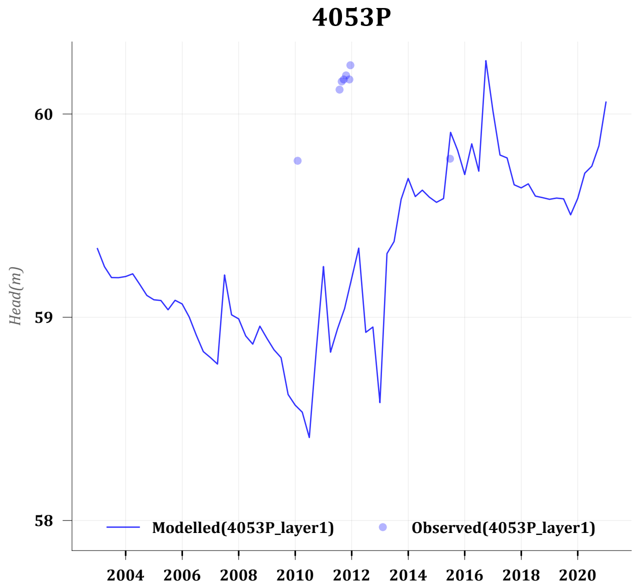

4037P
Head(m)
60
59
58
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(4037P_layer1)
Observed(4037P_layer1)

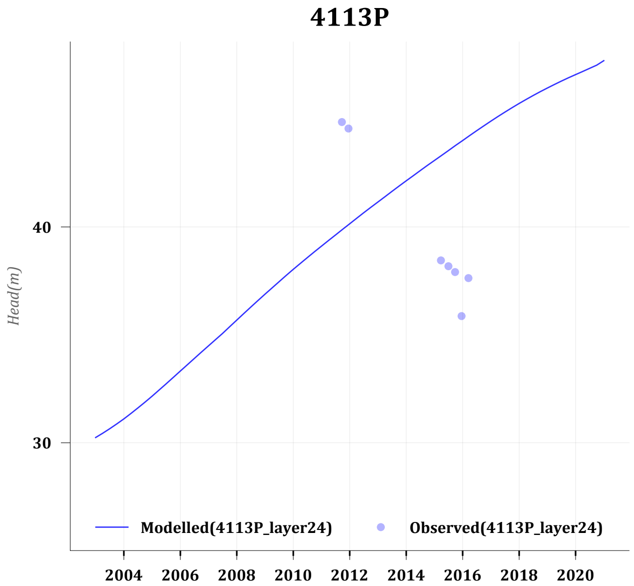

4038C
Head(m)
60
59
58
2004 2006 2008 2010 2012 2014 2016 2018 2020
Modelled(4038C_layer1)
Observed(4038C_layer1)

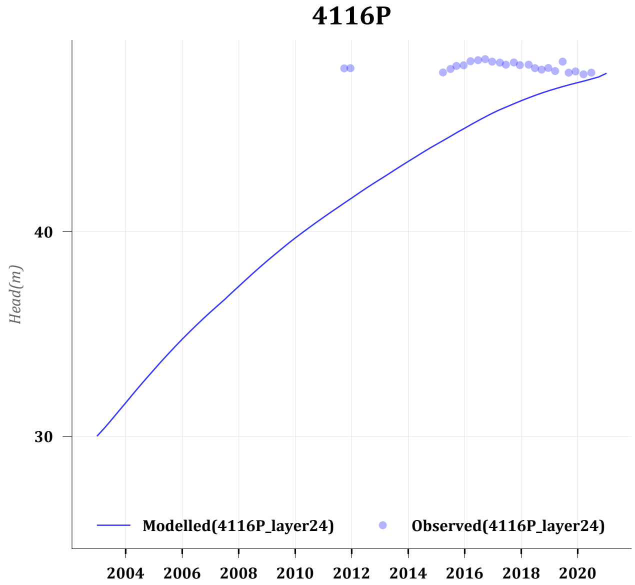

4040P
Head(m)
60
59
58
2004 2006 2008 2010 2012 2014 2016 2018 2020
Modelled(4040P_layer1)
Observed(4040P_layer1)

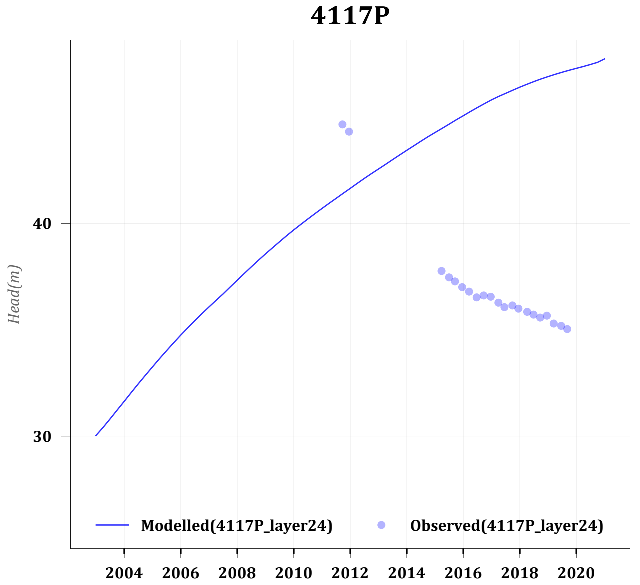

4051C
Head(m)
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
2004 2006 2008 2010 2012 2014 2016 2018 2020
Modelled(4051C_layer26)
Observed(4051C_layer26)

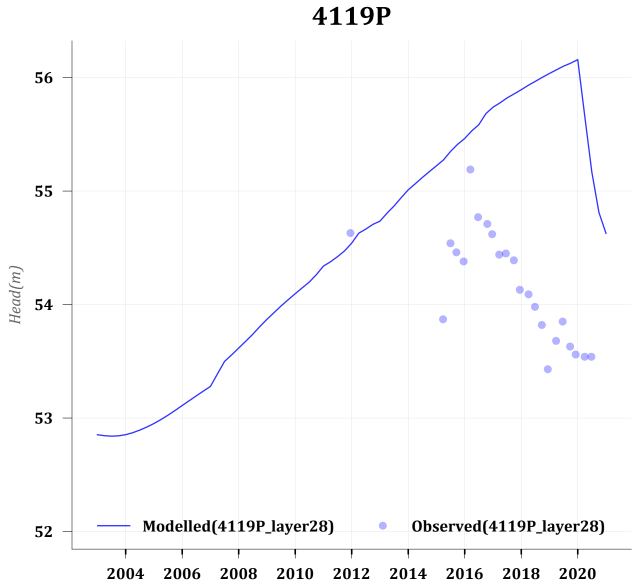

4052P
Head(m)
60
59
58
2004 2006 2008 2010 2012 2014 2016 2018 2020
Modelled(4052P_layer1)
Observed(4052P_layer1)

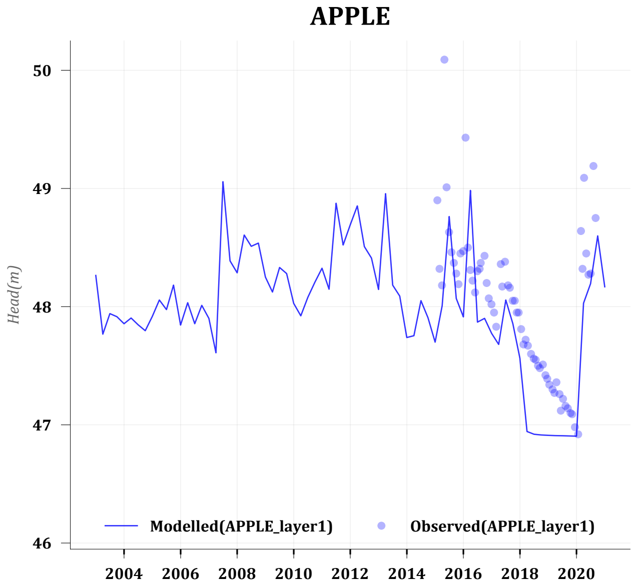

4053P
Head(m)
60
59
58
2004 2006 2008 2010 2012 2014 2016 2018 2020
Modelled(4053P_layer1)
Observed(4053P_layer1)

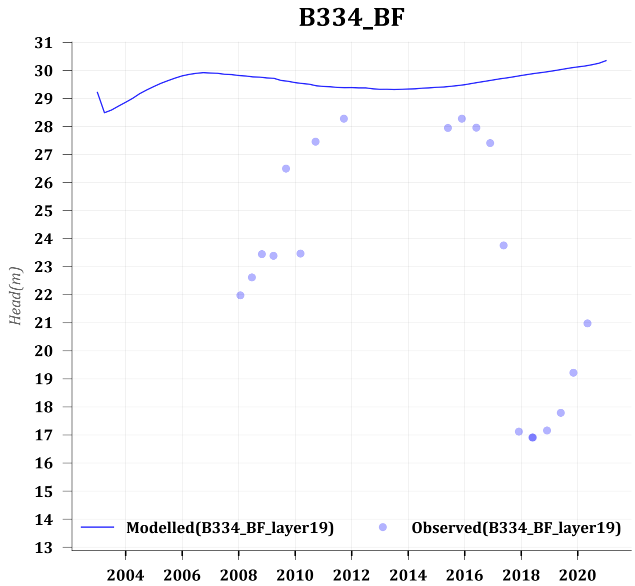

4113P
Head(m)
40
30
2004 2006 2008 2010 2012 2014 2016 2018 2020
Modelled(4113P_layer24)
Observed(4113P_layer24)

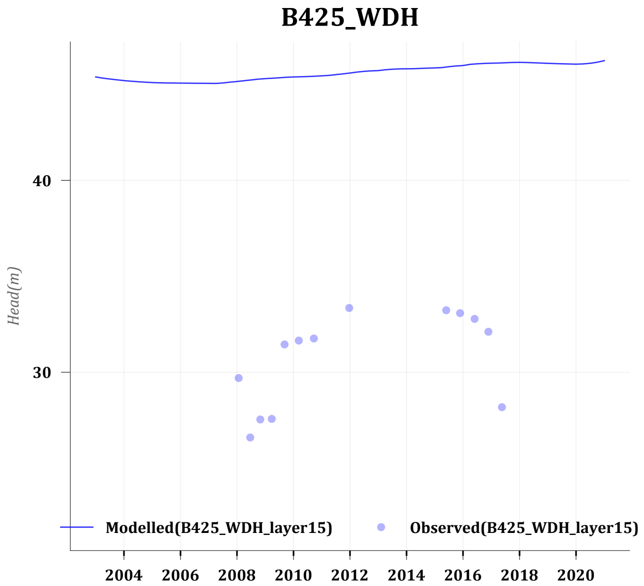

4116P
Head(m)
Modelled(4116P_layer24)
Observed(4116P_layer24)

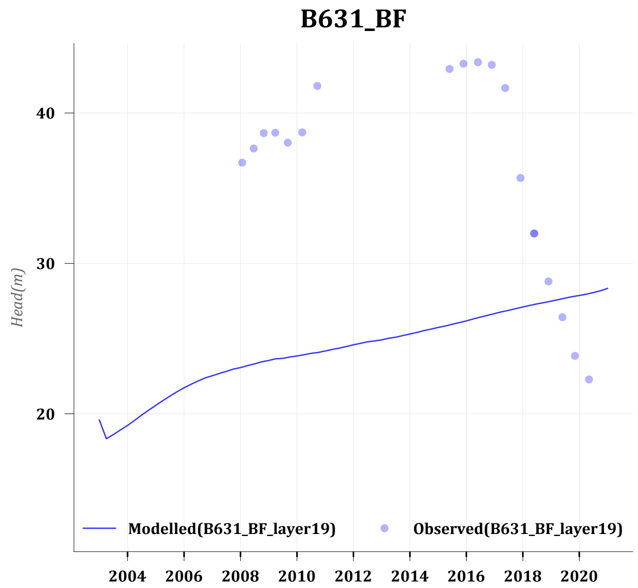

4117P
Head(m)
Modelled(4117P_layer24)
Observed(4117P_layer24)

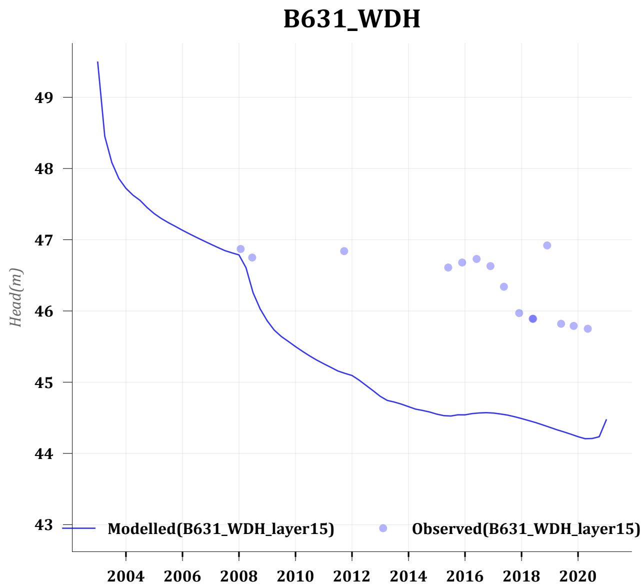

4119P
Head(m)
Modelled(4119P_layer28)
Observed(4119P_layer28)

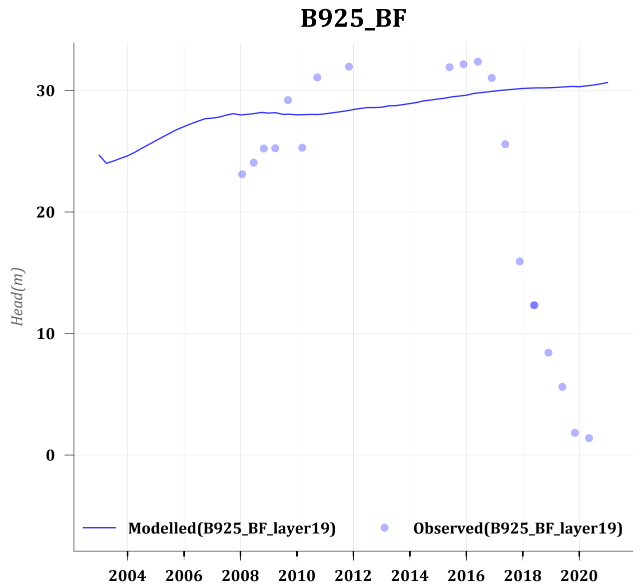

APPLE
Head(m)
Modelled(APPLE_layer1)
Observed(APPLE_layer1)

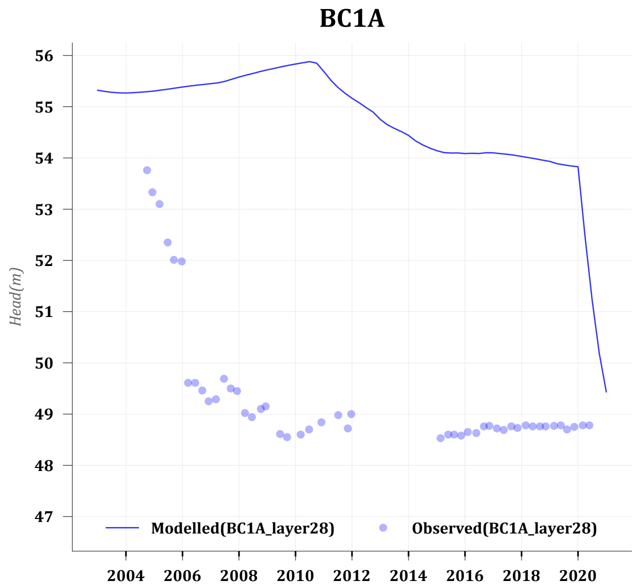

B334_BF
Head(m)
Modelled(B334_BF_layer19)
Observed(B334_BF_layer19)

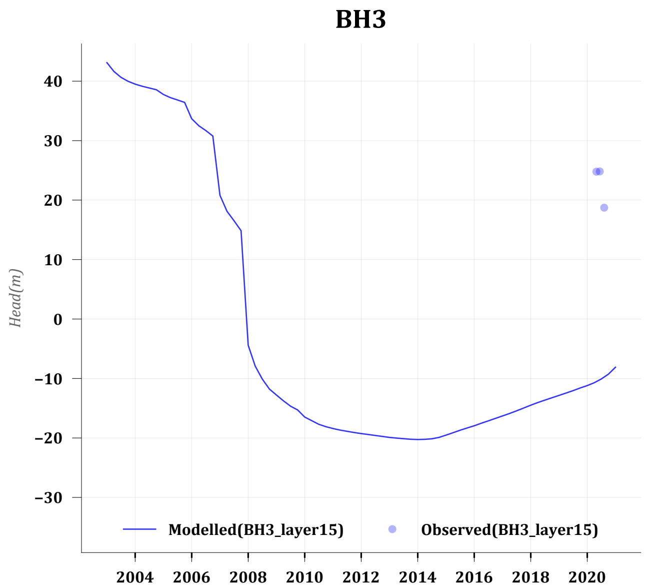

B425_WDH
Head(m)
Modelled(B425_WDH_layer15)
Observed(B425_WDH_layer15)

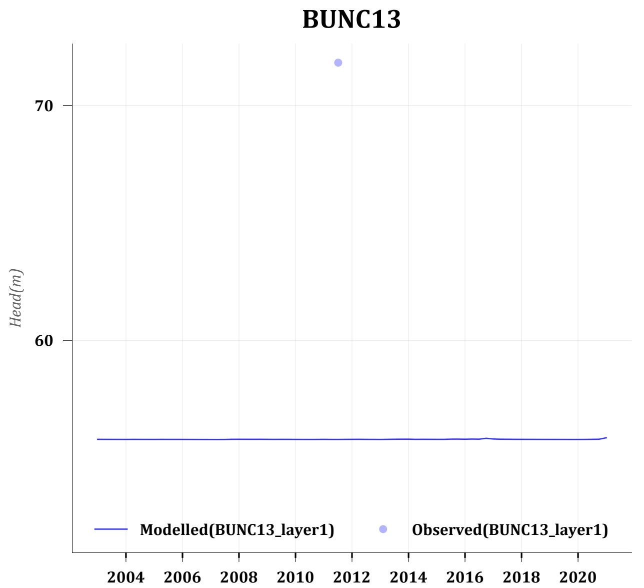

B631_BF
Head(m)
40
30
20
Modelled(B631_BF_layer19)
Observed(B631_BF_layer19)
2004 2006 2008 2010 2012 2014 2016 2018 2020

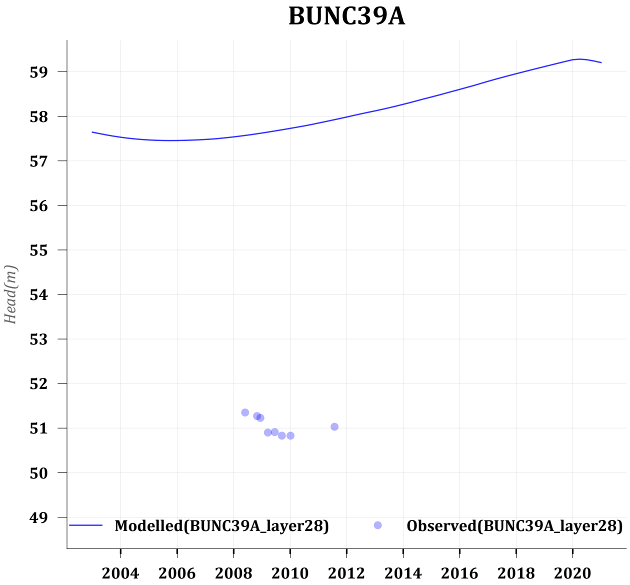

B631_WDH
Head(m)
49
48
47
46
45
44
43
Modelled(B631_WDH_layer15)
Observed(B631_WDH_layer15)
2004 2006 2008 2010 2012 2014 2016 2018 2020

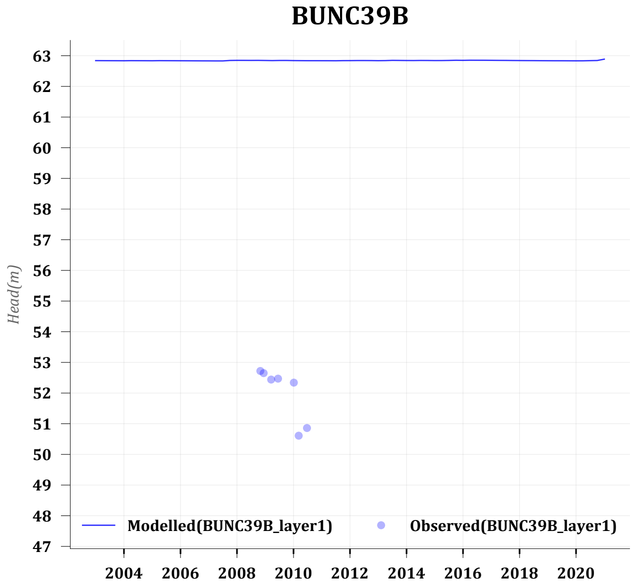

B925_BF
Head(m)
30
20
10
0
Modelled(B925_BF_layer19)
Observed(B925_BF_layer19)
2004 2006 2008 2010 2012 2014 2016 2018 2020

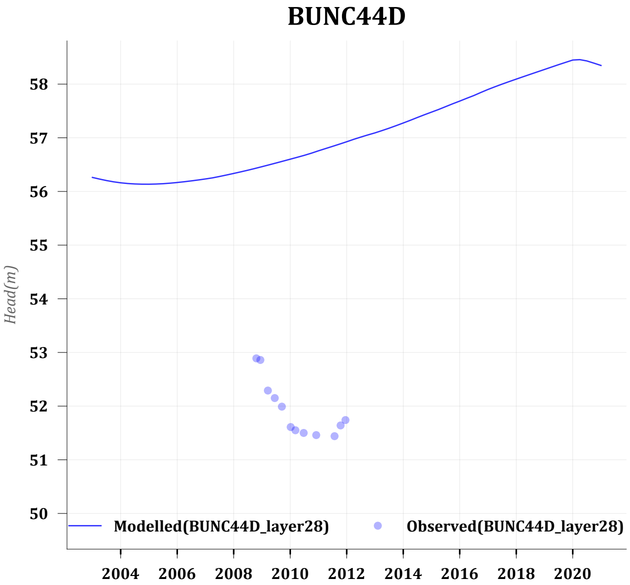

BC1A
Head(m)
56
55
54
53
52
51
50
49
48
47
Modelled(BC1A_layer28)
Observed(BC1A_layer28)
2004 2006 2008 2010 2012 2014 2016 2018 2020

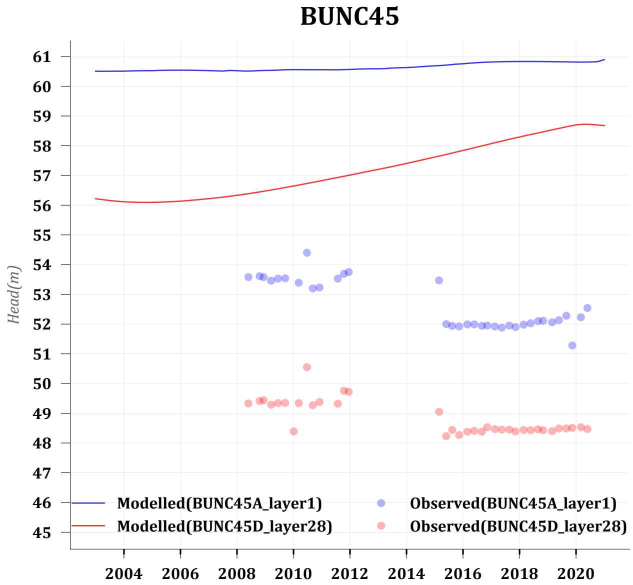

BH3
Head(m)
40
30
20
10
0
−10
−20
−30
Modelled(BH3_layer15)
Observed(BH3_layer15)
2004 2006 2008 2010 2012 2014 2016 2018 2020

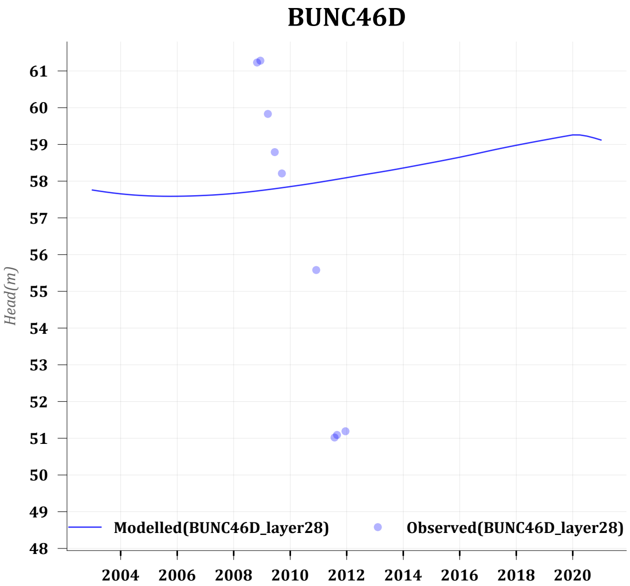

BUNC13
Head(m)
70
60
Modelled(BUNC13_layer1)
Observed(BUNC13_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020

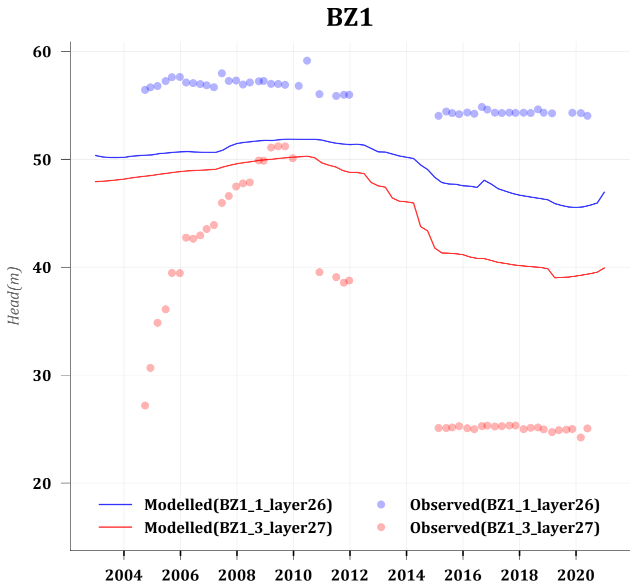

BUNC39A
Head(m)
Modelled(BUNC39A_layer28)
Observed(BUNC39A_layer28)
2004 2006 2008 2010 2012 2014 2016 2018 2020

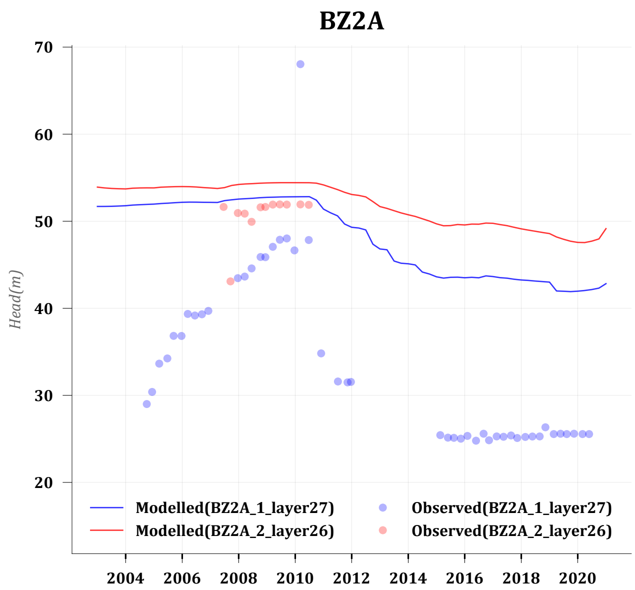

BUNC39B
Head(m)
Modelled(BUNC39B_layer1)
Observed(BUNC39B_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020

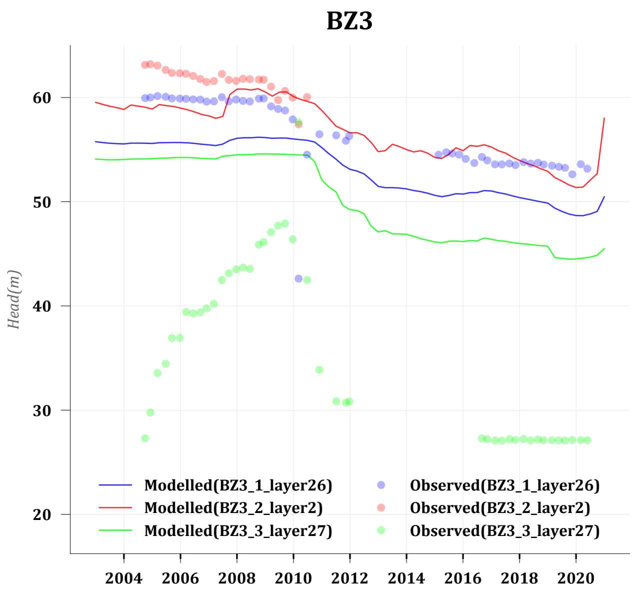

BUNC44D
Head(m)
Modelled(BUNC44D_layer28)
Observed(BUNC44D_layer28)
2004 2006 2008 2010 2012 2014 2016 2018 2020

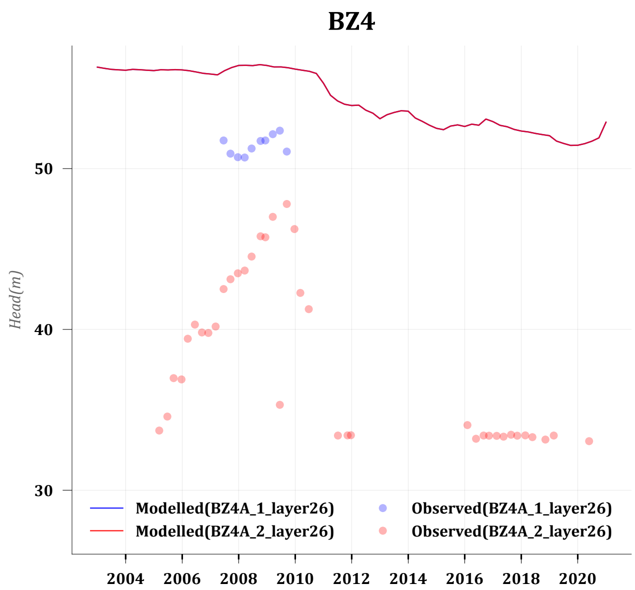

BUNC45
Head(m)
Modelled(BUNC45A_layer1)
Modelled(BUNC45D_layer28)
Observed(BUNC45A_layer1)
Observed(BUNC45D_layer28)
2004 2006 2008 2010 2012 2014 2016 2018 2020

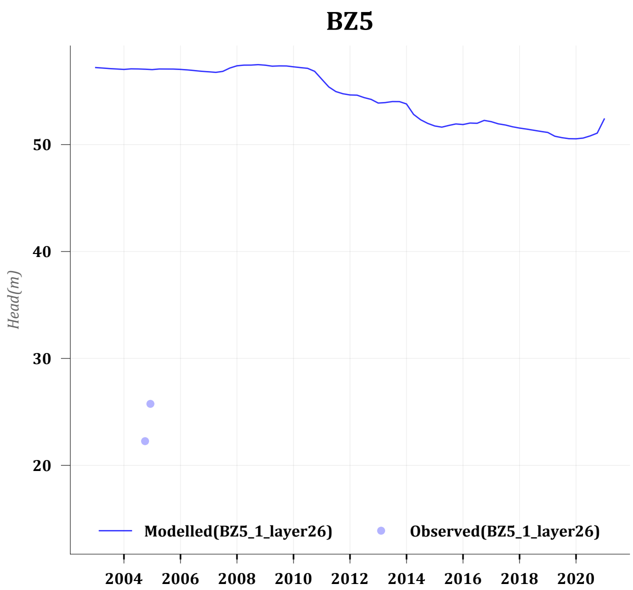

BUNC46D
Head(m)
Modelled(BUNC46D_layer28)
Observed(BUNC46D_layer28)
2004 2006 2008 2010 2012 2014 2016 2018 2020

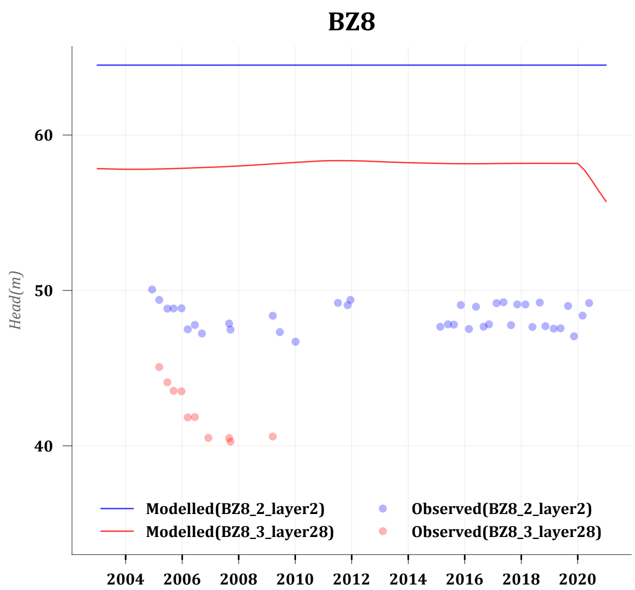

BZ1
Head(m)
Modelled(BZ1_1_layer26)
Modelled(BZ1_3_layer27)
Observed(BZ1_1_layer26)
Observed(BZ1_3_layer27)
2004 2006 2008 2010 2012 2014 2016 2018 2020

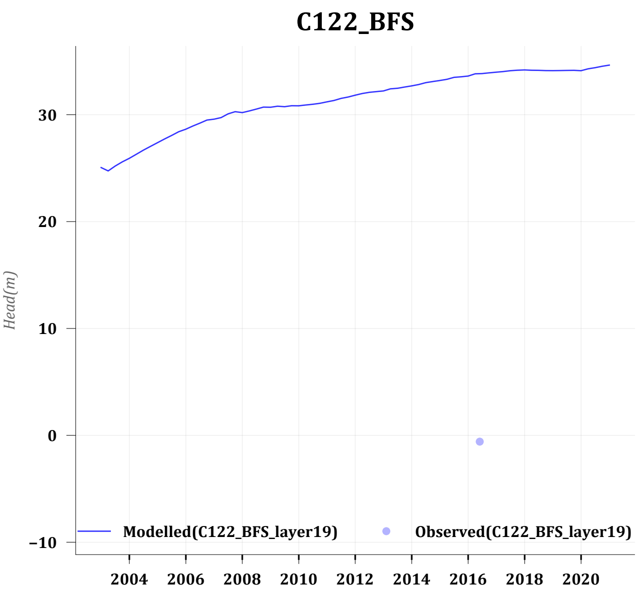

BZ2A
Head(m)
Modelled(BZ2A_1_layer27)
Modelled(BZ2A_2_layer26)
Observed(BZ2A_1_layer27)
Observed(BZ2A_2_layer26)

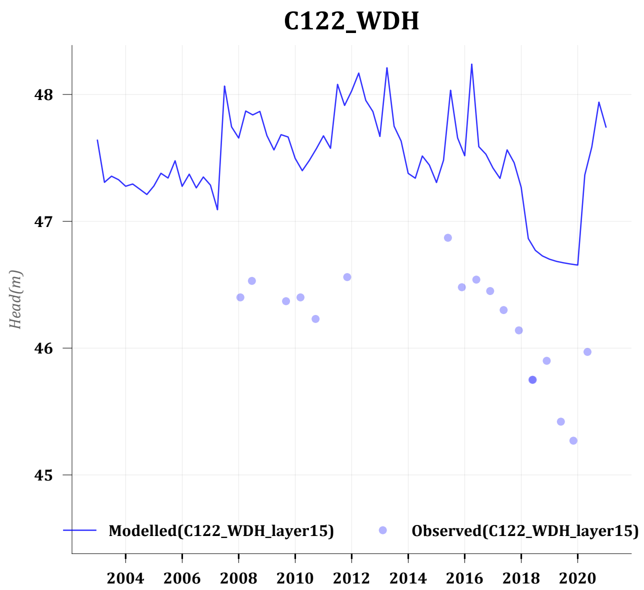

BZ3
Head(m)
Modelled(BZ3_1_layer26)
Modelled(BZ3_2_layer2)
Modelled(BZ3_3_layer27)
Observed(BZ3_1_layer26)
Observed(BZ3_2_layer2)
Observed(BZ3_3_layer27)

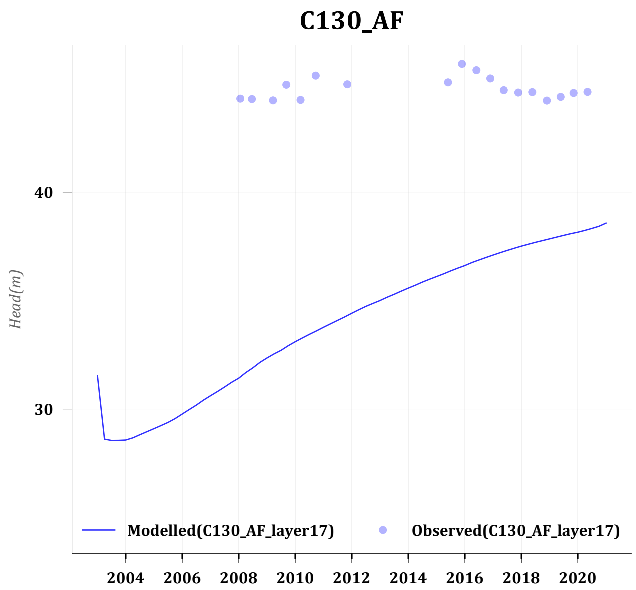

BZ4
Head(m)
Modelled(BZ4A_1_layer26)
Modelled(BZ4A_2_layer26)
Observed(BZ4A_1_layer26)
Observed(BZ4A_2_layer26)

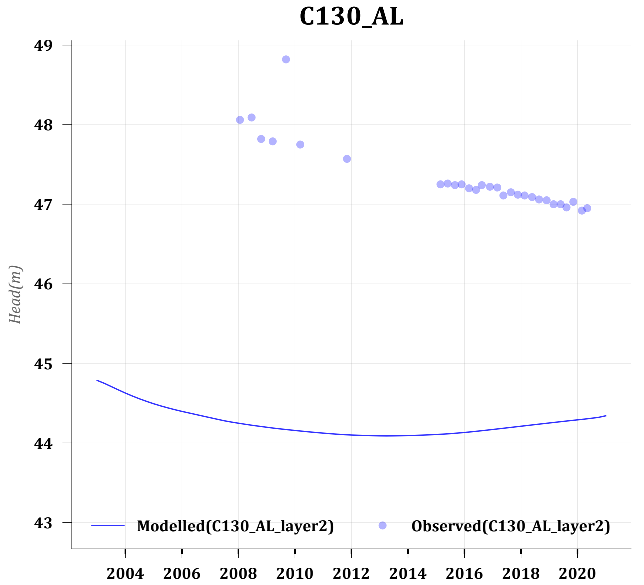

BZ5
Head(m)
Modelled(BZ5_1_layer26)
Observed(BZ5_1_layer26)

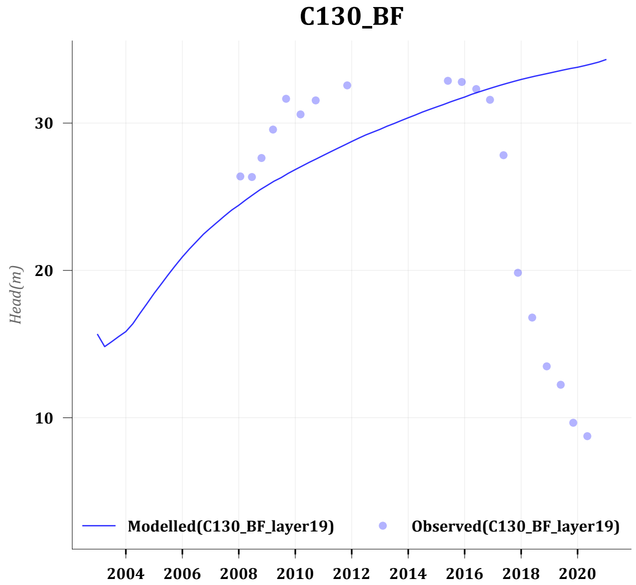

BZ8
Head(m)
Modelled(BZ8_2_layer2)
Modelled(BZ8_3_layer28)
Observed(BZ8_2_layer2)
Observed(BZ8_3_layer28)

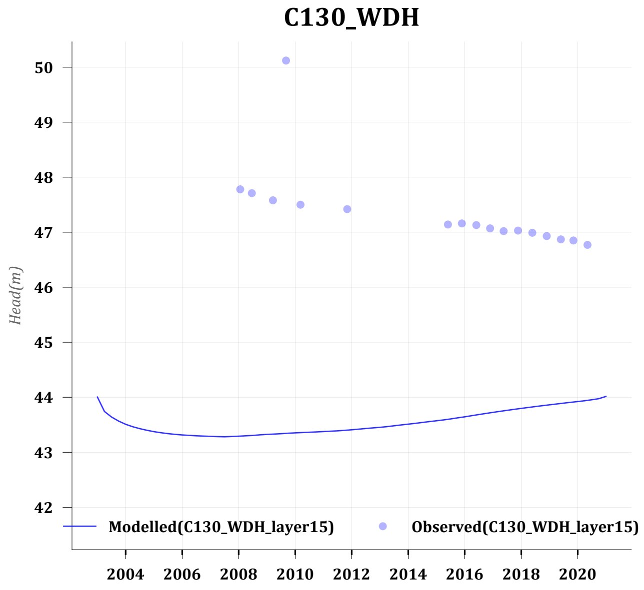

C122_BFS
Head(m)
Modelled(C122_BFS_layer19)
Observed(C122_BFS_layer19)

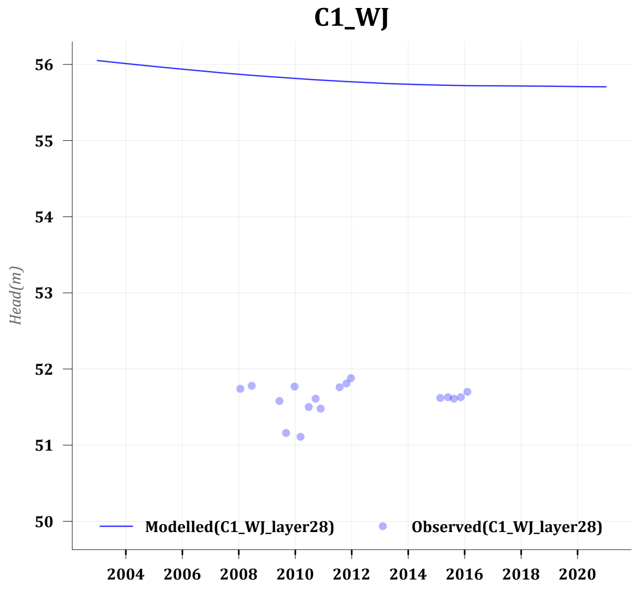

C122_WDH
Head(m)
48
47
46
45
Modelled(C122_WDH_layer15)
Observed(C122_WDH_layer15)
2004 2006 2008 2010 2012 2014 2016 2018 2020

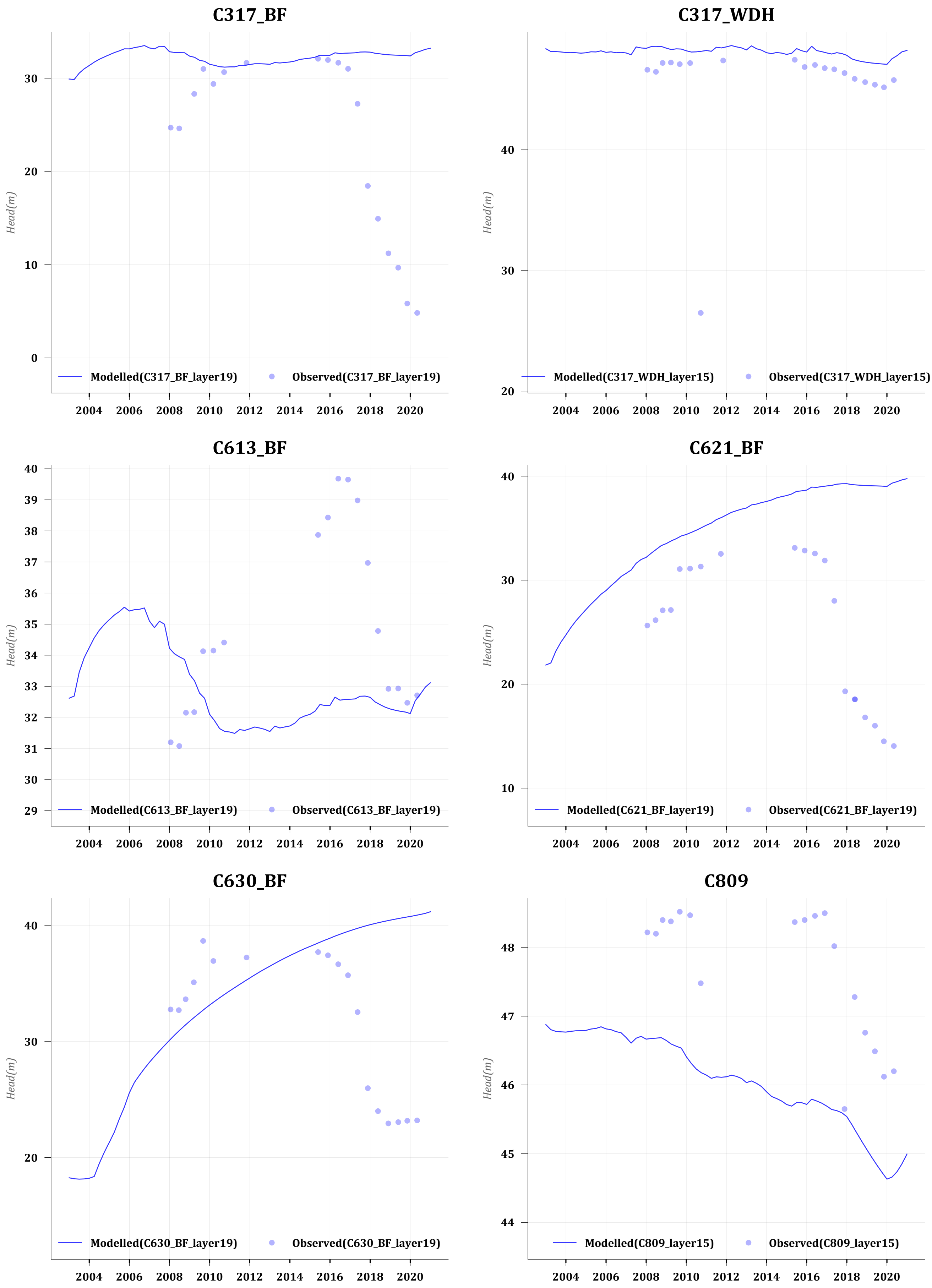

C130_AF
Head(m)
40
30
Modelled(C130_AF_layer17)
Observed(C130_AF_layer17)
2004 2006 2008 2010 2012 2014 2016 2018 2020

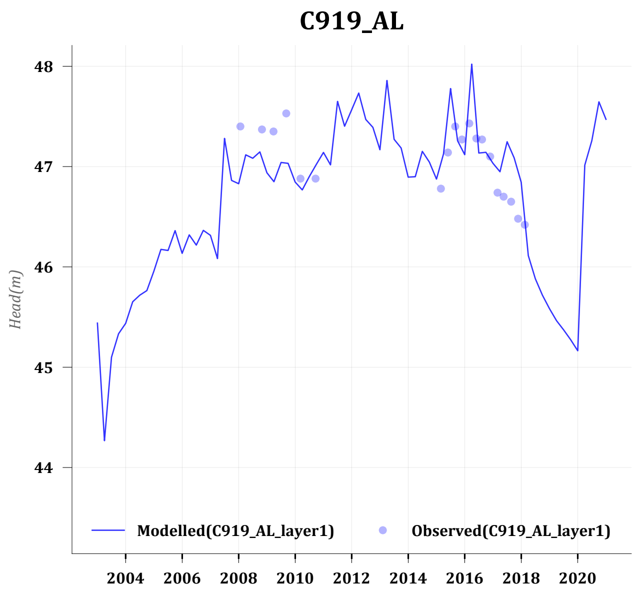

C130_AL
Head(m)
49
48
47
46
45
44
43
Modelled(C130_AL_layer2)
Observed(C130_AL_layer2)
2004 2006 2008 2010 2012 2014 2016 2018 2020

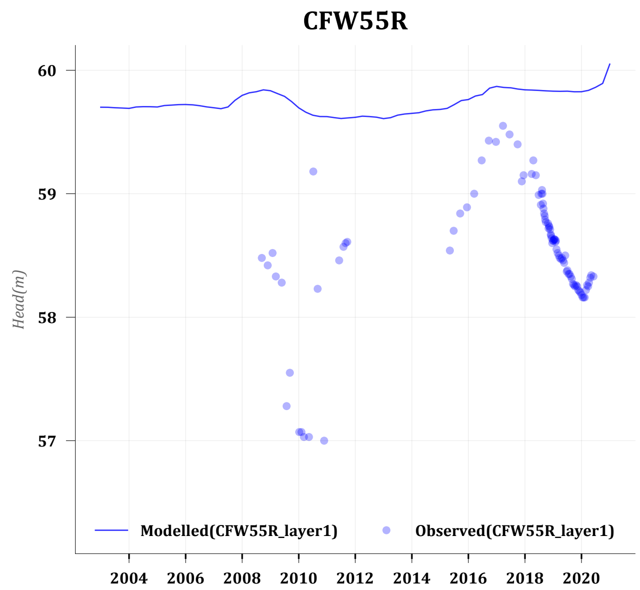

C130_BF
Head(m)
30
20
10
Modelled(C130_BF_layer19)
Observed(C130_BF_layer19)
2004 2006 2008 2010 2012 2014 2016 2018 2020

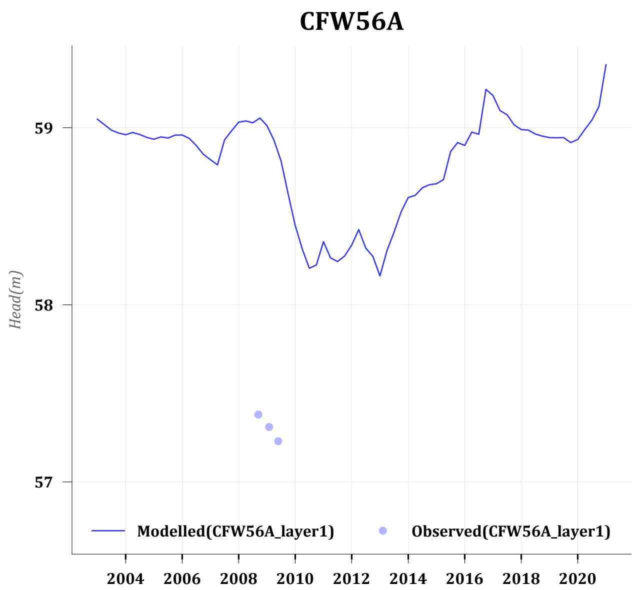

C130_WDH
Head(m)
50
49
48
47
46
45
44
43
42
Modelled(C130_WDH_layer15)
Observed(C130_WDH_layer15)
2004 2006 2008 2010 2012 2014 2016 2018 2020

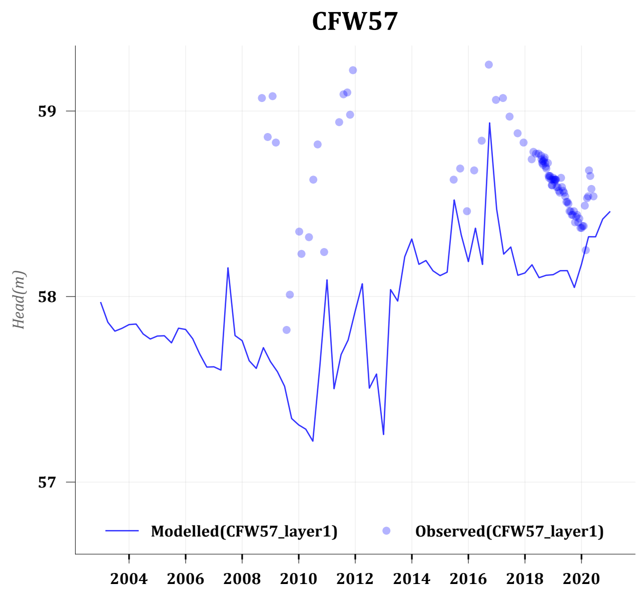

C1_WJ
Head(m)
56
55
54
53
52
51
50
Modelled(C1_WJ_layer28)
Observed(C1_WJ_layer28)
2004 2006 2008 2010 2012 2014 2016 2018 2020

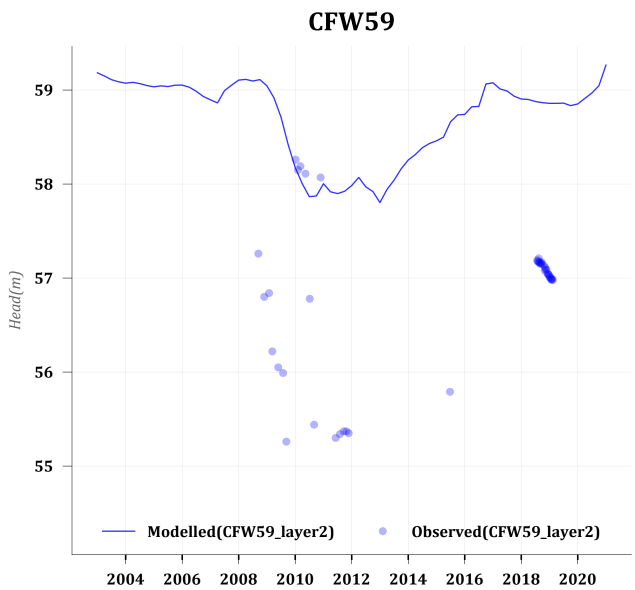

C317_BF
Head(m)
Modelled(C317_BF_layer19)
Observed(C317_BF_layer19)
C317_WDH
Head(m)
Modelled(C317_WDH_layer15)
Observed(C317_WDH_layer15)
C613_BF
Head(m)
Modelled(C613_BF_layer19)
Observed(C613_BF_layer19)
C621_BF
Head(m)
Modelled(C621_BF_layer19)
Observed(C621_BF_layer19)
C630_BF
Head(m)
Modelled(C630_BF_layer19)
Observed(C630_BF_layer19)
C809
Head(m)
Modelled(C809_layer15)
Observed(C809_layer15)
2004 2006 2008 2010 2012 2014 2016 2018 2020

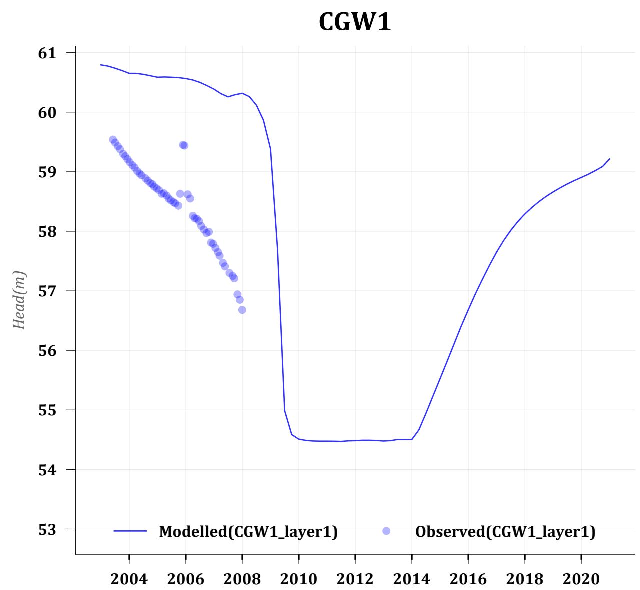

C919_AL
Head(m)
48
47
46
45
44
Modelled(C919_AL_layer1)
Observed(C919_AL_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

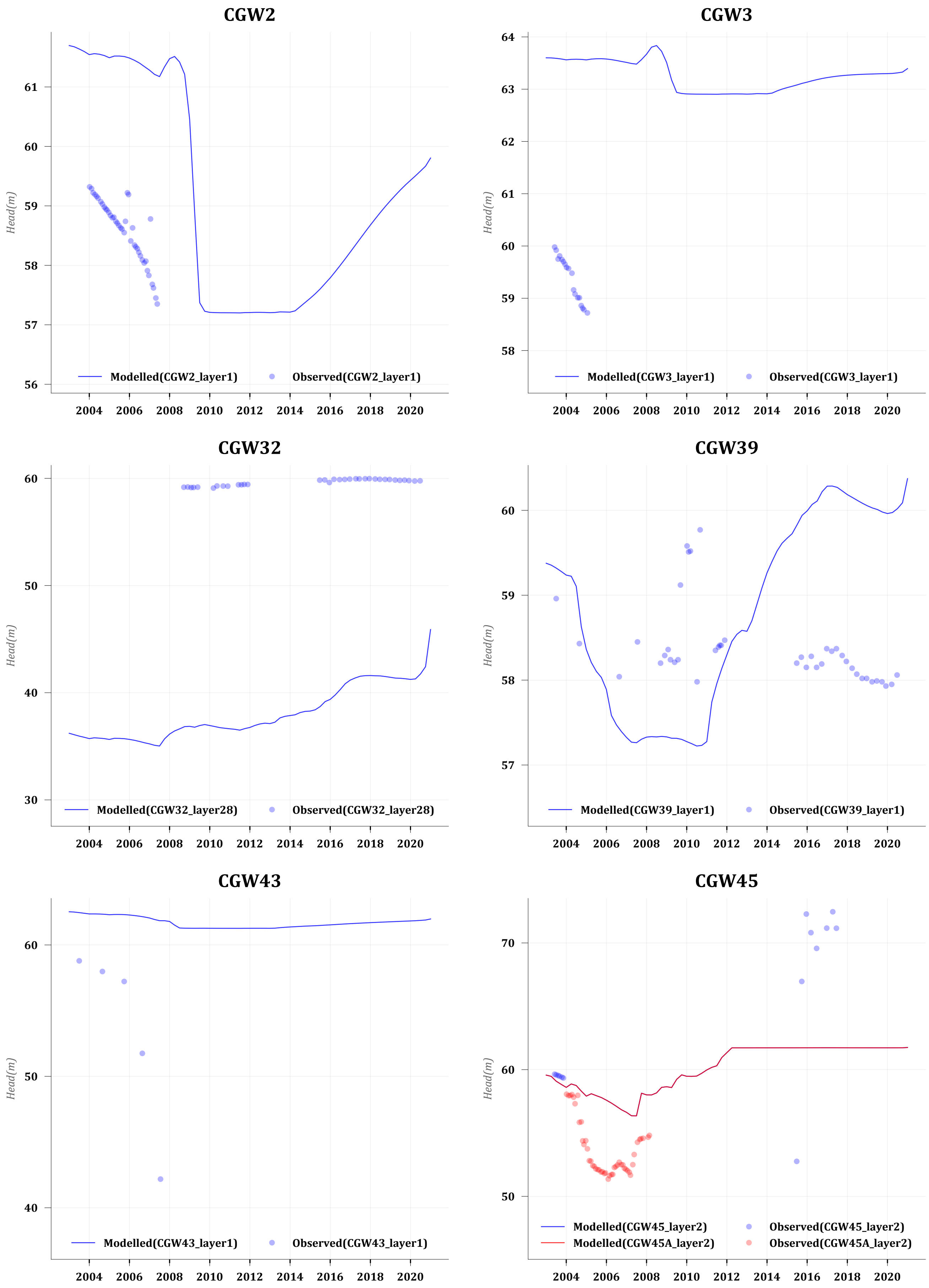

CFW55R
Head(m)
60
59
58
57
Modelled(CFW55R_layer1)
Observed(CFW55R_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020


CFW56A
Head(m)
59
58
57
Modelled(CFW56A_layer1)
Observed(CFW56A_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

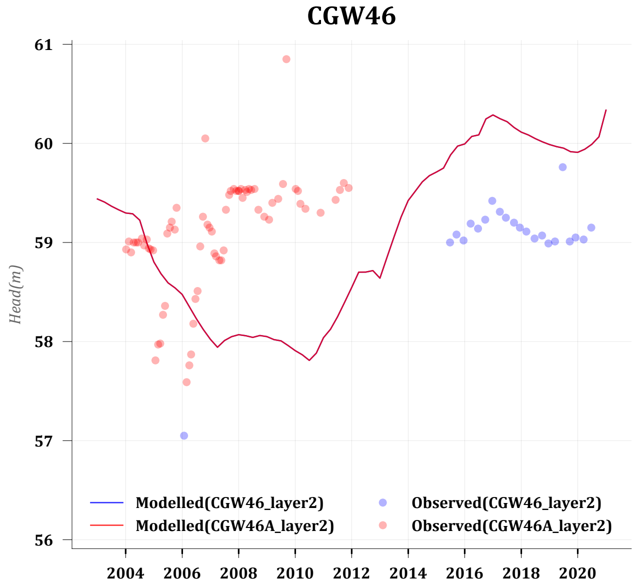

CFW57
Head(m)
59
58
57
Modelled(CFW57_layer1)
Observed(CFW57_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

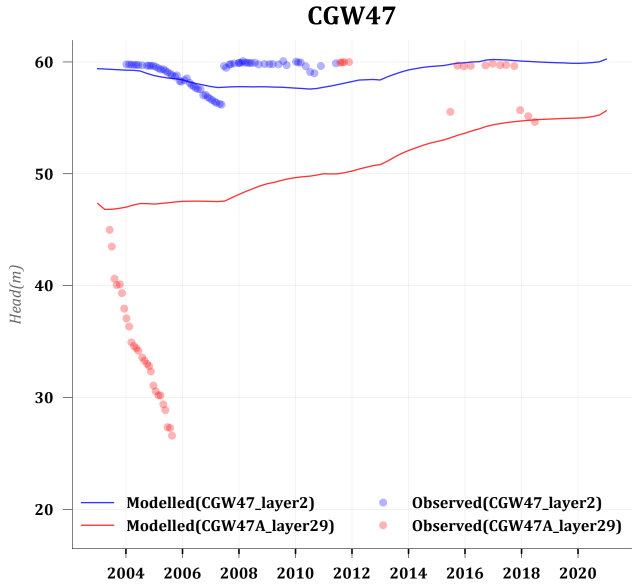

CFW59
Head(m)
59
58
57
56
55
Modelled(CFW59_layer2)
Observed(CFW59_layer2)
2004
2006
2008
2010
2012
2014
2016
2018
2020

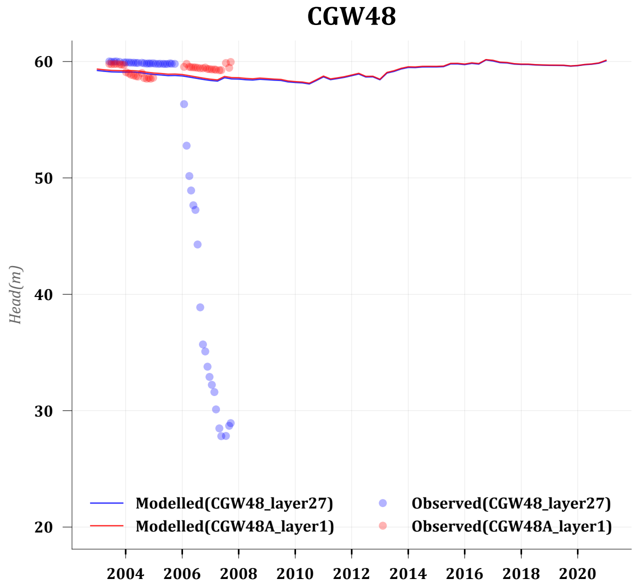

CGW1
Head(m)
61
60
59
58
57
56
55
54
53
Modelled(CGW1_layer1)
Observed(CGW1_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

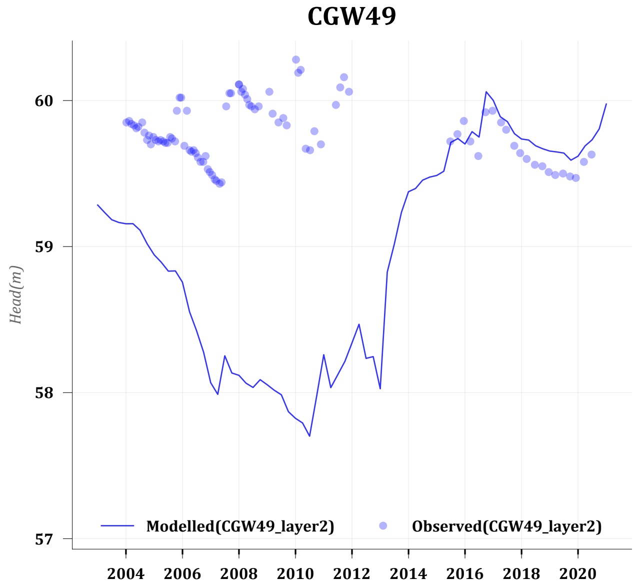


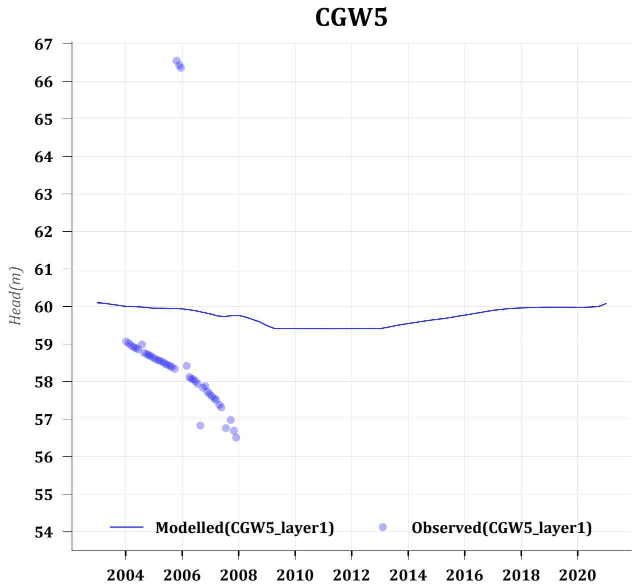
CGW2
Head(m)
Modelled(CGW2_layer1)
Observed(CGW2_layer1)
CGW3
Head(m)
Modelled(CGW3_layer1)
Observed(CGW3_layer1)
CGW32
Head(m)
Modelled(CGW32_layer28)
Observed(CGW32_layer28)
CGW39
Head(m)
Modelled(CGW39_layer1)
Observed(CGW39_layer1)
CGW43
Head(m)
Modelled(CGW43_layer1)
Observed(CGW43_layer1)
CGW45
Head(m)
Modelled(CGW45_layer2)
Modelled(CGW45A_layer2)
Observed(CGW45_layer2)
Observed(CGW45A_layer2)
2004 2006 2008 2010 2012 2014 2016 2018 2020

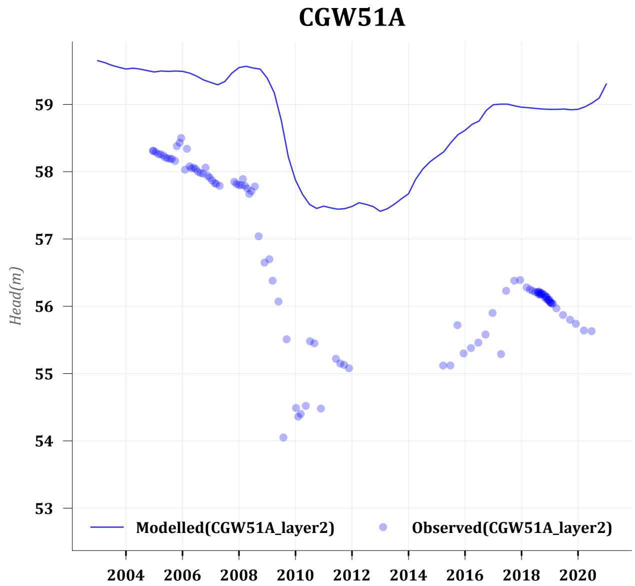

CGW46
Head(m)
Modelled(CGW46_layer2)
Modelled(CGW46A_layer2)
Observed(CGW46_layer2)
Observed(CGW46A_layer2)

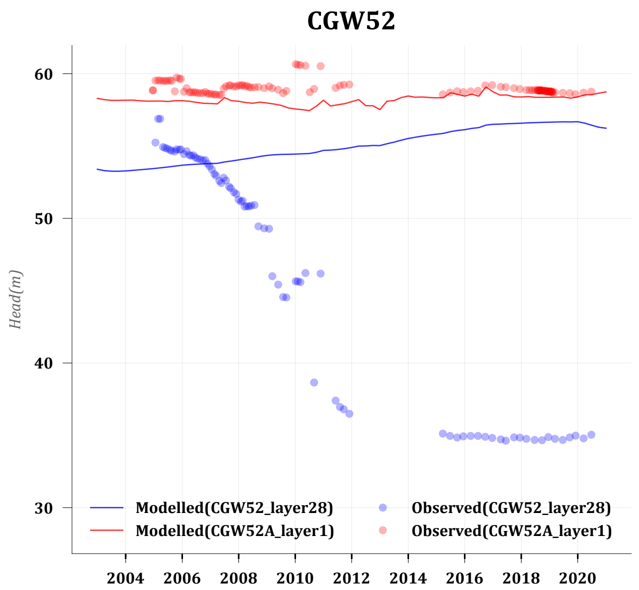

CGW47
Head(m)
Modelled(CGW47_layer2)
Modelled(CGW47A_layer29)
Observed(CGW47_layer2)
Observed(CGW47A_layer29)

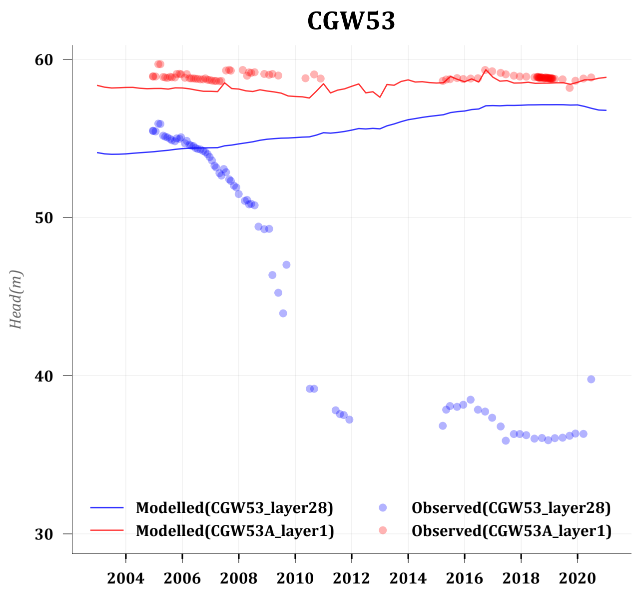

CGW48
Head(m)
Modelled(CGW48_layer27)
Modelled(CGW48A_layer1)
Observed(CGW48_layer27)
Observed(CGW48A_layer1)

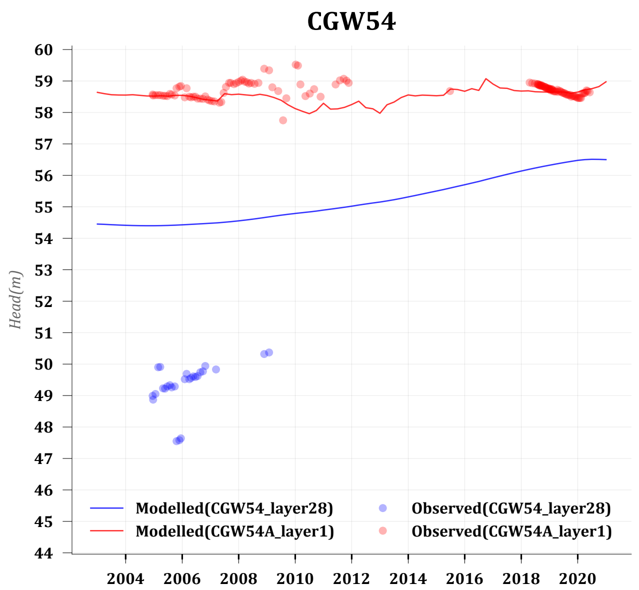

CGW49
Head(m)
Modelled(CGW49_layer2)
Observed(CGW49_layer2)

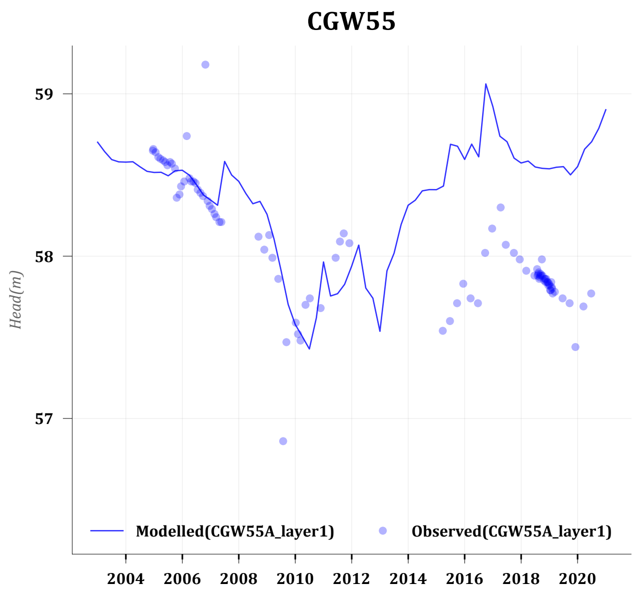

CGW5
Head(m)
Modelled(CGW5_layer1)
Observed(CGW5_layer1)

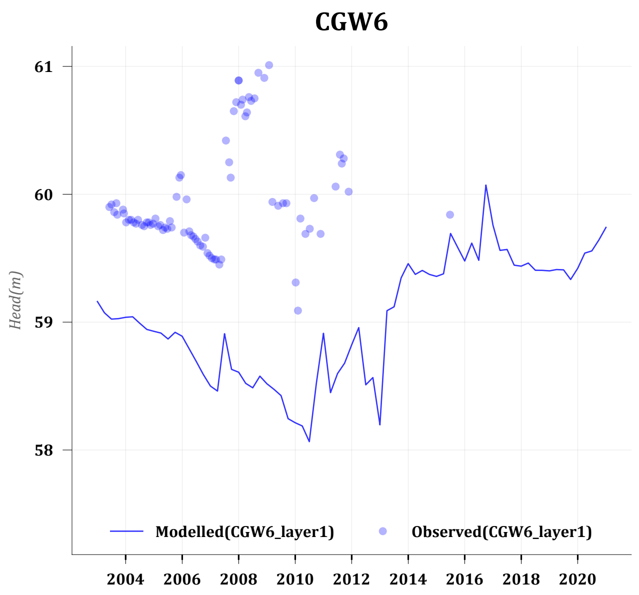

CGW51A
Head(m)
Modelled(CGW51A_layer2)
Observed(CGW51A_layer2)

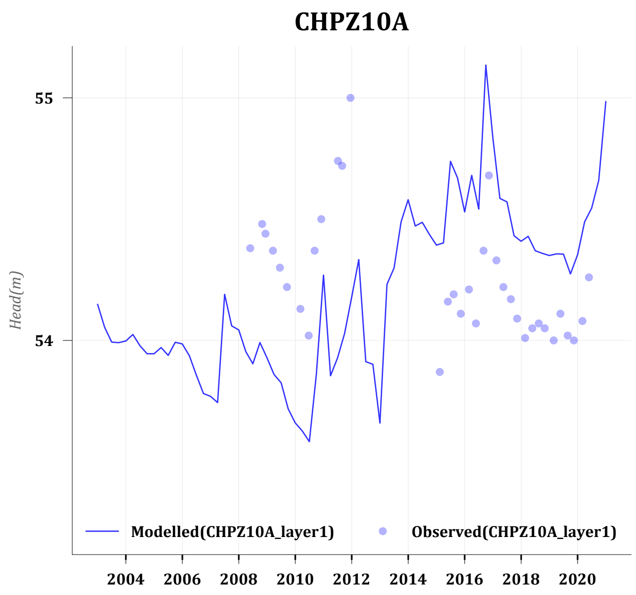

CGW52
Head(m)
60
50
40
30
Modelled(CGW52_layer28)
Modelled(CGW52A_layer1)
Observed(CGW52_layer28)
Observed(CGW52A_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020

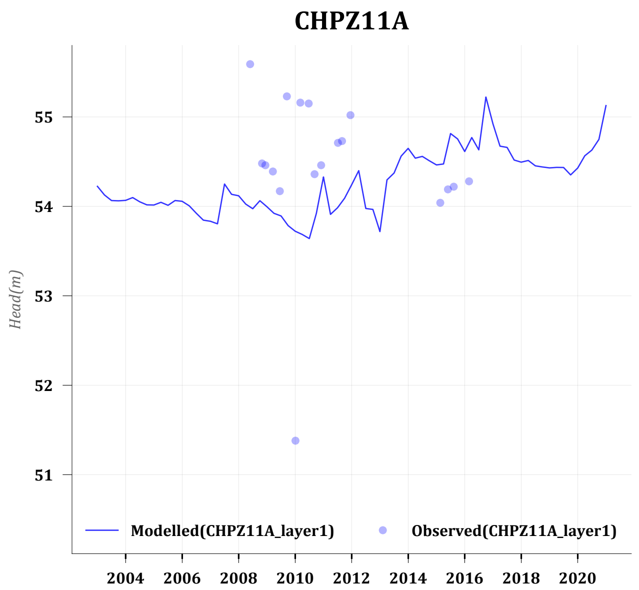

CGW53
Head(m)
60
50
40
30
Modelled(CGW53_layer28)
Modelled(CGW53A_layer1)
Observed(CGW53_layer28)
Observed(CGW53A_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020


CGW54
Head(m)
60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44
Modelled(CGW54_layer28)
Modelled(CGW54A_layer1)
Observed(CGW54_layer28)
Observed(CGW54A_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020

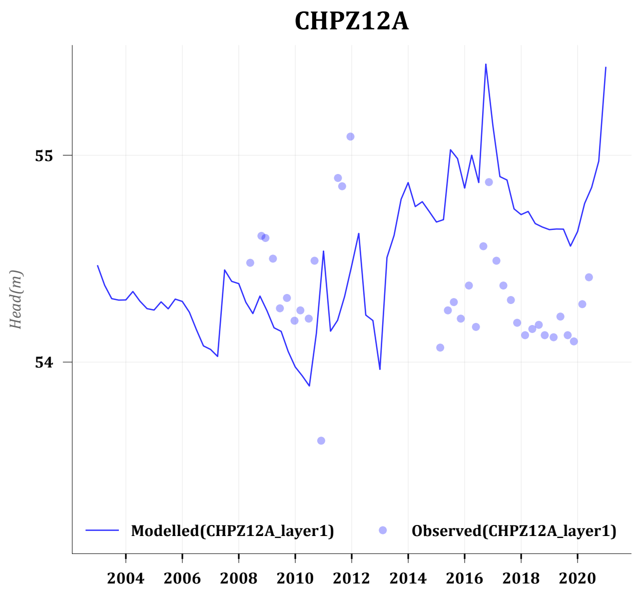

CGW55
Head(m)
59
58
57
Modelled(CGW55A_layer1)
Observed(CGW55A_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020


CGW6
Head(m)
61
60
59
58
Modelled(CGW6_layer1)
Observed(CGW6_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020

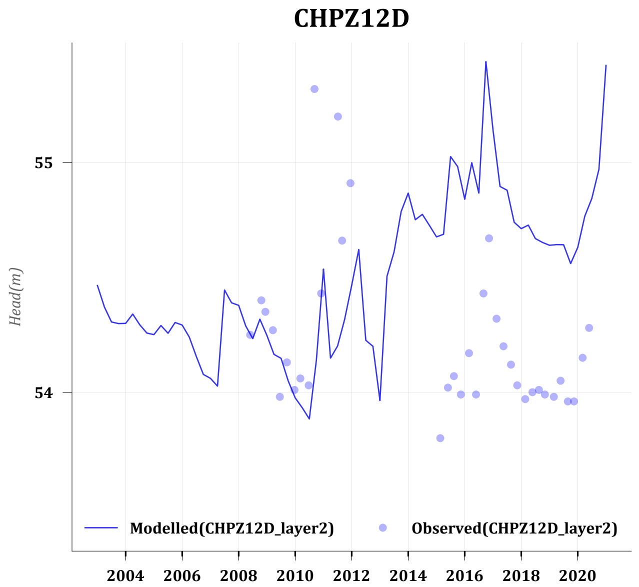

CHPZ10A
Head(m)
55
54
Modelled(CHPZ10A_layer1)
Observed(CHPZ10A_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020



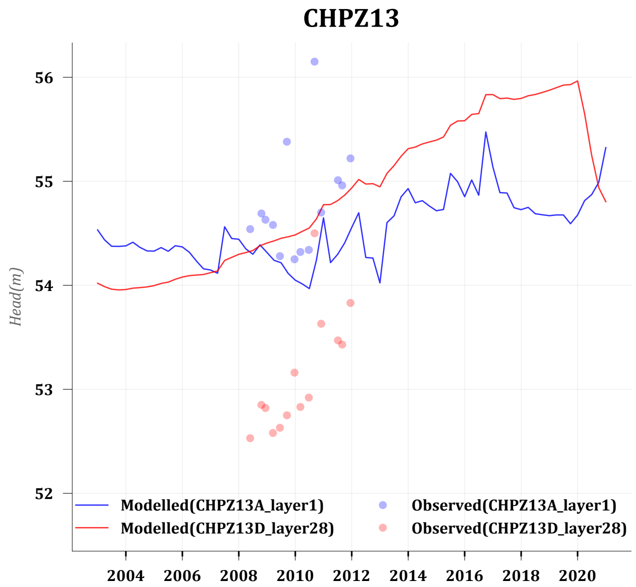
CHPZ11A
Head(m)
Modelled(CHPZ11A_layer1)
Observed(CHPZ11A_layer1)



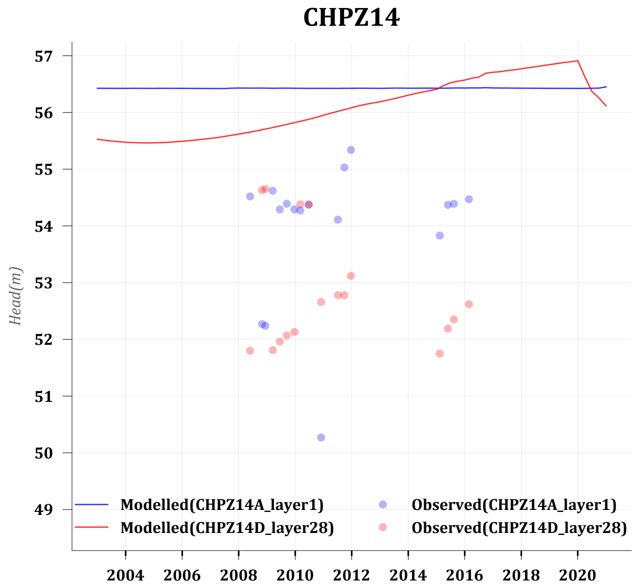
CHPZ12A
Head(m)
Modelled(CHPZ12A_layer1)
Observed(CHPZ12A_layer1)



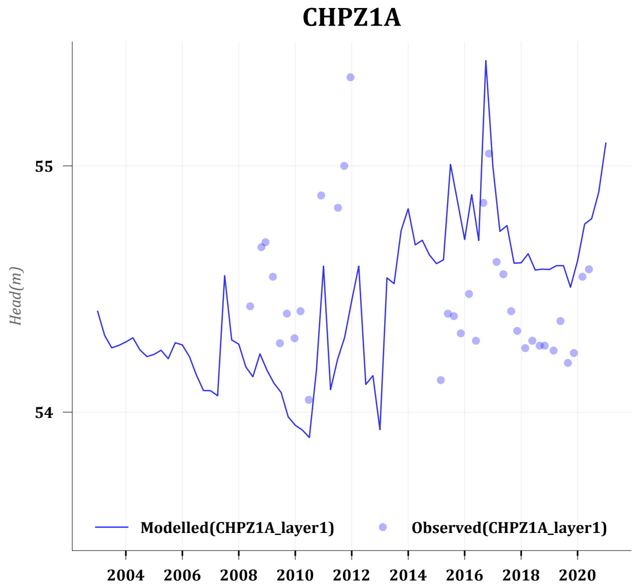
CHPZ12D
Head(m)
Modelled(CHPZ12D_layer2)
Observed(CHPZ12D_layer2)



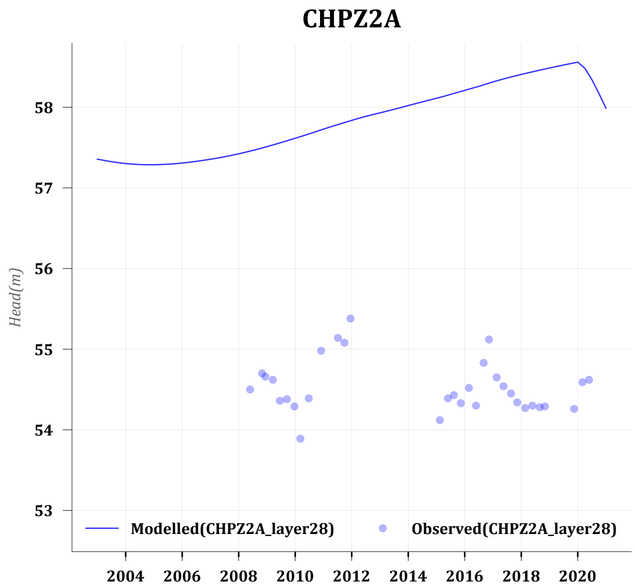
CHPZ13
Head(m)
Modelled(CHPZ13A_layer1)
Modelled(CHPZ13D_layer28)
Observed(CHPZ13A_layer1)
Observed(CHPZ13D_layer28)

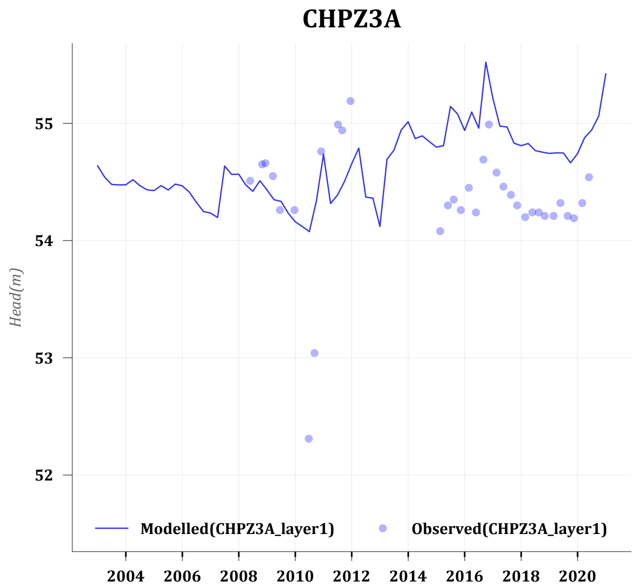


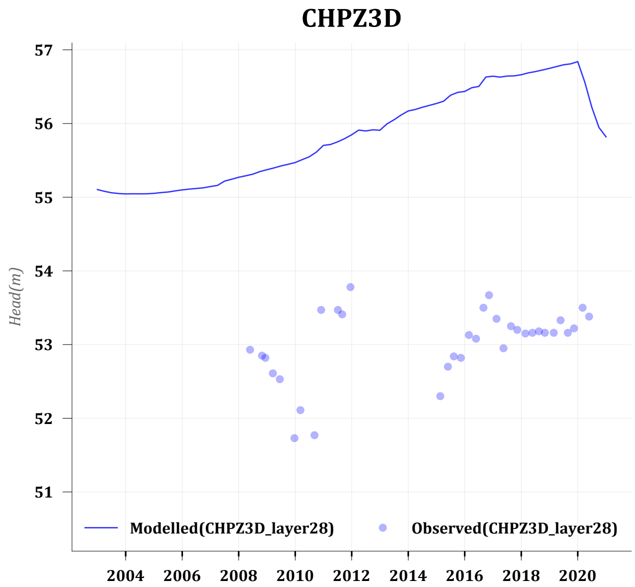
CHPZ14
Head(m)
Modelled(CHPZ14A_layer1)
Modelled(CHPZ14D_layer28)
Observed(CHPZ14A_layer1)
Observed(CHPZ14D_layer28)

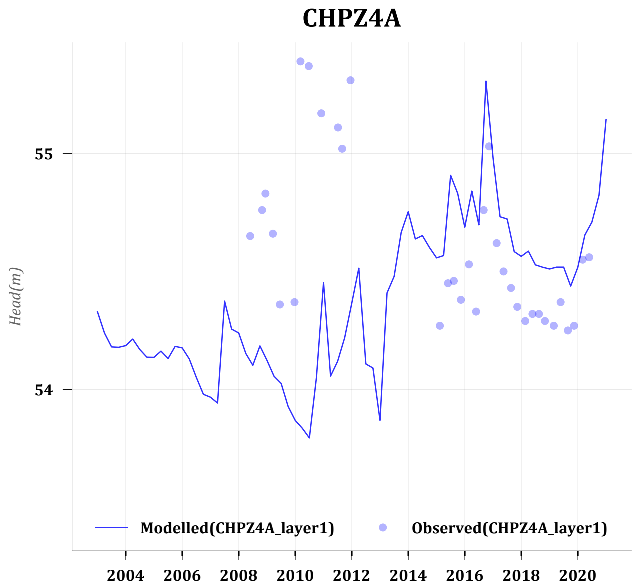


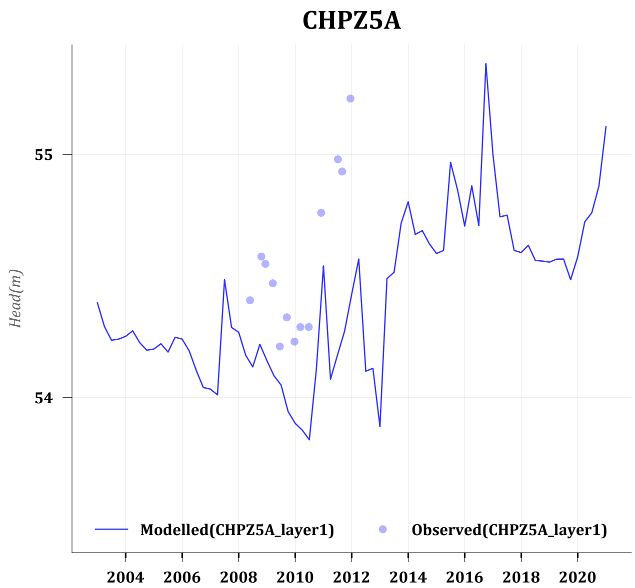
CHPZ1A
Head(m)
Modelled(CHPZ1A_layer1)
Observed(CHPZ1A_layer1)

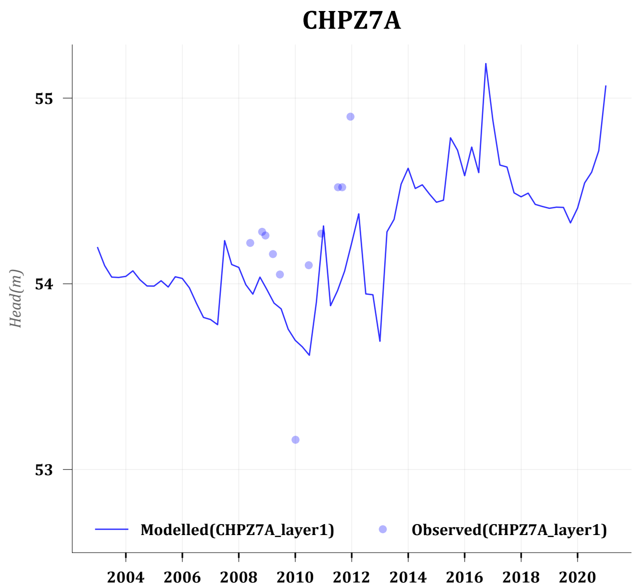

CHPZ2A
58
57
56
55
54
53
Head(m)
Modelled(CHPZ2A_layer28)
Observed(CHPZ2A_layer28)
2004 2006 2008 2010 2012 2014 2016 2018 2020

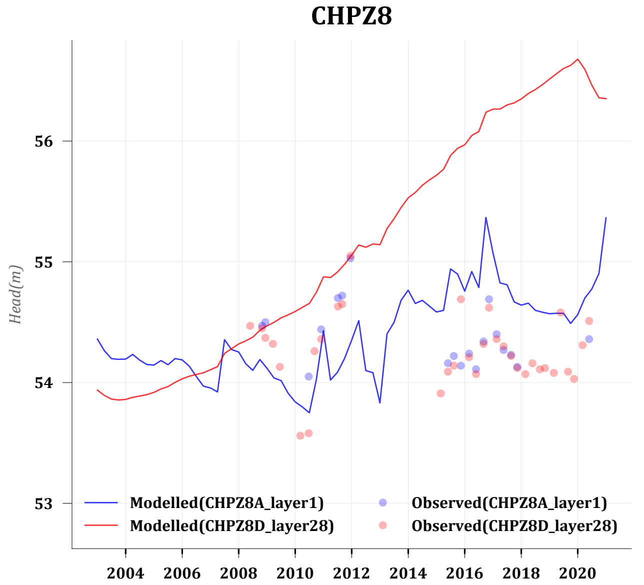

CHPZ3A
55
54
53
52
Head(m)
Modelled(CHPZ3A_layer1)
Observed(CHPZ3A_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020

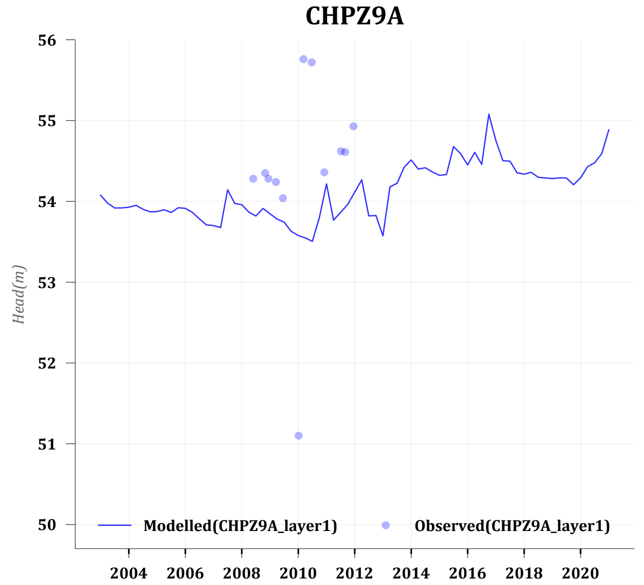

CHPZ3D
57
56
55
54
53
52
51
Head(m)
Modelled(CHPZ3D_layer28)
Observed(CHPZ3D_layer28)
2004 2006 2008 2010 2012 2014 2016 2018 2020

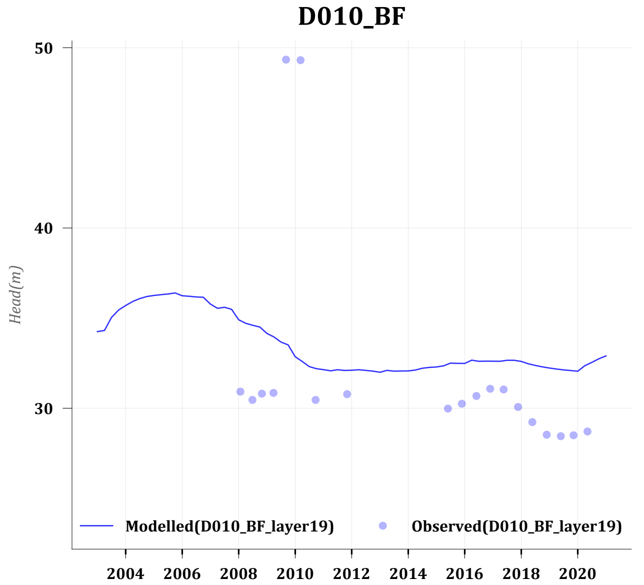

CHPZ4A
55
54
Head(m)
Modelled(CHPZ4A_layer1)
Observed(CHPZ4A_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020

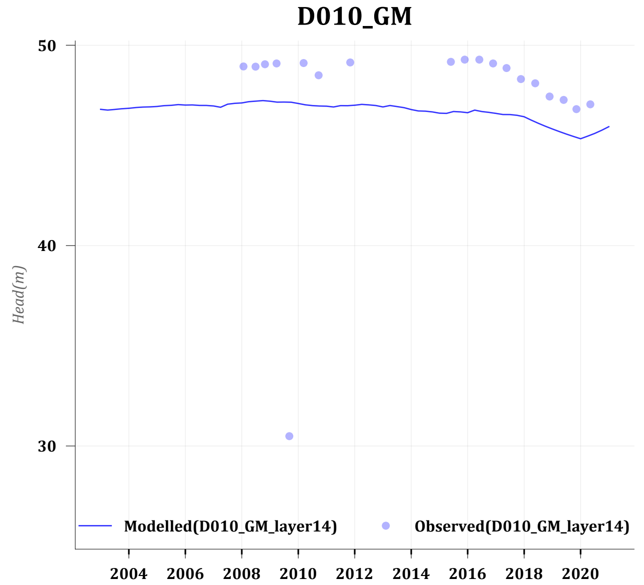

CHPZ5A
55
54
Head(m)
Modelled(CHPZ5A_layer1)
Observed(CHPZ5A_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020

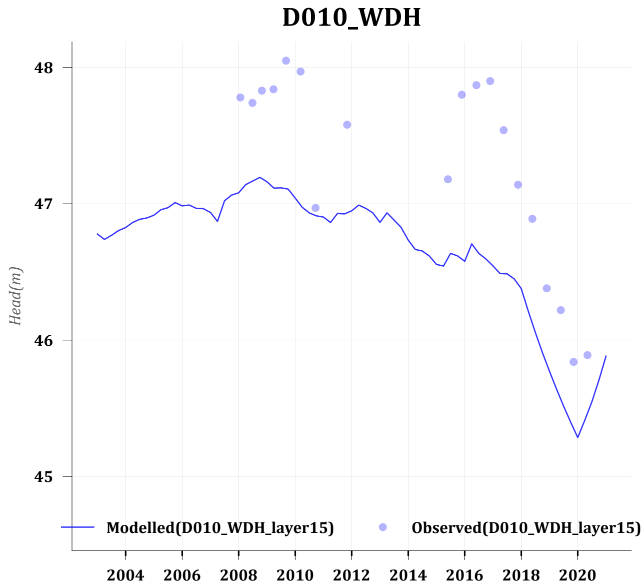

CHPZ7A
55
54
53
Head(m)
Modelled(CHPZ7A_layer1)
Observed(CHPZ7A_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020

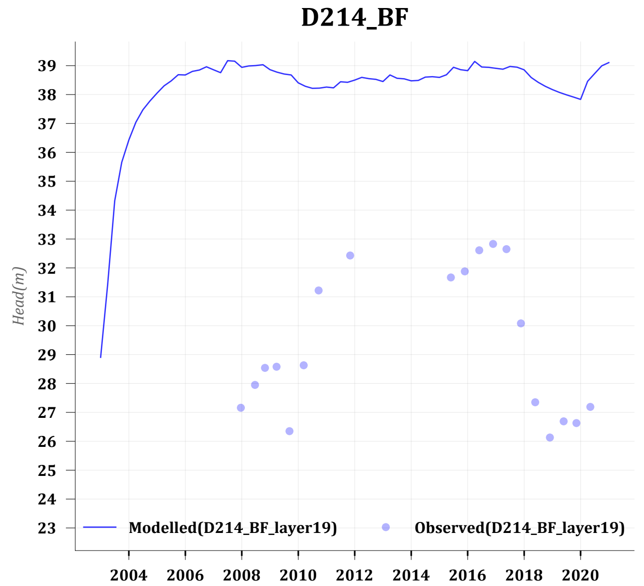

CHPZ8
Head(m)
Modelled(CHPZ8A_layer1)
Modelled(CHPZ8D_layer28)
Observed(CHPZ8A_layer1)
Observed(CHPZ8D_layer28)
53
54
55
56
2004
2006
2008
2010
2012
2014
2016
2018
2020


CHPZ9A
Head(m)
Modelled(CHPZ9A_layer1)
Observed(CHPZ9A_layer1)
50
51
52
53
54
55
56
2004
2006
2008
2010
2012
2014
2016
2018
2020

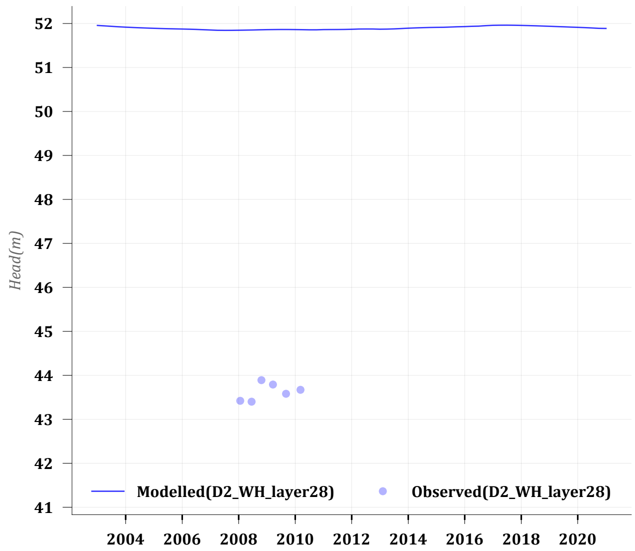

D010_BF
Head(m)
Modelled(D010_BF_layer19)
Observed(D010_BF_layer19)
30
40
50
2004
2006
2008
2010
2012
2014
2016
2018
2020


D010_GM
Head(m)
Modelled(D010_GM_layer14)
Observed(D010_GM_layer14)
30
40
50
2004
2006
2008
2010
2012
2014
2016
2018
2020

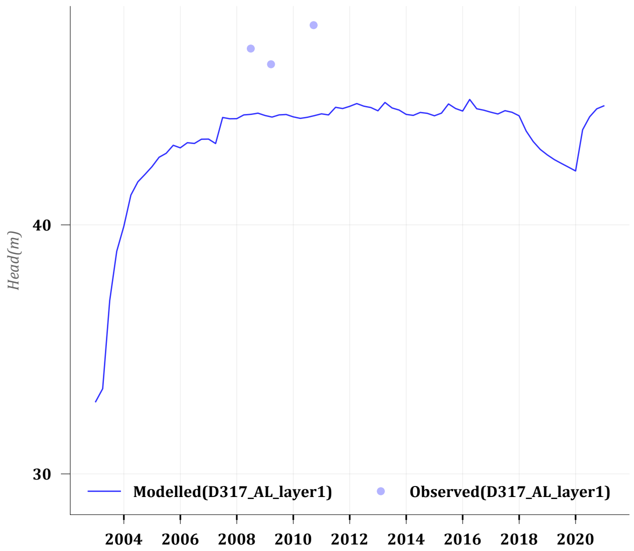

D010_WDH
Head(m)
Modelled(D010_WDH_layer15)
Observed(D010_WDH_layer15)
45
46
47
48
2004
2006
2008
2010
2012
2014
2016
2018
2020


D214_BF
Head(m)
Modelled(D214_BF_layer19)
Observed(D214_BF_layer19)
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
2004
2006
2008
2010
2012
2014
2016
2018
2020

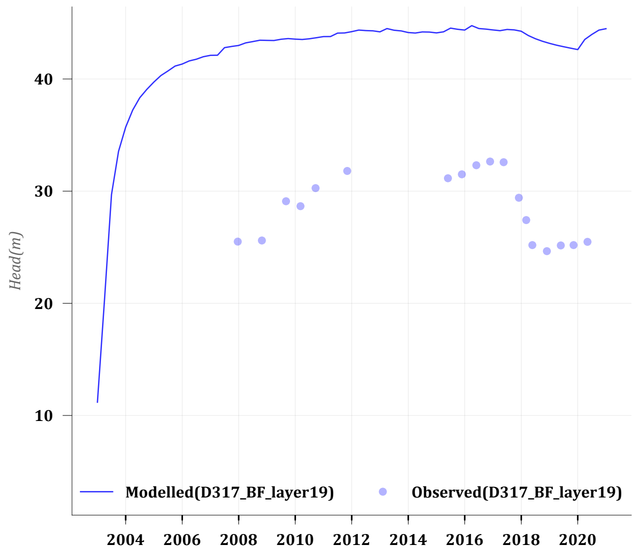
D2_WH



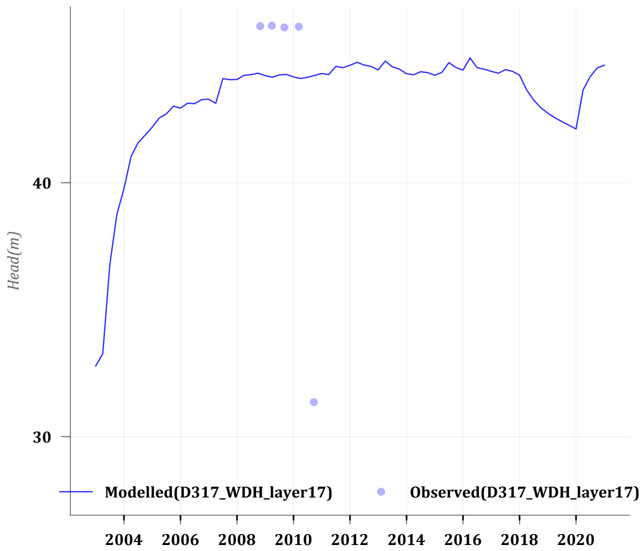
D317_AL



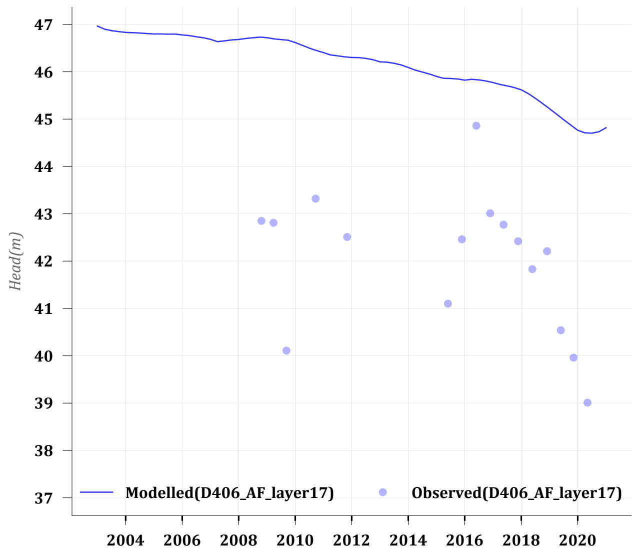
D317_BF



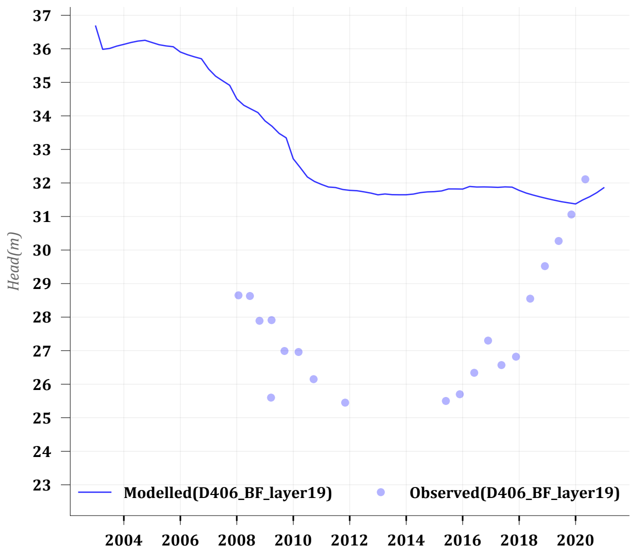
D317_WDH

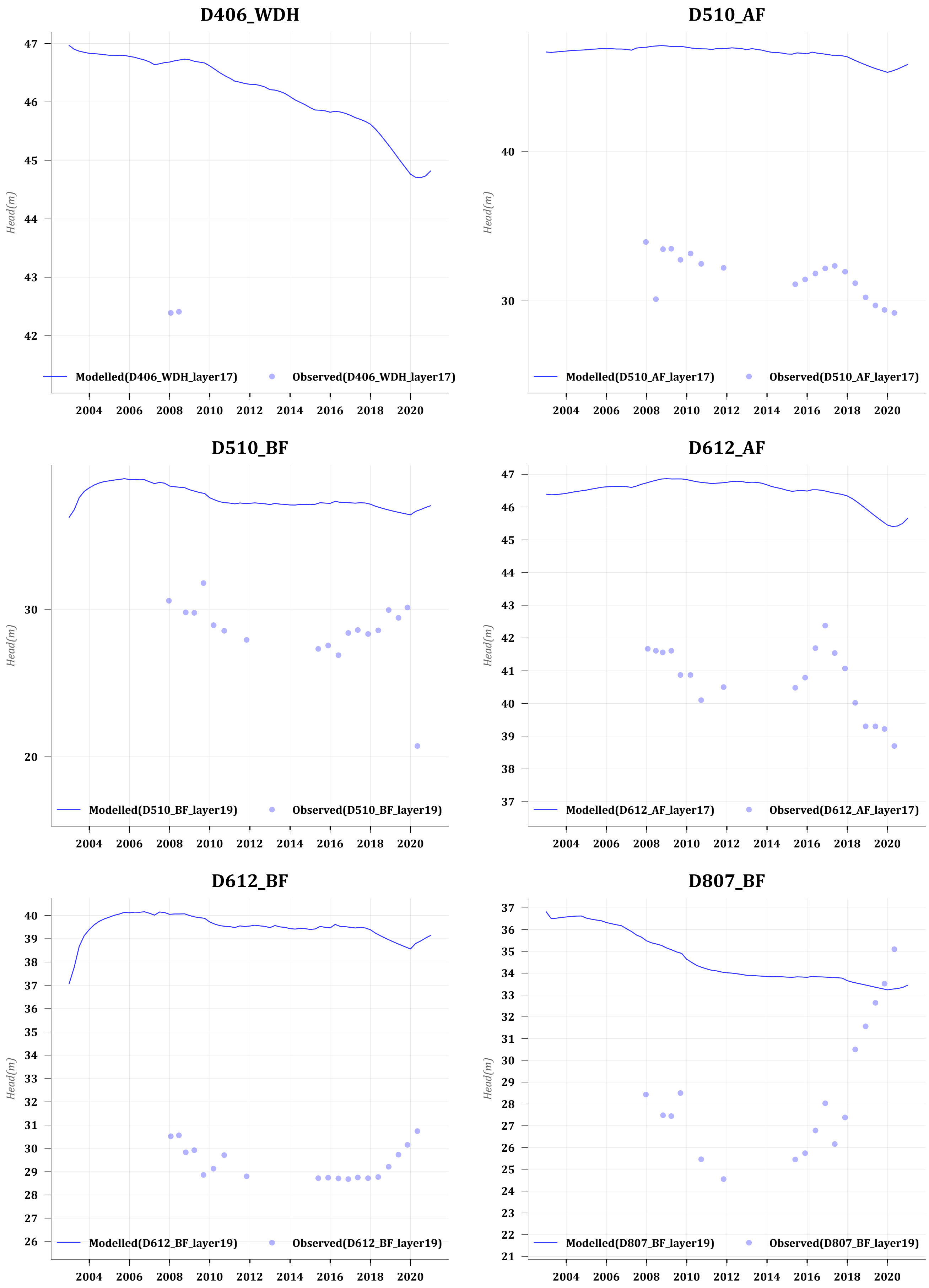


D406_AF

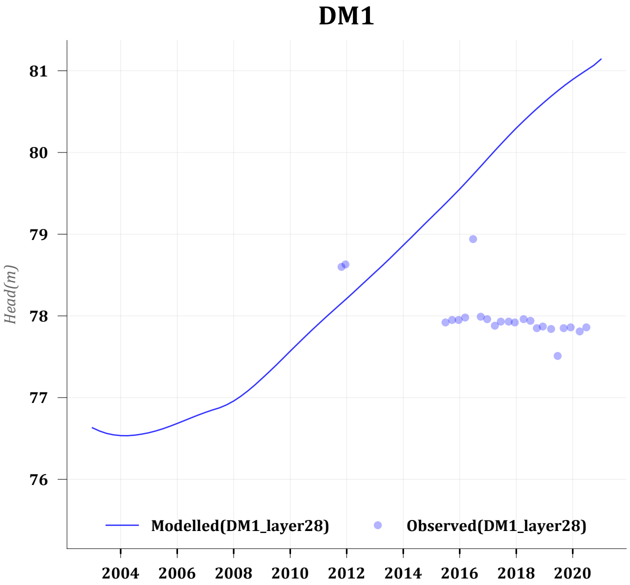


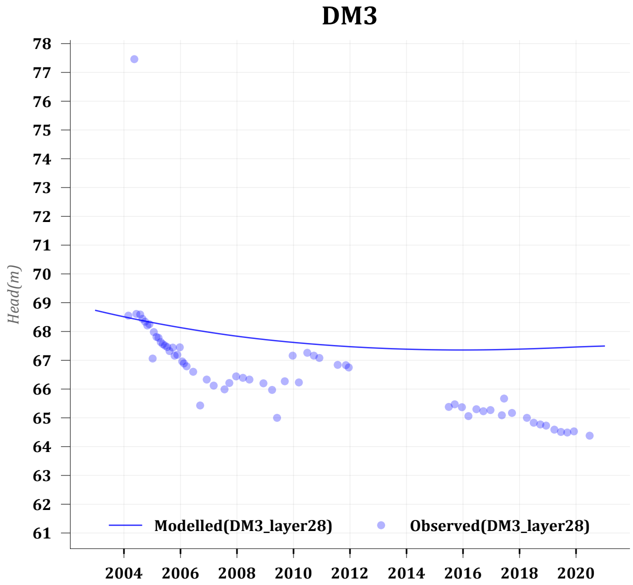
D406_BF

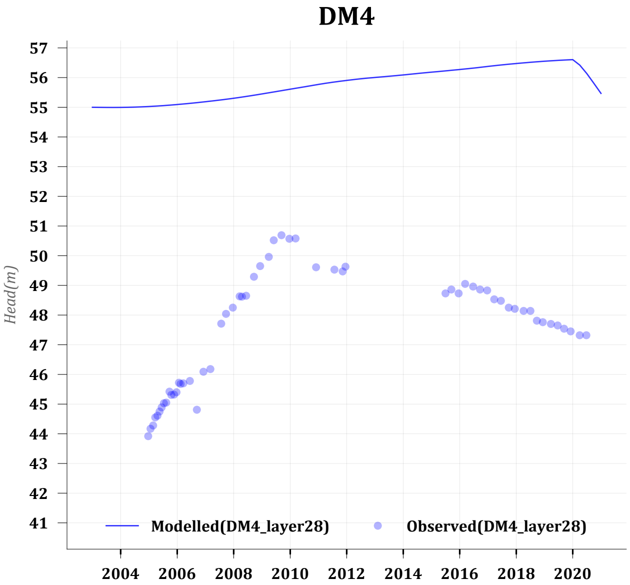


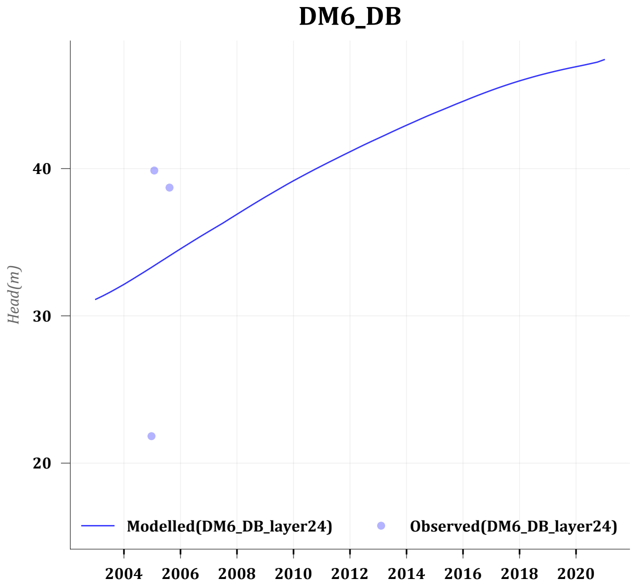


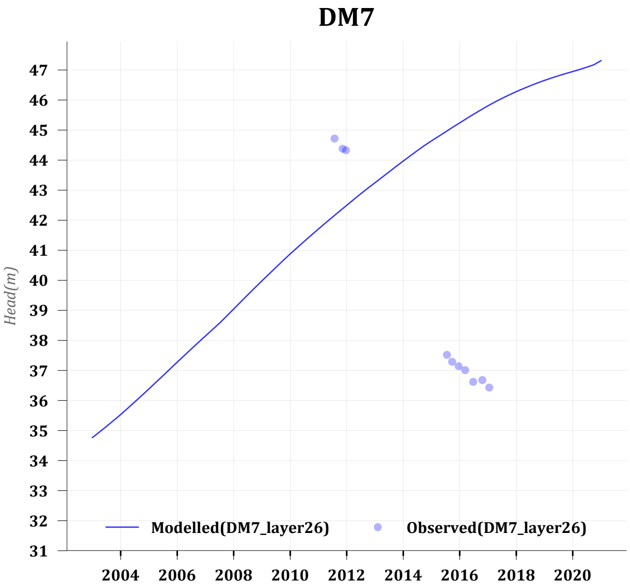
D406_WDH
Head(m)
47
46
45
44
43
42
Modelled(D406_WDH_layer17)
Observed(D406_WDH_layer17)
2004
2006
2008
2010
2012
2014
2016
2018
2020
D510_AF
Head(m)
40
30
Modelled(D510_AF_layer17)
Observed(D510_AF_layer17)
D510_BF
Head(m)
30
20
Modelled(D510_BF_layer19)
Observed(D510_BF_layer19)
D612_AF
Head(m)
47
46
45
44
43
42
41
40
39
38
37
Modelled(D612_AF_layer17)
Observed(D612_AF_layer17)
D612_BF
Head(m)
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
Modelled(D612_BF_layer19)
Observed(D612_BF_layer19)
D807_BF
Head(m)
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
Modelled(D807_BF_layer19)
Observed(D807_BF_layer19)

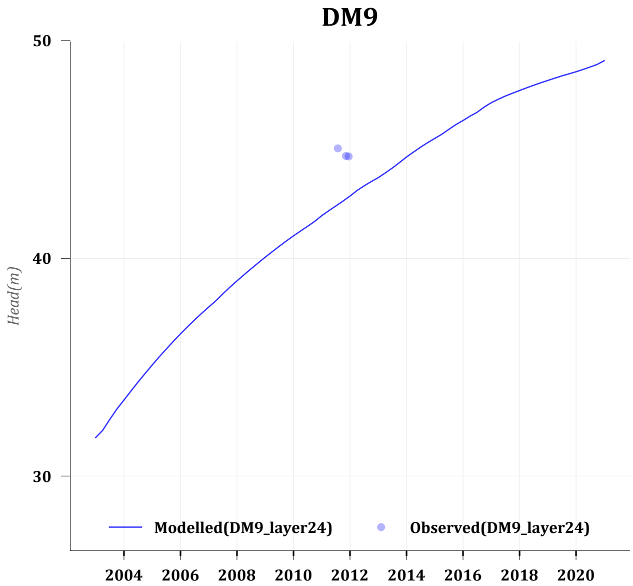

DM1
Head(m)
76
77
78
79
80
81
2004 2006 2008 2010 2012 2014 2016 2018 2020
Modelled(DM1_layer28)
Observed(DM1_layer28)

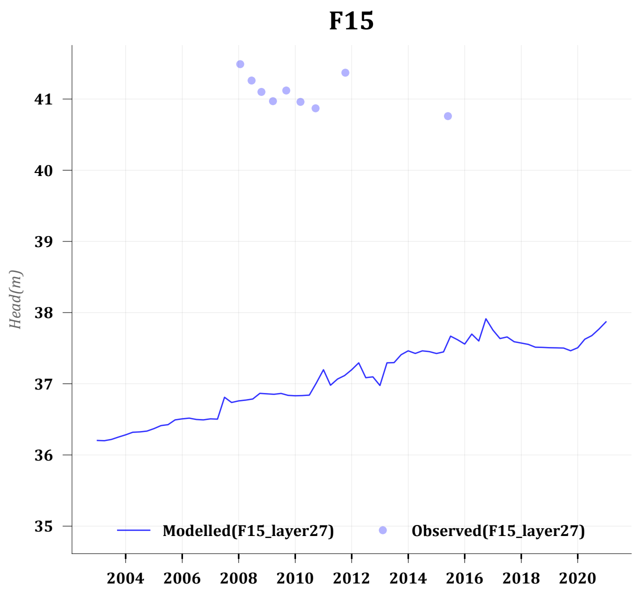

DM3
Head(m)
61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78
2004 2006 2008 2010 2012 2014 2016 2018 2020
Modelled(DM3_layer28)
Observed(DM3_layer28)

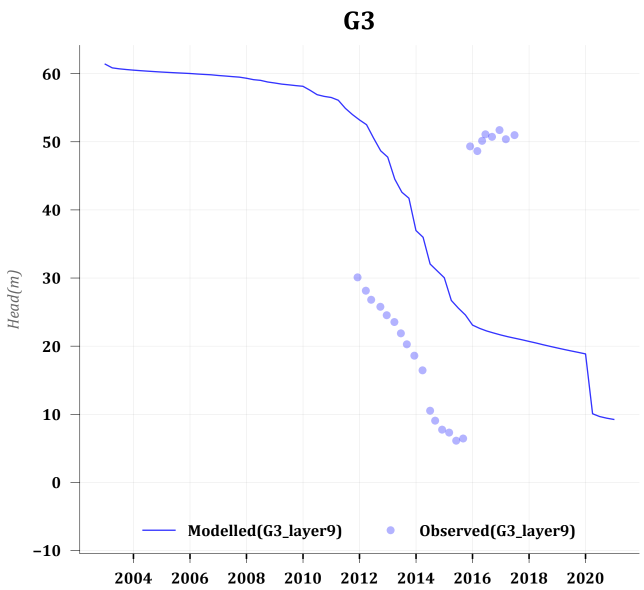

DM4
Head(m)
41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57
2004 2006 2008 2010 2012 2014 2016 2018 2020
Modelled(DM4_layer28)
Observed(DM4_layer28)

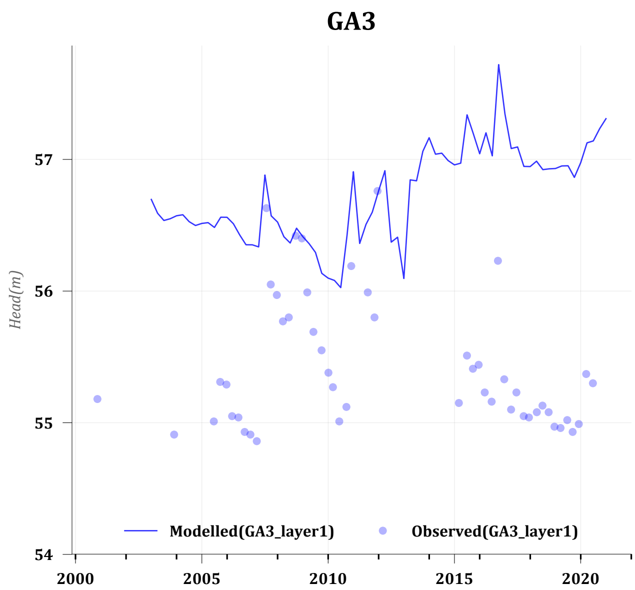

DM6_DB
Head(m)
20
30
40
2004 2006 2008 2010 2012 2014 2016 2018 2020
Modelled(DM6_DB_layer24)
Observed(DM6_DB_layer24)

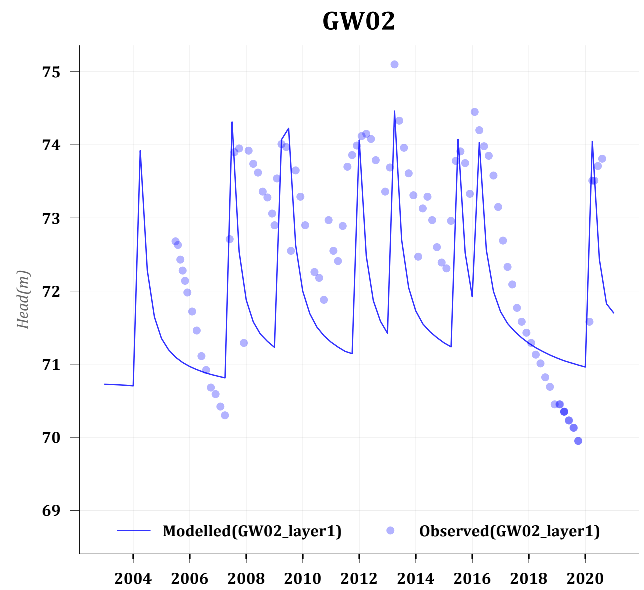

DM7
Head(m)
31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
2004 2006 2008 2010 2012 2014 2016 2018 2020
Modelled(DM7_layer26)
Observed(DM7_layer26)

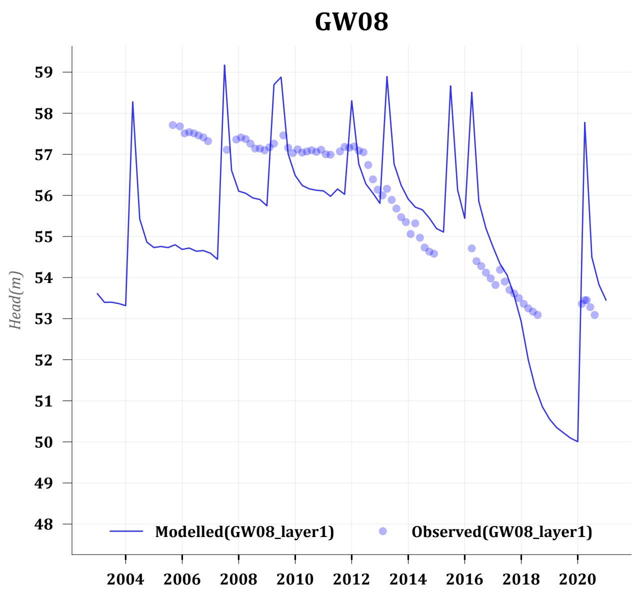

DM9
Head(m)
30
40
50
2004 2006 2008 2010 2012 2014 2016 2018 2020
Modelled(DM9_layer24)
Observed(DM9_layer24)

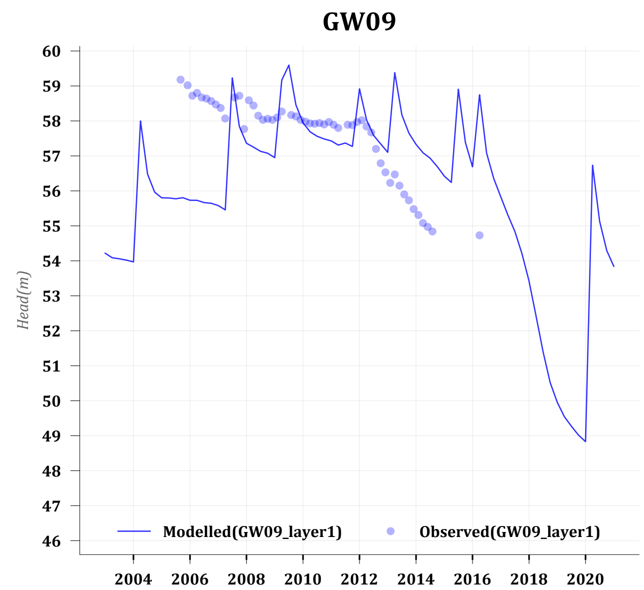

F15
Head(m)
Modelled(F15_layer27)
Observed(F15_layer27)
35
36
37
38
39
40
41
2004
2006
2008
2010
2012
2014
2016
2018
2020

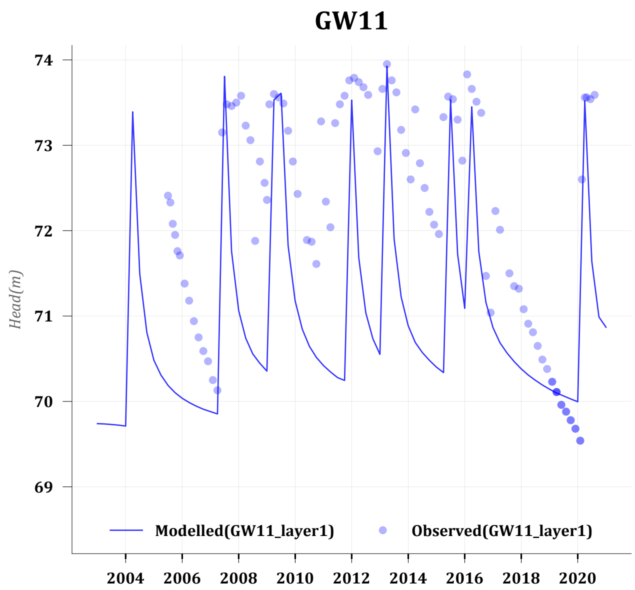

G3
Head(m)
Modelled(G3_layer9)
Observed(G3_layer9)
−10
0
10
20
30
40
50
60
2004
2006
2008
2010
2012
2014
2016
2018
2020

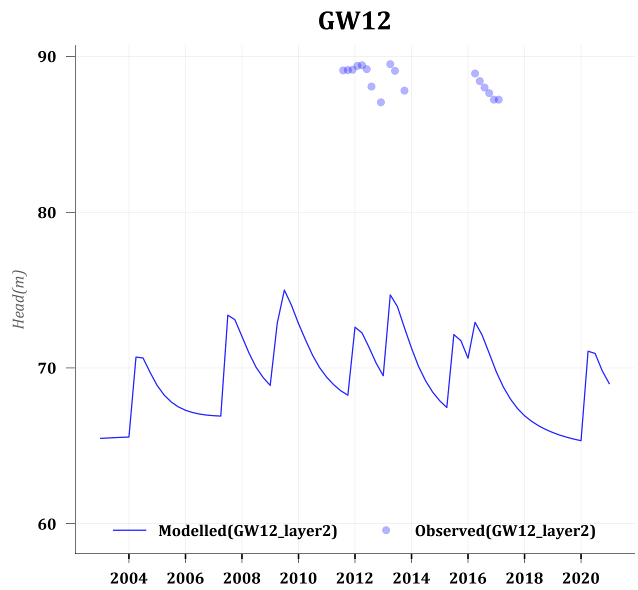

GA3
Head(m)
Modelled(GA3_layer1)
Observed(GA3_layer1)
54
55
56
57
2000
2005
2010
2015
2020

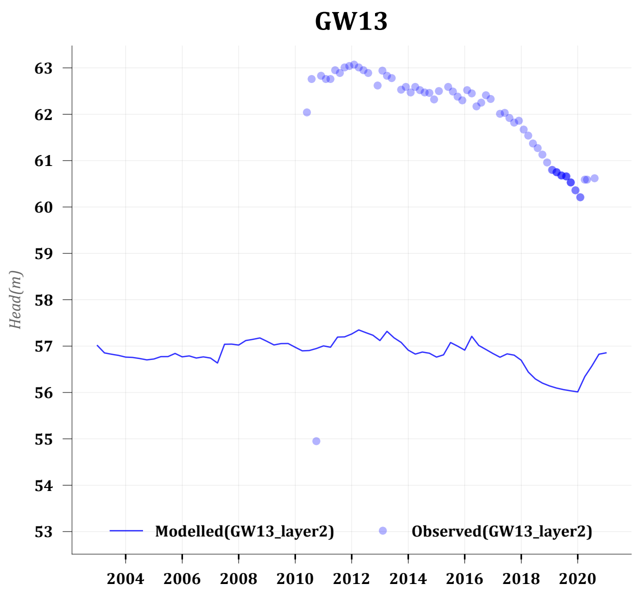

GW02
Head(m)
Modelled(GW02_layer1)
Observed(GW02_layer1)
69
70
71
72
73
74
75
2004
2006
2008
2010
2012
2014
2016
2018
2020

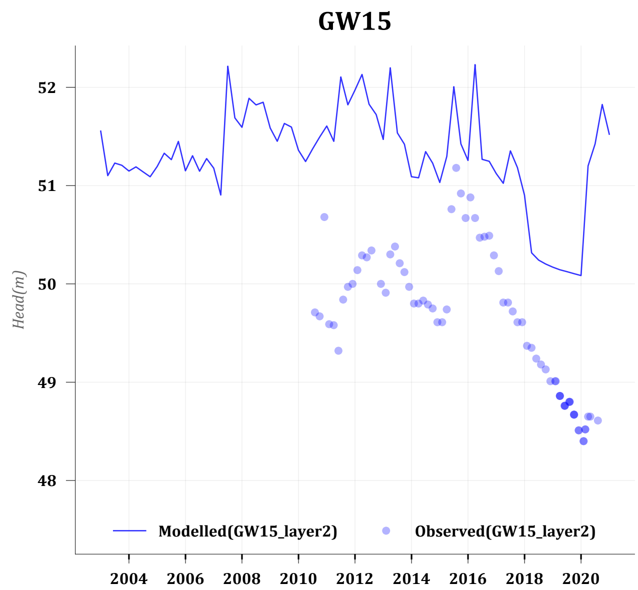

GW08
Head(m)
Modelled(GW08_layer1)
Observed(GW08_layer1)
48
49
50
51
52
53
54
55
56
57
58
59
2004
2006
2008
2010
2012
2014
2016
2018
2020

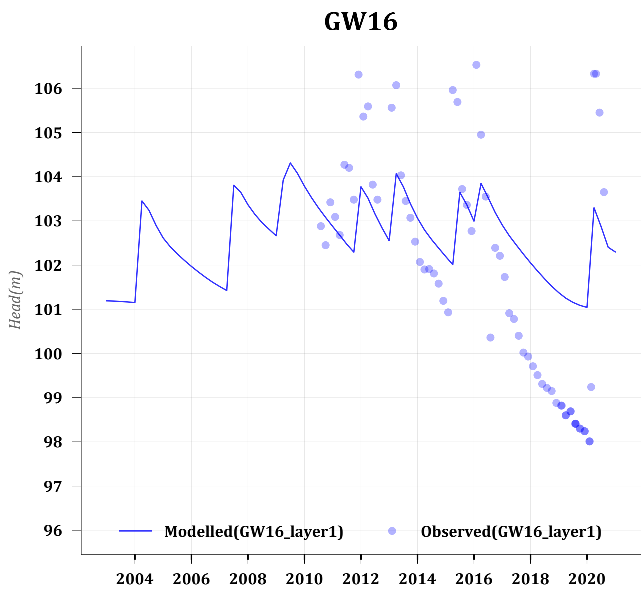

GW09
Head(m)
Modelled(GW09_layer1)
Observed(GW09_layer1)
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
2004
2006
2008
2010
2012
2014
2016
2018
2020

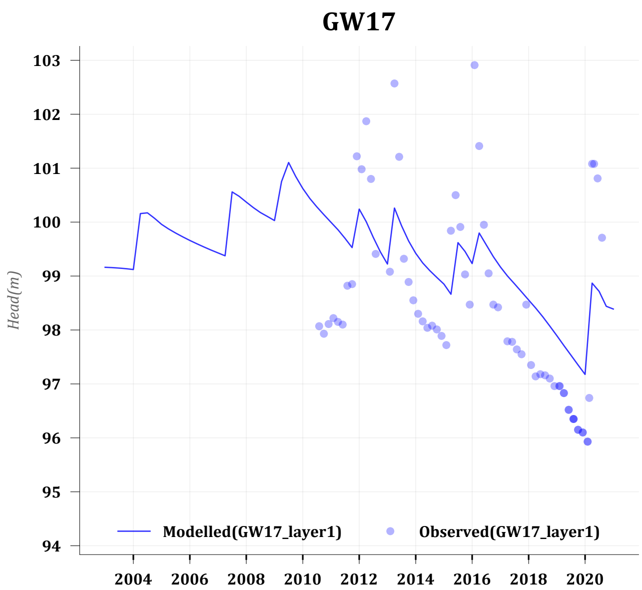

GW11
Head(m)
Modelled(GW11_layer1)
Observed(GW11_layer1)

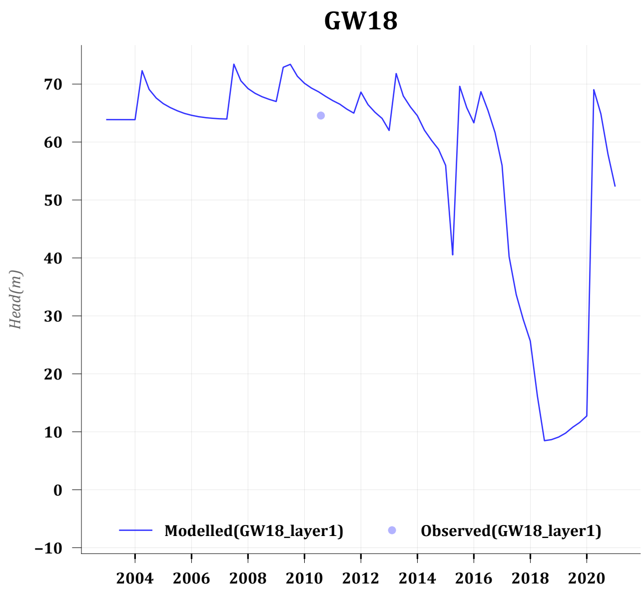

GW12
Head(m)
Modelled(GW12_layer2)
Observed(GW12_layer2)

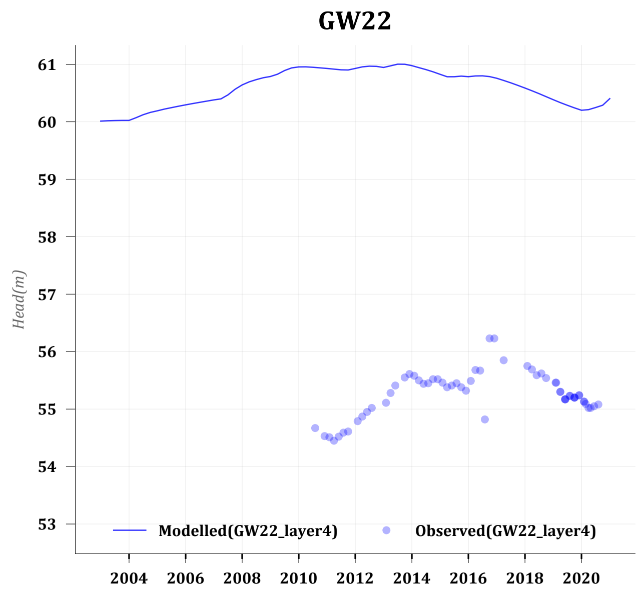

GW13
Head(m)
Modelled(GW13_layer2)
Observed(GW13_layer2)

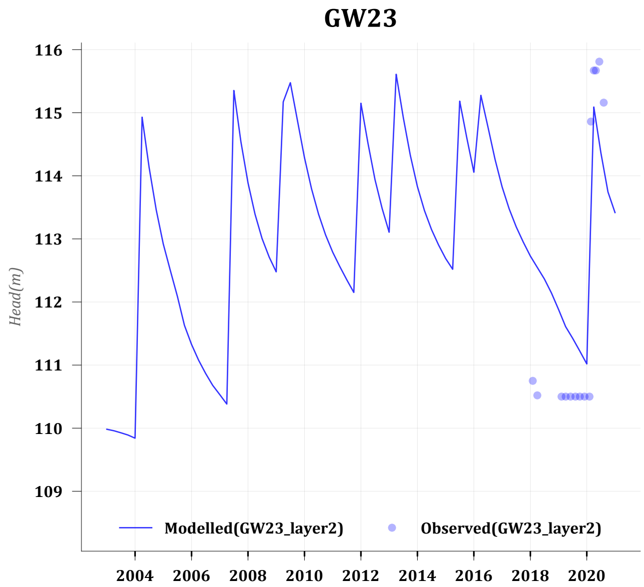

GW15
Head(m)
Modelled(GW15_layer2)
Observed(GW15_layer2)

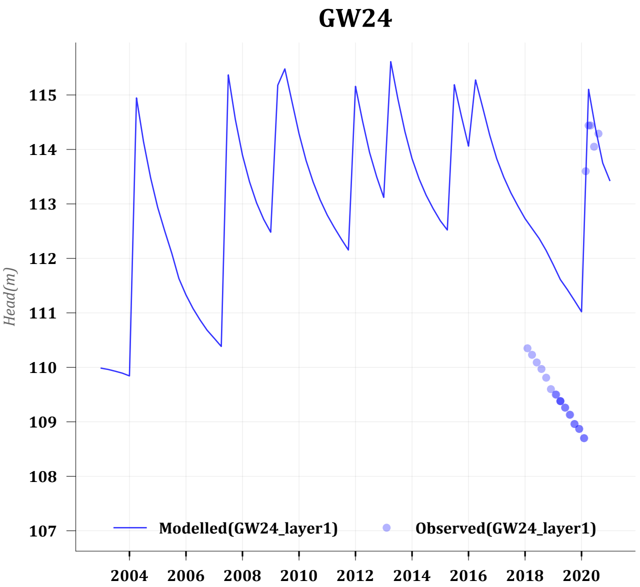

GW16
Head(m)
Modelled(GW16_layer1)
Observed(GW16_layer1)

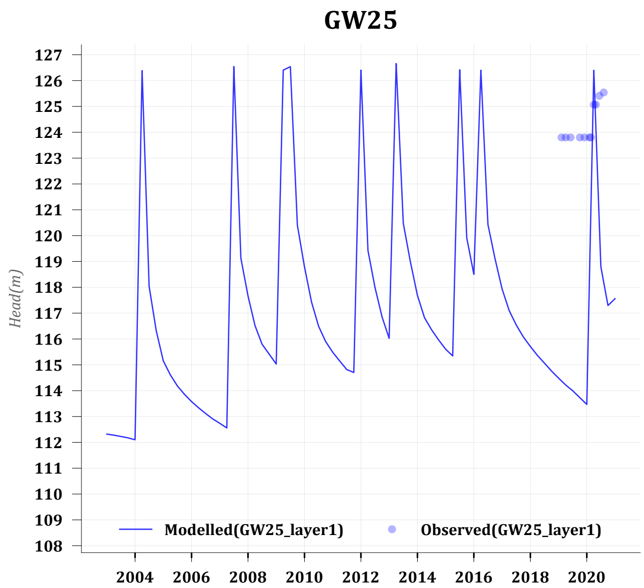

GW17
Head(m)
Modelled(GW17_layer1)
Observed(GW17_layer1)

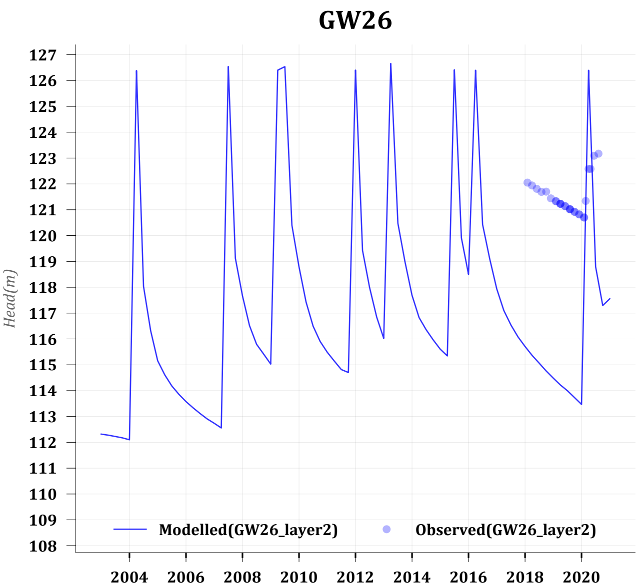

GW18
Head(m)
Modelled(GW18_layer1)
Observed(GW18_layer1)

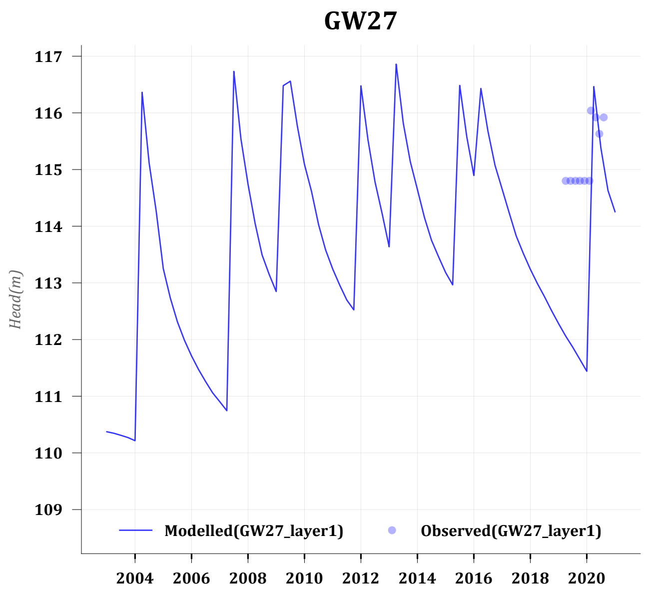

GW22
Head(m)
Modelled(GW22_layer4)
Observed(GW22_layer4)

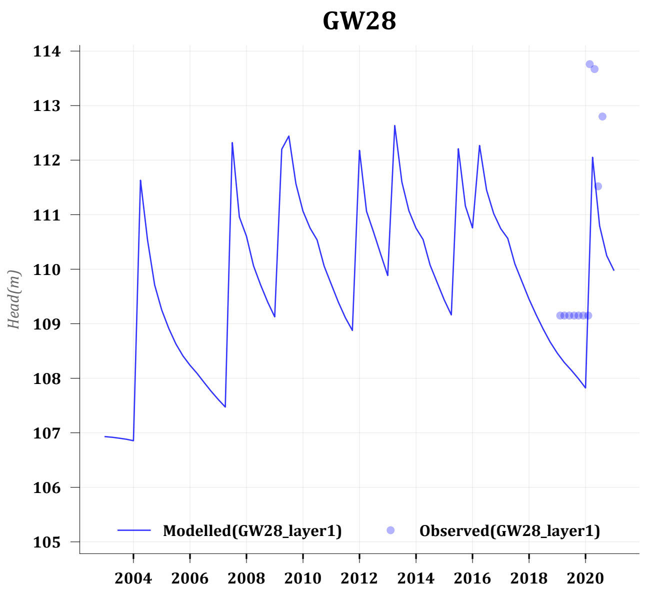

GW23
Head(m)
Modelled(GW23_layer2)
Observed(GW23_layer2)

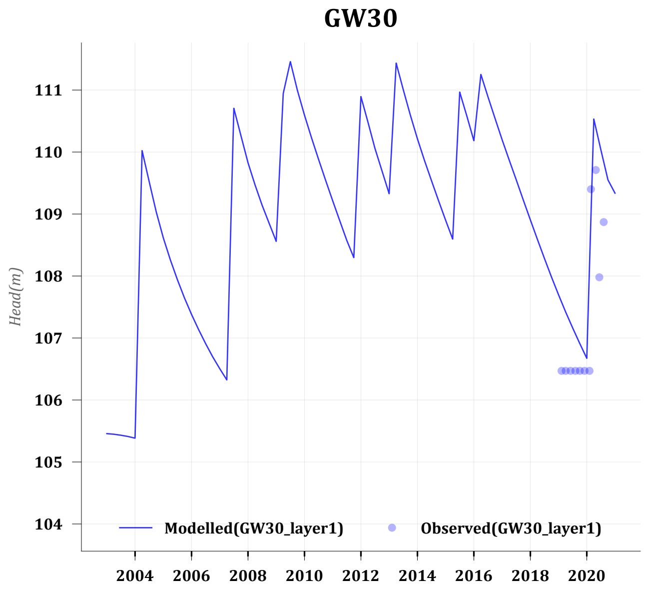

GW24
Head(m)
Modelled(GW24_layer1)
Observed(GW24_layer1)

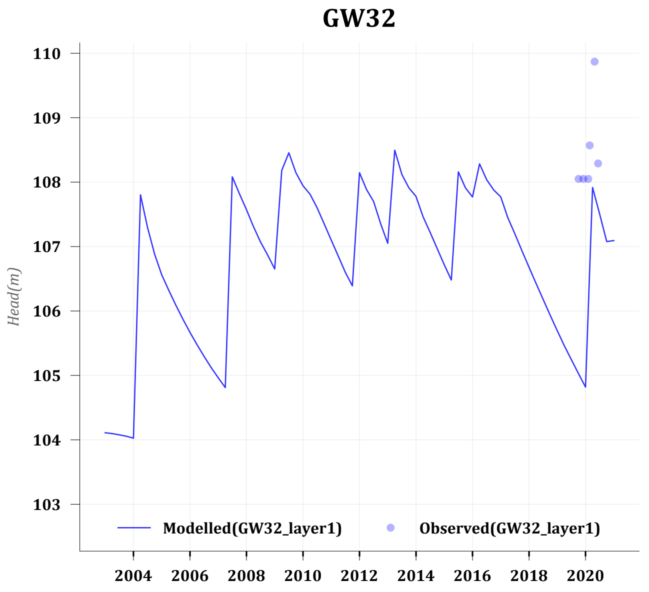

GW25
Head(m)
Modelled(GW25_layer1)
Observed(GW25_layer1)

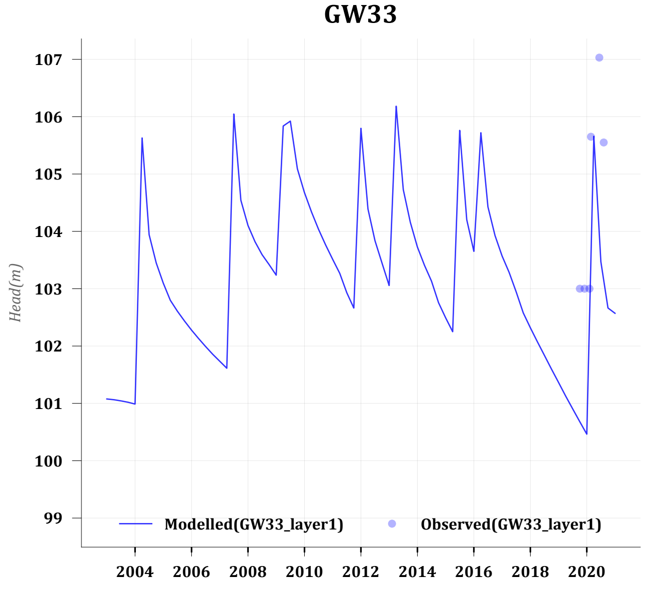

GW26
Head(m)
Modelled(GW26_layer2)
Observed(GW26_layer2)

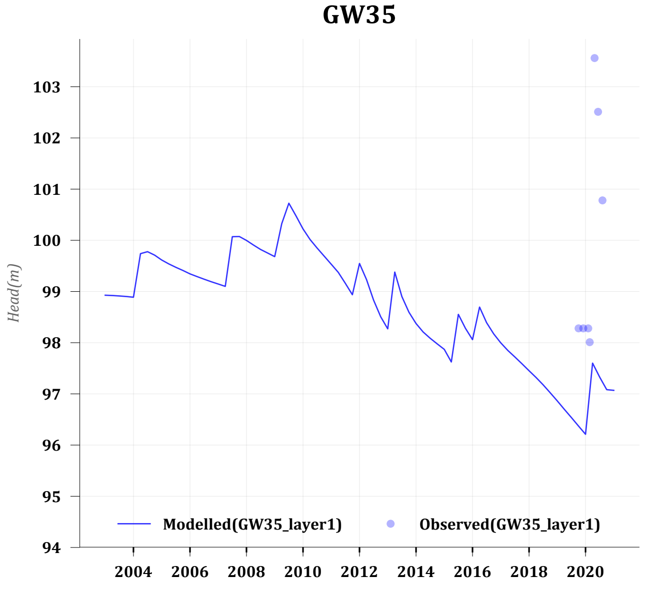

GW27
117
116
115
114
113
112
111
110
109
Head(m)
Modelled(GW27_layer1)
Observed(GW27_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

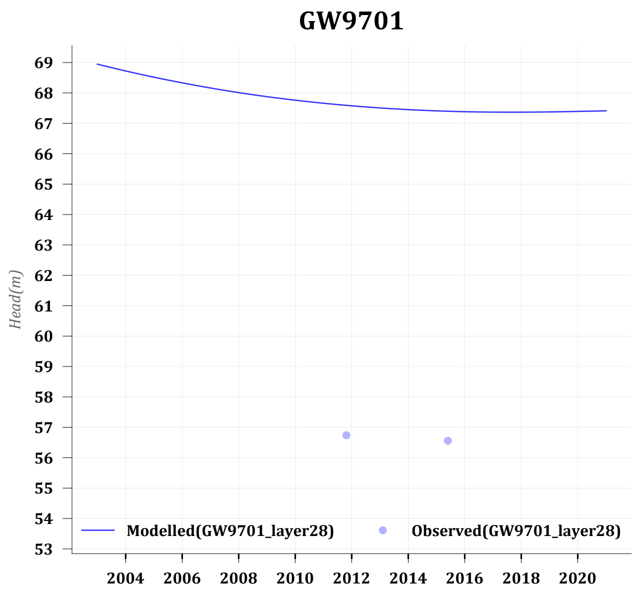

GW28
114
113
112
111
110
109
108
107
106
105
Head(m)
Modelled(GW28_layer1)
Observed(GW28_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

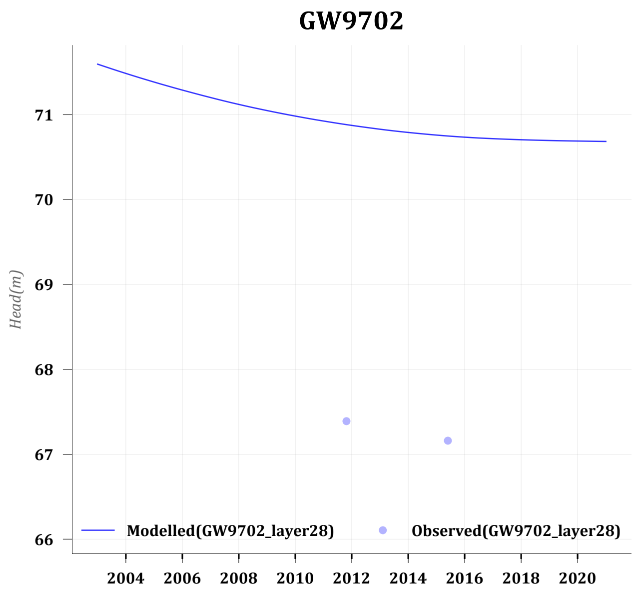

GW30
111
110
109
108
107
106
105
104
Head(m)
Modelled(GW30_layer1)
Observed(GW30_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

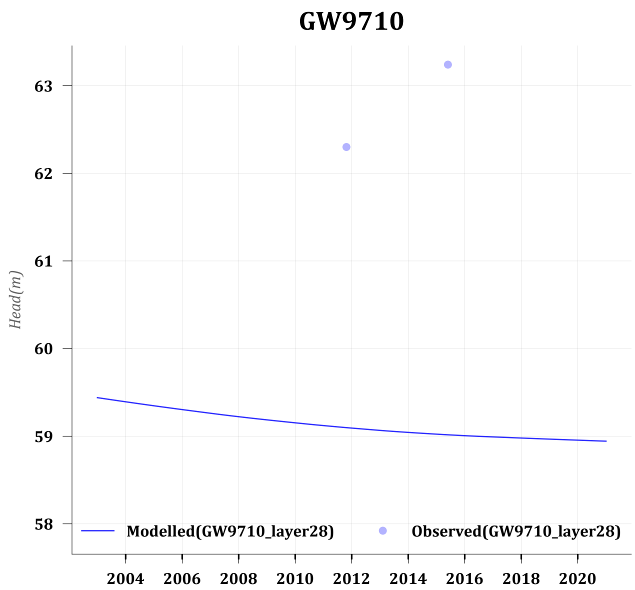

GW32
110
109
108
107
106
105
104
103
Head(m)
Modelled(GW32_layer1)
Observed(GW32_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

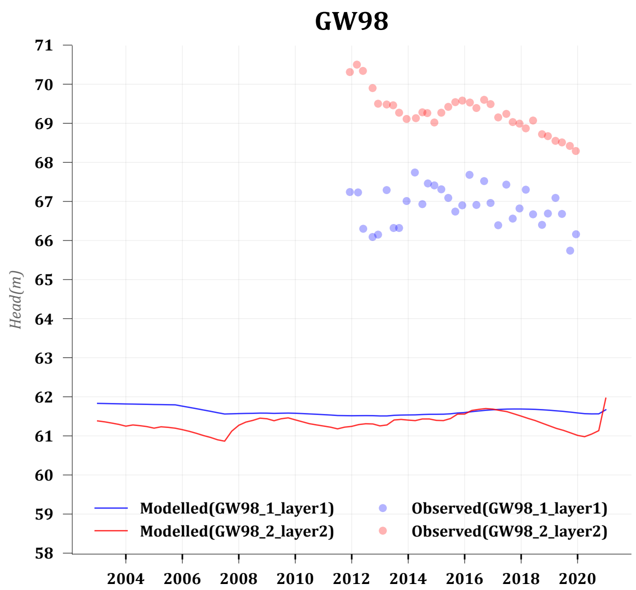

GW33
107
106
105
104
103
102
101
100
99
Head(m)
Modelled(GW33_layer1)
Observed(GW33_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

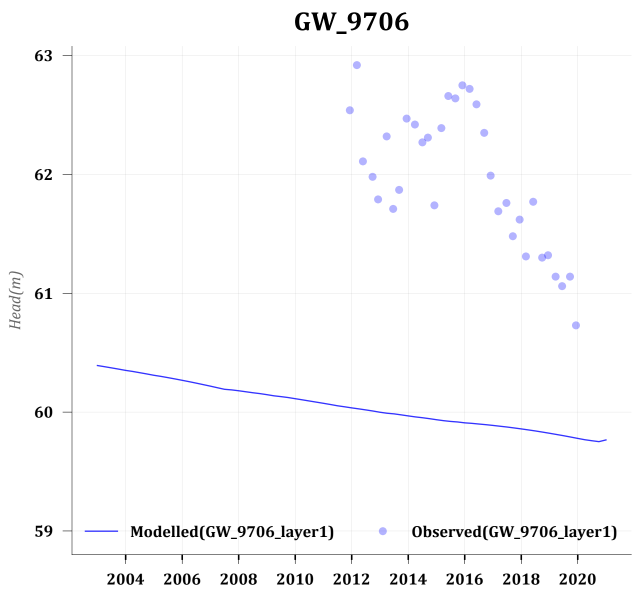

GW35
103
102
101
100
99
98
97
96
95
94
Head(m)
Modelled(GW35_layer1)
Observed(GW35_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

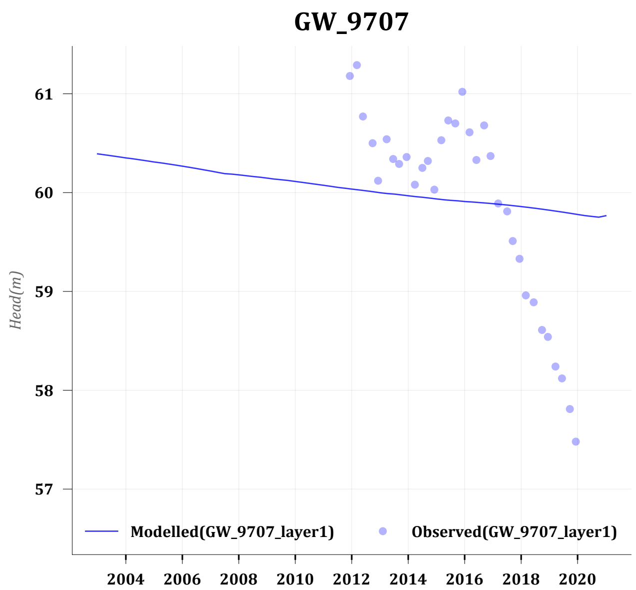

GW9701
Head(m)
Modelled(GW9701_layer28)
Observed(GW9701_layer28)

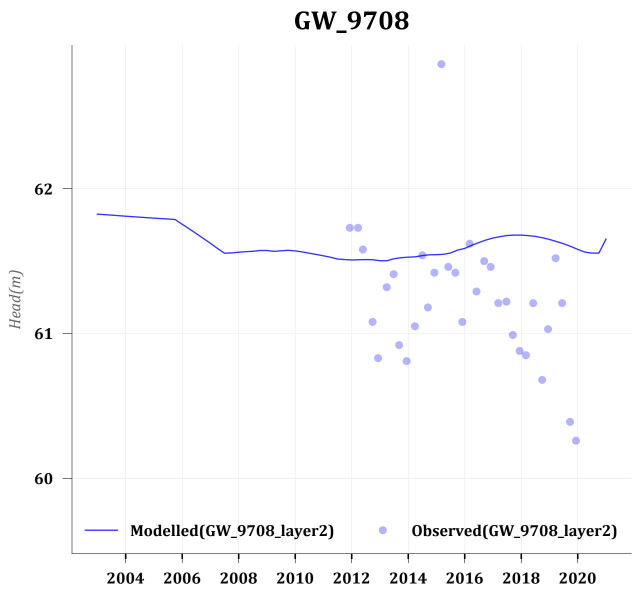

GW9702
Head(m)
Modelled(GW9702_layer28)
Observed(GW9702_layer28)

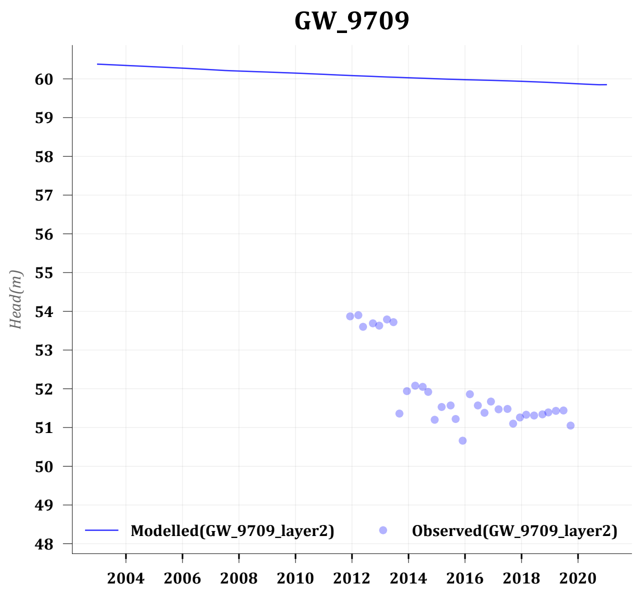

GW9710
Head(m)
Modelled(GW9710_layer28)
Observed(GW9710_layer28)

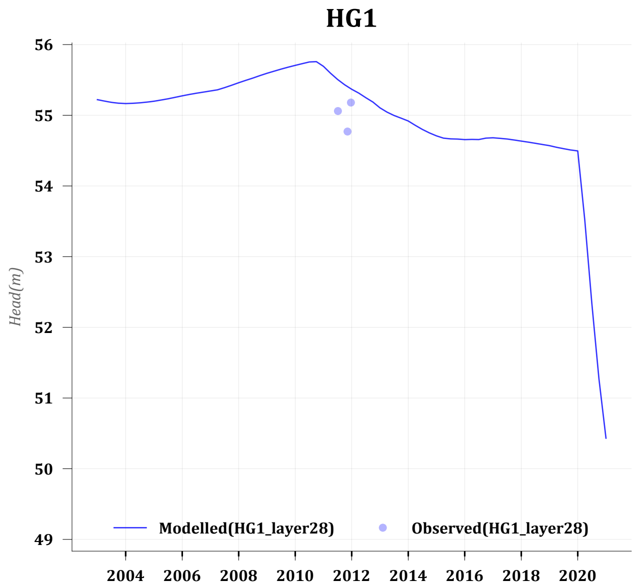

GW98
Head(m)
Modelled(GW98_1_layer1)
Observed(GW98_1_layer1)
Modelled(GW98_2_layer2)
Observed(GW98_2_layer2)

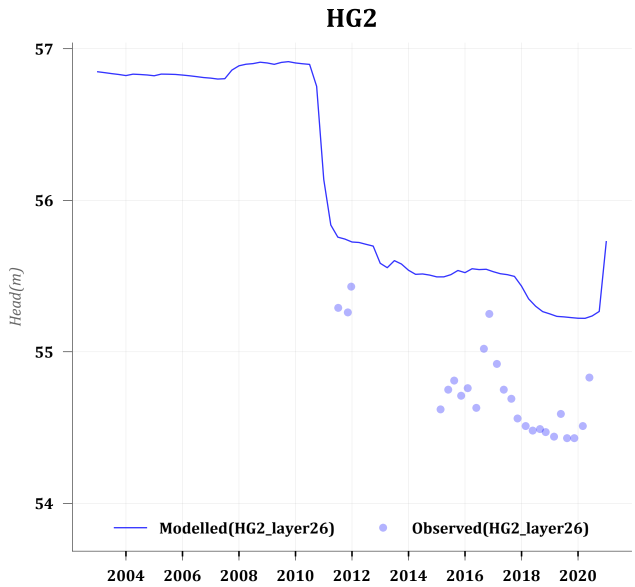

GW_9706
Head(m)
Modelled(GW_9706_layer1)
Observed(GW_9706_layer1)

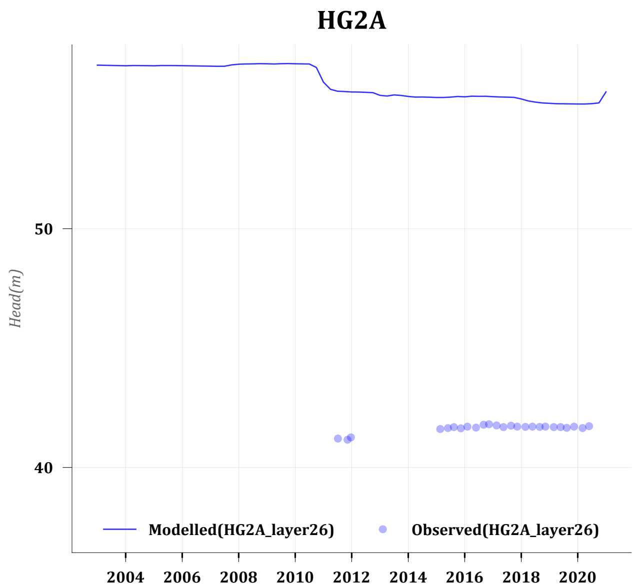

GW_9707
Head(m)
Modelled(GW_9707_layer1)
Observed(GW_9707_layer1)

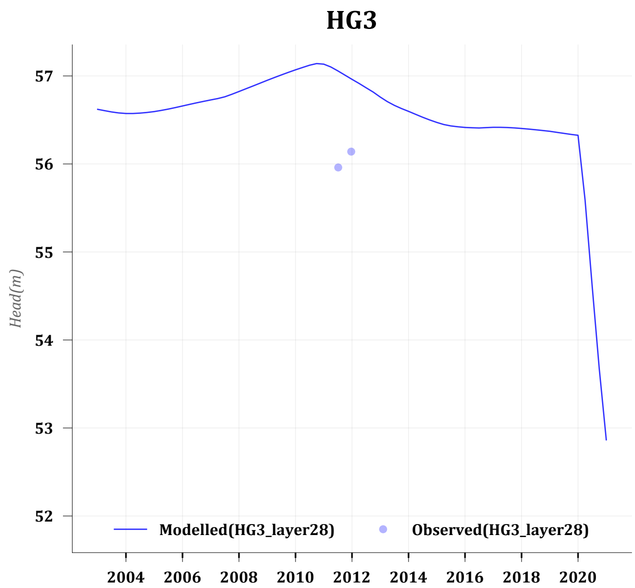

GW_9708
Head(m)
60
61
62
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(GW_9708_layer2)
Observed(GW_9708_layer2)

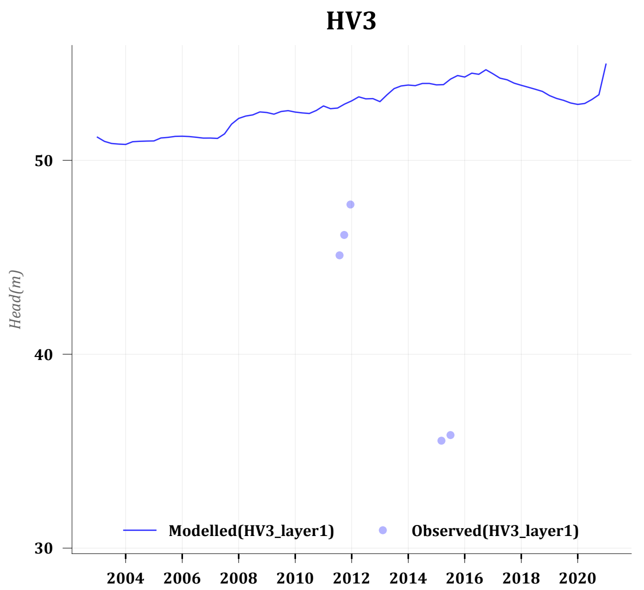

GW_9709
Head(m)
48
49
50
51
52
53
54
55
56
57
58
59
60
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(GW_9709_layer2)
Observed(GW_9709_layer2)

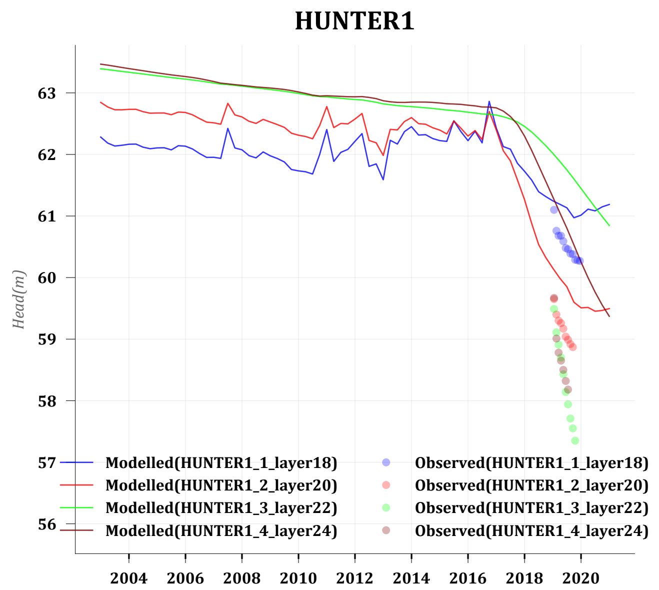

HG1
Head(m)
49
50
51
52
53
54
55
56
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(HG1_layer28)
Observed(HG1_layer28)


HG2
Head(m)
54
55
56
57
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(HG2_layer26)
Observed(HG2_layer26)


HG2A
Head(m)
40
50
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(HG2A_layer26)
Observed(HG2A_layer26)


HG3
Head(m)
52
53
54
55
56
57
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(HG3_layer28)
Observed(HG3_layer28)


HV3
Head(m)
50
40
30
Modelled(HV3_layer1)
Observed(HV3_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020


HUNTER1
Head(m)
63
62
61
60
59
58
57
56
Modelled(HUNTER1_1_layer18)
Modelled(HUNTER1_2_layer20)
Modelled(HUNTER1_3_layer22)
Modelled(HUNTER1_4_layer24)
Observed(HUNTER1_1_layer18)
Observed(HUNTER1_2_layer20)
Observed(HUNTER1_3_layer22)
Observed(HUNTER1_4_layer24)
2004
2006
2008
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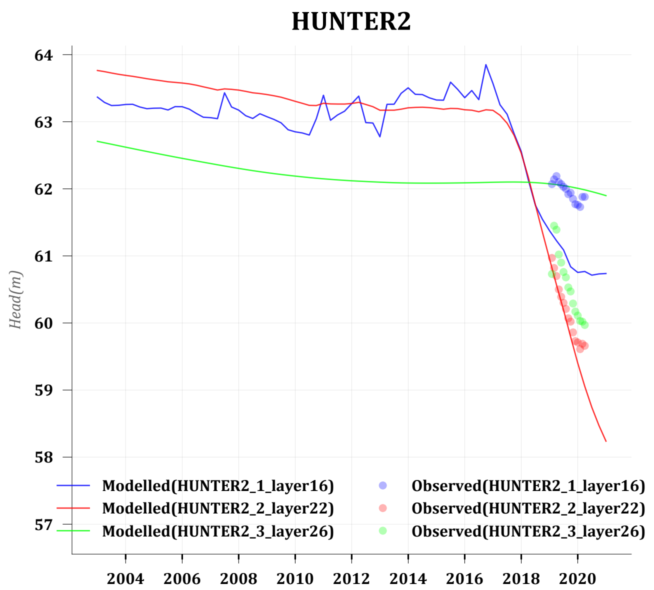
2012
2014
2016
2018
2020


HUNTER2
Head(m)
64
63
62
61
60
59
58
57
Modelled(HUNTER2_1_layer16)
Modelled(HUNTER2_2_layer22)
Modelled(HUNTER2_3_layer26)
Observed(HUNTER2_1_layer16)
Observed(HUNTER2_2_layer22)
Observed(HUNTER2_3_layer26)
2004
2006
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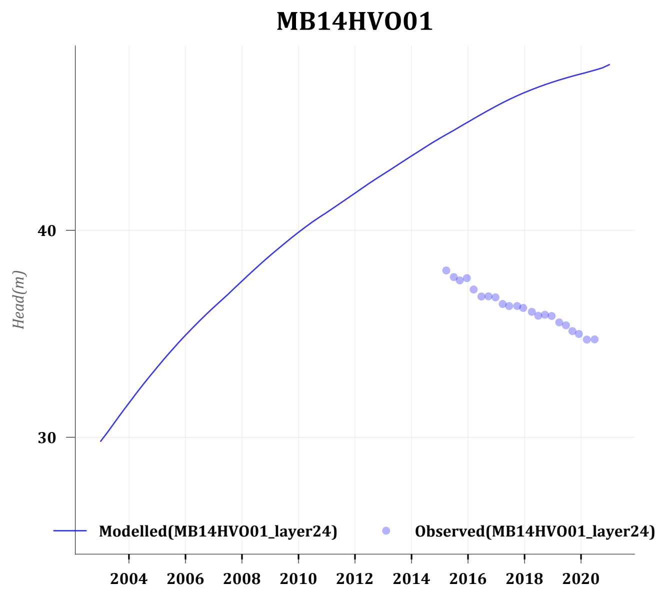
2012
2014
2016
2018
2020


MB14HVO01
Head(m)
40
30
Modelled(MB14HVO01_layer24)
Observed(MB14HVO01_layer24)
2004
2006
2008
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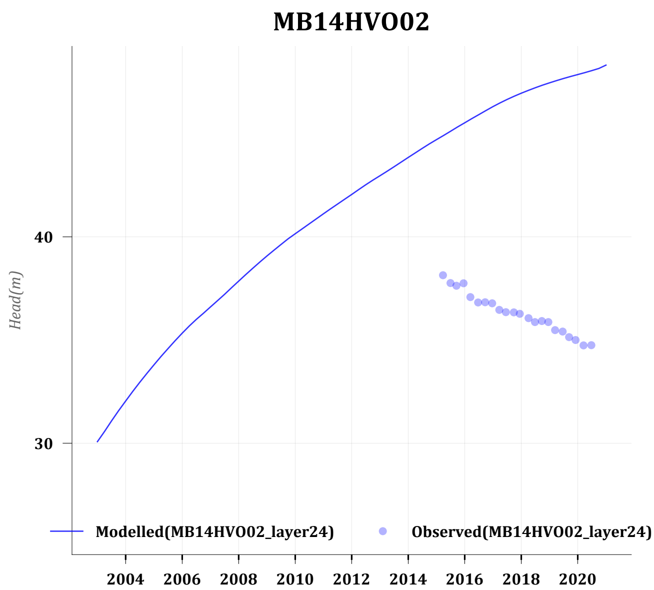
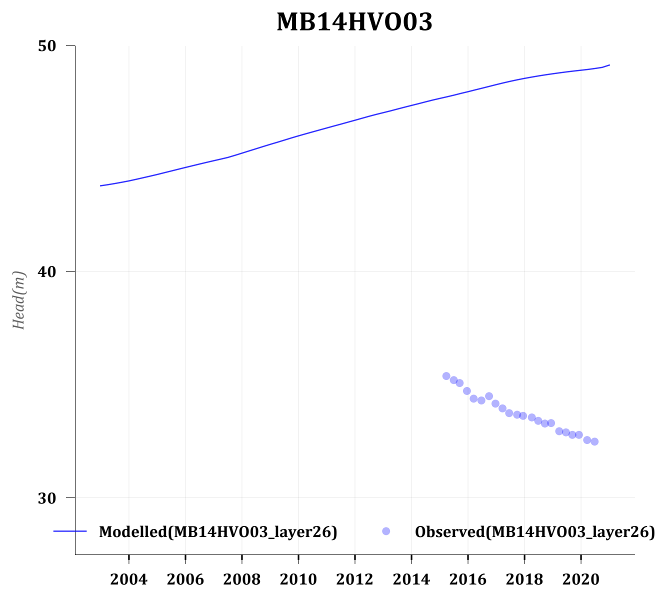
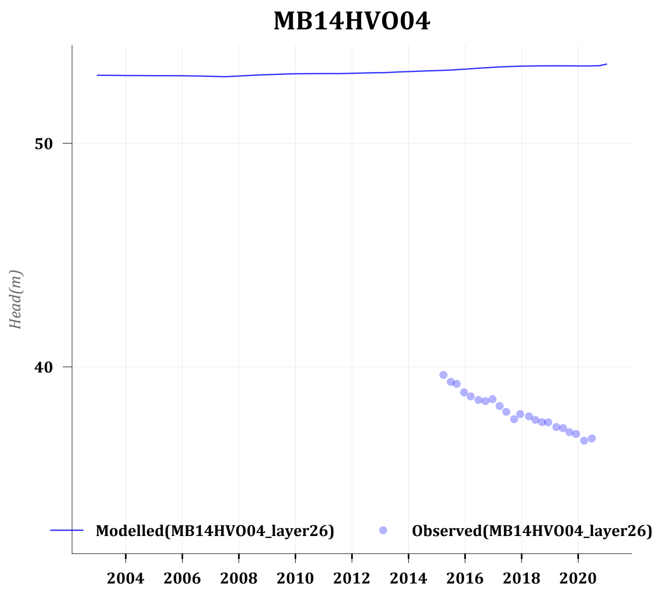
2012
2014
2016
2018
2020


MB14HVO02
Head(m)
40
30
Modelled(MB14HVO02_layer24)
Observed(MB14HVO02_layer24)
2004
2006
2008
2010
2012
2014
2016
2018
2020


MB14HVO03
Head(m)
50
40
30
Modelled(MB14HVO03_layer26)
Observed(MB14HVO03_layer26)
2004
2006
2008
2010
2012
2014
2016
2018
2020


MB14HVO04
50
40
Head(m)
Modelled(MB14HVO04_layer26)
Observed(MB14HVO04_layer26)
2004
2006
2008
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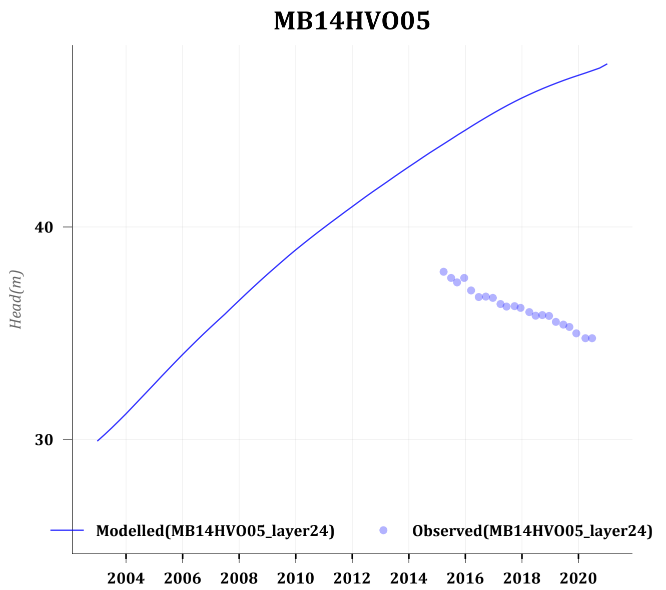
2012
2014
2016
2018
2020


MB14HVO05
40
30
Head(m)
Modelled(MB14HVO05_layer24)
Observed(MB14HVO05_layer24)
2004
2006
2008
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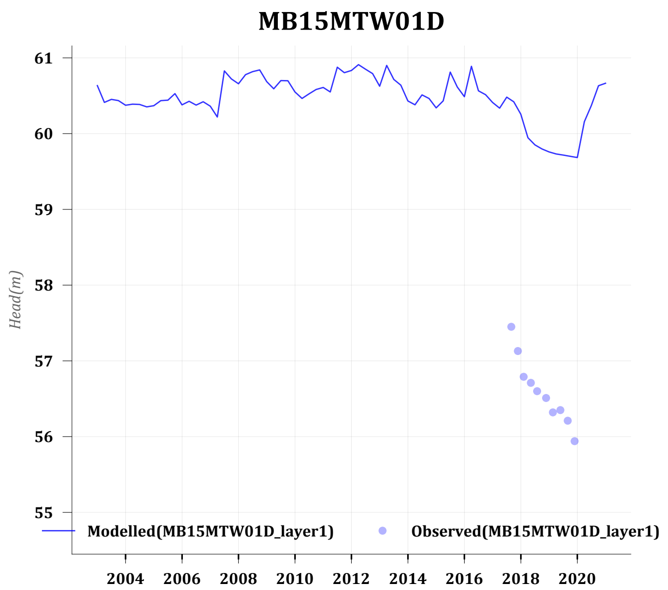
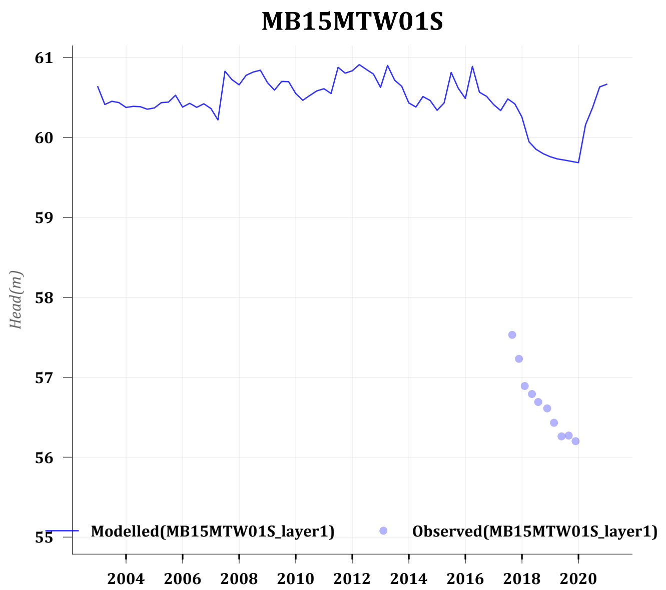
2012
2014
2016
2018
2020


MB15MTW01D
61
60
59
58
57
56
55
Head(m)
Modelled(MB15MTW01D_layer1)
Observed(MB15MTW01D_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020


MB15MTW01S
61
60
59
58
57
56
55
Head(m)
Modelled(MB15MTW01S_layer1)
Observed(MB15MTW01S_layer1)
2004
2006
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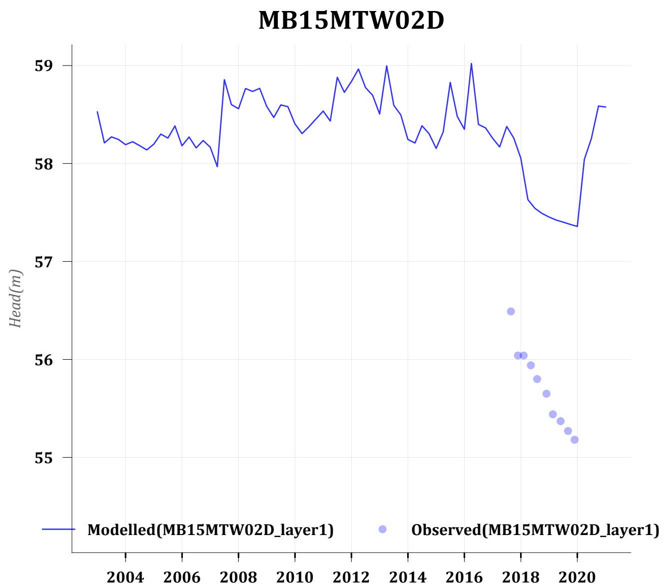
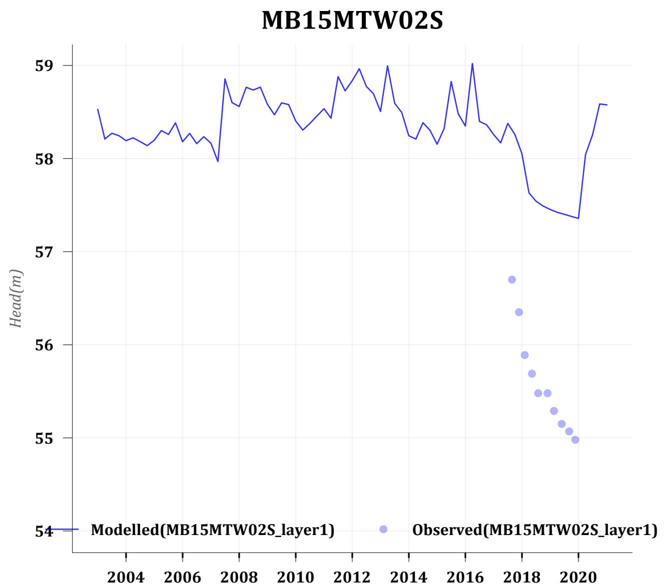
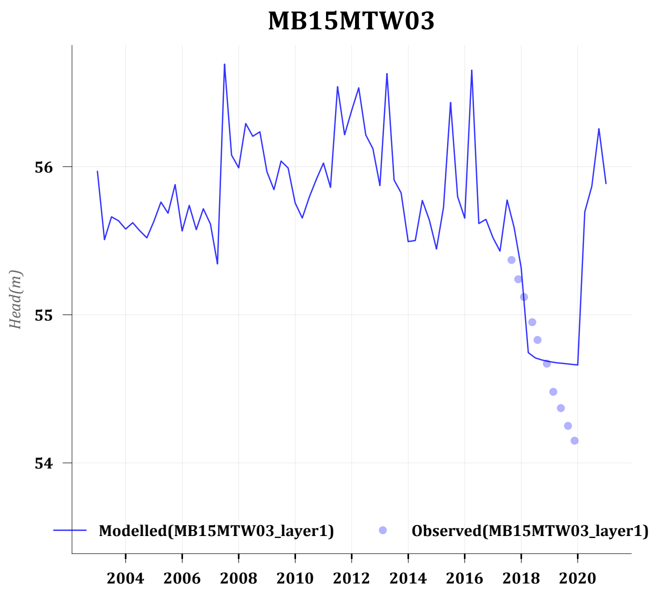
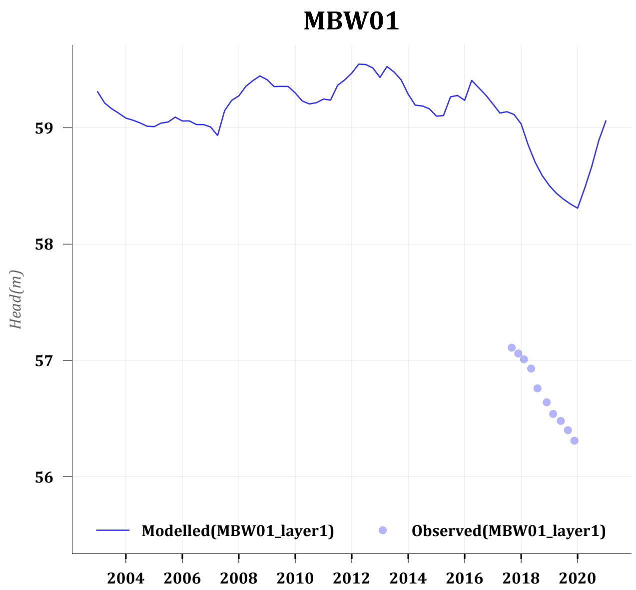
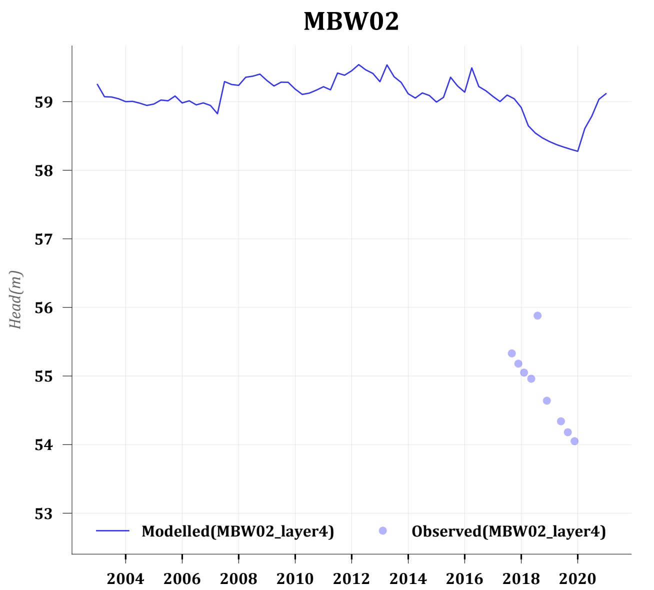
2012
2014
2016
2018
2020

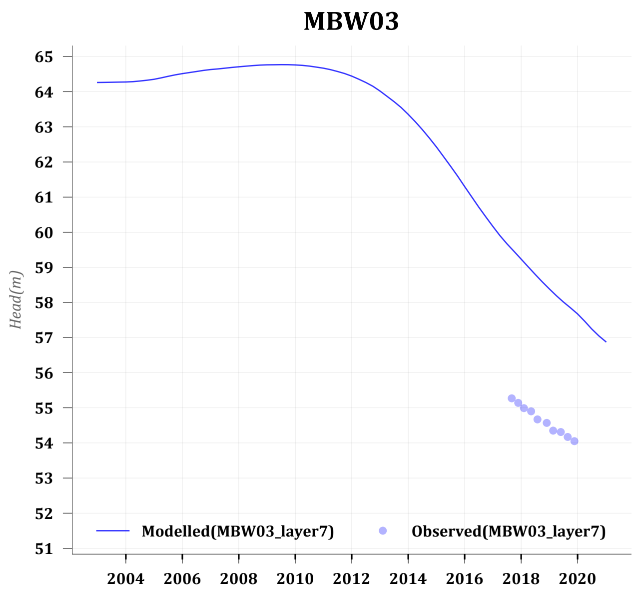

MB15MTW02D
59
58
57
56
55
Head(m)
Modelled(MB15MTW02D_layer1)
Observed(MB15MTW02D_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

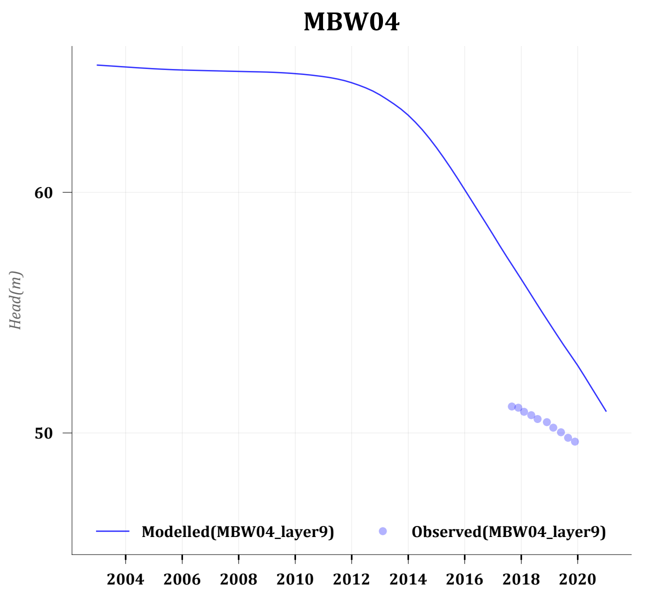

MB15MTW02S
59
58
57
56
55
54
Head(m)
Modelled(MB15MTW02S_layer1)
Observed(MB15MTW02S_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

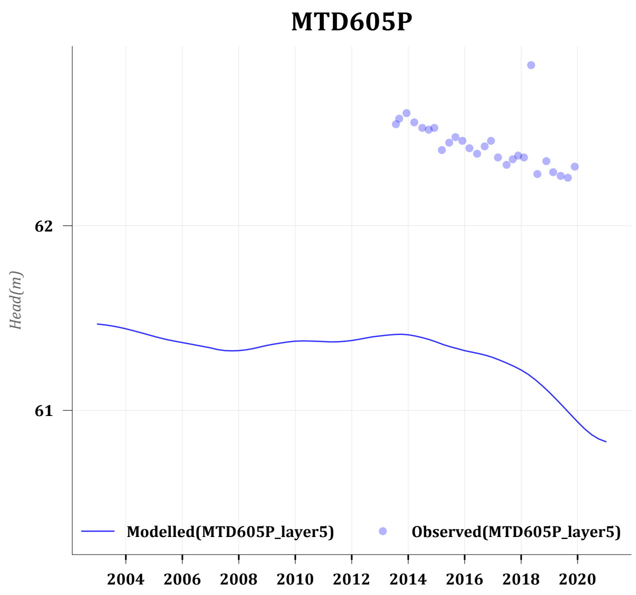

MB15MTW03
Head(m)
56
55
54
Modelled(MB15MTW03_layer1)
Observed(MB15MTW03_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020

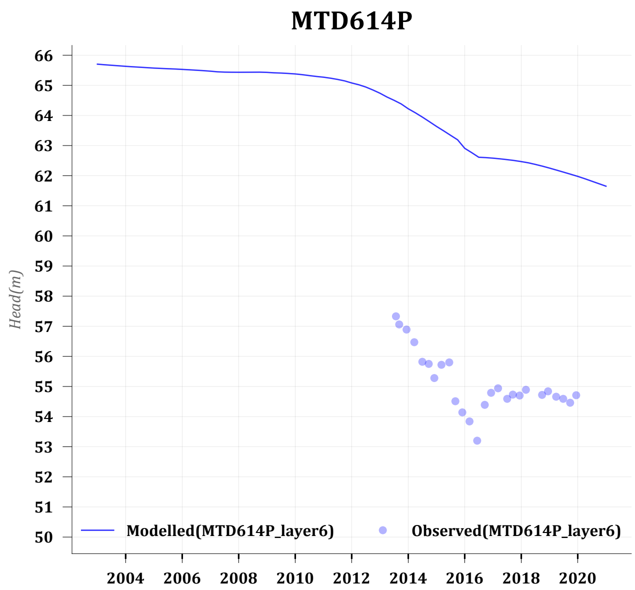

MBW01
Head(m)
59
58
57
56
Modelled(MBW01_layer1)
Observed(MBW01_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020

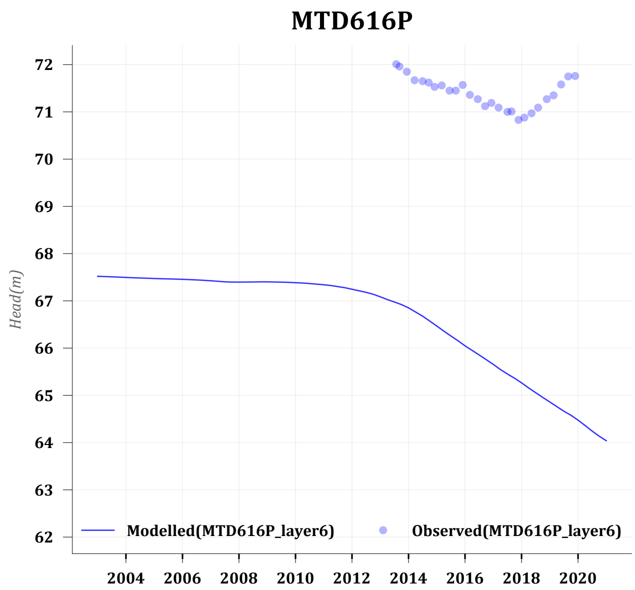

MBW02
Head(m)
59
58
57
56
55
54
53
Modelled(MBW02_layer4)
Observed(MBW02_layer4)
2004 2006 2008 2010 2012 2014 2016 2018 2020

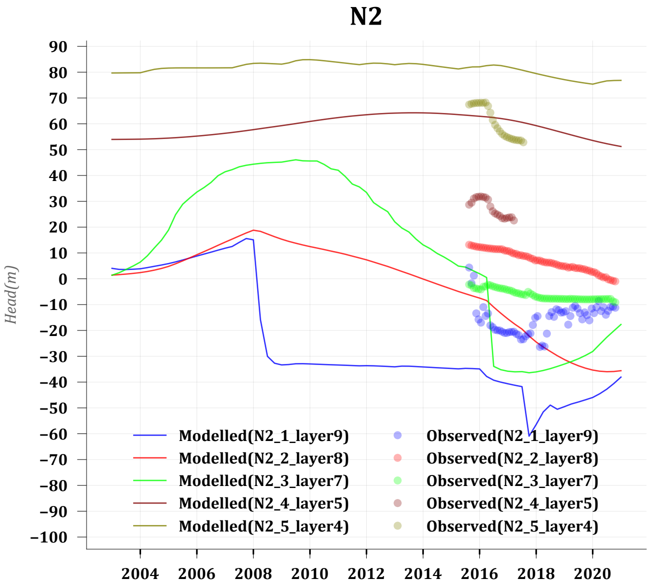

MBW03
Head(m)
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
Modelled(MBW03_layer7)
Observed(MBW03_layer7)
2004 2006 2008 2010 2012 2014 2016 2018 2020

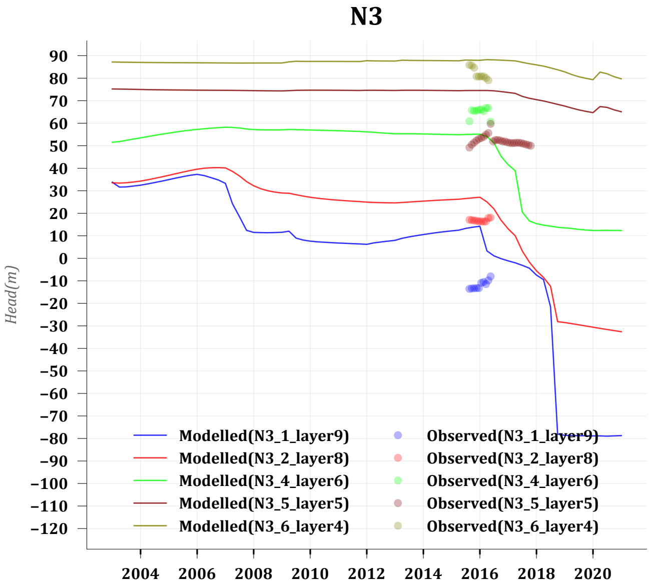

MBW04
Head(m)
60
50
Modelled(MBW04_layer9)
Observed(MBW04_layer9)
2004 2006 2008 2010 2012 2014 2016 2018 2020

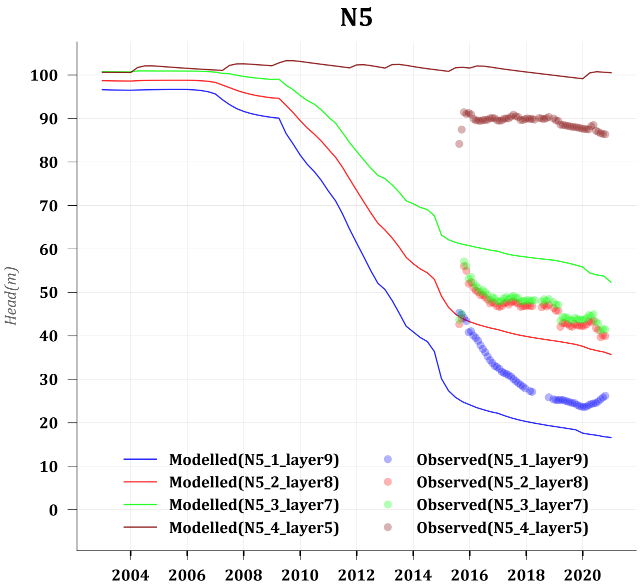

MTD605P
Head(m)
62
61
Modelled(MTD605P_layer5)
Observed(MTD605P_layer5)
2004 2006 2008 2010 2012 2014 2016 2018 2020

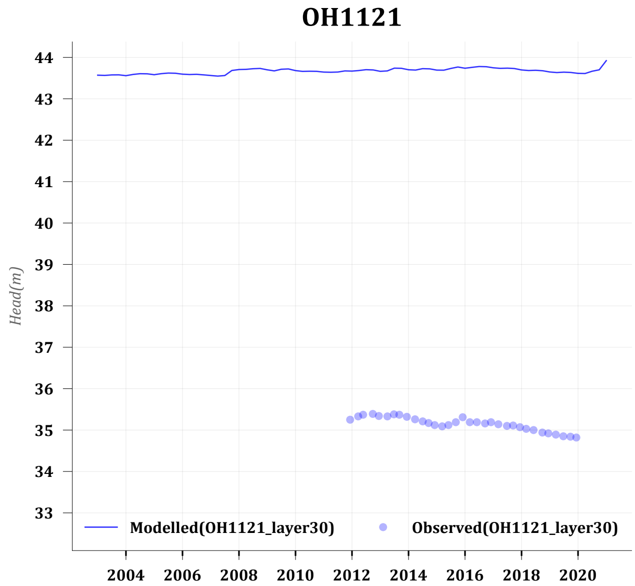

MTD614P
Head(m)
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
Modelled(MTD614P_layer6)
Observed(MTD614P_layer6)
2004 2006 2008 2010 2012 2014 2016 2018 2020

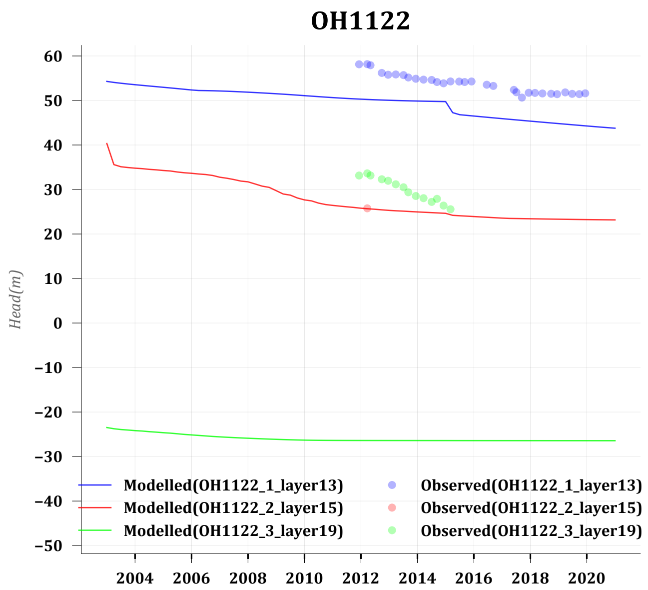

MTD616P
Head(m)
72
71
70
69
68
67
66
65
64
63
62
Modelled(MTD616P_layer6)
Observed(MTD616P_layer6)
2004 2006 2008 2010 2012 2014 2016 2018 2020

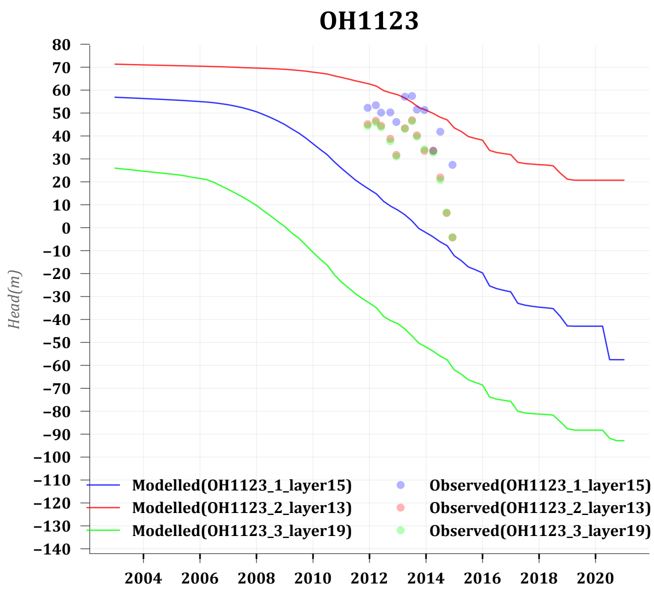

N2
Head(m)
90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −100
Modelled(N2_1_layer9)
Modelled(N2_2_layer8)
Modelled(N2_3_layer7)
Modelled(N2_4_layer5)
Modelled(N2_5_layer4)
Observed(N2_1_layer9)
Observed(N2_2_layer8)
Observed(N2_3_layer7)
Observed(N2_4_layer5)
Observed(N2_5_layer4)
2004 2006 2008 2010 2012 2014 2016 2018 2020

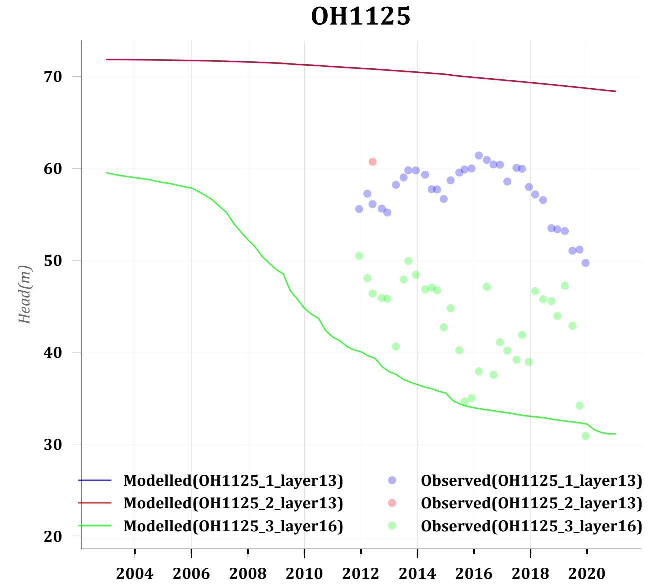

N3
Head(m)
90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −100 −110 −120
Modelled(N3_1_layer9)
Modelled(N3_2_layer8)
Modelled(N3_4_layer6)
Modelled(N3_5_layer5)
Modelled(N3_6_layer4)
Observed(N3_1_layer9)
Observed(N3_2_layer8)
Observed(N3_4_layer6)
Observed(N3_5_layer5)
Observed(N3_6_layer4)
2004 2006 2008 2010 2012 2014 2016 2018 2020

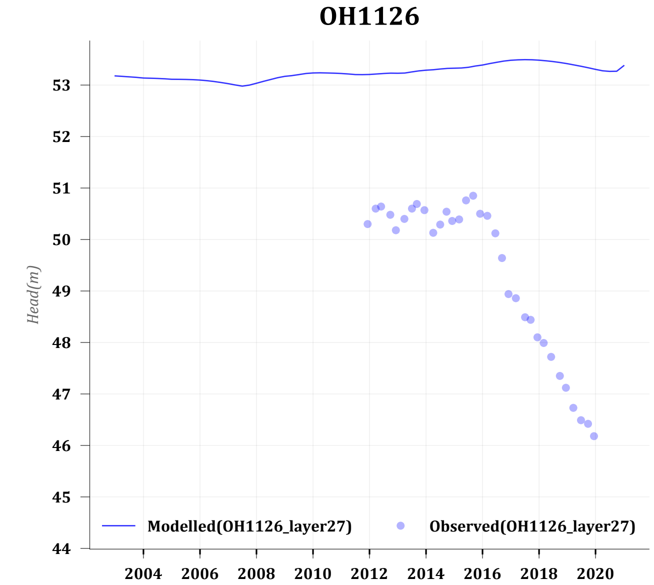

N5
Head(m)
100 90 80 70 60 50 40 30 20 10 0
Modelled(N5_1_layer9)
Modelled(N5_2_layer8)
Modelled(N5_3_layer7)
Modelled(N5_4_layer5)
Observed(N5_1_layer9)
Observed(N5_2_layer8)
Observed(N5_3_layer7)
Observed(N5_4_layer5)
2004 2006 2008 2010 2012 2014 2016 2018 2020

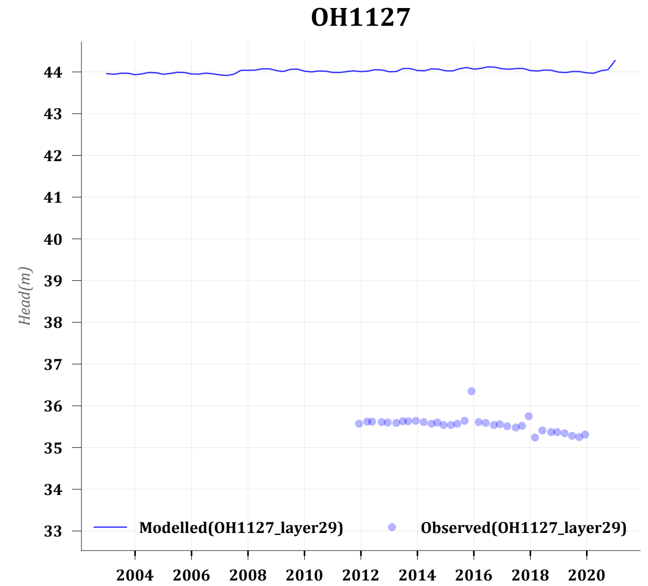

OH1121
Head(m)
44 43 42 41 40 39 38 37 36 35 34 33
Modelled(OH1121_layer30)
Observed(OH1121_layer30)
2004 2006 2008 2010 2012 2014 2016 2018 2020

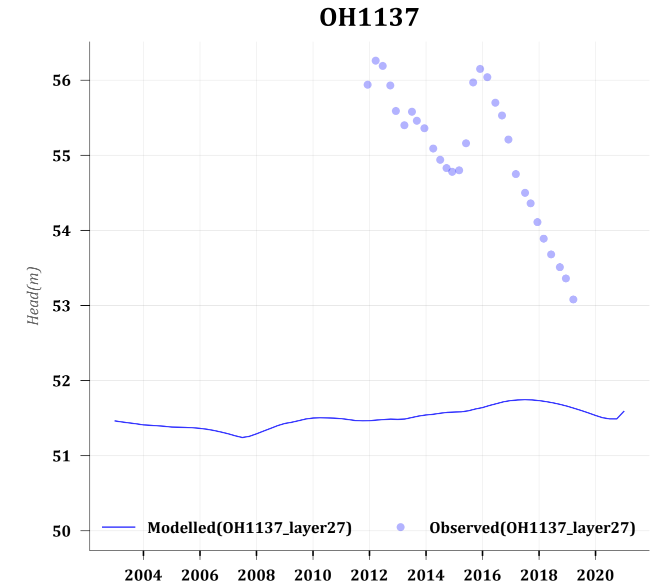

OH1122
Head(m)
Modelled(OH1122_1_layer13)
Modelled(OH1122_2_layer15)
Modelled(OH1122_3_layer19)
Observed(OH1122_1_layer13)
Observed(OH1122_2_layer15)
Observed(OH1122_3_layer19)


OH1123
Head(m)
Modelled(OH1123_1_layer15)
Modelled(OH1123_2_layer13)
Modelled(OH1123_3_layer19)
Observed(OH1123_1_layer15)
Observed(OH1123_2_layer13)
Observed(OH1123_3_layer19)

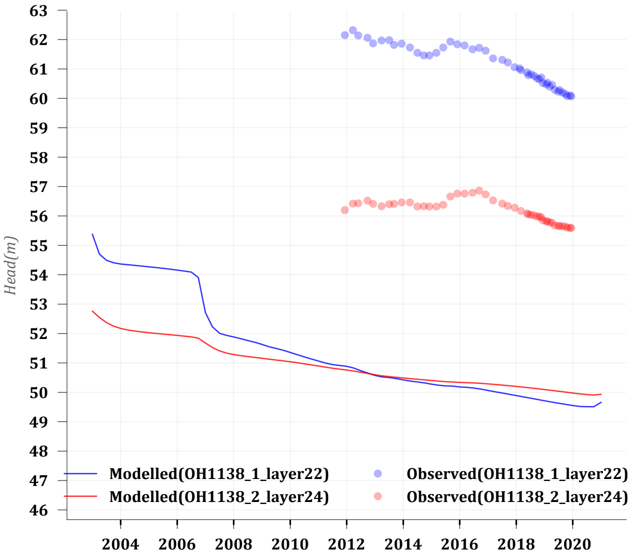

OH1125
Head(m)
Modelled(OH1125_1_layer13)
Modelled(OH1125_2_layer13)
Modelled(OH1125_3_layer16)
Observed(OH1125_1_layer13)
Observed(OH1125_2_layer13)
Observed(OH1125_3_layer16)


OH1126
Head(m)
Modelled(OH1126_layer27)
Observed(OH1126_layer27)

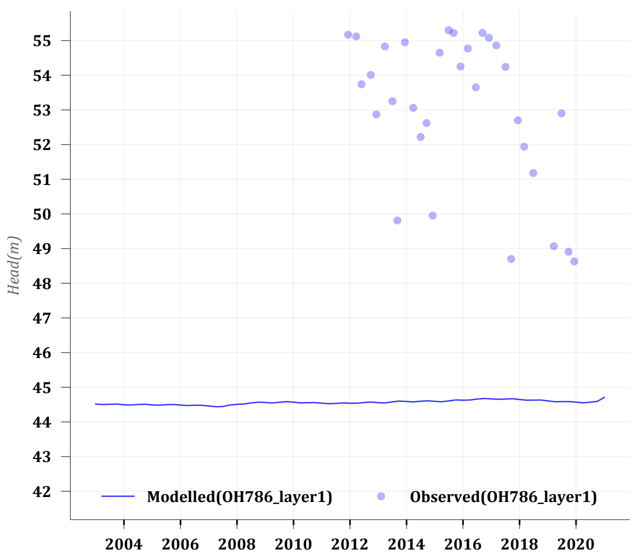

OH1127
Head(m)
Modelled(OH1127_layer29)
Observed(OH1127_layer29)


OH1137
Head(m)
Modelled(OH1137_layer27)
Observed(OH1137_layer27)

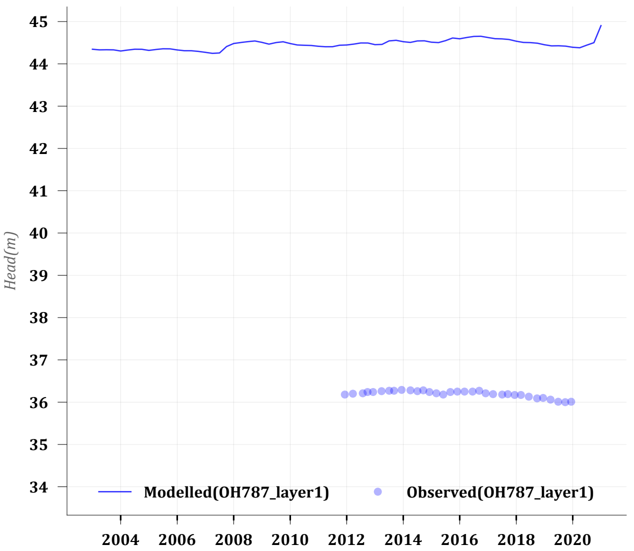
OH1138



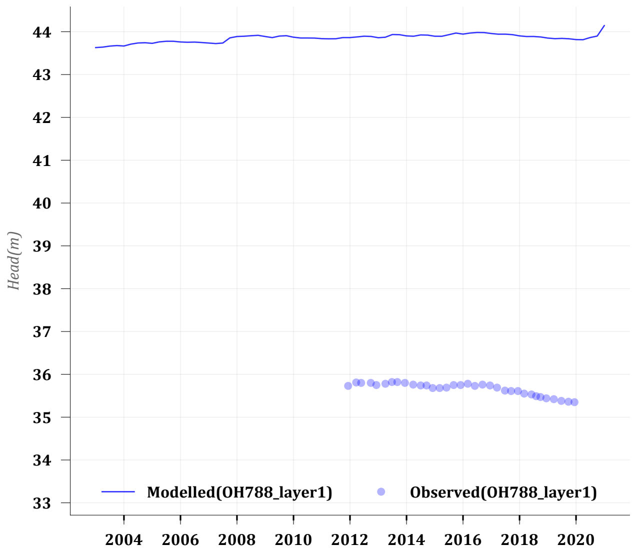
OH786



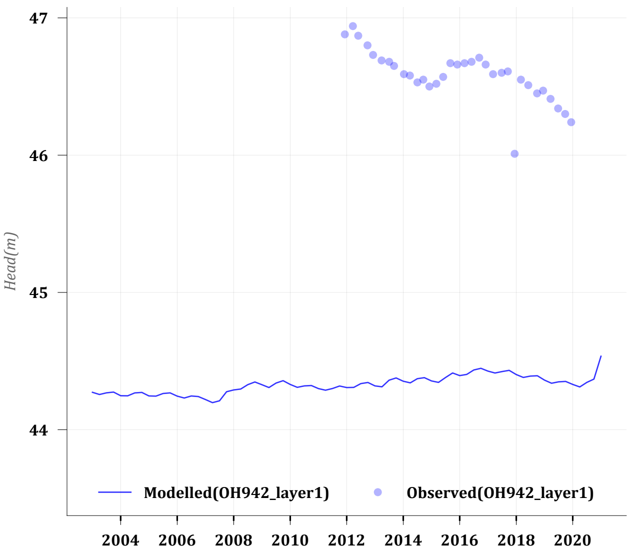
OH787



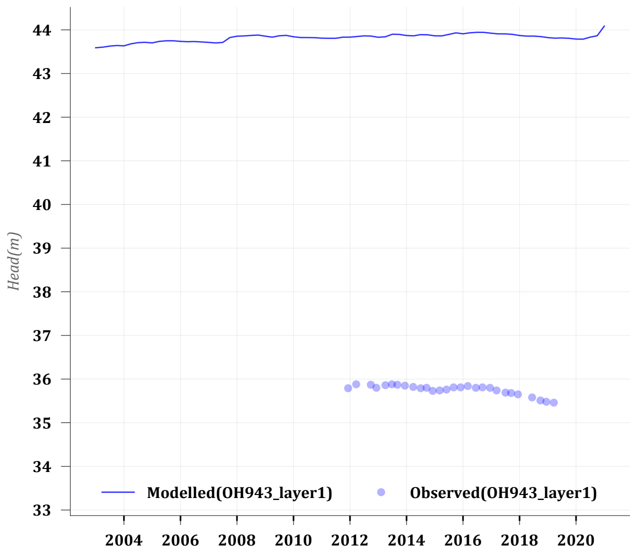
OH788

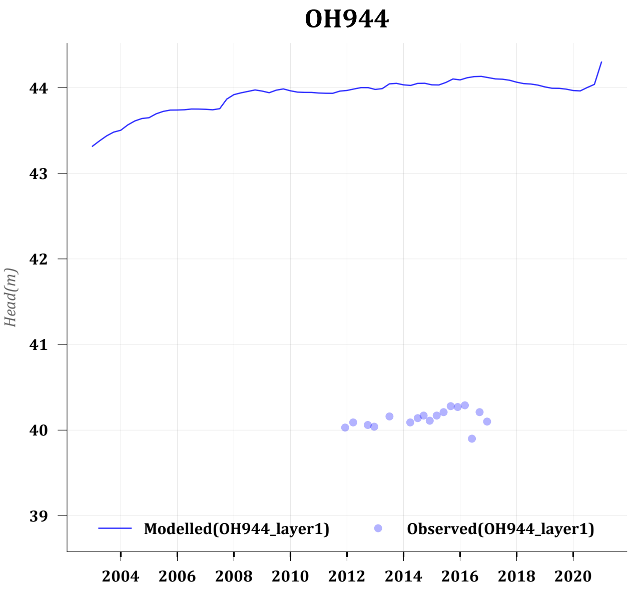


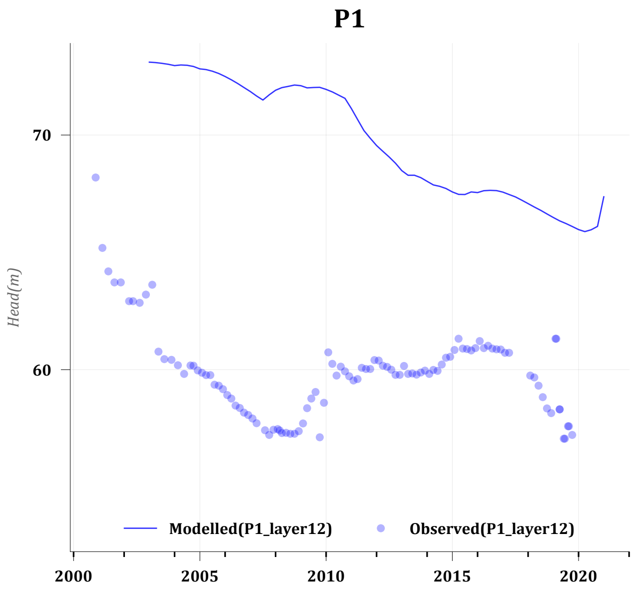
OH942

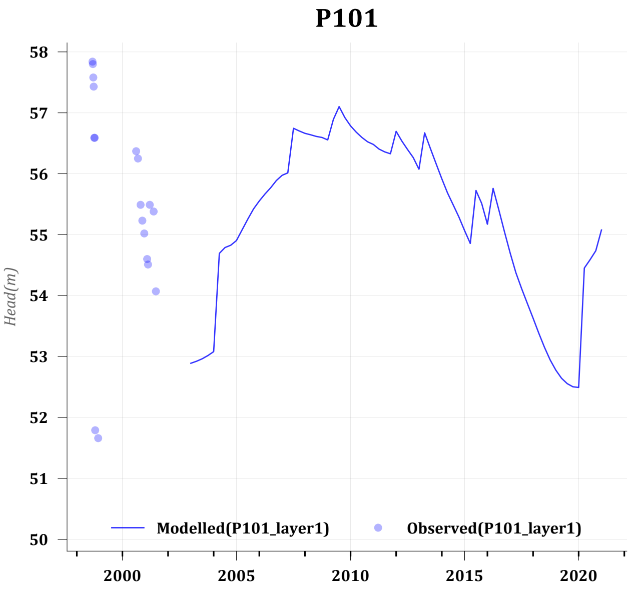


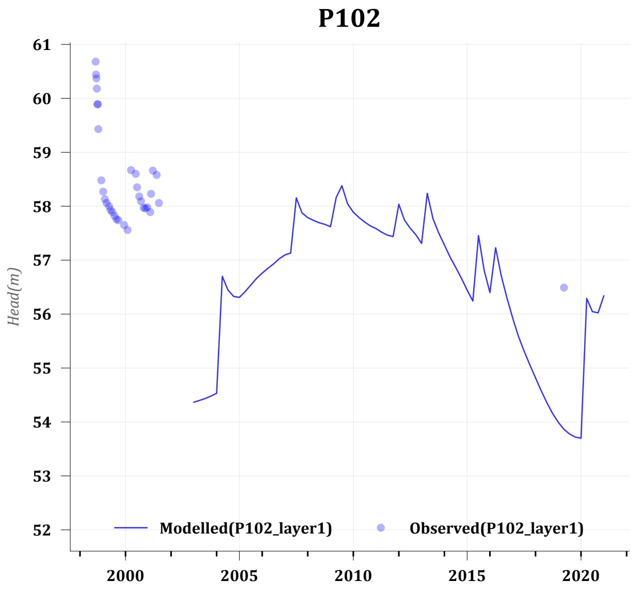
OH943

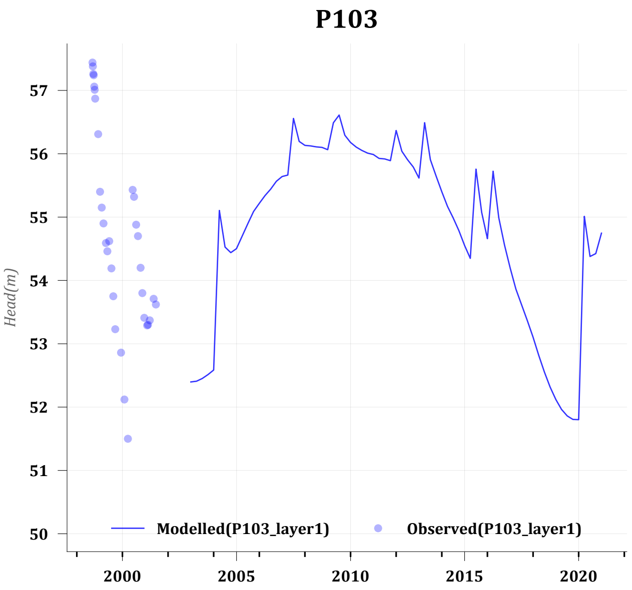


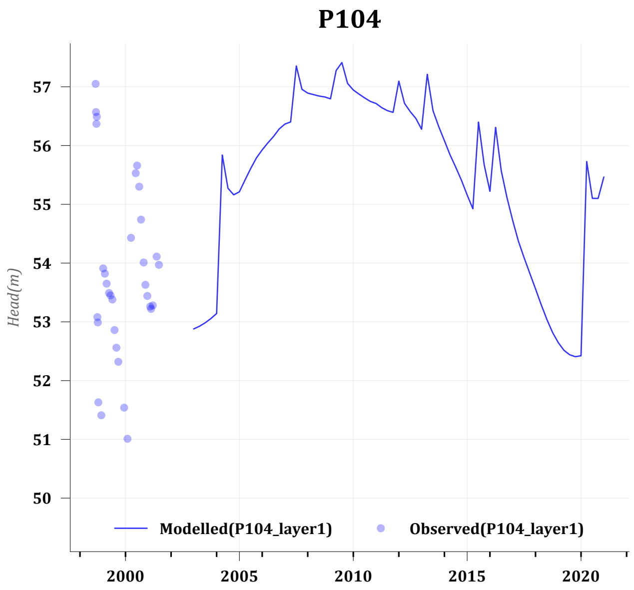

OH944
44
43
42
41
40
39
Head(m)
Modelled(OH944_layer1)
Observed(OH944_layer1)
2004
2006
2008
2010
2012
2014
2016
2018
2020

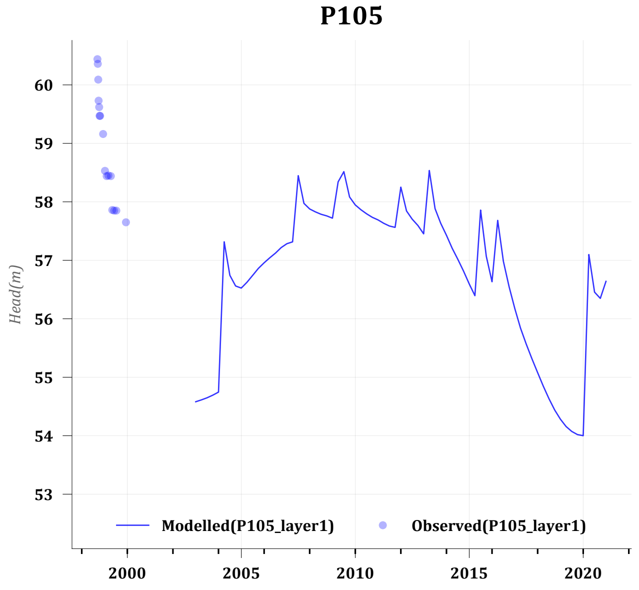

P1
70
60
Head(m)
Modelled(P1_layer12)
Observed(P1_layer12)
2000
2005
2010
2015
2020

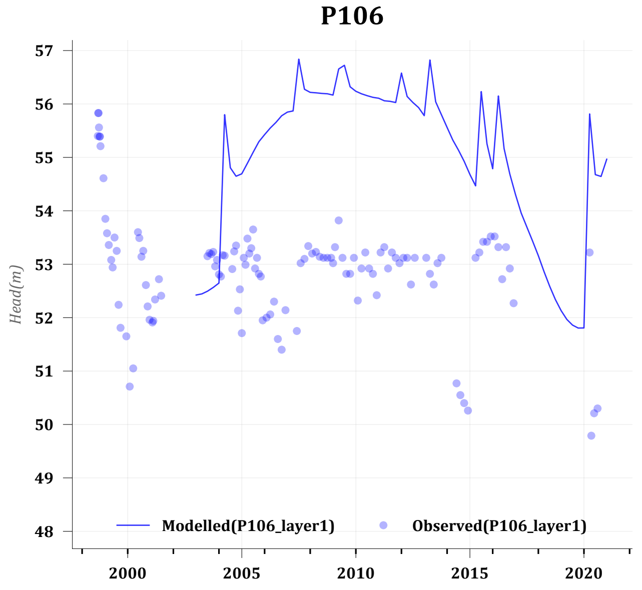

P101
58
57
56
55
54
53
52
51
50
Head(m)
Modelled(P101_layer1)
Observed(P101_layer1)
2000
2005
2010
2015
2020

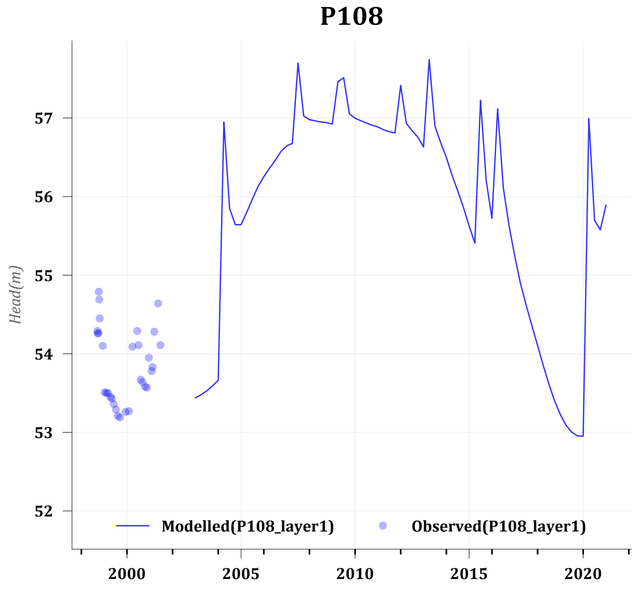

P102
61
60
59
58
57
56
55
54
53
52
Head(m)
Modelled(P102_layer1)
Observed(P102_layer1)
2000
2005
2010
2015
2020

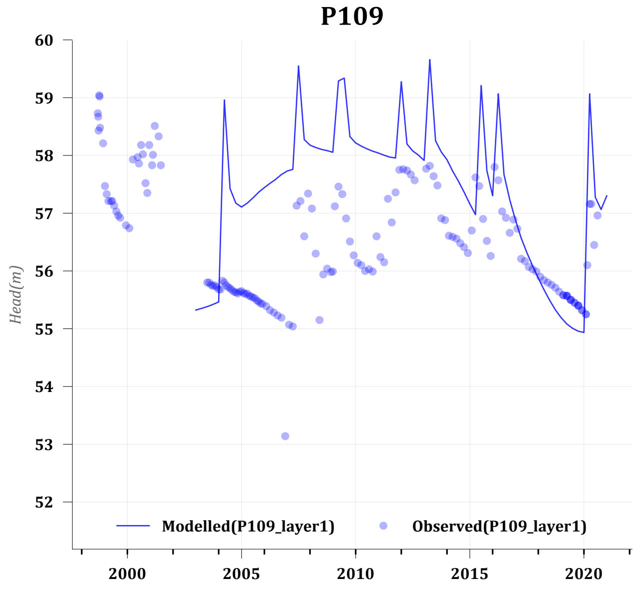

P103
57
56
55
54
53
52
51
50
Head(m)
Modelled(P103_layer1)
Observed(P103_layer1)
2000
2005
2010
2015
2020

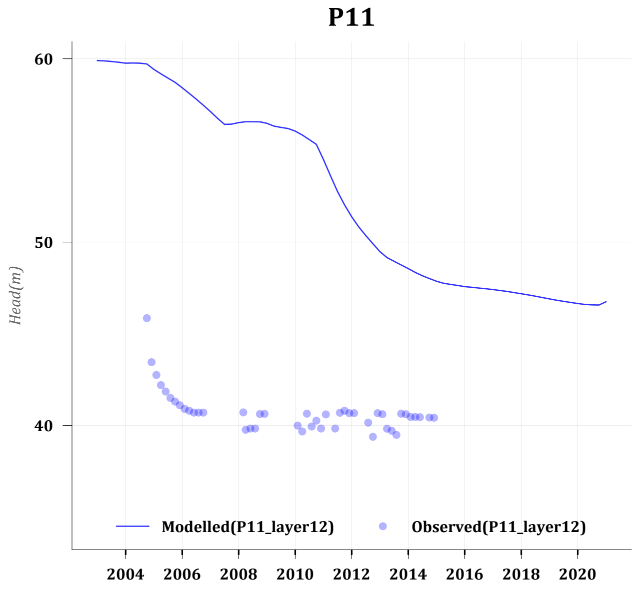

P104
57
56
55
54
53
52
51
50
Head(m)
Modelled(P104_layer1)
Observed(P104_layer1)
2000
2005
2010
2015
2020

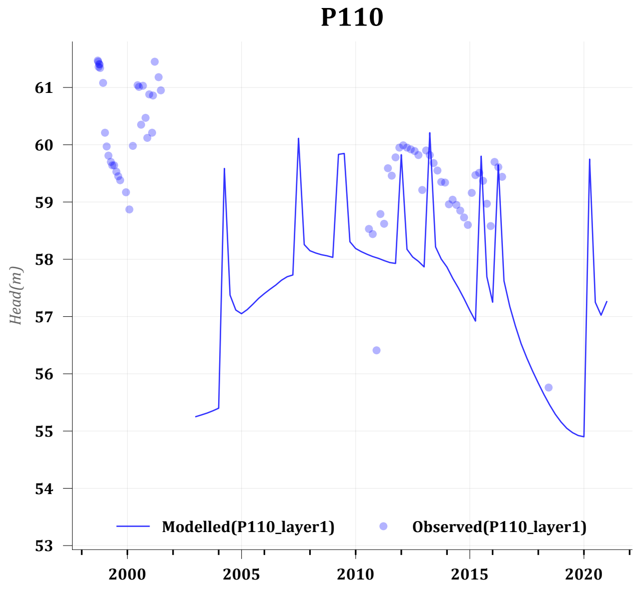

P105
Head(m)
60
59
58
57
56
55
54
53
2000
2005
2010
2015
2020
Modelled(P105_layer1)
Observed(P105_layer1)

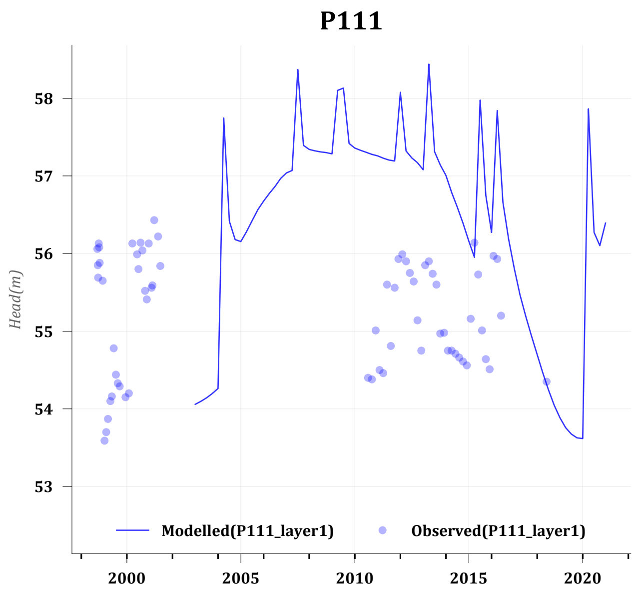

P106
Head(m)
57
56
55
54
53
52
51
50
49
48
2000
2005
2010
2015
2020
Modelled(P106_layer1)
Observed(P106_layer1)

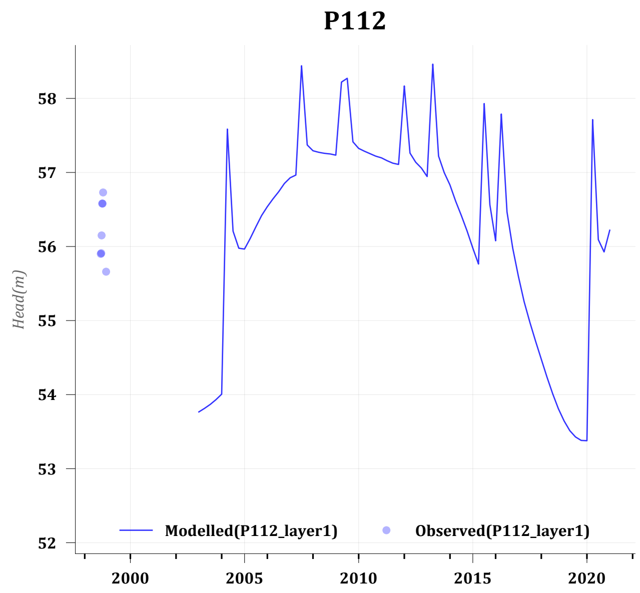

P108
Head(m)
57
56
55
54
53
52
2000
2005
2010
2015
2020
Modelled(P108_layer1)
Observed(P108_layer1)

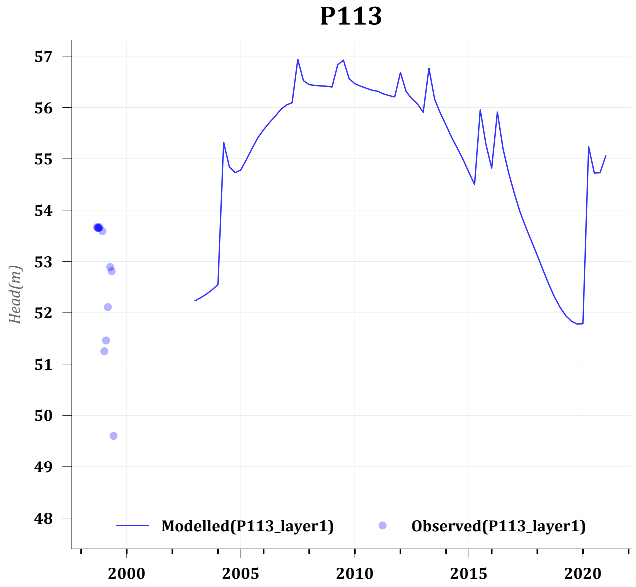

P109
Head(m)
60
59
58
57
56
55
54
53
52
2000
2005
2010
2015
2020
Modelled(P109_layer1)
Observed(P109_layer1)

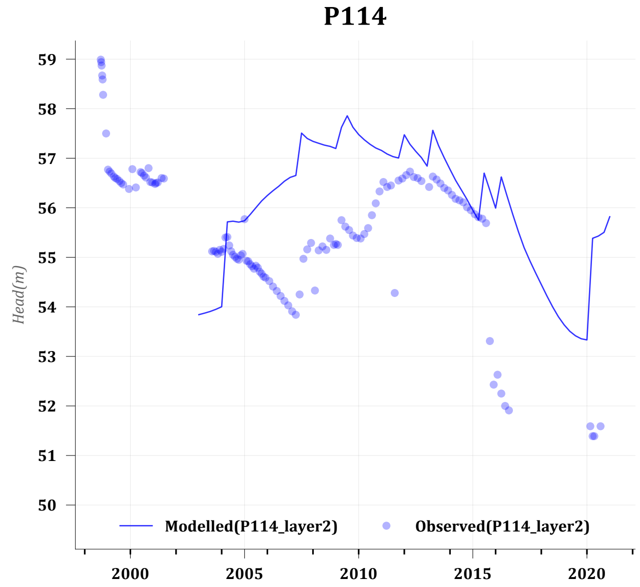

P11
Head(m)
60
50
40
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(P11_layer12)
Observed(P11_layer12)

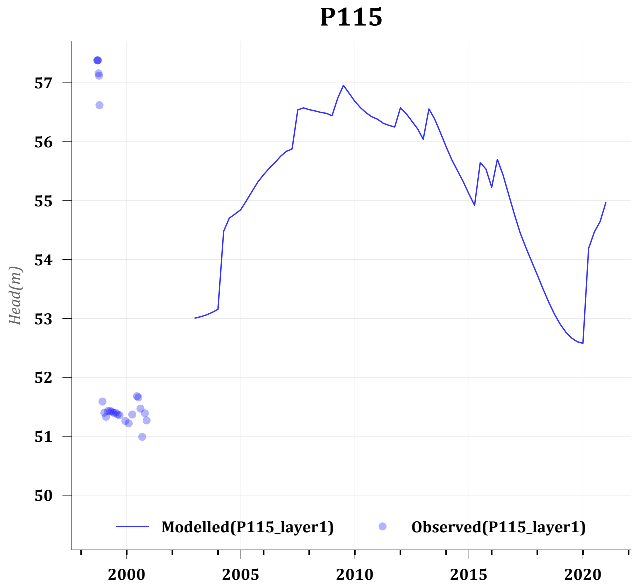

P110
Head(m)
61
60
59
58
57
56
55
54
53
2000
2005
2010
2015
2020
Modelled(P110_layer1)
Observed(P110_layer1)

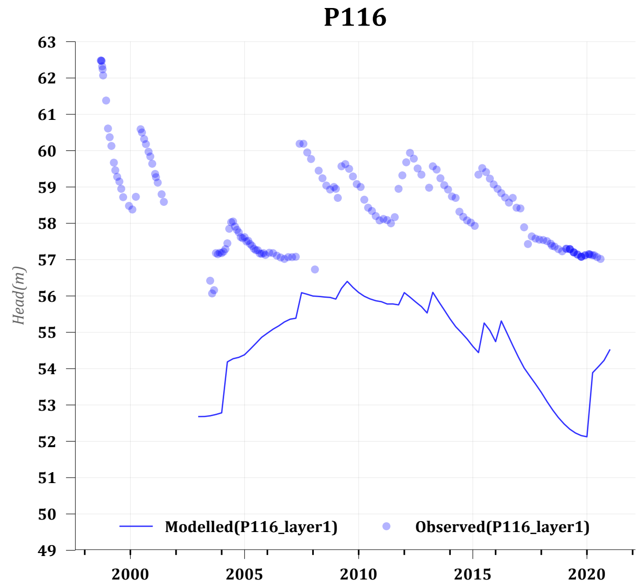

P111
58
57
56
55
54
53
Head(m)
2000
2005
2010
2015
2020
Modelled(P111_layer1)
Observed(P111_layer1)

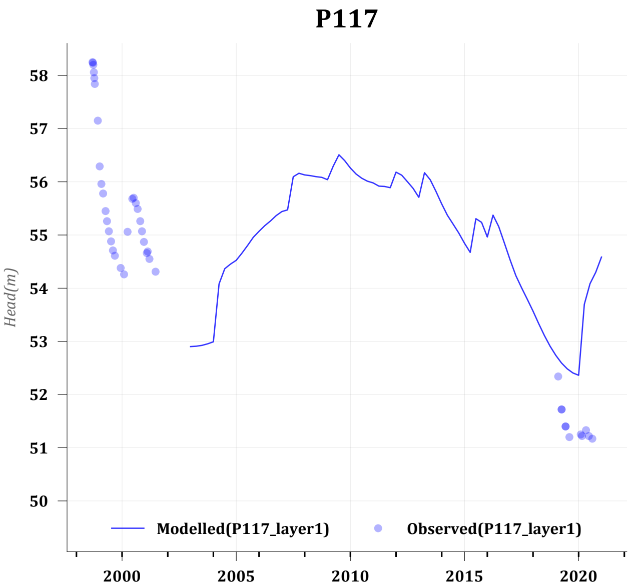

P112
58
57
56
55
54
53
52
Head(m)
2000
2005
2010
2015
2020
Modelled(P112_layer1)
Observed(P112_layer1)

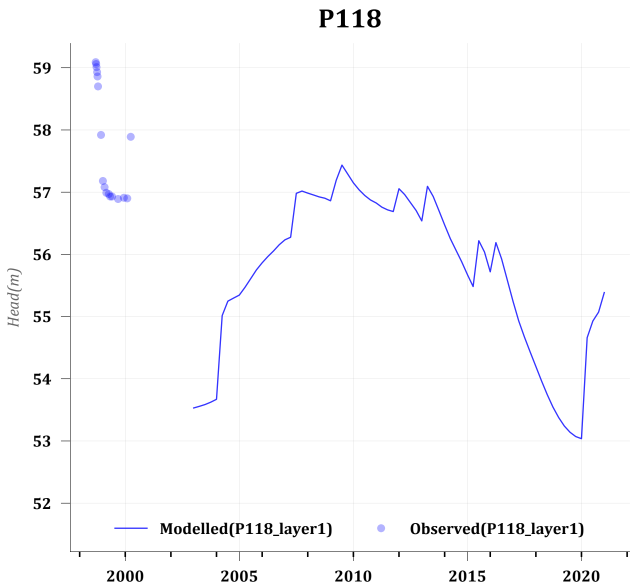

P113
57
56
55
54
53
52
51
50
49
48
Head(m)
2000
2005
2010
2015
2020
Modelled(P113_layer1)
Observed(P113_layer1)

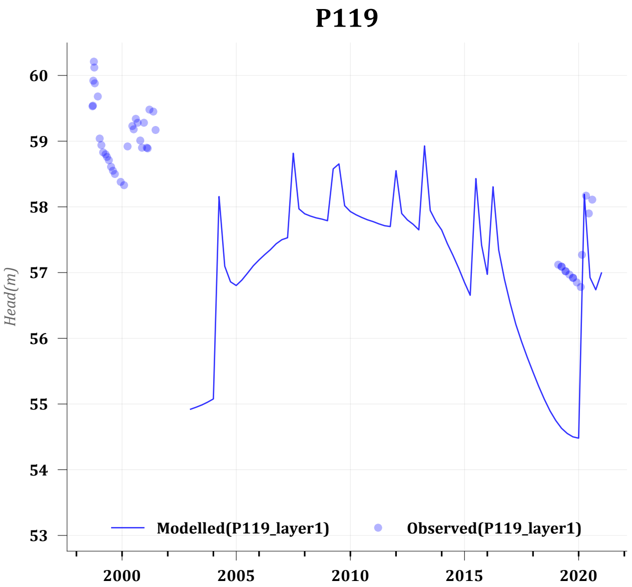

P114
59
58
57
56
55
54
53
52
51
50
Head(m)
2000
2005
2010
2015
2020
Modelled(P114_layer2)
Observed(P114_layer2)

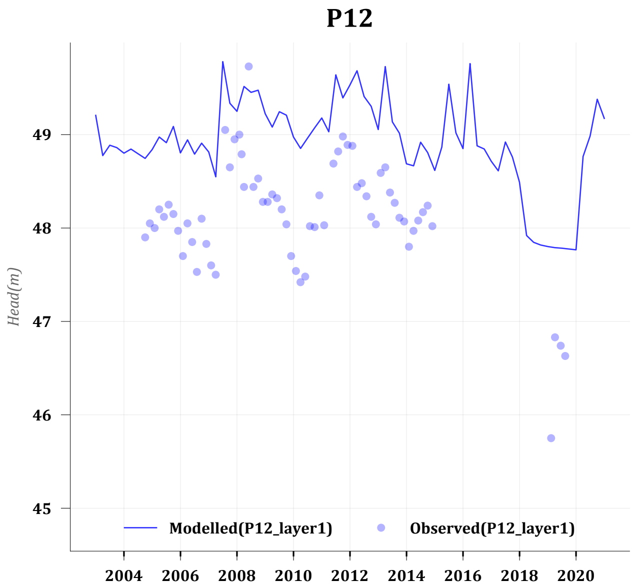

P115
57
56
55
54
53
52
51
50
Head(m)
2000
2005
2010
2015
2020
Modelled(P115_layer1)
Observed(P115_layer1)

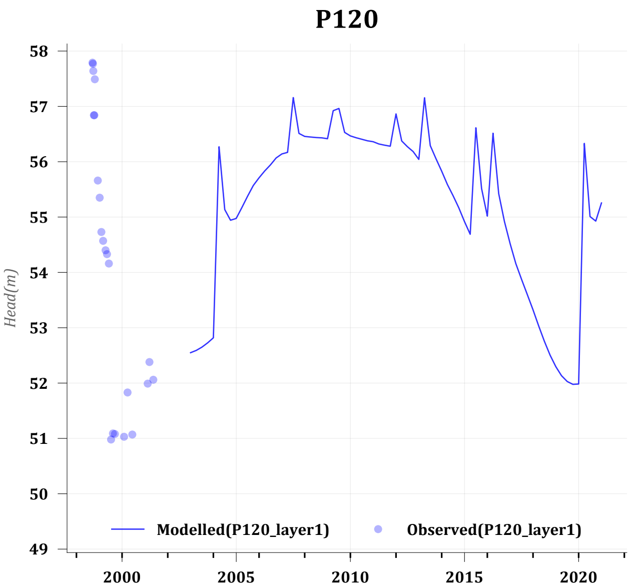

P116
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
Head(m)
2000
2005
2010
2015
2020
Modelled(P116_layer1)
Observed(P116_layer1)

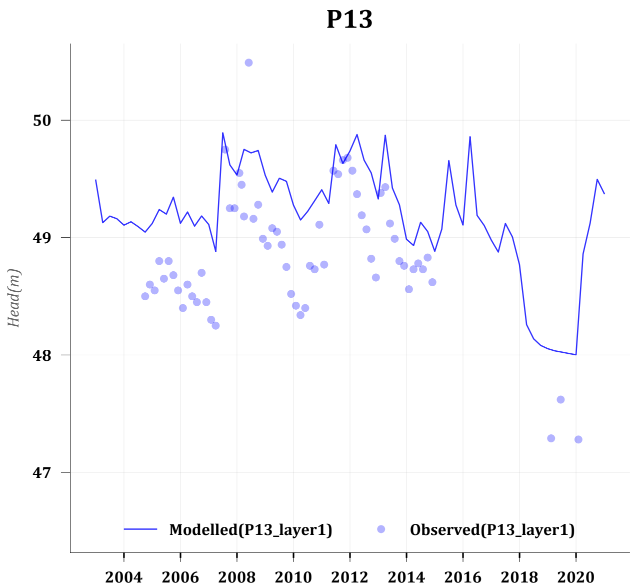

P117
Head(m)
58
57
56
55
54
53
52
51
50
2000
2005
2010
2015
2020
Modelled(P117_layer1)
Observed(P117_layer1)

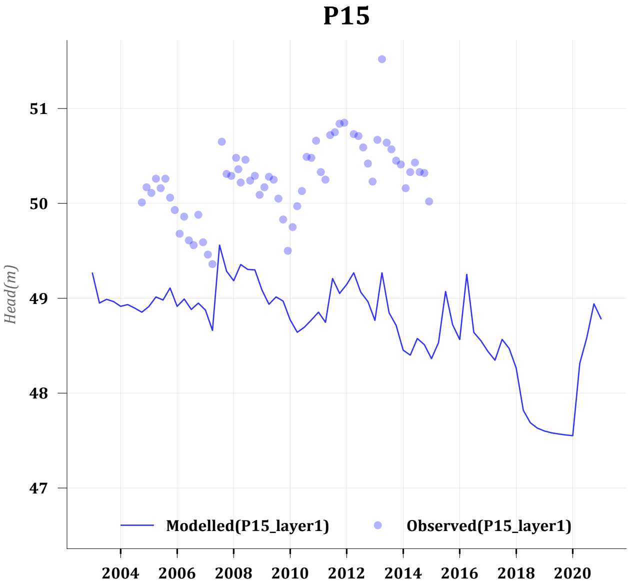

P118
Head(m)
59
58
57
56
55
54
53
52
2000
2005
2010
2015
2020
Modelled(P118_layer1)
Observed(P118_layer1)

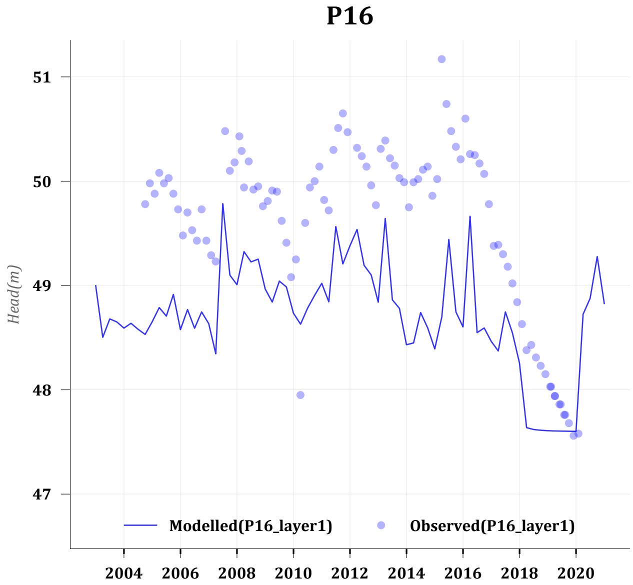

P119
Head(m)
60
59
58
57
56
55
54
53
2000
2005
2010
2015
2020
Modelled(P119_layer1)
Observed(P119_layer1)

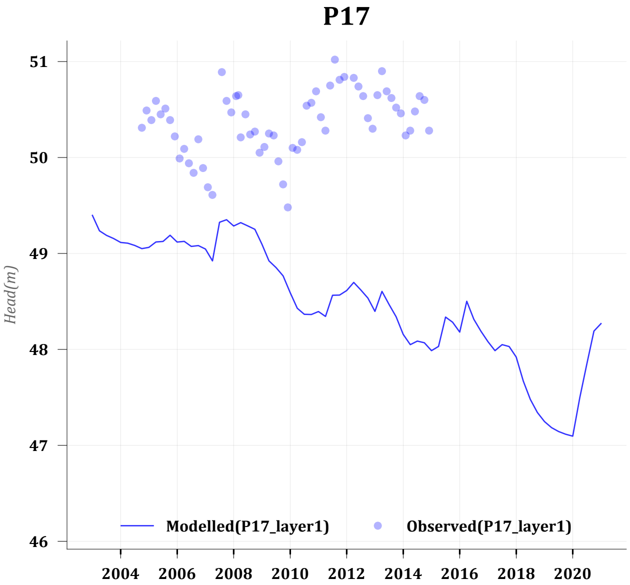

P12
Head(m)
49
48
47
46
45
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(P12_layer1)
Observed(P12_layer1)

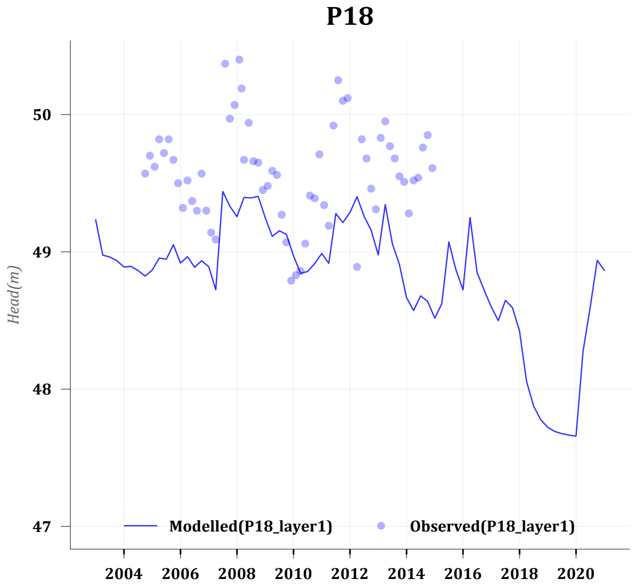

P120
Head(m)
58
57
56
55
54
53
52
51
50
49
2000
2005
2010
2015
2020
Modelled(P120_layer1)
Observed(P120_layer1)

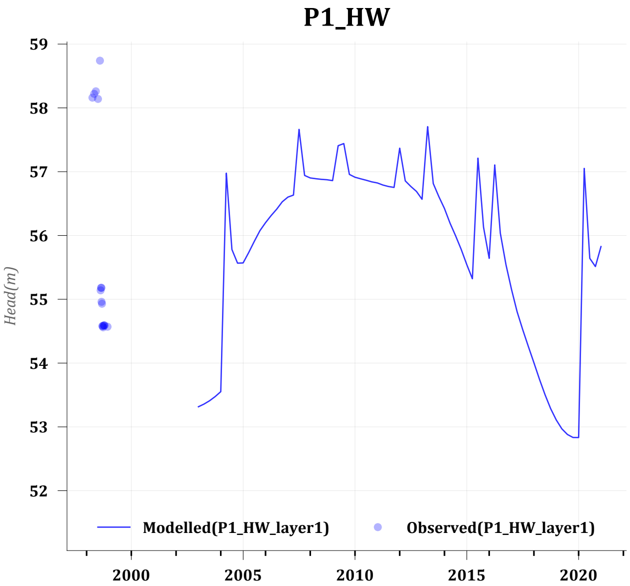

P13
Head(m)
50
49
48
47
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(P13_layer1)
Observed(P13_layer1)

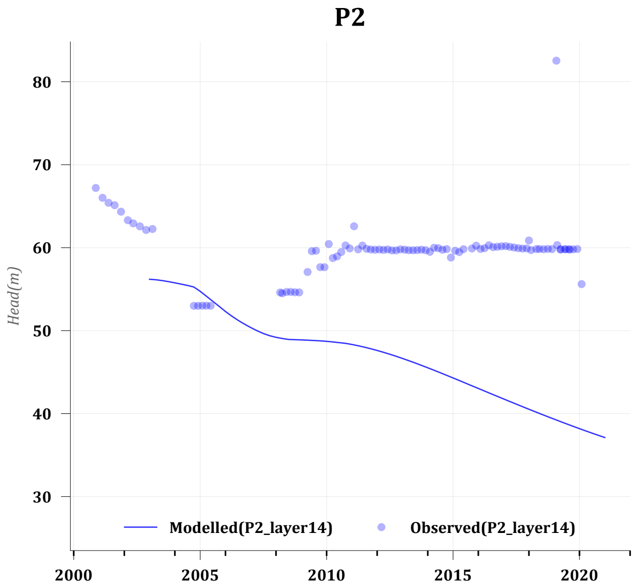

P15
Head(m)
47
48
49
50
51
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(P15_layer1)
Observed(P15_layer1)

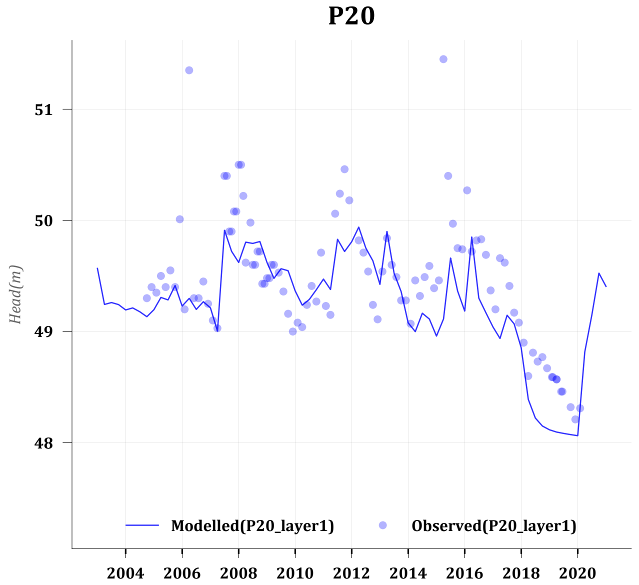

P16
Head(m)
47
48
49
50
51
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(P16_layer1)
Observed(P16_layer1)

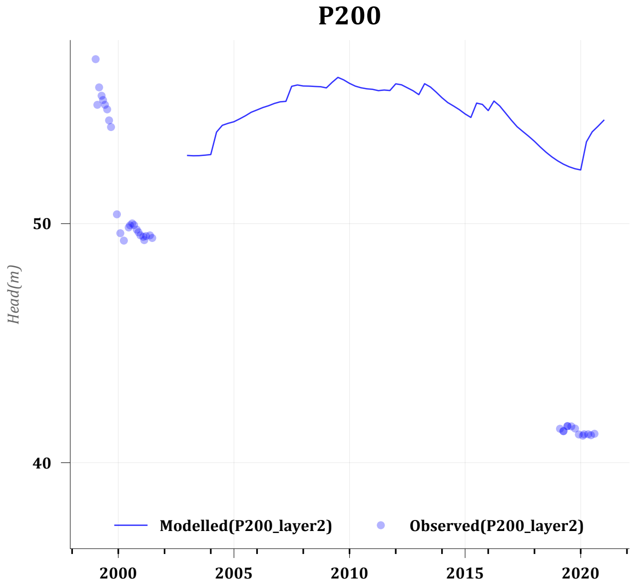

P17
Head(m)
46
47
48
49
50
51
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(P17_layer1)
Observed(P17_layer1)

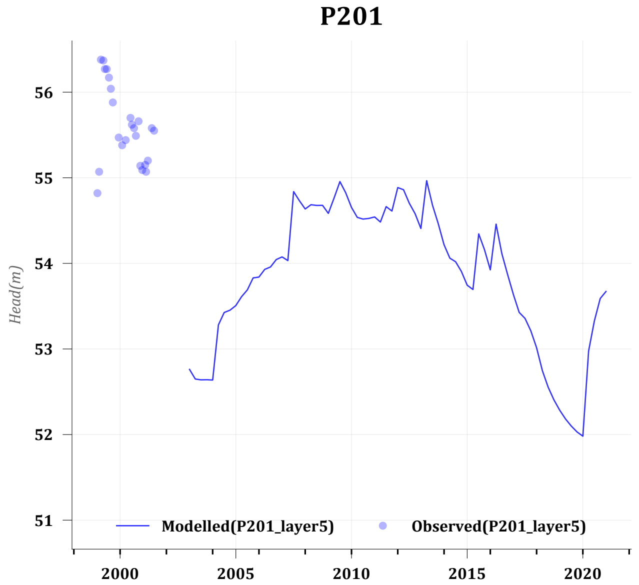

P18
Head(m)
47
48
49
50
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(P18_layer1)
Observed(P18_layer1)

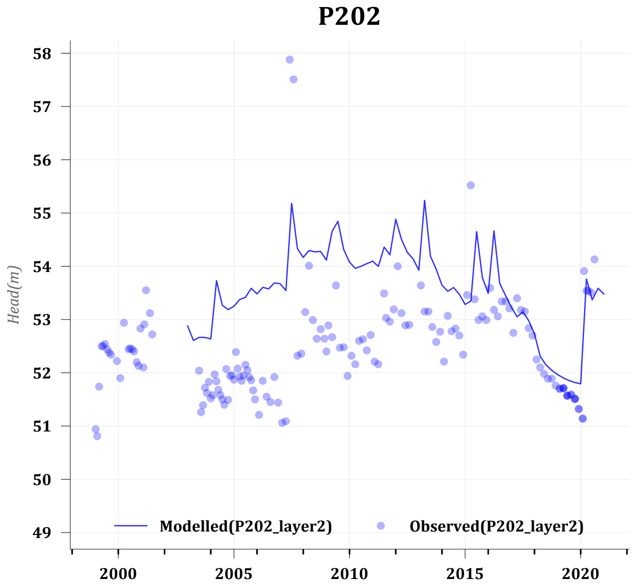

P1_HW
Head(m)
52
53
54
55
56
57
58
59
2000
2005
2010
2015
2020
Modelled(P1_HW_layer1)
Observed(P1_HW_layer1)

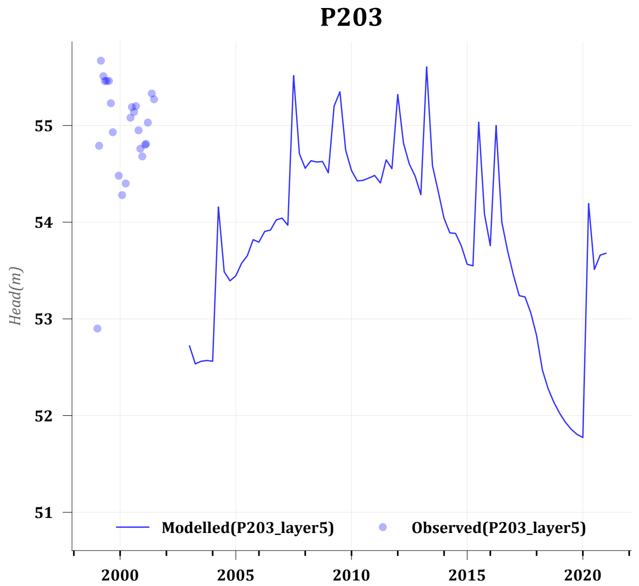

P2
Head(m)
30
40
50
60
70
80
2000
2005
2010
2015
2020
Modelled(P2_layer14)
Observed(P2_layer14)

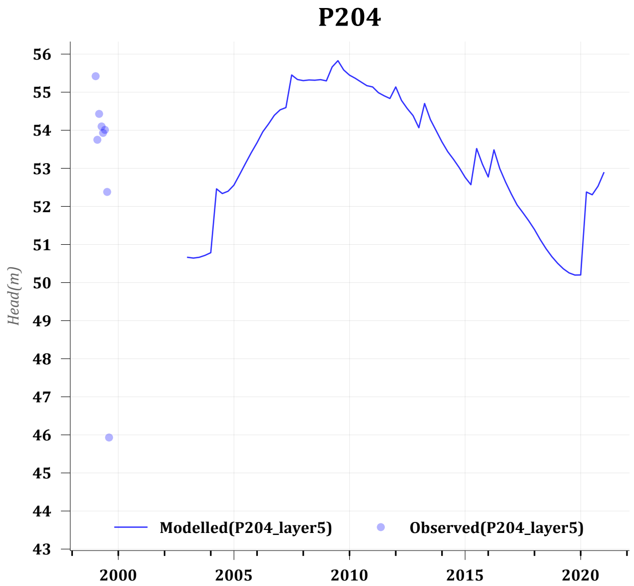

P20
Head(m)
51
50
49
48
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(P20_layer1)
Observed(P20_layer1)

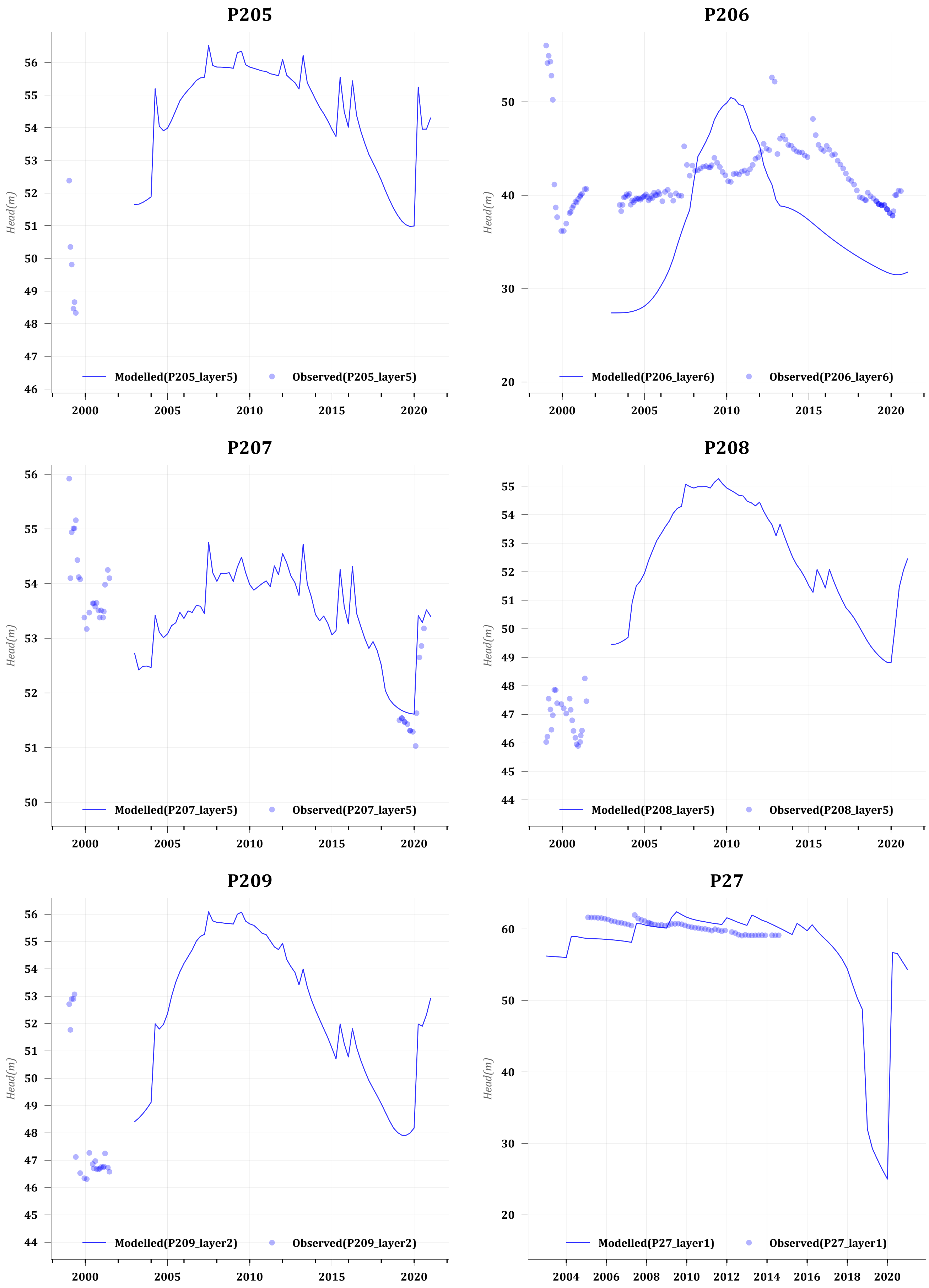

P200
Head(m)
50
40
2000
2005
2010
2015
2020
Modelled(P200_layer2)
Observed(P200_layer2)

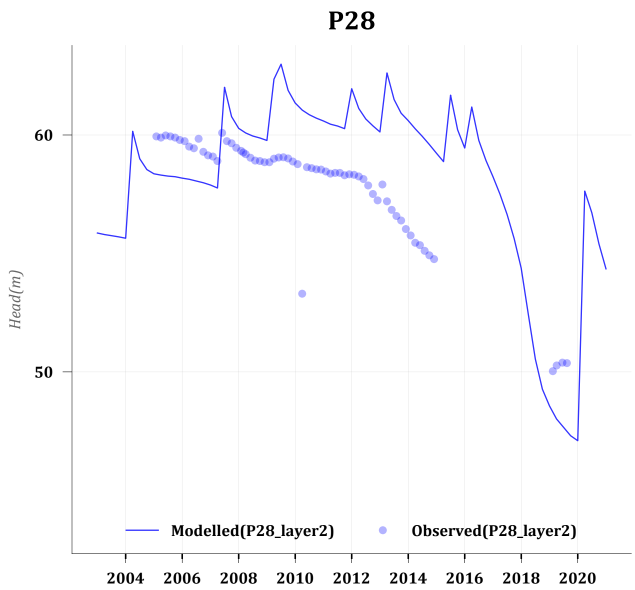

P201
Head(m)
56
55
54
53
52
51
2000
2005
2010
2015
2020
Modelled(P201_layer5)
Observed(P201_layer5)

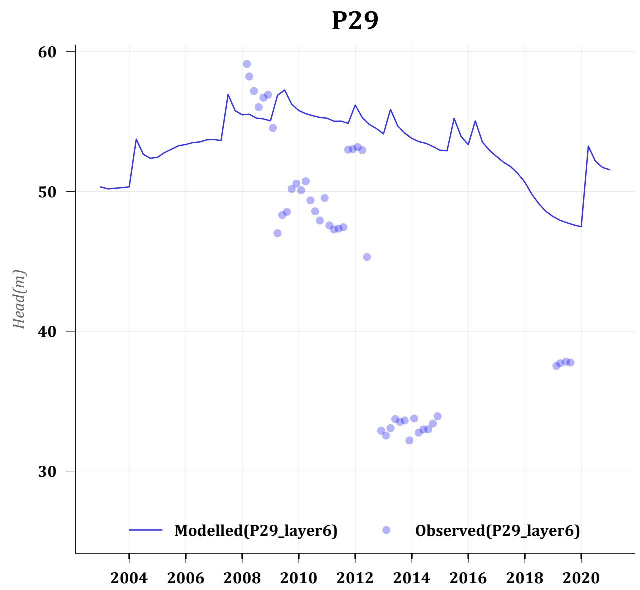

P202
Head(m)
58
57
56
55
54
53
52
51
50
49
2000
2005
2010
2015
2020
Modelled(P202_layer2)
Observed(P202_layer2)

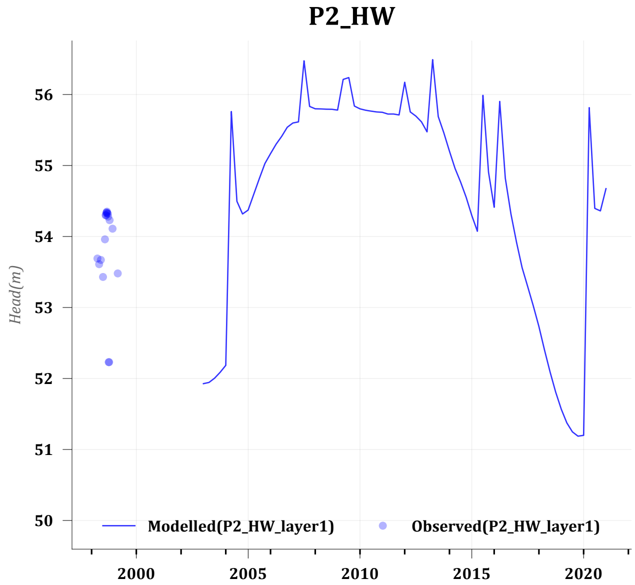

P203
Head(m)
55
54
53
52
51
2000
2005
2010
2015
2020
Modelled(P203_layer5)
Observed(P203_layer5)

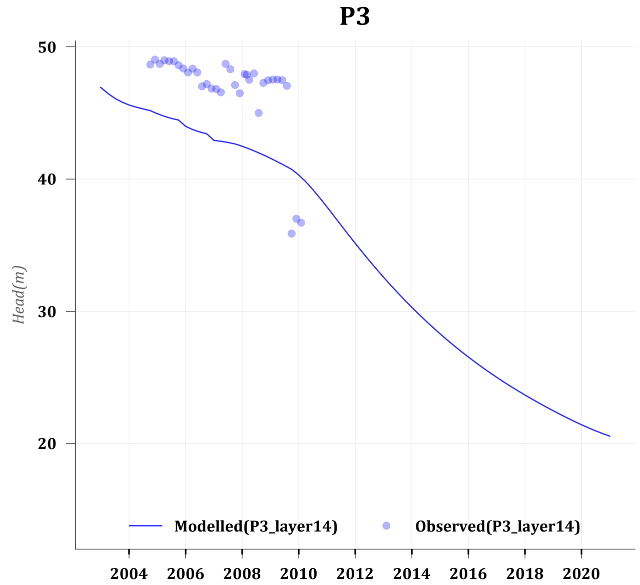

P204
Head(m)
56
55
54
53
52
51
50
49
48
47
46
45
44
43
2000
2005
2010
2015
2020
Modelled(P204_layer5)
Observed(P204_layer5)

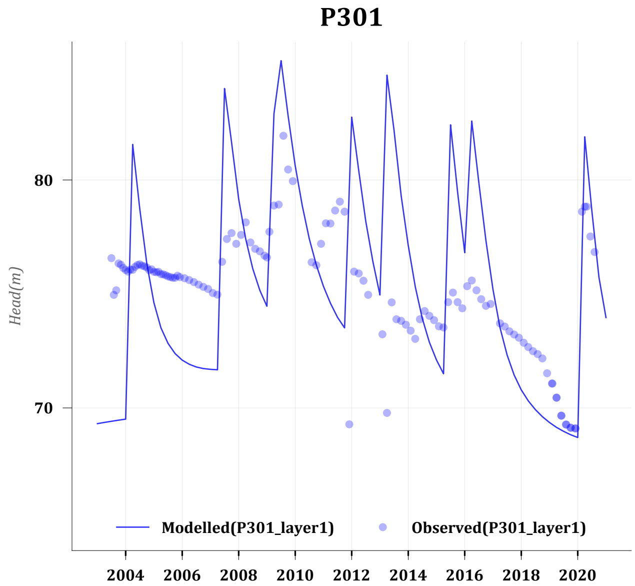

P205
Head(m)
Modelled(P205_layer5)
Observed(P205_layer5)
P206
Head(m)
Modelled(P206_layer6)
Observed(P206_layer6)
P207
Head(m)
Modelled(P207_layer5)
Observed(P207_layer5)
P208
Head(m)
Modelled(P208_layer5)
Observed(P208_layer5)
P209
Head(m)
Modelled(P209_layer2)
Observed(P209_layer2)
P27
Head(m)
Modelled(P27_layer1)
Observed(P27_layer1)

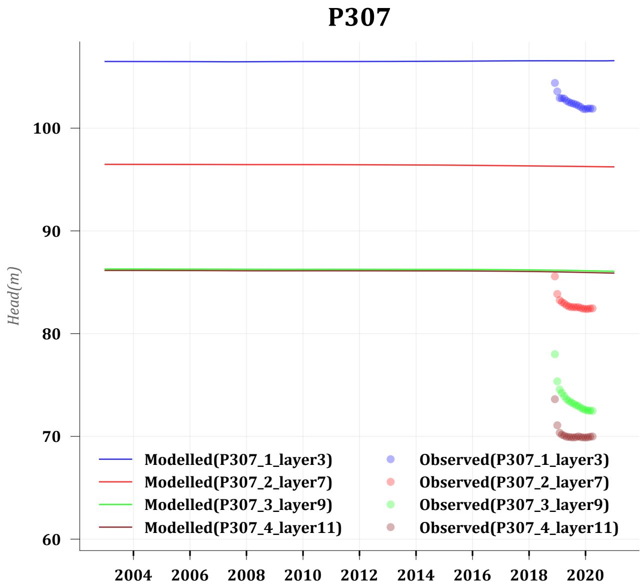

P28
60
50
Head(m)
Modelled(P28_layer2)
Observed(P28_layer2)
2004 2006 2008 2010 2012 2014 2016 2018 2020

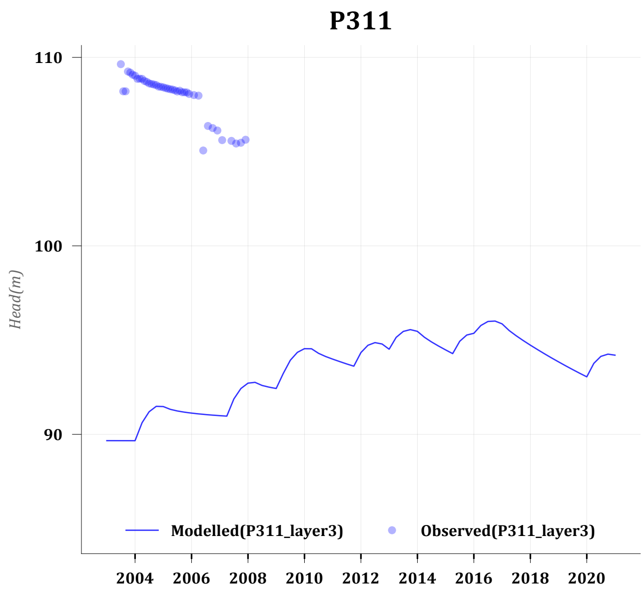

P29
60
50
40
30
Head(m)
Modelled(P29_layer6)
Observed(P29_layer6)
2004 2006 2008 2010 2012 2014 2016 2018 2020

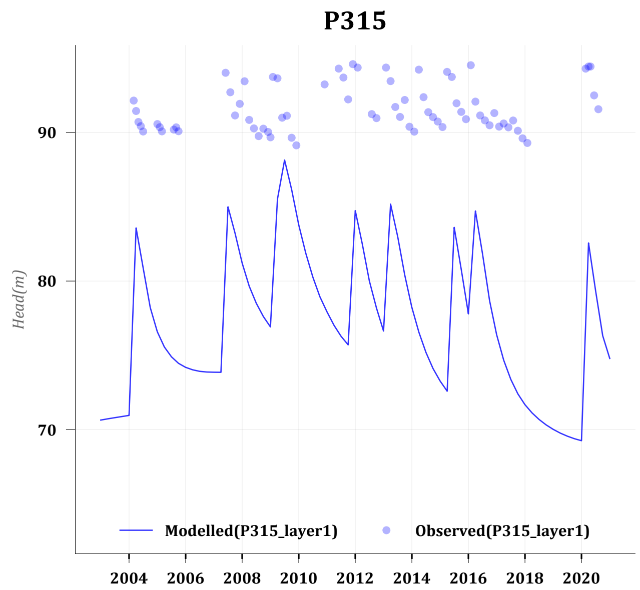

P2_HW
56
55
54
53
52
51
50
Head(m)
Modelled(P2_HW_layer1)
Observed(P2_HW_layer1)
2000 2005 2010 2015 2020

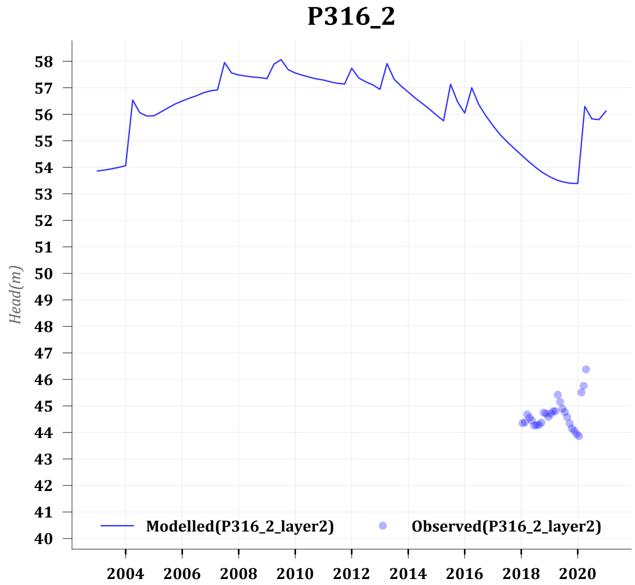

P3
50
40
30
20
Head(m)
Modelled(P3_layer14)
Observed(P3_layer14)
2004 2006 2008 2010 2012 2014 2016 2018 2020

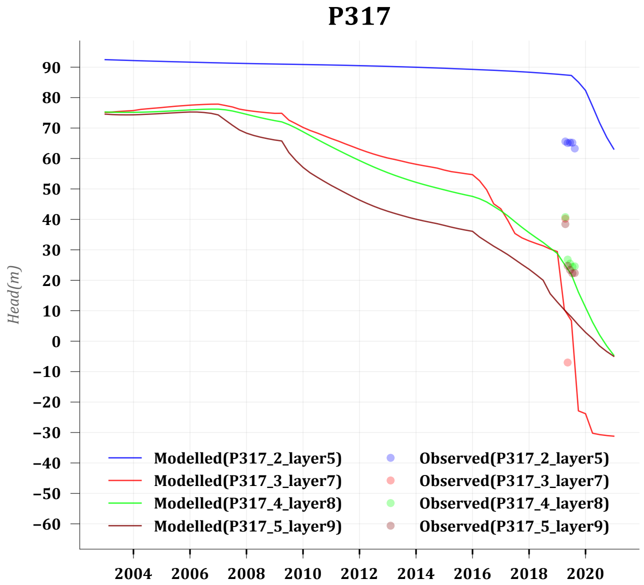

P301
80
70
Head(m)
Modelled(P301_layer1)
Observed(P301_layer1)
2004 2006 2008 2010 2012 2014 2016 2018 2020

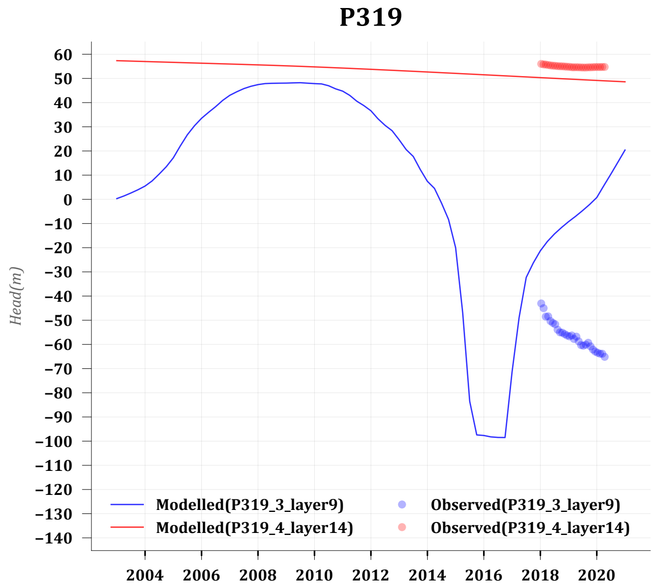

P307
100
90
80
70
60
Head(m)
Modelled(P307_1_layer3)
Modelled(P307_2_layer7)
Modelled(P307_3_layer9)
Modelled(P307_4_layer11)
Observed(P307_1_layer3)
Observed(P307_2_layer7)
Observed(P307_3_layer9)
Observed(P307_4_layer11)
2004 2006 2008 2010 2012 2014 2016 2018 2020

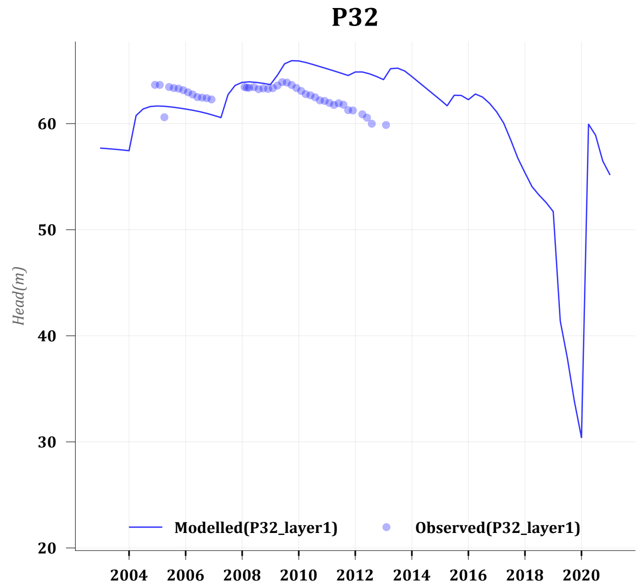

P311
Head(m)
Modelled(P311_layer3)
Observed(P311_layer3)

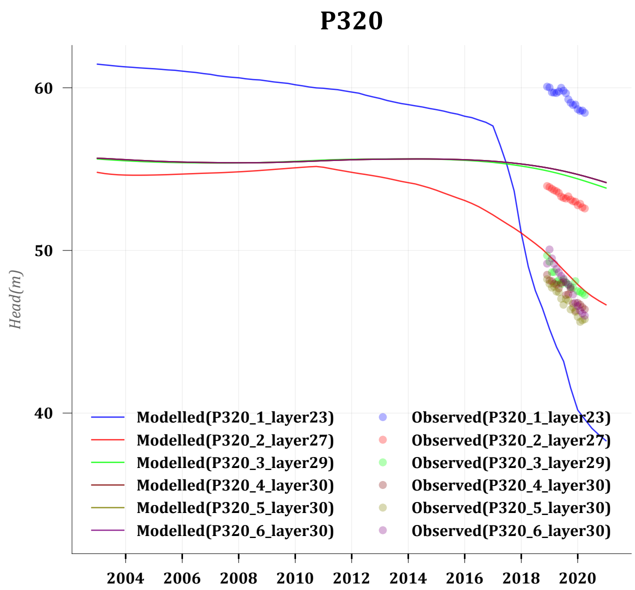

P315
Head(m)
Modelled(P315_layer1)
Observed(P315_layer1)

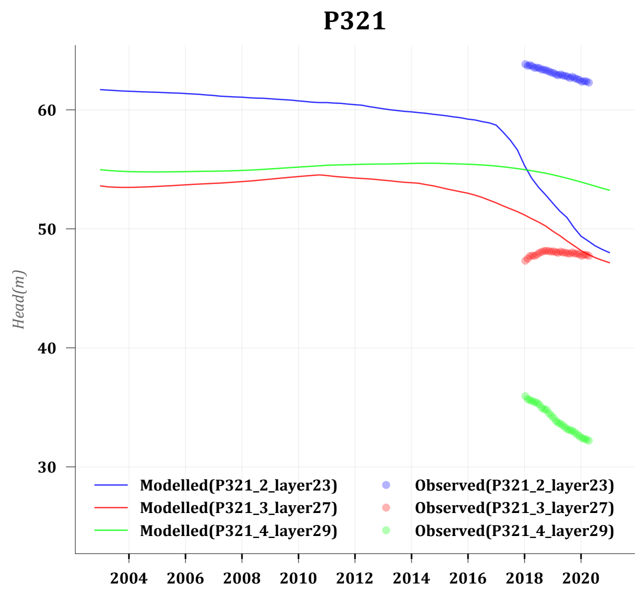

P316_2
Head(m)
Modelled(P316_2_layer2)
Observed(P316_2_layer2)

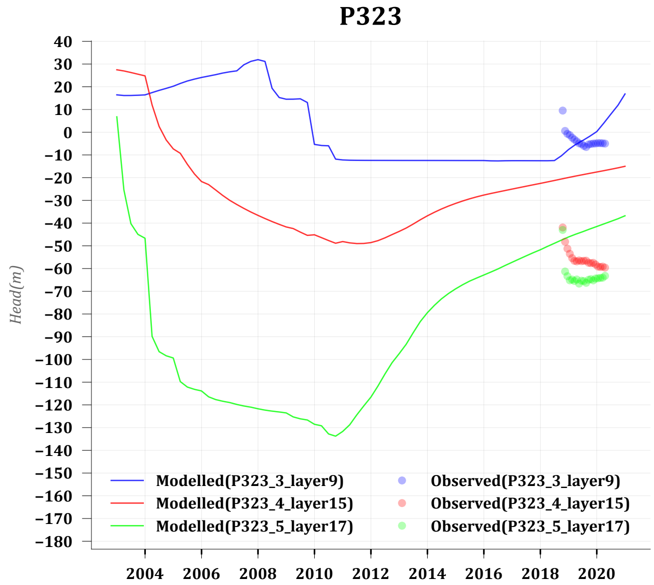

P317
Head(m)
Modelled(P317_2_layer5)
Modelled(P317_3_layer7)
Modelled(P317_4_layer8)
Modelled(P317_5_layer9)
Observed(P317_2_layer5)
Observed(P317_3_layer7)
Observed(P317_4_layer8)
Observed(P317_5_layer9)

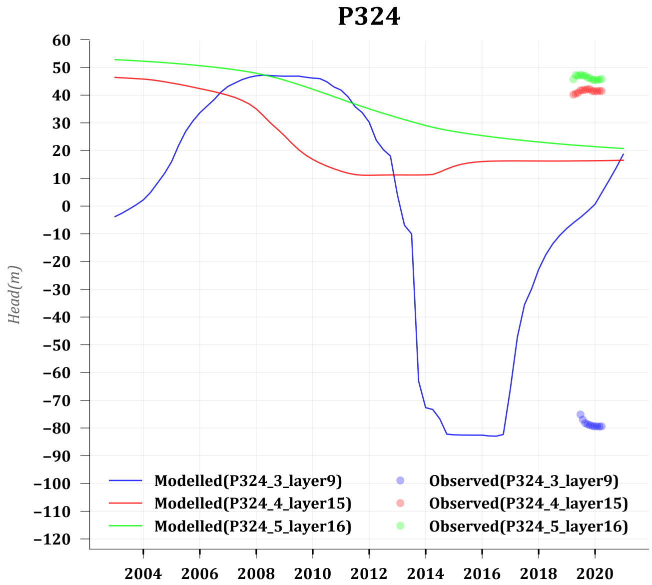

P319
Head(m)
Modelled(P319_3_layer9)
Modelled(P319_4_layer14)
Observed(P319_3_layer9)
Observed(P319_4_layer14)

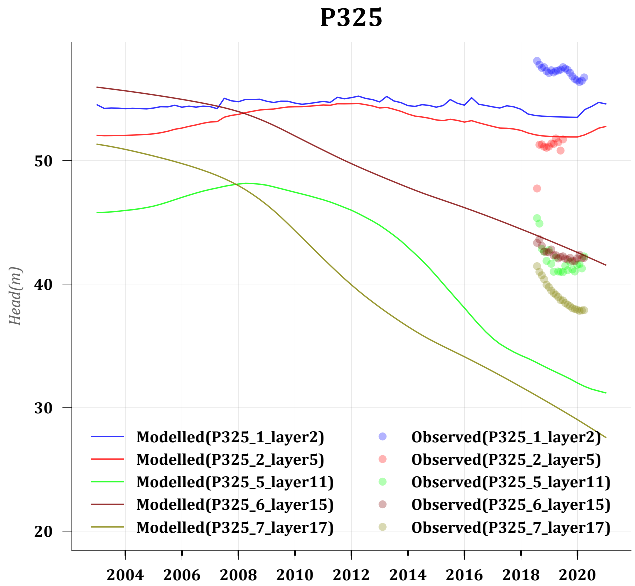

P32
Head(m)
Modelled(P32_layer1)
Observed(P32_layer1)

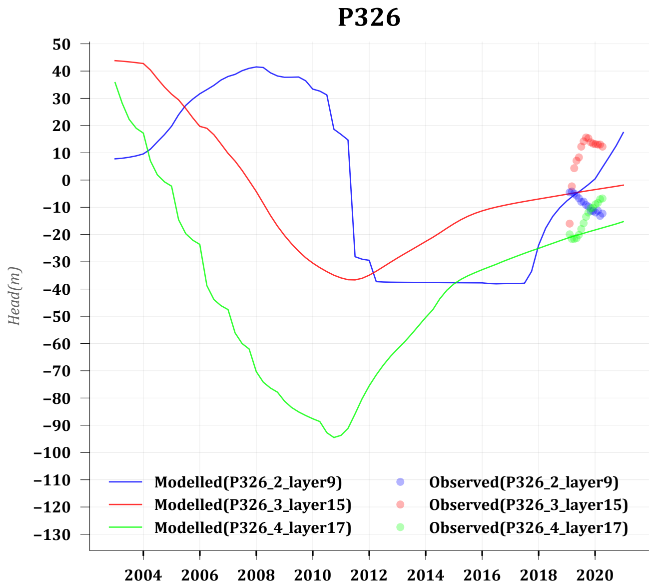

P320
Head(m)
Modelled(P320_1_layer23)
Modelled(P320_2_layer27)
Modelled(P320_3_layer29)
Modelled(P320_4_layer30)
Modelled(P320_5_layer30)
Modelled(P320_6_layer30)
Observed(P320_1_layer23)
Observed(P320_2_layer27)
Observed(P320_3_layer29)
Observed(P320_4_layer30)
Observed(P320_5_layer30)
Observed(P320_6_layer30)

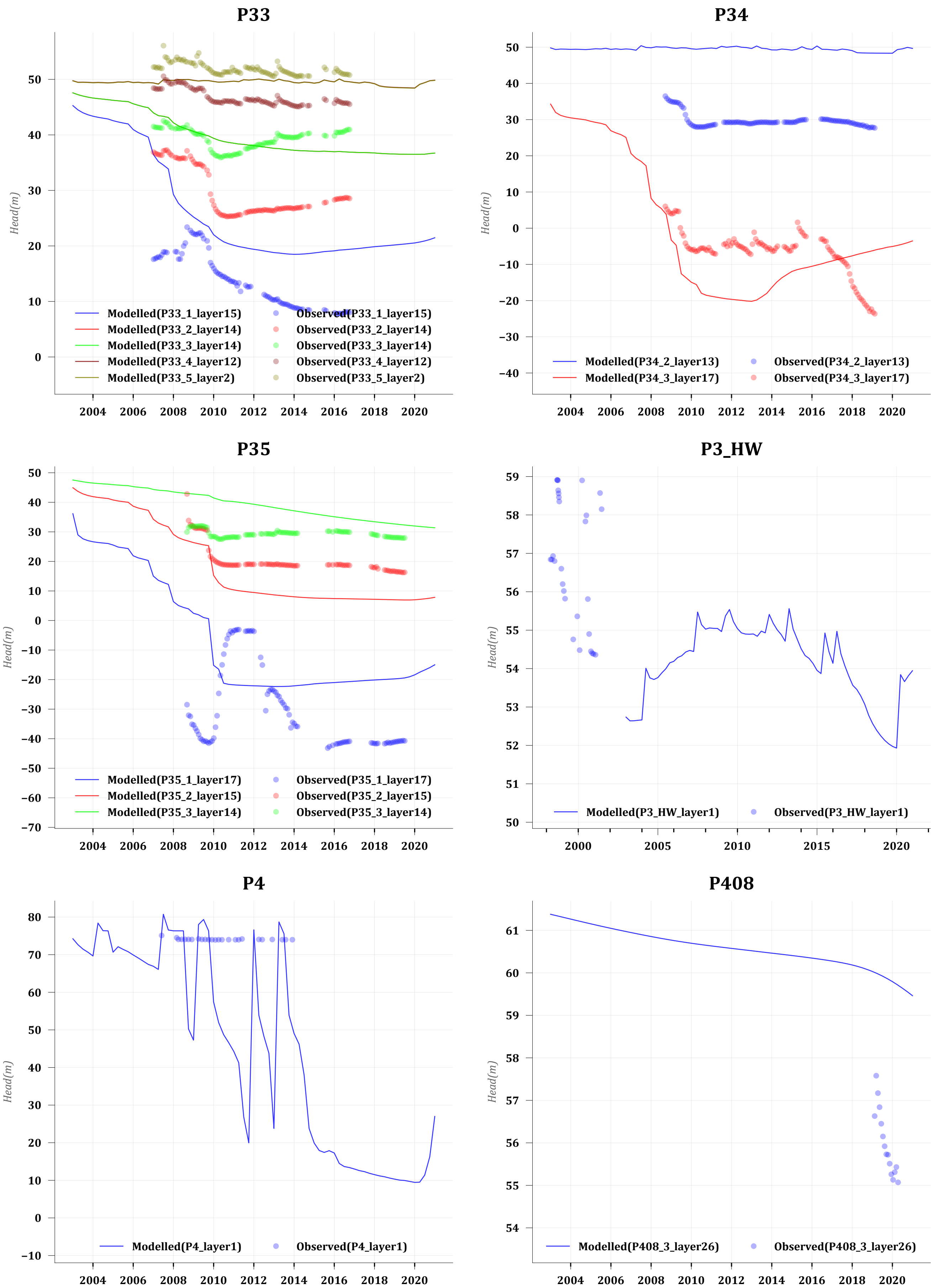

P321
Head(m)
Modelled(P321_2_layer23)
Modelled(P321_3_layer27)
Modelled(P321_4_layer29)
Observed(P321_2_layer23)
Observed(P321_3_layer27)
Observed(P321_4_layer29)

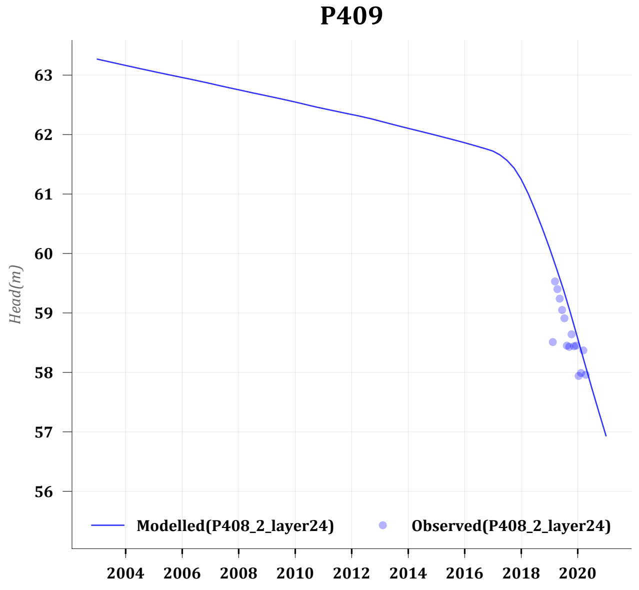

P323
Head(m)
Modelled(P323_3_layer9)
Modelled(P323_4_layer15)
Modelled(P323_5_layer17)
Observed(P323_3_layer9)
Observed(P323_4_layer15)
Observed(P323_5_layer17)

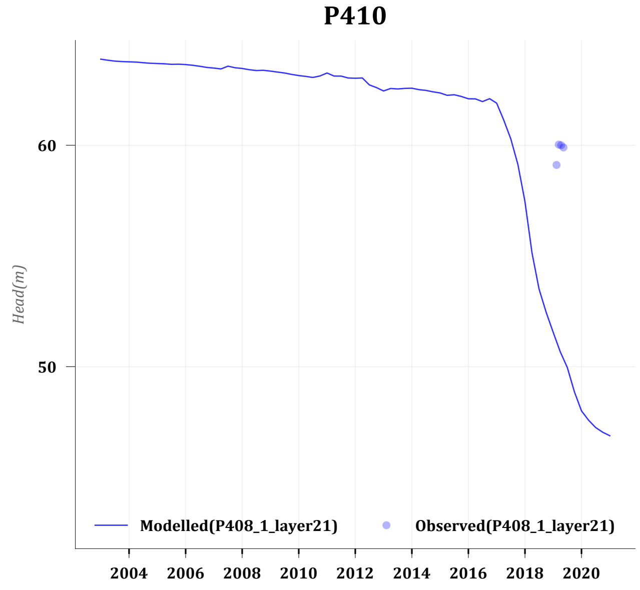

P324
Head(m)
Modelled(P324_3_layer9)
Modelled(P324_4_layer15)
Modelled(P324_5_layer16)
Observed(P324_3_layer9)
Observed(P324_4_layer15)
Observed(P324_5_layer16)

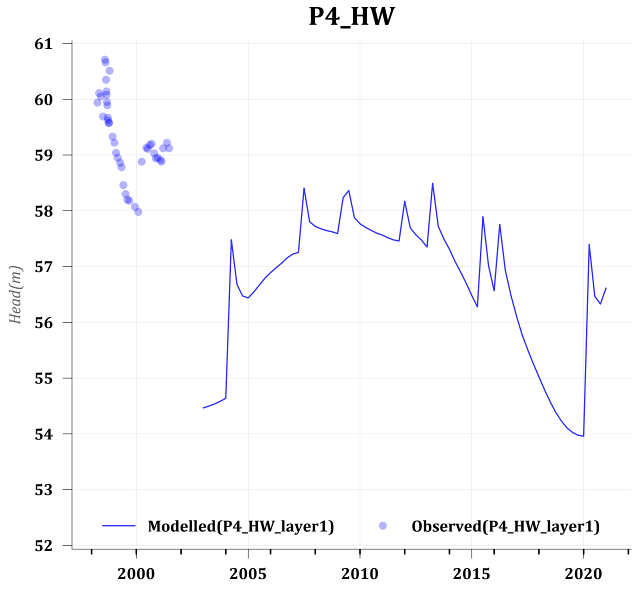

P325
Head(m)
Modelled(P325_1_layer2)
Modelled(P325_2_layer5)
Modelled(P325_5_layer11)
Modelled(P325_6_layer15)
Modelled(P325_7_layer17)
Observed(P325_1_layer2)
Observed(P325_2_layer5)
Observed(P325_5_layer11)
Observed(P325_6_layer15)
Observed(P325_7_layer17)

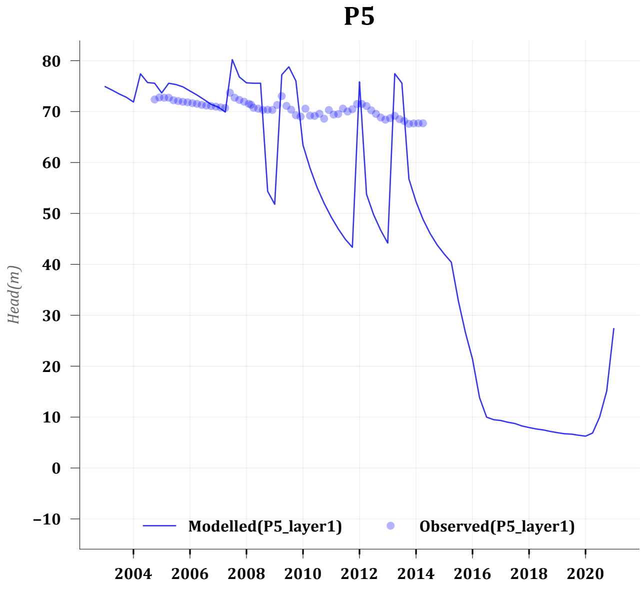

P326
Head(m)
Modelled(P326_2_layer9)
Modelled(P326_3_layer15)
Modelled(P326_4_layer17)
Observed(P326_2_layer9)
Observed(P326_3_layer15)
Observed(P326_4_layer17)

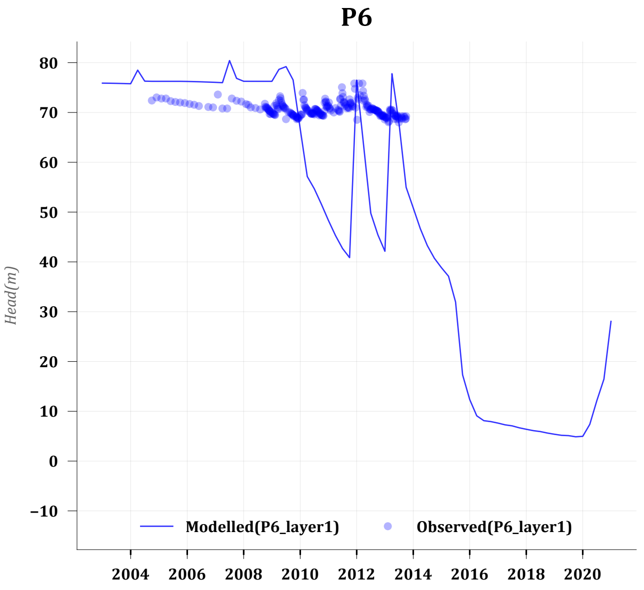

P33
Head(m)
Modelled(P33_1_layer15)
Modelled(P33_2_layer14)
Modelled(P33_3_layer14)
Modelled(P33_4_layer12)
Modelled(P33_5_layer2)
Observed(P33_1_layer15)
Observed(P33_2_layer14)
Observed(P33_3_layer14)
Observed(P33_4_layer12)
Observed(P33_5_layer2)
P34
Head(m)
Modelled(P34_2_layer13)
Modelled(P34_3_layer17)
Observed(P34_2_layer13)
Observed(P34_3_layer17)
P35
Head(m)
Modelled(P35_1_layer17)
Modelled(P35_2_layer15)
Modelled(P35_3_layer14)
Observed(P35_1_layer17)
Observed(P35_2_layer15)
Observed(P35_3_layer14)
P3_HW
Head(m)
Modelled(P3_HW_layer1)
Observed(P3_HW_layer1)
P4
Head(m)
Modelled(P4_layer1)
Observed(P4_layer1)
P408
Head(m)
Modelled(P408_3_layer26)
Observed(P408_3_layer26)

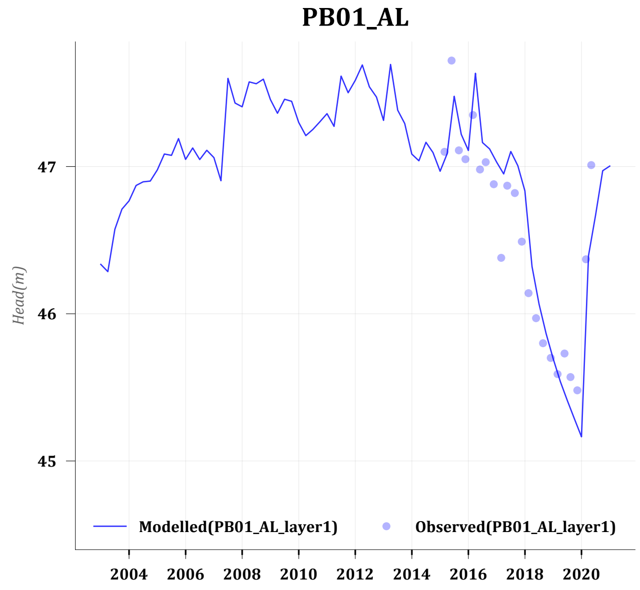

P409
Head(m)
Modelled(P408_2_layer24)
Observed(P408_2_layer24)

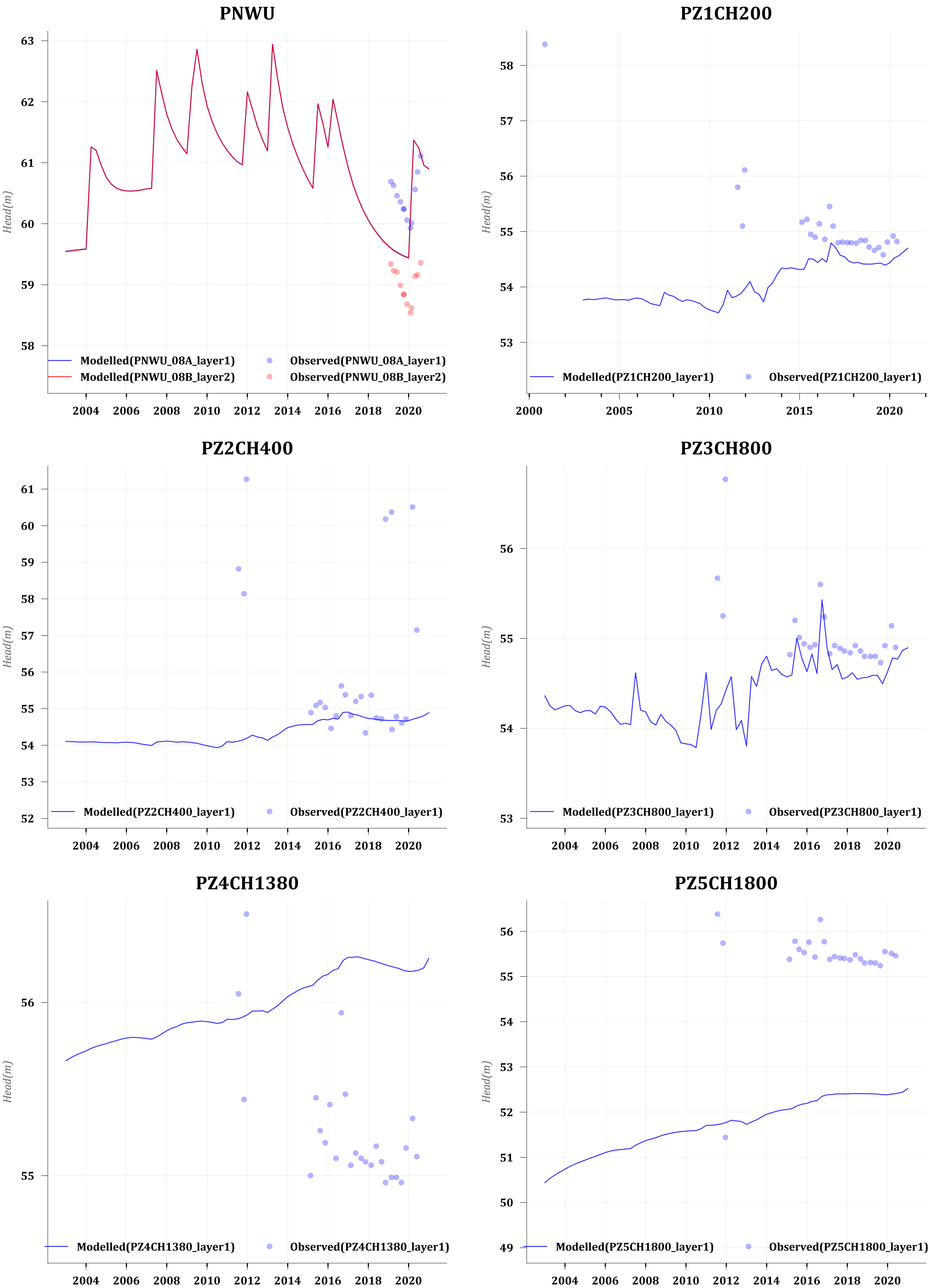

P410
Head(m)
Modelled(P408_1_layer21)
Observed(P408_1_layer21)

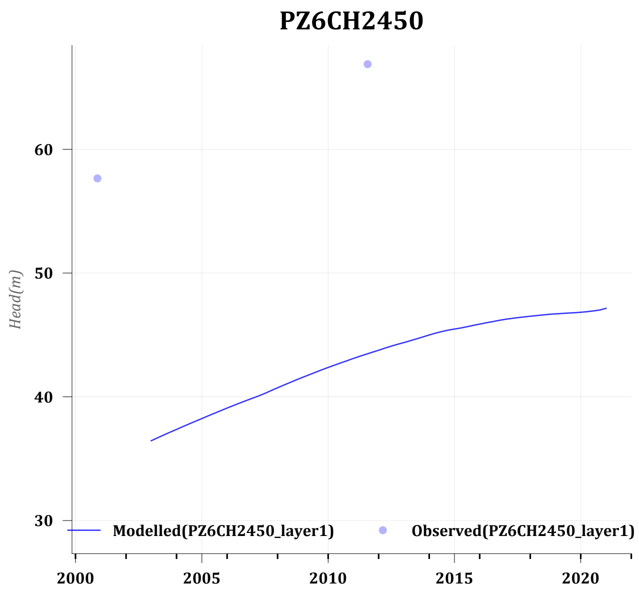

P4_HW
Head(m)
Modelled(P4_HW_layer1)
Observed(P4_HW_layer1)

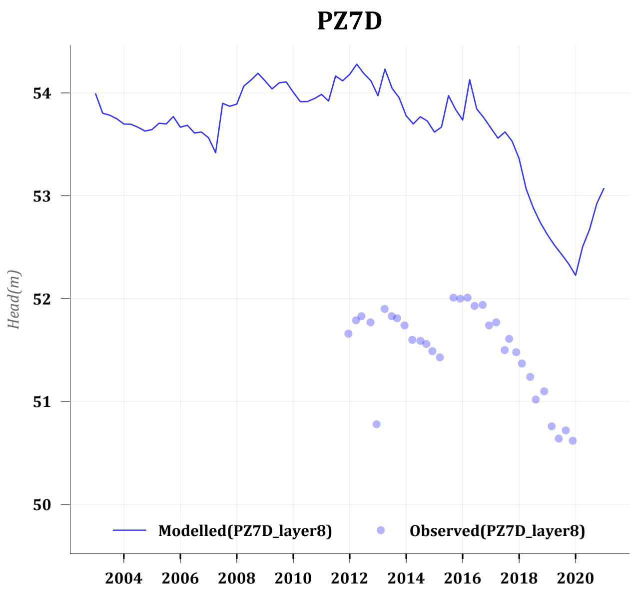

P5
Head(m)
Modelled(P5_layer1)
Observed(P5_layer1)

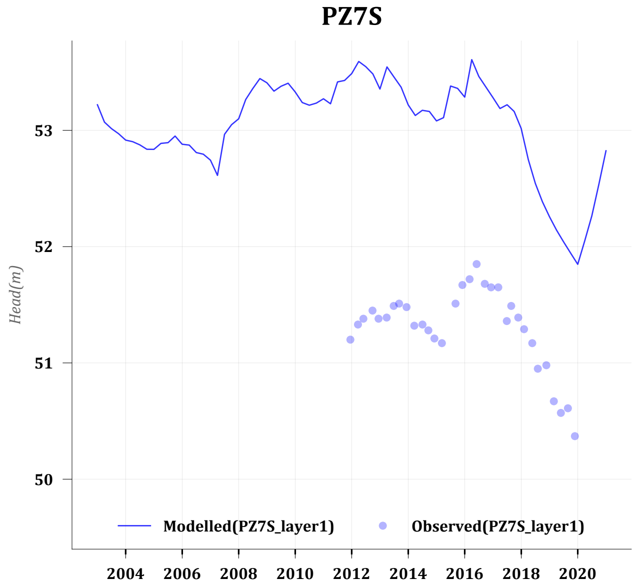

P6
Head(m)
Modelled(P6_layer1)
Observed(P6_layer1)

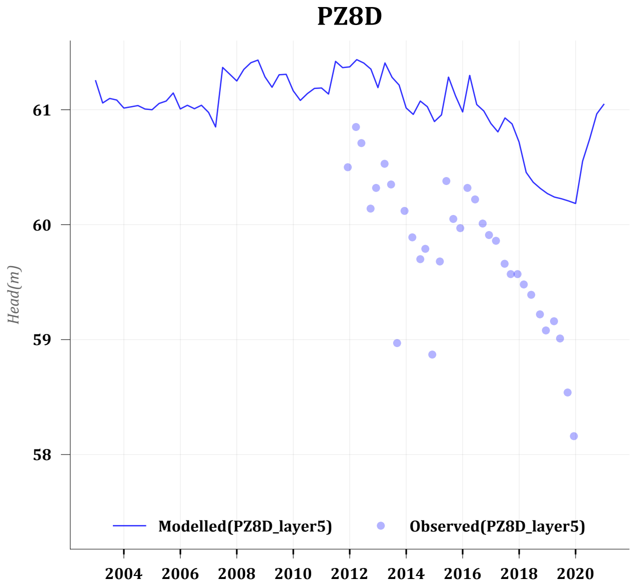

PB01_AL
Head(m)
Modelled(PB01_AL_layer1)
Observed(PB01_AL_layer1)

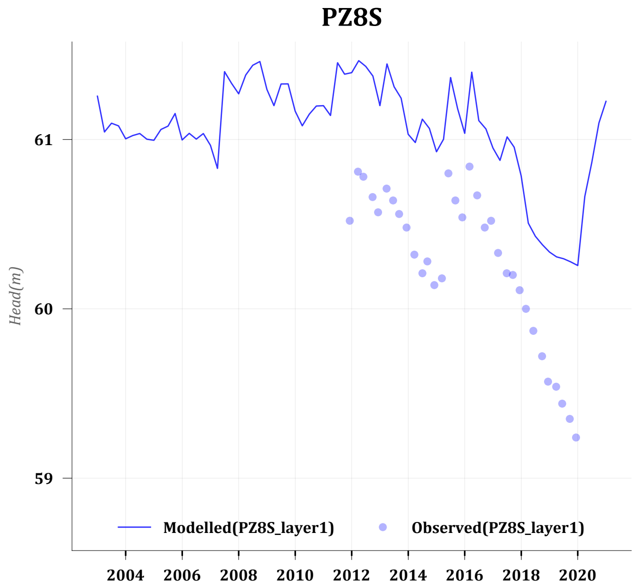

PNWU
Head(m)
Modelled(PNWU_08A_layer1)
Modelled(PNWU_08B_layer2)
Observed(PNWU_08A_layer1)
Observed(PNWU_08B_layer2)
PZ1CH200
Head(m)
Modelled(PZ1CH200_layer1)
Observed(PZ1CH200_layer1)
PZ2CH400
Head(m)
Modelled(PZ2CH400_layer1)
Observed(PZ2CH400_layer1)
PZ3CH800
Head(m)
Modelled(PZ3CH800_layer1)
Observed(PZ3CH800_layer1)
PZ4CH1380
Head(m)
Modelled(PZ4CH1380_layer1)
Observed(PZ4CH1380_layer1)
PZ5CH1800
Head(m)
Modelled(PZ5CH1800_layer1)
Observed(PZ5CH1800_layer1)

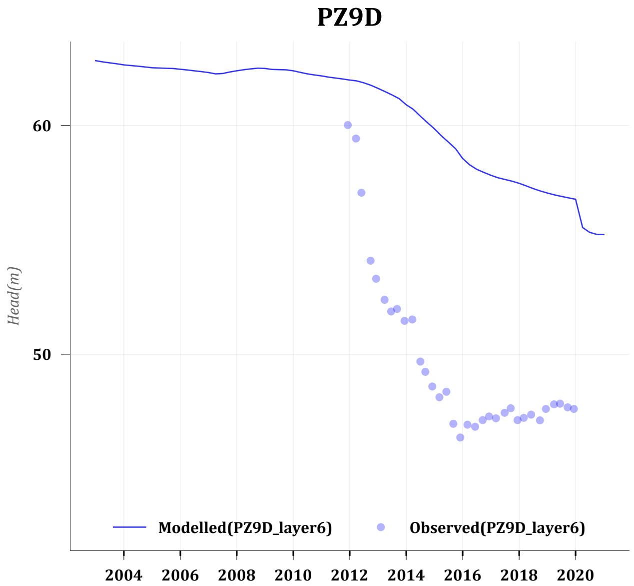

PZ6CH2450
Head(m)
30
40
50
60
2000
2005
2010
2015
2020
Modelled(PZ6CH2450_layer1)
Observed(PZ6CH2450_layer1)

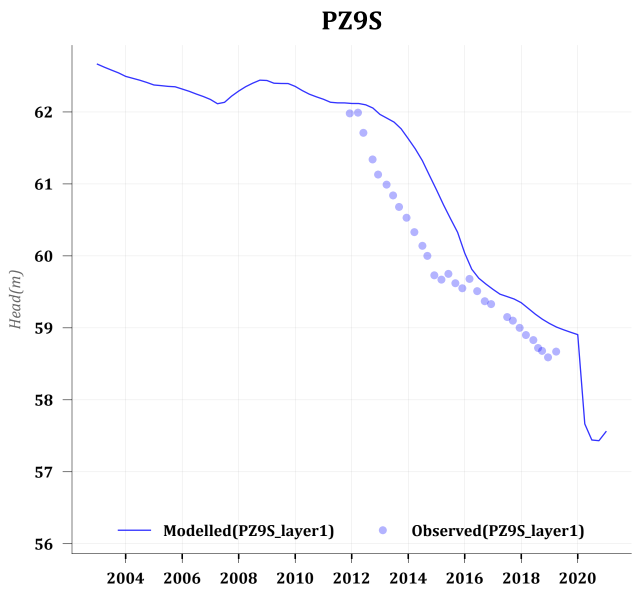

PZ7D
Head(m)
50
51
52
53
54
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(PZ7D_layer8)
Observed(PZ7D_layer8)

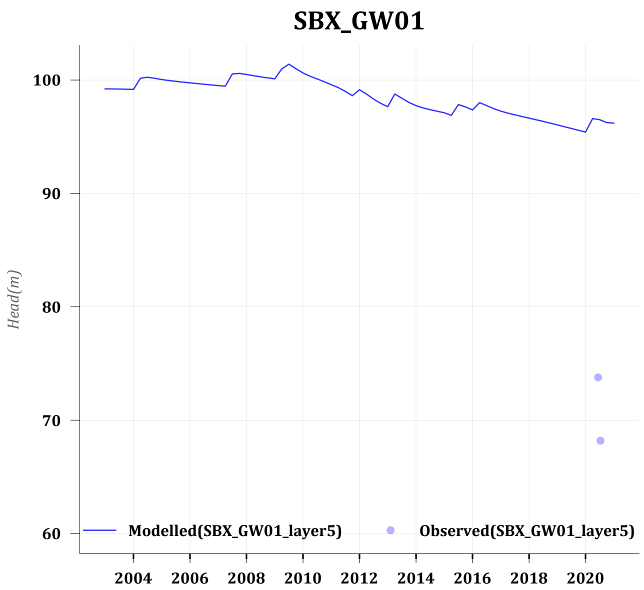

PZ7S
Head(m)
50
51
52
53
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(PZ7S_layer1)
Observed(PZ7S_layer1)

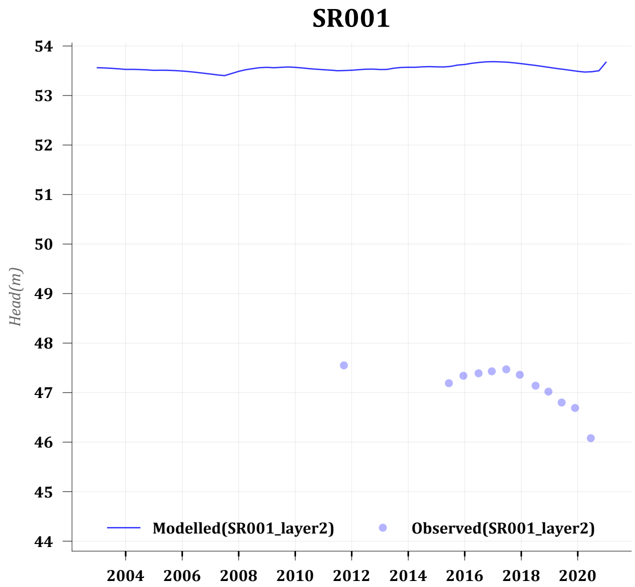

PZ8D
Head(m)
58
59
60
61
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(PZ8D_layer5)
Observed(PZ8D_layer5)

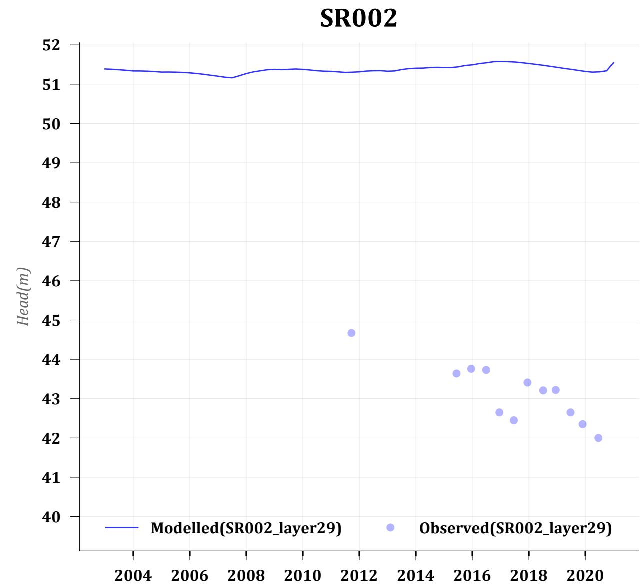

PZ8S
Head(m)
59
60
61
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(PZ8S_layer1)
Observed(PZ8S_layer1)

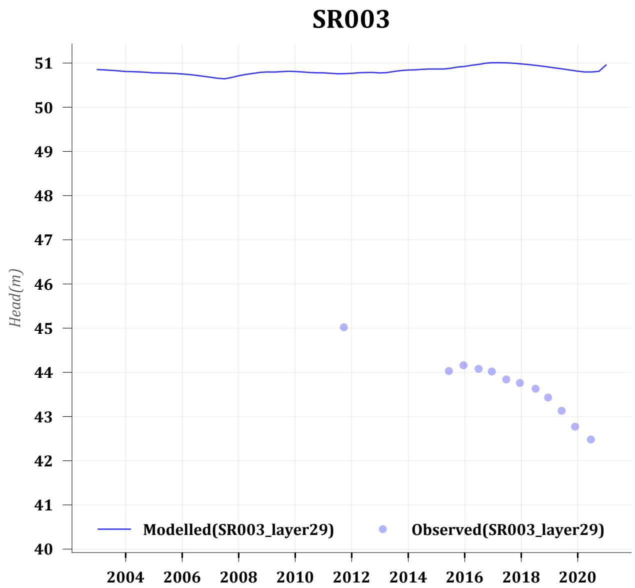

PZ9D
Head(m)
50
60
2004
2006
2008
2010
2012
2014
2016
2018
2020
Modelled(PZ9D_layer6)
Observed(PZ9D_layer6)

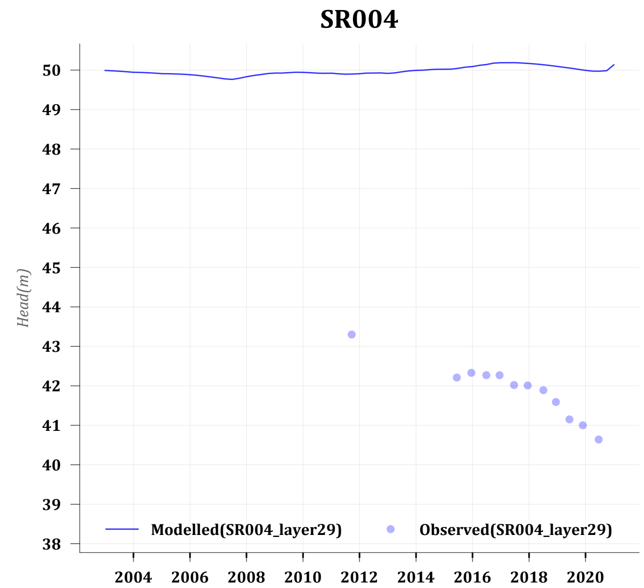

PZ9S
Head(m)
Modelled(PZ9S_layer1)
Observed(PZ9S_layer1)


SBX_GW01
Head(m)
Modelled(SBX_GW01_layer5)
Observed(SBX_GW01_layer5)

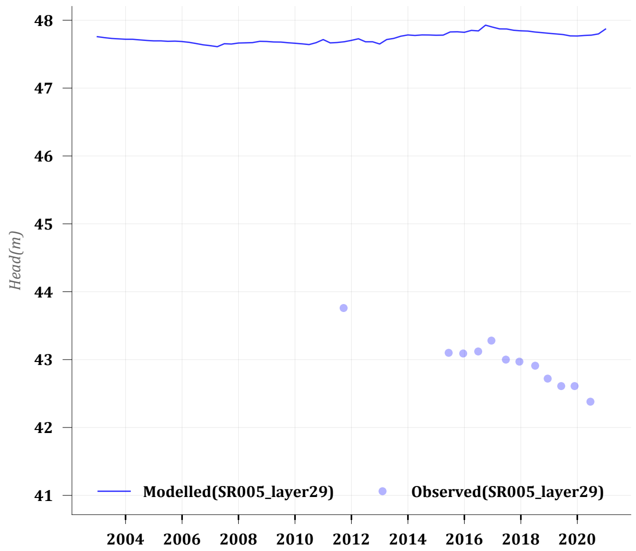

SR001
Head(m)
Modelled(SR001_layer2)
Observed(SR001_layer2)


SR002
Head(m)
Modelled(SR002_layer29)
Observed(SR002_layer29)

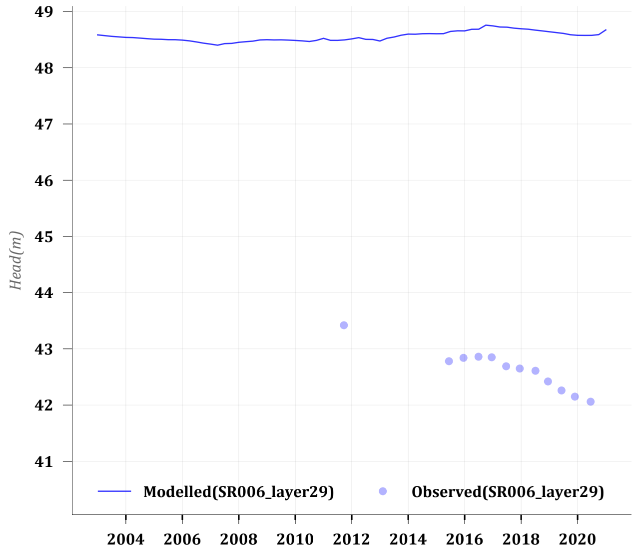

SR003
Head(m)
Modelled(SR003_layer29)
Observed(SR003_layer29)


SR004
Head(m)
Modelled(SR004_layer29)
Observed(SR004_layer29)

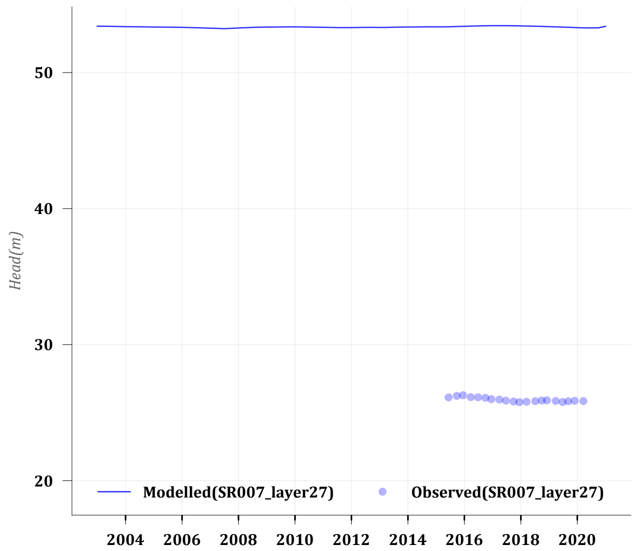
SR005



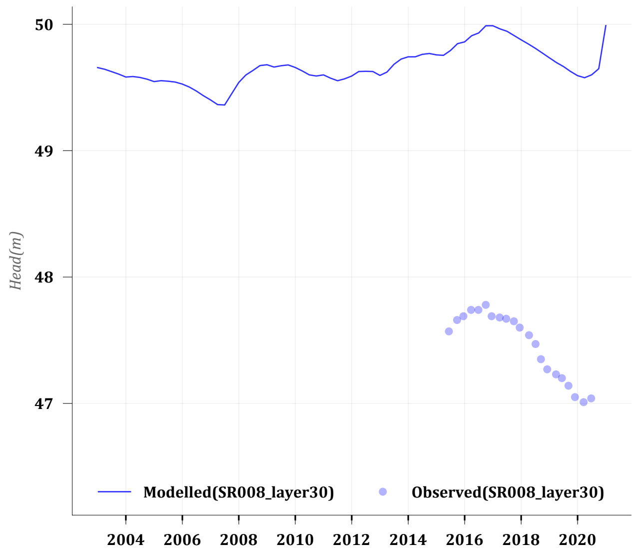
SR006



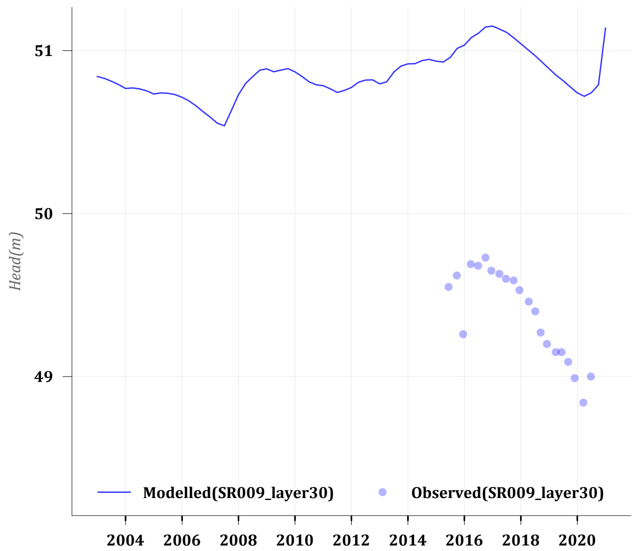
SR007



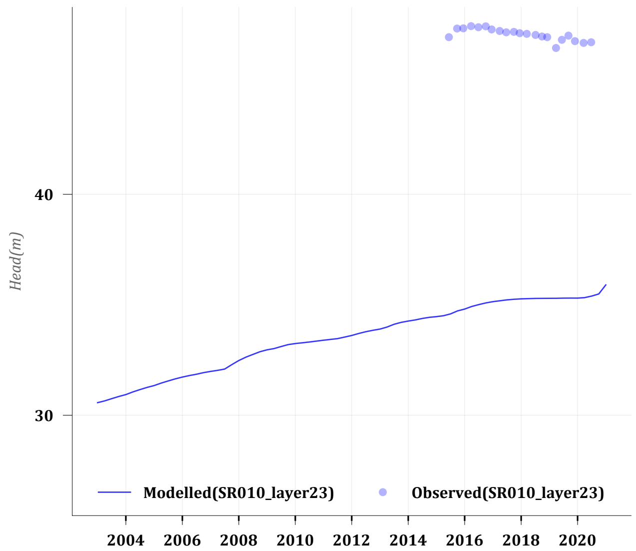
SR008

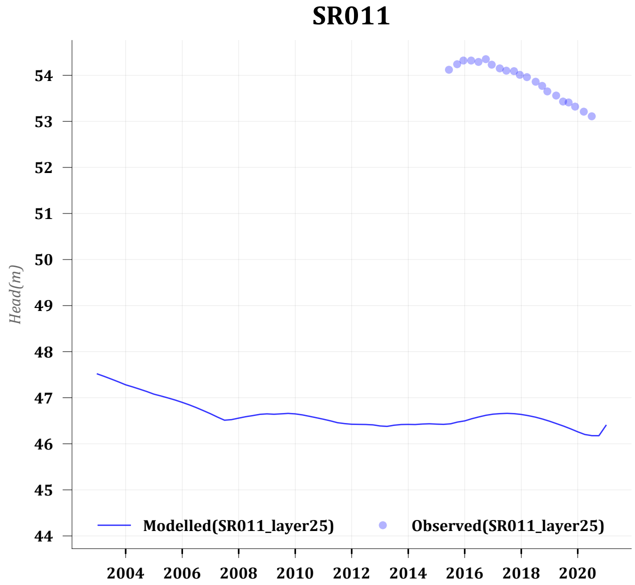


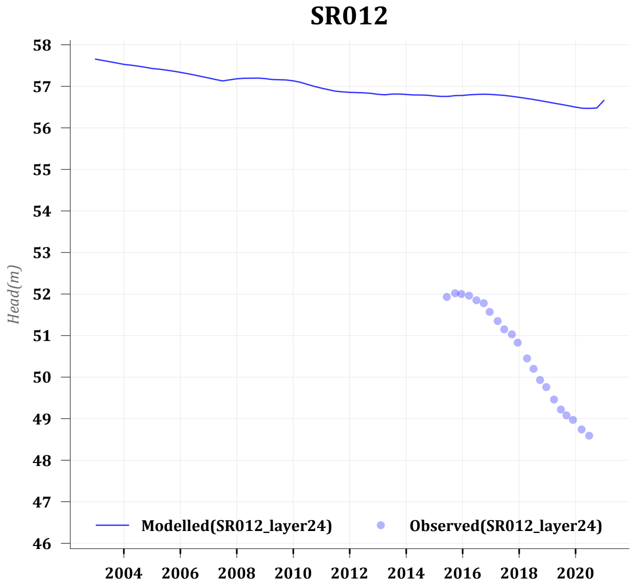
SR009

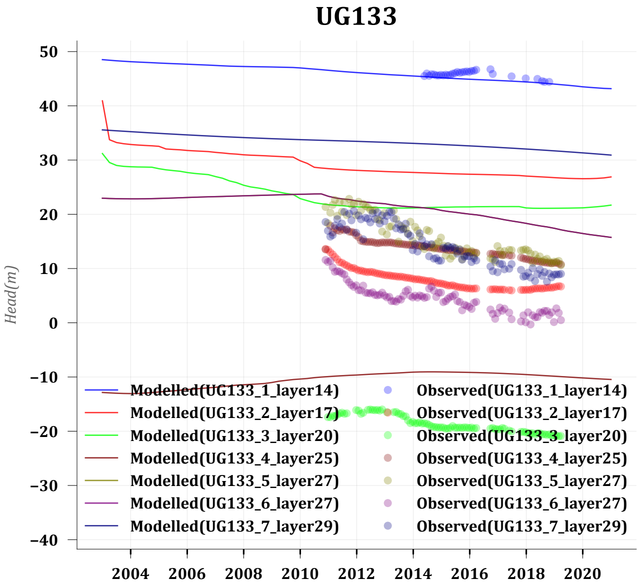


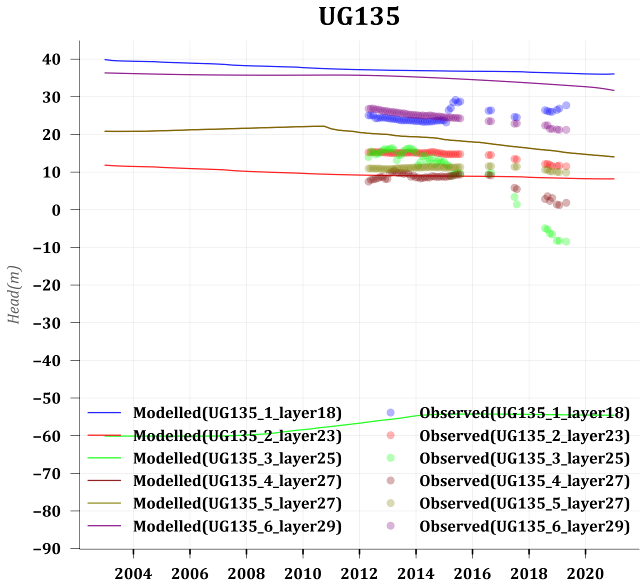
SR010

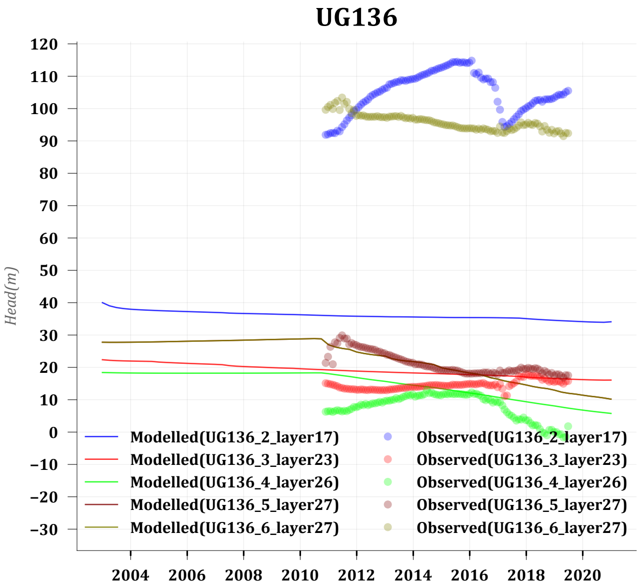


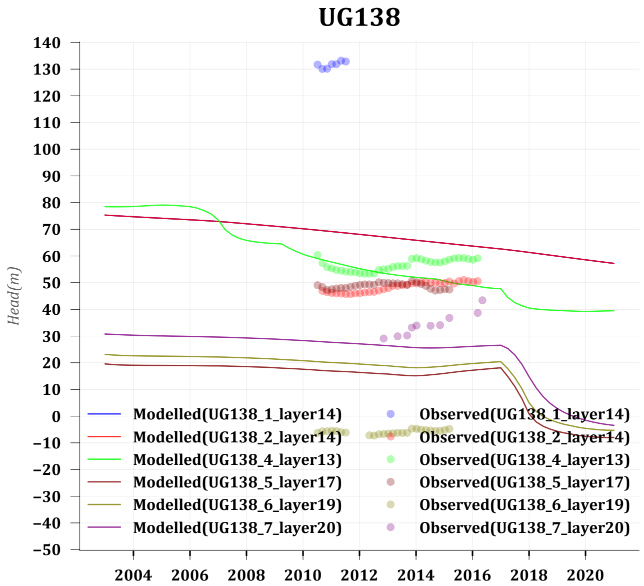

SR011
Head(m)
54
53
52
51
50
49
48
47
46
45
44
Modelled(SR011_layer25)
Observed(SR011_layer25)
2004 2006 2008 2010 2012 2014 2016 2018 2020

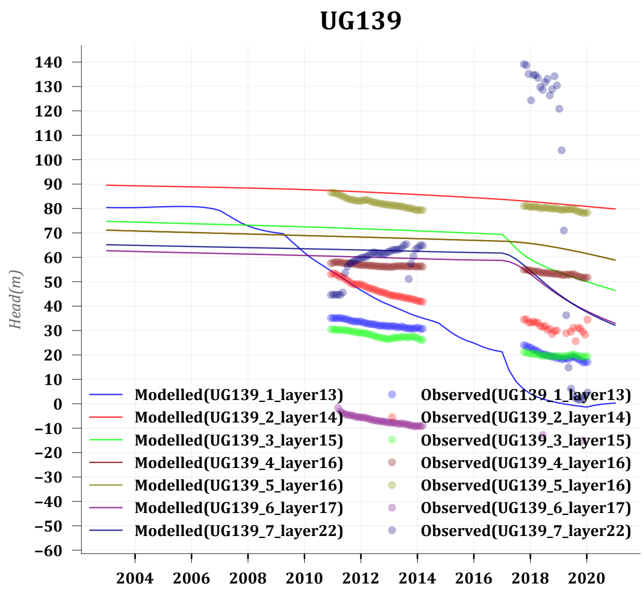

SR012
Head(m)
58
57
56
55
54
53
52
51
50
49
48
47
46
Modelled(SR012_layer24)
Observed(SR012_layer24)
2004 2006 2008 2010 2012 2014 2016 2018 2020

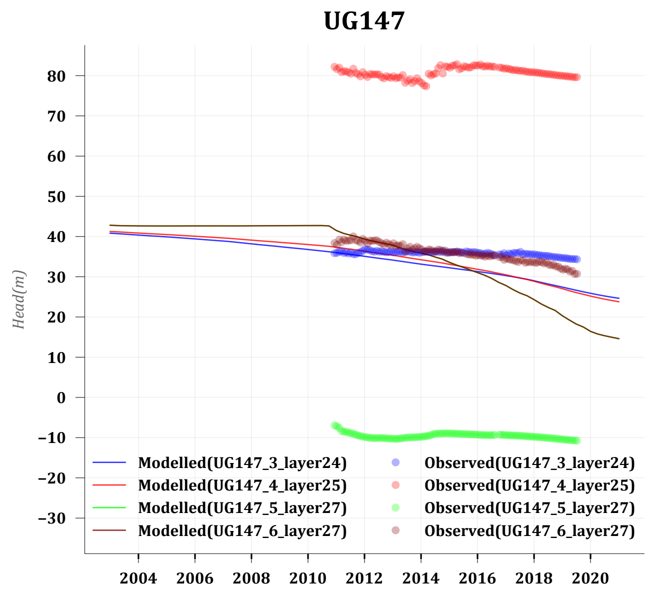

UG133
Head(m)
50
40
30
20
10
0
−10
−20
−30
−40
Modelled(UG133_1_layer14)
Modelled(UG133_2_layer17)
Modelled(UG133_3_layer20)
Modelled(UG133_4_layer25)
Modelled(UG133_5_layer27)
Modelled(UG133_6_layer27)
Modelled(UG133_7_layer29)
Observed(UG133_1_layer14)
Observed(UG133_2_layer17)
Observed(UG133_3_layer20)
Observed(UG133_4_layer25)
Observed(UG133_5_layer27)
Observed(UG133_6_layer27)
Observed(UG133_7_layer29)
2004 2006 2008 2010 2012 2014 2016 2018 2020

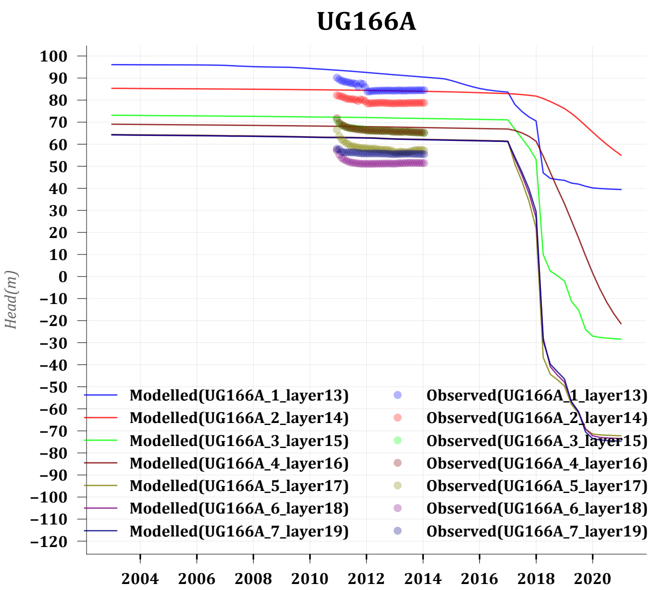

UG135
Head(m)
40
30
20
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
Modelled(UG135_1_layer18)
Modelled(UG135_2_layer23)
Modelled(UG135_3_layer25)
Modelled(UG135_4_layer27)
Modelled(UG135_5_layer27)
Modelled(UG135_6_layer29)
Observed(UG135_1_layer18)
Observed(UG135_2_layer23)
Observed(UG135_3_layer25)
Observed(UG135_4_layer27)
Observed(UG135_5_layer27)
Observed(UG135_6_layer29)
2004 2006 2008 2010 2012 2014 2016 2018 2020

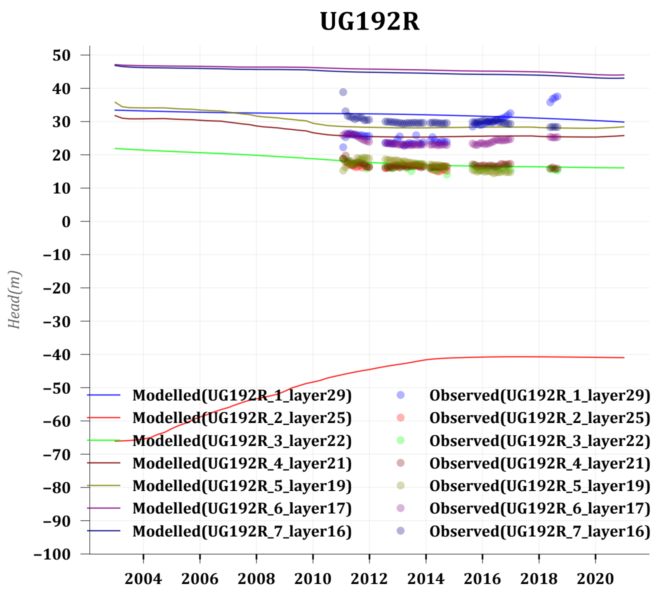

UG136
Head(m)
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20
−30
Modelled(UG136_2_layer17)
Modelled(UG136_3_layer23)
Modelled(UG136_4_layer26)
Modelled(UG136_5_layer27)
Modelled(UG136_6_layer27)
Observed(UG136_2_layer17)
Observed(UG136_3_layer23)
Observed(UG136_4_layer26)
Observed(UG136_5_layer27)
Observed(UG136_6_layer27)
2004 2006 2008 2010 2012 2014 2016 2018 2020

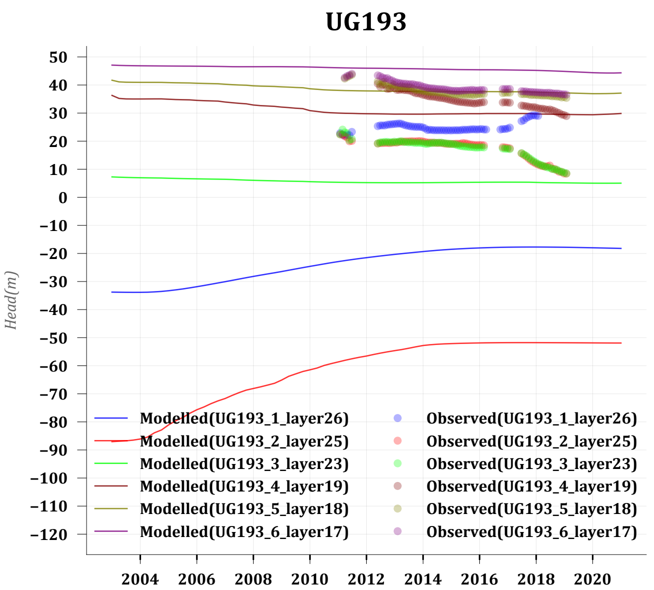

UG138
Head(m)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
−20
−30
−40
−50
Modelled(UG138_1_layer14)
Modelled(UG138_2_layer14)
Modelled(UG138_4_layer13)
Modelled(UG138_5_layer17)
Modelled(UG138_6_layer19)
Modelled(UG138_7_layer20)
Observed(UG138_1_layer14)
Observed(UG138_2_layer14)
Observed(UG138_4_layer13)
Observed(UG138_5_layer17)
Observed(UG138_6_layer19)
Observed(UG138_7_layer20)
2004 2006 2008 2010 2012 2014 2016 2018 2020

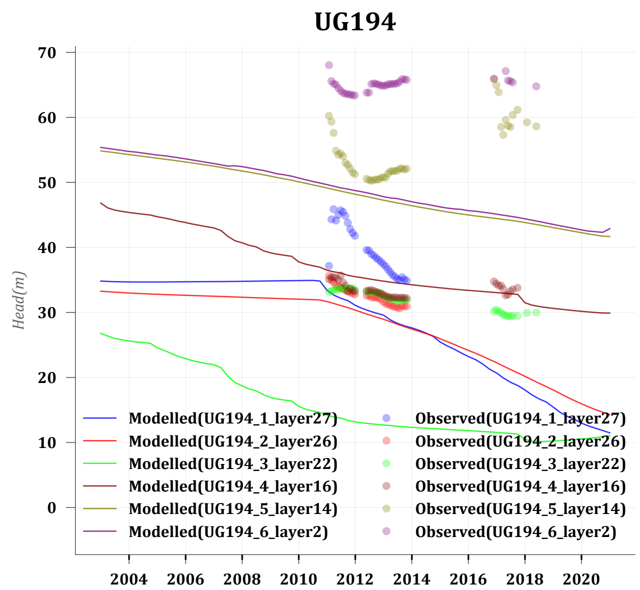

UG139
Head(m)
Modelled(UG139_1_layer13)
Modelled(UG139_2_layer14)
Modelled(UG139_3_layer15)
Modelled(UG139_4_layer16)
Modelled(UG139_5_layer16)
Modelled(UG139_6_layer17)
Modelled(UG139_7_layer22)
Observed(UG139_1_layer13)
Observed(UG139_2_layer14)
Observed(UG139_3_layer15)
Observed(UG139_4_layer16)
Observed(UG139_5_layer16)
Observed(UG139_6_layer17)
Observed(UG139_7_layer22)
2004 2006 2008 2010 2012 2014 2016 2018 2020

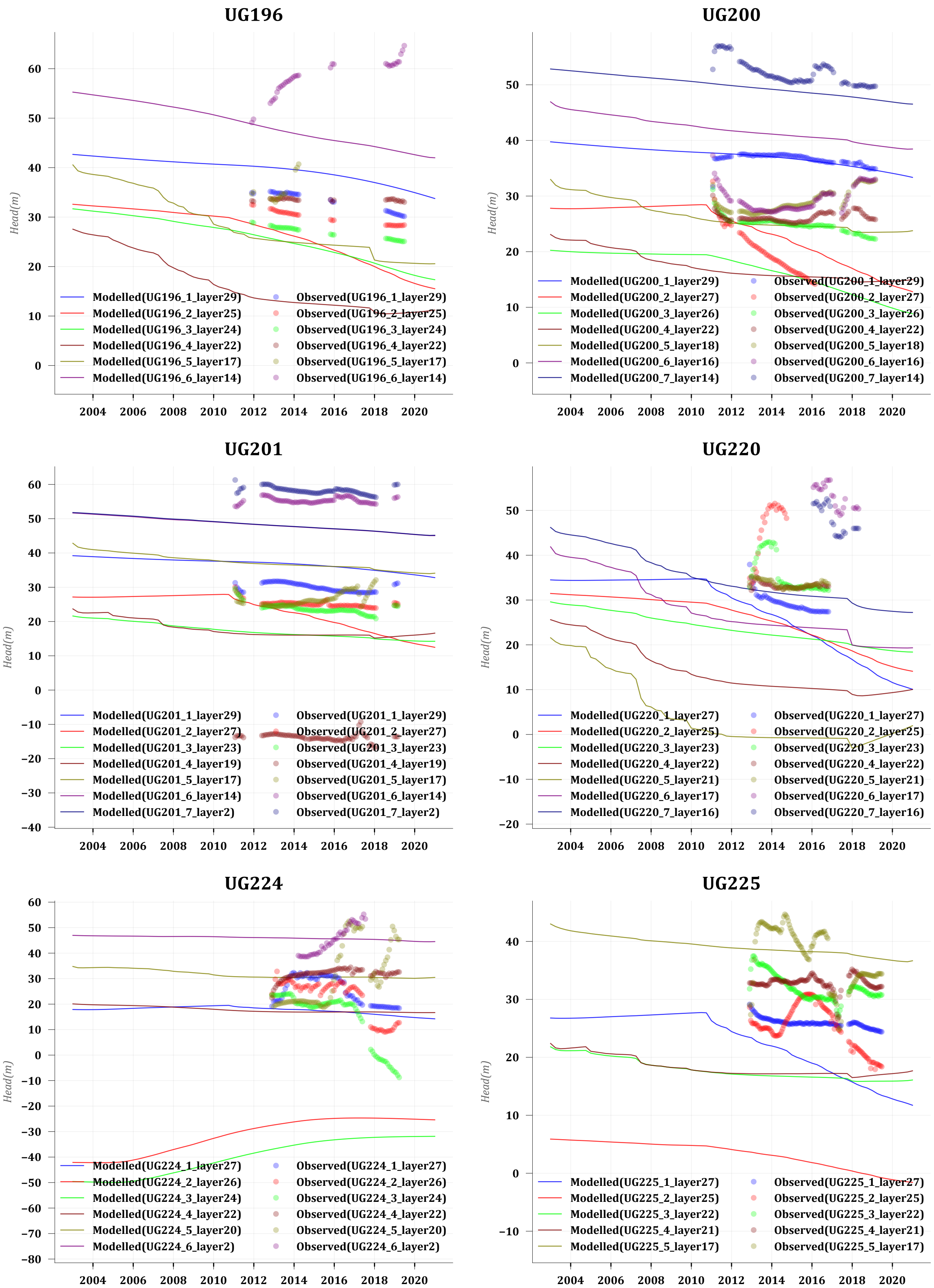

UG147
Head(m)
Modelled(UG147_3_layer24)
Modelled(UG147_4_layer25)
Modelled(UG147_5_layer27)
Modelled(UG147_6_layer27)
Observed(UG147_3_layer24)
Observed(UG147_4_layer25)
Observed(UG147_5_layer27)
Observed(UG147_6_layer27)
2004 2006 2008 2010 2012 2014 2016 2018 2020


UG166A
Head(m)
Modelled(UG166A_1_layer13)
Modelled(UG166A_2_layer14)
Modelled(UG166A_3_layer15)
Modelled(UG166A_4_layer16)
Modelled(UG166A_5_layer17)
Modelled(UG166A_6_layer18)
Modelled(UG166A_7_layer19)
Observed(UG166A_1_layer13)
Observed(UG166A_2_layer14)
Observed(UG166A_3_layer15)
Observed(UG166A_4_layer16)
Observed(UG166A_5_layer17)
Observed(UG166A_6_layer18)
Observed(UG166A_7_layer19)
2004 2006 2008 2010 2012 2014 2016 2018 2020

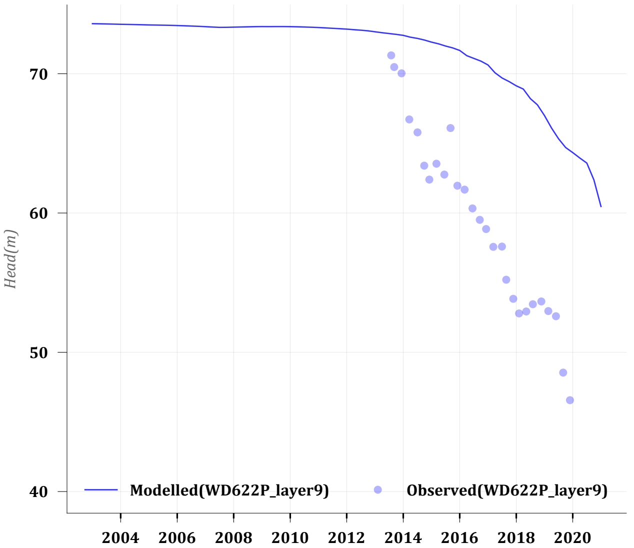

UG192R
Head(m)
Modelled(UG192R_1_layer29)
Modelled(UG192R_2_layer25)
Modelled(UG192R_3_layer22)
Modelled(UG192R_4_layer21)
Modelled(UG192R_5_layer19)
Modelled(UG192R_6_layer17)
Modelled(UG192R_7_layer16)
Observed(UG192R_1_layer29)
Observed(UG192R_2_layer25)
Observed(UG192R_3_layer22)
Observed(UG192R_4_layer21)
Observed(UG192R_5_layer19)
Observed(UG192R_6_layer17)
Observed(UG192R_7_layer16)
2004 2006 2008 2010 2012 2014 2016 2018 2020


UG193
Head(m)
Modelled(UG193_1_layer26)
Modelled(UG193_2_layer25)
Modelled(UG193_3_layer23)
Modelled(UG193_4_layer19)
Modelled(UG193_5_layer18)
Modelled(UG193_6_layer17)
Observed(UG193_1_layer26)
Observed(UG193_2_layer25)
Observed(UG193_3_layer23)
Observed(UG193_4_layer19)
Observed(UG193_5_layer18)
Observed(UG193_6_layer17)
2004 2006 2008 2010 2012 2014 2016 2018 2020

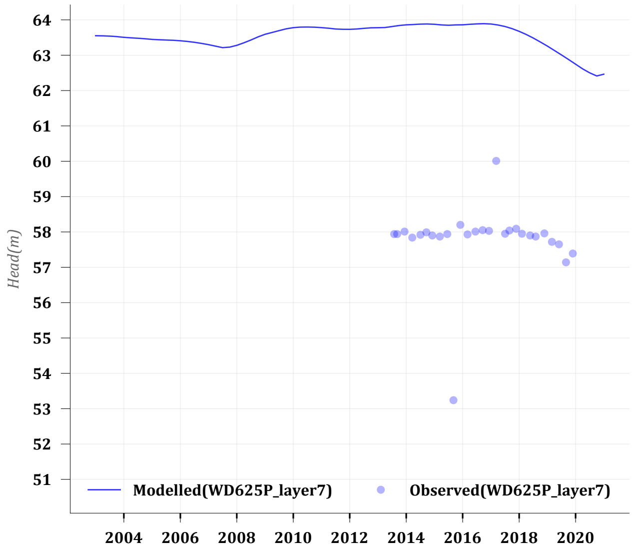

UG194
Head(m)
Modelled(UG194_1_layer27)
Modelled(UG194_2_layer26)
Modelled(UG194_3_layer22)
Modelled(UG194_4_layer16)
Modelled(UG194_5_layer14)
Modelled(UG194_6_layer2)
Observed(UG194_1_layer27)
Observed(UG194_2_layer26)
Observed(UG194_3_layer22)
Observed(UG194_4_layer16)
Observed(UG194_5_layer14)
Observed(UG194_6_layer2)
2004 2006 2008 2010 2012 2014 2016 2018 2020


UG196
Head(m)
Modelled(UG196_1_layer29)
Modelled(UG196_2_layer25)
Modelled(UG196_3_layer24)
Modelled(UG196_4_layer22)
Modelled(UG196_5_layer17)
Modelled(UG196_6_layer14)
Observed(UG196_1_layer29)
Observed(UG196_2_layer25)
Observed(UG196_3_layer24)
Observed(UG196_4_layer22)
Observed(UG196_5_layer17)
Observed(UG196_6_layer14)
UG200
Head(m)
Modelled(UG200_1_layer29)
Modelled(UG200_2_layer27)
Modelled(UG200_3_layer26)
Modelled(UG200_4_layer22)
Modelled(UG200_5_layer18)
Modelled(UG200_6_layer16)
Modelled(UG200_7_layer14)
Observed(UG200_1_layer29)
Observed(UG200_2_layer27)
Observed(UG200_3_layer26)
Observed(UG200_4_layer22)
Observed(UG200_5_layer18)
Observed(UG200_6_layer16)
Observed(UG200_7_layer14)
UG201
Head(m)
Modelled(UG201_1_layer29)
Modelled(UG201_2_layer27)
Modelled(UG201_3_layer23)
Modelled(UG201_4_layer19)
Modelled(UG201_5_layer17)
Modelled(UG201_6_layer14)
Modelled(UG201_7_layer2)
Observed(UG201_1_layer29)
Observed(UG201_2_layer27)
Observed(UG201_3_layer23)
Observed(UG201_4_layer19)
Observed(UG201_5_layer17)
Observed(UG201_6_layer14)
Observed(UG201_7_layer2)
UG220
Head(m)
Modelled(UG220_1_layer27)
Modelled(UG220_2_layer25)
Modelled(UG220_3_layer23)
Modelled(UG220_4_layer22)
Modelled(UG220_5_layer21)
Modelled(UG220_6_layer17)
Modelled(UG220_7_layer16)
Observed(UG220_1_layer27)
Observed(UG220_2_layer25)
Observed(UG220_3_layer23)
Observed(UG220_4_layer22)
Observed(UG220_5_layer21)
Observed(UG220_6_layer17)
Observed(UG220_7_layer16)
UG224
Head(m)
Modelled(UG224_1_layer27)
Modelled(UG224_2_layer26)
Modelled(UG224_3_layer24)
Modelled(UG224_4_layer22)
Modelled(UG224_5_layer20)
Modelled(UG224_6_layer2)
Observed(UG224_1_layer27)
Observed(UG224_2_layer26)
Observed(UG224_3_layer24)
Observed(UG224_4_layer22)
Observed(UG224_5_layer20)
Observed(UG224_6_layer2)
UG225
Head(m)
Modelled(UG225_1_layer27)
Modelled(UG225_2_layer25)
Modelled(UG225_3_layer22)
Modelled(UG225_4_layer21)
Modelled(UG225_5_layer17)
Observed(UG225_1_layer27)
Observed(UG225_2_layer25)
Observed(UG225_3_layer22)
Observed(UG225_4_layer21)
Observed(UG225_5_layer17)
2004 2006 2008 2010 2012 2014 2016 2018 2020

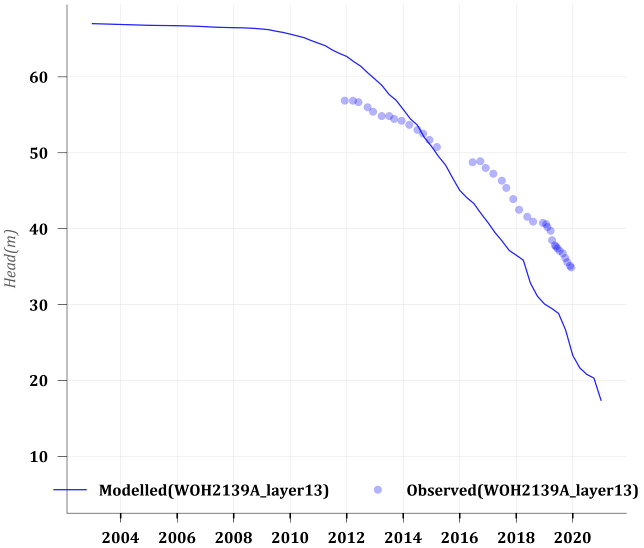
WD622P



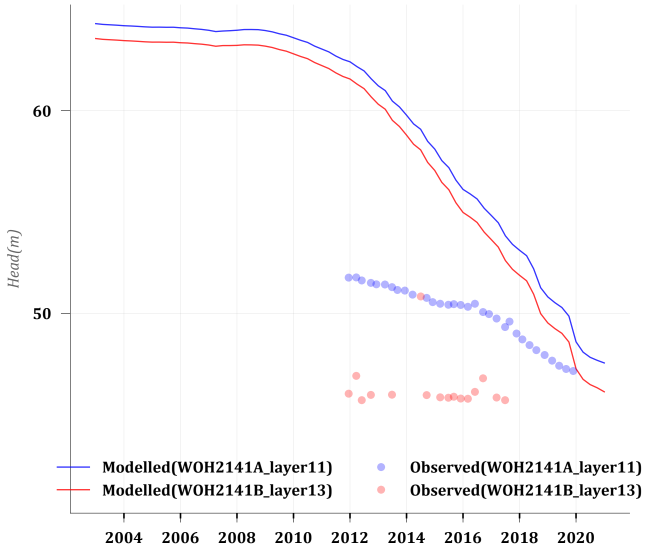
WD625P



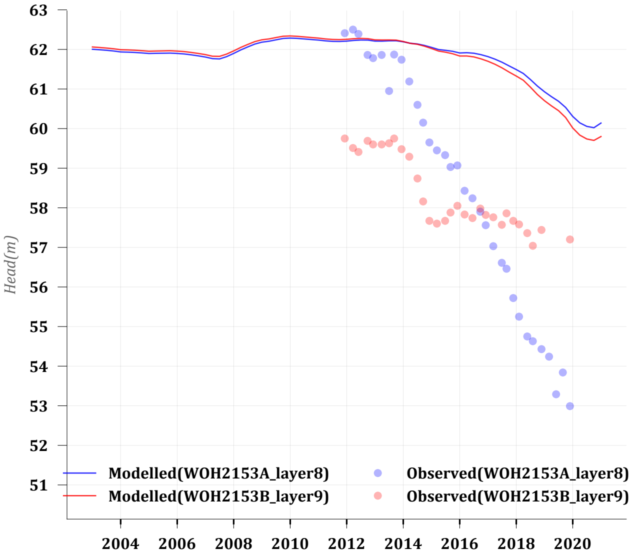
WOH2139A



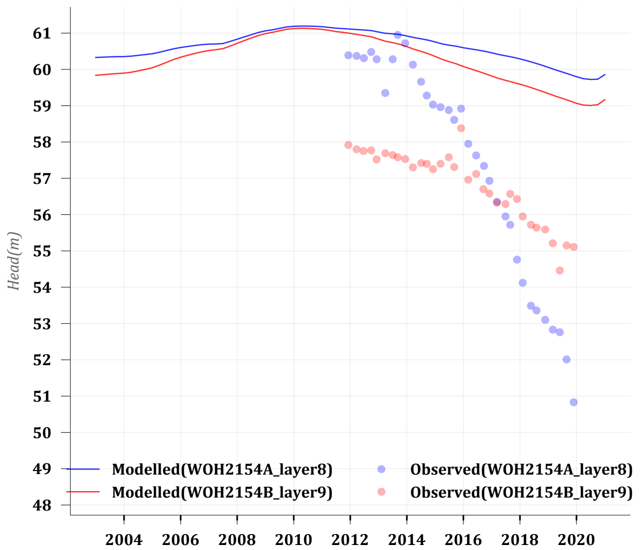
WOH2141

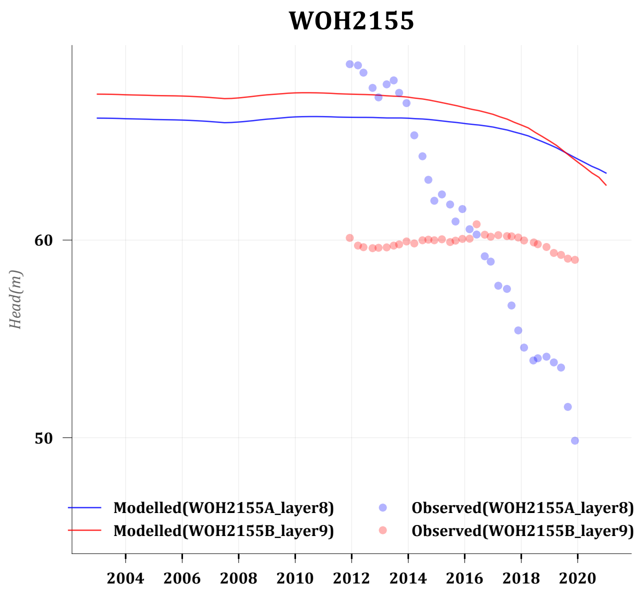


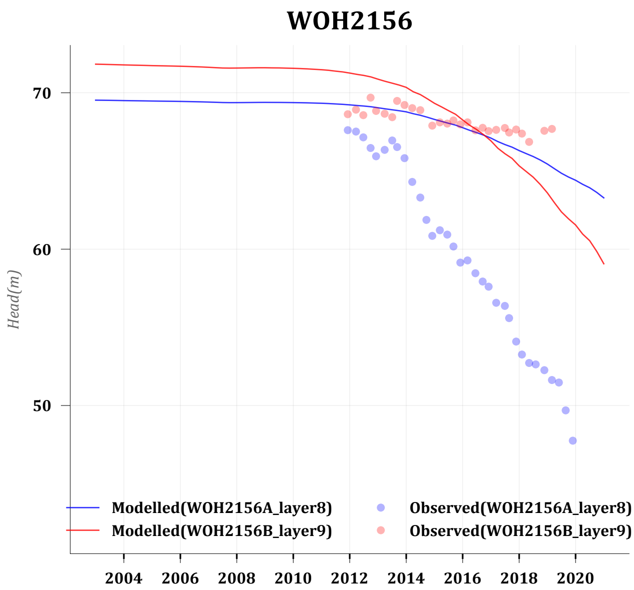
WOH2153



WOH2154

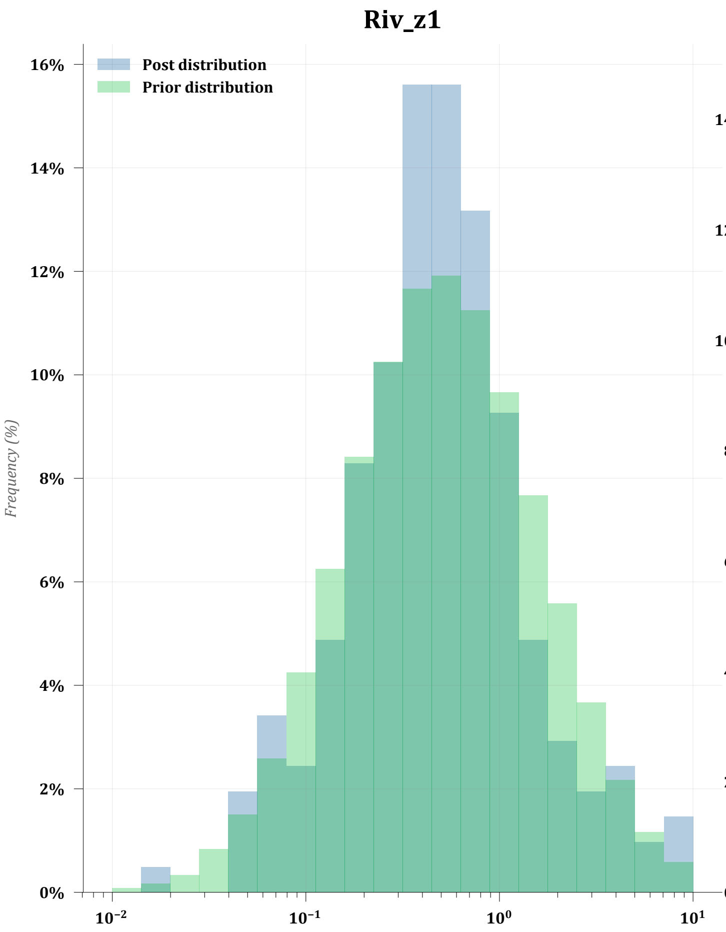


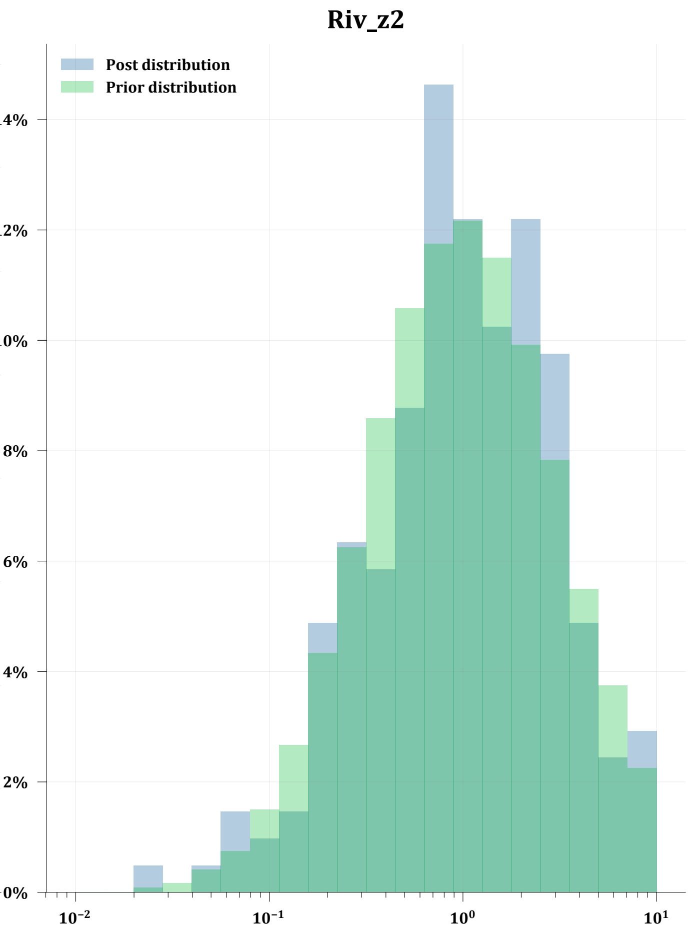

WOH2155
Head(m)
60
50
Modelled(WOH2155A_layer8)
Modelled(WOH2155B_layer9)
Observed(WOH2155A_layer8)
Observed(WOH2155B_layer9)
2004
2006
2008
2010
2012
2014
2016
2018
2020

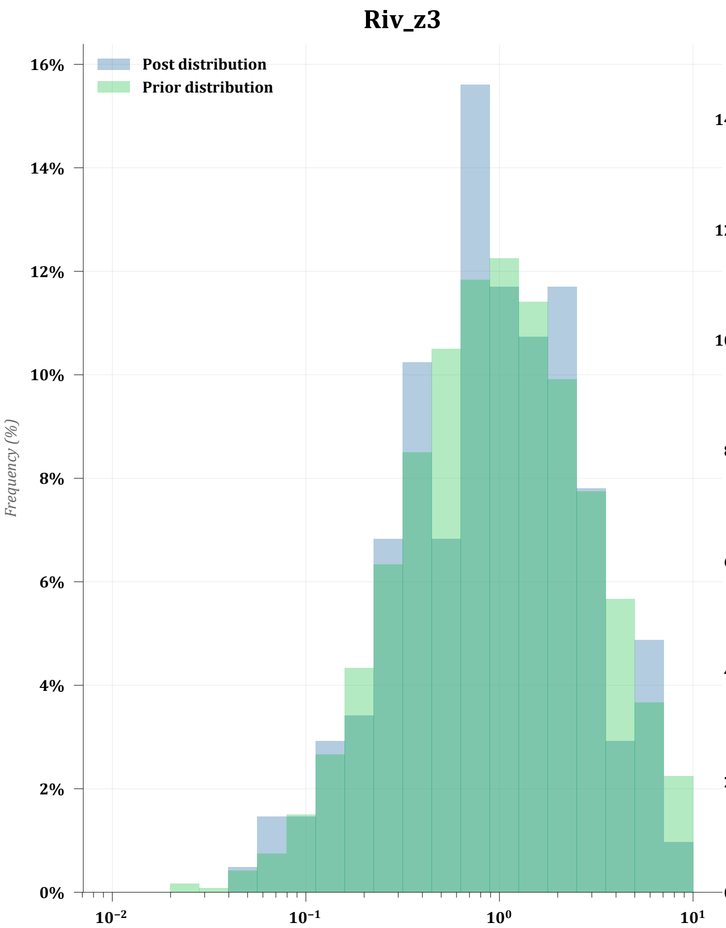

WOH2156
Head(m)
70
60
50
Modelled(WOH2156A_layer8)
Modelled(WOH2156B_layer9)
Observed(WOH2156A_layer8)
Observed(WOH2156B_layer9)
2004
2006
2008
2010
2012
2014
2016
2018
2020

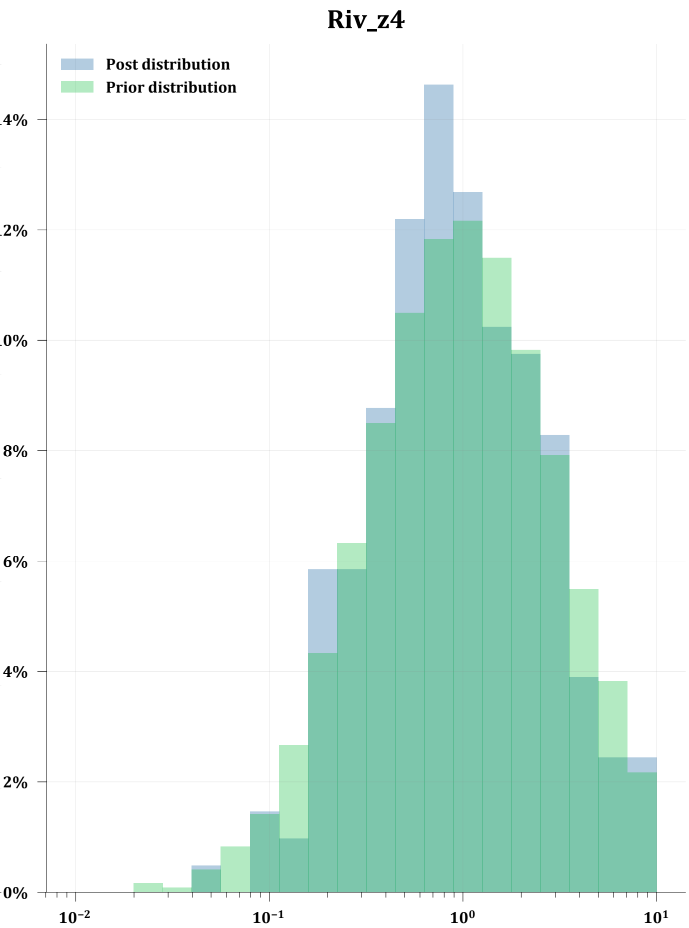
ATTACHMENT C

Uncertainty Analysis Parameter Distributions


Riv_z1
Post distribution
Prior distribution
Frequency (%)
16%
14%
12%
10%
8%
6%
4%
2%
0%
10^{-2}
10^{-1}
10^{0}
10^{1}


Riv_z2
Post distribution
Prior distribution
14%
12%
10%
8%
6%
4%
2%
0%
10^{-2}
10^{-1}
10^{0}
10^{1}


Riv_z3
Post distribution
Prior distribution
Frequency (%)
16%
14%
12%
10%
8%
6%
4%
2%
0%
10^{-2}
10^{-1}
10^{0}
10^{1}


Riv_z4
Post distribution
Prior distribution
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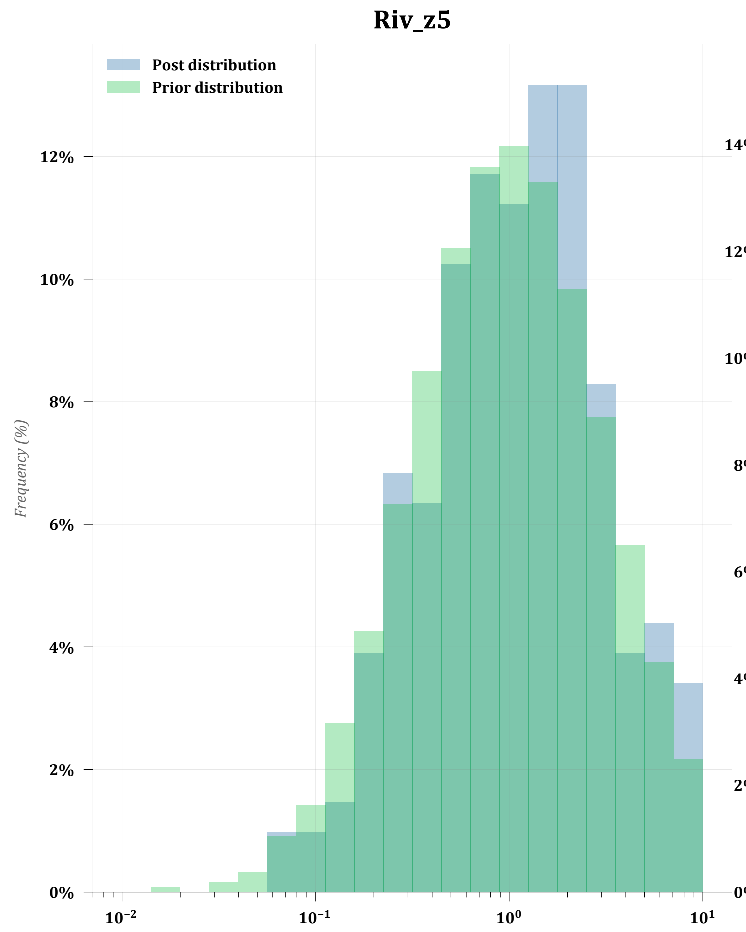
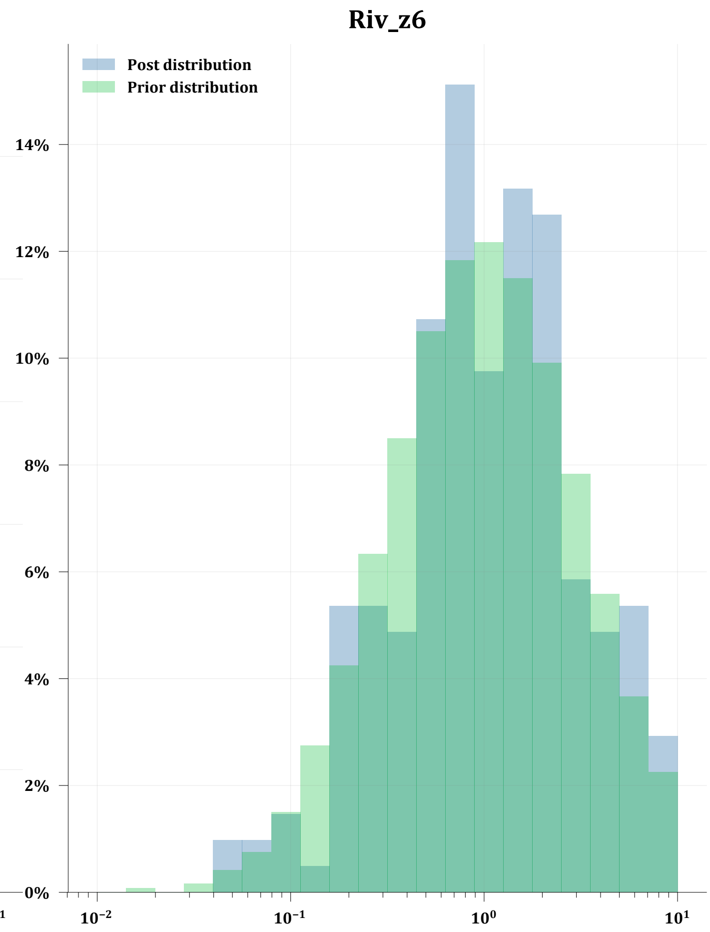
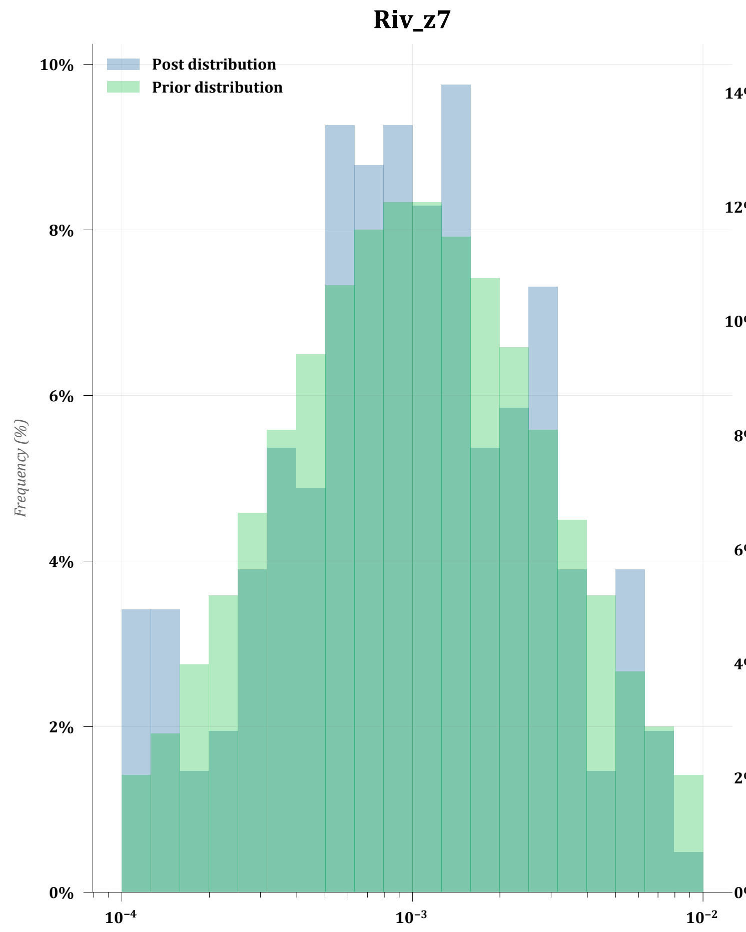
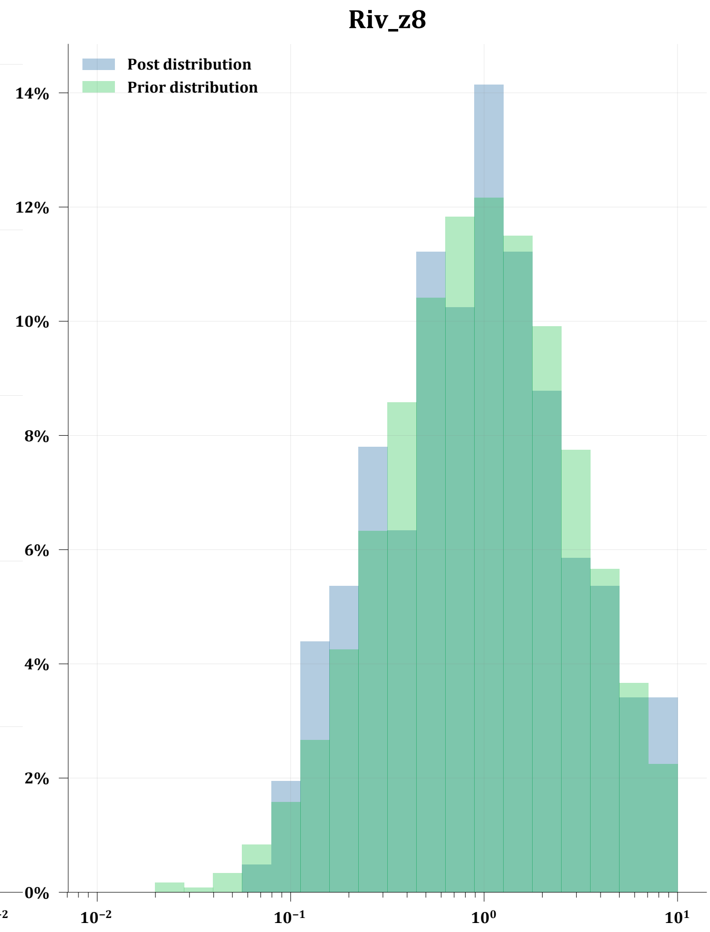
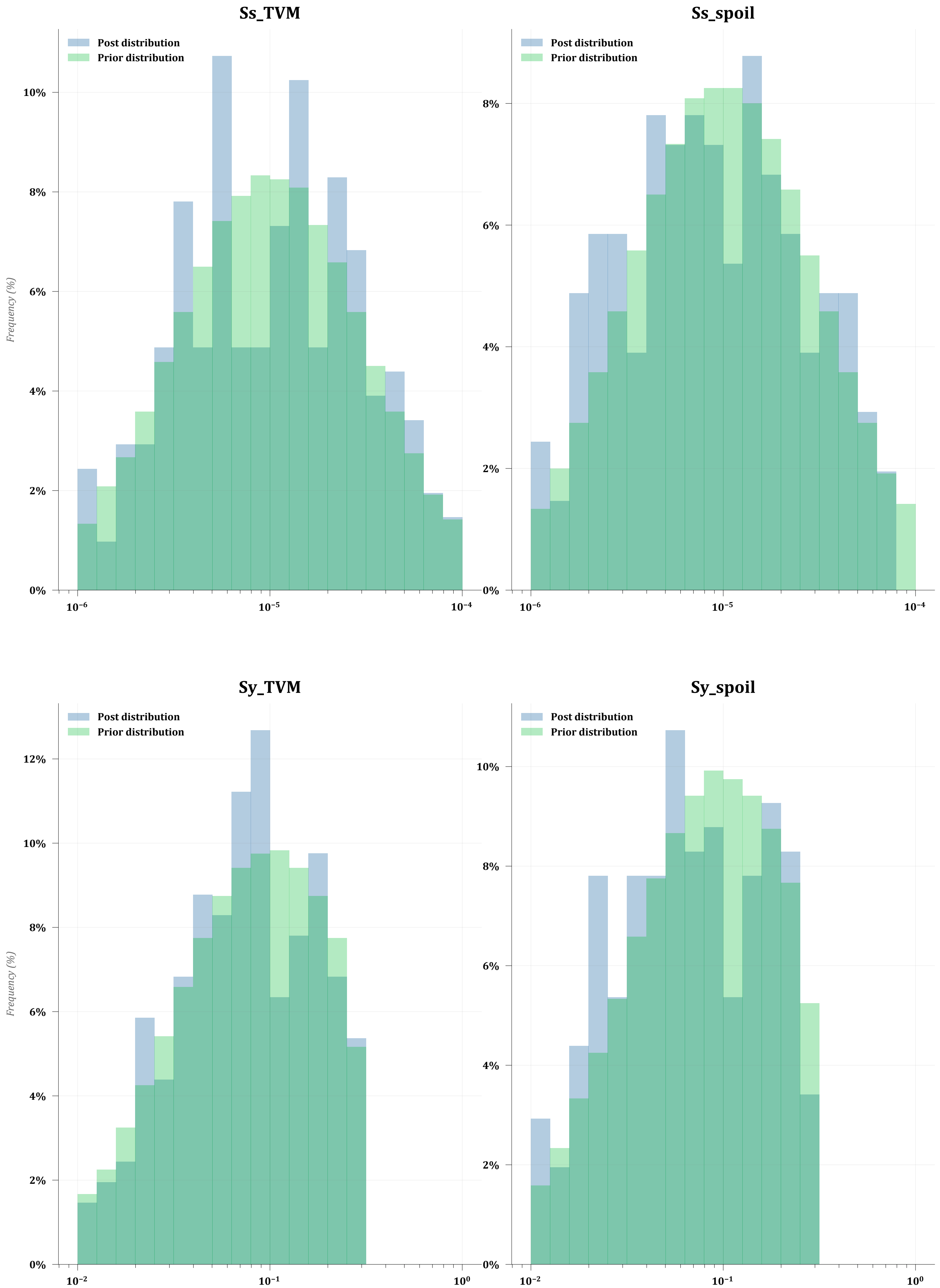
12%
10%
8%
6%
4%
2%
0%
10^{-2}
10^{-1}
10^{0}
10^{1}

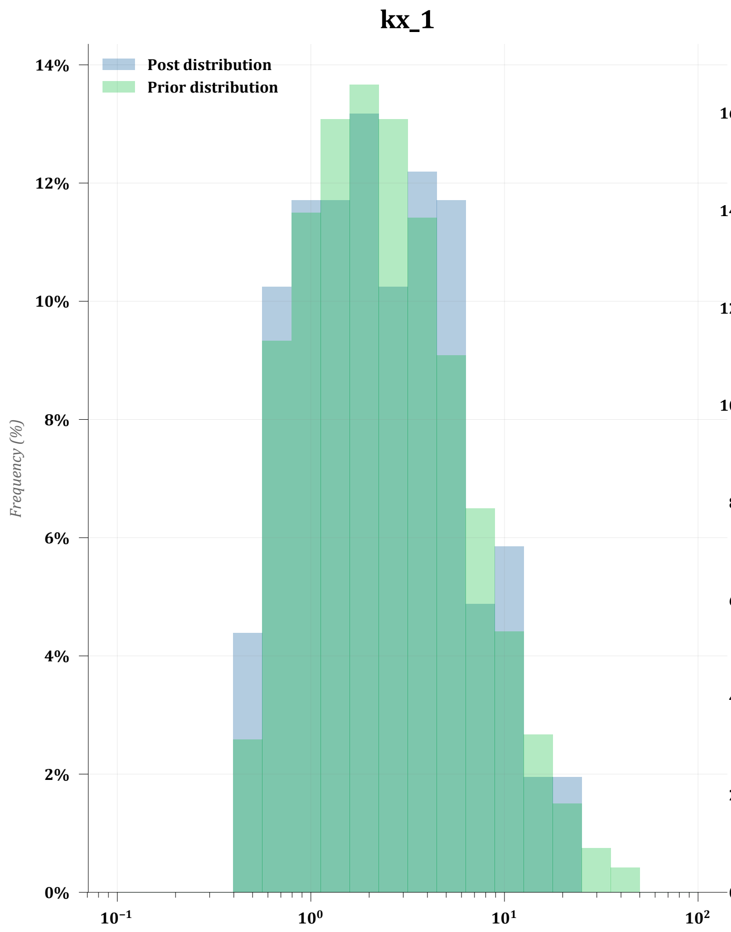

Riv_z5
Post distribution
Prior distribution
Frequency (%)

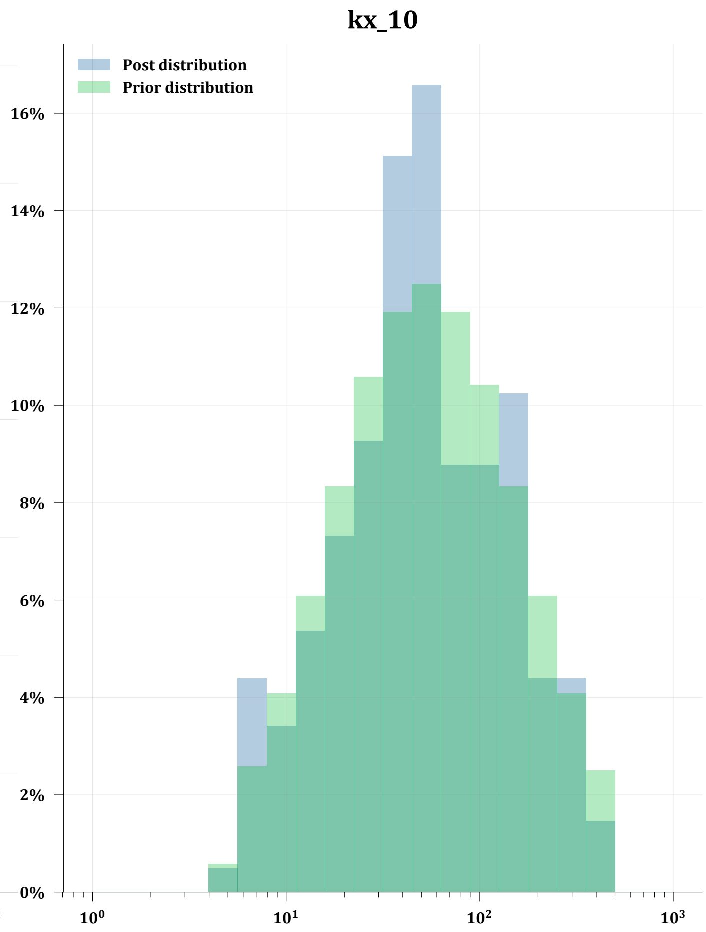

Riv_z6
Post distribution
Prior distribution

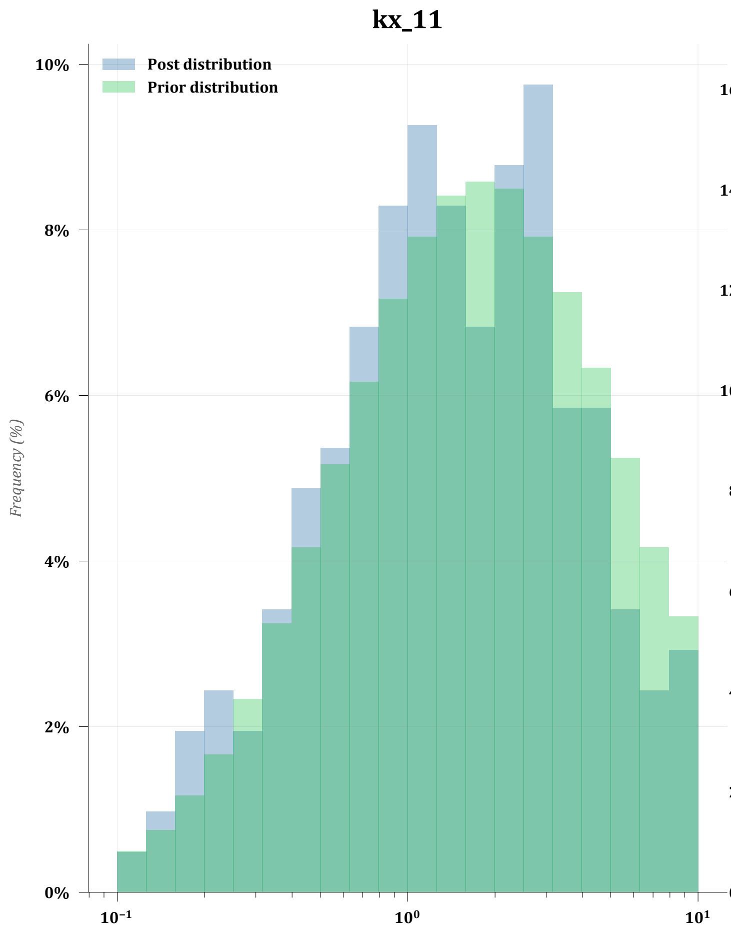

Riv_z7
Post distribution
Prior distribution
Frequency (%)

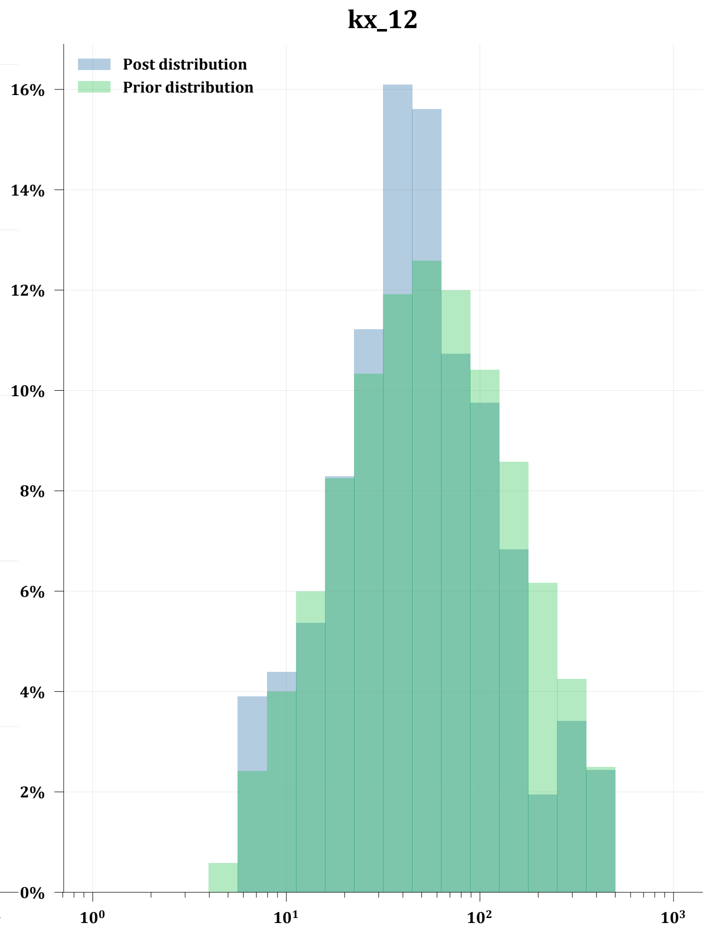

Riv_z8
Post distribution
Prior distribution


Ss_TVM
Ss_spoil
Sy_TVM
Sy_spoil
Post distribution
Prior distribution
Frequency (%)
0%
2%
4%
6%
8%
10%
12%
10^{-6}
10^{-5}
10^{-4}
10^{-2}
10^{-1}
10^{0}

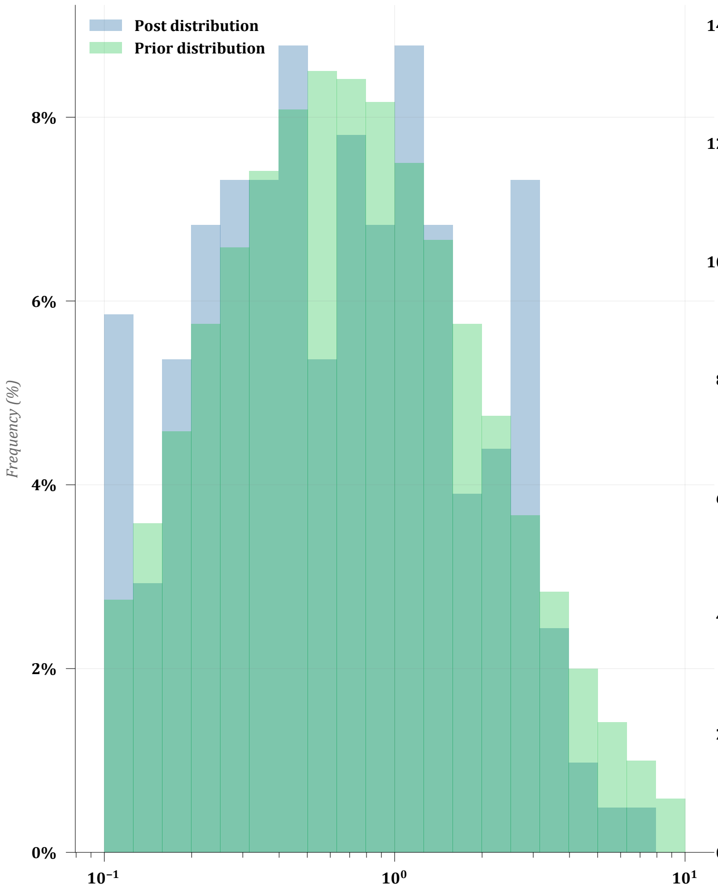

kx_1
Post distribution
Prior distribution
Frequency (%)
14%
12%
10%
8%
6%
4%
2%
0%
10^{-1}
10^{0}
10^{1}
10^{2}


kx_10
Post distribution
Prior distribution
16%
14%
12%
10%
8%
6%
4%
2%
0%
10^{0}
10^{1}
10^{2}
10^{3}

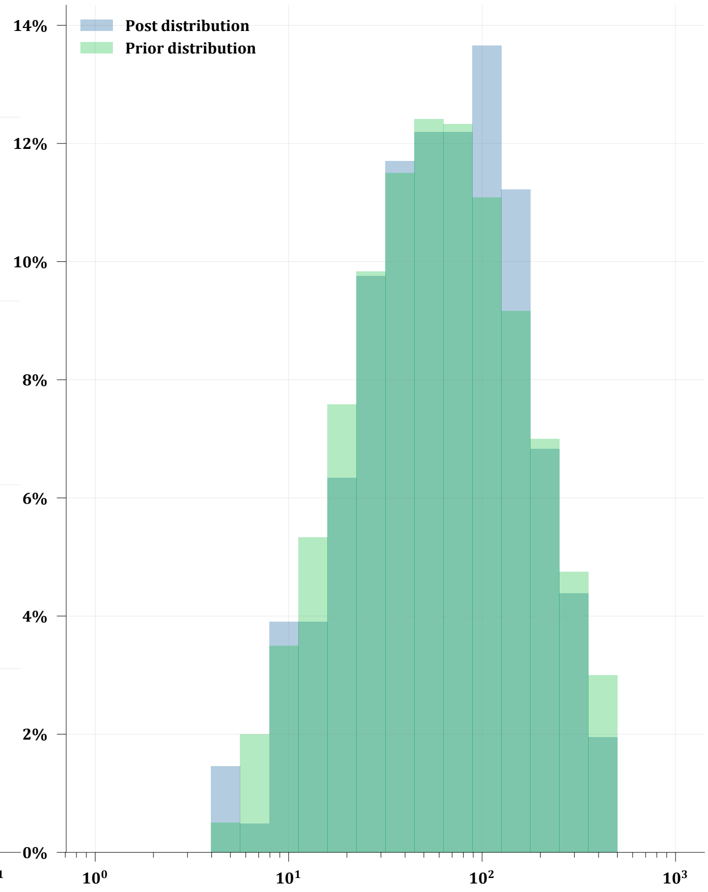

kx_11
Post distribution
Prior distribution
Frequency (%)
10%
8%
6%
4%
2%
0%
10^{-1}
10^{0}
10^{1}


kx_12
Post distribution
Prior distribution
16%
14%
12%
10%
8%
6%
4%
2%
0%
10^{0}
10^{1}
10^{2}
10^{3}

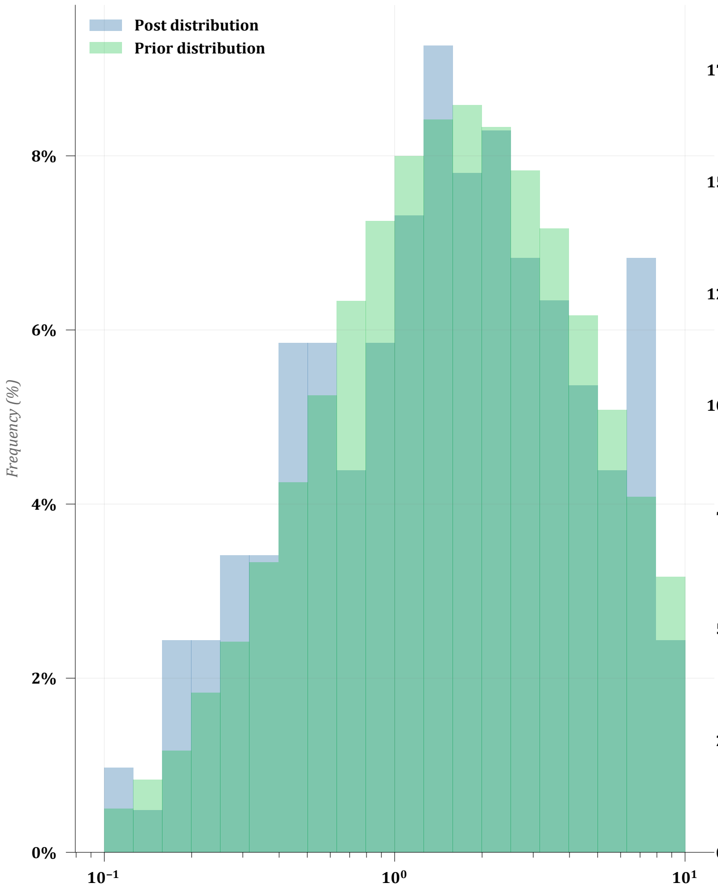
kx_13



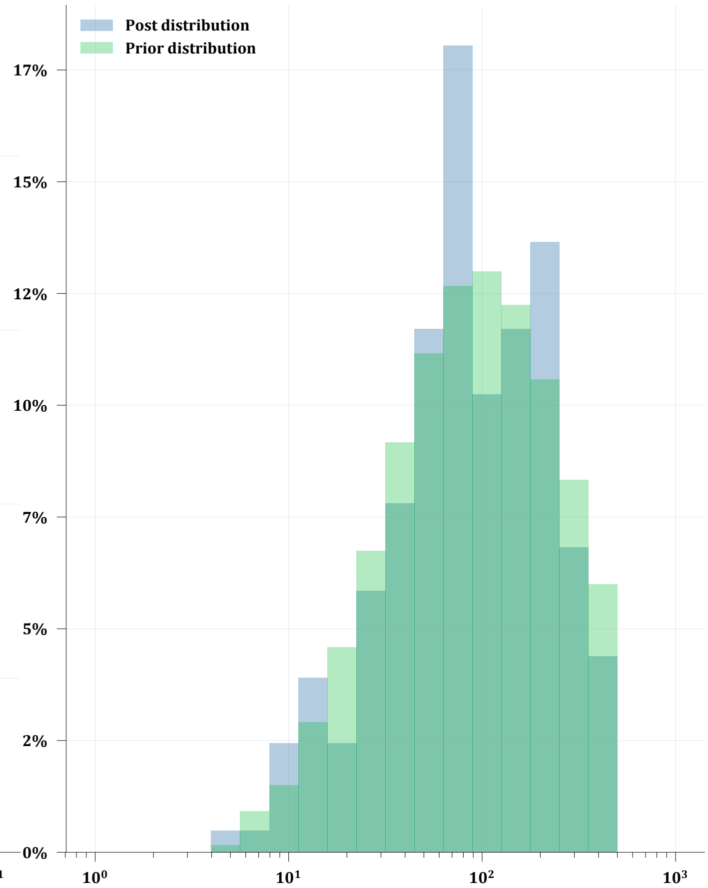
kx_14

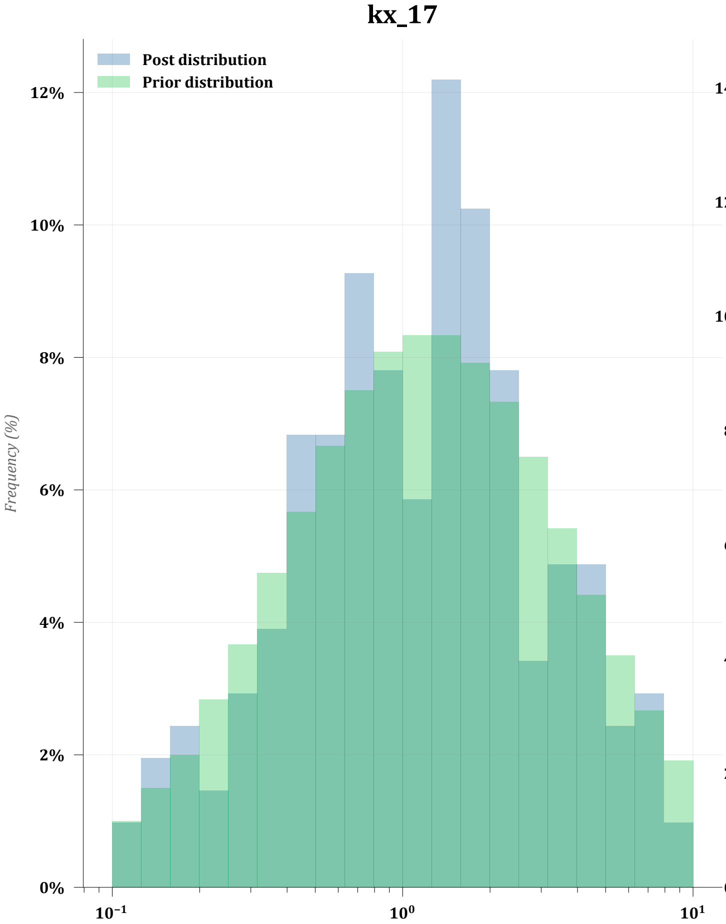


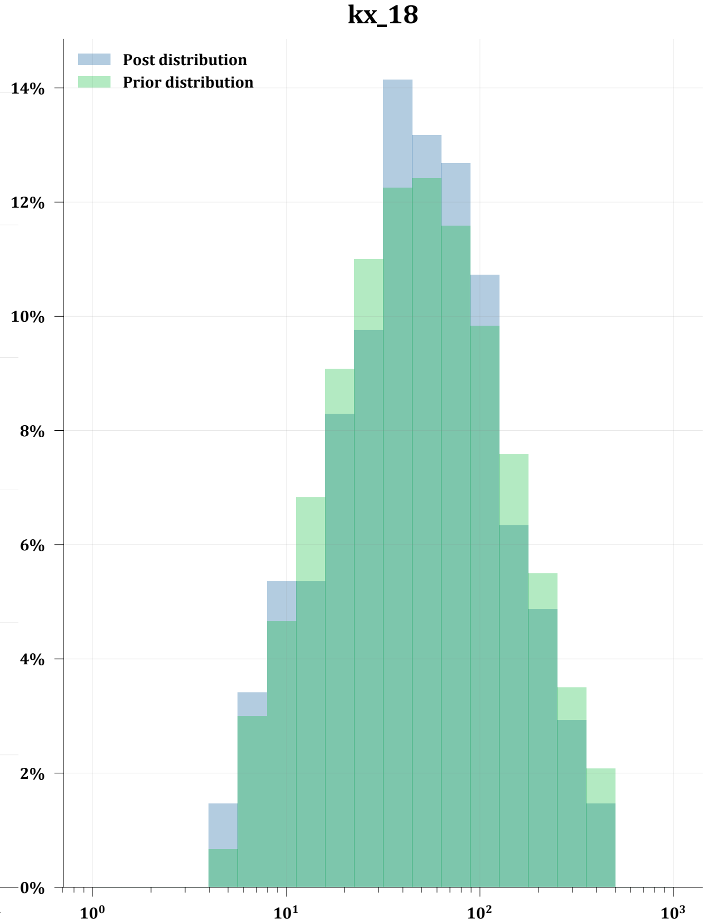
kx_15

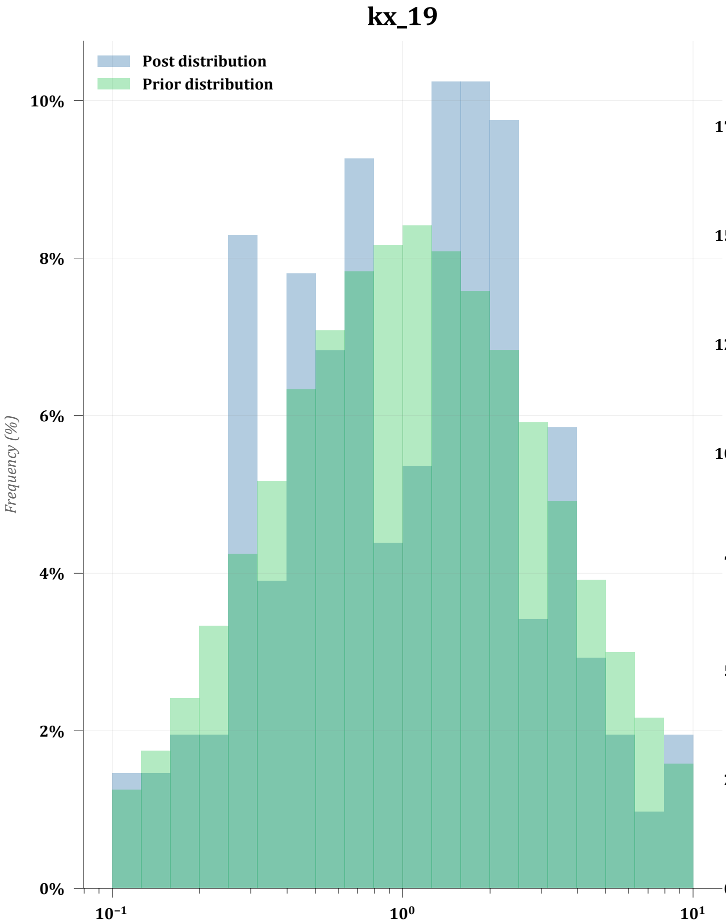


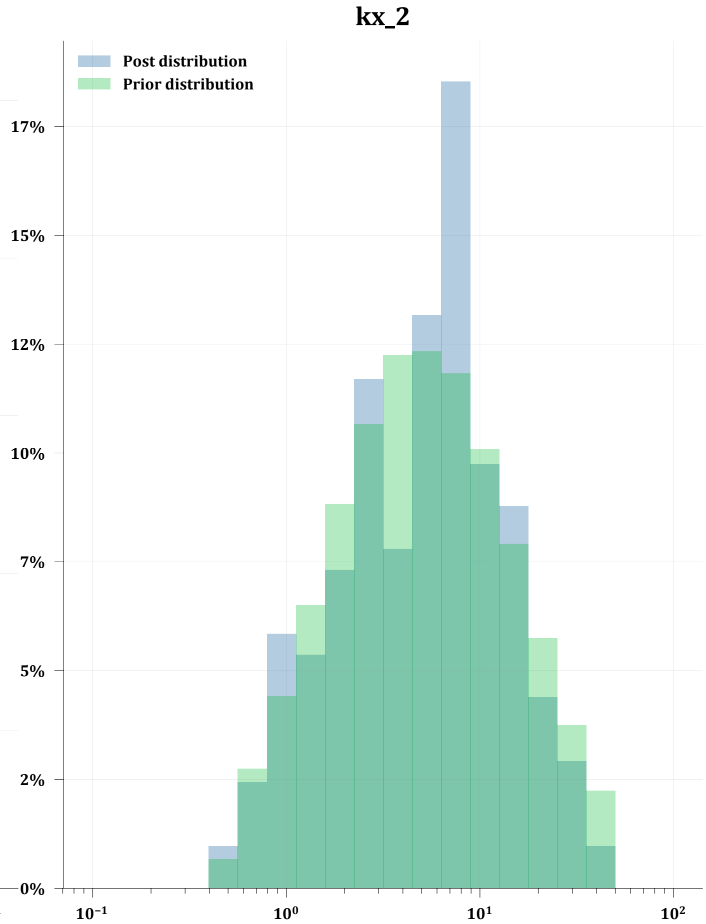
kx_16

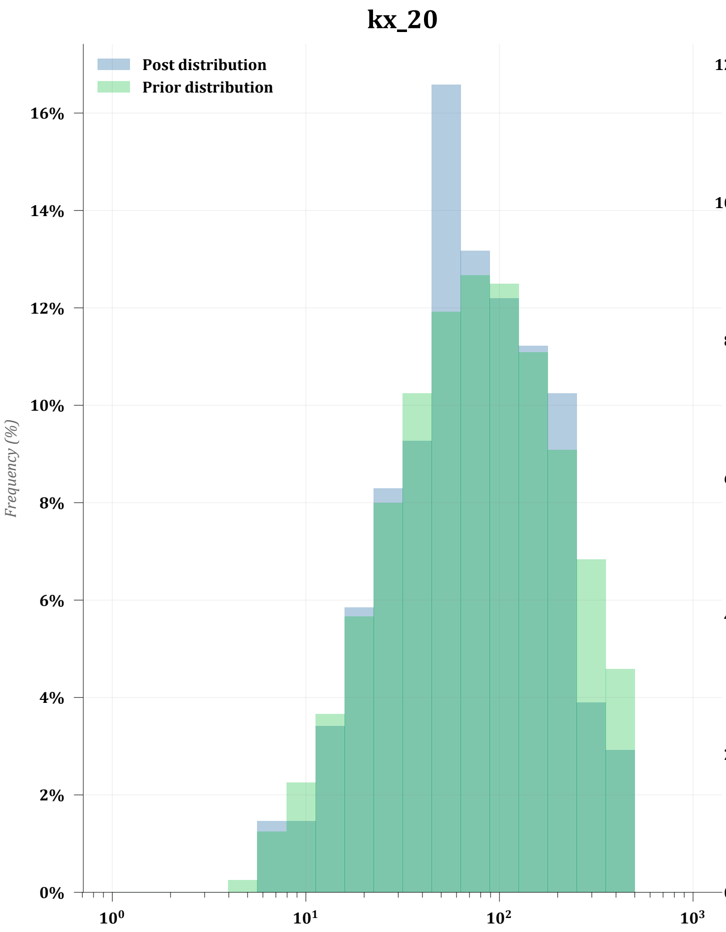


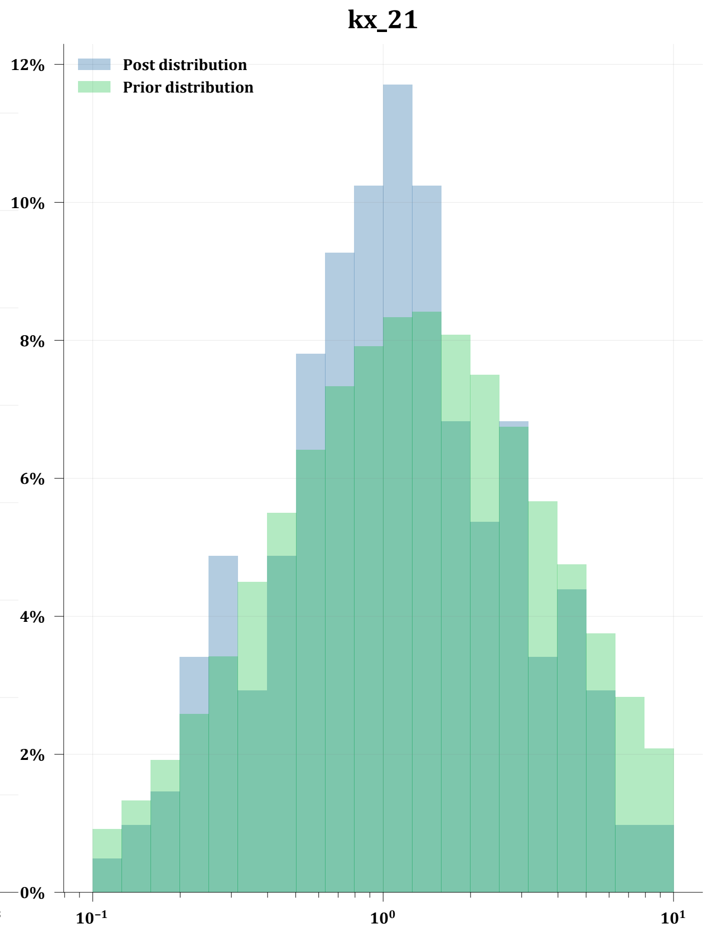

kx_17
Post distribution
Prior distribution
Frequency (%)
0%
2%
4%
6%
8%
10%
12%
10^{-1}
10^{0}
10^{1}

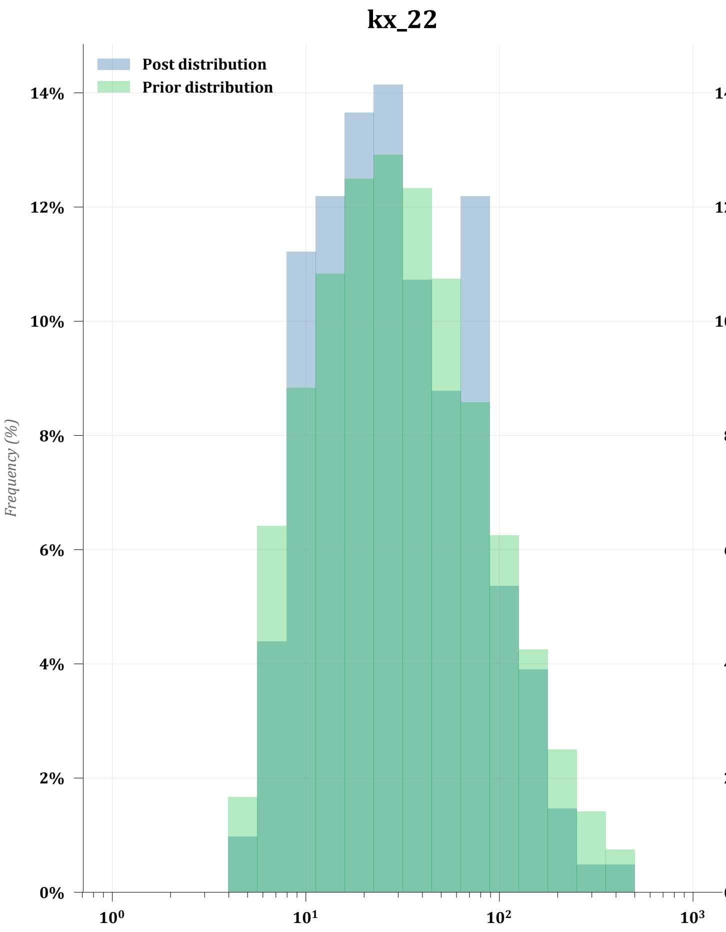

kx_18
Post distribution
Prior distribution
0%
2%
4%
6%
8%
10%
12%
14%
10^{0}
10^{1}
10^{2}
10^{3}

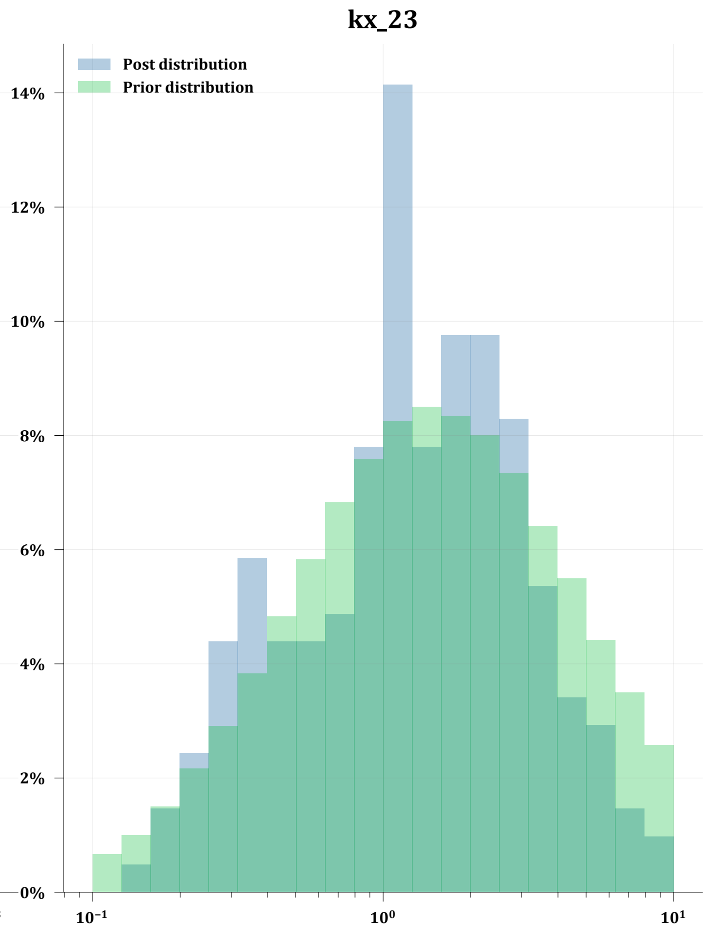

kx_19
Post distribution
Prior distribution
Frequency (%)
0%
2%
4%
6%
8%
10%
10^{-1}
10^{0}
10^{1}

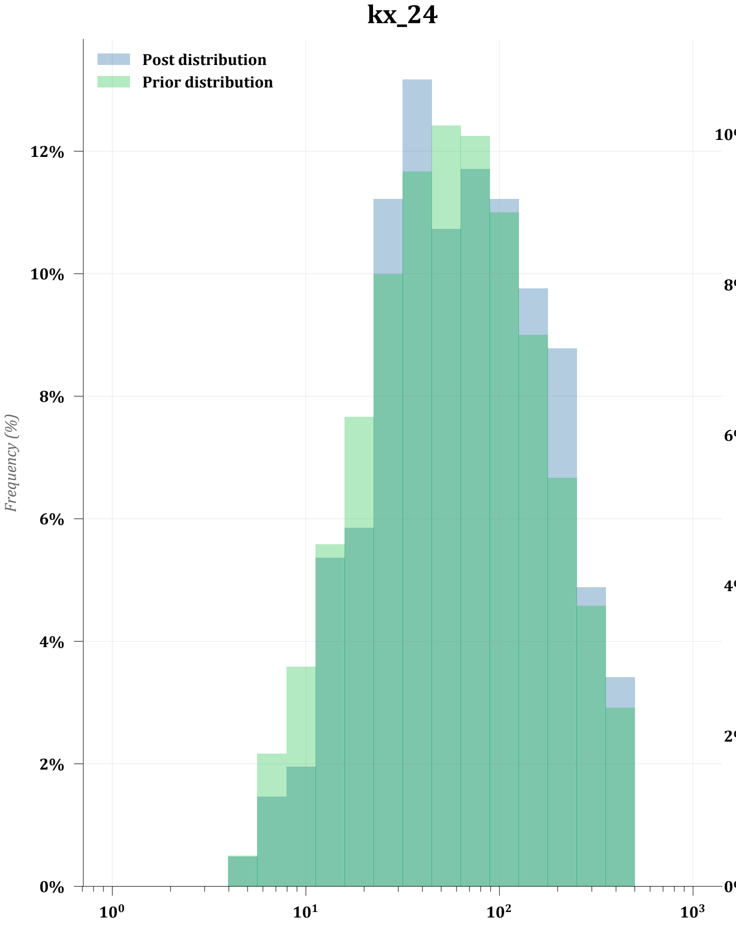

kx_2
Post distribution
Prior distribution
0%
2%
5%
7%
10%
12%
15%
17%
10^{-1}
10^{0}
10^{1}
10^{2}

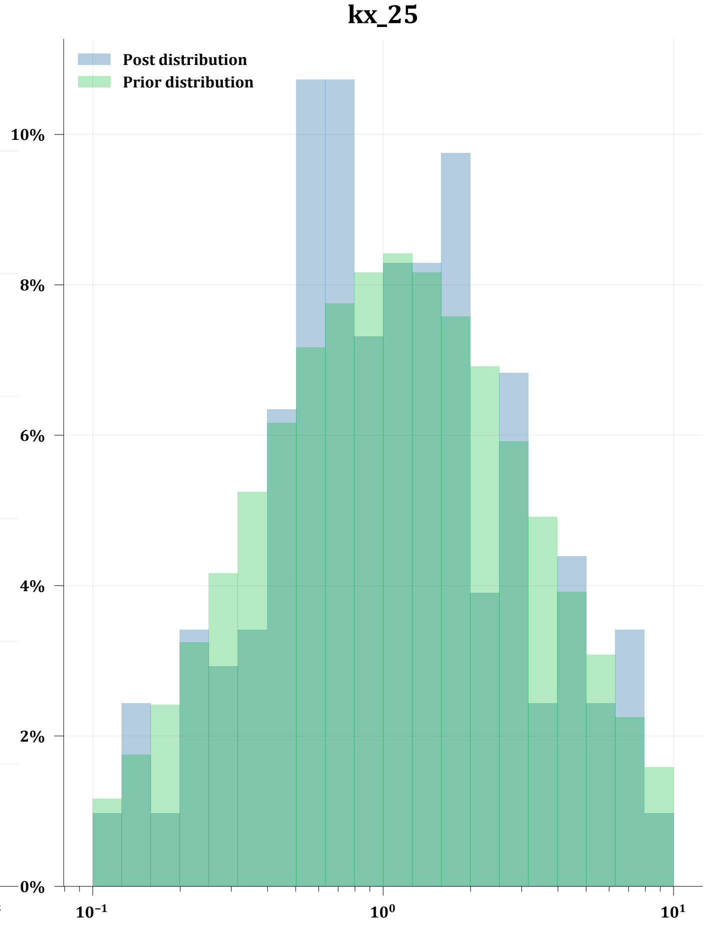

kx_20
Post distribution
Prior distribution
Frequency (%)
16%
14%
12%
10%
8%
6%
4%
2%
0%
10^0
10^1
10^2
10^3

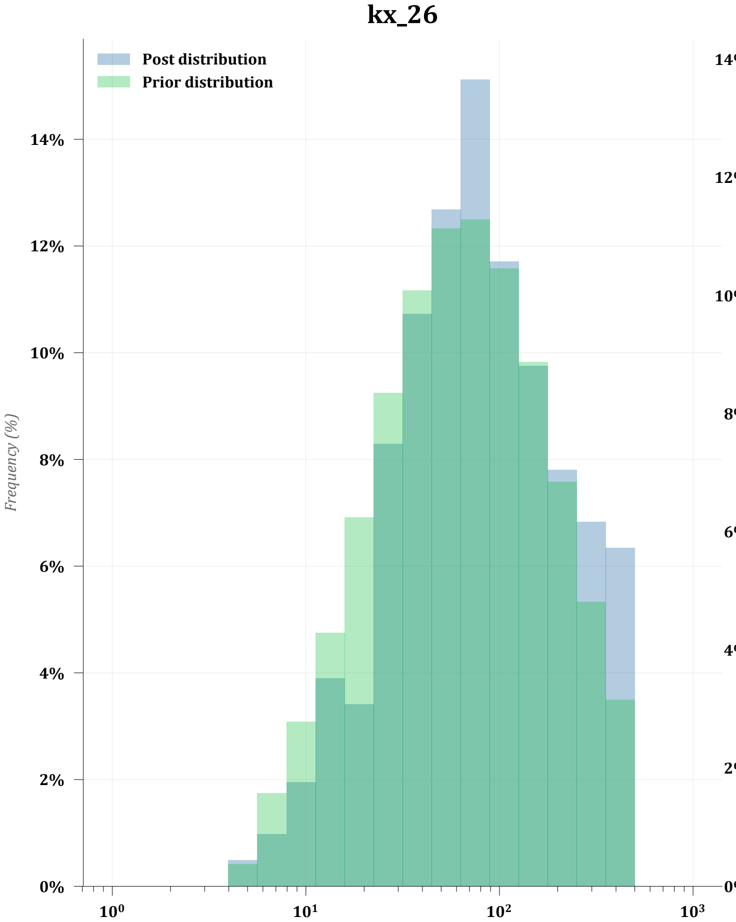

kx_21
Post distribution
Prior distribution
12%
10%
8%
6%
4%
2%
0%
10^{-1}
10^0
10^1


kx_22
Post distribution
Prior distribution
Frequency (%)
14%
12%
10%
8%
6%
4%
2%
0%
10^0
10^1
10^2
10^3


kx_23
Post distribution
Prior distribution
14%
12%
10%
8%
6%
4%
2%
0%
10^{-1}
10^0
10^1


kx_24
Post distribution
Prior distribution
Frequency (%)
0%
2%
4%
6%
8%
10%
12%
10^0
10^1
10^2
10^3


kx_25
Post distribution
Prior distribution
0%
2%
4%
6%
8%
10%
10^{-1}
10^0
10^1


kx_26
Post distribution
Prior distribution
Frequency (%)
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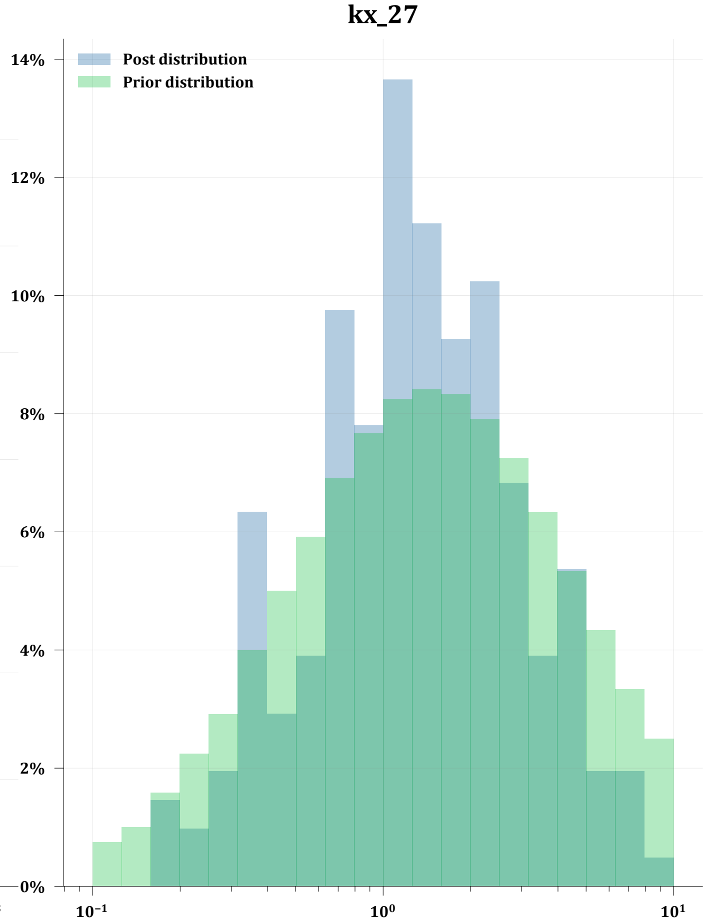
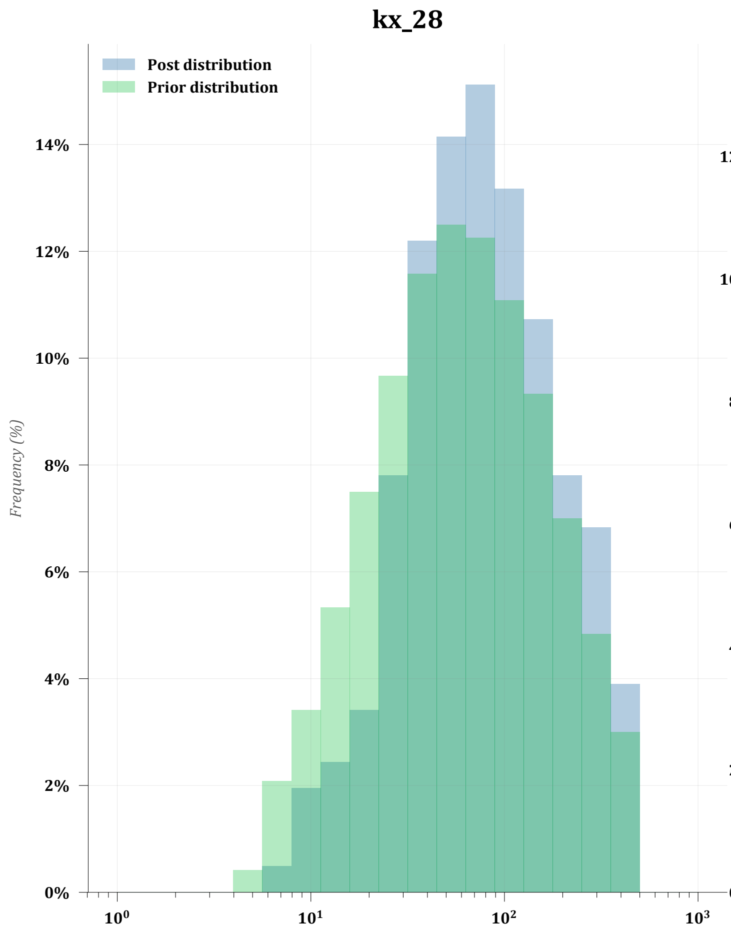
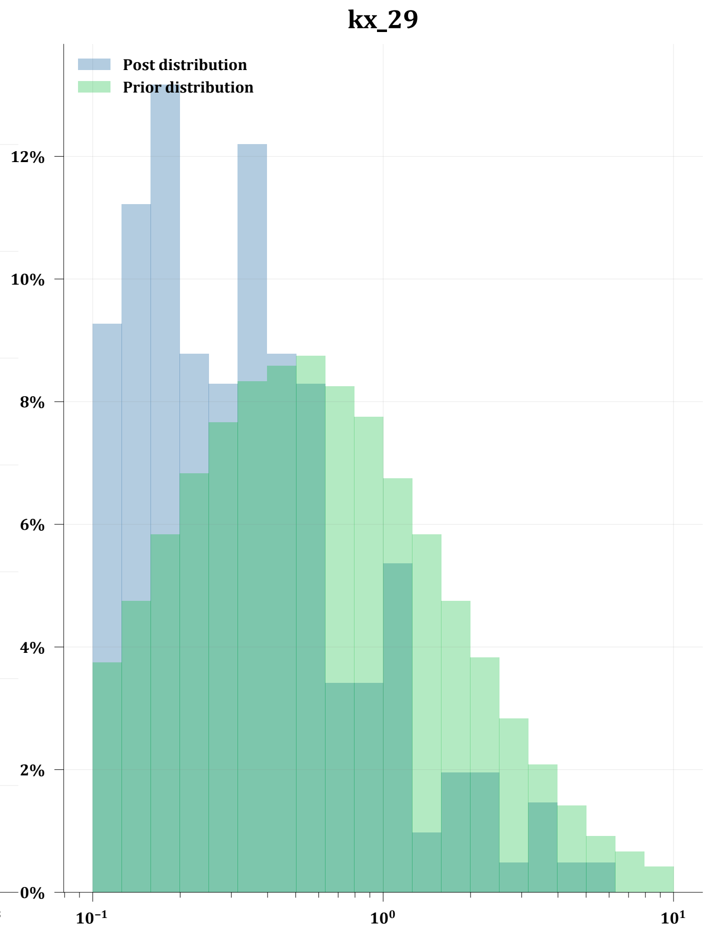
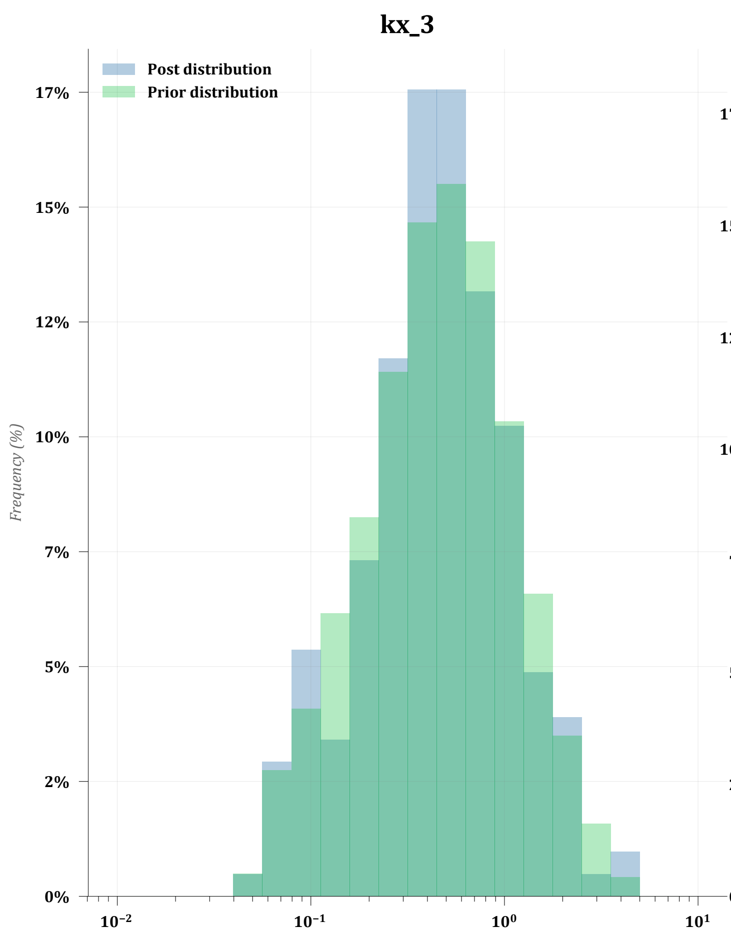
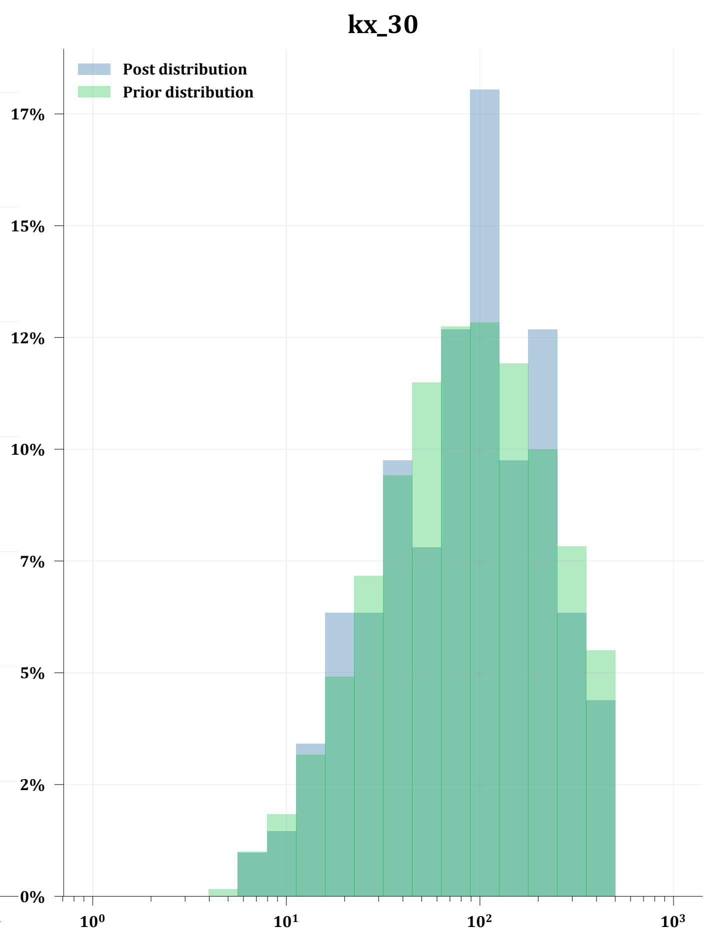
2%
4%
6%
8%
10%
12%
14%
10^0
10^1
10^2
10^3

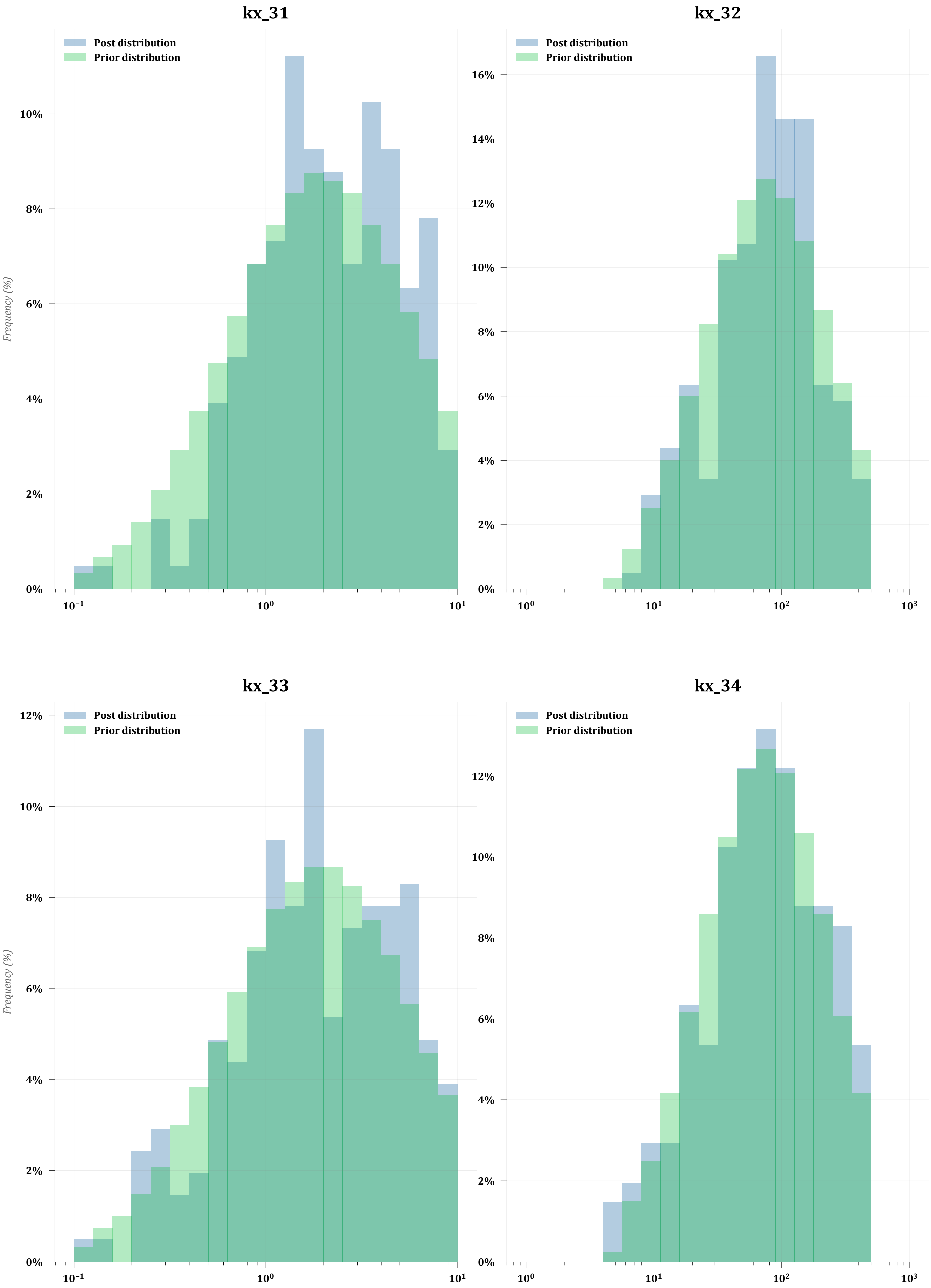

kx_27
Post distribution
Prior distribution
0%
2%
4%
6%
8%
10%
12%
14%
10^{-1}
10^0
10^1


kx_28
Post distribution
Prior distribution
Frequency (%)
14%
12%
10%
8%
6%
4%
2%
0%
10⁰
10¹
10²
10³

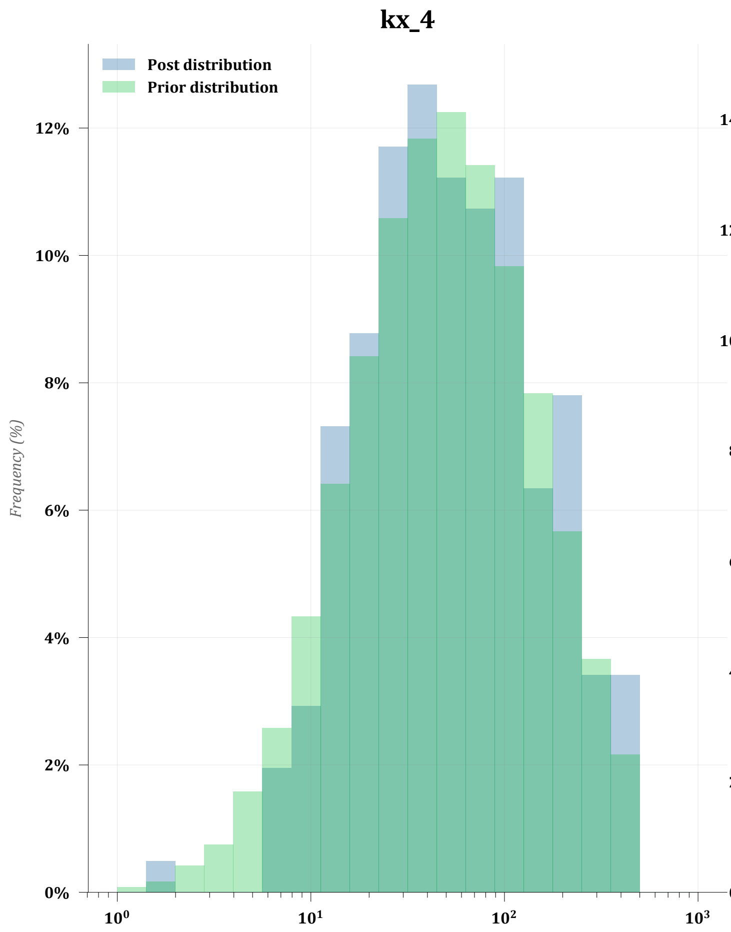

kx_29
Post distribution
Prior distribution
12%
10%
8%
6%
4%
2%
0%
10⁻¹
10⁰
10¹


kx_3
Post distribution
Prior distribution
Frequency (%)
17%
15%
12%
10%
7%
5%
2%
0%
10⁻²
10⁻¹
10⁰
10¹


kx_30
Post distribution
Prior distribution
17%
15%
12%
10%
7%
5%
2%
0%
10⁰
10¹
10²
10³



kx_31
Post distribution
Prior distribution
Frequency (%)
kx_32
Post distribution
Prior distribution
kx_33
Post distribution
Prior distribution
Frequency (%)
kx_34
Post distribution
Prior distribution


kx_4
Post distribution
Prior distribution
Frequency (%)
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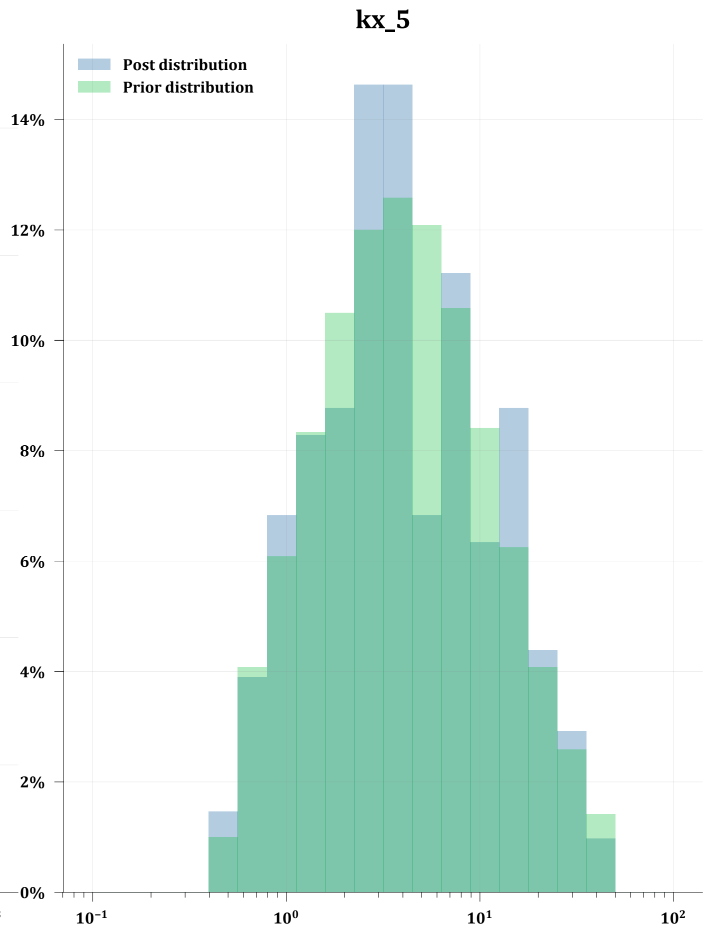
10%
8%
6%
4%
2%
0%
10^0
10^1
10^2
10^3


kx_5
Post distribution
Prior distribution
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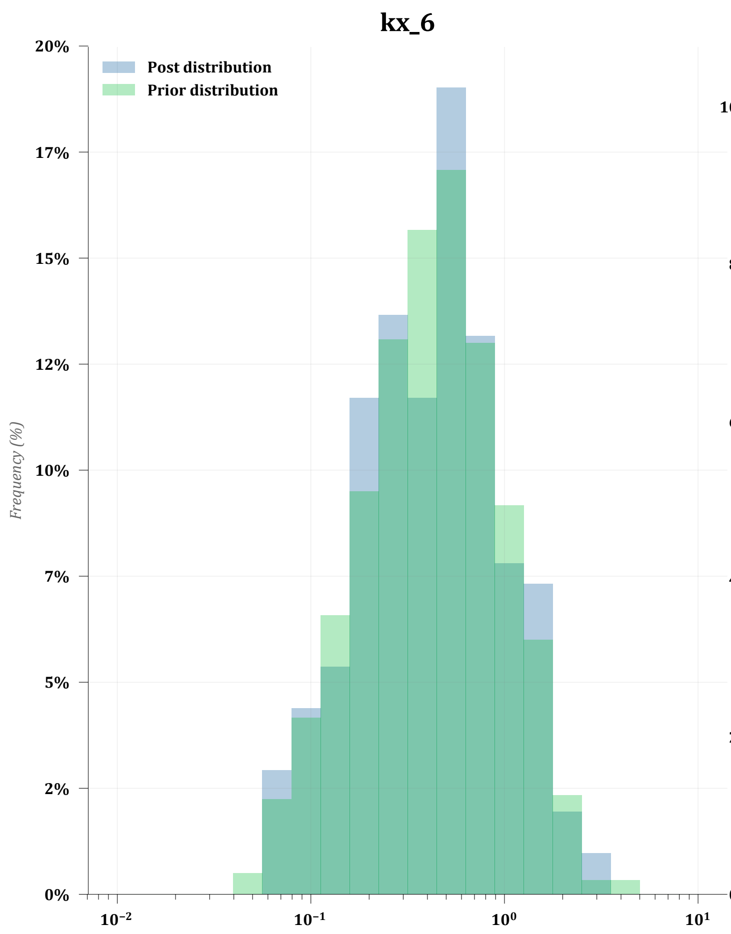
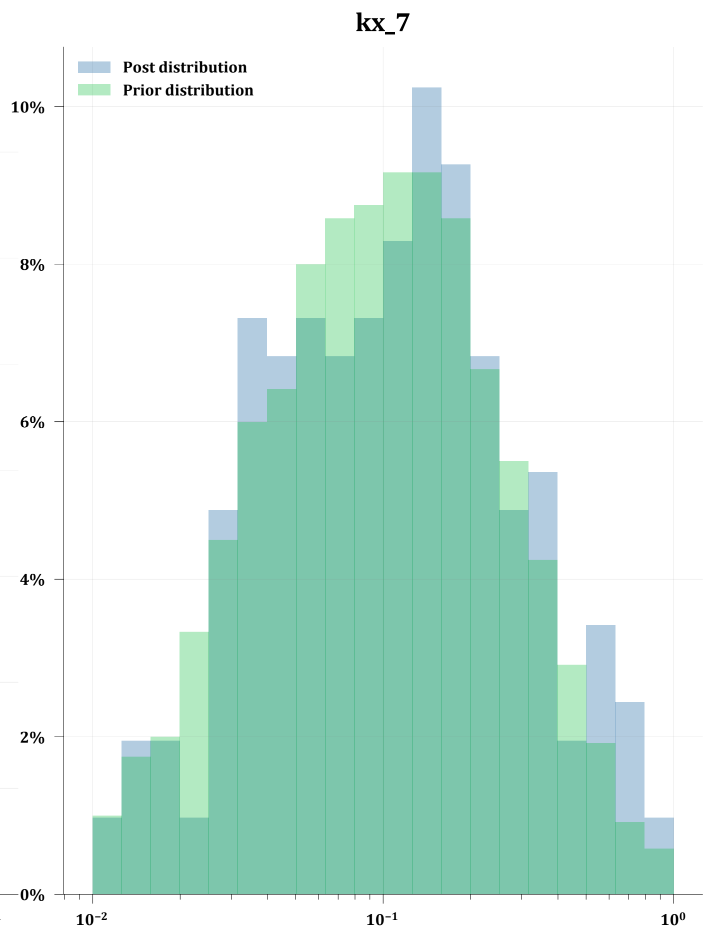
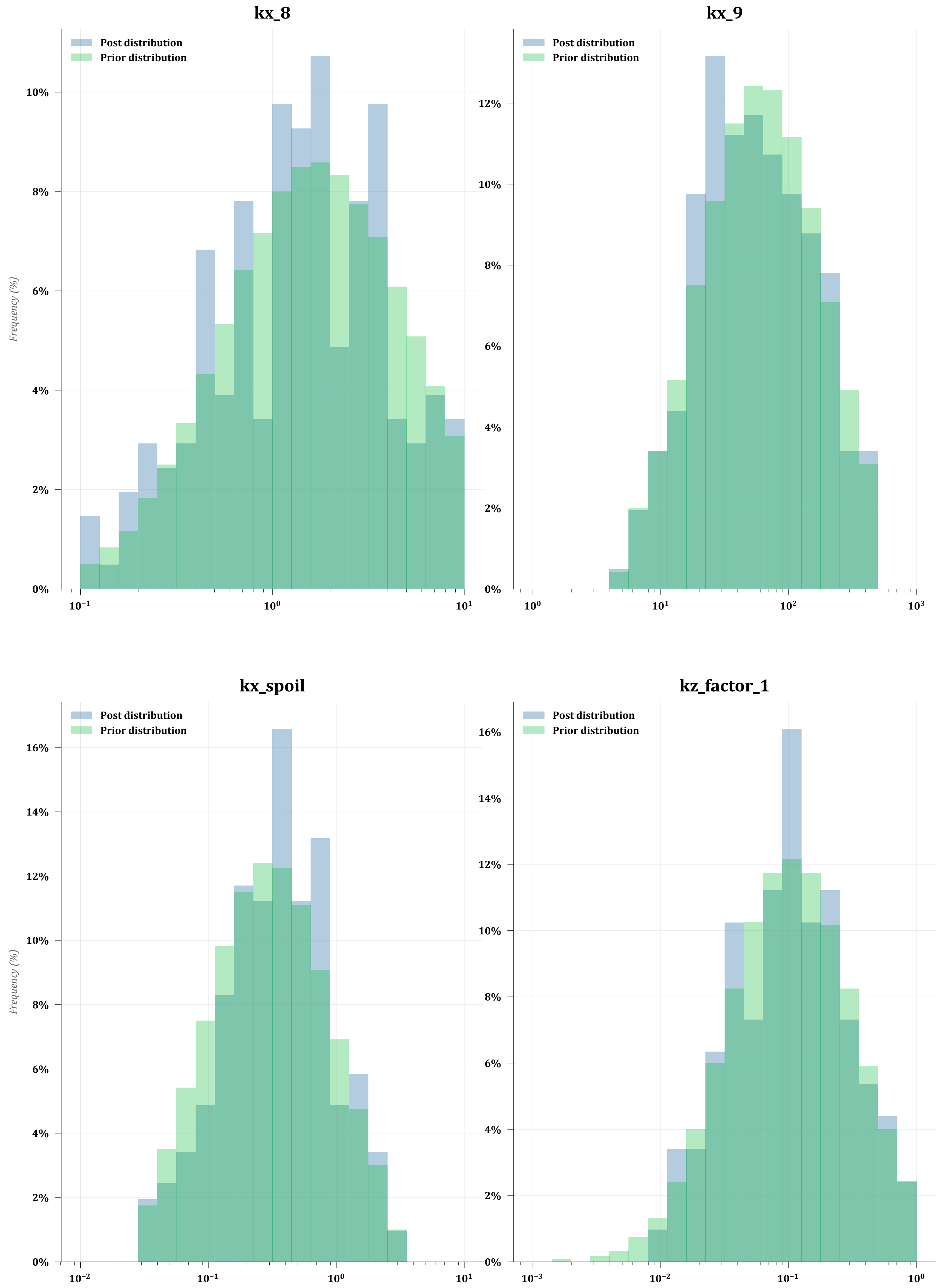
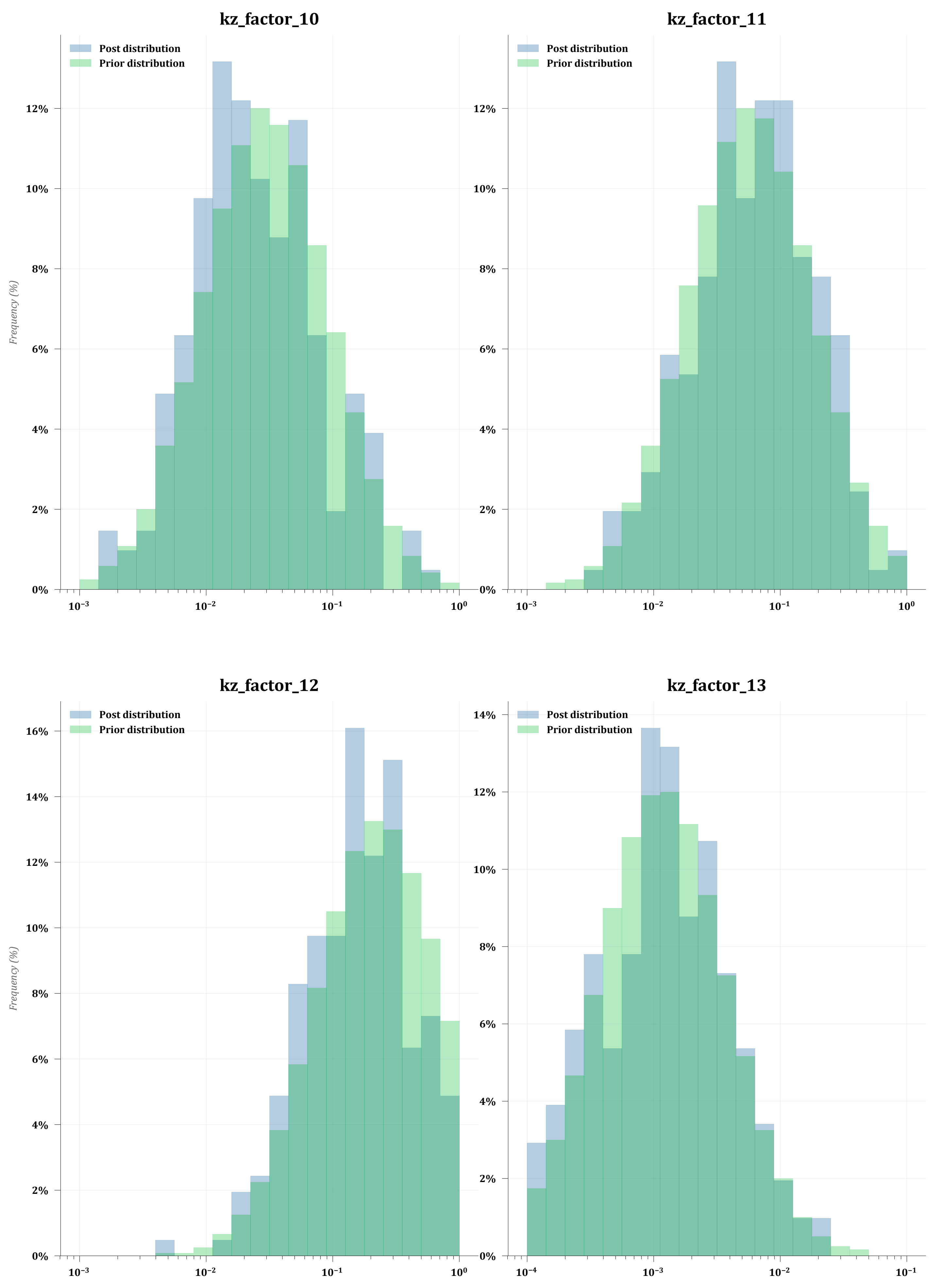
12%
10%
8%
6%
4%
2%
0%
10^{-1}
10^0
10^1
10^2

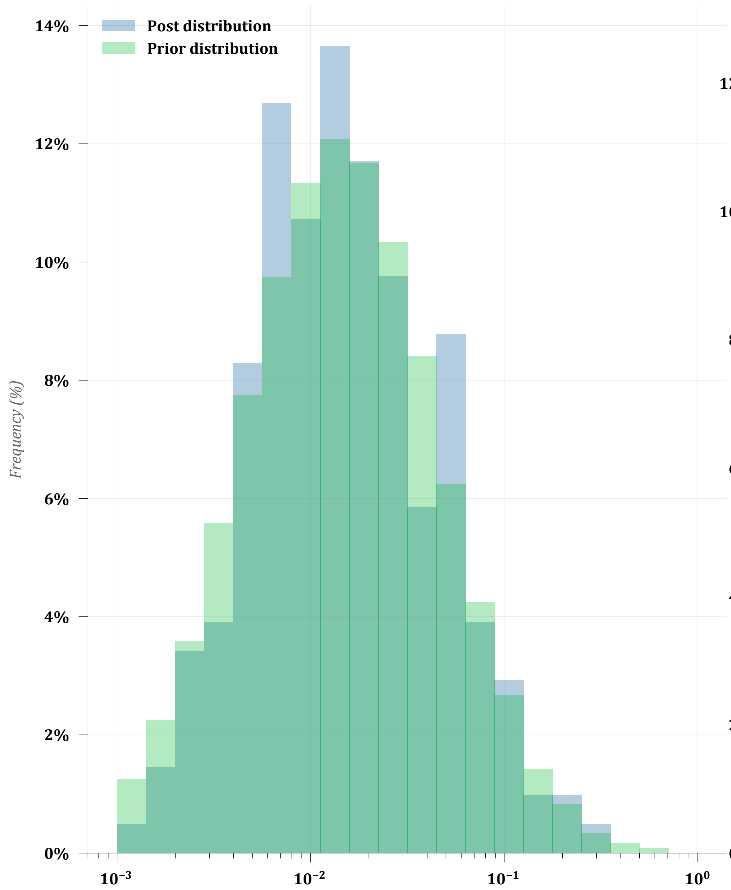

kx_6
Post distribution
Prior distribution
Frequency (%)
20%
17%
15%
12%
10%
7%
5%
2%
0%
10^{-2}
10^{-1}
10^0
10^1


kx_7
Post distribution
Prior distribution
10%
8%
6%
4%
2%
0%
10^{-2}
10^{-1}
10^0

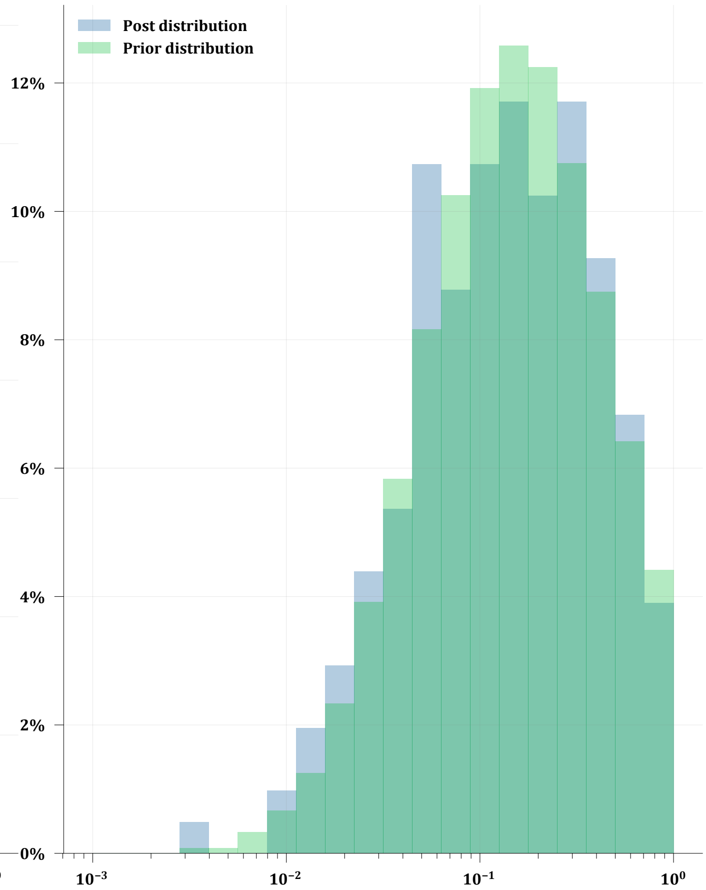

kx_8
Post distribution
Prior distribution
Frequency (%)
kx_9
Post distribution
Prior distribution
kx_spoil
Post distribution
Prior distribution
Frequency (%)
kz_factor_1
Post distribution
Prior distribution


kz_factor_10
kz_factor_11
kz_factor_12
kz_factor_13
Post distribution
Prior distribution
Frequency (%)

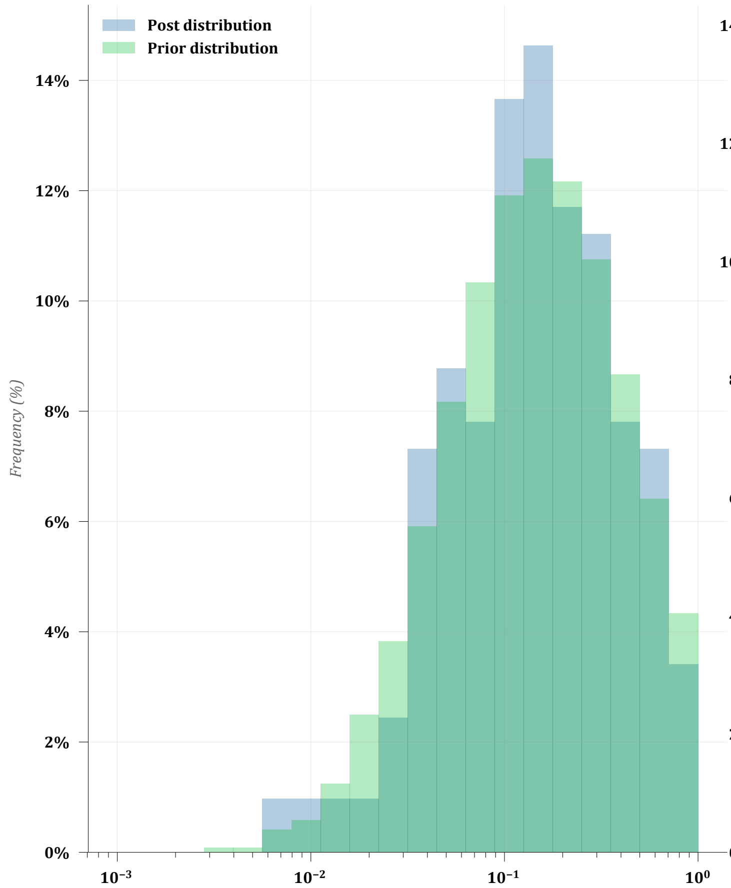
kz_factor_14



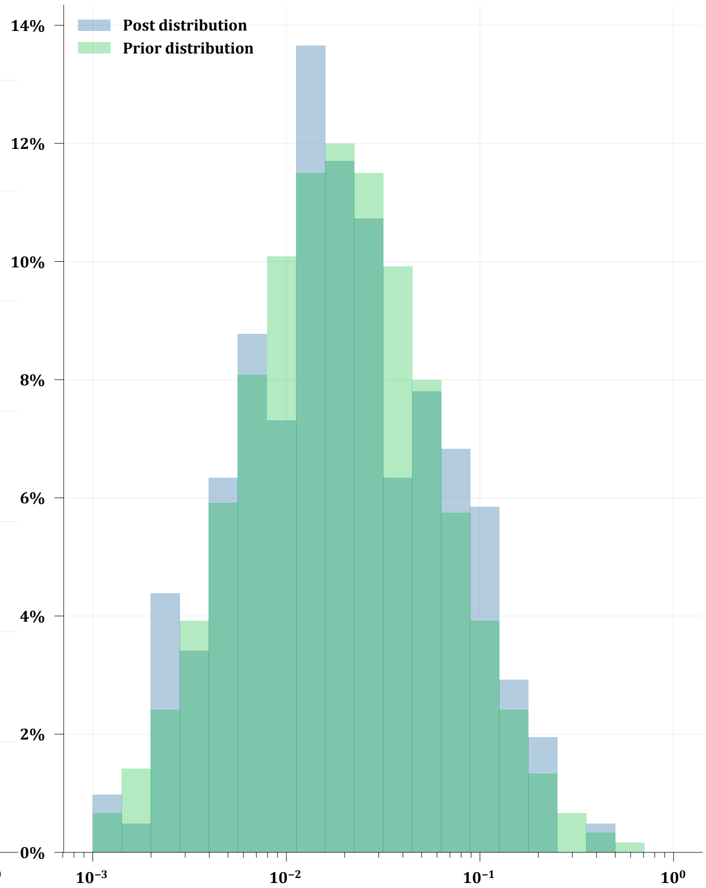
kz_factor_15

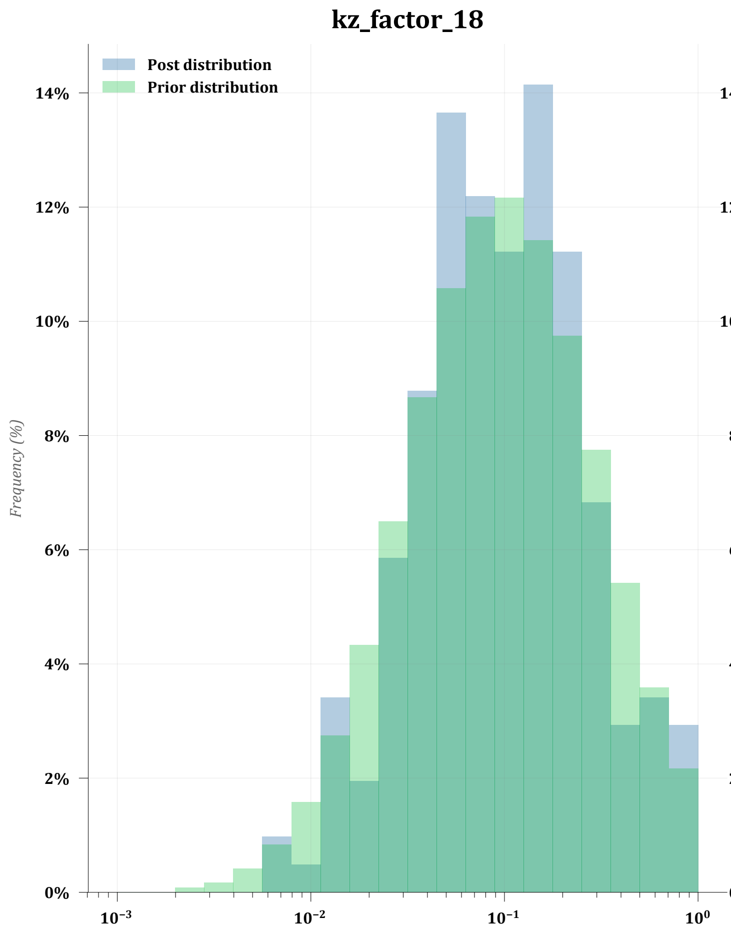


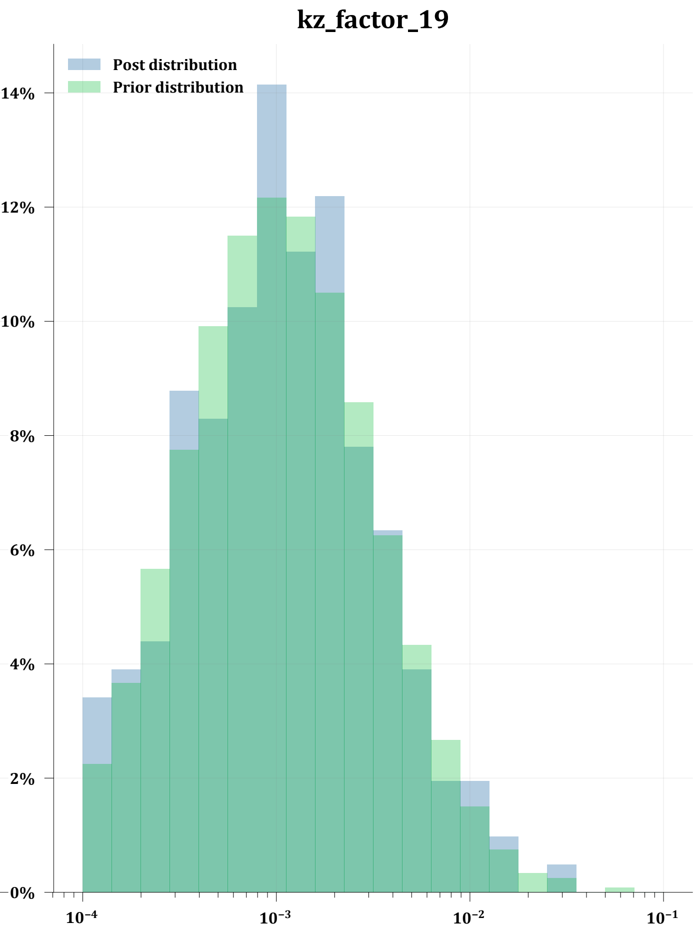
kz_factor_16

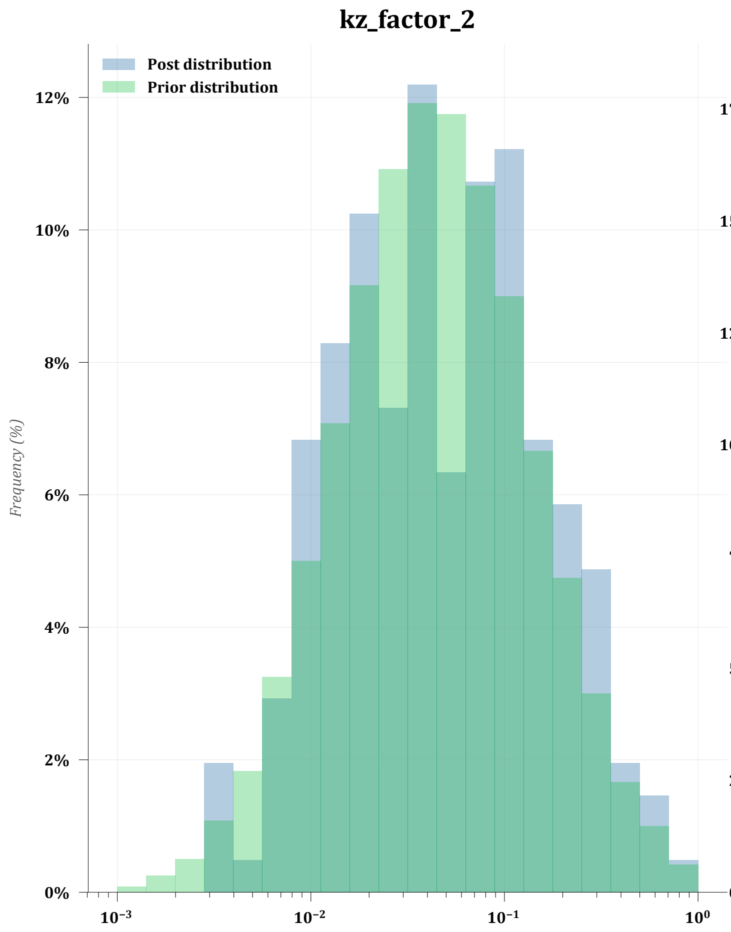


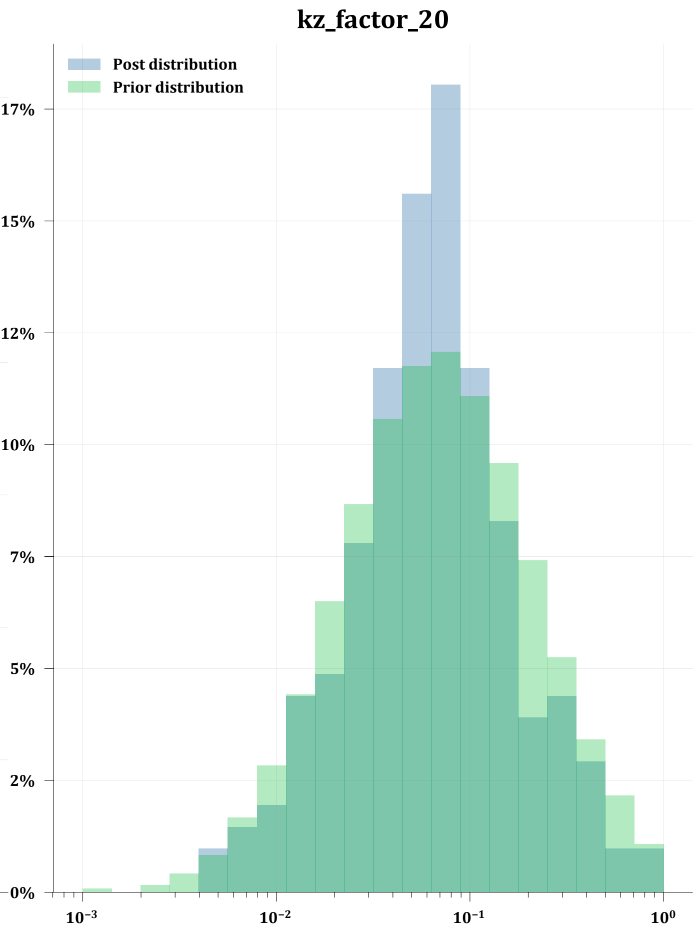
kz_factor_17



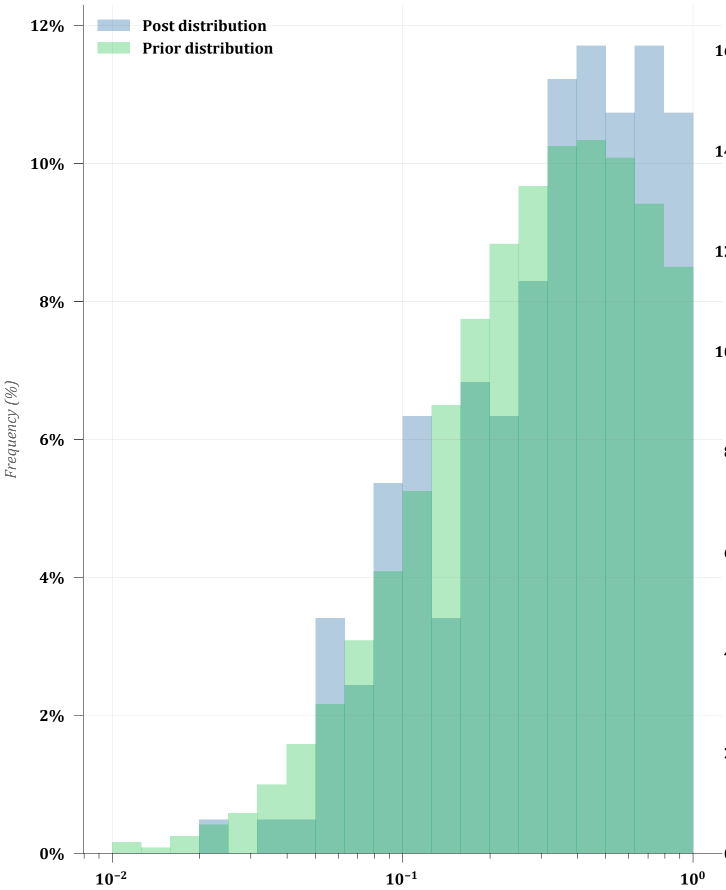

kz_factor_18
Post distribution
Prior distribution
Frequency (%)
14%
12%
10%
8%
6%
4%
2%
0%
10^{-3}
10^{-2}
10^{-1}
10^{0}


kz_factor_19
Post distribution
Prior distribution
14%
12%
10%
8%
6%
4%
2%
0%
10^{-4}
10^{-3}
10^{-2}
10^{-1}

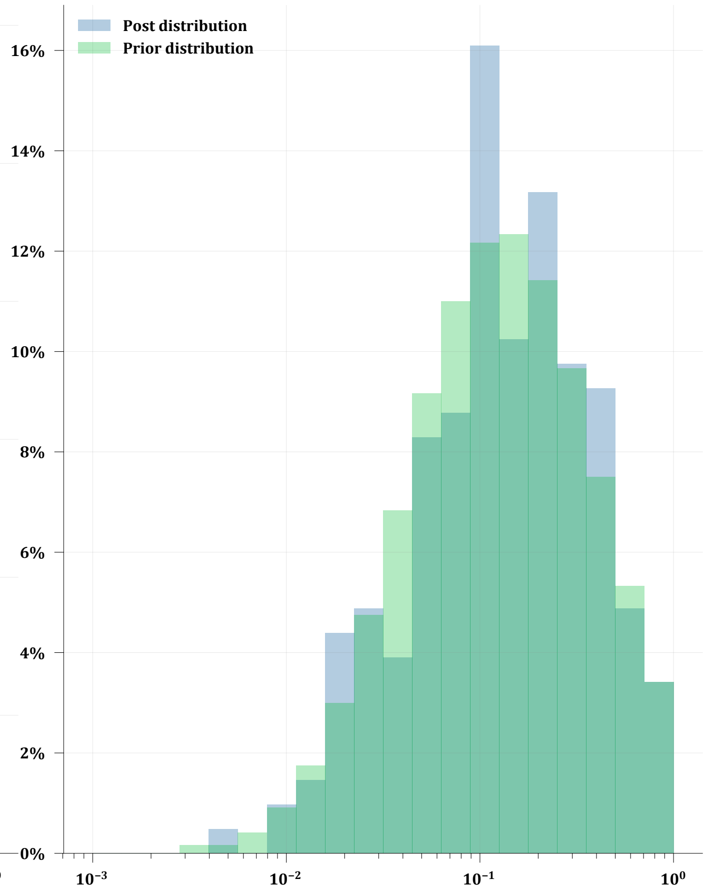

kz_factor_2
Post distribution
Prior distribution
Frequency (%)
12%
10%
8%
6%
4%
2%
0%
10^{-3}
10^{-2}
10^{-1}
10^{0}


kz_factor_20
Post distribution
Prior distribution
17%
15%
12%
10%
7%
5%
2%
0%
10^{-3}
10^{-2}
10^{-1}
10^{0}

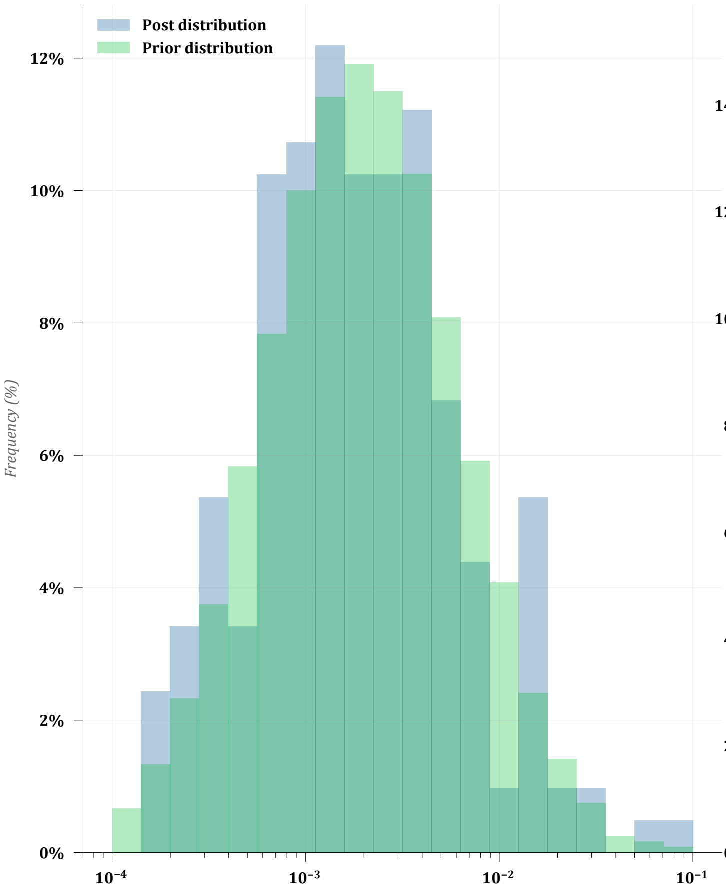
kz_factor_21



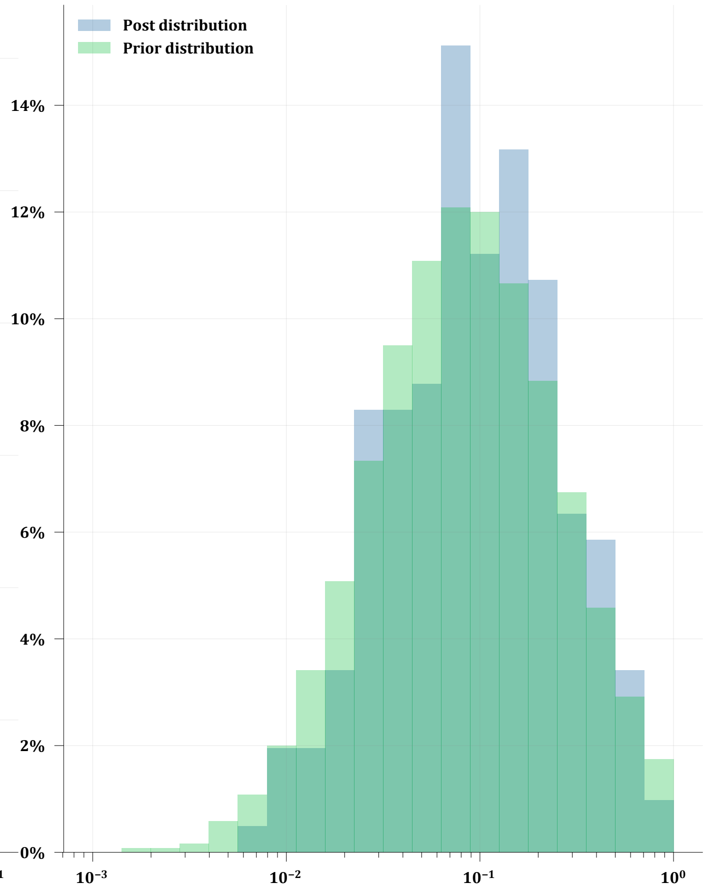
kz_factor_22



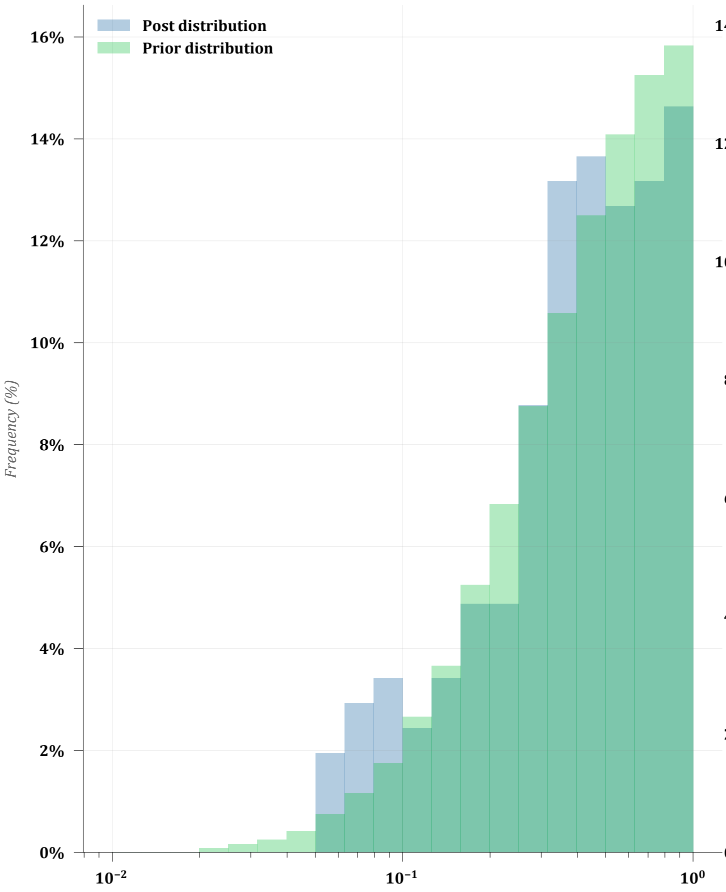
kz_factor_23



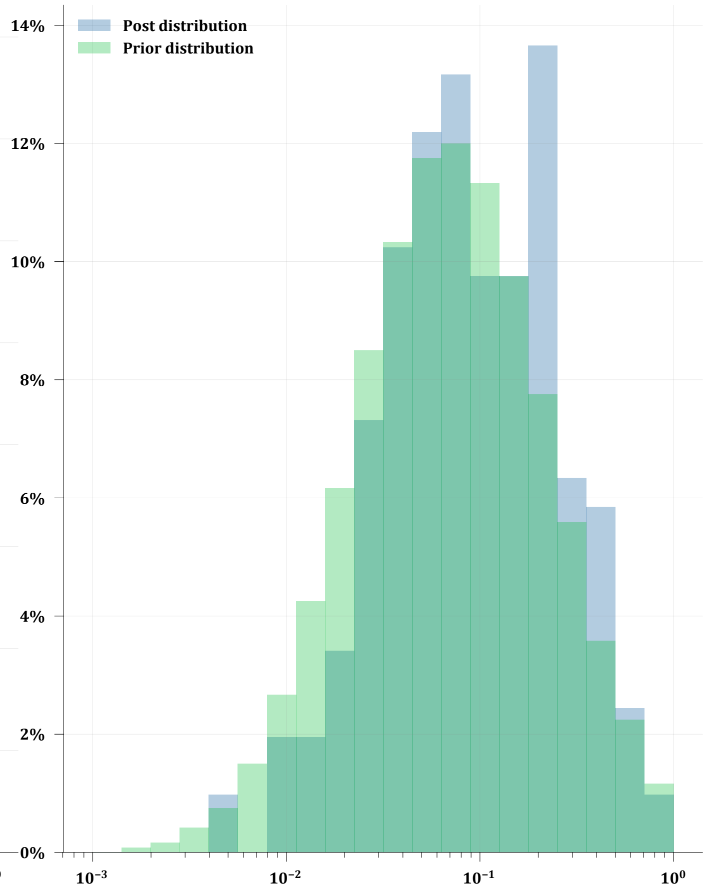
kz_factor_24



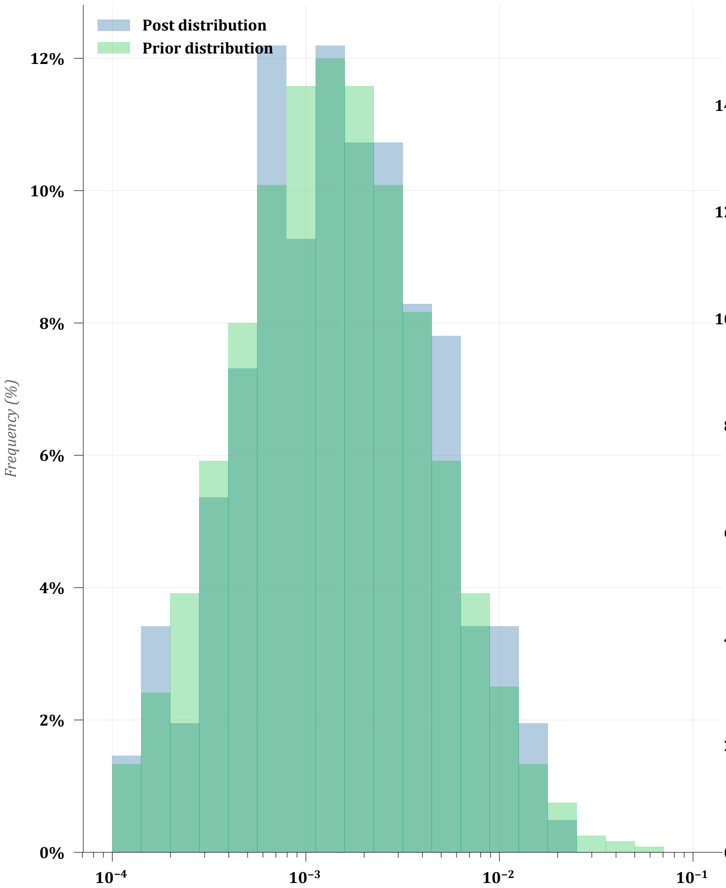
kz_factor_25



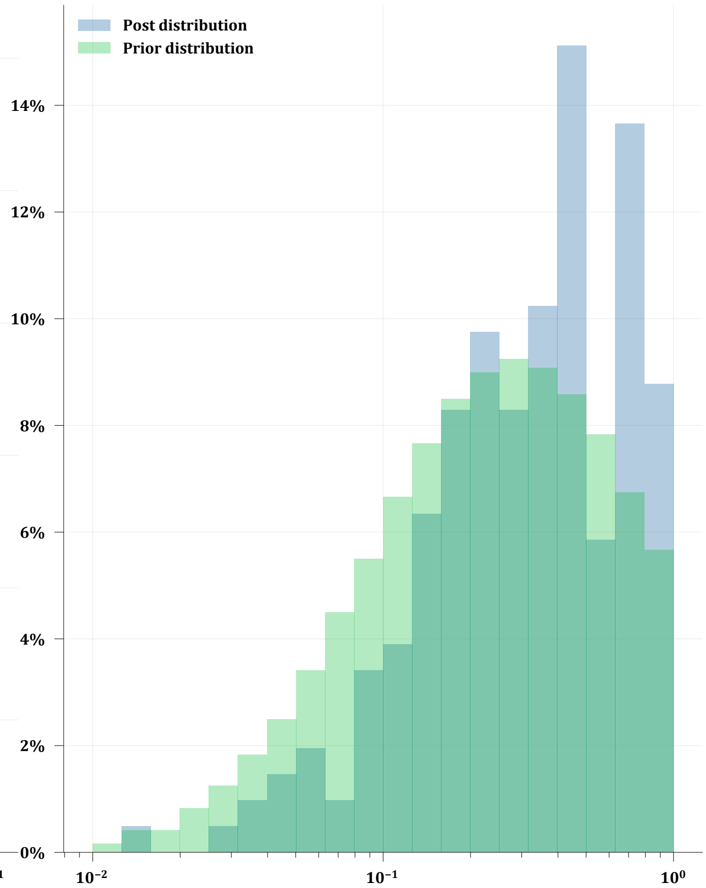
kz_factor_26

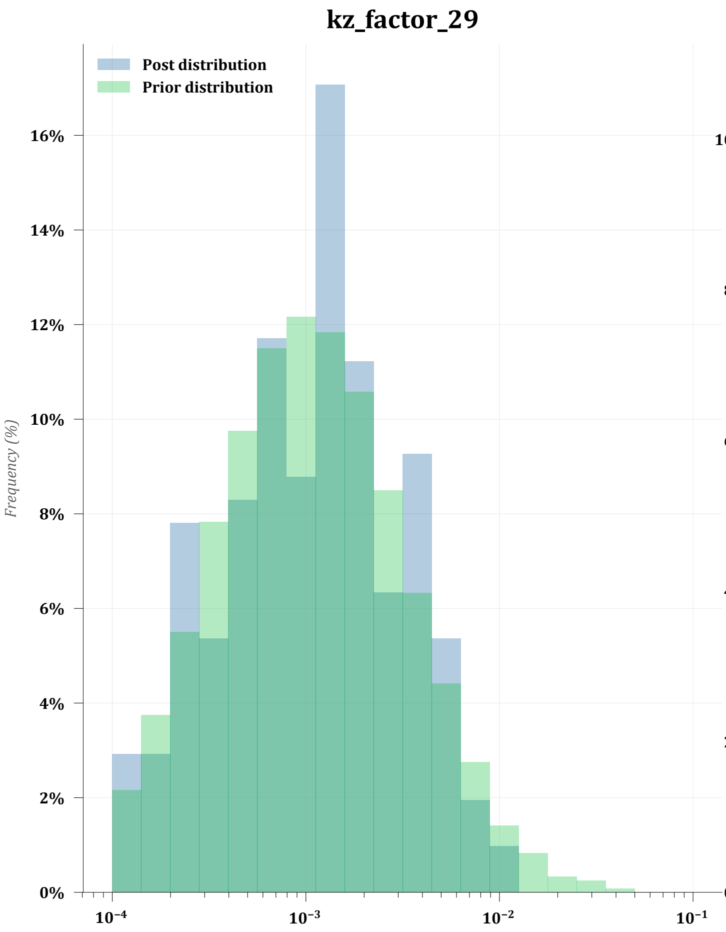


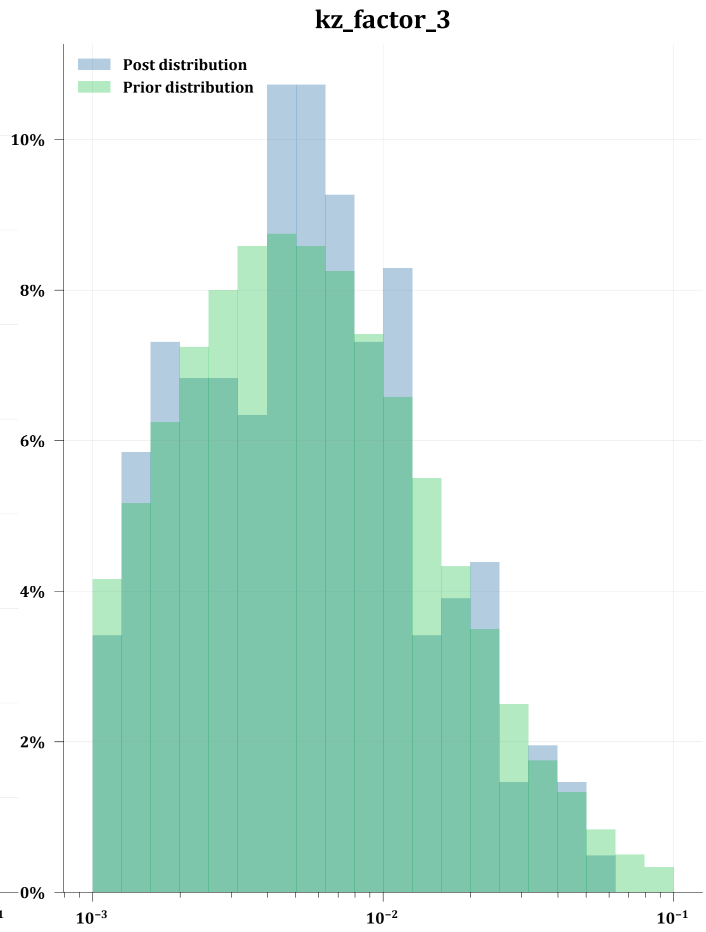
kz_factor_27



kz_factor_28




kz_factor_29
Post distribution
Prior distribution
Frequency (%)
0%
2%
4%
6%
8%
10%
12%
14%
16%
10^{-4}
10^{-3}
10^{-2}
10^{-1}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Post distribution
Prior distribution
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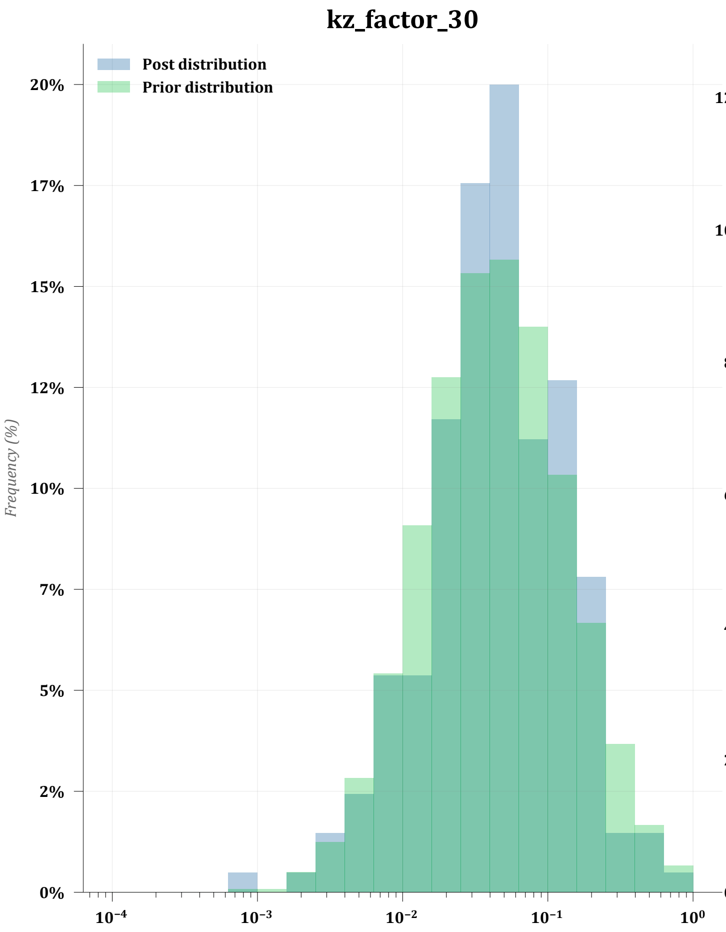
2%
4%
6%
8%
10%
10^{-3}
10^{-2}
10^{-1}


kz_factor_30
Post distribution
Prior distribution
Frequency (%)
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10%
12%
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17%
20%
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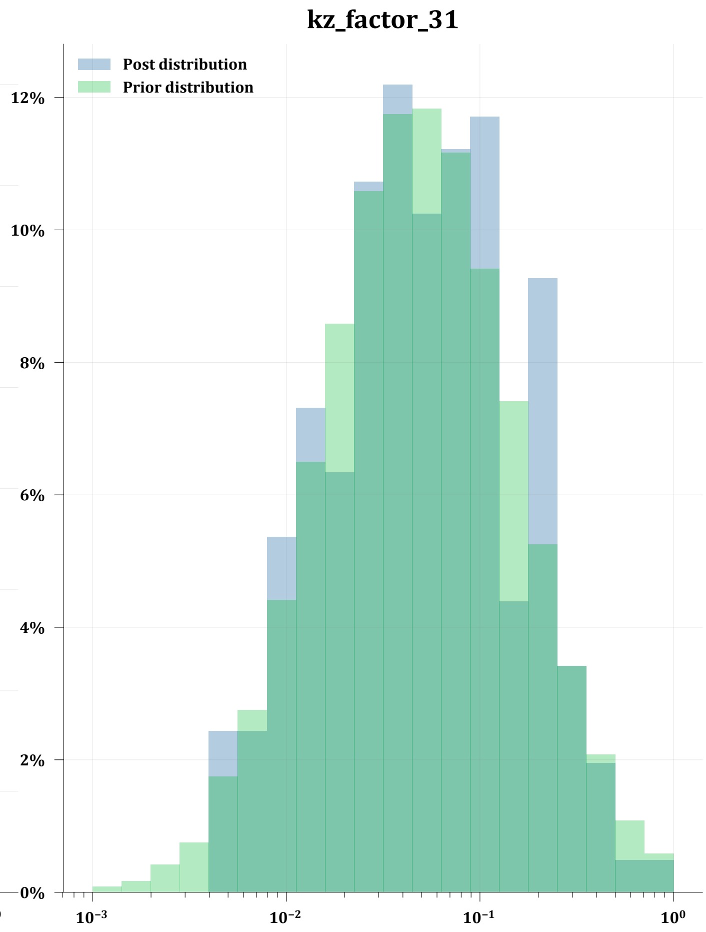
10^{-1}
10^{0}


kz_factor_31
Post distribution
Prior distribution
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10%
12%
10^{-3}
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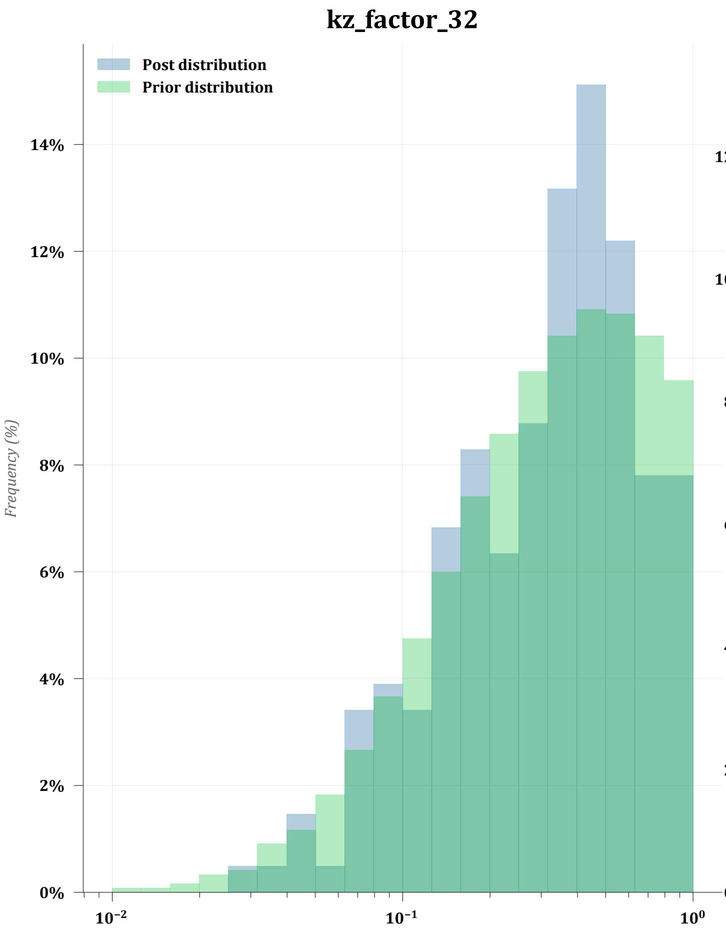
10^{-1}
10^{0}


kz_factor_32
Post distribution
Prior distribution
Frequency (%)
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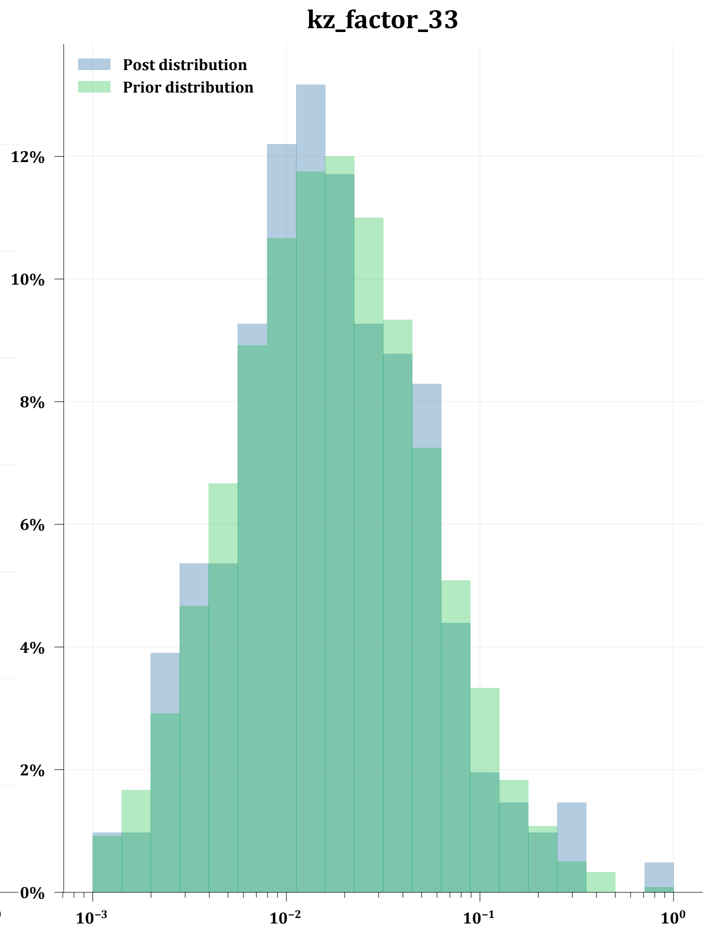
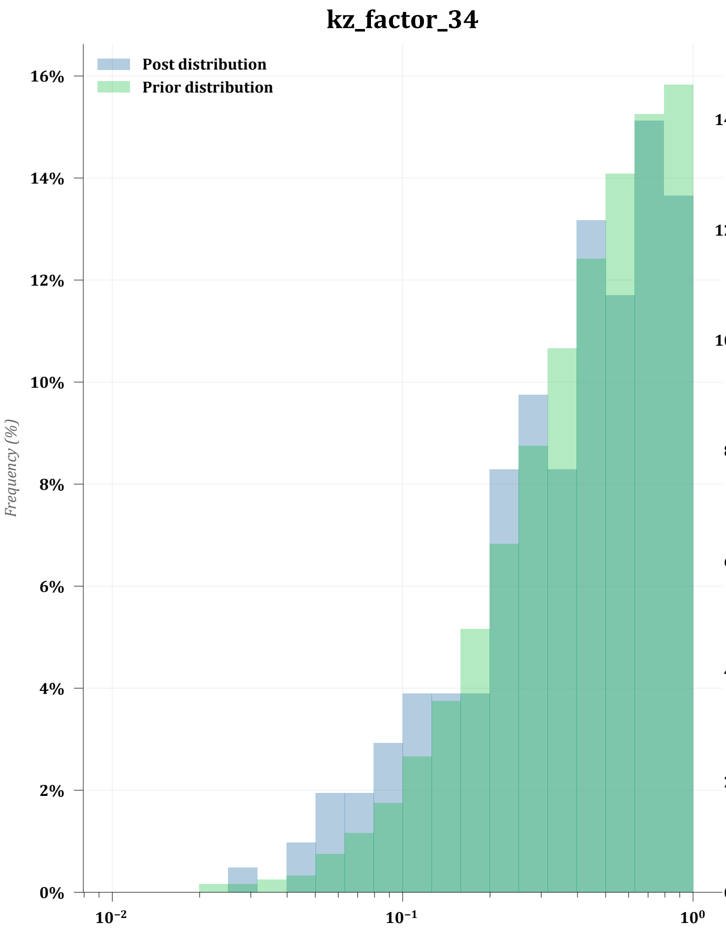
12%
10%
8%
6%
4%
2%
0%
10⁻²
10⁻¹
10⁰


kz_factor_33
Post distribution
Prior distribution
12%
10%
8%
6%
4%
2%
0%
10⁻³
10⁻²
10⁻¹
10⁰


kz_factor_34
Post distribution
Prior distribution
Frequency (%)
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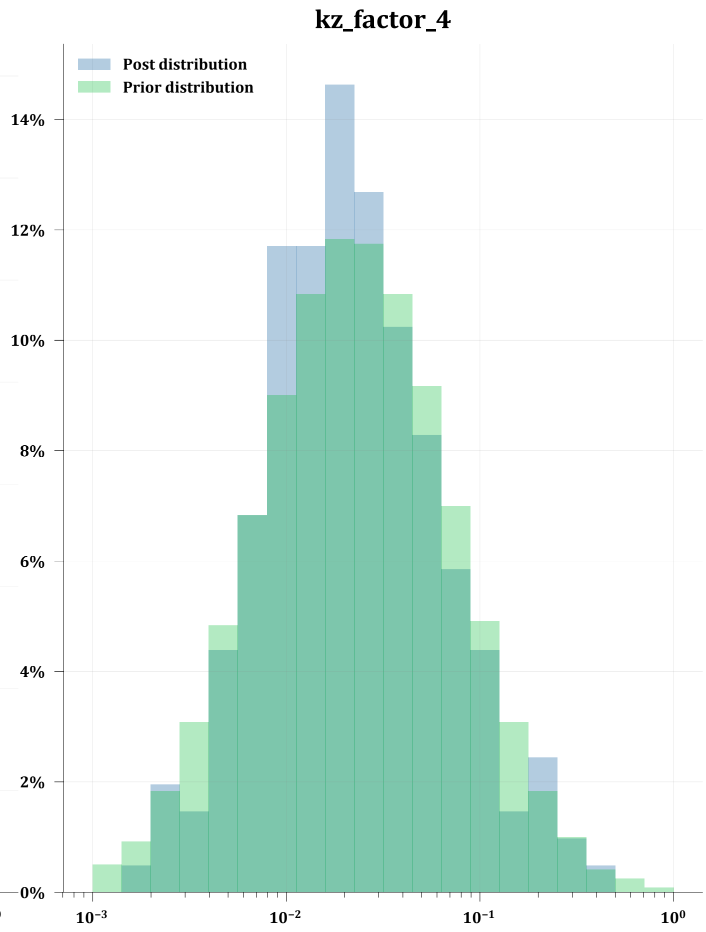
14%
12%
10%
8%
6%
4%
2%
0%
10⁻²
10⁻¹
10⁰


kz_factor_4
Post distribution
Prior distribution
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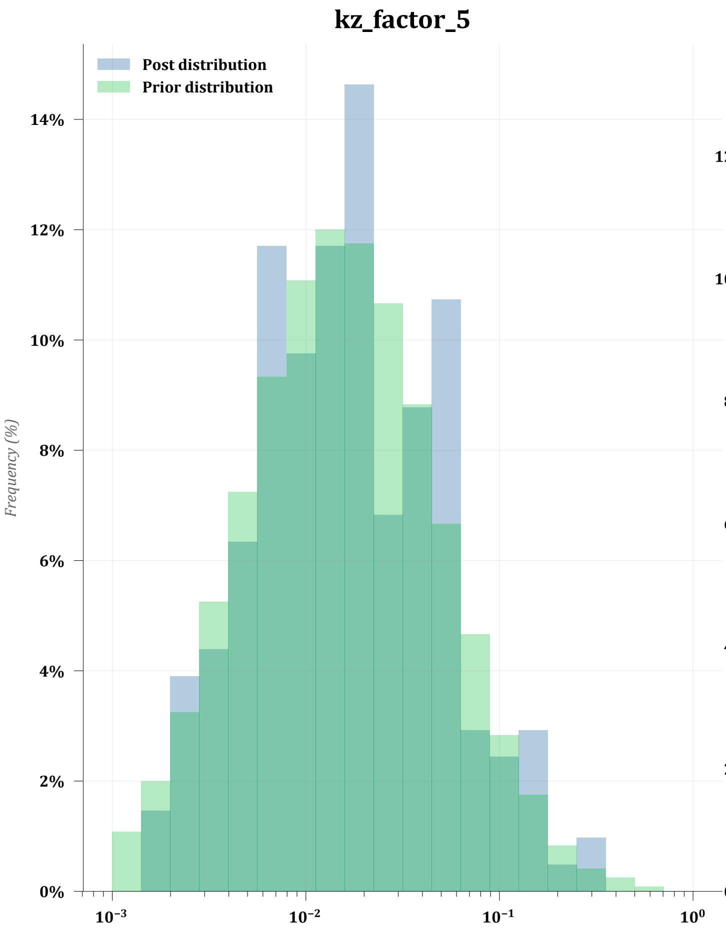
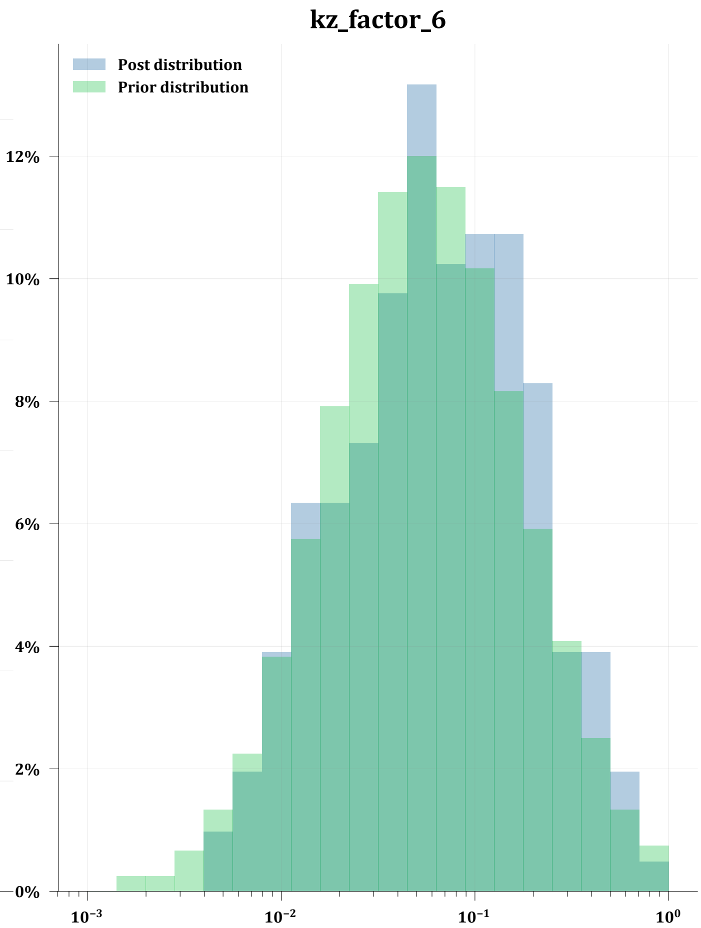
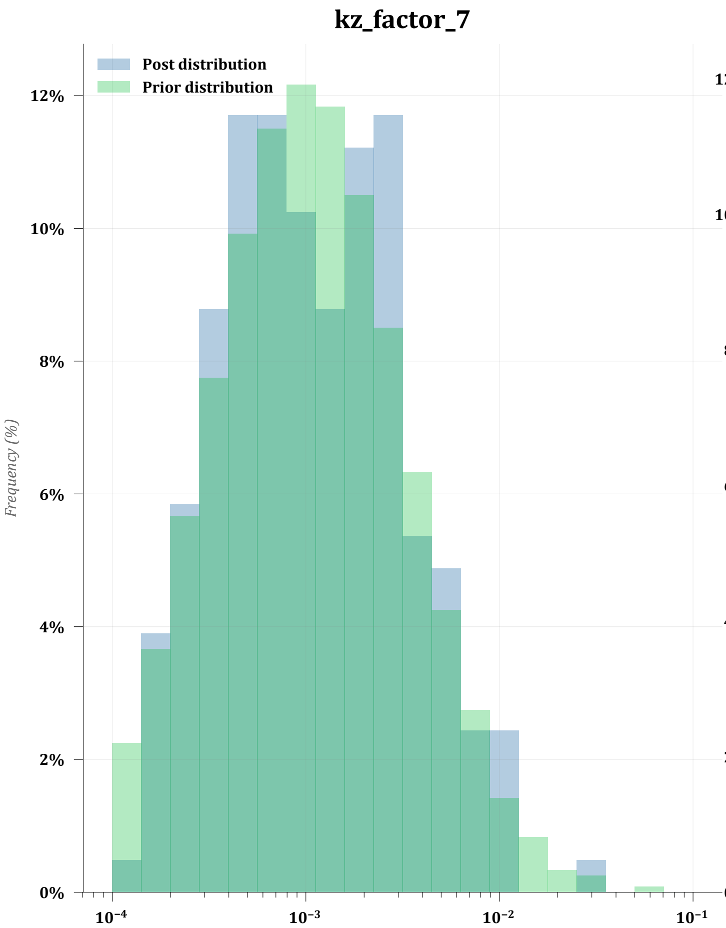
12%
10%
8%
6%
4%
2%
0%
10⁻³
10⁻²
10⁻¹
10⁰



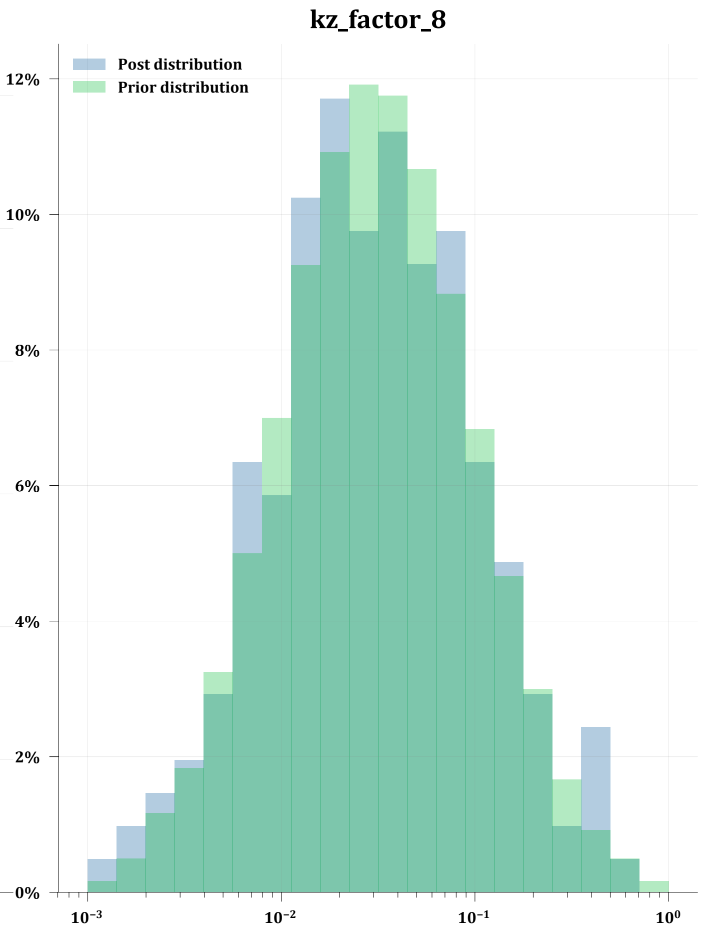
kz_factor_5
Post distribution
Prior distribution
Frequency (%)



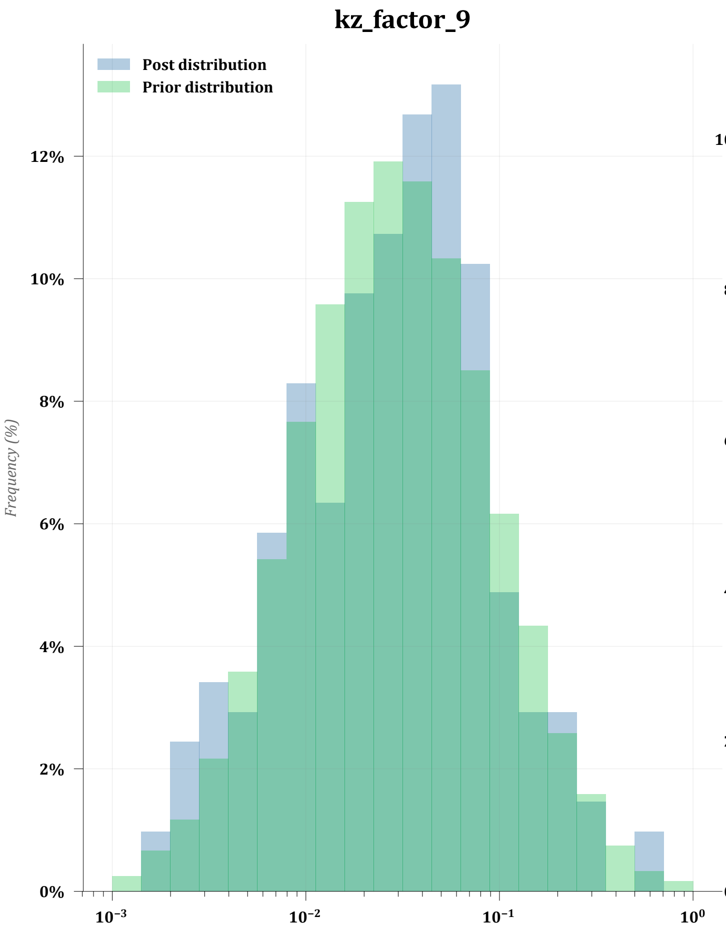
kz_factor_6
Post distribution
Prior distribution



kz_factor_7
Post distribution
Prior distribution
Frequency (%)



kz_factor_8
Post distribution
Prior distribution


kz_factor_9
Post distribution
Prior distribution
Frequency (%)
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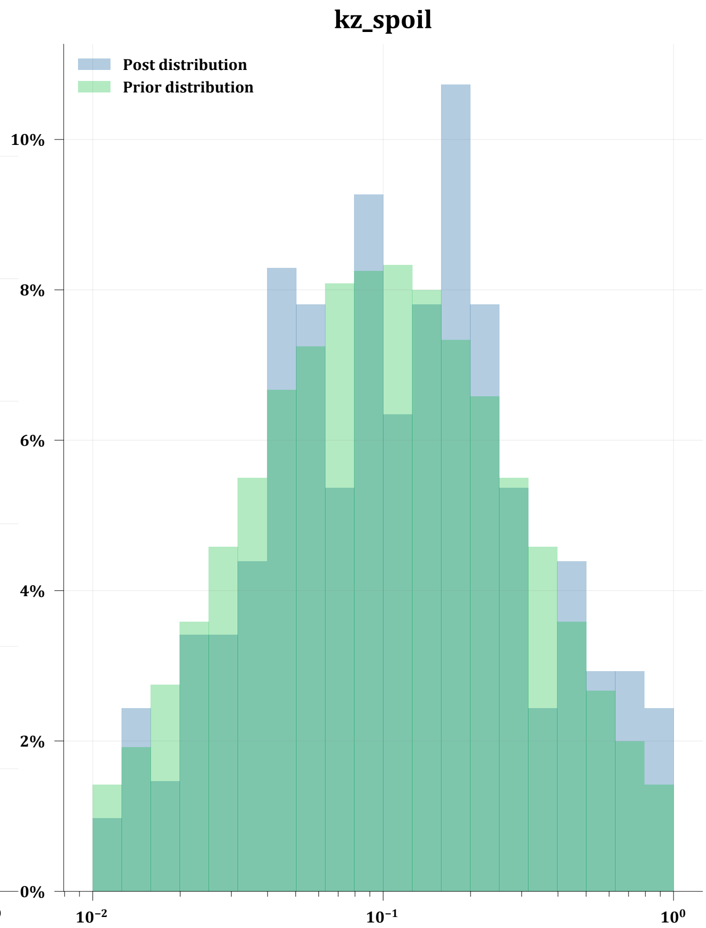
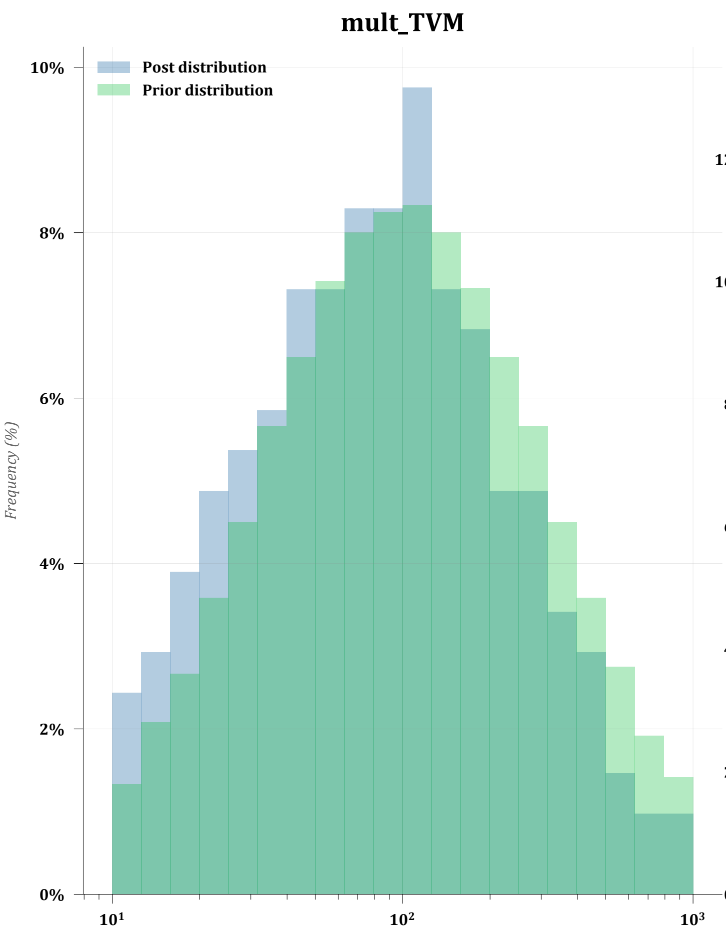
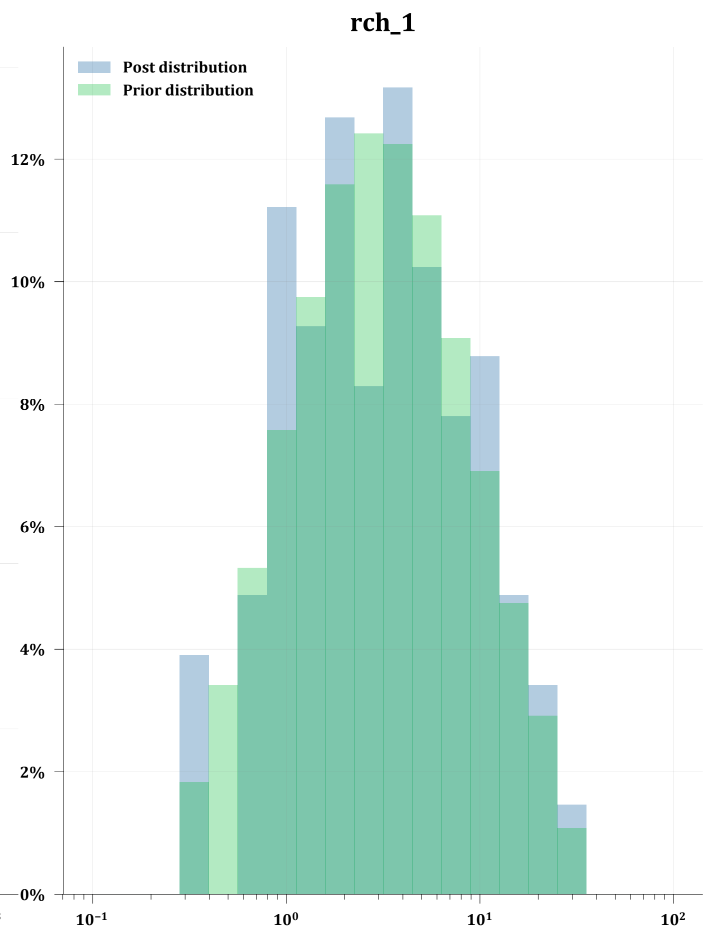
4%
6%
8%
10%
12%
10^{-3}
10^{-2}
10^{-1}
10^{0}


kz_spoil
Post distribution
Prior distribution
0%
2%
4%
6%
8%
10%
10^{-2}
10^{-1}
10^{0}


mult_TVM
Post distribution
Prior distribution
Frequency (%)
0%
2%
4%
6%
8%
10%
10^{1}
10^{2}
10^{3}


rch_1
Post distribution
Prior distribution
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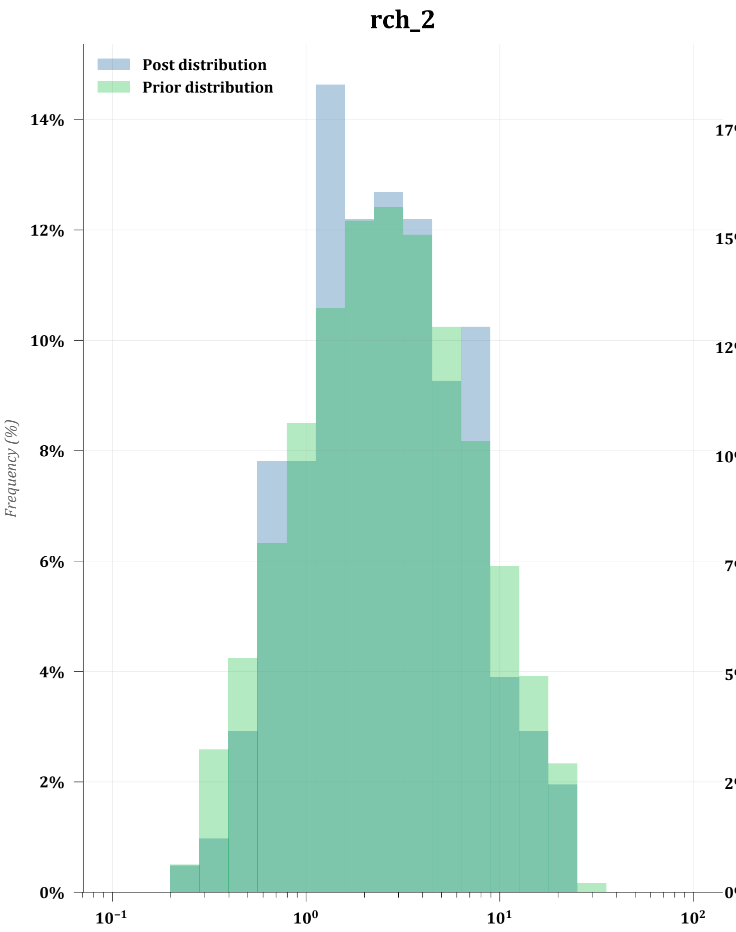
2%
4%
6%
8%
10%
12%
10^{-1}
10^{0}
10^{1}
10^{2}


rch_2
Post distribution
Prior distribution
Frequency (%)
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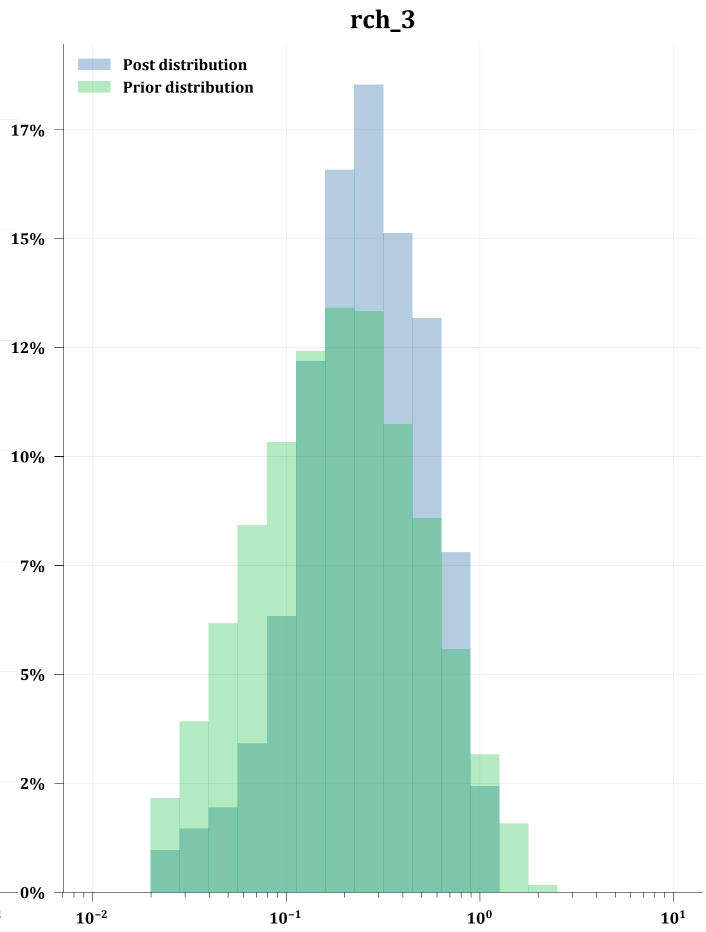
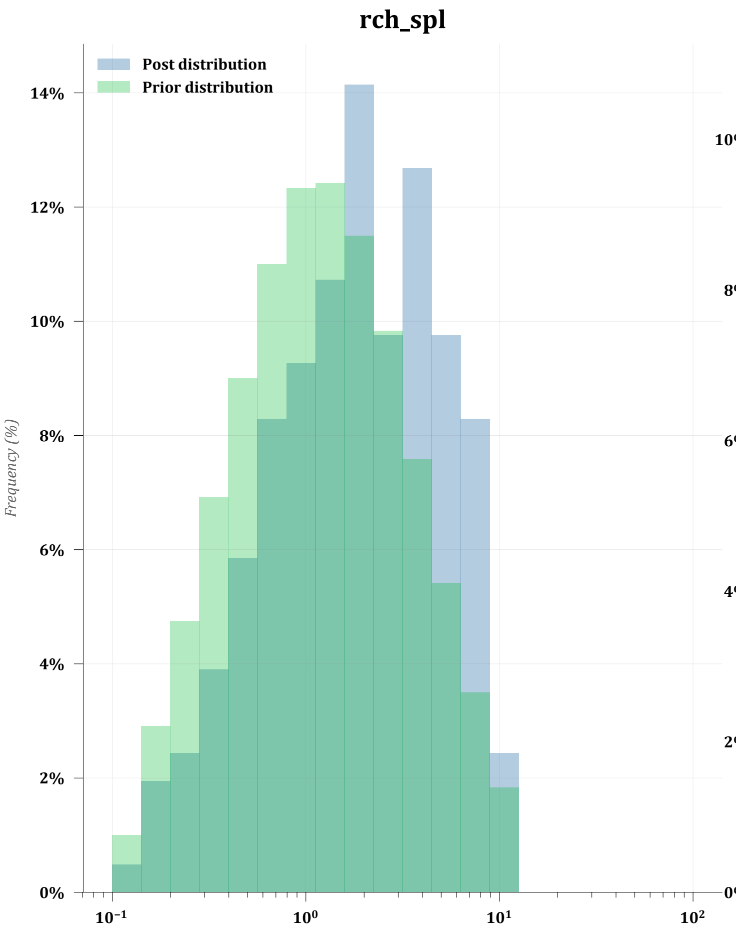
2%
4%
6%
8%
10%
12%
14%
10^{-1}
10^{0}
10^{1}
10^{2}


rch_3
Post distribution
Prior distribution
0%
2%
5%
7%
10%
12%
15%
17%
10^{-2}
10^{-1}
10^{0}
10^{1}


rch_spl
Post distribution
Prior distribution
Frequency (%)
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4%
6%
8%
10%
12%
14%
10^{-1}
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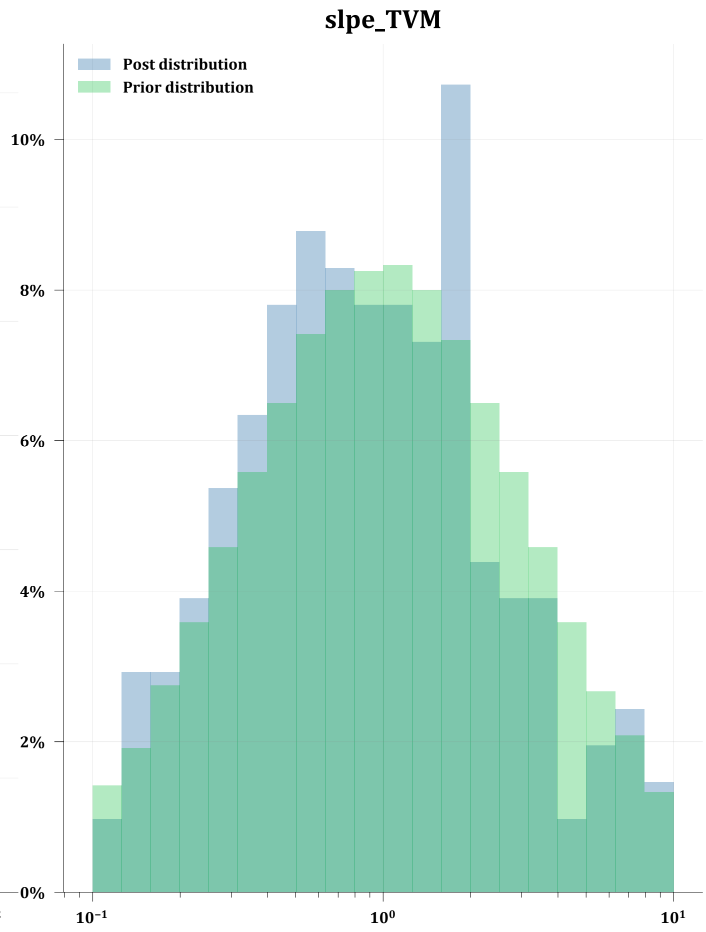
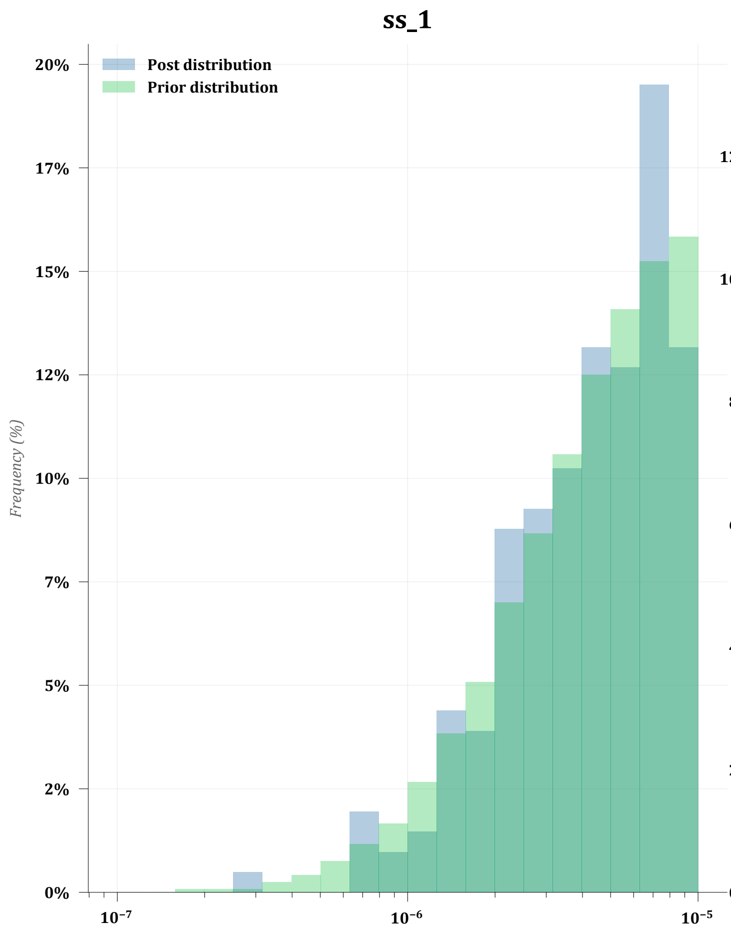
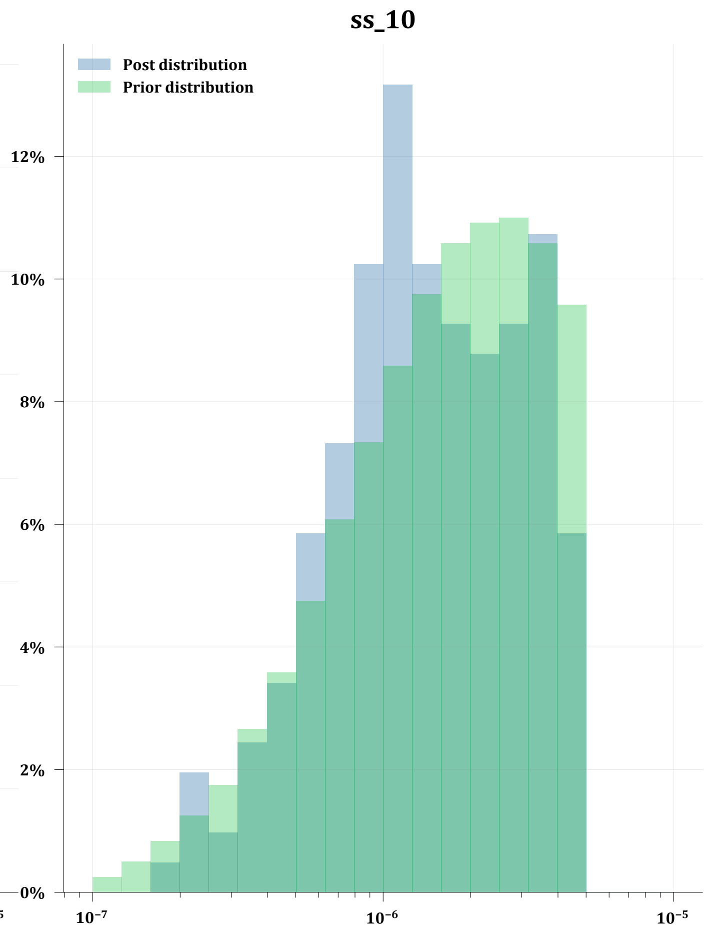
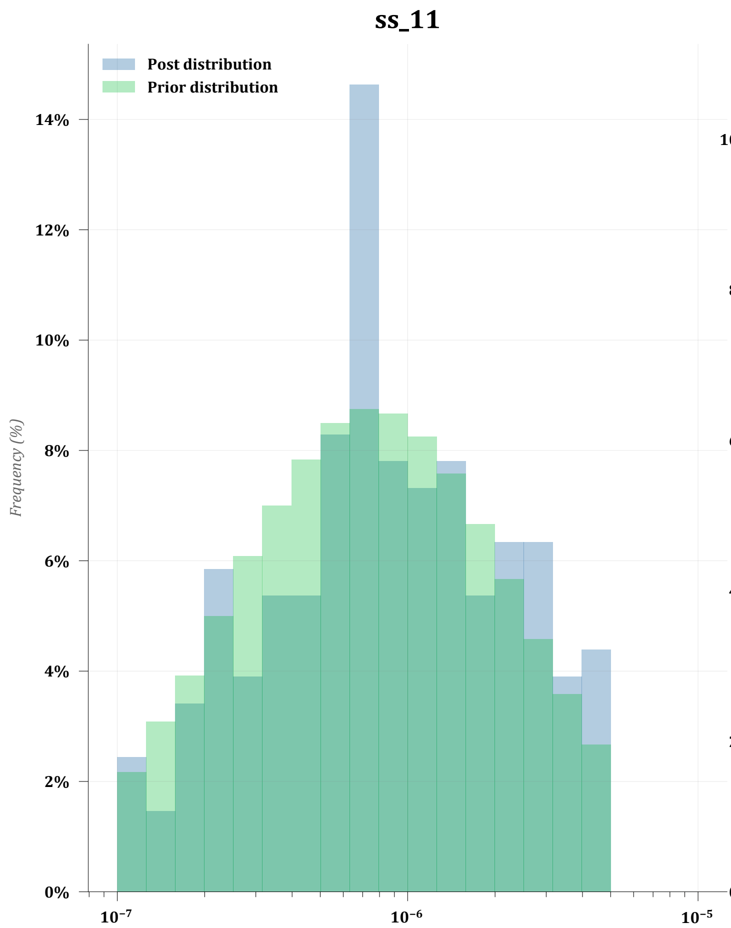
10^{1}
10^{2}


slpe_TVM
Post distribution
Prior distribution
0%
2%
4%
6%
8%
10%
10^{-1}
10^{0}
10^{1}


ss_1
Post distribution
Prior distribution
Frequency (%)
20%
17%
15%
12%
10%
7%
5%
2%
0%
10^{-7}
10^{-6}
10^{-5}


ss_10
Post distribution
Prior distribution
12%
10%
8%
6%
4%
2%
0%
10^{-7}
10^{-6}
10^{-5}


ss_11
Post distribution
Prior distribution
Frequency (%)
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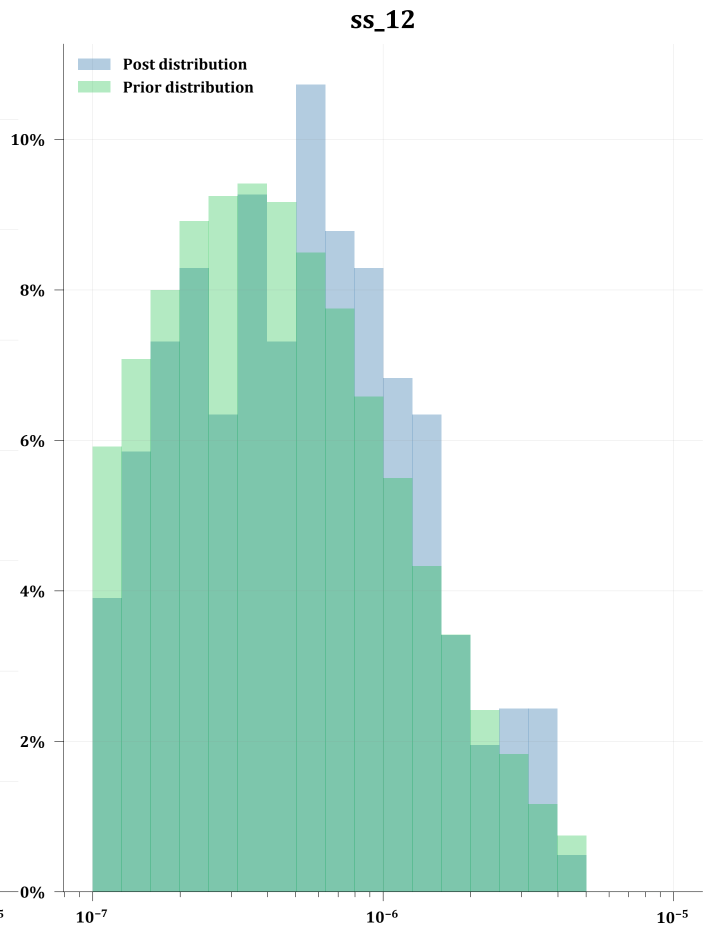
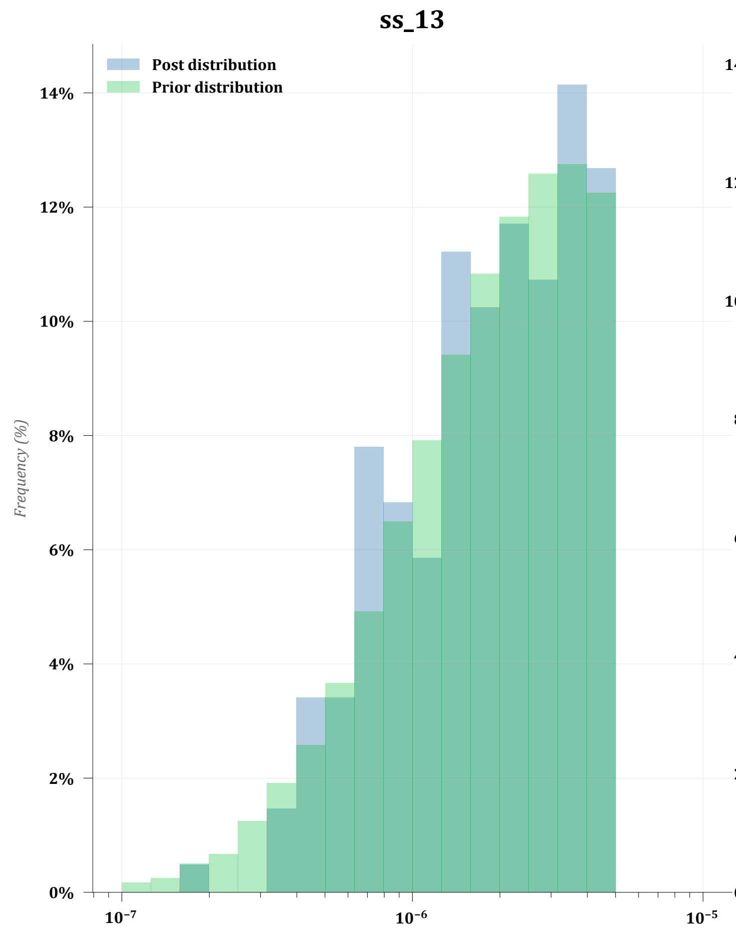
12%
10%
8%
6%
4%
2%
0%
10^{-7}
10^{-6}
10^{-5}


ss_12
Post distribution
Prior distribution
10%
8%
6%
4%
2%
0%
10^{-7}
10^{-6}
10^{-5}


ss_13
Post distribution
Prior distribution
Frequency (%)
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4%
6%
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10%
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10^{-7}
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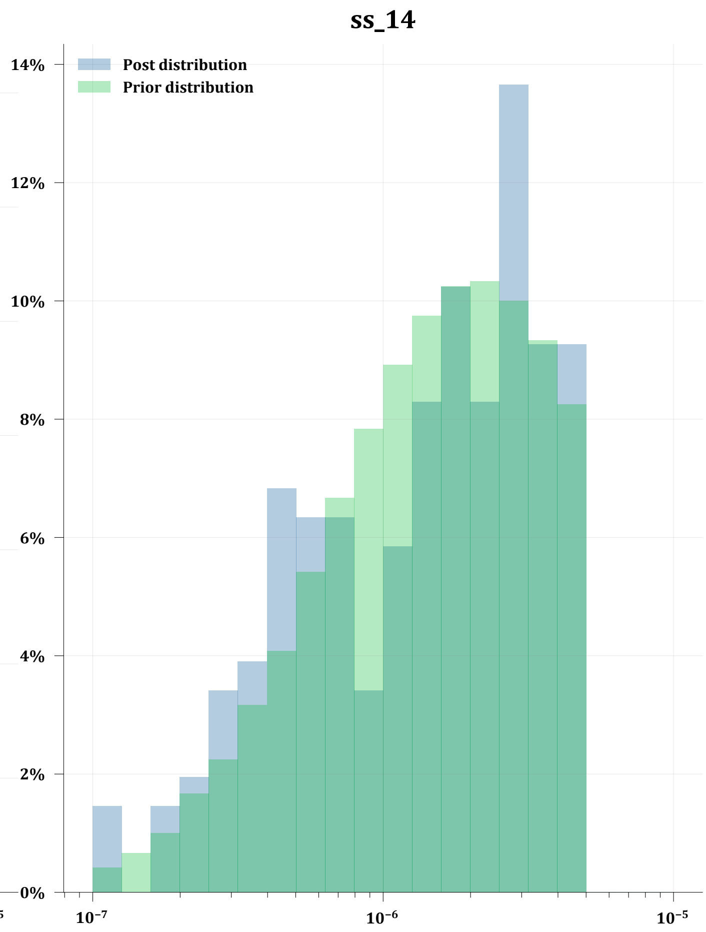
ss_14
Post distribution
Prior distribution
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2%
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6%
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10%
12%
14%
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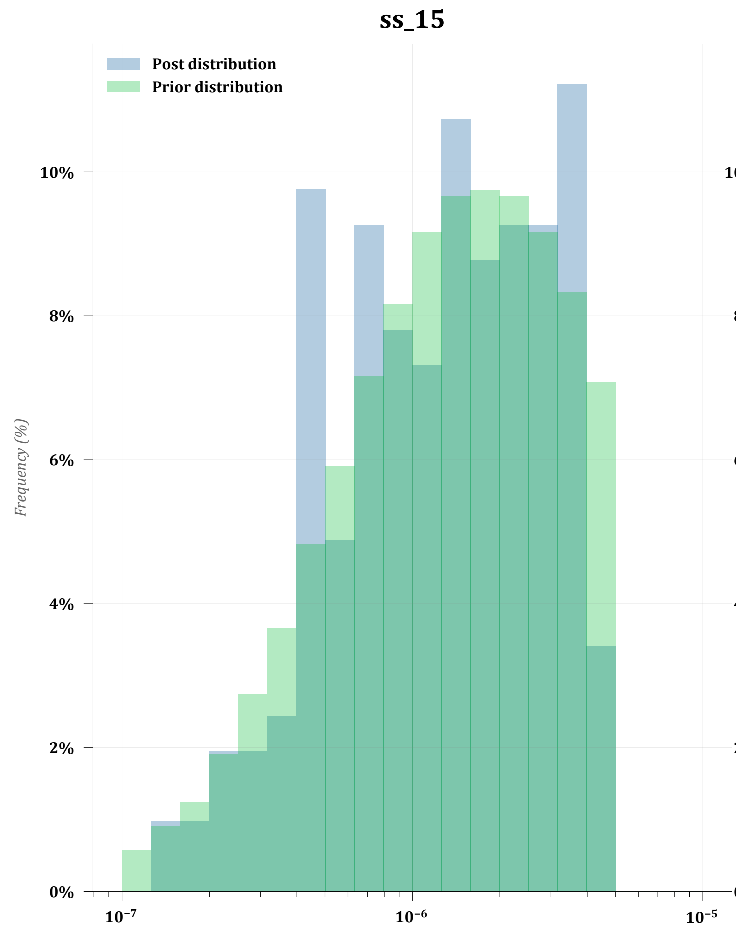
10^{-6}
10^{-5}


ss_15
Post distribution
Prior distribution
Frequency (%)
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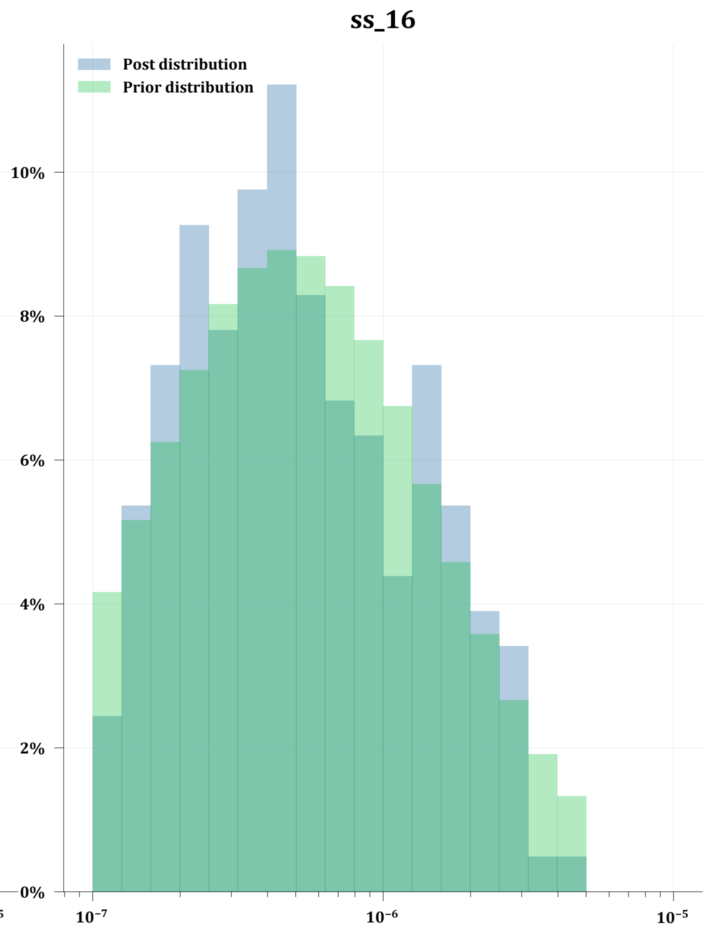
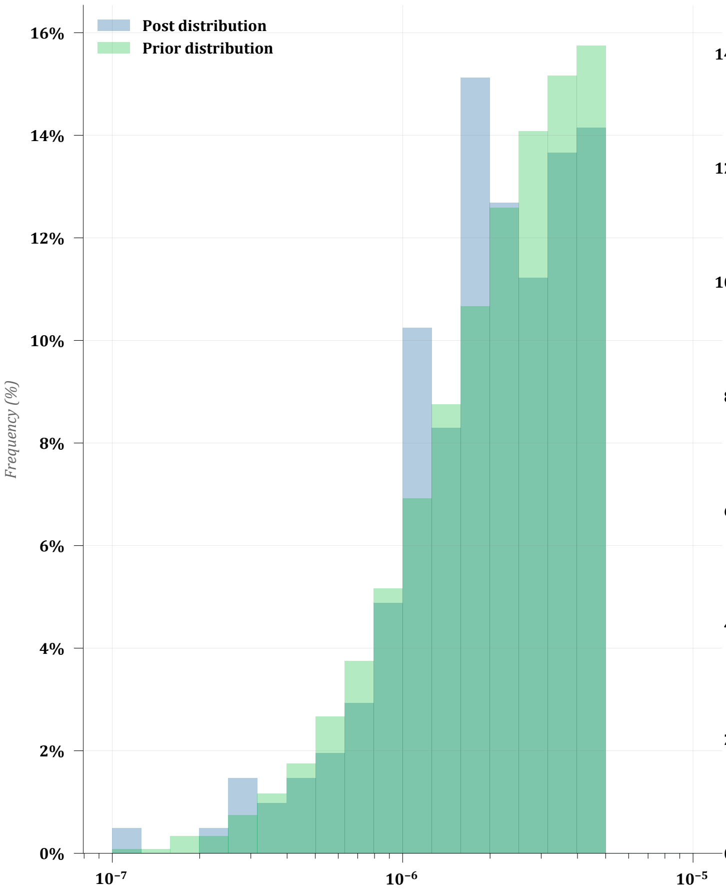
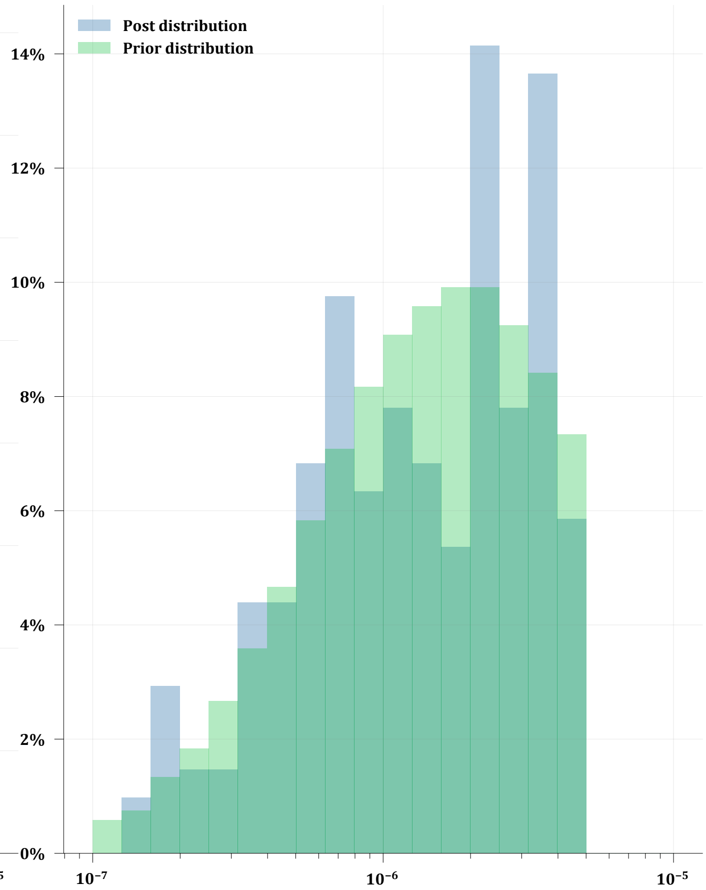
2%
4%
6%
8%
10%
10^{-7}
10^{-6}
10^{-5}


ss_16
Post distribution
Prior distribution
0%
2%
4%
6%
8%
10%
10^{-7}
10^{-6}
10^{-5}

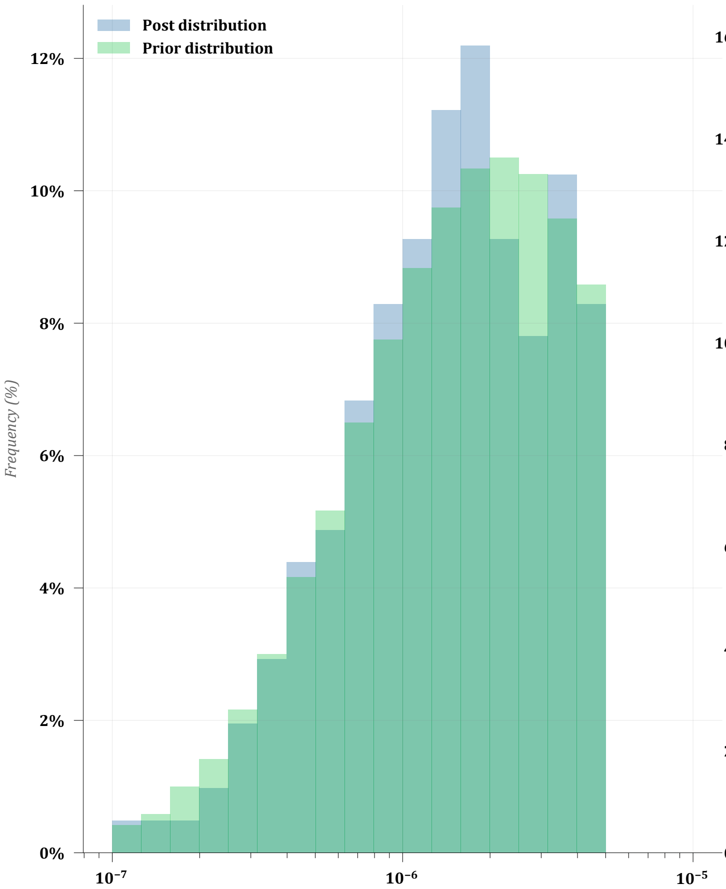
ss_17



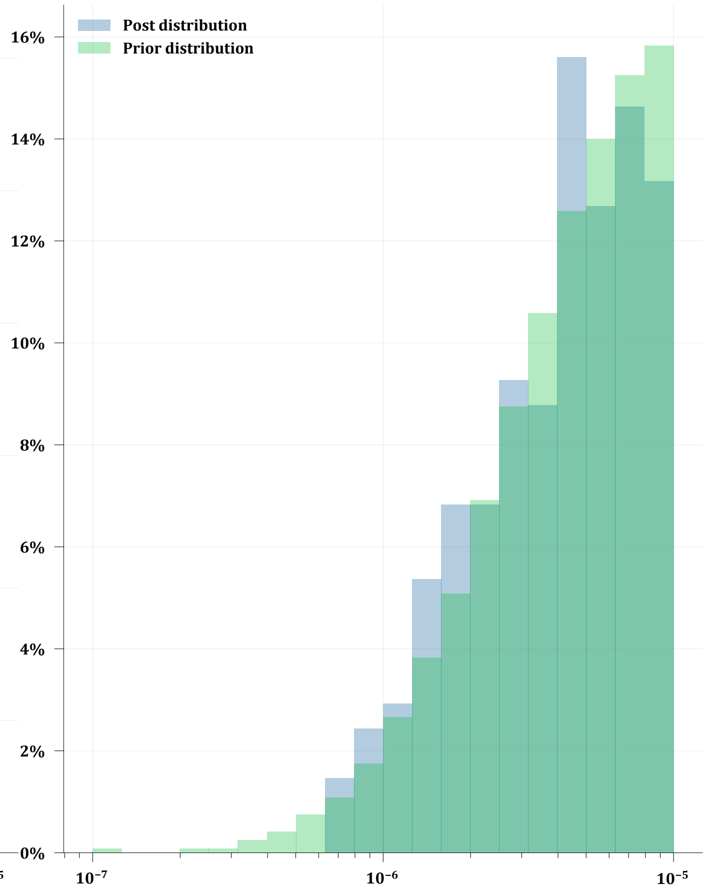
ss_18

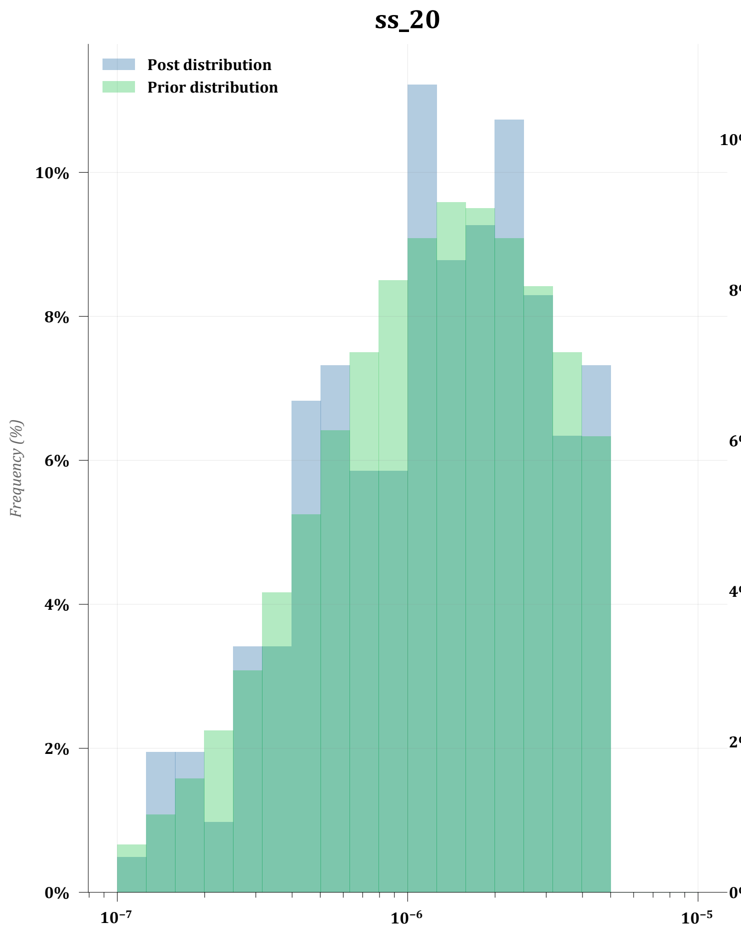


ss_19



ss_2




ss_20
Post distribution
Prior distribution
Frequency (%)
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2%
0%
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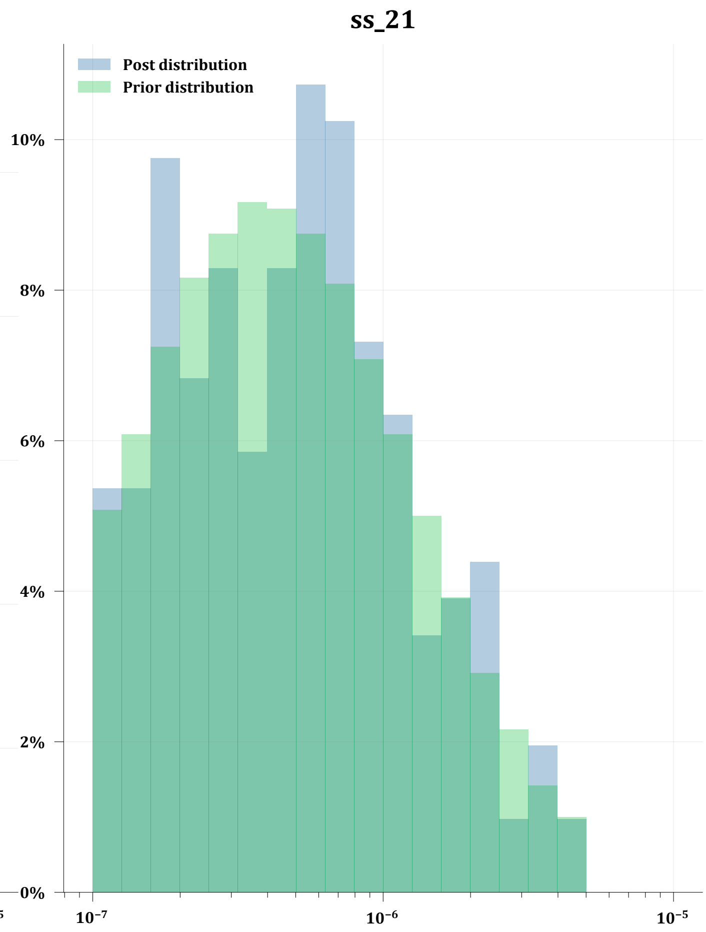
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Prior distribution
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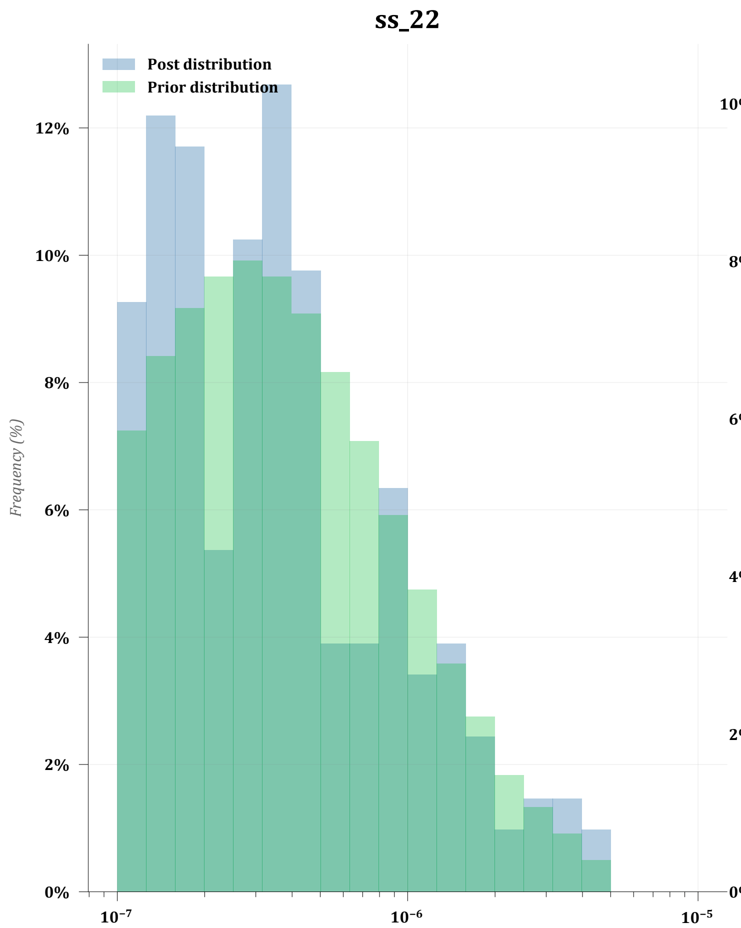
ss_22
Post distribution
Prior distribution
Frequency (%)
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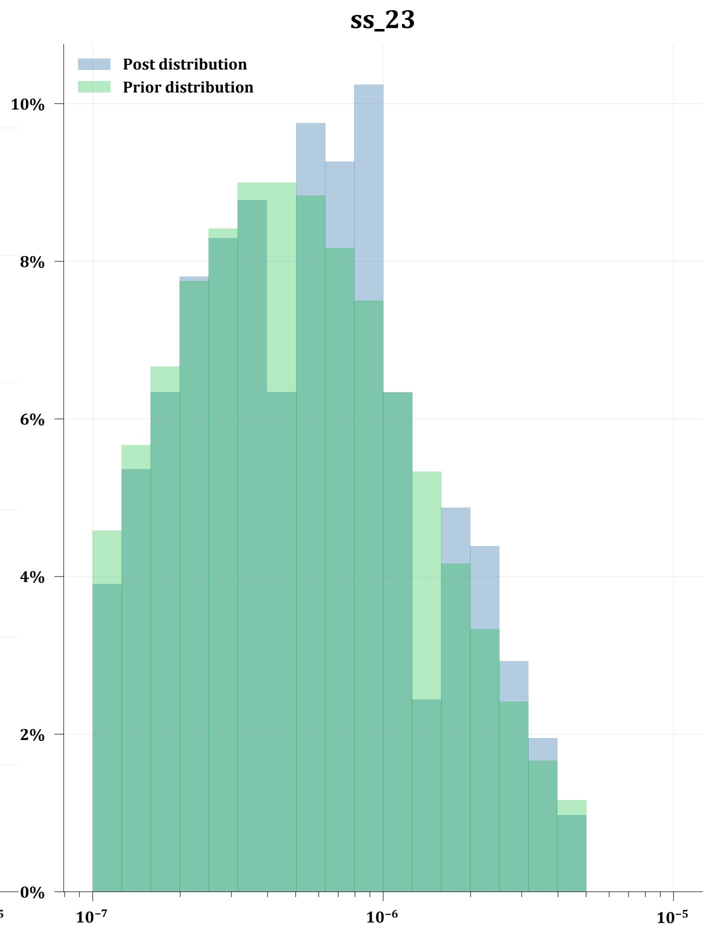
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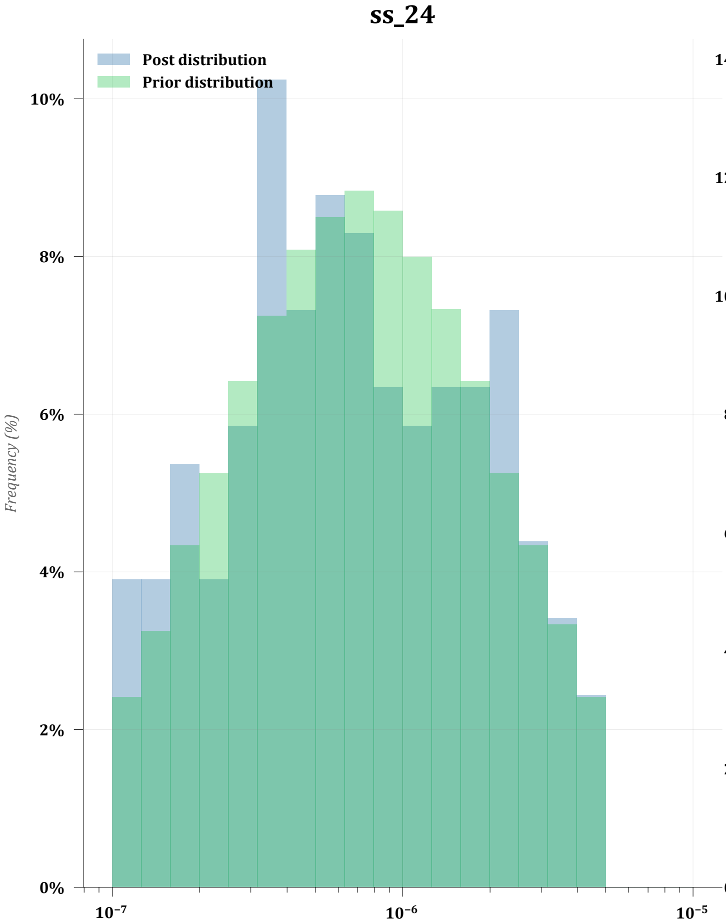
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Frequency (%)
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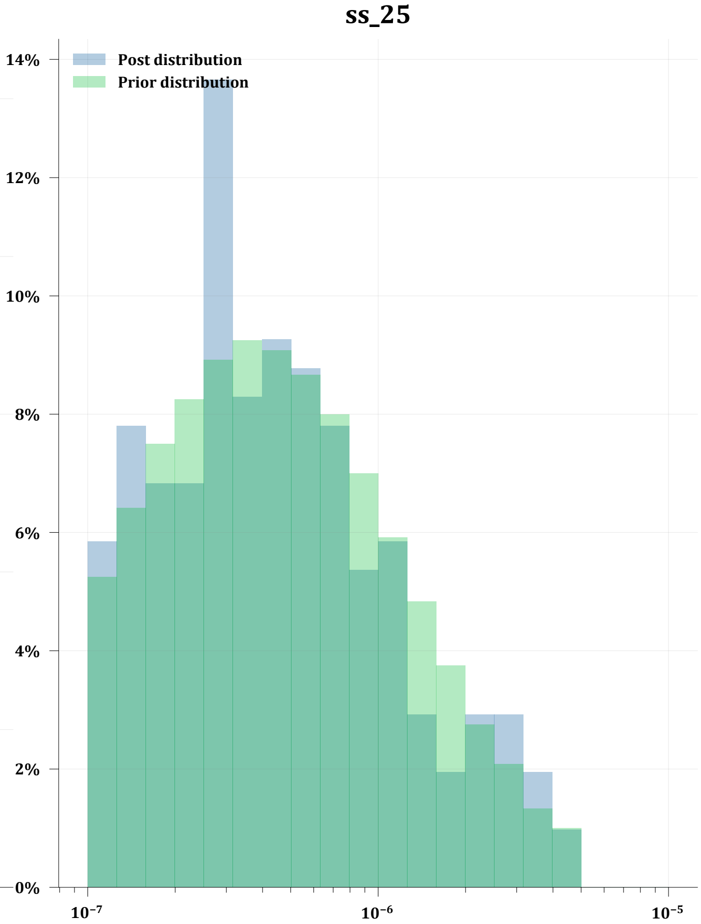
ss_25
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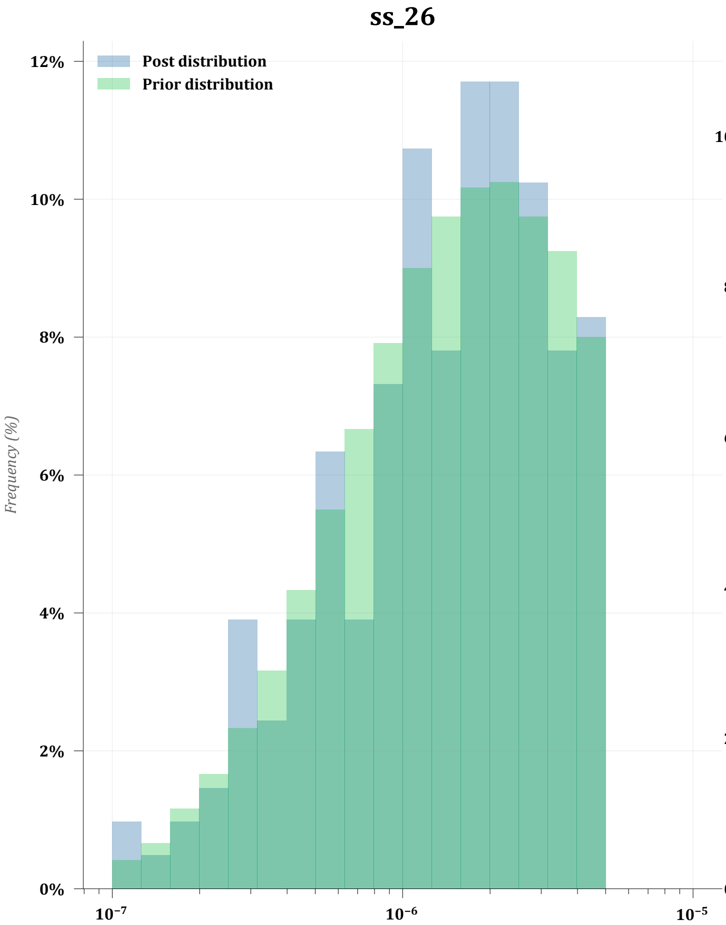
ss_26
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Frequency (%)
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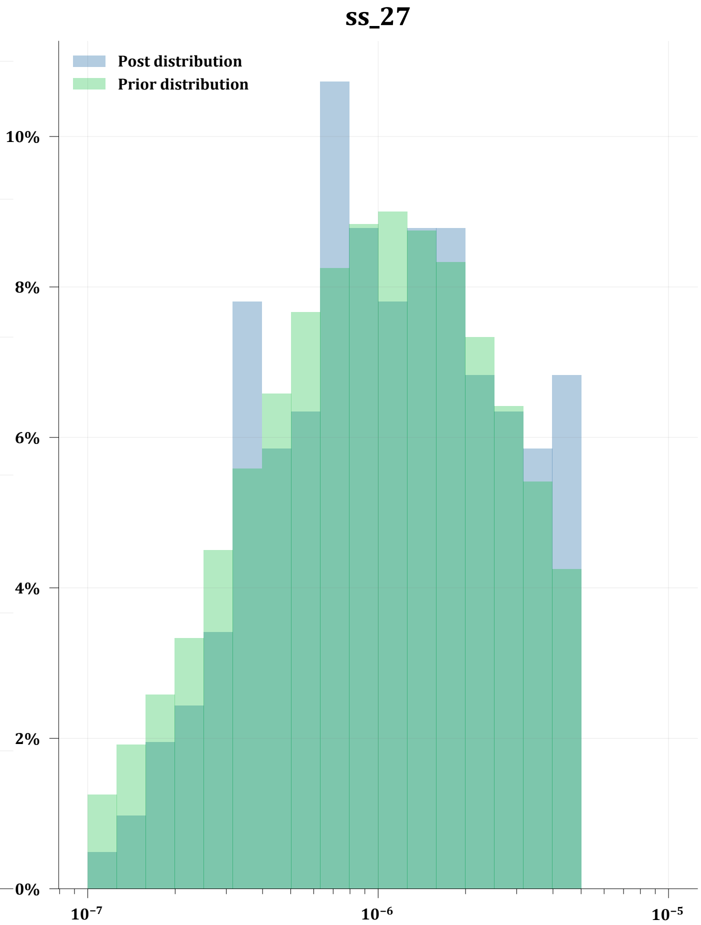
10^{-5}


ss_27
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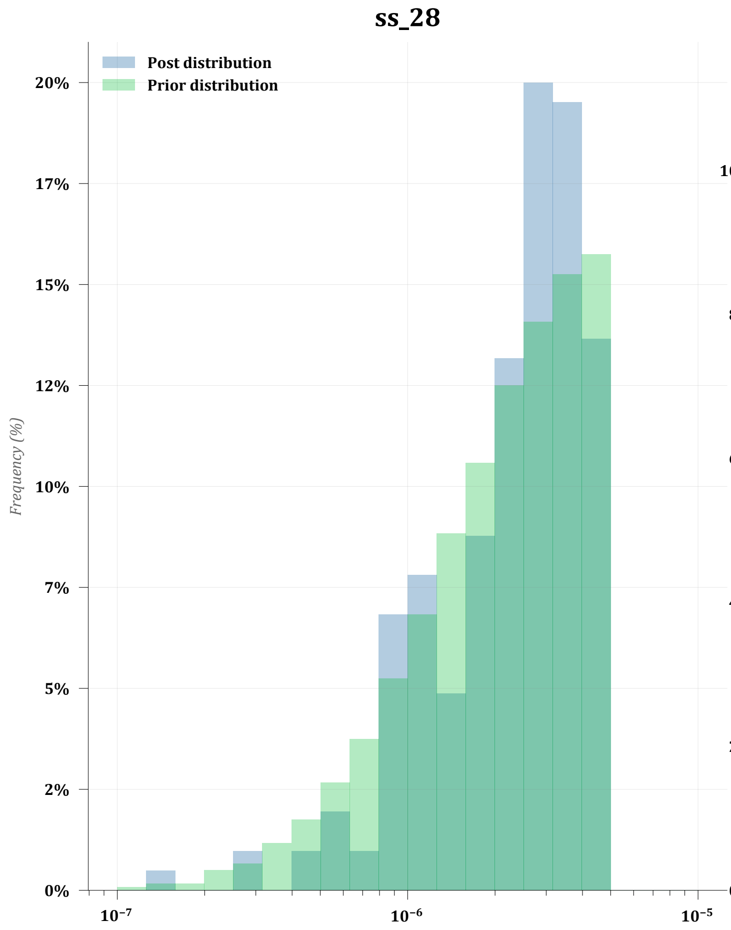
ss_28
Post distribution
Prior distribution
Frequency (%)
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15%
12%
10%
7%
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2%
0%
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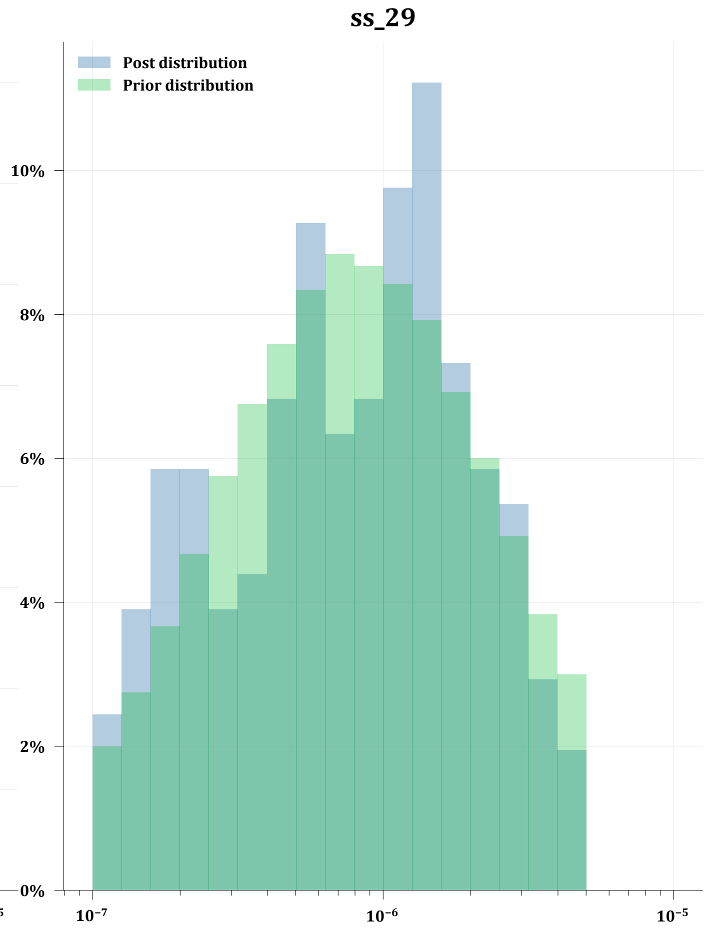
ss_29
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Prior distribution
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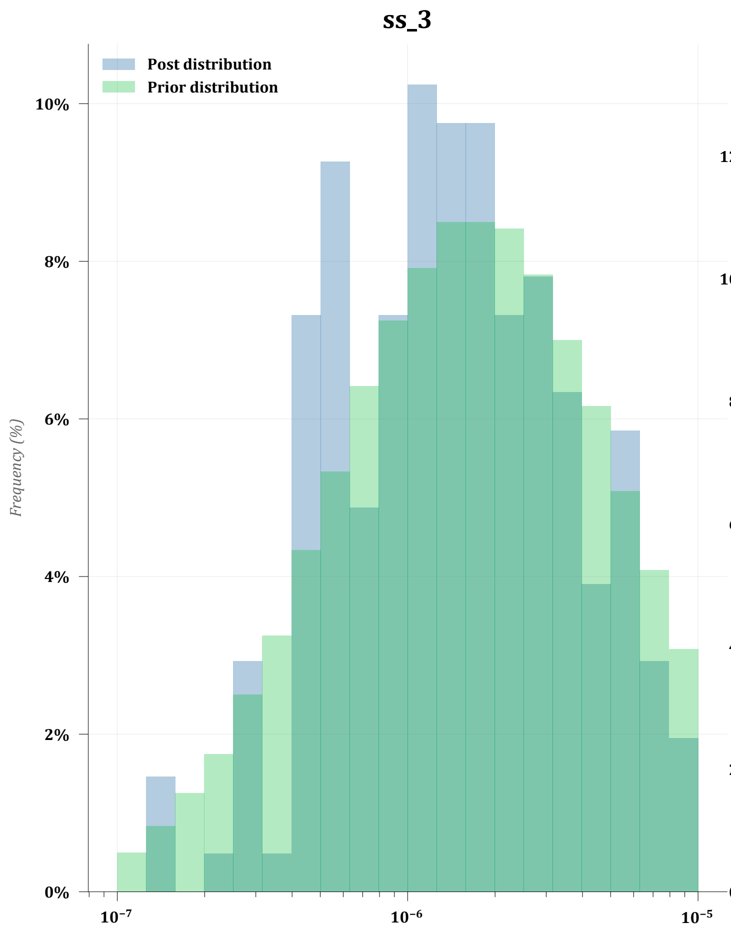
ss_3
Post distribution
Prior distribution
Frequency (%)
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2%
0%
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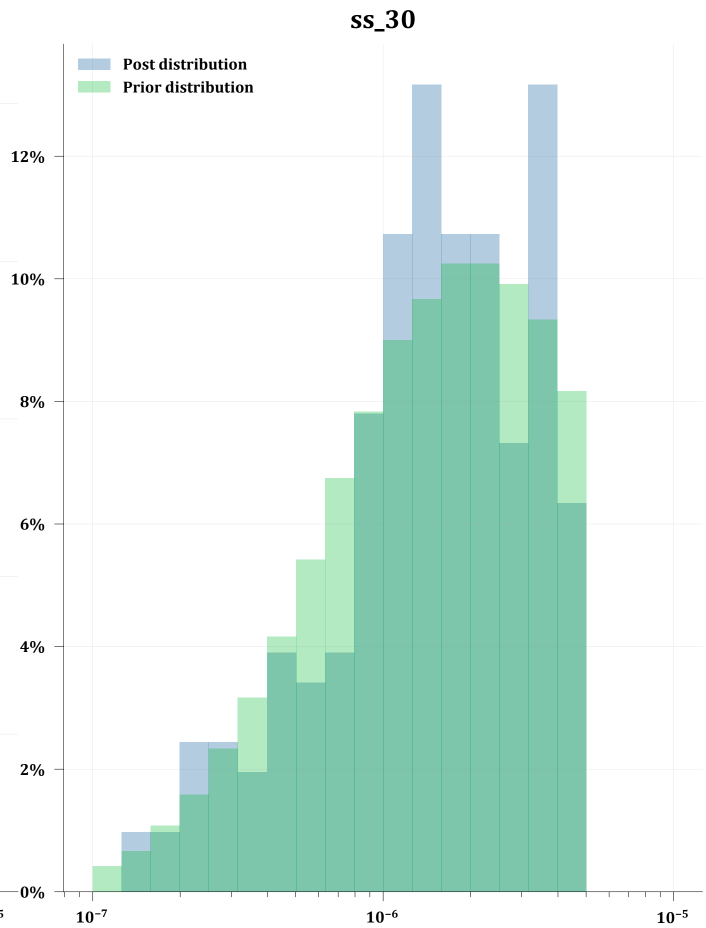
ss_30
Post distribution
Prior distribution
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0%
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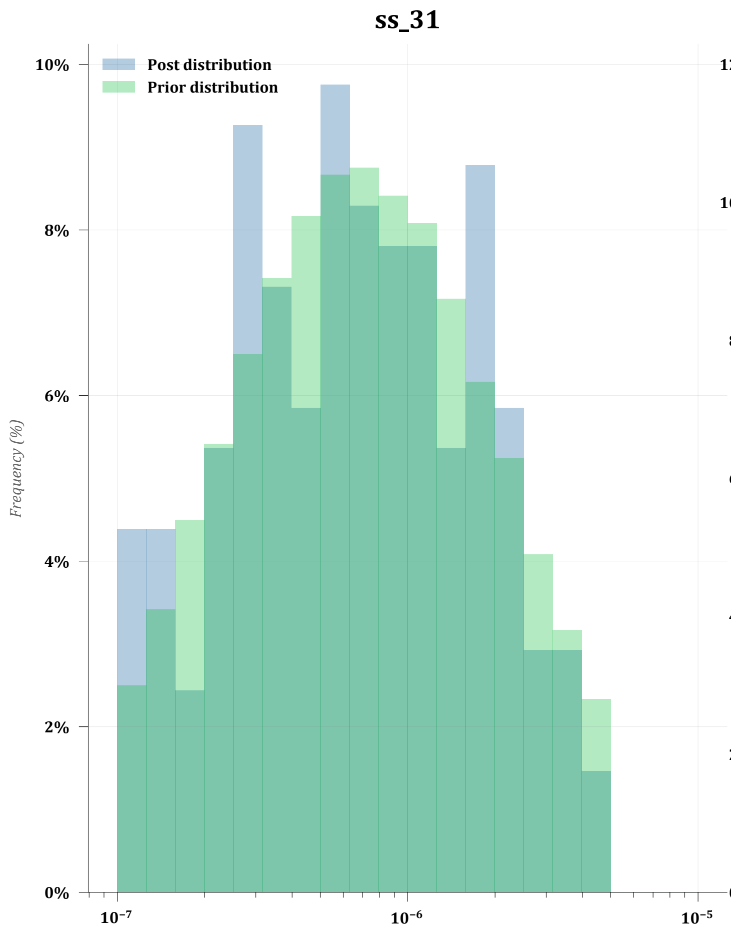
ss_31
Post distribution
Prior distribution
Frequency (%)
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6%
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2%
0%
10^{-7}
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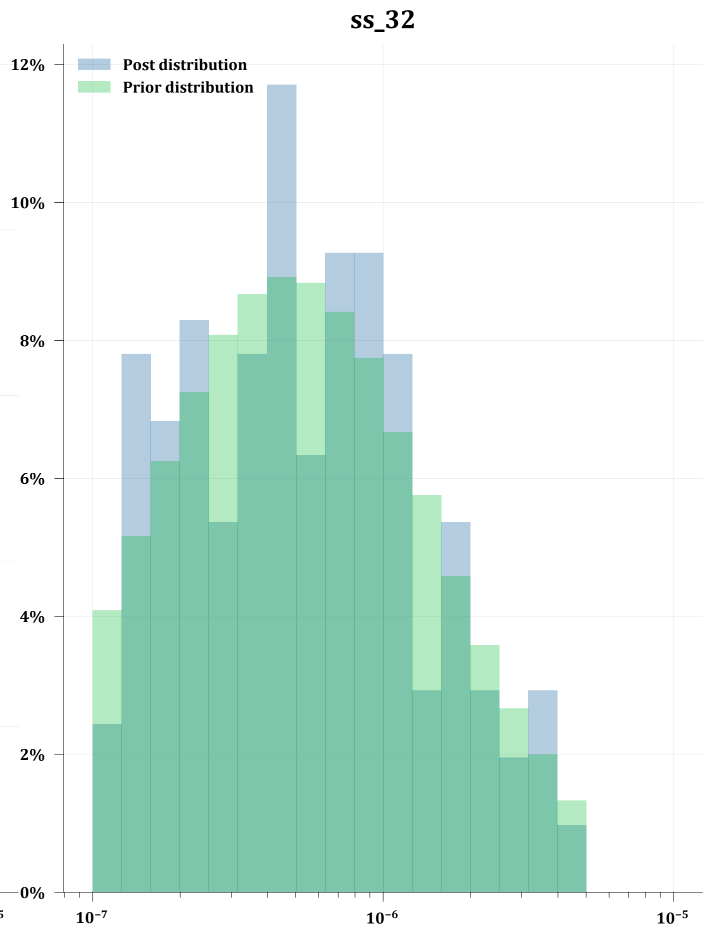
ss_32
Post distribution
Prior distribution
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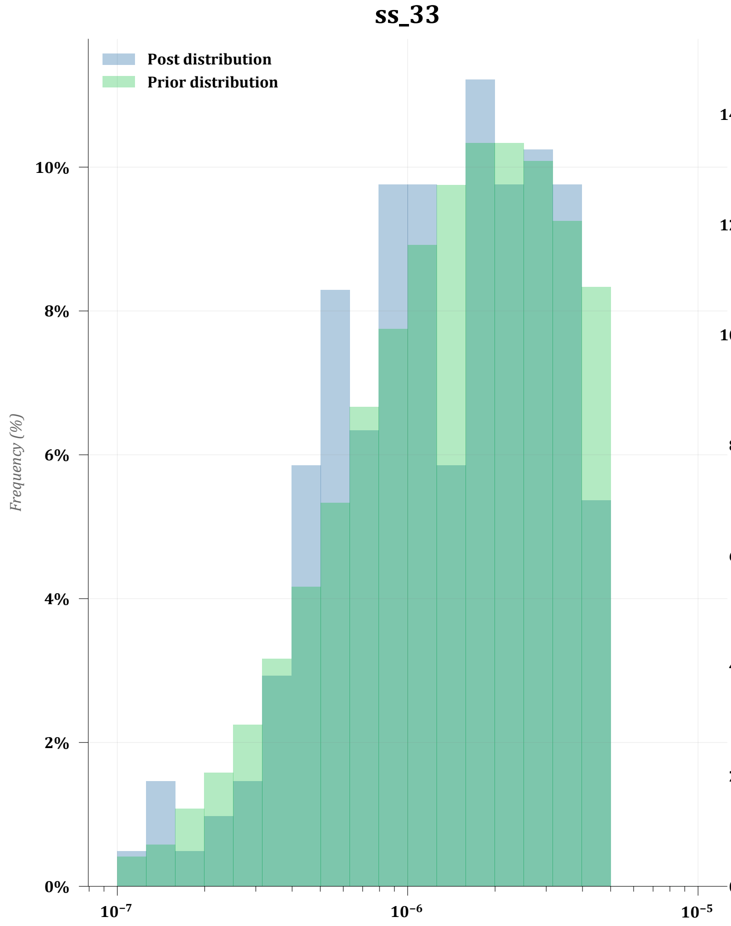
ss_33
Post distribution
Prior distribution
Frequency (%)
10%
8%
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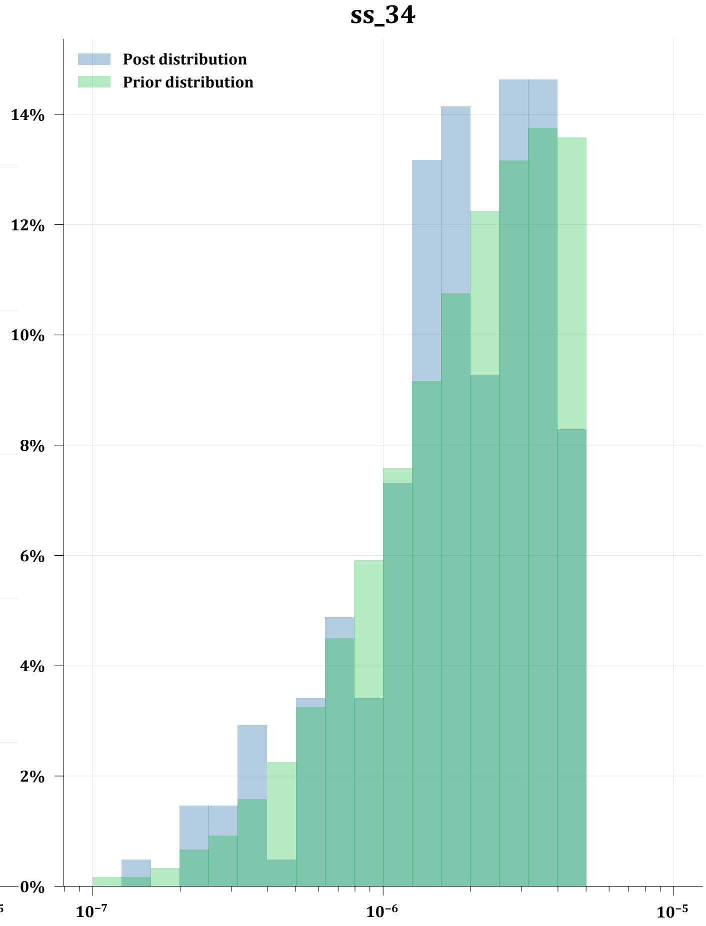
ss_34
Post distribution
Prior distribution
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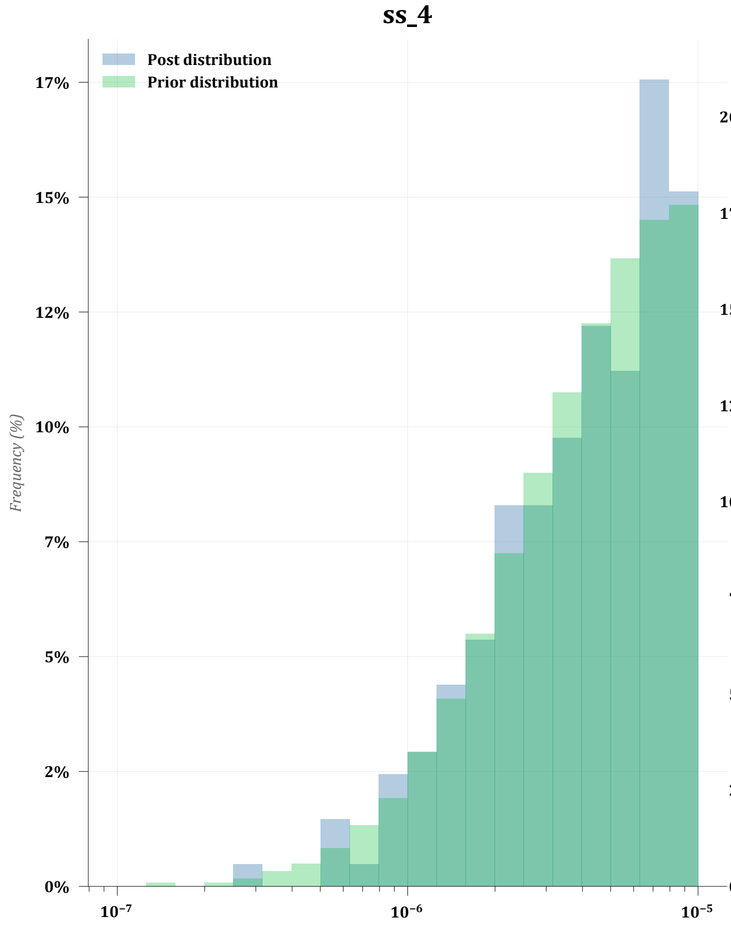
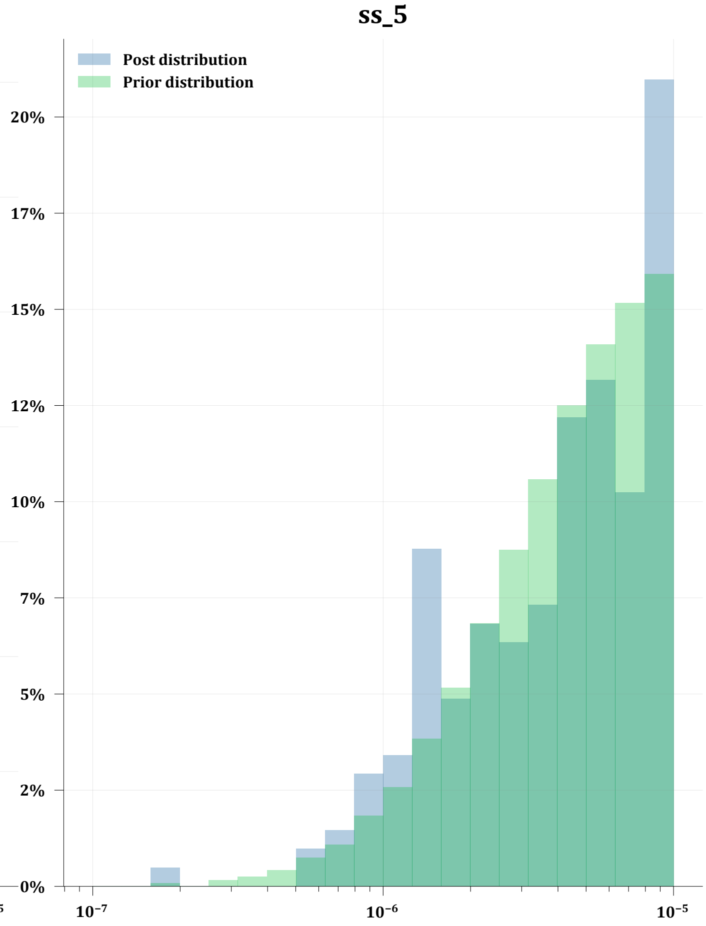
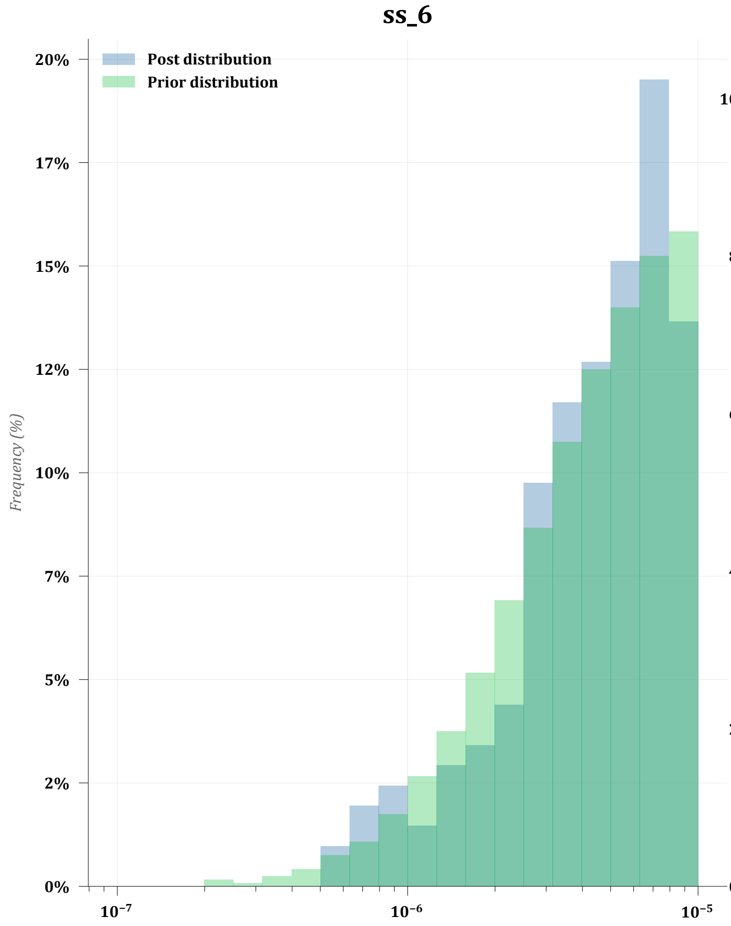
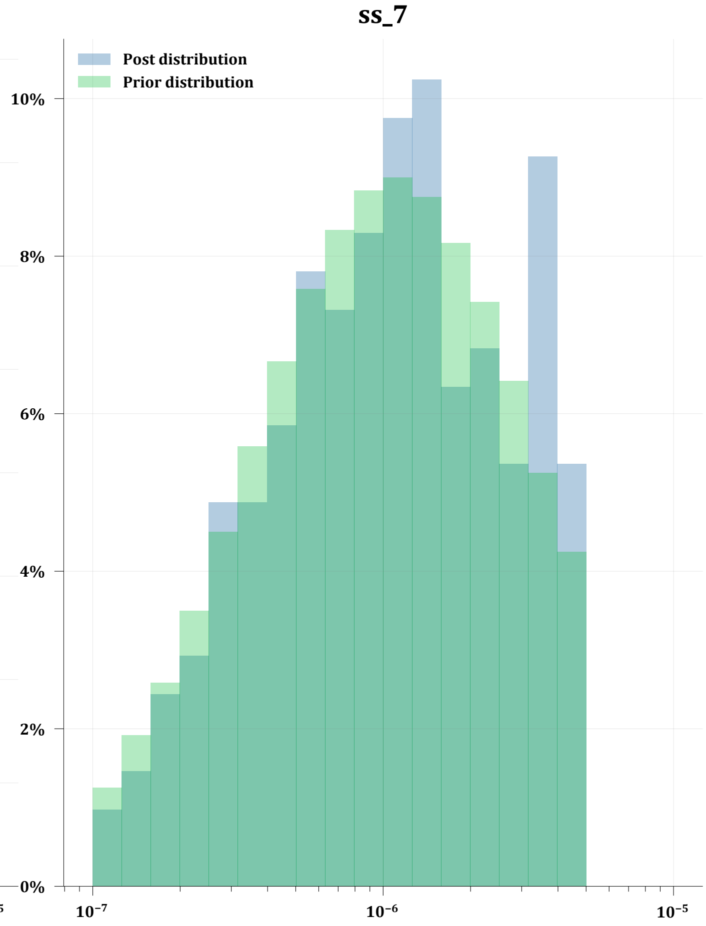
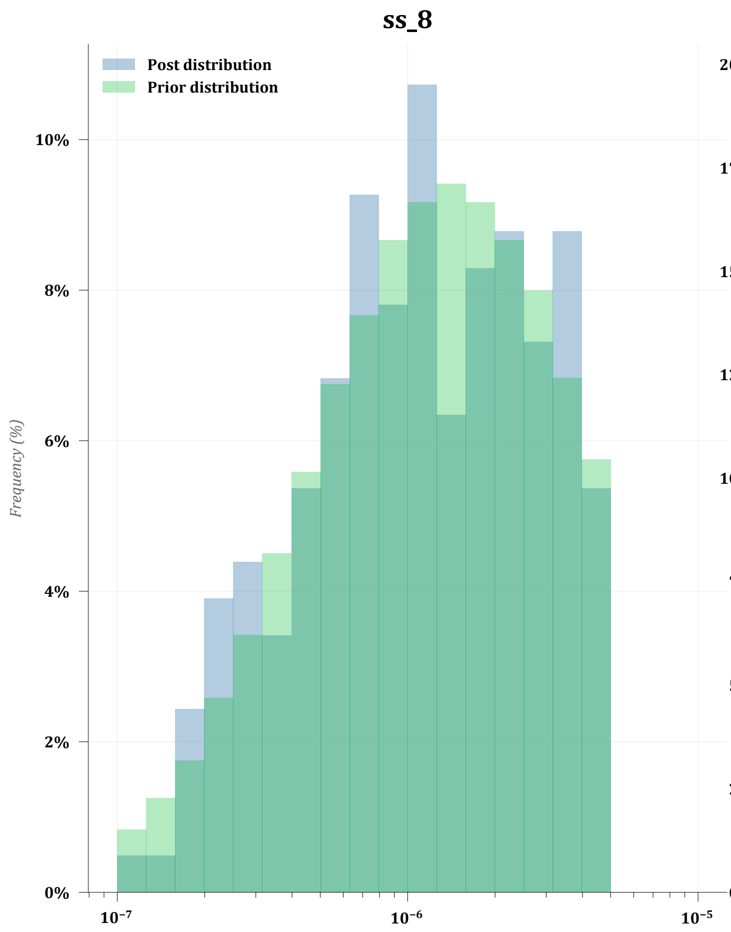
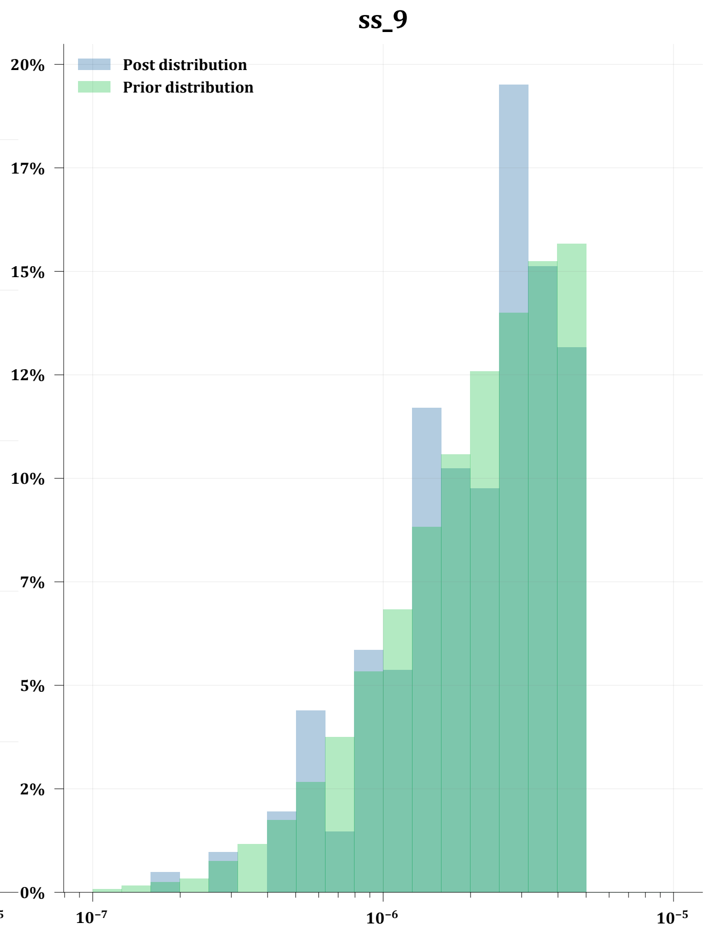

ss_4
Post distribution
Prior distribution
Frequency (%)
17%
15%
12%
10%
7%
5%
2%
0%
10^{-7}
10^{-6}
10^{-5}

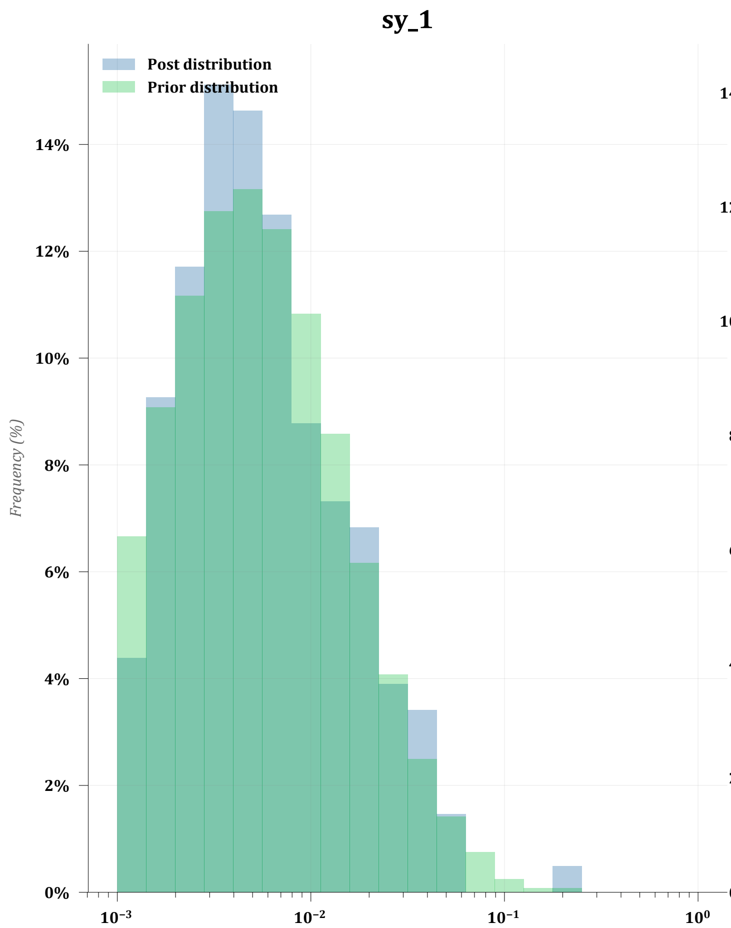

ss_5
Post distribution
Prior distribution
20%
17%
15%
12%
10%
7%
5%
2%
0%
10^{-7}
10^{-6}
10^{-5}

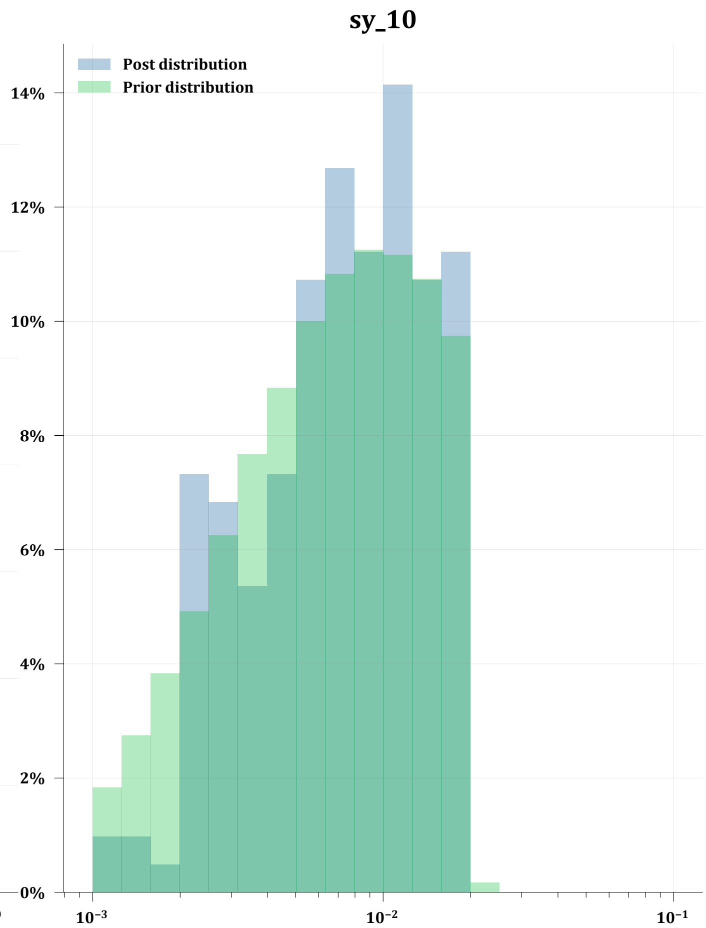

ss_6
Post distribution
Prior distribution
Frequency (%)
20%
17%
15%
12%
10%
7%
5%
2%
0%
10^{-7}
10^{-6}
10^{-5}

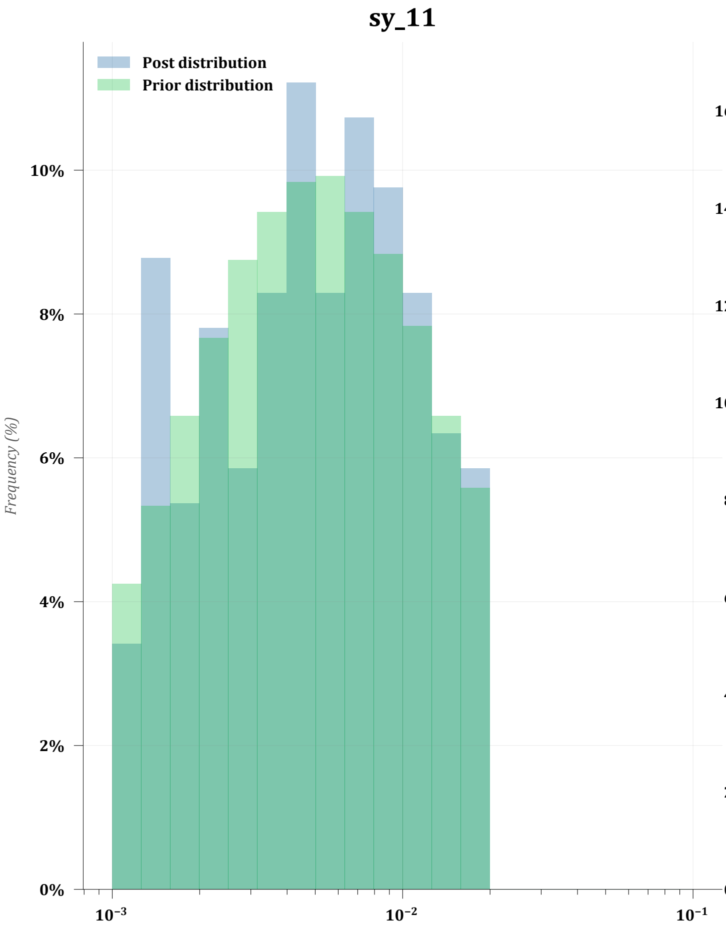

ss_7
Post distribution
Prior distribution
10%
8%
6%
4%
2%
0%
10^{-7}
10^{-6}
10^{-5}

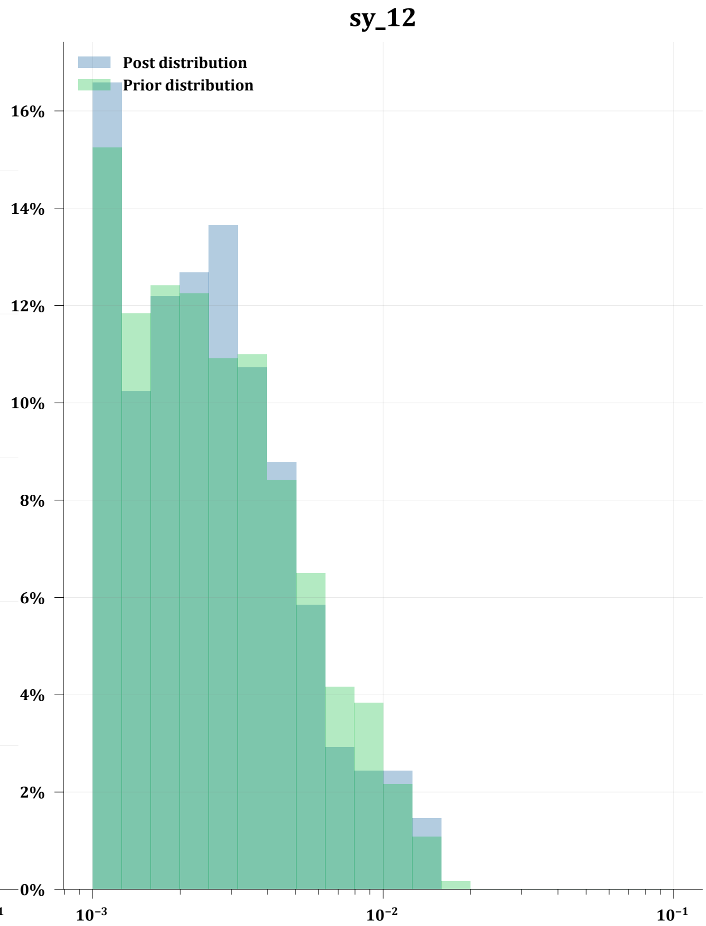

ss_8
Post distribution
Prior distribution
Frequency (%)
10%
8%
6%
4%
2%
0%
10^{-7}
10^{-6}
10^{-5}

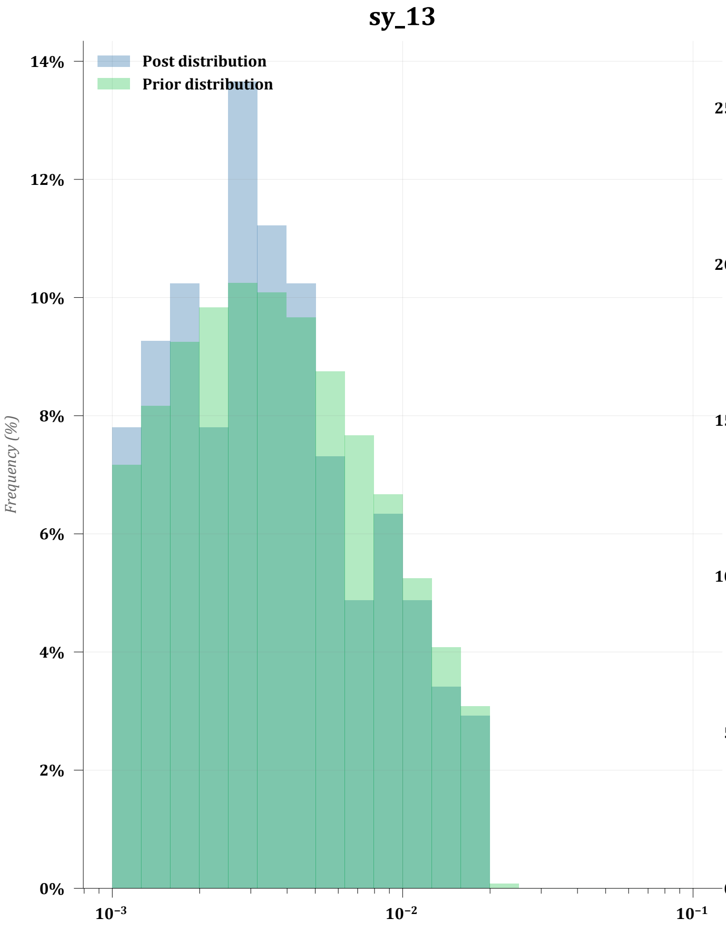

ss_9
Post distribution
Prior distribution
20%
17%
15%
12%
10%
7%
5%
2%
0%
10^{-7}
10^{-6}
10^{-5}

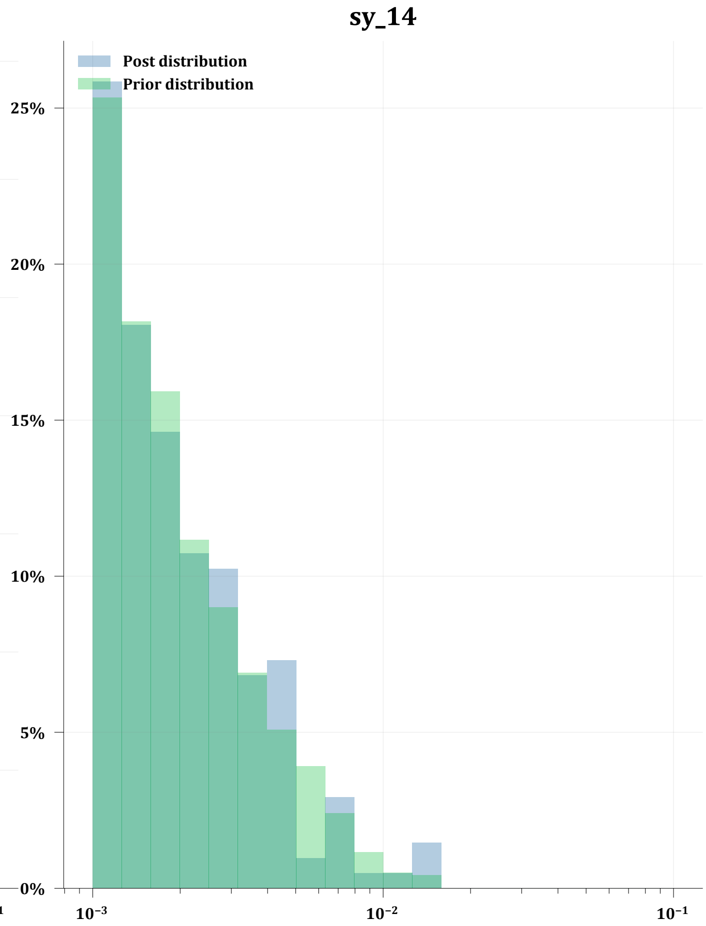

sy_1
Post distribution
Prior distribution
Frequency (%)
14%
12%
10%
8%
6%
4%
2%
0%
10^{-3}
10^{-2}
10^{-1}
10^{0}

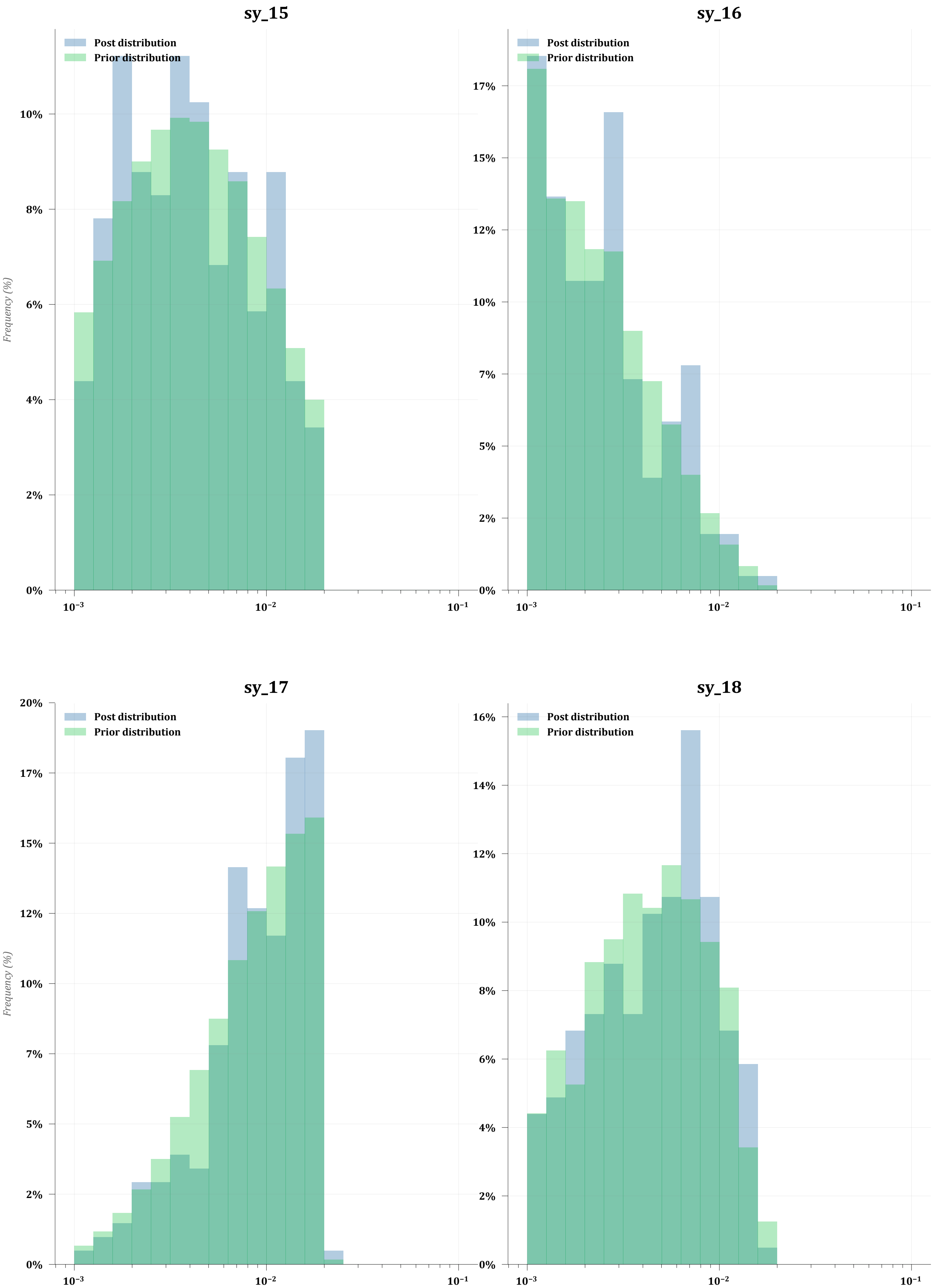

sy_10
Post distribution
Prior distribution
14%
12%
10%
8%
6%
4%
2%
0%
10^{-3}
10^{-2}
10^{-1}

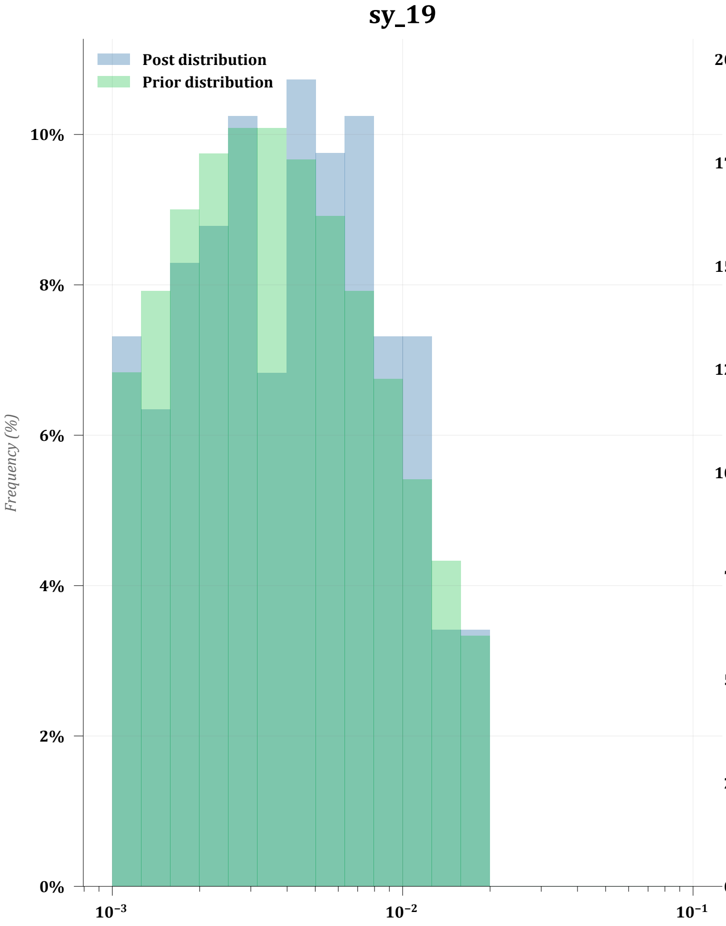

sy_11
Post distribution
Prior distribution
Frequency (%)
0%
2%
4%
6%
8%
10%
10^{-3}
10^{-2}
10^{-1}

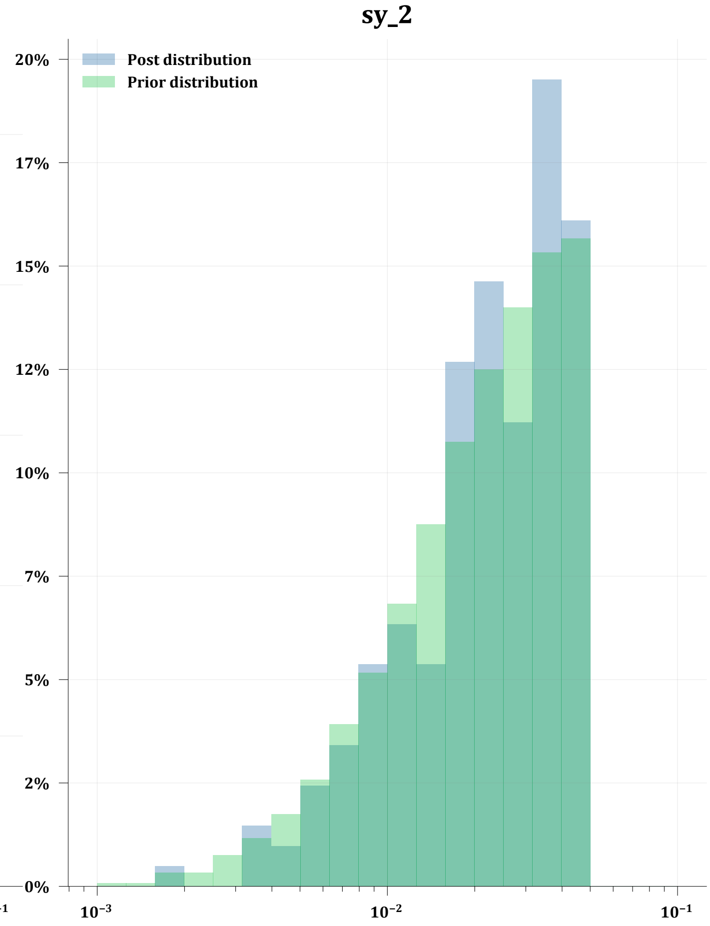

sy_12
Post distribution
Prior distribution
0%
2%
4%
6%
8%
10%
12%
14%
16%
10^{-3}
10^{-2}
10^{-1}

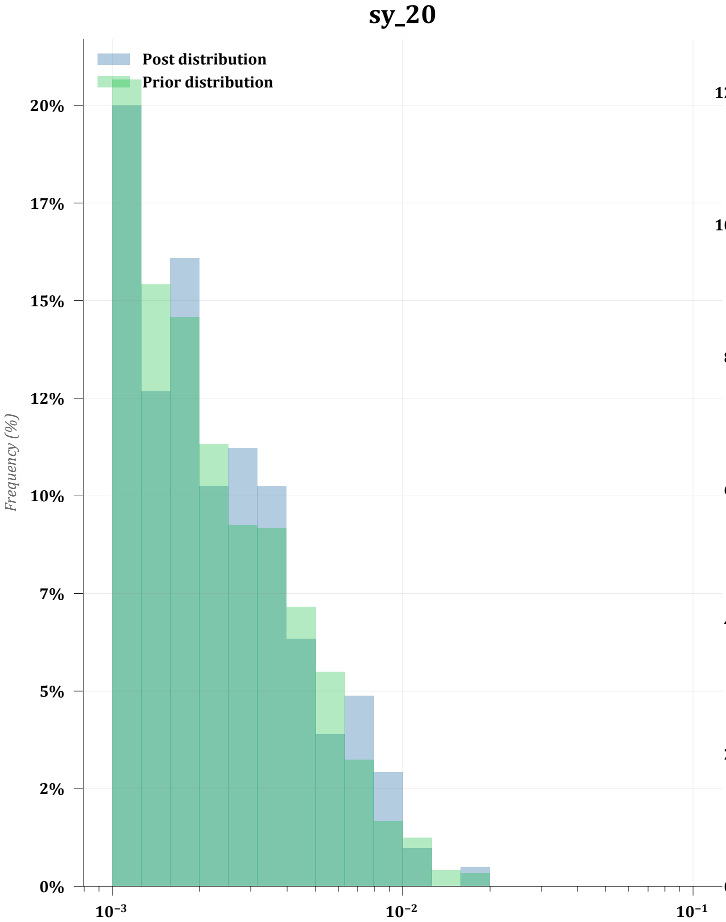

sy_13
Post distribution
Prior distribution
Frequency (%)
0%
2%
4%
6%
8%
10%
12%
14%
10^{-3}
10^{-2}
10^{-1}

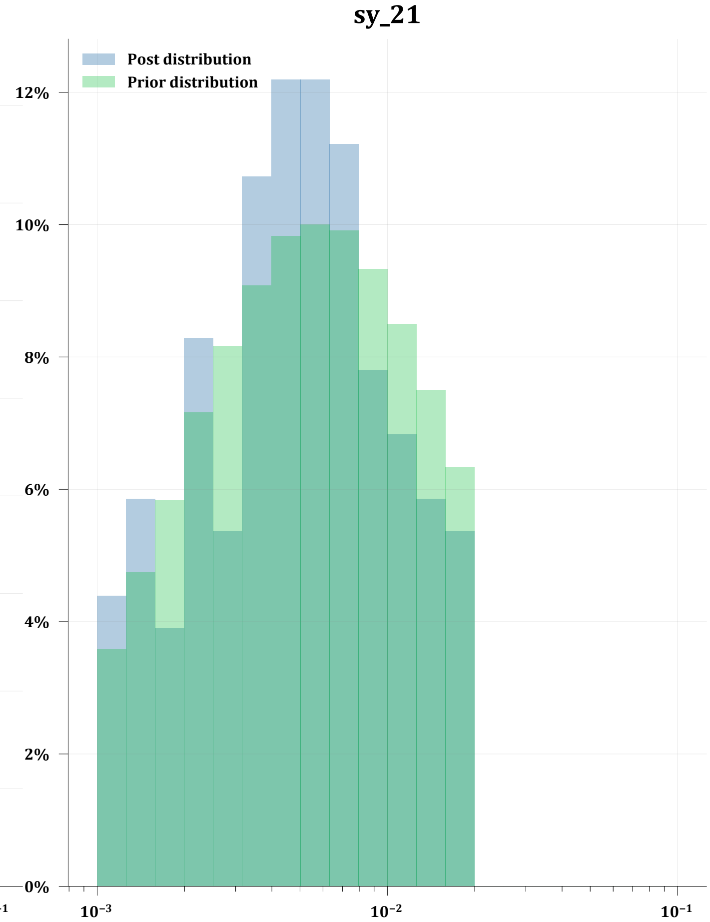

sy_14
Post distribution
Prior distribution
0%
5%
10%
15%
20%
25%
10^{-3}
10^{-2}
10^{-1}

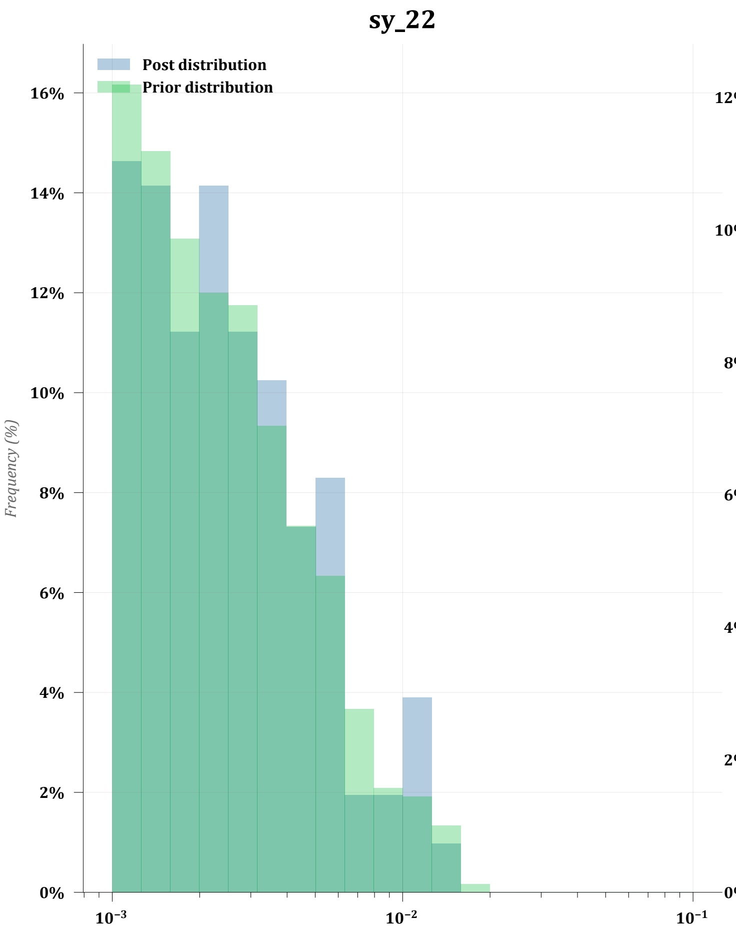

sy_15
Post distribution
Prior distribution
Frequency (%)
sy_16
Post distribution
Prior distribution
sy_17
Post distribution
Prior distribution
Frequency (%)
sy_18
Post distribution
Prior distribution

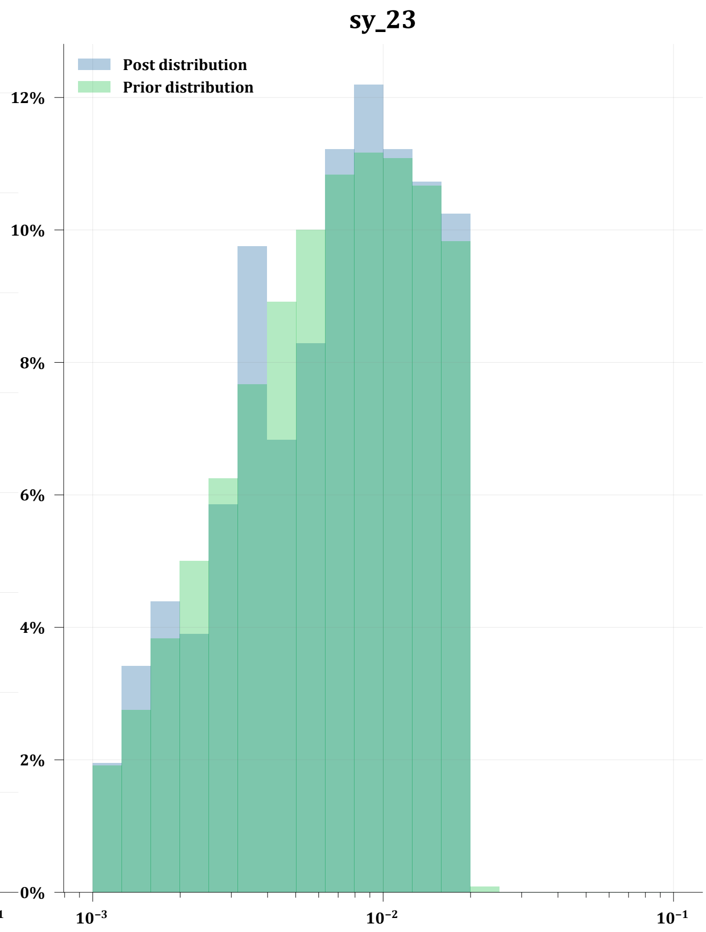

sy_19
Post distribution
Prior distribution
Frequency (%)
0%
2%
4%
6%
8%
10%
10^{-3}
10^{-2}
10^{-1}

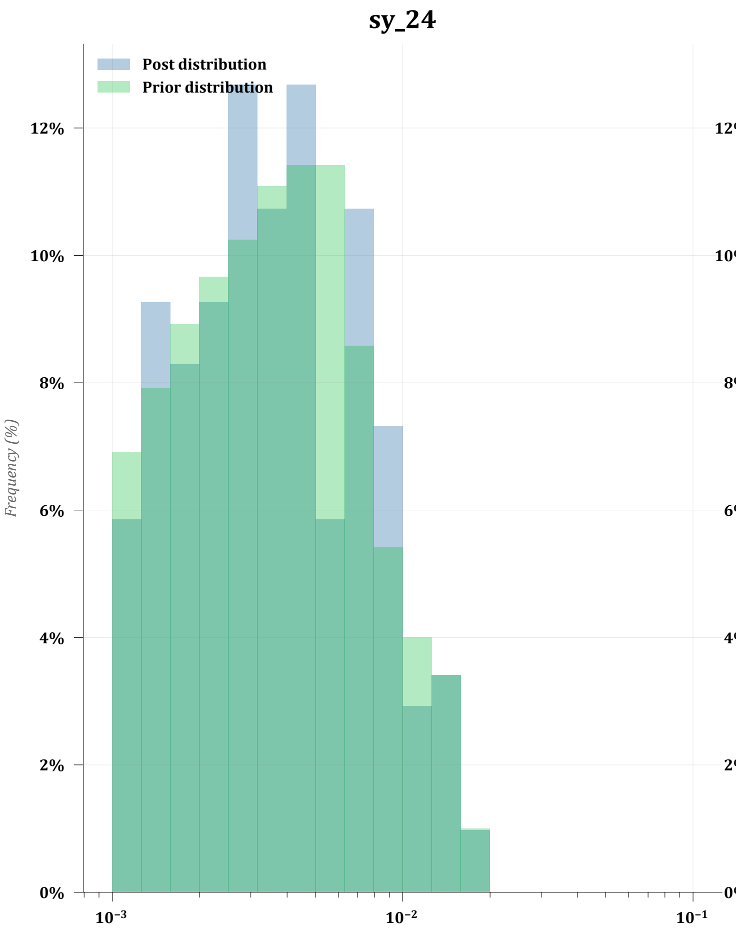

sy_2
Post distribution
Prior distribution
0%
2%
5%
7%
10%
12%
15%
17%
20%
10^{-3}
10^{-2}
10^{-1}

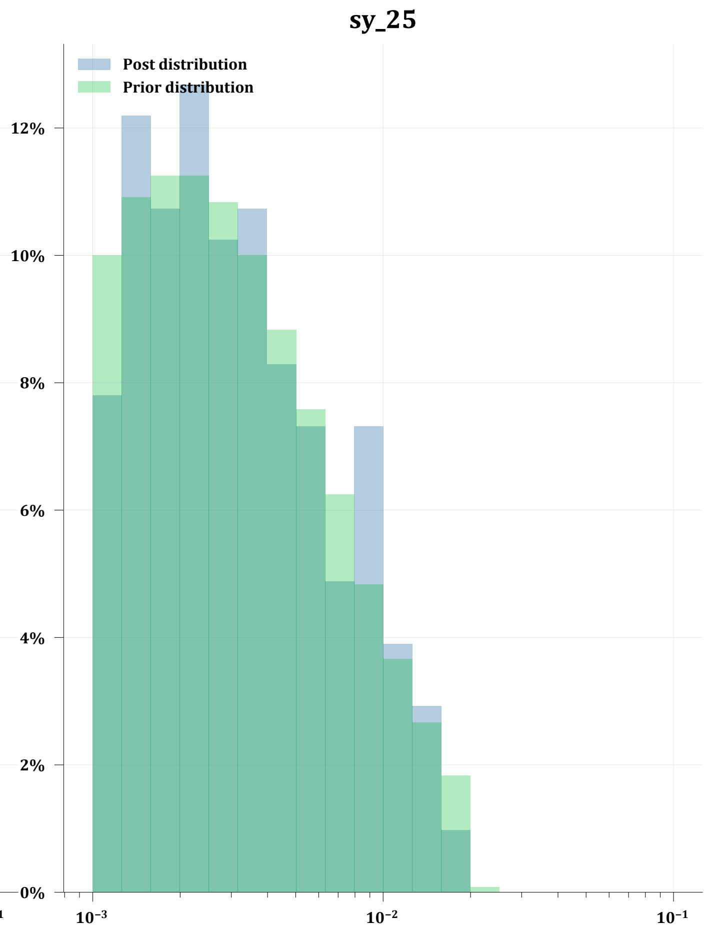

sy_20
Post distribution
Prior distribution
Frequency (%)
0%
2%
5%
7%
10%
12%
15%
17%
20%
10^{-3}
10^{-2}
10^{-1}

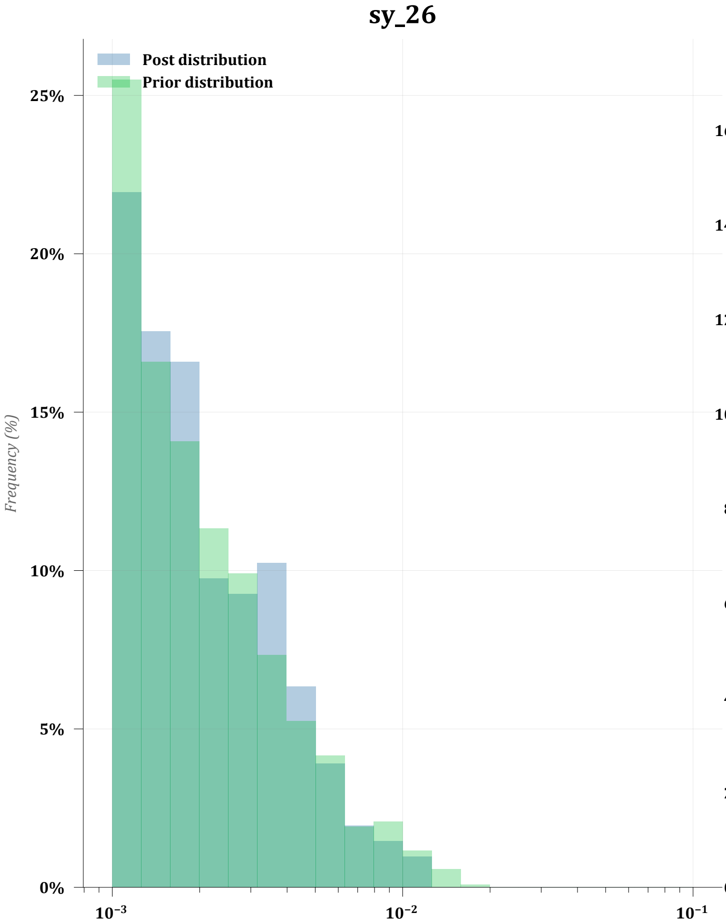

sy_21
Post distribution
Prior distribution
0%
2%
4%
6%
8%
10%
12%
10^{-3}
10^{-2}
10^{-1}

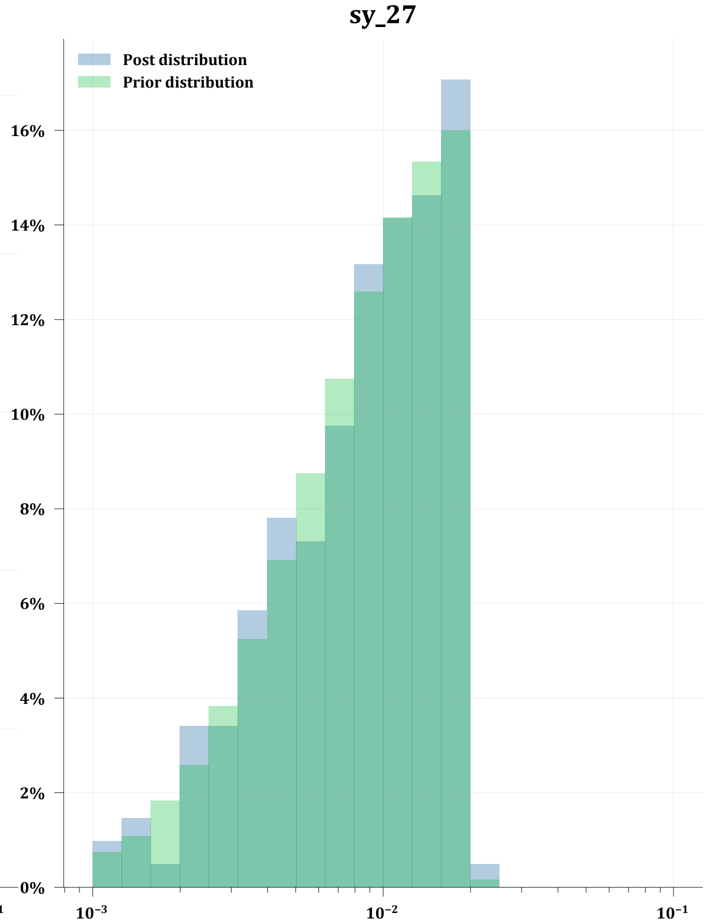

sy_22
Post distribution
Prior distribution
Frequency (%)
16%
14%
12%
10%
8%
6%
4%
2%
0%
10^{-3}
10^{-2}
10^{-1}

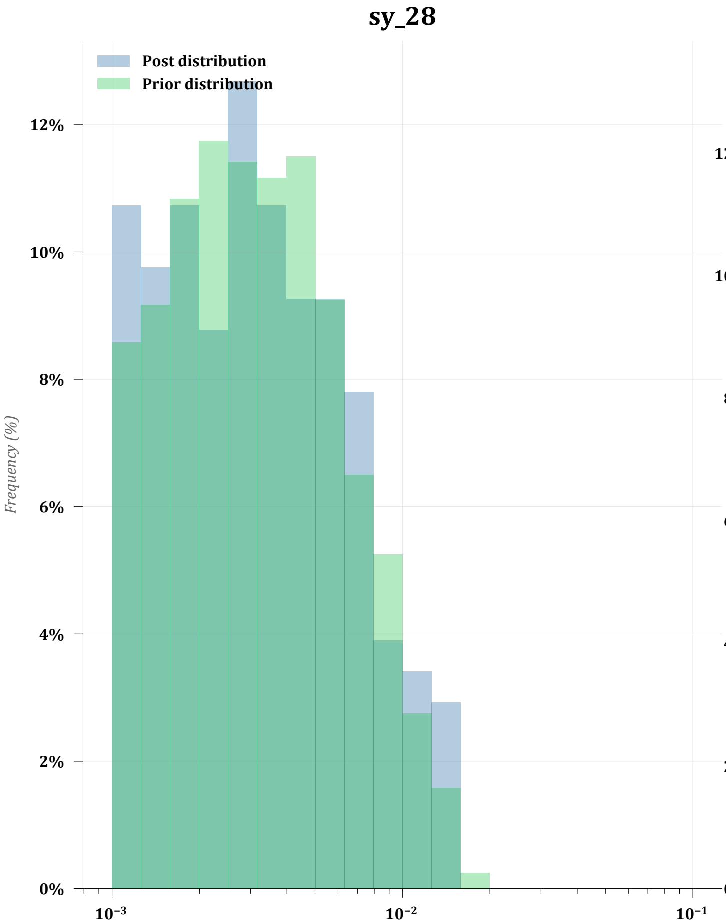

sy_23
Post distribution
Prior distribution
12%
10%
8%
6%
4%
2%
0%
10^{-3}
10^{-2}
10^{-1}

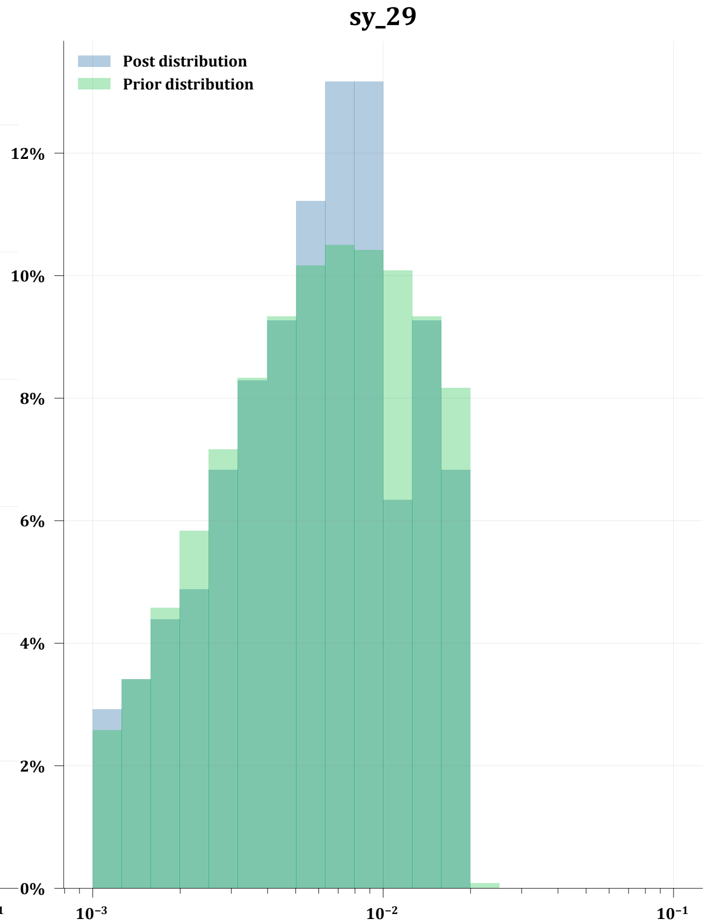

sy_24
Post distribution
Prior distribution
Frequency (%)
12%
10%
8%
6%
4%
2%
0%
10^{-3}
10^{-2}
10^{-1}

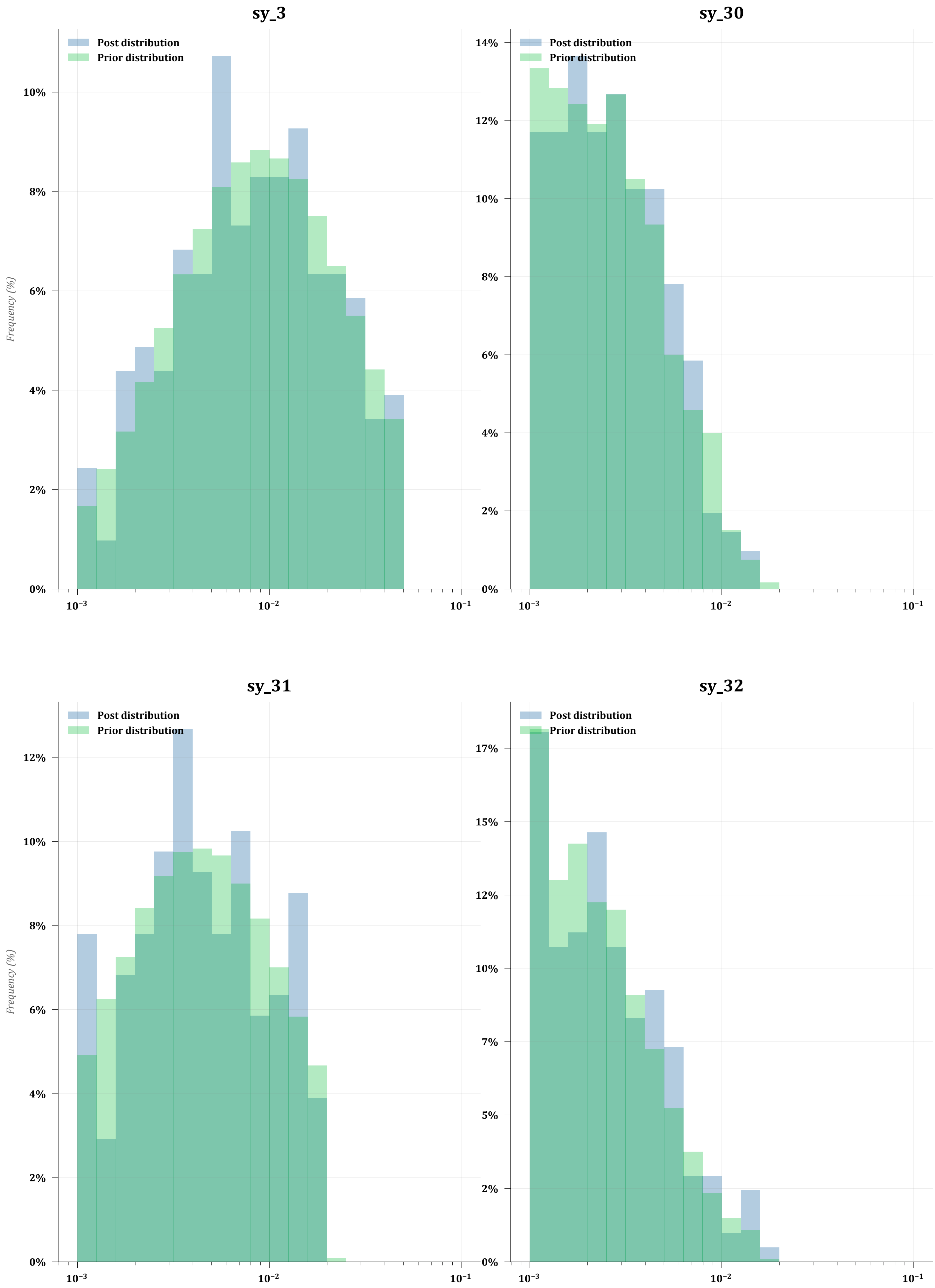

sy_25
Post distribution
Prior distribution
12%
10%
8%
6%
4%
2%
0%
10^{-3}
10^{-2}
10^{-1}

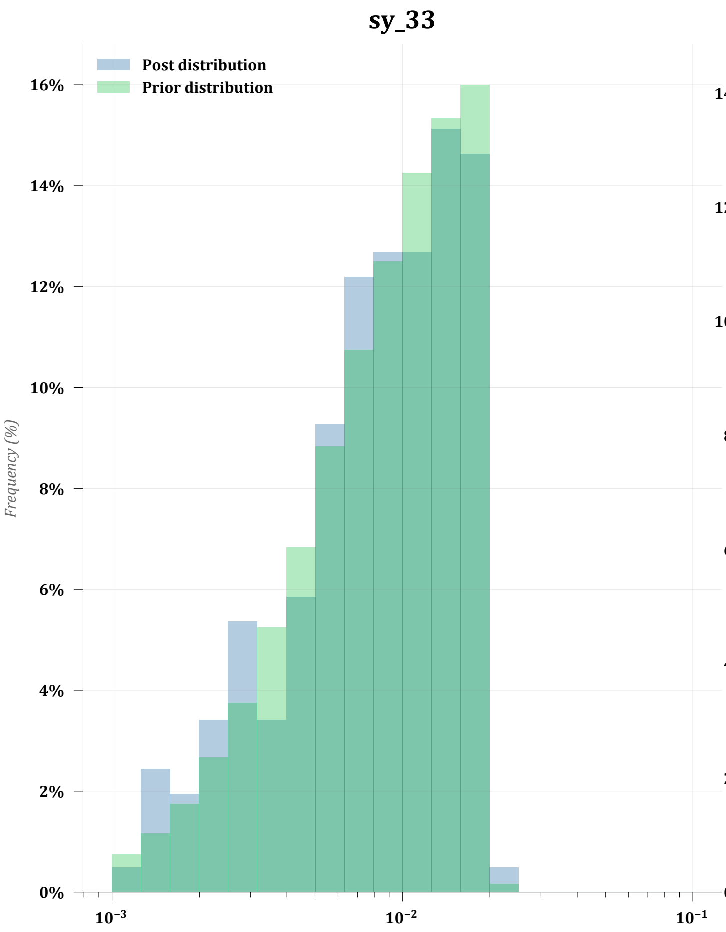

sy_26
Post distribution
Prior distribution
Frequency (%)
25%
20%
15%
10%
5%
0%
10^{-3}
10^{-2}
10^{-1}

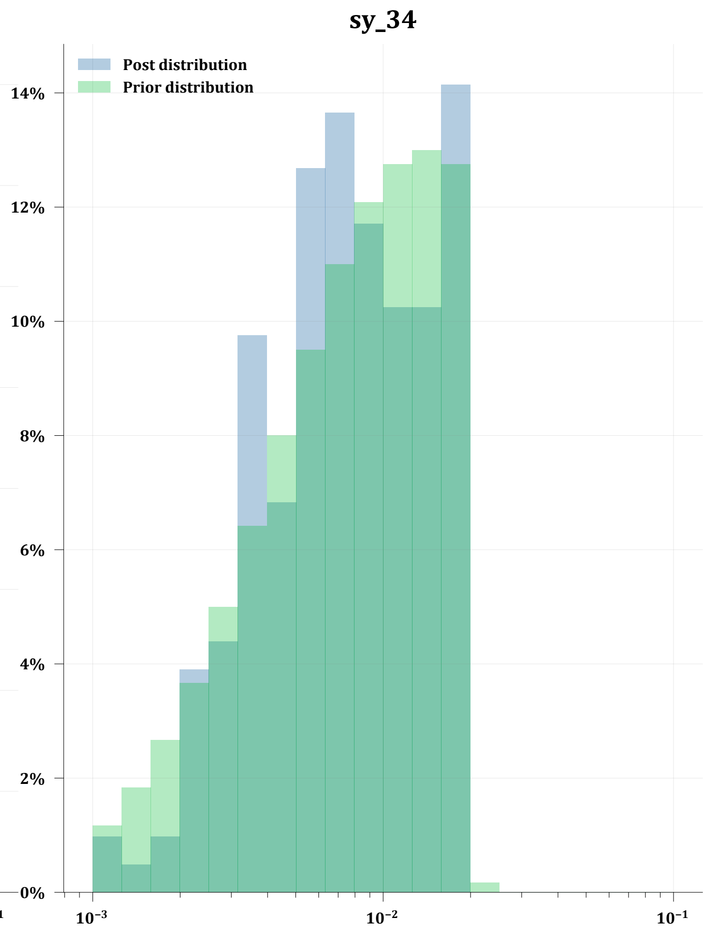

sy_27
Post distribution
Prior distribution
16%
14%
12%
10%
8%
6%
4%
2%
0%
10^{-3}
10^{-2}
10^{-1}

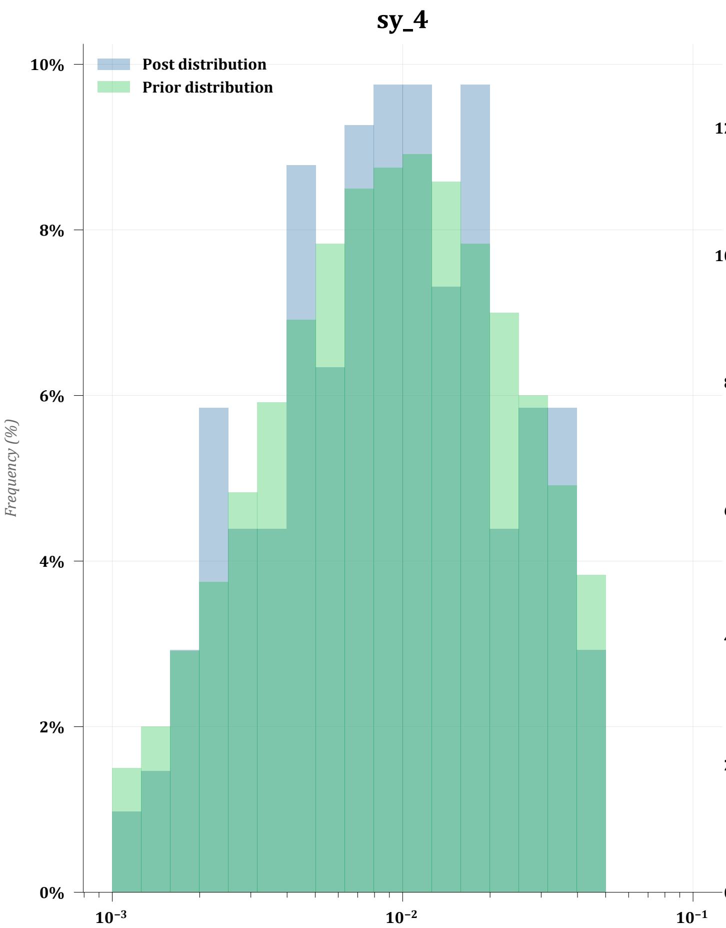

sy_28
Post distribution
Prior distribution
Frequency (%)
12%
10%
8%
6%
4%
2%
0%
10^{-3}
10^{-2}
10^{-1}

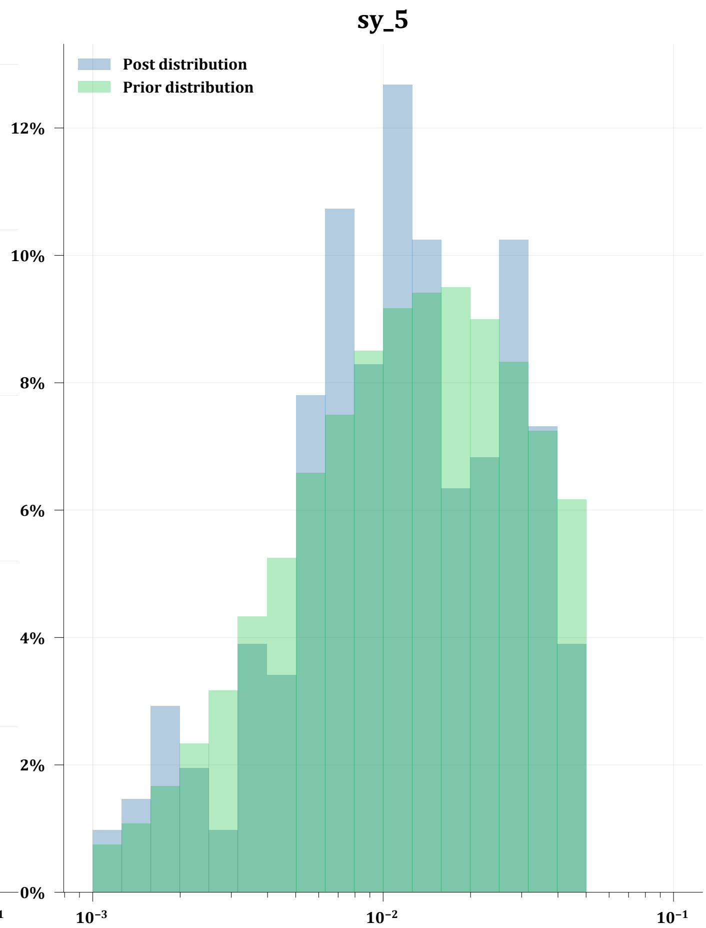

sy_29
Post distribution
Prior distribution
12%
10%
8%
6%
4%
2%
0%
10^{-3}
10^{-2}
10^{-1}

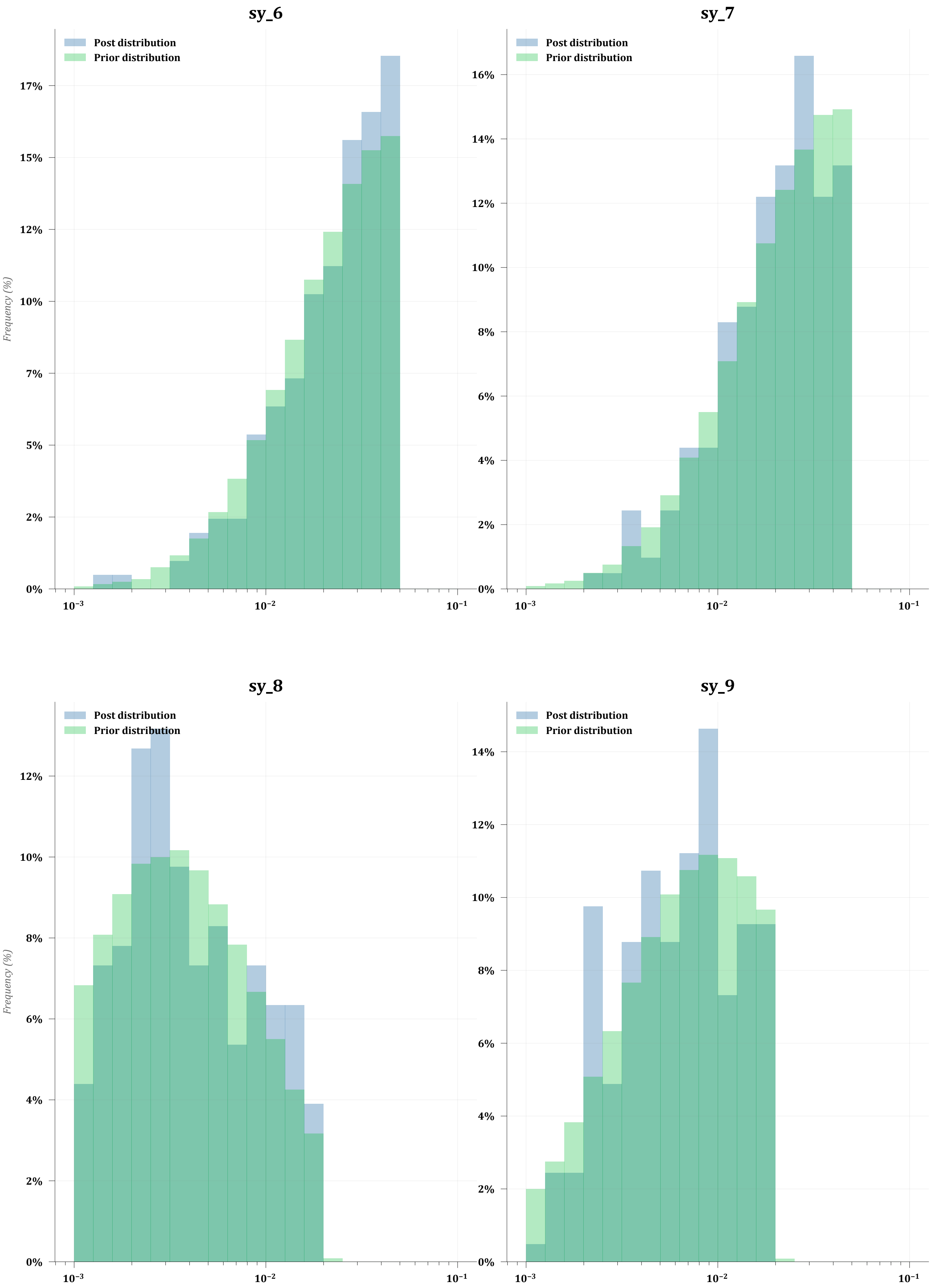

sy_3
sy_30
sy_31
sy_32
Post distribution
Prior distribution
Frequency (%)
0%
2%
4%
6%
8%
10%
12%
14%
5%
7%
15%
17%
10⁻³
10⁻²
10⁻¹


sy_33
Post distribution
Prior distribution
Frequency (%)
16%
14%
12%
10%
8%
6%
4%
2%
0%
10⁻³
10⁻²
10⁻¹


sy_34
Post distribution
Prior distribution
14%
12%
10%
8%
6%
4%
2%
0%
10⁻³
10⁻²
10⁻¹


sy_4
Post distribution
Prior distribution
Frequency (%)
10%
8%
6%
4%
2%
0%
10⁻³
10⁻²
10⁻¹


sy_5
Post distribution
Prior distribution
12%
10%
8%
6%
4%
2%
0%
10⁻³
10⁻²
10⁻¹


sy_6
Post distribution
Prior distribution
Frequency (%)
0%
2%
5%
7%
10%
12%
15%
17%
10⁻³
10⁻²
10⁻¹
sy_7
Post distribution
Prior distribution
0%
2%
4%
6%
8%
10%
12%
14%
16%
10⁻³
10⁻²
10⁻¹
sy_8
Post distribution
Prior distribution
Frequency (%)
0%
2%
4%
6%
8%
10%
12%
10⁻³
10⁻²
10⁻¹
sy_9
Post distribution
Prior distribution
0%
2%
4%
6%
8%
10%
12%
14%
10⁻³
10⁻²
10⁻¹

ATTACHMENT D

Maximum Drawdowns at registered bores

Work No. (bore ID)	Location (GDA94 z56)		Use	Depth (mbgl)	Aquifer	Calibrated Model - Predicted Drawdown (m)		95th Percentile Uncertainty Drawdown (m)	
	mE	mN				Wambo Complex (after 2003)	Incremental	Wambo Complex (after 2003)	Incremental
10010974	316585	6394626	Unknown	0	Alluvium	0.0	0.0	0.2	0.0
10011156	306219	6400469	Unknown	0	Alluvium	0.0	0.0	0.1	0.0
GW005327	314683	6394498	Bore Use	10.4	Aquifer	0.0	0.0	0.0	0.0
GW017462	315339	6391460	Stock	0	Alluvium	0.0	0.0	0.0	0.0
GW017644	306708	6399431	Farming	11.6	-	7.6	0.0	14.6	0.0
GW017646	306937	6399774	Irrigation	11	Weathered Permian	0.1	0.0	0.3	0.0
GW017647	307326	6399905	Unknown	9.1	Alluvium	0.1	0.0	0.3	0.0
GW017648	307397	6400276	Unknown	12.8	Weathered Permian	0.0	0.0	0.2	0.0
GW017798	307290	6399042	Irrigation	12.2	Alluvium	0.6	0.0	6.3	0.0
GW017799	306598	6398412	Unknown	12.2	Weathered Permian	1.9	0.0	6.3	0.5
GW017800	304413	6398000	Unknown	27.4	Weathered Permian	0.2	0.0	2.2	0.6
GW017801	304320	6397443	Unknown	42.7	Triassic Narrabeen	0.0	0.0	0.7	0.1
GW018045	302941	6398556	Stock	27.4	Triassic Narrabeen	0.0	0.0	0.3	0.0
GW018046	303013	6398866	Unknown	18.3	Coal (Newcastle Coal Measures)	0.0	0.0	0.0	0.0
GW018047	302620	6398920	Unknown	36.3	Coal (Newcastle Coal Measures)	0.0	0.0	0.2	0.0
GW022685	309088	6401184	Unknown	14.6	Coal (Newcastle Coal Measures)	0.0	0.0	0.0	0.0
GW027120	309501	6401185	Stock	13.4	Alluvium	0.0	0.0	0.0	0.0
GW030731	316680	6397640	Irrigation	0	Alluvium	0.0	0.0	0.0	0.0
GW037184	309685	6393911	Unknown	21	Alluvium	25.1	0.0	39.1	5.8
GW037734	309553	6401502	Exploration	13.4	Sandstone (overburden)	0.0	0.0	0.0	0.0
GW037998	311589	6392530	Irrigation	10.9	Alluvium	9.2	0.0	12.0	3.7
GW037999	311482	6392713	Irrigation	13.7	Alluvium	11.7	0.0	15.6	5.2
GW038000	311457	6392620	Irrigation	9.4	Shale	6.1	0.0	8.7	2.8

Work No. (bore ID)	Location (GDA94 z56)		Use	Depth (mbgl)	Aquifer	Calibrated Model - Predicted Drawdown (m)		95th Percentile Uncertainty Drawdown (m)	
	mE	mN				Wambo Complex (after 2003)	Incremental	Wambo Complex (after 2003)	Incremental
GW038579	309738	6393882	Irrigation	20.9	Shale	27.0	0.0	40.6	6.9
GW042364	316824	6397645	Exploration	13.3	Weathered Permian	0.0	0.0	0.0	0.0
GW043225	303653	6398949	Unknown	22.5	Alluvium	0.0	0.0	0.5	0.1
GW043673	311486	6392467	Irrigation	9.4	Sandstone	5.9	0.0	8.6	2.7
GW043674	311303	6392525	Exploration	8.2	Shale	6.6	0.0	8.9	2.9
GW043675	311433	6392527	Exploration	8.5	Alluvium	5.8	0.0	8.4	2.6
GW043676	311480	6392805	Exploration	10.6	Alluvium	11.9	0.0	15.1	5.6
GW053123	309631	6402062	Exploration	13.1	Shale	0.0	0.0	0.0	0.0
GW053173	309101	6401449	Irrigation		Alluvium	0.0	0.0	0.0	0.0
GW053292	317670	6398097	Irrigation and stock	10	Alluvium	0.0	0.0	0.0	0.0
GW060326	314104	6393348	Irrigation	9.8	Alluvium	0.0	0.0	0.1	0.0
GW060327	314181	6393442	Mining	9.8		0.0	0.0	0.1	0.0
GW060328	314205	6393534	Mining	10	-	0.0	0.0	0.1	0.0
GW060329	311904	6392474	Mining	6.4	-	4.6	0.0	5.9	1.7
GW060330	311727	6392163	Mining	6.2	-	4.8	0.0	6.9	2.2
GW060750	314310	6394923	Mining	24.4	-	2.2	0.0	3.6	0.2
GW060780	305961	6399379	Domestic	25.5	Weathered Permian	1.9	0.0	7.2	0.1
GW064382	303908	6394477	Stock and domestic	60	Weathered Permian	0.1	0.0	1.5	0.0
GW065014	305777	6400368	HUSE	14.5	Sandstone	0.4	0.0	1.3	0.0
GW065117	311154	6390735	Irrigation	0	Weathered Permian	2.9	0.0	5.6	2.1
GW066606	311207	6390674	Irrigation	0	-	3.1	0.0	5.6	2.4
GW078055	310105	6390490	Domestic	0	-	87.5	0.0	103.8	49.5
GW078477	304007	6398988	Test	102.5	-	0.1	0.0	1.0	0.2

Work No. (bore ID)	Location (GDA94 z56)		Use	Depth (mbgl)	Aquifer	Calibrated Model - Predicted Drawdown (m)		95th Percentile Uncertainty Drawdown (m)	
	mE	mN				Wambo Complex (after 2003)	Incremental	Wambo Complex (after 2003)	Incremental
GW078574	309174	6390605	Domestic	0	Sandstone	1.3	0.0	2.8	0.7
GW078575	309505	6389687	Farming	0	-	0.4	0.0	1.3	0.4
GW078576	309764	6389784	Farming	0	-	0.0	0.0	0.0	0.0
GW078577	309969	6389973	Farming	0	-	0.3	0.0	1.6	0.3
GW079060	314596	6394852	Domestic	14.6	-	1.2	0.0	2.4	0.1
GW080502	308897	6390160	Unknown	0	-	68.3	0.1	86.8	52.5
GW080519	313622	6394161	Mining	10.5	Coarse Sand	0.2	0.0	0.9	0.1
GW080951	314619	6394878	Unknown	3.14	Alluvium	0.0	0.0	0.0	0.0
GW080952	314643	6394904	Unknown	1.59	Alluvium	0.0	0.0	0.0	0.0
GW200361	311833	6392209	Unknown	0	Alluvium	4.9	0.0	6.2	1.7
GW200624	310166	6392650	Test	260	Alluvium	9.8	0.0	202.7	30.0
GW200625	310901	6393375	Dewatering	270	-	95.8	0.0	133.1	30.1
GW200942	312325	6395750	Mining	37	-	32.3	0.0	78.8	1.0
GW200943	312332	6395760	Test	30	-	10.6	0.0	20.1	0.4
GW203459	311820	6392560	Test	55	-	11.7	0.0	21.3	4.8
Unbore	305430	6401656	Dewatering	0	Jerrys Plains, SG	0.0	0.0	0.0	0.0
GW34	307357	6395779	Dewatering	4	Jerrys Plains, SG	1.7	0.0	2.6	0.0
GW35	306988	6396012	Dewatering	9	Jerrys Plains, SG	6.1	0.1	10.0	0.6
GW36a	306248	6395901	Dewatering	16.4	Jerrys Plains, SG	2.7	0.2	17.4	0.6
GW36b	306247	6395907	Dewatering	7.9	Jerrys Plains, SG	3.9	0.4	6.4	0.8
SBXGW01	307010	6395886	Dewatering	51	Jerrys Plains, SG	23.6	0.0	46.5	1.0
SBXGW02_1	306911	6395943	Dewatering	65.8	Jerrys Plains, SG	60.7	0.0	67.2	10.8
SBXGW02_2	306911	6395943	Dewatering	61.7	Jerrys Plains, SG	21.7	0.0	43.3	1.1

Work No. (bore ID)	Location (GDA94 z56)		Use	Depth (mbgl)	Aquifer	Calibrated Model - Predicted Drawdown (m)		95th Percentile Uncertainty Drawdown (m)	
	mE	mN				Wambo Complex (after 2003)	Incremental	Wambo Complex (after 2003)	Incremental
SBXGW02_3	306911	6395943	Dewatering	53.7	Jerrys Plains, SG	21.7	0.0	43.3	1.1
SBXGW02a	306905	6395946	Dewatering	20	Jerrys Plains, SG	5.8	0.1	10.3	0.7
LW24_1	306148.9	6397786.7	Dewatering	40	Jerrys Plains, SG	11.3	6.0	6.4	0.8
LW24_2	306148.9	6397786.7	Dewatering	70	Jerrys Plains, SG	24.8	1.6	6.4	0.8
LW24_3	306148.9	6397786.7	Dewatering	125	Jerrys Plains, SG	47.1	0.4	6.4	0.8
LW25_1	305774.8	6397518.6	Dewatering	30	Jerrys Plains, SG	0.0	0.0	6.4	0.8
LW25_2	305774.8	6397518.6	Dewatering	55	Jerrys Plains, SG	1.0	0.6	6.4	0.8
LW25_3	305774.8	6397518.6	Dewatering	62	Jerrys Plains, SG	1.0	0.6	6.4	0.8
SBXX_ST07_1	305387.9	6396870.2	Dewatering	50	Jerrys Plains, SG	1.0	0.0	7.3	2.2
SBXX_ST07_2	305387.9	6396870.2	Dewatering	100	Jerrys Plains, SG	1.0	0.0	7.3	2.2
SBXX_ST07_3	305387.9	6396870.2	Dewatering	200	Jerrys Plains, SG	6.5	0.9	62.3	32.2
SBXX_ST07_4	305387.9	6396870.2	Dewatering	250	Jerrys Plains, SG	47.9	6.4	73.3	21.2

Appendix E:

Peer Review

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noel.merrick@hydroalgorithmics.com

DATE: 30 July 2022

TO: Wambo Coal Pty Limited
c/- Resource Strategies
PO Box 1842
Milton QLD 4064

FROM: Dr Noel Merrick

RE: Wambo Longwalls 24-26 Modification - Groundwater Peer Review

YOUR REF: PO 0453202366

OUR REF: HA2022/11a

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1. Introduction

This report provides a peer review of the groundwater assessment (GA) and associated modelling for the Wambo Longwalls 24-26 Modification (the Project). The GA has been prepared by SLR Consulting Australia Pty Ltd (SLR) under the coordination of Resource Strategies Pty Ltd (RS), for Wambo Coal Pty Ltd (WCPL) - a subsidiary of Peabody Energy Australia Pty Limited.

The Wambo Coal Mine is an existing open cut and underground mining operation situated approximately 15 kilometres (km) west of Singleton, near the village of Warkworth, New South Wales (NSW). The proposed Modification involves reorientation of approved Longwalls 24 and 25, and the addition of Longwall 26, for the South Bates Extension (SBX) mine at the northern limit of historical underground mining.

In addition, timing changes are proposed for the approved South Wambo Underground Mine to the south of SBX:

- mining to commence two years later than currently scheduled; and
- mine duration to increase from four to six years.

2. Documentation

The review is based on the following reports:

1. SLR, 2022, Wambo Coal Mine Longwalls 24-26 Modification: Groundwater Assessment. Report 665.10008.00815-R01-v4.0 prepared for Wambo Coal Pty Ltd, 28 July 2022. 134p (main) + 5 Appendices.

2. SLR, 2022, Wambo Coal Mine South Bates Extension Longwalls 24-26 Modification: Groundwater Modelling Technical Report. Report 665.10008.00815-R02-v4.0 prepared for Wambo Coal Pty Ltd, 28 July 2022. 124p (main) + 4 Attachments. *[Appendix D of Document #1]*

Document #1 has the following major sections:

1. Introduction
2. Legislative requirements and guidelines
3. Data requirements
4. Existing conditions
5. Geology
6. Hydrogeology
7. Groundwater Simulation Model
8. Impacts on groundwater resources
9. Conclusions
10. References

The Appendices to Document #1 are:

A. IESC Information Checklist
B. Structure of Groundwater Modelling Report – Following Groundwater Assessment Toolbox for Major Projects in NSW DPE (2022)
C. Preliminary VWP Hydrographs
D. Groundwater Modelling Technical Report
E. Peer Review

Document #2 has the following major sections:

1. Introduction
2. Model Construction and Development
3. Model Calibration
4. Predictive Modelling
5. Uncertainty analysis
6. Post mining recovery
7. Model confidence level classification
8. Groundwater model and data limitations
9. Conclusions
10. References.

The Attachments to Document #2 are:

A. Calibration Residuals
B. Calibration Hydrographs
C. Hydraulic Parameters and Recharge Zone Distribution
D. Uncertainty Analysis and Parameter Distribution

3. Review Methodology

While there are no standard procedures for peer reviews of entire groundwater assessments, there are two accepted guides to the review of groundwater models: the Murray-Darling Basin Commission (**MDBC**) Groundwater Flow Modelling Guideline[1], issued in 2001, and guidelines issued by the National Water Commission (**NWC**) in June 2012 (Barnett *et al.*, 2012[2]). Both guides also offer techniques for reviewing the non-modelling components of a groundwater impact assessment.

The NWC national guidelines were built upon the original MDBC guide, with substantial consistency in the model conceptualisation, design, construction and calibration principles, and the performance and review criteria, although there are differences in details.

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[1] MDBC (2001). Groundwater flow modelling guideline. Murray-Darling Basin Commission. URL: www.mdbc.gov.au/nrm/water_management/groundwater/groundwater_guides

[2] Barnett, B, Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A. (2012). *Australian Groundwater Modelling Guidelines*. Waterlines report 82, National Water Commission, Canberra.

The NWC guide promotes the concept of "model confidence level", which is defined using a number of criteria that relate to data availability, calibration, and prediction scenarios. The NWC guide is almost silent on coal mine modelling and offers no direction on best practice methodology for such applications. There is, however, an expectation of more effort in uncertainty analysis, although the guide is not prescriptive as to which methodology should be adopted.

Guidelines on uncertainty analysis for groundwater models were issued by the Independent Expert Scientific Committee (**IESC**) on Coal Seam Gas and Large Coal Mining Development in February 2018 in draft form and finalised in December 2018[3].

The groundwater guides include useful checklists for peer review. This groundwater assessment is being reviewed according to the review checklist in NWC (2012) and the 10-question Compliance Checklist in the NWC guide. The review checklist has questions on (1) Planning; (2) Conceptualisation; (3) Design and construction; (4) Calibration and sensitivity; (5) Prediction; (6) Uncertainty; (7) Solute transport; and (8) Surface water-groundwater interaction. The solute transport component is not relevant for this project. Non-modelling components of the groundwater assessment are addressed by the first two sections of the checklist.

This review was conducted progressively, with involvement of the peer reviewer at all stages of model development and application. The reviewer was the developer of an early groundwater model for the Wambo Mine, referenced in Document #1 as Heritage Computing (2012), and provided technical direction for most of the subsequent groundwater assessments by HydroSimulations (prior to 2019).

The interaction has been conducted through:

- Several videoconferences with RS and SLR.
- Three telephone discussions with the SLR modeller.
- Review of progressive report text.
- Progressive update and resolution of a Log of Issues.
- Progressive update and disclosure of the NWC checklist.

The finalised peer review checklist is presented at **Table A**. This contains the primary detail on the review of the groundwater assessment, but supplementary comments on groundwater modelling aspects are offered in the following sections.

Table B is the NWC Compliance Checklist, which concludes that the groundwater model is “fit for purpose”, where the purpose is the prediction of quantitative potential water level impacts and inferred qualitative potential water quality and ecosystem impacts due to Project mining and cumulative impacts.

During the progressive review of draft report sections, minor editorial changes and comments were proffered in track-changes versions of Word documents.

4. Model Design and Construction

The modelling objectives are itemised in Section 1 of Document #2 in the form of five dot points:

- *“assess the groundwater inflow to the mine workings as a function of mine position and timing;*
- *simulate and predict the extent of dewatering due to the Project and the level and rate of drawdown at specific locations;*
- *identify areas of potential risk, where groundwater impact mitigation/control measures may be necessary;*
- *estimate direct and indirect water take; and*
- *estimate post-mining recovery conditions.”*

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[3] Middlemis H and Peeters LJM (2018) *Uncertainty analysis—Guidance for groundwater modelling within a risk management framework*. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy, Commonwealth of Australia 2018.

The technical modelling report (Document #2) consists of 124 pages of text and figures, plus four Attachments. It documents the update of a groundwater model that has had a long period of evolution since 2012, having been developed initially by Heritage Computing and subsequently modified by HydroSimulations and SLR. Document #2 describes the first version of the model that makes use of an unstructured grid of Voronoi cells achieved by coupling MODFLOW-USG and AlgoMesh software.

Voronoi cells allow variable internal resolution, down to a minimum cell dimension of 25 m for this model. At the same time, the computational effort is reduced by the number of cells going from about 2 million to just over 1 million cells, a pragmatic target for efficient modelling. The modelled area is about 20 km (east-west) by about 22 km (north-south) but the model extent is no longer rectangular. There are 30 layers in the model, 12 of which represent coal seams targeted by the various coal mines within the model extent.

The model includes several temporal stages:

- a warm-up period from 1970 to January 2003;
- a transient calibration period from January 2003 to December 2020;
- a prediction period from January 2021 to December 2041; and
- a post-mining recovery period from January 2042 to December 2400.

The model has been constructed and applied to address the specified objectives.

Overall, there are no significant matters of concern in the model design and construction phase. However, there are minimal technical details provided on the solver attributes that are adopted for efficient convergence of the simulations.

The report includes an assessment of model confidence level classification, in the form advocated by the IESC. This indicates that the model is about 53% Class 3, 42% Class 2 and 5% Class 1. A confidence level of Class 2 is sufficient for mining groundwater assessments.

Sufficient detail is included in Document #2 on how the fracture zone has been implemented. However, a map should have been included of predicted fracturing to land surface to supplement the description in the body of the report.

5. Model Calibration

Calibration has been based entirely on matches to historical groundwater level datasets. There are no reliable measured or inferred or anecdotal inflow estimates that could be relied upon as quantitative mine inflow targets. Instead, a comparison has been made with inflows predicted by earlier models to ensure consistency. There is no specific incorporation of other data types in the automated calibration using PEST++ software; e.g. vertical head differences.

The dataset available for calibration is huge: namely, 16,138 target heads at 464 bores being monitored for four different mines. This ranks amongst the largest datasets for any model so far developed in NSW. Similarly, there is a large number of estimable parameters based on a network of 6,080 pilot points, for various model parameter types: horizontal hydraulic conductivity (Kx); vertical hydraulic conductivity (Kz); specific yield (Sy); specific storage (Ss); and rainfall recharge rate.

All calibration hydrographs are disclosed in **Attachment B**, with residual error statistics for each bore in **Attachment A**.

Calibration performance is generally good in most areas of the model, with overall satisfactory statistics of 6.0 %RMS and 13.1 mRMS. The transient scatter plot (Figure 3-3 of Document #1) is generally linear over about 200 m range in head values. However, the scatter is substantial for water level observations less than zero (mAHD), those values most representative of severe stresses due to deep mining, suggesting difficulty at some sites in simulating the onset or duration of mining.

There is a detailed examination of hydrographic calibration performance for the nine most relevant groupings of bores. In each case, where poor performance is noted, a possible explanation is put forward for consideration in the next model upgrade. All suggestions are sensible. In the Log of Issues, the reviewer has offered additional hints on the direction in which key parameters could be modified to achieve better calibration in the future.

While most calibrated parameters appear plausible, there are exceptions:

- The Sy for highly productive alluvium is very low, being 0.8% in Layer 1 and 1.4% in Layer 2.
- The Sy values in deeper layers are also low, being from 0.3% to 3%. Higher values would have an effect on the magnitude of predicted mine inflow.
- The Kx for highly productive alluvium is low in Layer 1, being 2.5 m/day, and high in Layer 2, being 84 m/day. Different values should have minimal effect on any predictions of interest.

The best calibrated model has baseflow (primarily to Hunter River and Wollombi Brook) exceeding leakage. As leakage is expected along Wollombi Brook close to mining, and along some reaches of the Hunter River, separate rates for the two main watercourses should have been derived to better understand where the predicted baseflow is focused and to ensure consistency with the conceptual model.

No separate sensitivity analysis or identifiability analysis has been undertaken to identify those model properties that are either well defined, or not well defined, by the available measurements. The approach taken has been to allow all model hydraulic and storage properties, and some boundary conditions, to be adjusted automatically in a full *monte carlo* uncertainty analysis, with the proviso that models with poor calibration performance are excluded.

Document #2 would have benefitted from inclusion, as an attachment, of maps of the structure contours, layer isopachs and hydraulic conductivity fields for a few key layers (e.g. the target coal seams).

6. Model Prediction

The predictive phase of modelling is based on simulation of four distinct scenarios for a period of 21 years, with differencing between pairs of scenario results allowing unpacking of Project-only impacts or cumulative impacts, or separation of underground and open cut water takes. This approach is standard practice.

As stated in Document #2, the scenarios are:

- "**Null Run** – No Wambo Complex mining after 2003 (i.e. when Development Consent (DA305-7-2003) was issued). This scenario does include mining at other approved mining operations around Wambo.
- **No Wambo Underground** – No Wambo underground mining after 2003 (i.e. when Development Consent (DA305-7-2003) was issued). This scenario does include mining at other approved mining operations around Wambo, does include Wambo and UWOCP open cut mining, and does include United Underground mining.
- **Approved** – Approved mining at Wambo (i.e. in accordance with Development Consent (DA305-7-2003) and mining at other approved mining operations around Wambo.
- **Modification** – Approved mining at Wambo (i.e. in accordance with Development Consent [DA305-7-2003]) plus the Modification and mining at other approved mining operations around Wambo."

The prediction outputs focus on:

- Global water balances, showing progressive changes in key components of interest (e.g. surface water / groundwater interaction; mine inflows) as more or different stresses are added to the scenarios.
- Comparison of Approved versus Modification spatial groundwater heads for the water table, alluvium/regolith, and three target coal seams, at end of mining.
- Maximum Project-only and cumulative drawdown maps for the water table, alluvium/regolith, and three target coal seams.
- Predicted underground mine inflows during each year of the prediction simulation, with a comparison of Approved and Modification scenarios.
- Time-varying alluvial water takes for four watercourses, with a comparison of Approved and Modification scenarios.
- Time-varying losses of water from four watercourses, with a comparison of Approved and Modification scenarios.
- Drawdown (incremental and cumulative) at private landowner bores.

The analysis and reporting of model results is extremely thorough, and the reviewer concurs with all interpretations. An important observation is that, in all cases, there is very little difference between the Approved and Modification predictions. Overall, the Modification has slightly less impact, as is to be expected from the realignment of Longwalls 24 and 25 and the addition of longwall 26. Some apparent differences between Approved and Modification scenario results is due simply to timing and duration changes proposed for the already-approved South Wambo Mine (yet to be commenced).

A comprehensive IESC-compliant Type-3 uncertainty analysis has been undertaken by means of a *monte carlo* technique, using 113 alternative calibrated realisations out of a trial set of 2,000 selections, using a calibration cutoff of 6.5 %RMS (compared to base case performance of 6.0 %RMS). The parameters subject to variation were horizontal hydraulic conductivity, hydraulic conductivity anisotropy, specific yield, specific storage, spoil properties, diffuse recharge and riverbed vertical hydraulic conductivity. The assumed standard deviations were 0.5 (log10 space) for all adjustable properties, which means that 95% of values will lie within one order of magnitude either side of the base case calibrated value. Proof of convergence, as encouraged by the IESC Explanatory Note on Uncertainty Analysis, is offered for total mine inflows and maximum drawdown. The curves are still trending downwards after 113 runs, but have almost stabilised at their asymptotes; further runs would add negligible benefit.

For each of three targeted underground coal seams, the base case model has a little more inflow than the 50th percentile of the 113 realisations. This means that predictions using the base case model alone would tend to give conservatively higher mine inflows than those most likely to occur. On the other hand, for the two open cut pits, the base case model is in good agreement with the median of the uncertainty analysis.

The temporal uncertainty results are presented in Document #2 in Figures 5-3 to 5-7 as 5th, 33rd, 50th, 67th and 95th percentiles for progressive inflow. The spatial uncertainty results are presented in Document #2 in Figures 5-8 to 5-11 as 10%, 50% and 90% probabilities of exceeding 1 m maximum drawdown in alluvium/regolith, Whybrow Seam, Arrowfield Seam and Vaux Seam.

For six private landowner bores, the 95th percentile maximum drawdown is declared for incremental and cumulative stresses. Only one breach of the 2 m minimal harm criterion is predicted, that being cumulative drawdown at bore GW078574.

For four watercourses, uncertainty at the 5th and 95th percentiles is reported for surface water take and alluvial take.

Recovery in the presence of two final voids has been shown for pit lake water levels determined by surface water modellers, using time-varying constant heads provided from the surface water model. The reviewer endorses deference to surface water modelling for a more robust analysis of final void behaviour than is readily achievable in a groundwater model. As the equilibrium water table contours in Figure 6-2 [Document #2] have a coarse 40 m interval, it is not visually clear whether the two voids will act as permanent groundwater sinks. There is a statement in the report that the United pit is a sink, but the degree of freeboard for each void should have been disclosed.

7. Conclusion

The design of the groundwater model is much improved over earlier models, by use of new software that allows spatially varying scale within a single model so that attention is focused on features that have the most significant hydraulic roles. The calibration also is definitely an improvement on what had been achieved with earlier versions of the model.

The reviewer is of the opinion that the documented groundwater assessment is best practice and concludes that the model is *fit for purpose*, where the purpose is defined by the objectives listed in Document #2:

- *"assess the groundwater inflow to the mine workings as a function of mine position and timing;*
- *simulate and predict the extent of dewatering due to the Project and the level and rate of drawdown at specific locations;*
- *identify areas of potential risk, where groundwater impact mitigation/control measures may be necessary;*
- *estimate direct and indirect water take; and*
- *estimate post-mining recovery conditions."*

The groundwater modelling has been conducted to a very high standard and a rigorous monte carlo uncertainty analysis offsets much of the uncertainty that is inherent in a groundwater model, as noted in the Limitations Section 8 of Document #2

The reviewer believes that this study has demonstrated that there will be negligible difference between the impacts predicted for the Approved mine plan and the Modification mine plan.

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Table A: Review checklist (2012 National Guidelines) *(at 28 July 2022)*

		#1:Main Report
		#2: Modelling Technical Report
Review questions	*Yes/No*	*Comment*
1. Planning		
1.1 Are the project objectives stated?	Y	Section 1.4: 8 tasks
1.2 Are the model objectives stated?	Y	Section 1: 5 tasks.
1.3 Is it clear how the model will contribute to meeting the project objectives?	Y	Articulated in modelling technical report.
1.4 Is a groundwater model the best option to address the project and model objectives?	Y	No real option.
1.5 Is the target model confidence-level classification stated and justified?	Y	Table 6-1
1.6 Are the planned limitations and exclusions of the model stated?	Y	Table 7-1
2. Conceptualisation		
2.1 Has a literature review been completed, including examination of prior investigations?	Y	S1.5 information sources. S4.2 hydrology. S4.3.1 subsidence. S5 geology. S6 hydrogeology; K (S6.2.1). S6.3.7 baseflow.
2.2 Is the aquifer system adequately described?	Y	S6.3
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)	Y	S6.3 description of 6 groundwater systems.
2.2.2 lateral extent, boundaries and significant internal features such as faults and regional folds	Y	Subcrops and structural geology (S5.3) faults and dykes.
2.2.3 aquifer geometry including layer elevations and thicknesses	Partial	Topo Fig.4-3. Alluvium thicknesses are recorded. Layer geometry shown in conceptual model sections (Figs.6-14, 6-15). No structure contour/ isopach maps. Average layer thicknesses Table 2-1.
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?	Y	Varying confinement is discussed in S6.3. Hydrographs show fluctuations and amplitudes.
2.3 Have data on groundwater stresses been collected and analysed?	Y	Rain, stream stage, mining. Hydrographs are compared with CRD and mining onsets.
2.3.1 recharge from rainfall, irrigation, floods, lakes	Y	CRD comparison.
2.3.2 river or lake stage heights	Y	S4.2. Gauges in Figure 6-1.
2.3.3 groundwater usage (pumping, returns etc)	N	Bore censuses 2014 & 2016 plus database searches. 122 bores within 4km: 27 registered for use: Table 6-5, Figure 6-12.
2.3.4 evapotranspiration	Y	S4.1
2.3.5 other?	Y	Antecedent Precipitation Index for ephemeral flow. Baseflow analysis (by AGE). Salinity S6.4.1. GDEs S6.6.
2.4 Have groundwater level observations been collected and analysed?	Y	S6.1 monitoring network, 94 sites, earliest 2010 – extensive; Figure 6-1.
2.4.1 selection of representative bore hydrographs	Y	Focused near SBX for analysis. All used in calibration.
2.4.2 comparison of hydrographs	Y	Grouped near SBX by lithology.
2.4.3 effect of stresses on hydrographs	Y	Cause-and-effect analysis for hydrographs near SBX. Sw/gw interaction Figure 6-7.

Table A: Review checklist (2012 National Guidelines) *(at 28 July 2022)*

		#1:Main Report
		#2: Modelling Technical Report
Review questions	*Yes/No*	*Comment*
2.4.4 watertable maps/piezometric surfaces?	N	Flow directions are described in words. No head maps prior to modelling outputs.
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	N/A	
2.5 Have flow observations been collected and analysed?	Y	Stage heights; mentions of Hunter River flow magnitudes.
2.5.1 baseflow in rivers	Y	Wollombi Brook & Hunter River (by AGE).
2.5.2 discharge in springs	N/A	
2.5.3 location of diffuse discharge areas?	N/A	
2.6 Is the measurement error or data uncertainty reported?	N	
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	N	
2.6.2 spatial variability/heterogeneity of parameters	N	Parameter fields not shown spatially. Each layer has spatial K(x,y) using pilot points. K declines with depth.
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	N	
2.7 Have consistent data units and geometric datum been used?	Y	
2.8 Is there a clear description of the conceptual model?	Y	S6.7
2.8.1 Is there a graphical representation of the conceptual model?	Y	N-S and W-E sections (at 2021 activity).
2.8.2 Is the conceptual model based on all available, relevant data?	Y	
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	Y	
2.9.1 Are the relevant processes identified?	Y	Private abstraction does not occur along the chosen sections.
2.9.2 Is justification provided for omission or simplification of processes?	N	Private abstraction is likely to be insignificant relative to mining stresses. Not commented on. Assumed excluded from model.
2.10 Have alternative conceptual models been investigated?	N	But uncertainty analysis examines different parameter fields.
3. Design and construction		
3.1 Is the design consistent with the conceptual model?	Y	Key processes are included. Conceptualisation in main report.
3.2 Is the choice of numerical method and software appropriate?	Y	MODFLOW-USG + AlgoMesh + PEST.
3.2.1 Are the numerical and discretisation methods appropriate?	Y	Voronoi grid for internal spatial detail. Temporal periods are appropriate – quarterly for calibration; quarterly for prediction; decadal for recovery. Long stress periods for warm-up seem to be affecting initial conditions for the calibration period.

Table A: Review checklist (2012 National Guidelines) *(at 28 July 2022)*

		#1:Main Report
		#2: Modelling Technical Report
Review questions	*Yes/No*	*Comment*
3.2.2 Is the software reputable?	Y	State-of-art.
3.2.3 Is the software included in the archive or are references to the software provided?	OK	References. AlgoMesh is proprietary.
3.3 Are the spatial domain and discretisation appropriate?	Y	Total 1.07 million cells. Near the practical limit. (Previous HS model ~2 million cells – too big.)
3.3.1 1D/2D/3D		3D
3.3.2 lateral extent		About 20km (E-W) x 22km (N-S).
3.3.3 layer geometry?		30 layers.
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	Y	Min 25m cell size. Features detailed at 25, 50, 75, 100, 150, 250m. Quite fine.
3.3.5 Is the vertical discretisation appropriate? Are aquitards divided in multiple layers to model time lags of propagation of responses in the vertical direction?	Y N	30 layers. Separate layers for 12 coal seams. Alluvium split into 2 layers. Aquitards are individual layers – a common pragmatic compromise with many layers.
3.4 Are the temporal domain and discretisation appropriate?	Y	
3.4.1 steady state or transient		Both
3.4.2 stress periods	Y	3 SP for warm-up (33 yrs 1970-Jan.2003); 72 SP for calibration (qtly Jan.2003-Dec.2020); 77 SP for prediction (Jan.2021-Dec.2041); recovery for 358 years to 2400. Quarterly stress periods are suitable.
3.4.3 time steps?	Y	Model presumably uses ATS (S2.5) – automatic time stepping – to set dynamic time steps. Not stated.
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?	Y	Some no-flow natural boundaries. Also GHB (west and east). DRNs represent mines to north and south. Rainfall recharge seasonality is included: quarterly averages of AWRA sequence
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	Y	
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?	Y	Sufficiently distant.
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	Y	3 zones based on lithology.
3.5.4 Are lateral boundaries time-invariant?	Y	
3.6 Are the initial conditions appropriate?	Not everywhere	Based on steady-state pre-2003. Some calibration hydrographs start low.
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?		Model
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	Y	Recognition of deleterious effect on some hydrographs due to warm-up assumptions.
3.6.3 How is the initial concentration of solutes obtained (when relevant)?	N/A	
3.7 Is the numerical solution of the model adequate?	Y	
3.7.1 Solution method/solver		USG solver and options are not stated

Table A: Review checklist (2012 National Guidelines) *(at 28 July 2022)*

		#1:Main Report
		#2: Modelling Technical Report
Review questions	*Yes/No*	*Comment*
3.7.2 Convergence criteria		Mass discrepancy 0.0%
3.7.3 Numerical precision		Assumed single
4. Calibration and sensitivity		**2003-2020 (quarterly)**
4.1 Are all available types of observations used for calibration?	Y	Heads quantitatively. No availability of fluxes.
4.1.1 Groundwater head data	Y	16,138 target heads at 464 bores. Huge dataset.
4.1.2 Flux observations	N	Not available. Reliance on prior model estimates for consistency.
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	Y	Explicit assessment of predicted vertical gradients. Not included as special PEST targets.
4.2 Does the calibration methodology conform to best practice?	Y	PEST ++ using pilot points, and manual.
4.2.1 Parameterisation	Y	6,080 pilot points. Two vertical K-depth functions.
4.2.2 Objective function	Y	PEST phi (sum of squares) 2,772,549 m^2.
4.2.3 Identifiability of parameters	N	
4.2.4 Which methodology is used for model calibration?		PEST ++ and manual.
4.3 Is a sensitivity of key model outcomes assessed against?		Through uncertainty analysis with retention only of calibrated realisations. No separate sensitivity analysis.
4.3.1 parameters	Y	Host & spoil: Kx, Kz/Kx, Ss, Sy; riverbed Kz
4.3.2 boundary conditions	N	*Not essential*
4.3.3 initial conditions	N	*Not essential*
4.3.4 stresses	Y	Rainfall recharge.
4.4 Have the calibration results been adequately reported?	Y	Section 3.2.
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	Y	Figures 3-5 to 3-12 for 46 sites. All sites shown in Attachment B.
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	Y	Many VWP plots – some good, some poor. Two sites have outliers that should be removed or weighted low.
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	Y	Table 3-1, key statistics 6.0 %RMS, 13.1 mRMS. Good.
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?	Y	Scattergram Figure 3-3 – generally linear over a wide range of elevations (~200 m). Good for obs > 25 mAHD. Much scatter for obs < 0 mAHD (appears dominated by a few bores).
4.5.1 spatially	Y	Average, min and max residuals for all bores (Attachment A). Average residual spatial map (Fig.3-4).
4.5.2 temporally	Y	Figures 3-5 to 3-15 and Attachment B.
4.6 Are the calibrated parameters plausible?	Mostly	Table 3-5: Recharge rates are plausible (0.5-6.7% of rainfall). Table 3-4: Hydraulic conductivities cover expected ranges. Except Kx1 is low (2.5

Table A: Review checklist (2012 National Guidelines) (at 28 July 2022)

		#1:Main Report
		#2: Modelling Technical Report
Review questions	*Yes/No*	*Comment*
		m/day); Kx2 is high (84 m/day) Ss reasonable. Sy values are very low in highly productive alluvium: 0.8% (layer 1) and 1.4% (layer 2). Generally low Sy in Triassic and Permian layers.
4.7 Are the water volumes and fluxes in the water balance realistic?	Y	Magnitudes ~ 9 ML/day for all mine inflows – compares well with previous models. Baseflow exceeds leakage. Need to split Hunter River from Wollombi Brook to ensure compliance with conceptualisation. No ground-truthing against current mine takes.
4.8 has the model been verified?	N	No data have been withheld from calibration – normal practice.
5. Prediction		**2021-2041 (quarterly)**
5.1 Are the model predictions designed in a manner that meets the model objectives?	Y	• *"assess the groundwater inflow to the mine workings as a function of mine position and timing;* • *simulate and predict the extent of dewatering due to the Project and the level and rate of drawdown at specific locations;* • *identify areas of potential risk, where groundwater impact mitigation/control measures may be necessary;* • *estimate direct and indirect water take; and* • *estimate post-mining recovery conditions."* All objectives are able to be assessed by the model design.
5.2 Is predictive uncertainty acknowledged and addressed?	Y	Uncertainty analysis in Section 5.
5.3 Are the assumed climatic stresses appropriate?	Y	S4.1.1, Table 2: prediction and recovery assumptions for long-term recharge and future stream stage.
5.4 Is a null scenario defined?	Y	External mining is included but all Wambo mining since 2003 is excluded.
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?	Y	"Null", "No Wambo Underground" (i.e. Null + open cuts), "Approved" and "Modification" scenarios.
5.5.1 Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there reference to the associated reduction in model confidence?	Y	Continuation of similar mining stresses.
5.5.2 Are well losses accounted for when estimating maximum pumping rates per well?	N/A	
5.5.3 Is the temporal scale of the predictions commensurate with the calibrated model? If not, is there reference to the associated reduction in model	Y	Both quarterly.

Table A: Review checklist (2012 National Guidelines) (at 28 July 2022)

		#1:Main Report
		#2: Modelling Technical Report
Review questions	*Yes/No*	*Comment*
confidence?		
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?	Y	Objectives at item 5.1.
5.6 Do the prediction results meet the stated objectives?	Y	Objectives at item 5.1 are addressed in full.
5.7 Are the components of the predicted mass balance realistic?	Y	Table 4-2. Systematic trend from Null to Modification. Mine inflows: 3.8 to 5.9 to 6.8 to 6.9 ML/day averages.
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?	N/A	
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?	N	Very small rates relative to surface flow.
5.7.3 Are there any anomalous boundary fluxes due to superposition of head dependent sinks (e.g. evapotranspiration) on head-dependent boundary cells (Type 1 or 3 boundary conditions)?	N	
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	Y	0.5% to 6.7% of annual rainfall.
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?	N	
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	N	Not required
6. Uncertainty		
6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	Y	Qualitative in Table 7-1. Quantitative in Section 5.
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	Y	113 calibrated realisations from 2000 candidate models.
6.3 Are the sources of uncertainty discussed?	Y	Table 7-1.
6.3.1 measurement of uncertainty of observations and parameters	Y	Table 7-1.
6.3.2 structural or model uncertainty	Y	Table 7-1.
6.4 Is the approach to estimation of uncertainty described and appropriate?	Y	Type-3 IESC compliant methodology.
6.5 Are there useful depictions of uncertainty?	Y	Demonstration of convergence with number of realisations (Figs. 5-1, 5-2). Contours of 1m drawdown (P10 to P90). Temporal charts for P5, P33, P50, P67, P95. Registered bore drawdowns: P5, P95.
7. Solute transport	N/A	
8. Surface water–groundwater interaction		
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	Y	• *"estimate direct and indirect water take."* Potential for baseflow loss is assessed as minor for Project only impact.
8.2 Is the implementation of surface water–groundwater	Y	RIV for main watercourses with positive

Table A: Review checklist (2012 National Guidelines) *(at 28 July 2022)*

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		#2: Modelling Technical Report
Review questions	*Yes/No*	*Comment*
interaction appropriate?		stage; some ephemeral stages are inferred from an empirical rainfall-flow relationship. RIV with zero stage (=DRN) for minor creeks.
8.3 Is the groundwater model coupled with a surface water model?	Y (loosely)	For two final voids
8.3.1 Is the adopted approach appropriate?	Y	Imposed constant heads in void lakes
8.3.2 Have appropriate time steps and stress periods been adopted?	Y	
8.3.3 Are the interface fluxes consistent between the groundwater and surface water models?	Y	Linked

Table B: Compliance checklist

Question	*Yes/No*
1. Are the model objectives and model confidence level classification clearly stated?	Yes
2. Are the objectives satisfied?	Yes
3. Is the conceptual model consistent with objectives and confidence level classification?	Yes
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes
5. Does the model design conform to best practice?	Yes
6. Is the model calibration satisfactory?	Yes
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes
8. Do the model predictions conform to best practice?	Yes
9. Is the uncertainty associated with the predictions reported?	Yes
10. Is the model fit for purpose?	Yes

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