

APPENDIX G – Environmental Impact Statement

Groundwater impact assessment

Prepared for Lake Lyell Project Pty Ltd



Lake Lyell Pumped Hydro Energy Storage

Groundwater impact assessment

Lake Lyell Project Pty Ltd

E221111 RP13

November 2025

Version	Date	Prepared by	Reviewed by	Comments
1	7 November 2024	Henry Noakes	Katharine Bond	Draft for client review
2	23 June 2025	Henry Noakes	Katharine Bond	Updated draft for client review
3	13 August 2025	Henry Noakes	Katharine Bond	Final draft for client review
4	24 November 2025	Henry Noakes	Katharine Bond	Final

Approved by

Katharine Bond

Katharine Bond

Associate Environmental Scientist

24 November 2025

Level 10 201 Pacific Highway

St Leonards NSW 2065

ABN: 28 141 736 558

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Executive Summary

ES1 Introduction

EnergyAustralia Portfolio Holdings Pty Ltd (EnergyAustralia) in partnership with EDF power solutions Australia (EDFA), referred to as Lake Lyell Project Pty Ltd (LLP) as trustee, is developing the Lake Lyell Pumped Hydro Energy Storage (PHES) Project (the project). The project that is anticipated to store up to 3,080 megawatt hours (MWh) of energy and generate at 385 megawatts (MW) for 8 hours or generate up to 440 MW for a shorter period.

At a basic level, the project will consist of upper and lower water reservoirs, an underground waterway connecting them, and a hydro-electric power station connected to the national electricity market (NEM) that is capable of generating or consuming electricity.

The project has been declared by the NSW Government to be critical State significant infrastructure (CSSI) under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). Infrastructure projects are declared to be CSSI if, in the opinion of the NSW Minister for Planning, they are essential to the State for economic, environmental, or social reasons.

The expected operational lifespan of the project is in excess of 80 years.

ES2 Regulatory setting and water resources

The surface water and groundwater sources of relevance to the project area are subject to water sharing plans (WSPs) and therefore most aspects of project water management are regulated under the NSW *Water Management Act 2000* (WM Act). The NSW Aquifer Interference Policy (AIP) establishes the criteria for impact assessment of projects that intercept groundwater and requirements for licensing.

The groundwater resources for the project are managed under the Greater Metropolitan Region Groundwater Sources 2023 and the NSW Murray–Darling Basin Fractured Rock Groundwater Sources 2020.

Surface water resources (as assessed in the Surface Water Impact Assessment (EMM 2025)) within the project area are managed under the Greater Metropolitan Region Unregulated River Water Sources 2023 (forming part of the Sydney drinking water catchment) and the Macquarie Bogan Unregulated and Alluvial Water Sources 2012.

This groundwater impact assessment has been undertaken in accordance with the WM Act, the AIP and the tending WSPs.

ES3 Baseline characterisation program

A water monitoring network was designed and implemented to establish pre-construction baseline data for the project. The water monitoring network has been designed to ensure that the project can be adequately assessed against the AIP. The *Guidelines for Groundwater Documentation for SSD/SSI Projects* (DPE Water 2022) was considered during network development.

Extensive baseline investigation and monitoring works were undertaken to characterise the existing environment near the project. Works included geological borehole drilling, hydraulic testing, groundwater monitoring bore / vibrating wire piezometers installation and water quality sampling from groundwater and surface water.

The network covers 17 monitoring locations providing ongoing water quality and/or water level data, the majority of which will continue to provide data throughout post-approval. The groundwater monitoring network targets various depths and geological units near the project, and have been co-located to ensure vertical variability in groundwater levels and flow can be adequately characterised. Surface water monitoring locations target areas upstream and downstream of the project, within watercourses providing aquatic habitats and sustained flows for downstream users.

The extent, duration and frequency of baseline monitoring, for which this GIA has been based on, is considered fit-for-purpose in line with the *Guidelines for Groundwater Documentation for SSD/SSI Projects* (DPE 2022).

Additional data will continue to provide targets for model recalibration exercises (nominally every two-years, or as stipulated in the project conditions of consent), and monitor project impacts during / following commencement of construction.

ES4 Assessment and findings

Groundwater inflow to key project elements (i.e. the headrace, tailrace, reservoirs, access tunnels and the underground power station) is expected during construction, operation and post-closure of the project. The resultant groundwater level drawdown or mounding (i.e. lowering or raising of the watertable) and effects on the surrounding watercourses (i.e. reduced groundwater contributions to streams) has been predicted using a numerical groundwater model.

The numerical groundwater model is based on a conceptual representation (or conceptual model) of the hydrogeological systems intercepted by the project. The conceptual model provides a simplified understanding of the hydrogeology near the site, as the complexity of any hydrogeological system cannot be absolutely represented. In accordance with the Australian Groundwater Modelling Guidelines (Barnett, et al. 2012), the numerical groundwater model is designed to provide conservative predictions, accounting for any potential under-prediction of impacts caused by the conceptual simplifications.

Therefore, the model predictions of inflow, baseflow reduction and watertable drawdown are likely to be overestimating project impacts. The results of this conservative model approach need to be considered within this overall context to accurately assess the project on its true merits.

Groundwater modelling predicts localised watertable drawdown in the vicinity of the project throughout construction and operation. Watertable drawdown, once the project has advanced into the final year of construction and into operations, is predicted to extend up to approximately 1.1 kilometres (km) from the centre of the project (near the PHES power station complex), over approximately 173 hectares (ha).

Based on the groundwater modelling, drawdown is not predicted at any private groundwater users and watertable drawdown is predicted to have negligible impacts on terrestrial groundwater dependant ecosystems (GDEs). There will be a minor reduction in baseflow available to rivers and creeks, however impacts are predicted to discrete stream-lengths only and residual impact are predicted to be negligible.

Water quality objectives have been provided to develop an indicative standard for project related water quality. These objectives will be monitored throughout the construction and operation of the project to ensure discharged water is of sufficient quality to meet this standard.

ES5 Mitigation and management

Groundwater drawdown and inflow will be monitored during construction of the project as part of a Water Management Plan developed and implemented for the project (following approval). If required, mitigation and management options available during construction include:

- pre-grouting (i.e. grouting through pilot holes at the excavation face if inflows are un-manageable via pumping)
- post-grouting (i.e. following excavation via drill and blast methodologies).

These mitigation and management measures will be implemented (if required) to reduce groundwater inflow.

ES6 Water licensing and overall take

The peak groundwater inflow, impacts and take are considered for each groundwater source. The peak, cumulative take (including direct take, arising from inflow to project components and indirect take, arising from reduced baseflow to watercourses) occurs over the third year of construction (85.3 megalitres (ML)). The peak surface water take, resulting from induced leakage under watercourses, occurs in the fourth year of construction (0.6 ML).

Water allocation has been obtained to sufficiently license the groundwater take induced by the project. Further information on surface water licenses is provided in the project water licensing strategy (EMM 2025).

It is noted that the numerical groundwater model is conservative and with the inclusion of design mitigation options and a potential refinement of the hydraulic parameters, inflow volumes may be reduced.

1 Introduction

1.1 Background

EnergyAustralia Portfolio Holdings Pty Ltd (EnergyAustralia) in partnership with EDF power solutions Australia (EDFA), referred to as Lake Lyell Project Pty Ltd (LLP) as trustee, is developing the Lake Lyell Pumped Hydro Energy Storage (PHES) Project (the project). The project that will have the capacity to store up to 3,080 megawatt hours (MWh) of energy and generate at 385 megawatts (MW) for 8 hours or generate up to around 440 MW for a shorter period. At a basic level, it will consist of upper and lower water reservoirs, a pipeline connecting them, and a hydro-electric power station connected to the national energy grid that is capable of generating or consuming electricity.

The project is located approximately 5 kilometres (km) west of Lithgow and 110 km west of the Sydney central business district, shown in Figure 1.1 and Figure 1.2. The project takes advantage of existing infrastructure (i.e. Lake Lyell) associated with Mt Piper power station which will be decommissioned in the coming decades and allows Lake Lyell to continue to serve a specific purpose in electricity generation (consistent with its existing use).

In June 2024, the Minister for Planning and Public Spaces declared the project to be critical State significant infrastructure (CSSI). Accordingly, approval for the project is required under Part 5, Division 5.2 of the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act). This requires the preparation of an environmental impact statement (EIS) for the project in accordance with Secretary's environmental assessment requirements (SEARs) and the approval of the Minister. EMM Consulting Pty Limited (EMM) has been engaged by EnergyAustralia to prepare the EIS.

This groundwater impact assessment (GIA) is an appendix to the project's EIS and should be read in conjunction with it. The GIA addresses the SEARs issued for the project.

1.2 Assessment guidelines and requirements

1.2.1 Secretary's environmental assessment requirements

This GIA has been prepared to address the SEARs issued by the NSW Department of Planning, Housing and Infrastructure (DPHI). This assessment also considers relevant governmental assessment requirements, guidelines and policies, and has been developed in consultation with NSW Department of Climate Change, Energy, the Environment and Water (NSW DCCEEW).

Table 1.1 lists the matters relevant to this assessment and where they are addressed in this report.

Table 1.1 Relevant matters raised in SEARs

Requirement	Section addressed
A detailed site water balance for the project, including the water take from each surface and groundwater source, any licensing requirements, and determine whether an adequate and secure water supply is available for the development.	Section 9.4.1 Section 9.4.2 Section 12.2 Lake Lyell Water Licensing Strategy (EMM 2025)
An assessment of the impacts of the project on:	
the water catchment and quantity and quality of the region's surface and ground water	Section 6.5 Lake Lyell Surface Water Impact Assessment (EMM 2025)
resources, including Lake Lyell, Coxs River and Farmers Creek	Section 9.4.2

Requirement	Section addressed
water security for local downstream receivers including other dependent water industries	Lake Lyell Water Licensing Strategy (EMM 2025)
hydrological flows on site, including any potential flooding impacts	Lake Lyell Surface Water Impact Assessment (EMM 2025)
key water features on site, including potential impacts on riparian land	Section 6.7 Section 8.1.3iii Lake Lyell Surface Water Impact Assessment (EMM 2025)
type and extent of any dredging or reclamation activities within 'water land'	Lake Lyell Surface Water Impact Assessment (EMM 2025)
water-related infrastructure, basic landholder rights and the entitlements of water users	Lake Lyell Water Licensing Strategy (EMM 2025)
A description of the likely changes to the hydrological regime of the Lake Lyell, Coxs River and Farmers Creek, and any associated biodiversity impacts.	Lake Lyell Surface Water Impact Assessment (EMM 2025)

1.2.2 Agency requirements

DPHI invited government agencies, including Lithgow City Council (Council), to recommend matters to be addressed in the EIS. These matters were considered by the Secretary for DPHI when preparing the SEARs. Comments made by agencies relating to the assessment of [technical study] and where they are addressed in this report are listed in the following sections

i NSW Department of Climate Change, Energy, the Environment and Water

The NSW Department of Planning and Environment – Water (DPE Water), now NSW DCCEEW in its undated attachment to the SEARs response raised several groundwater-related assessment requirements. DPE Water assessment requirements and EMM responses are provided in Table 1.2.

Table 1.2 NSW DCCEEW comments and EMM responses

No.	NSW DCCEEW assessment requirements	EMM responses/information location
1	A detailed and consolidated site water balance.	Lake Lyell Surface Water Impact Assessment (EMM 2025)
2	Description of all works/activities that may intercept, extract, use, divert or receive surface water and/or groundwater. This includes the description of any development, activities or structures that will intercept, interfere with or remove groundwater, both temporary and permanent.	Section 2
3	Details of all water take for the life of the project and post closure where applicable. This is to include water taken directly and indirectly (including through inflow and seepage), and the relevant water source where water entitlements are required to account for the water take. If the water is to be taken from an alternative source confirmation should be provided by the supplier that the appropriate volumes can be obtained.	Section 9.4

No.	NSW DCCEEW assessment requirements	EMM responses/information location
4	Details of Water Access Licences (WALs) held to account for any take of water where required, or demonstration that WALs can be obtained prior to take of water occurring. This should include an assessment of the current market depth where water entitlement is required to be purchased. Any exemptions or exclusions to requiring approvals or licenses under the Water Management Act 2000 should be detailed by the proponent.	Lake Lyell Water Licensing Strategy (EMM 2025)
5	A description of groundwater conditions that provides an understanding of groundwater level across the site under a range of wet and dry conditions.	Section 5.3.1
6	The development of a thorough groundwater conceptual model with supporting cross section and extraction mining depth supported by field data.	Section 7
7	Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, groundwater dependent ecosystems, and ground water levels; including measures proposed to reduce and mitigate these impacts.	Section 9.3 Section 10
8	Proposed surface and groundwater monitoring activities and methodologies and details of a proposed water management plan.	Section 11.4.1
9	Assessment of project against relevant policies and guidelines	Section 4

ii [WaterNSW](#)

WaterNSW in its letter dated 10 August 2023 raised a number of groundwater-related comments. WaterNSW comments and EMM responses are provided in Table 1.3.

Table 1.3 [WaterNSW comments and EMM responses](#)

No.	WaterNSW assessment requirements	EMM responses/information location
1	The full description of the development and existing environment should also include those aspects which have the potential to impact on the quality and quantity of surface and ground water and landform at and adjacent to the site. This should also include:	Section 2 Section 3 Section 5 Section 6 Section 9.3 Section 10
2	- maps with: - the proposed project boundary - detailed description of all waterbodies and watercourses - areas of vegetation clearance and offsets	Section 3.4 Lake Lyell Biodiversity Development Assessment Report (EMM 2025)
3	- specific attention and consideration for project design and route/site selections to ensure to avoid and/or minimise impacts on: - surface and ground water quantity and quality - riparian zones and any wetland vegetation - groundwater dependent ecosystems - landform	Lake Lyell Surface Water Impact Assessment (EMM 2025) Section 9.3 Section 10

No.	WaterNSW assessment requirements	EMM responses/information location
4	- assessment of impacts including cumulative impacts on: - groundwater using sufficient and appropriate baseline data including: - baseflows in Coxs River, Farmers Creek, and tributaries - groundwater quality - groundwater dependent ecosystems - landforms with specific attention to the long-term geotechnical stability of proposed upper storage reservoir	Section 3.4 Section 6.5 Section 6.7
5	concept design plans for erosion and sediment controls for construction phase including management of groundwater required as part of groundwater dewatering	Lake Lyell Surface Water Impact Assessment (EMM 2025)
6	concept surface and ground water monitoring programs.	Section 11.4

1.3 Purpose of this report

This GIA forms an appendix to the project's EIS, and should be read in conjunction with the EIS. The GIA addresses the SEARs issued for the project and has been prepared in accordance with the *Guidelines for Groundwater Documentation for SSD/SSI Projects* (DPE 2022).

The key objectives of this GIA are to:

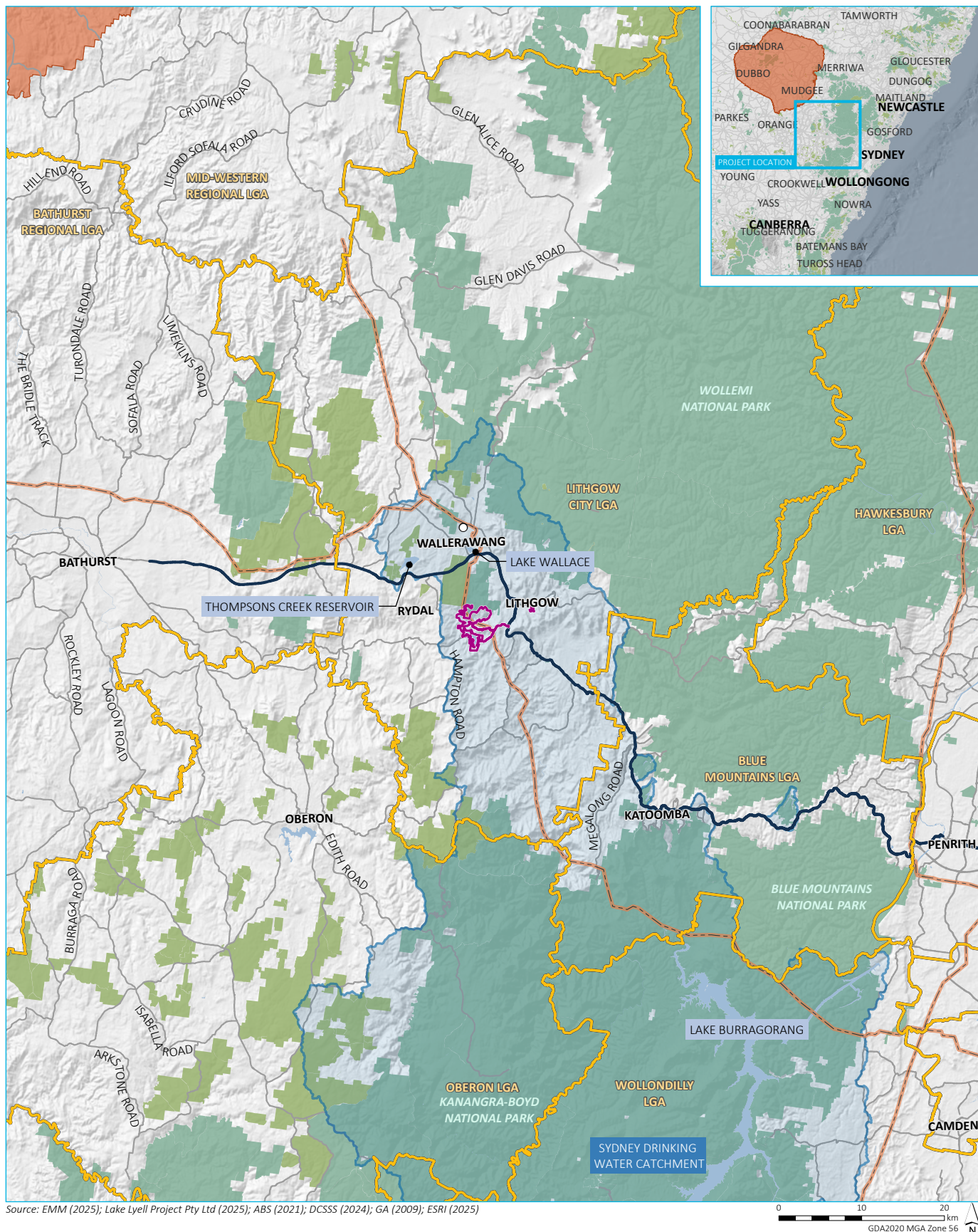
- provide the regulatory setting (regarding water management) within which the project will operate
- quantify the water requirements for the project during construction and operation, with arrangements detailed to acquire sufficient water allocations through the relevant legislative pathway
- assess the existing groundwater environment, baseline groundwater conditions and groundwater users within and near the project area
- quantify (through predictions) the potential impacts induced by the project on the existing groundwater environment, baseline groundwater conditions and groundwater users within and near the project area
- develop management measures for implementation during construction and operation of the project to mitigate groundwater related impacts
- provide commitments to continued groundwater monitoring, supporting:
 - predictions of potential groundwater impacts
 - an assessment of the efficacy of the implemented management measures
- provide project relevant information to the wider community, including the potential groundwater impacts at a local and regional scale.

This report consists of the following sections:

- Section 2 – The project description, summarising the key project components and definition of the project and study area.
- Section 3 – Project setting, providing a groundwater relevant background for the project area including topography, land use, climate, geology, existing surface water and groundwater conditions and regulation of water sources.

- Section 4 – Regulatory and policy context and assessment, outlining the relevant regulatory policies and documents considered during development of this GIA.
- Section 5 – Baseline monitoring program, summarising the relevant field surveys of the pre-project environment.
- Section 6 – Groundwater characterisation, discussing the outcomes from the baseline monitoring program.
- Section 7 – Conceptual model, providing an interpretive assessment of the existing groundwater environment prior to project construction.
- Section 8 – Assessment approach, providing the basis and rationale for assessing potential impacts induced by the project.
- Section 9 – Groundwater flow assessment, discussing the potential impacts induced by the project arising from reduced groundwater levels or availability.
- Section 10 – Water quality assessment, discussing the potential impacts induced by the project arising from altered water quality and chemistry.
- Section 11 – Impact summary and risk assessment, providing a summary of the consequence of impacts associated with the project.
- Section 12 – Water licensing, providing the water licensing pathway for the project and outlining commitments to navigate the appropriate water regulation and licensing.
- Section 13 – NSW Aquifer Interference Policy (AIP) assessment framework, providing a summary of the relevant requirements stipulated in the AIP and referencing the relevant section of this GIA.
- Section 14 – Conclusions, concluding this GIA with the key findings, management strategies and commitments.

This GIA has been collated in consideration of the project surface water assessment (EMM 2025) and biodiversity development assessment report (BDAR), (EMM 2025). This GIA should be read in conjunction with these reports.



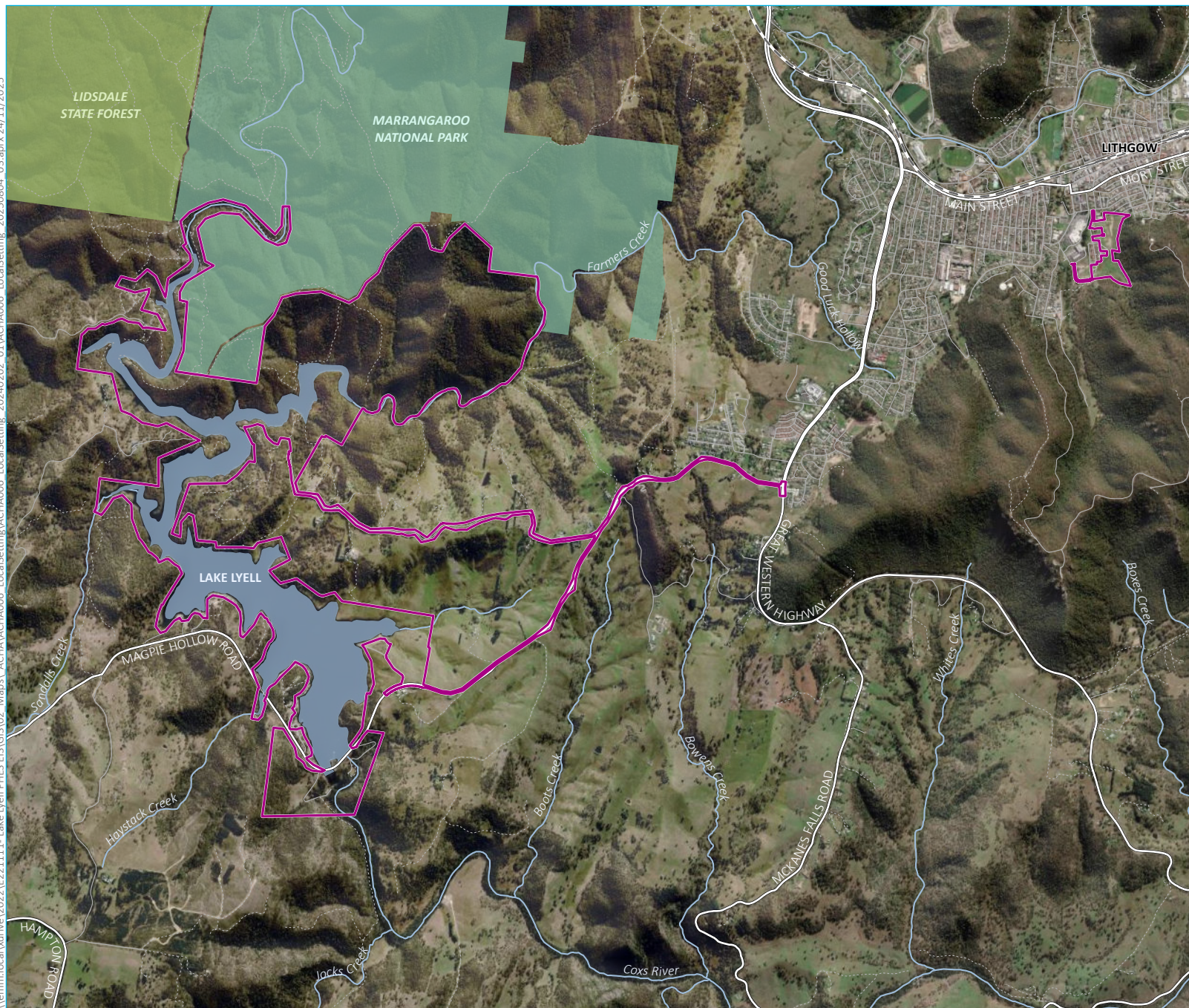
KEY

- ▬ Project area
 - ▬ Local government area
 - ▬ Sydney Drinking Water Catchment
 - ▬ Central West Orana Renewable Energy Zone
 - Mt Piper Power Station
 - ▬ Major road
 - ▬ Great Western Highway
 - ▬ 330 kV transmission line
 - ▬ Named waterbody
 - ▬ NPWS reserve
 - ▬ State forest
 - ▬ State forest
- ## INSET KEY
- ▬ Major road
 - ▬ NPWS reserve
 - ▬ State forest
 - ▬ Central West Orana Renewable Energy Zone

Regional context

Lake Lyell PHES
Groundwater Impact Assessment
Figure 1.1

\\emm.local\ydrive\2021\E22111-1- Lake Lyell PHES EIS\GIS\02- Maps\ ACHAVA\ACHA006 Local\Setting\ACHA006 Local\Setting_20250804_03.aprx 24/11/2025



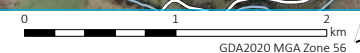
- KEY
- Project area
 - Existing environment
 - Rail line
 - Major road
 - Minor road
 - Vehicular track
 - Named watercourse
 - Named waterbody
 - NPWS reserve
 - State forest

Local context

Lake Lyell PHES
Groundwater Impact Assessment
Figure 1.2



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2024); GA (2009); ESRI (2025)



2 Description of the project

A detailed description of the project, including an overview of its design, construction and operation is provided in the project's EIS. The EIS (specifically Chapter 3 and Appendix B) should be read in conjunction with this report. A summary of the project's key elements is provided below.

The project design, as shown in Figure 2.1, can be broadly categorised into:

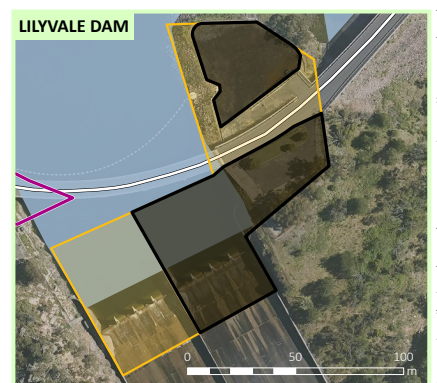
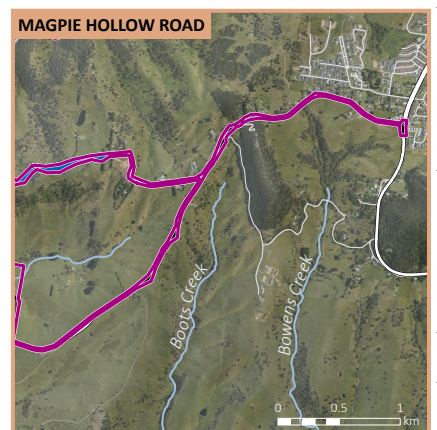
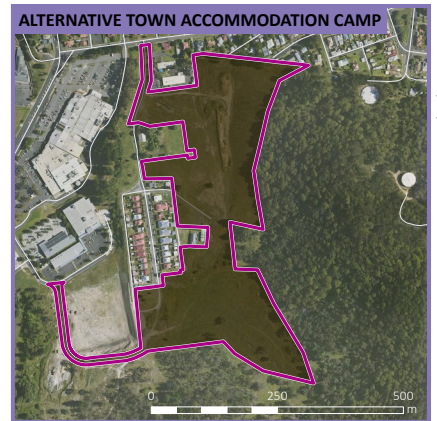
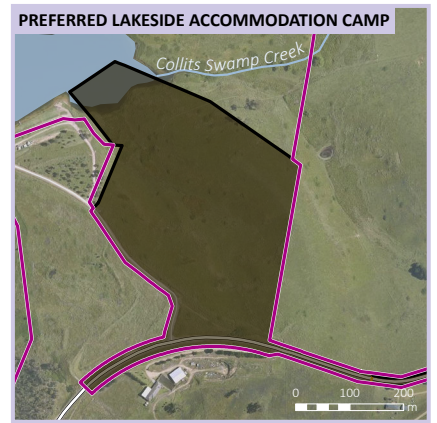
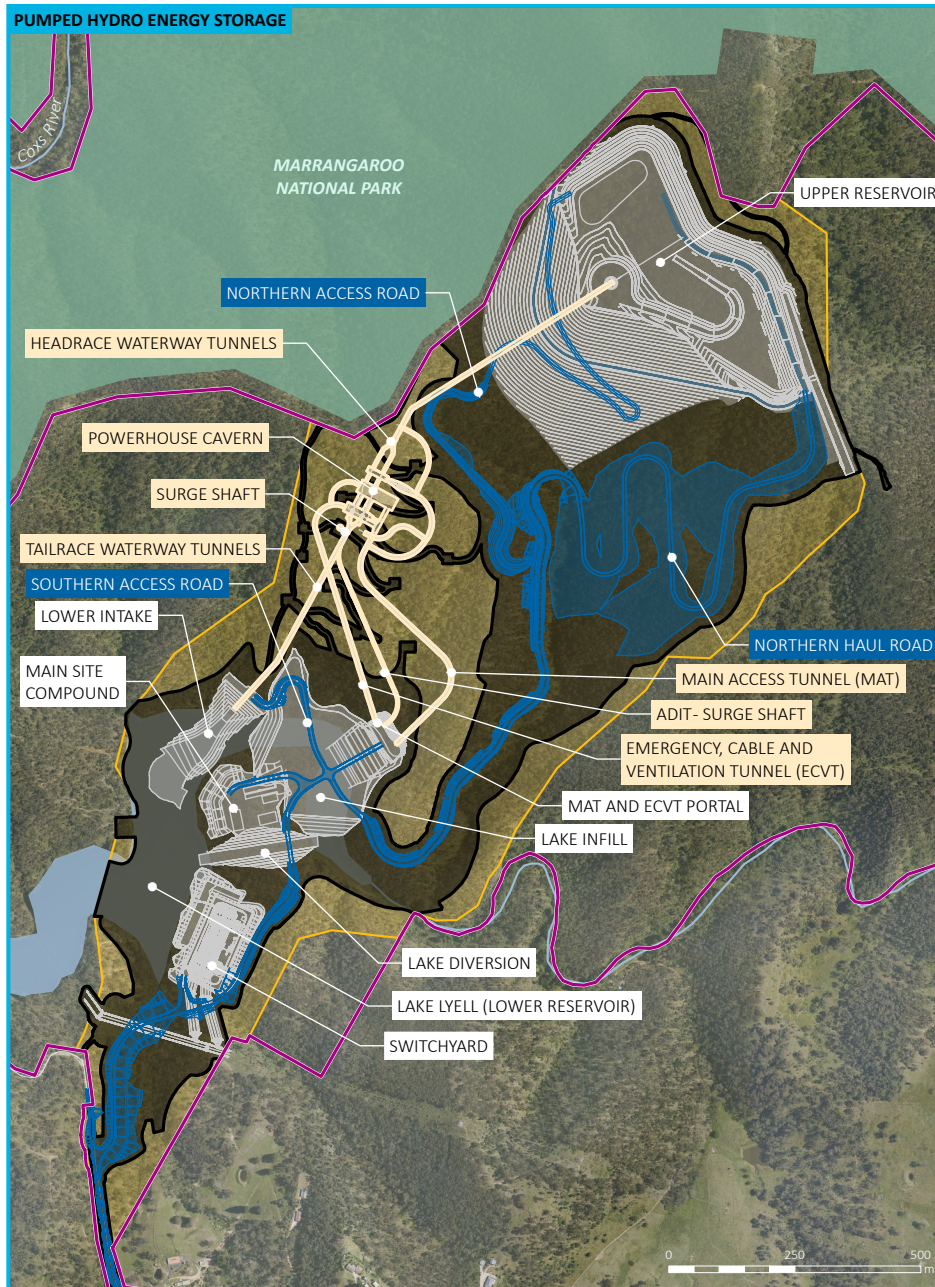
- pumped hydro generation components – including a 5.3 gegalitre (GL) upper reservoir to be constructed behind the southern ridge of Mount Walker, a 33.5 GL lower reservoir (existing Lake Lyell), inlet/outlet structures, and an underground powerhouse, surge shaft and waterway tunnels
- transmission connection components – including a new high voltage switchyard and connection to the existing 330 kilovolt (kV) transmission line that runs through the site
- site access and ancillary facilities – including upgrade of existing and construction of new access roads and bridges, a diversion and infill of a section of Lake Lyell, administration and utilities
- other construction components or works – including geotechnical investigations, temporary workforce accommodation, site work pads, laydown areas and facilities, and spoil management.

Construction will be completed in stages, including:

- pre-construction / enabling works – consisting of initial access works (internal and external roads), geotechnical investigations, site establishment and preparation of the worker's accommodation camp
- main works – consisting of all other construction activities needed to enable operation of the project.

During operation, the project will act as an electrical energy storage system through the conversion of electrical to kinetic energy to gravitational energy and back via water as it is transferred from the elevated upper reservoir to a lower reservoir. The project will provide services to the wholesale 'spot' market on the national electricity market (NEM), and support ancillary services used to manage the power system reliably.

After the 80 to 100-year design life of the project, the asset may remain viable for a plant refurbishment and extension of life as has been seen for other older assets globally. Following the plant's final refurbishment or once it has reached the end of its serviceable life then the project would look to return the site to a more natural state and encourage community beneficial use.

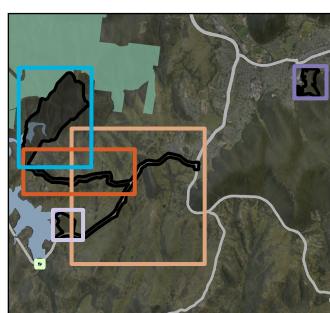


Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2024); GA (2009); MetroMap (2025)

GDA2020 MGA Zone 56



Project overview



KEY

- | | |
|-----------------------|----------------------|
| Project area | Existing environment |
| Permanent road | Major road |
| Above ground design | Minor road |
| Underground design | Named watercourse |
| Construction envelope | Named waterbody |
| Disturbance footprint | NPWS reserve |

Lake Lyell PHES
Groundwater Impact Assessment
Figure 2.1



2.1 The study area

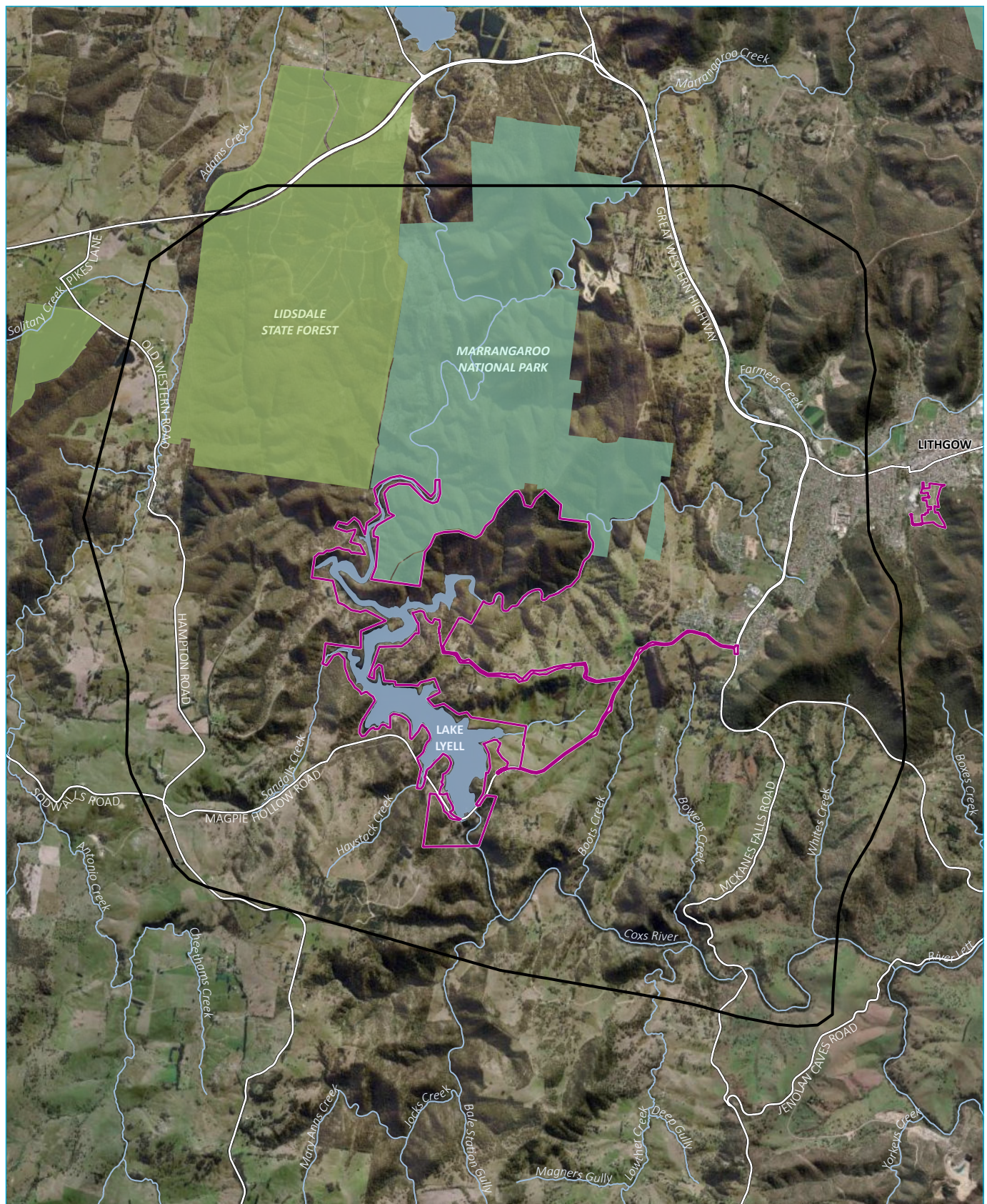
The study area presented in this GIA aligns with the numerical groundwater model boundary, as indicated in Figure 2.2. The study area, which is larger than the project area, encompasses the:

- project related sub-surface excavations
- project related water monitoring network
- nearby licensed groundwater bores
- nearby potential groundwater dependant ecosystems (GDEs).

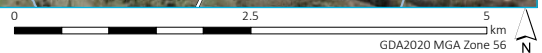
Infrastructure elements that are considered to effect groundwater include:

- the upper reservoir
- the headrace and tailrace tunnels
- ancillary access tunnels and adits
- surge shafts.

Other infrastructure components will be designed to mitigate permanent interception of the regional groundwater table. Temporary de-watering may be required for footing or trench excavations; however, potential impacts are considered minor and temporary and are not considered as part of the detailed assessment incorporating the study area.



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)



KEY

- Project area
- Study area
- Existing environment
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest

Study area setting

Lake Lyell PHES
Groundwater Impact Assessment
Figure 2.2

3 Study area setting

3.1 Data sources

Data sources used to inform understanding of the study area setting are detailed in Table 3.1.

Table 3.1 Data sources for project setting

Setting	Public data	Site specific data
Topography	NSW Elevation Data Service – Topographic elevation contours (DCS Spatial Services 2024)	-
Land use	Land use spatial mapping data (DCCEEW 2017)	-
Climate	SILO climate data (DES 2023). Gridded data accessed at 33 30'S; 150 06'E NARCLiM climate change prediction data (DCCEEW 2024). Accessed at 33 30'S; 150 06'E	-
Hydrology	WaterNSW real time data register (WaterNSW 2022) Water Management (General) Regulation 2018 hydroline spatial data (DPE 2022) NSW Water Quality and River Flow Objectives (DECCW 2006)	
Geology	NSW seamless geology dataset (Colquhoun, et al. 2022) Hydrologic soil groups of NSW (DPE 2012); Australian Soil Type classification soil type of NSW (DPIE 2021)	Lake Lyell PHES Geotechnical Investigation Program (GHD 2023) Lake Lyell Phase 2 PHES Geotechnical Investigation Program (GHD 2024)
Hydrogeology	Guide to groundwater resources in NSW (DPE 2023) Hydrogeological Landscapes of the Capertee and Cocks River Valleys (DPIE 2020)	Lake Lyell PHES Geotechnical Investigation Program (GHD 2023) Lake Lyell Phase 2 PHES Geotechnical Investigation Program (GHD 2024)
Groundwater receptors	National Groundwater Information System (BoM 2013) Greater Metropolitan Region Groundwater Sources 2023 (DPI 2016b) High ecological value aquatic ecosystem database (DPE 2022) Bureau of Meteorology groundwater dependent ecosystem atlas (BoM 2017) Key fish habitats (DPI 2009) NSW Wetlands dataset (DCCEEW 2023)	Lake Lyell PHES Biodiversity Development Assessment Report (EMM 2025)
Nearby groundwater affecting activities	Statement of environmental effects for the proposed expansion of the Marrangaroo Quarry (RWCorkery&Co 2024)	

3.2 Topography and land use

The study area includes three distinct terrains, comprising:

- north-south trending steep ridges and valleys extending north of Lake Lyell (around Mount Walker), providing the topographic relief to support development of the project
- escarpments defining the western extent of the Sydney Basin (refer to Section 3.5) located within the eastern portion of the study area
- rolling foothills occupying the lower elevations within the remainder of the study area.

Elevations within the study area ranges between 1,130 metres Australian Height Datum (mAHD) at Hassans Wall (within the aforementioned escarpments) to approximately 700 mAHD in the south-eastern portion of the study area (within the aforementioned lower-lying foothills). Topography generally slopes down toward the south-east of the study area, providing surface water relief to Coxs River (refer to Section 3.4).

Topographic contours are provided on Figure 3.1.

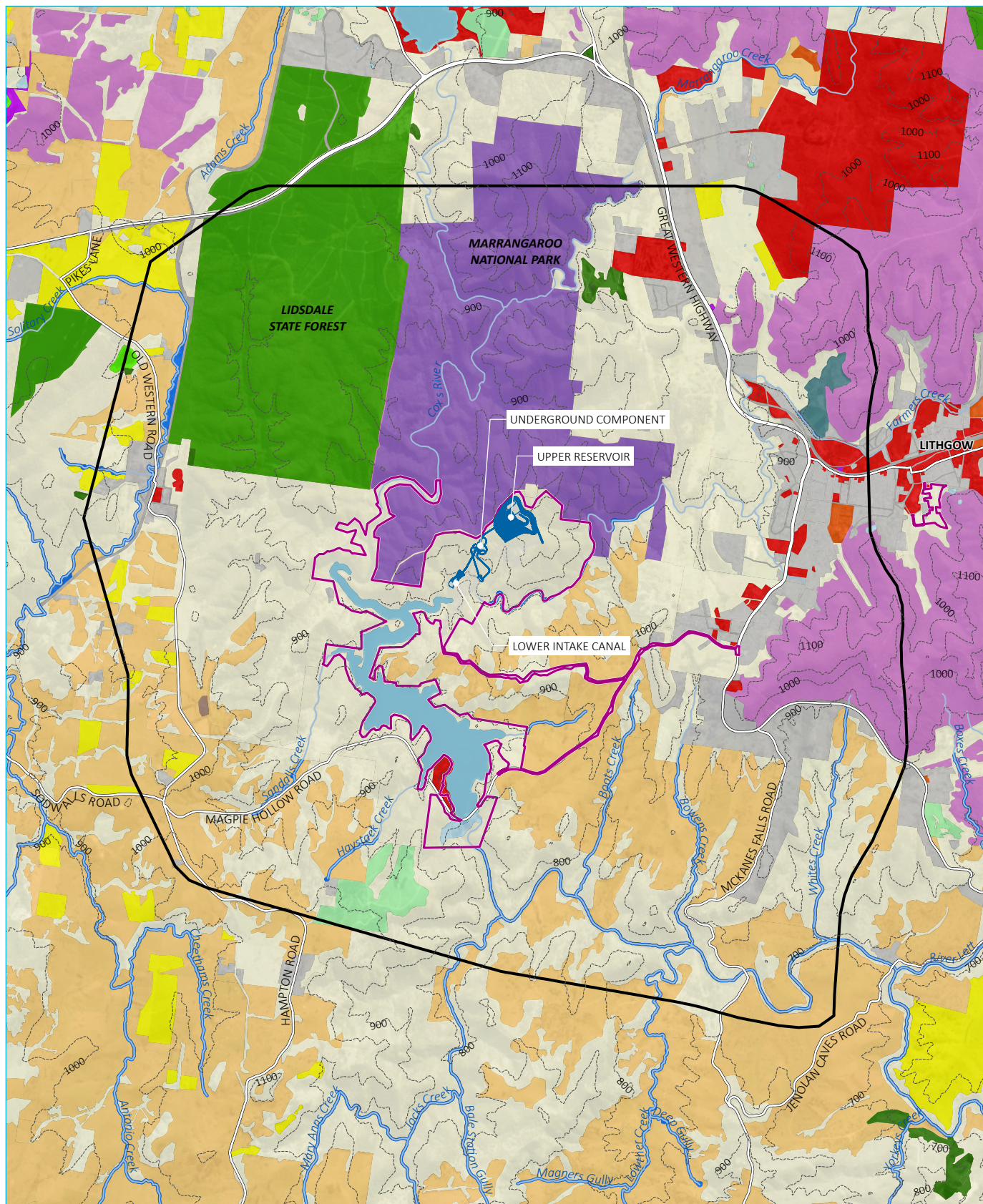
Land within the study area is predominantly used for primary production including grazing, cropping, horticulture and forestry plantations within the foothills. National parks and natural conservation areas represent approximately 12% of the study area. The remaining land uses include residential townships, areas of minimal use (i.e. steep and exposed areas unsuitable for farmland), utilities, waterbodies and mining.

A summary of land use areas is provided in Table 3.2 and indicated on Figure 3.1.

Table 3.2 Land use within the study area

Land use	Sub-categories	Coverage (ha)	Coverage (% of study area)
Primary production	Grazing, cropping, horticulture and forestry plantations	8,993	69
Nature Conservation	National parks	1,521	12
Residential	Townships and areas zoned for residential development	762	6
Minimal use	Escarpments	743	6
Utility	Services, utilities and waste treatment	409	3
Water	Lakes, rivers, reservoirs and wetlands	407	3
Mining	Quarries and mining leases	26	<1

Source: New South Wales Land Use mapping dataset (DCCEEW 2017)



KEY

 Project area	 3.3.0 Cropping	 6.1.0 Lake
 Study area	 3.4.0 Perennial horticulture	 6.2.0 Reservoir/dam
 Key project infrastructure	 5.1.0 Intensive horticulture	 6.3.0 River
Secondary	 5.3.0 Manufacturing and industrial	 6.5.0 Marsh/wetland
 1.1.0 Nature conservation	 5.4.0 Residential and farm infrastructure	Existing environment
 1.3.0 Other minimal use	 5.5.0 Services	 Major road
 2.1.0 Grazing native vegetation	 5.6.0 Utilities	 Topographic contour (100 m interval)
 2.2.0 Production native forestry	 5.7.0 Transport and communication	 Named watercourse
 3.1.0 Plantation forests	 5.8.0 Mining	
 3.2.0 Grazing modified pastures	 5.9.0 Waste treatment and disposal	

Topography and land use

Lake Lyell PHES
Groundwater Impact Assessment
Figure 3.1

3.3 Climate

3.3.1 Overview

This section provides a summary of the climate within the study area. An assessment of climatic stressors (i.e. rainfall and evaporation) provides a baseline for understanding how groundwater systems vary seasonally, prior to project construction. This understanding forms the basis for determining whether changes in the groundwater systems are a result of project activities or climatic fluctuations.

3.3.2 Temperature

The climate of the study area is classified as temperate, with no dry-season and a mild summer (Geiger 1954). Temperatures typically vary between a maximum of 25.4°C in January and a minimum of 0.9°C in July (DES 2023).

A summary of average temperatures is provided in Table 3.3.

Table 3.3 Average temperatures within the study area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average maximum daily temperature (°C)	25.4	24.3	22.1	18.4	14.3	11.0	10.3	11.9	15.3	18.7	21.6	24.2
Average minimum daily temperature (°C)	12.6	12.6	10.7	7.2	4.0	2.1	0.9	1.8	3.7	6.6	8.9	11.1

Source: Silo gridded climate data at location 33 30'S; 150 06'E (DES 2023)

3.3.3 Average rainfall and evaporation

Average rainfall is generally highest in January (~89¹mm/month) and lowest in May and September (~55 mm/month). Occasional snowfalls occur in winter however, snow-melt is not considered a major contributor to hydrologic processes within the study area. Average evaporation is generally highest in January (~176 mm/month) and lowest in July (~36 mm/month) (DES 2023).

A summary of average monthly rainfall and evaporation is provided in Table 3.4.

Table 3.4 Average rainfall and evaporation within the study area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average monthly rainfall (mm/month)	89.4	75.6	73.6	58.3	54.7	70.6	59.5	60.4	55.9	65.2	68.7	76.9
Average monthly evaporation (mm/month)	176.1	135.7	116.1	74.8	46.3	29.8	36.0	56.2	85.8	120.7	141.0	176.0

Source: Silo gridded climate data at location 33 30'S; 150 06'E (DES 2023)

¹ millimetres per month

As provided on Figure 3.2, average rainfall and evaporation data (DES 2023) generally indicates:

- wetter periods are expected between May and August, when rainfall typically exceeds evaporation
- drier periods are expected between September and April, when evaporation typically exceeds rainfall.

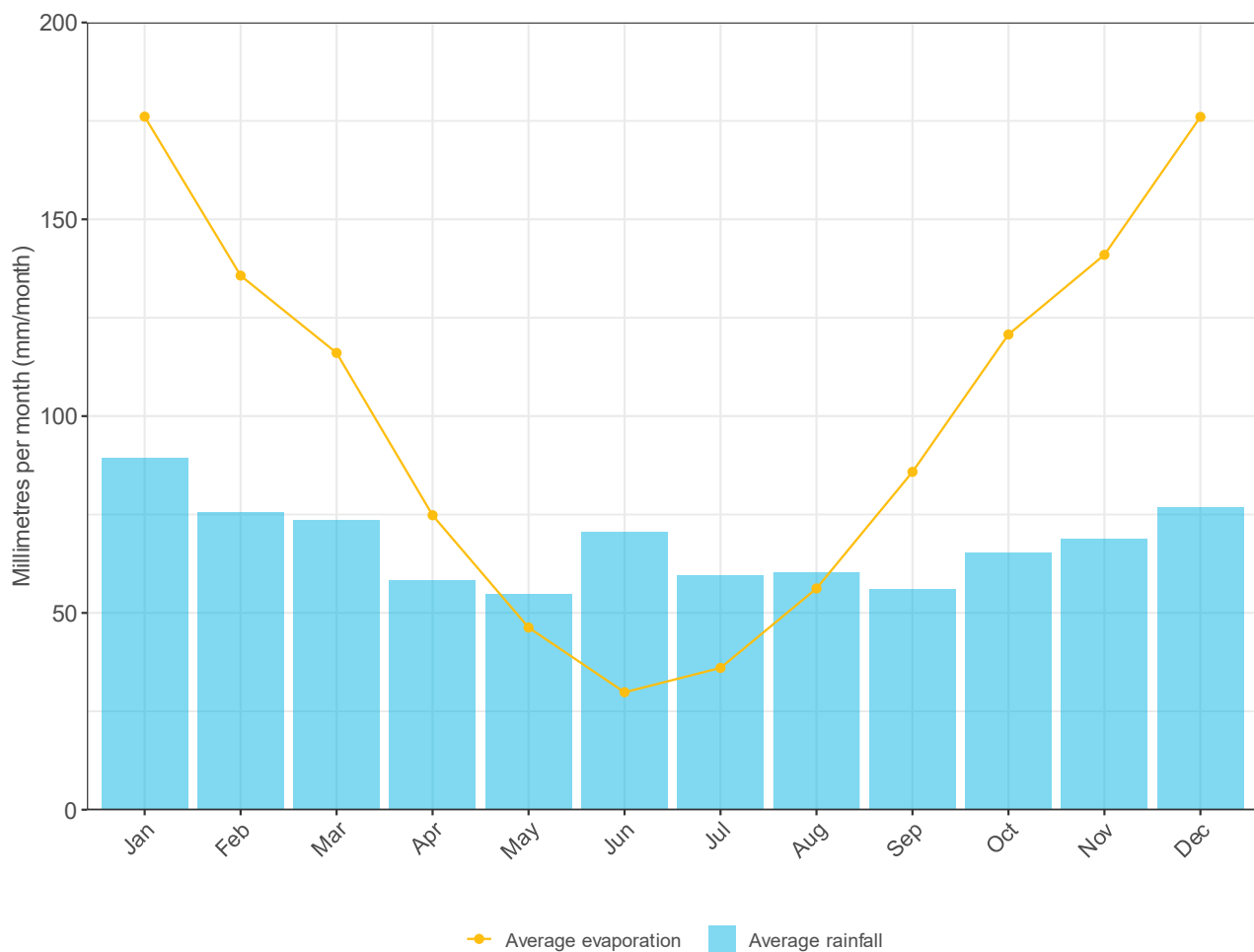


Figure 3.2 Average monthly rainfall and evaporation within the study area

3.3.4 Recent rainfall trends

As provided on Figure 3.3, rainfall records (DES 2023) between February 2023 and August 2024 (representing the baseline groundwater monitoring period, as further discussed in Section 5.3.1) indicate:

- below average rainfall (typical of a dry period) over 11 months, comprising:
 - February 2023 (one month)
 - May to November 2023 (six months)
 - February 2023 to April 2024 (two months)
 - July 2024 to September 2024 (two months)
- above average rainfall (typical of a wet period) over the remaining 8 months, comprising:
 - March to May 2023 (two months)

- November 2023 to February 2024 (three months)
- April to July 2024 (three months).

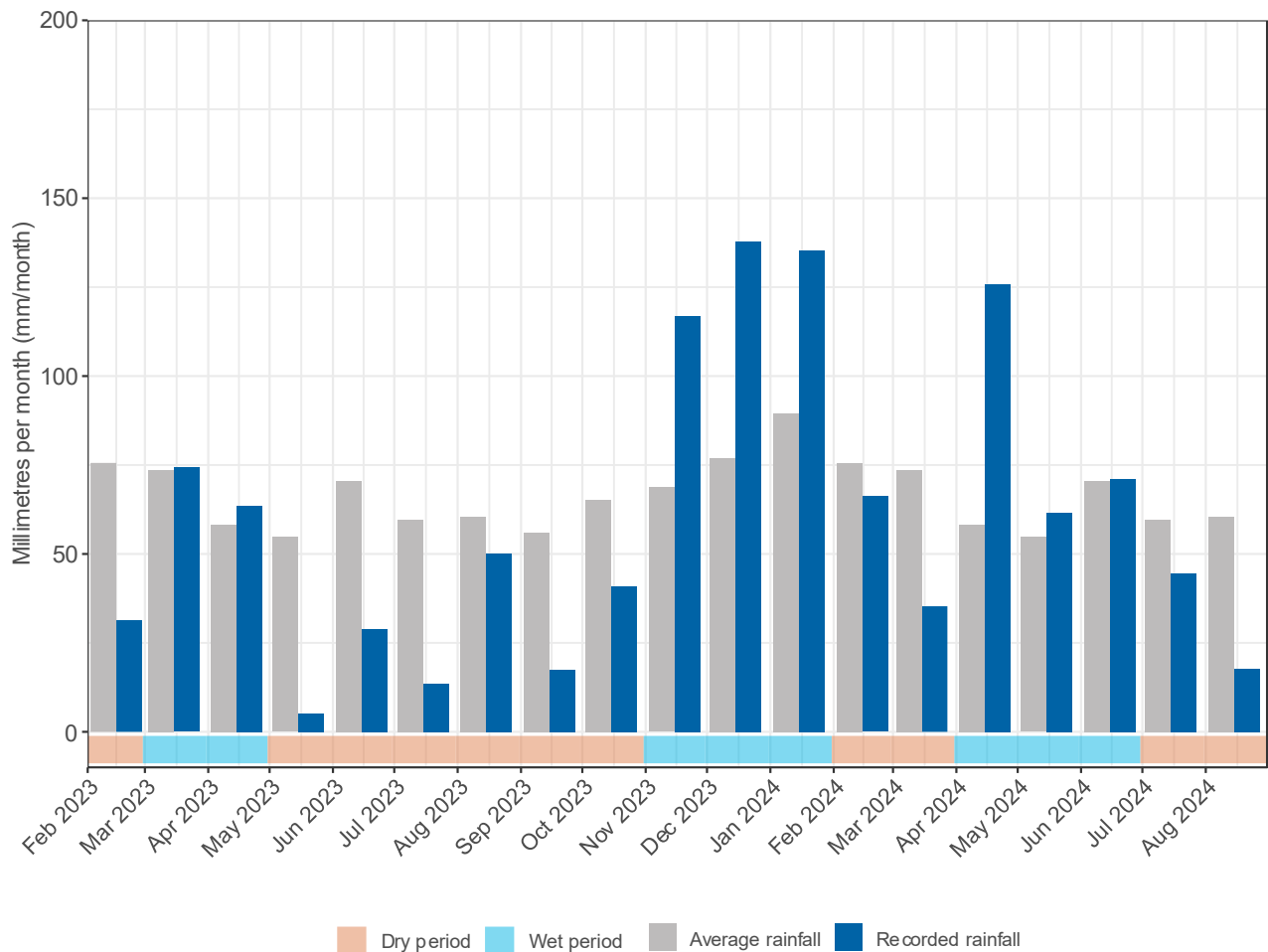


Figure 3.3 Rainfall records within the study area between February 2023 and August 2024

3.3.5 Climate change

As provided on Figure 3.4 and Figure 3.5, climate change prediction data (DCCEEW 2024) indicates:

- maximum average temperatures are predicted to increase by 1.36 to 3.91°C by 2099, under a low or high emission² scenario respectively
- minimum average temperatures are predicted to increase by 1.13 to 3.53°C by 2099, under a low or high emission scenario respectively
- average rainfall is predicted to decrease by up to 14.31% (in 2069) under a high emission scenario and 11.43% (in 2079) under a low emission scenario.

² High and low emission scenarios reflect the relative emission levels of greenhouse gases during the predictive phase of modelling (DCCEEW 2024).

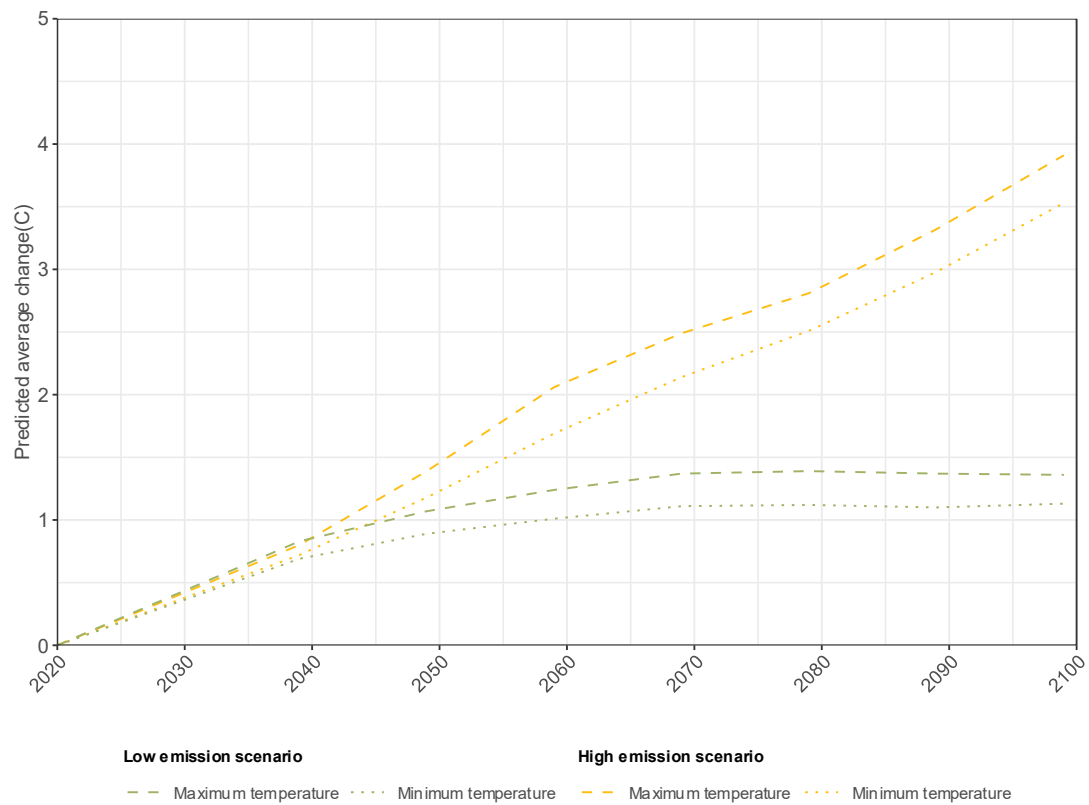


Figure 3.4 **Predicted temperature increase within the study area**

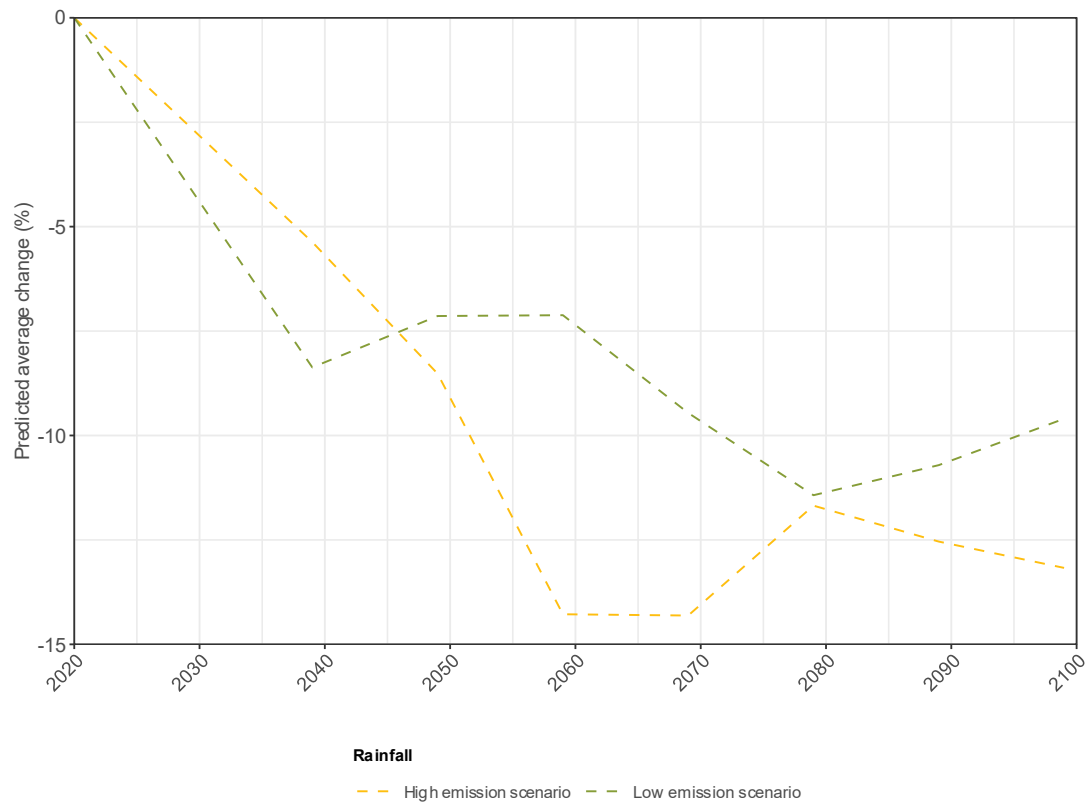


Figure 3.5 **Predicted rainfall decrease within the study area**

3.4 Hydrology

Lake Lyell is a 33.5 GL, man-made lake that forms the project lower reservoir. The lake was constructed on the Coxs River to provide cooling water for the Mt Piper (operational) and Wallerawang (decommissioned) coal-fired power stations. Cooling water is currently pumped from Lake Lyell to Thompsons Creek Dam (~11 km north-west) to support power generation at Mt Piper power station. Recreational purposes are also permitted on Lake Lyell, including boating, skiing, fishing and swimming (EnergyAustralia 2021).

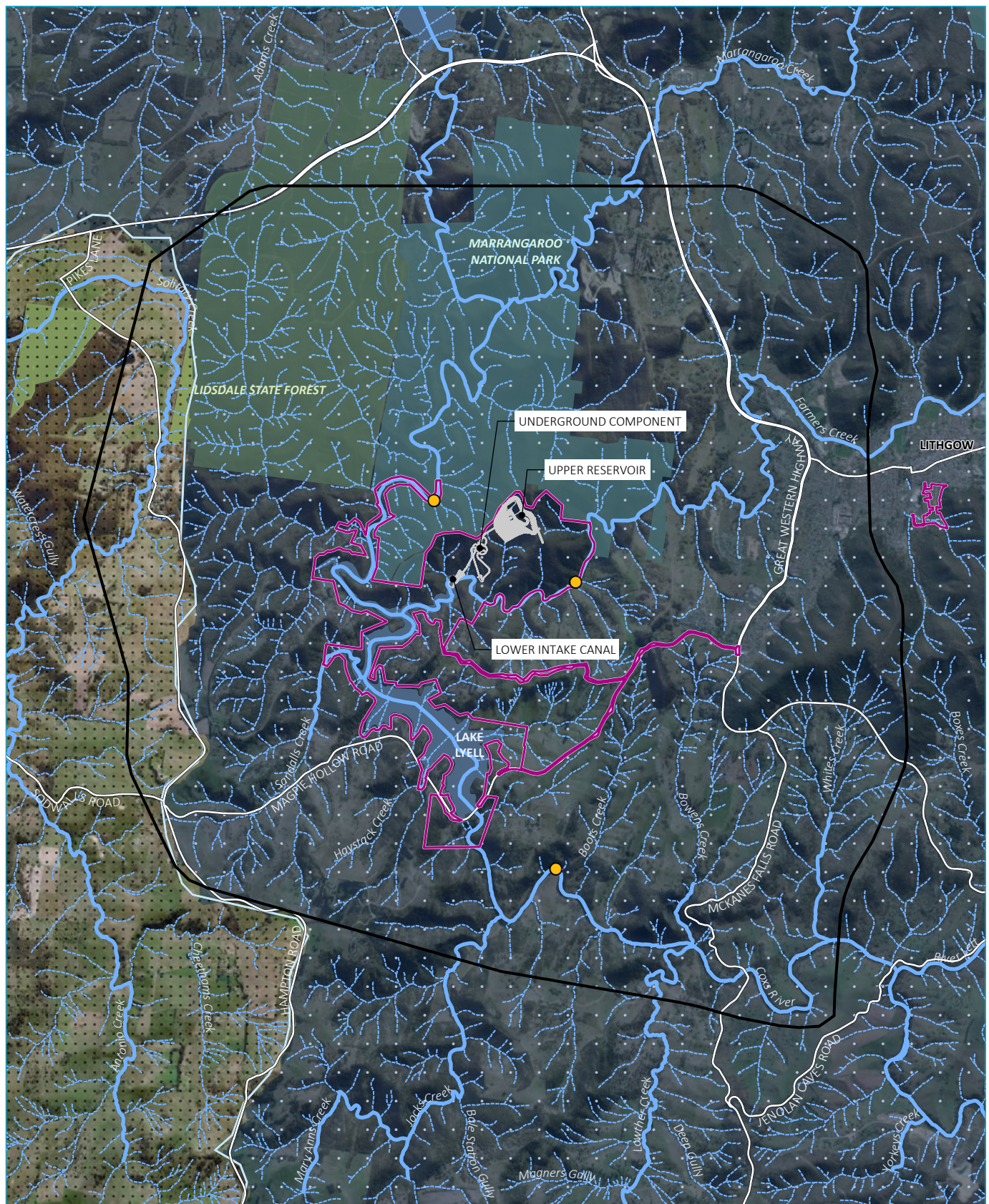
The study area straddles the Hawkesbury-Nepean catchment of the Sydney drinking water catchment (WaterNSW 2015) and the Macquarie-Bogan catchment (DECCW 2006). Watercourses within the study area generally flow towards Coxs River, a 6th-order perennial watercourse within the Hawkesbury-Nepean catchment. Solitary Creek (4th-order perennial watercourse) lies within the Macquarie-Bogan catchment and generally flows west to confluence with Fish River (beyond the study area). Watercourse level and discharge gauging stations are located on Coxs River and Farmers Creek (4th-order perennial watercourse), (WaterNSW 2022).

A summary of perennial watercourses and gauging stations is provided in Table 3.5 and shown on Figure 3.6.

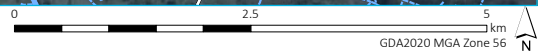
Table 3.5 Perennial watercourses and gauging stations

Watercourse	Catchment	Discharges to	Stream order	Gauging station ID
Farmers Creek	Hawkesbury-Nepean	Lake Lyell/Coxs River	4	212042
Sandalls Creek		Lake Lyell/Coxs River	4	-
Coxs River		Lake Burragorang (~50 km south-east of study area)	6	212008 212058 212011
Bowens Creek		Coxs River	4	-
Jocks Creek		Coxs River	4	-
Lowther Creek		Coxs River	5	-
Whites Creek		Coxs River	4	-
Marangaroo Creek		Coxs River	5	-
Solitary Creek		Fish River (~18 km west of study area)	4	-
	Macquarie Bogan			

Source: WaterNSW real time data register (WaterNSW 2022); Water Management (General) Regulation hydroline spatial data (DPE 2022)



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009); DPE (2010); DPI (2017); SCA (2011)



KEY

- | | |
|---|--|
| Project Area | Water catchment |
| Study area | Hawkesbury |
| ● Stream flow gauge | Macquarie |
| — Key project infrastructure | Sydney drinking water catchment |
| Watercourse classification | Existing environment |
| — Perennial stream | — Major road |
| - - - Ephemeral stream | NPWS reserve |
| | State forest |

Hydrological setting

Lake Lyell PHES
Groundwater Impact Assessment
Figure 3.6

3.5 Geology

3.5.1 Rock units

The study area lies within the Palaeozoic Lachlan Fold Belt (LFB) geological province. Rock units associated with the younger Permo-Triassic Sydney Basin (the Sydney Basin) conformably overlie the LFB, within the eastern portion of the study area. Geological provinces are outlined on Figure 3.7.

The LFB underlies the south-eastern portion of Australia, extending from southern Queensland to central Tasmania and across the majority of NSW (refer to Figure 3.7). Deformation occurred via tectogenesis during the early-Carboniferous Kanimblan Orogeny, resulting in a series of structural zones that are broadly categorised by tectonic history.

The study area lies within the Capertee Anticlinorium structural zone of the LFB, comprising volcanic rocks (such as the Bathurst Batholith), sedimentary and metamorphic rock units (Gilligan and Scheibner 1978). The project will intercept rock units associated with the Devonian Lambie group (a subgroup of the LFB), including the Gibbons Creek Sandstone and the Rydal Formation. A summary of LFB rock units within the study area is provided in Table 3.6 and indicated on Figure 3.7.

The Sydney Basin overlies the LFB regionally, extending north-west of Batemans Bay, NSW to beyond the NSW and Queensland border. Tectonic activity throughout the early Permian resulted in the deposition of sediments. Subsequent loading, sedimentation and uplift until the mid-Triassic resulted in the formation of the sedimentary rocks that are typical of the Sydney Basin.

Within the eastern portion of the study area, the Permian Illawarra Coal Measures, Permian Shoalhaven group and Triassic Narrabeen Group overlie the LFB rock units. Based on lithological logs accessed via the National Groundwater Information System (BoM 2013), the Sydney Basin rock units dip downward to the east at approximately 20° and are up to 105 metres (m) thick within the study area. A summary of Sydney Basin rock units within the study area is provided in Table 3.6 and indicated on Figure 3.7.

Table 3.6 Geological units within the study area

Province	Age	Group/suite	Dominant type	Unit	Dominant lithology
Lachlan Fold Belt	Devonian	Lambie Group	Sedimentary/Me tamorphic	¹ Gibbons Creek Sandstone	Sandstone / Quartzite
				¹ Rydal Formation	Mudstone / Quartzite
	Carboniferous	Bathurst Batholith	Igneous (plutonic)	Hartley Suite	Granite
				Blaxland Granite	Granite
				Lett Granite	Granite
	Sydney Basin	Permian	Illawarra Coal Measures	Sedimentary	Illawarra Coal Measures
Shoalhaven group			Bery Siltstone		Siltstone
Triassic		Narrabeen Group	Sedimentary	Banks Wall Sandstone	Sandstone
				Caley Formation	Mudstone

Source: NSW seamless geology dataset (Colquhoun, et al. 2022)

Notes: 1. Units intercepted by sub-surface project infrastructure.

3.5.2 Structural geology

Deformation of the rock units within the Capertee Anticlinorium structural zone has resulted in the formation of geological structures within the study area. A summary of geological structures is provided in Table 3.7 and indicated on Figure 3.7.

Table 3.7 Geological structures within the study area

Structure	Distance from project (km) ¹	Direction from project
Rydal syncline	2	West
Syncline (unnamed)	1.8	East
Anticline (unnamed)	1.1	East

Source: The palaeogeographic development of the Lambie and Catombal Groups (Killick 1987)

Notes: 1. Distance measured in kilometres from centroid of powerhouse to closest axial intercept of structure.

3.5.3 Soils

Residual soils within the Mount Walker area are typically shallow (<0.5 metre (m)) along ridgelines, becoming deeper (<2 m) along the base of ridges where colluvial deposits mix with underlying residual material. Topsoils are typically acidic (pH of 6.0 to 6.5) and sub-soils are typically acidic to alkaline (pH of 6.0 to 7.5). Rural capability is limited by low fertility, a high potential for aluminium toxicity and low water holding capacity (high permeability). (DCCEEW 2024)

In accordance with the Australian Soil Classification system, soils within the study area include (DPIE 2021):

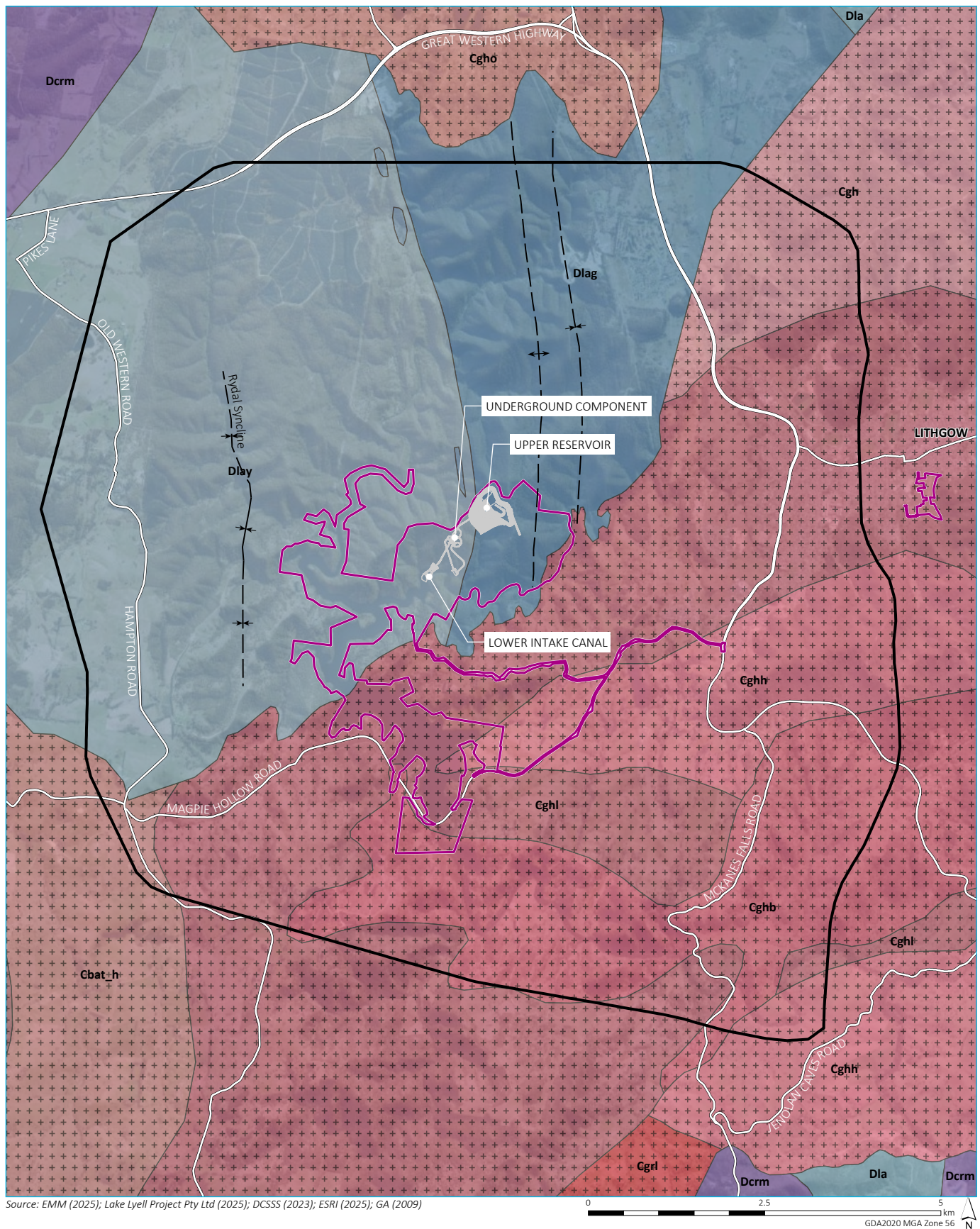
- Kurosols, identified by a clear and abrupt contrast between upper and lower, acidic soil horizons
- Kurosols (natric), as in Kurosols with a sodic soil horizon
- Kandosols, which typically lack strong texture contrasts and are not calcareous
- Rudosols, which area typically 'young' soils with a low level of pedological development
- Rudosols (alluvial), as in Rudosols yet occupying valley floors near watercourses.

A summary of soil locations, infiltration rates and distribution within the study area is provided in Table 3.8. Soil extents are indicated on Figure 3.8.

Table 3.8 **Soil mapping within the study area**

Soil type	General location	Infiltration rate	Distribution within study area (ha)
Kurosols	Lower lying and relatively flat areas	Slow	4,777
Kandosols	Elevated areas around Mount Walker and Lithgow	Very slow	4,154
Rudosols	Sloping areas along valley edges	High	3,171
Rudosols (alluvial)	Confined to Coxs Creek, downstream of Lake Lyell	High	78
Kurosols (natric)	Confined to Solitary Creek, west of Mount Walker mountain range	Very slow	42

Source: Hydrologic soil groups of NSW (DPE 2012); Australian Soil Type classification soil type of NSW (DPIE 2021)



KEY

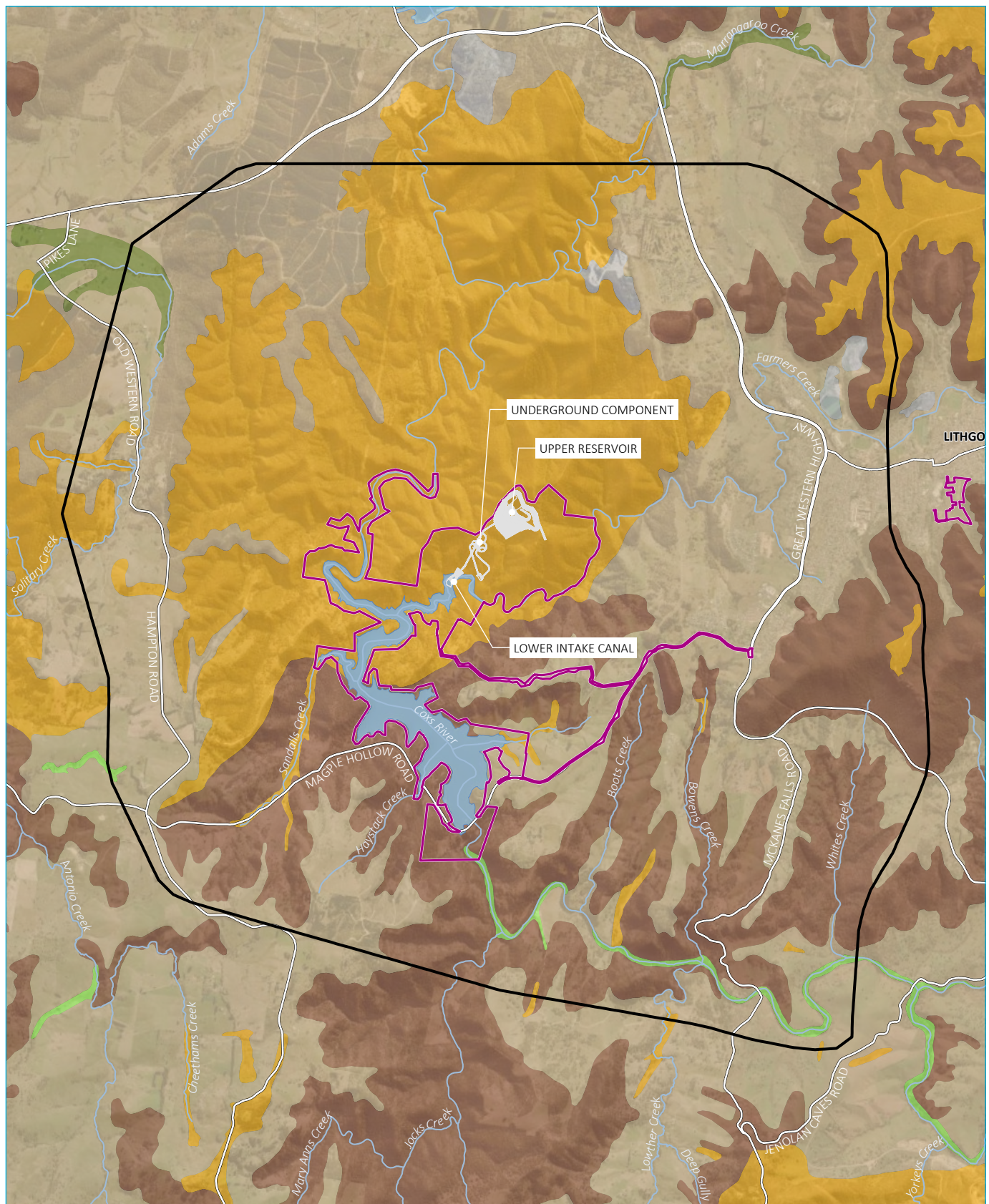
- Project area
- Study area
- Key project infrastructure
- Fold axes
- Anticline, position approximate
- Syncline, position accurate
- Syncline, position approximate
- Seamless geology | Lachlan Orogen
- Carboniferous
- Cgh | Hartley Suite

- Cghb | Blaxland Granite
- Cghl | Lett Granite
- Cgho | Bonny Hills Granite
- Cghh | Hartley Granodiorite
- Cgri | Lowther Creek Granodiorite
- Cbat_h | Tarana Granite - hornblende granite (phase 9)
- Cbat_l | Tarana Granite - leucogranite (phase 11)

- Middle to late Devonian basins
- Dla | Lambie Group
- Dlag | Gibbons Creek Sandstone
- Dlas | Slowmans Creek Conglomerate
- Dlay | Rydal Formation
- Silurian to Mid Devonian basins
- Dcrm | Merriens Formation
- Existing environment
- Major road

Geological setting (rock units)

Lake Lyell PHES
Groundwater Impact Assessment
Figure 3.7



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009); DPIE (2022)

KEY

- Project area
- Study area
- Key project infrastructure
- Existing environment
- Major road
- Named watercourse

Dominant ASC - Order

- Kandosols (KA)
- Kurosols (KU)
- Kurosols - natric (KUn)
- Rudosols (RU)
- Rudosols - alluvial (RUa)
- Not assessed
- Water

Geological setting (soils)

Lake Lyell PHES
Groundwater Impact Assessment
Figure 3.8

3.6 Hydrogeology

3.6.1 Hydrogeological landscapes

The study area predominantly comprises fractured rock groundwater systems associated with the LFB and Sydney Basin geology. Minor porous rock groundwater systems likely form part of the Sydney Basin geology. Alluvial and colluvial deposits occupy valley floors near watercourses. These localised systems typically reflect the flow regimes in the associated watercourse and are not considered a regional groundwater system.

Groundwater within the LFB is typically fresh (<100 microsiemens per centimetre (µs/cm)) however, beneficial use is limited by low bore yields (<5 litres per second (L/s)) that are typical of low permeability, volcanic rock units. Groundwater is accessed for stock watering, domestic household supply, small scale irrigation and mining (DPE 2023).

Groundwater within the Sydney Basin is typically fresh (<200 µs/cm) and beneficial use can be supported by high-yielding (~50 L/s) bores targeting Triassic sandstone units (DPE 2023). Groundwater is accessed for stock watering, domestic household supply and recreation (DPE 2023). Coal extraction occurs within the Sydney Basin (typically targeting the Illawarra Coal Measures) at the Western Coalfields near Lithgow (DPE 2023), resulting in localised de-pressurisation and changes to water quality.

Hydrogeological landscapes (HGLs) provide an indication of general hydrogeological settings within a regional area. There are nine HGLs within the study area, broadly constrained by topography and geological setting (refer Section 3.5). A summary of HGLs within the study area is provided in Table 3.9 and indicated on Figure 3.9.

Table 3.9 Summary of hydrogeological landscapes within the study area

Name	Associated geology	Recharge	Confinement	Flow type	Hydraulic conductivity (m/d)		Specific yield (%)		Groundwater quality (µs/cm)
Mount Walker	Lambie Group	Low	Unconfined	Fractured rock	0.01	>10	5	15	<100 (fresh)
Hassans Walls	Sydney Basin	High	Unconfined	Fractured and porous rock	0.01	>10	5	15	<100 (fresh)
Hampton	Bathurst Batholith	Moderate to high	Unconfined	Fractured rock	0.01	>10	5	15	<200 (fresh)
Angus Place	Sydney Basin	High	Unconfined	Fractured and porous rock	>10	-	5	15	<200 (fresh)
Pipers Flat	Bathurst Batholith	Moderate to high	Unconfined	Fractured rock	0.01	>10	5	15	<200 (fresh)
³ Stuart Town	Lambie Group	Low	Unconfined	Fractured rock	0.01	>10	5	15	<100 (fresh)
³ Glanmire	Lambie Group	Low	Unconfined	Fractured rock	0.01	>10	5	15	<100 (fresh)
³ Dunedoo	Lambie Group	Low	Unconfined	Fractured rock	0.01	>10	5	15	<100 (fresh)
³ Dunkeld	Lambie Group	Low	Unconfined	Fractured rock	0.01	>10	5	15	<100 (fresh)

Source: Hydrogeological Landscapes of the Capertee and Cops River Valleys (DPIE 2020)

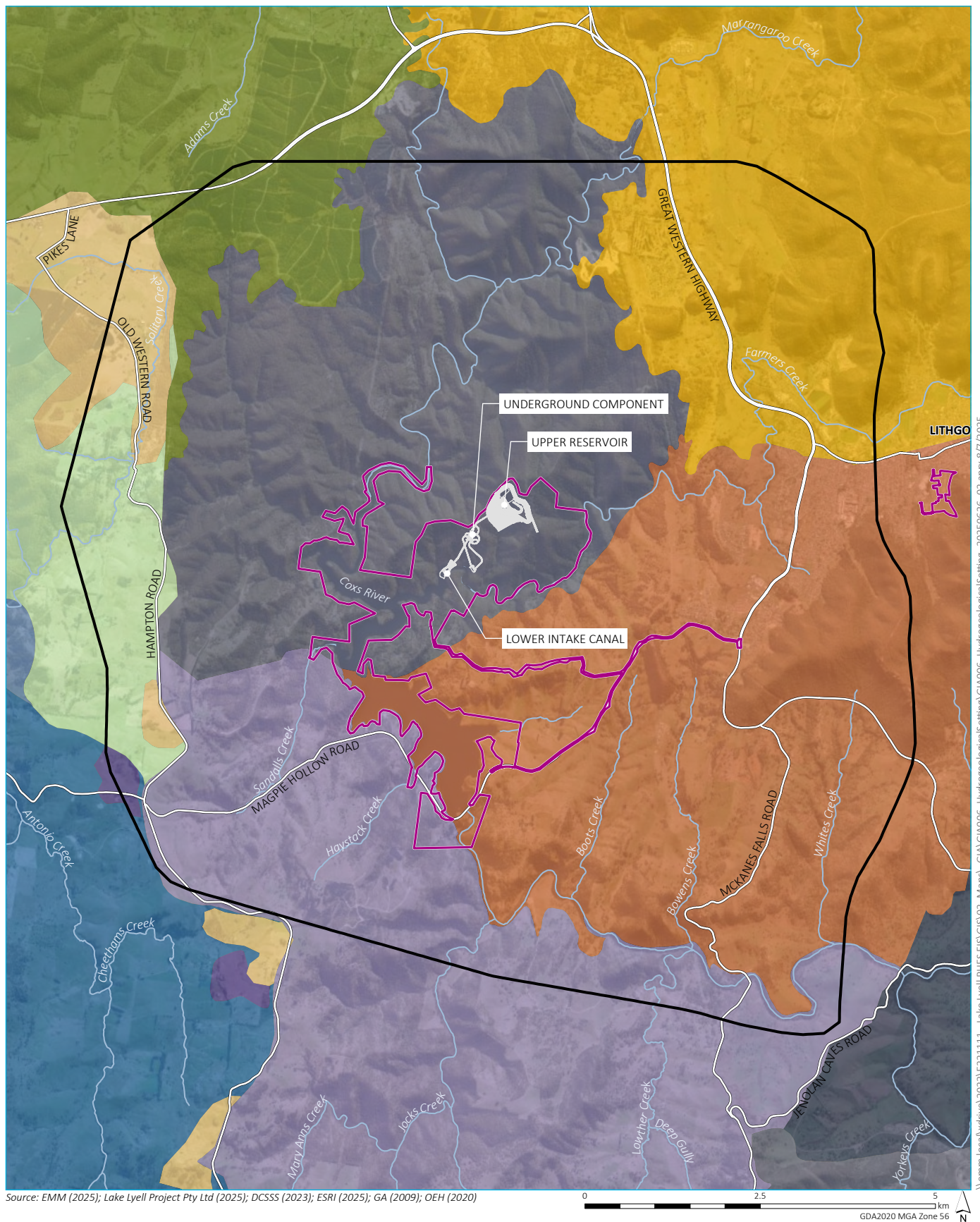
Notes: 1. metres per day, 2. microsiemens per centimetre, 3. values inferred from Mount Walker review, based on similar geology

3.6.2 Hydraulic parameters

Hydraulic parameters were sourced from various literature sources, ensuring a range was considered beyond values derived from site-specific testing. Hydraulic parameters from literature sources are summarised in Table 3.10.

Table 3.10 Hydraulic parameters – Literature sourced

Hydraulic parameter	Source	Study area geology	Reference geology	Lower bound	Upper bound
Hydraulic conductivity (m/d)	(Domenico and Schwartz 1990)	Bathurst Batholith	Weathered granite	2.8×10^{-1}	4.5
		Lambie Group Bathurst Batholith	Fractured igneous and metamorphic rock	6.9×10^{-4}	2.6×10^1
			Unfractured igneous and metamorphic rock	2.6×10^{-9}	1.7×10^{-5}
		Lambie Group Sydney Basin	Sandstone	2.6×10^{-5}	5.2×10^{-1}
			Shale	8.6×10^{-9}	1.7×10^{-4}
			Siltstone	8.6×10^{-7}	1.2×10^{-3}
	(Cherry and Freeze 1979)	Bathurst Batholith	Granite	8.6×10^{-9}	8.6×10^{-4}
	(Karro and Lahermo 1999)	Bathurst Batholith	Granite	8.6×10^{-8}	4.3×10^{-1}
Specific yield (%)	(Heath 1983)	Bathurst Batholith	Granite	9	
		Lambie Group Sydney Basin	Sandstone (unconsolidated)	6	
			Sandstone, fine grained	21	
			Sandstone, medium grained	27	
			Siltstone	12	
	(Morris and Johnson 1967)	Bathurst Batholith	Granite	14	
Specific storage	(Domenico and Mifflin 1965)	Lambie Group Bathurst Batholith	Rock, fissured	3.0×10^{-7}	6.4×10^{-6}
	(Acworth, Rau and Timms 2018)	Sydney Basin	-	-	1.3×10^{-5}
	(Rau, et al. 2022)		Consolidated materials	1×10^{-6}	1×10^{-5}



KEY

- Project area
- Study area
- Key project infrastructure
- Existing environment
- Major road
- Named watercourse

Hydrogeological landscape

- | | |
|--|--|
| Angus Place | Hampton |
| Dunedoo | Hassans Walls |
| Dunkeld | Mid Cocks River |
| Euchareena | Mount Walker |
| Glanmire | Pipers Flat |
| | Stuart Town |

Hydrogeological setting - desktop based

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Groundwater Impact Assessment
Figure 3.9

3.7 Groundwater receptors

3.7.1 Private groundwater users

Based on a search of the National Groundwater Information System (BoM 2013), private groundwater users within the study area include landholders and commercial entities with registered water bores. Private groundwater users typically target HGLs supported by the Sydney Basin geology (i.e. Hassan's Wall HGL and Angus Place HGL).

A summary of active water supply works (i.e. water supply works that are not abandoned, backfilled, decommissioned or designated for monitoring) is provided in Table 3.11. A location plan is provided as Figure 3.10.

Table 3.11 Landholder bores within the study area

Bore ID	¹ Easting	¹ Northing	Elevation (² mAHD)	Screen top (³ mbgl)	Screen bottom (³ mbgl)	Yield (⁴ L/s)	Water level (³ mbgl)	Drilled date	Geology	Hydrogeological landscape	Purpose
GW044385	232180	6287632	891.3	0.5	3.7	0.3	0.9	-	Sandstone	Angus Place	Household
GW045761	231716	6289043	981.0	17.1	51.8	0.2	13.7	1/03/1977	Sandstone	Angus Place	Household
GW052606	233741	6289623	963.4	-	-	0.5	19.8	1/10/1980	Sandstone	Angus Place	Household
GW053081	232055	6295435	924.4	4.5	6.1	0.1	0.3	1/12/1980	Sandstone	Angus Place	Irrigation
GW053934	232413	6289093	949.4	7.6	38.1	0.1	2.4	1/06/1981	Sandstone	Angus Place	Irrigation
GW055053	232063	6295158	926.1	6.4	12.5	0.4	6.1	1/07/1981	Sandstone	Angus Place	Water Supply
GW057432	234048	6291605	911.9	-	-	0.3	-	1/01/1983	Sandstone	Angus Place	Water Supply
GW059292	233479	6292417	907.3	-	-	6.3	30.5	1/06/1983	Sandstone	Angus Place	Commercial/Industrial
GW060112	232058	6294418	941.2	17.1	30.2	9.1	12.2	1/02/1983	Sandstone	Angus Place	Recreation
GW060113	231462	6294463	975.9	-	-	-	-	1/02/1983	Sandstone	Angus Place	Recreation
GW063721	233143	6292567	902.4	21.3	21.9	0.5	-	1/10/1986	Sandstone	Angus Place	Household
GW068241	225098	6287806	1,030.9	-	-	0.1	30.5	11/02/1990	Volcanics	Mount Walker	Household
GW070637	233046	6287661	947.0	10.0	16.0	0.3	-	1/01/1993	Sandstone	Angus Place	Stock and domestic
GW071207	232875	6289167	940.0	12.0	25.0	0.3	8	1/11/1992	Sandstone	Angus Place	Household
GW072313	230868	6288252	944.0	17.0	21.0	1.0	17	11/07/1994	Sandstone	Angus Place	Household
GW100967	232631	6294137	961.8	38.0	50.0	8.0	-	12/08/1995	Sandstone	Angus Place	Household
GW102428	232196	6294113	948.7	9.1	38.1	1.3	28.9	7/01/1992	Sandstone	Angus Place	Household
GW103197	224816	6287921	1,020.6	0.0	36.6	-	-	1/01/1997	Sandstone	Angus Place	Irrigation
GW104751	233697	6291121	920.2	0.0	135.0	-	-	12/12/1980	Sandstone	Angus Place	Household

Bore ID	¹ Easting	¹ Northing	Elevation (² mAHD)	Screen top (³ mbgl)	Screen bottom (³ mbgl)	Yield (⁴ L/s)	Water level (³ mbgl)	Drilled date	Geology	Hydrogeological landscape	Purpose
GW105910	233620	6288001	922.9	-	-	-	-	12/05/2005	Sandstone	Angus Place	Household
⁵ GW109204	228975	6288355	874.7	0.0	3.0	-	-	12/08/2008	Sandstone	Angus Place	Commercial/Industrial
GW111670	232246	6294107	947.4	30.0	48.0	0.5	18	14/03/2012	Sandstone	Angus Place	Household
GW114873	232252	6294076	⁶ 946.6	-	-	-	-	30/04/2014	Sandstone	Angus Place	Household
GW115819	232636	6289115	⁶ 942.1	9.5	120.0	-	-	11/05/2018	Sandstone	Angus Place	Household
GW115854	232423	6288933	⁶ 951.2	18.0	33.0	-	-	8/05/2018	Sandstone	Angus Place	Household

Source: National Groundwater Information System (BoM 2013); WaterNSW Real Time Data register (WaterNSW 2022)

- Notes:
1. GDA94/MGA Zone 56
 2. Metres above Australian Height Datum
 3. Metres below ground level
 4. Litres per second
 5. Excavation registered as groundwater bore
 6. Projected using ELVIS digital elevation model

3.7.2 Environmental groundwater receptors

i Terrestrial groundwater dependant ecosystems

Based on the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2023 (further discussed in Section 4.2.2i) (DPI 2016b), high priority terrestrial GDEs are mapped within the study area. To further understand the occurrence and distribution of terrestrial GDEs within the study area, plant community types (PCTs) mapping was collated from various data sources, including:

- GDEs – High Priority (DPI 2022), hereafter referred to as the high priority dataset
- High probability GDEs, as mapped in the High Ecological Values Aquatic Ecosystems (HEVAE) Vegetation Groundwater Dependent Ecosystems Value – Hawkesbury Nepean database (DPE 2022), hereafter referred to as the HEVAE dataset
- High potential GDEs, as mapped in the Bureau of Meteorology’s Groundwater Dependant Ecosystem Atlas (BoM 2017), hereafter referred to as the GDE atlas dataset.

High priority GDEs (as designated in the high priority dataset) correlate to high probability GDEs (as designated in the HEVAE dataset). High potential GDEs (as designated in the GDE atlas dataset) refer to plant community types (PCTs) that are highly likely to rely on access to groundwater (at varying dependency levels) to sustain ecosystem health.

Publicly available data presented in this section is generally provided at a regional scale. Further assessment and characterisation were undertaken, the outcomes of which are presented in Section 6.7.1.

A summary of the high potential and high probability terrestrial GDEs is provided in Table 3.12 and indicated on Figure 3.11.

Table 3.12 Desktop based assessment - Terrestrial groundwater dependant ecosystems

PCT ¹ ID	¹ PCT name	High priority ²	Source
3369	Central Tableland Ranges Peppermint-Gum Grassy Forest	Yes	HEVAE Vegetation Groundwater Dependent Ecosystems Value - Hawkesbury Nepean (DPE 2022)
3735	Central Tableland Peppermint Shrub-Grass Forest	Yes	
3303	Central Tableland Ribbon Gum Sheltered Forest	Yes	
78	River Red Gum riparian tall woodland/open forest wetland in the Nandewar Bioregion and Brigalow Belt South Bioregion	No	Probable Vegetation Groundwater Dependent Ecosystems - Central Tablelands (DPE 2022)
85	River Oak forest and woodland wetland of the NSW South-Western Slopes and South-Eastern Highlands bioregion;	No	Bureau of Meteorology Groundwater Dependent Ecosystem Atlas (BoM 2017)
732	Broad-leaved Peppermint - Ribbon Gum grassy open forest in the north-east of the South-Eastern Highlands bioregion;	No	
1191	Snow Gum - Candle Bark woodland on broad Valley flats of the tablelands and slopes of the South-Eastern Highlands bioregion;	No	
731	Broad-leaved Peppermint - Red Stringybark grassy open forest on undulating hills of the South-Eastern Highlands bioregion; and	No	
1197	Snow Gum - Mountain Gum tussock grass-herb forest of the South-Eastern Highlands bioregion.	No	

PCT ¹ ID	¹ PCT name	High priority ²	Source
1093	Red Stringybark - Brittle Gum - Inland Scribbly Gum dry open forest of the tablelands; South Eastern Highlands Bioregion	No	
1247	Sydney Peppermint - Narrow-leaved Peppermint shrubby open forest on sheltered slopes of the Newnes Plateau; Sydney Basin Bioregion	No	
1864	Western Blue Mountains Pagoda Woodland	No	

Notes: 1. Plant community type
2. As defined in the relevant water sharing plan

ii Aquatic groundwater dependant ecosystems

Aquatic GDEs can comprise rivers, wetland and springs that rely on the surface expression of groundwater for sustainment (BoM 2017). Based on a search of the GDE atlas (BoM 2017), the key fish habitats spatial dataset (DPI 2009) and the NSW Wetlands dataset (DCCEEW 2023), aquatic GDEs include:

- 3rd order (or greater) watercourses within the study area
- Lake Lyell.

Aquatic GDEs are indicated on Figure 3.12.

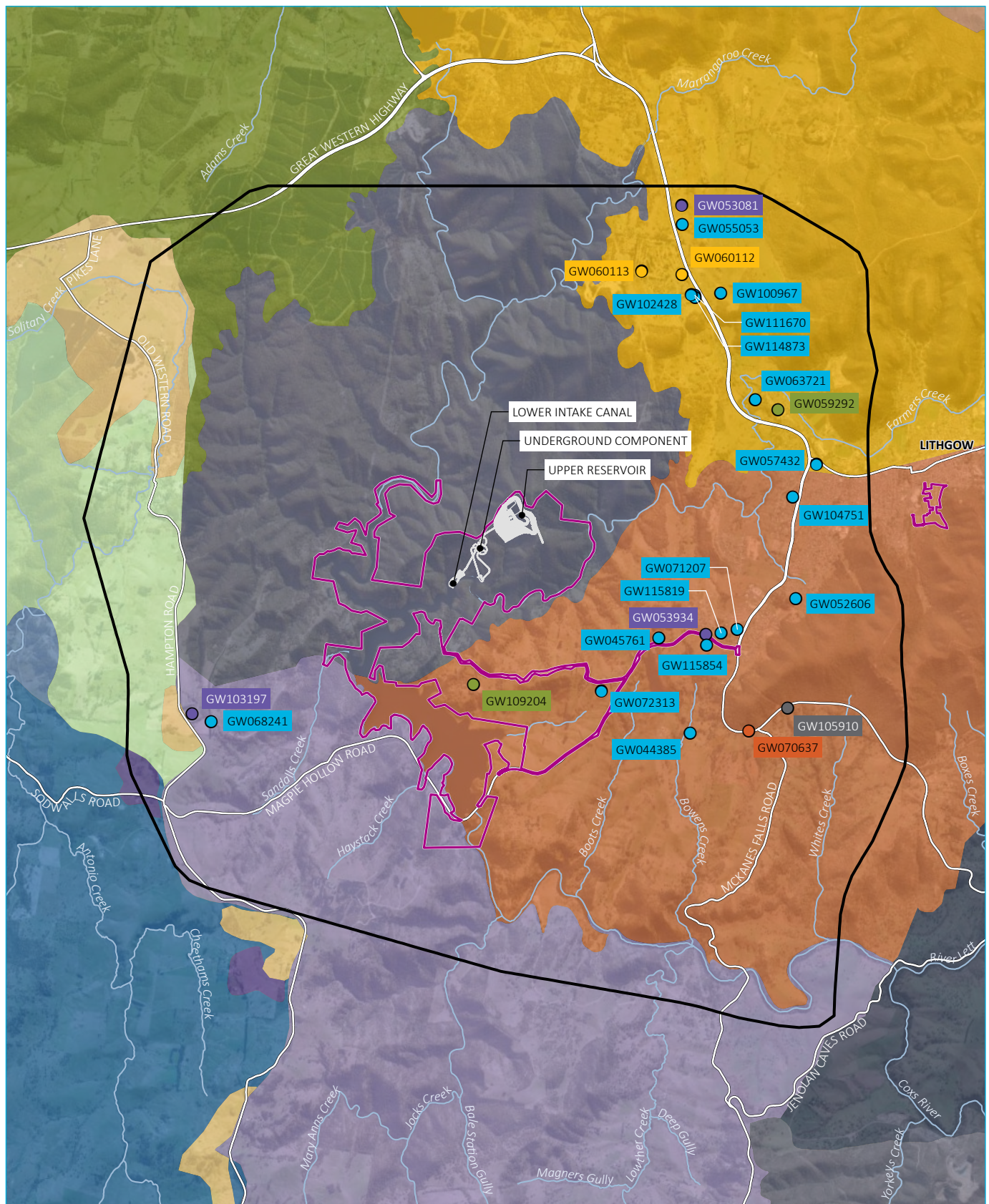
iii Subterranean groundwater dependant ecosystems

Existing stygofauna are assumed to be like those encountered in other fractured rock systems in NSW. Stygofauna are likely to be more common in bogs and fens, hyporheic zones and shallow fractured rock groundwater systems due to the greater availability of dissolved oxygen and nutrients. Further characterisation has been undertaken to assess the absence / presence of stygofauna in Section 5.

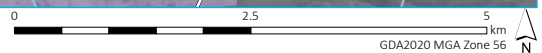
3.8 Nearby groundwater affecting activities

Marrangaroo Quarry is located approximately 4.3 km north-east of the project (Figure 3.13). Up to 135,000 tonnes per annum (tpa) of quartzite are extracted from the quarry for civil construction and concrete aggregate (Metromix 2010). Quarrying activities target the metamorphic sequences within the Gibbons Creek Sandstone of the Lambie Group (refer Section 3.5).

Based on an application to extend the operational life of the Marrangaroo Quarry by two years (RWCorkery&Co 2024), approximately 0.015 L/s of fresh (i.e. low salinity) groundwater will be intercepted by quarrying activities, resulting in drawdown propagation up to approximately 500 m east of the quarry. Three groundwater monitoring bores were installed at the Marrangaroo Quarry in November 2022. Groundwater level and quality data has been considered in this GIA.



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009); OEH (2020)



KEY

- ▬ Project area
- Study area
- Key project infrastructure
- Existing environment
- Major road
- Named watercourse

- Private groundwater user
- Commercial and industrial
- Irrigation
- Other
- Stock and domestic
- Unknown
- Water supply

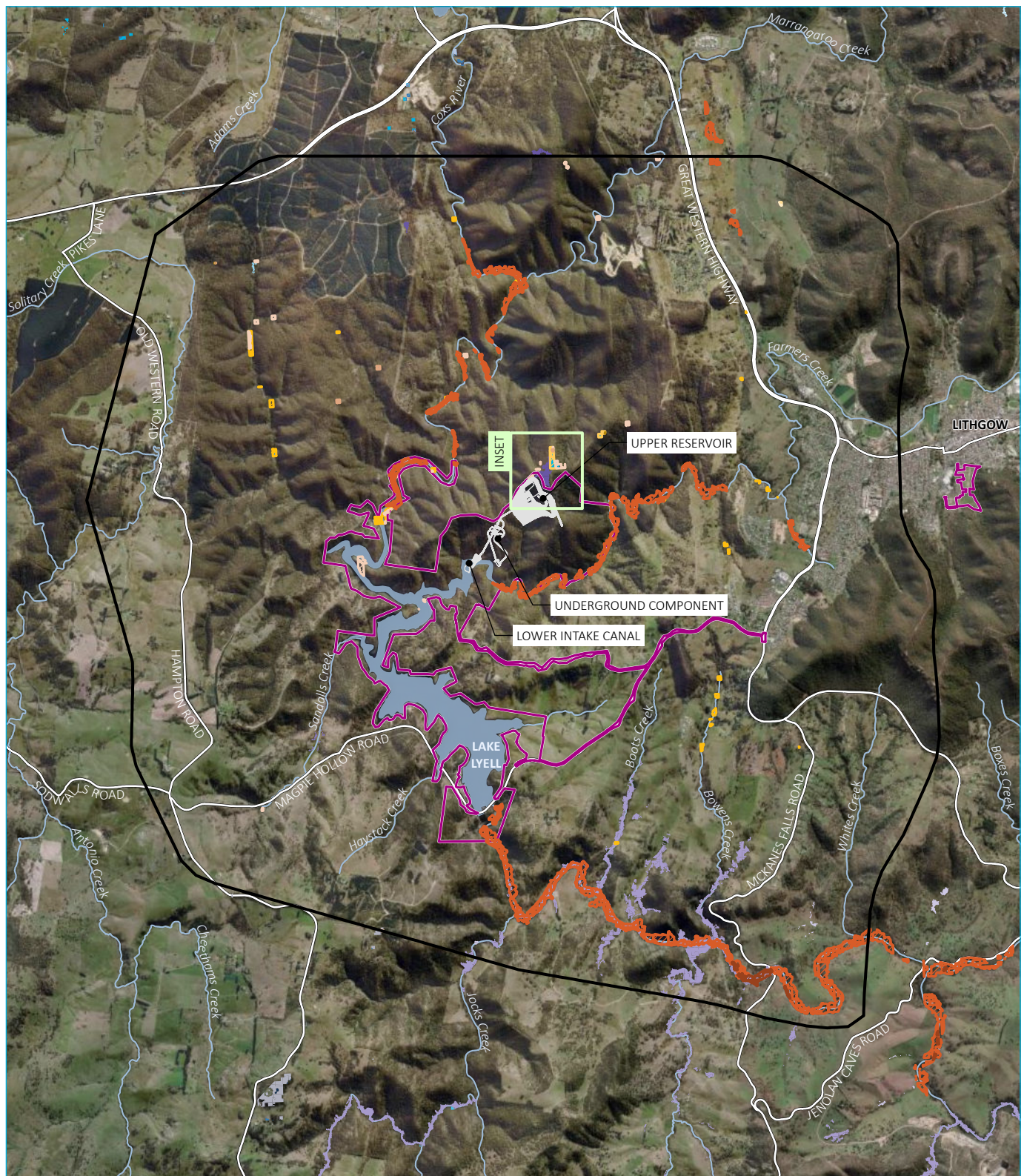
- Hydrogeological landscape
- Angus Place
- Dunedoo
- Dunkeld
- Euchareena
- Glanmire
- Hampton
- Hassans Walls
- Hawkesbury Sandstone

- Private groundwater users
- Mid Cocks River
- Mount Walker
- Pipers Flat
- Stuart Town

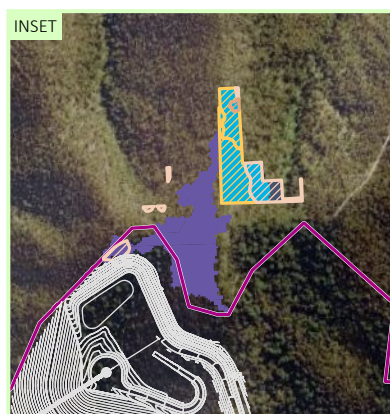
Private groundwater users

Lake Lyell PHES
Groundwater Impact Assessment
Figure 3.10





Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009); OEH (2020); BOM (2024); DEECW (2024)

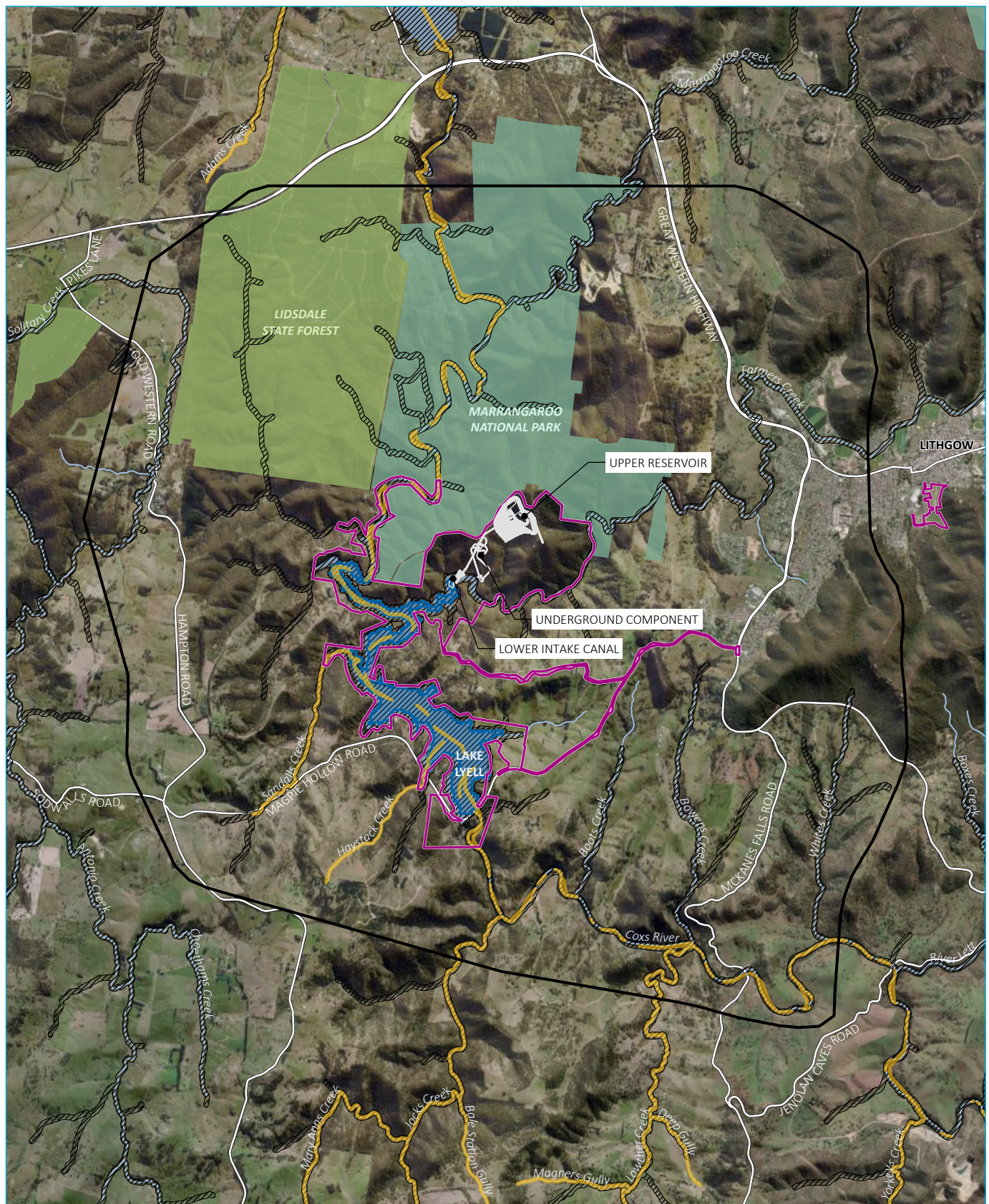


KEY

 Project area	 732	 3366
 Study area	 1093	 3367
 Key project infrastructure	 1191	 3369
Existing environment	 1197	 3385
 Major road	 1247	 3735
 Named watercourse	 1864	 3738
Groundwater Dependent Ecosystem (GDE) probability (by PCT ID)	High Ecological Value Aquatic Ecosystems (HEVAE) GDEs	 3932
 78	 3294	 3945
 85	 3303	 3946
 731	 3347	 3981
	 3348	 4063
		 4064

Terrestrial groundwater dependent ecosystems- public data

Lake Lyell PHES
Groundwater Impact Assessment
Figure 3.11



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009); BOM (2019); DEECW (2024)

KEY

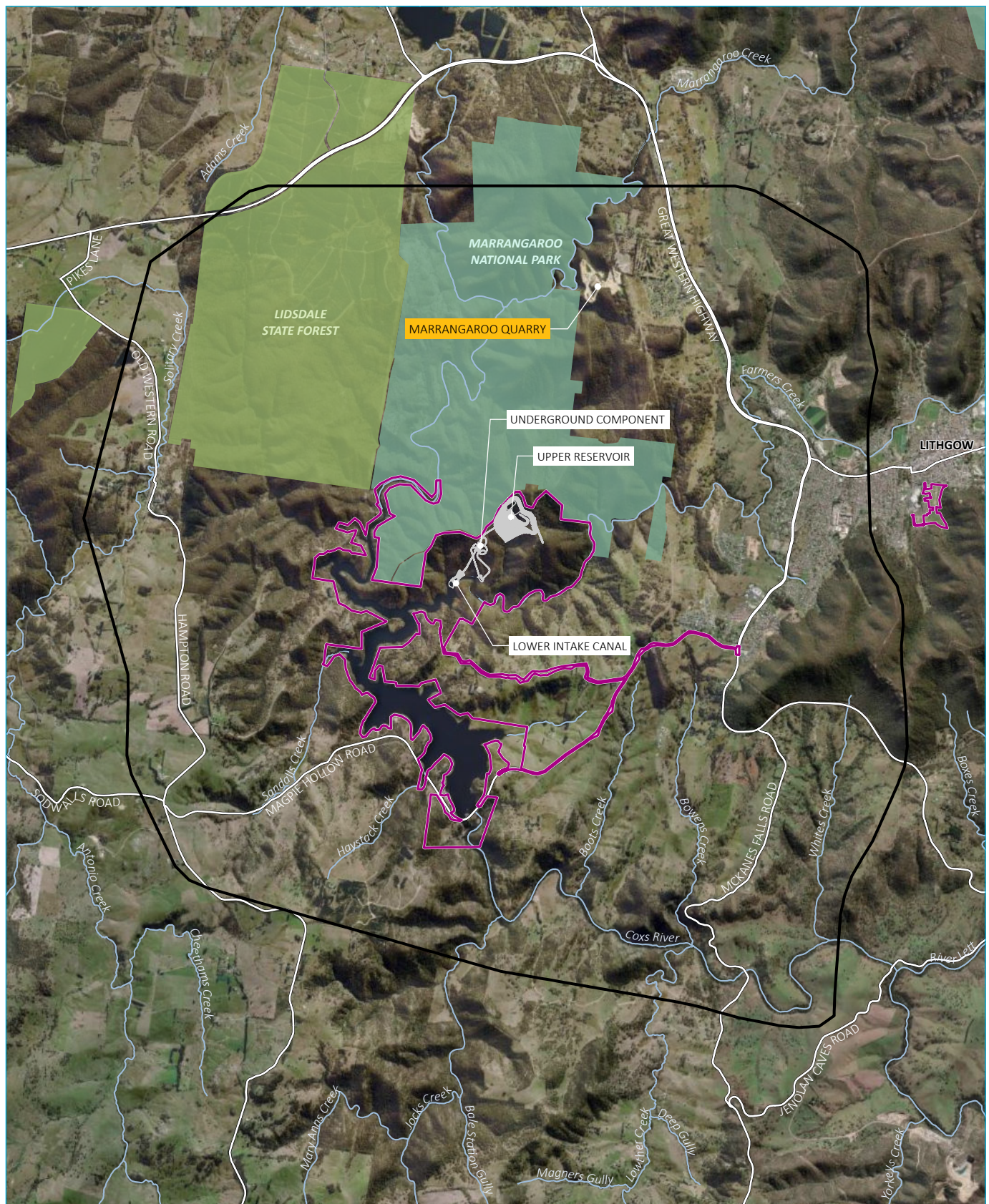
- Project area
- Study area
- Key project infrastructure
- Aquatic GDE
- Wetland
- Key fish habitat

Existing environment

- Major road
- Named watercourse
- NPWS reserve
- State forest

Aquatic groundwater dependent ecosystems - public data

Lake Lyell PHES
Groundwater Impact Assessment
Figure 3.12



KEY

- Project area
- Study area
- Key project infrastructure
- Existing environment
- Major road
- Named watercourse
- NPWS reserve
- State forest

Groundwater affecting activities near the Project

Lake Lyell PHES
Groundwater Impact Assessment
Figure 3.13

4 Regulatory and policy context

An overview of the regulatory framework and guidelines relevant to the GIA is provided in Sections 4.1 to 4.3. Further description and the requirements of the legislations, policies and guidelines are included in Annexure A.

4.1 Legislation overview

The primary groundwater related statutes that apply to the project are the *Water Management Act 2000* (WM Act), *Protection of the Environment Operations Act 1997* (POEO Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Table 4.1 lists the legislation relevant to the project to assess potential impacts on groundwater resources and groundwater-dependent assets.

Table 4.1 Relevant legislation and regulations

Legislation	Authority
<i>Environmental Planning and Assessment Act 1979</i>	DPHI
<i>Water Management Act 2000</i>	NSW DCCEEW – Water Group Natural Resources Access Regulator (NRAR)
<i>Water Management (General) Regulation 2018</i>	NSW DCCEEW – Water Group
<i>Protection of Environment Operations Act 1997</i>	NSW Environment Protection Authority (EPA)
<i>Environment Protection and Biodiversity Conservation Act 1999</i>	Commonwealth DCCEEW
<i>Biodiversity Conservation Act 2016</i>	NSW DCCEEW – Environment and Heritage
<i>Fisheries Management Act 1994</i>	Department of Primary Industries and Regional Development

4.2 Relevant NSW policies

4.2.1 Overview

The GIA is required to consider the following policies and plans to characterise and assess potential impacts on groundwater resources:

- relevant water sharing plans (WSPs)
- Aquifer Interference Policy (AIP) (2012)
- State Groundwater Dependent Ecosystems Policy (2002)
- Non-Urban Water Metering Policy (2020).

The relevant WSPs are key documents dictating the assessment of the potential impacts of the project on water resources and are described in Section 4.2.2. Other relevant policies and plans are further detailed in Annexure A.

4.2.2 Water sharing plans

WSPs are statutory documents dictating the management and sharing of water sources. The WSPs set the water management vision and objectives, management rules for water access licences (WALs), what water is available within the various water sources, and procedures for dealing in licences and water allocations, water supply works approvals and the extraction of water. WSPs are designed to establish sustainable use and management of water resources and are periodically reviewed (every 10 years).

Each WSP documents the water available and how it is shared between environmental, extractive, and other uses. The WSPs outline the water availability for extractive uses within different categories, such as local water utilities, domestic and stock, basic rights and WALs.

WSPs generally provide rules for either surface water sources (including water contained within the streams and often the connected alluvial deposits) or groundwater sources (including water contained within rock units and unconsolidated deposits not connected to a surface water source).

Within the study area, groundwater sources are managed under two WSPs – the Water Sharing Plan for the:

- Greater Metropolitan Region Groundwater Sources 2023
- NSW Murray–Darling Basin (MDB) Fractured Rock Groundwater Sources 2020.

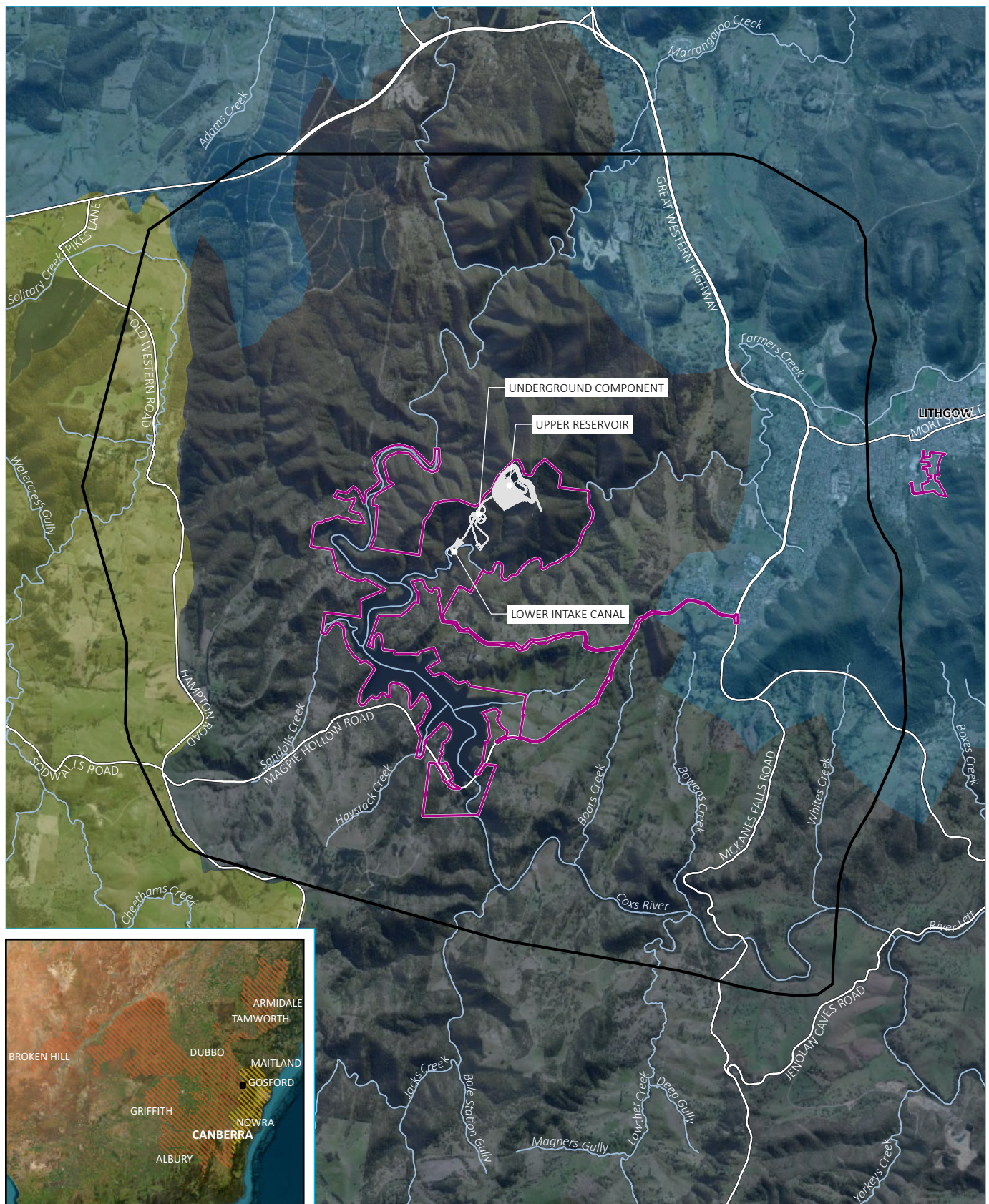
As of 11 July 2025, EnergyAustralia holds 350 units (access license reference WAL45574) within the Lachlan Fold Belt Greater Metropolitan Groundwater Source, managed under the Greater Metropolitan Region Groundwater Sources (2023) water sharing plan. Groundwater WSPs and associated groundwater sources are provided on Figure 4.1. Further discussion of extraction limits and available water determinations, within the relevant groundwater sources, is presented in Sections 4.2.2i to 4.2.2ii. A pathway to secure allocations is presented in the project water licensing strategy (EMM 2025).

Within the study area, surface water (and connected alluvial) resources are managed under two WSPs:

- the WSP for the Greater Metropolitan Region Unregulated River Water Sources 2023
- the WSP for the Macquarie Bogan Unregulated and Alluvial Water Sources 2012.

EnergyAustralia currently holds a Specific Purpose Access License (SPAL) for 25,000 megalitres per year (ML/yr) of entitlement within the Wywandy Water Source (managed under the WSP for the Greater Metropolitan Region Unregulated River Water Sources 2023). EnergyAustralia currently do not hold WALs within any water source managed under the WSP for the Macquarie Bogan Unregulated and Alluvial Water Sources 2012.

Surface water WSPs and associated surface water sources are provided on Figure 4.2. Further discussion of extraction limits and available water determinations, within the relevant surface water sources, is presented in the project water licensing strategy (EMM 2025).



KEY

- Project area
- Model extent
- Key project infrastructure
- Existing environment
- Major road
- Named watercourse

Water sharing plan boundary (refer to inset)

— Greater Metropolitan Region Groundwater Sources 2023

— NSW Murray Darling Basin Fractured Rock Groundwater Sources 2020

Groundwater source

Greater Metropolitan Region Groundwater Sources 2023

— Lachlan Fold Belt Greater Metropolitan Groundwater Source

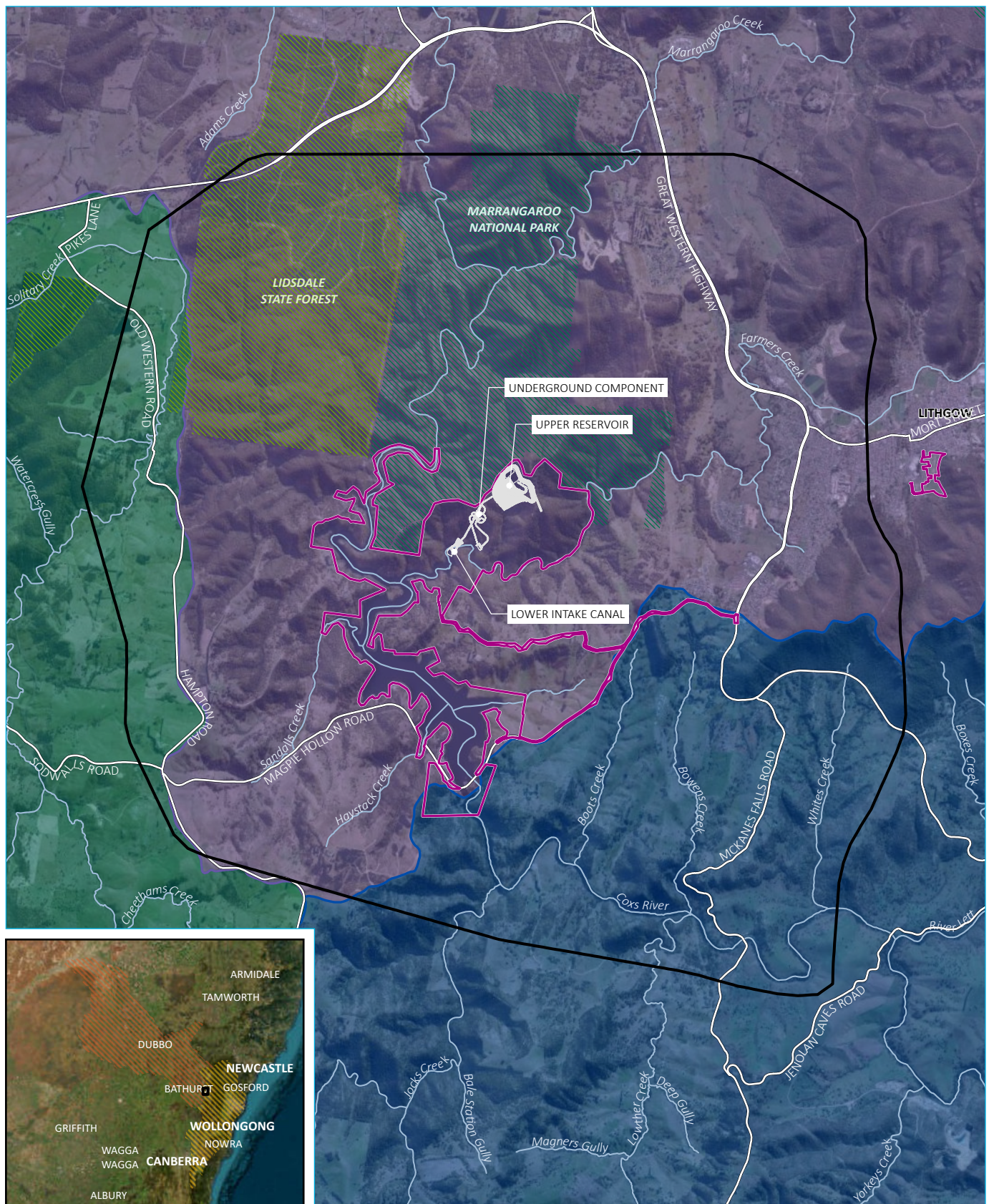
— Sydney Basin West Groundwater Source

NSW Murray Darling Basin Fractured Rock Groundwater Sources 2020

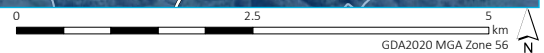
— Lachlan Fold Belt MDB Groundwater Source

Groundwater sources

Lake Lyell PHES
Groundwater Impact Assessment
Figure 4.1



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009); DPIE (2021)



KEY

- ▬ Project area
- Model extent
- Key project infrastructure
- Existing environment
- Major road
- Named watercourse
- ▨ NPWS reserve
- ▨ State forest

- Water sharing plan boundary (refer to inset)
- ▨ Greater Metropolitan Region Unregulated River Water Sources 2023
- ▨ Macquarie Bogan Unregulated Rivers Water Sources 2012
- Surface water source**
- ▨ Macquarie Bogan Unregulated Rivers Water Sources 2012
- ▨ Fish River Water Source
- ▨ Greater Metropolitan Region Unregulated River Water Sources 2023
- ▨ Wywanddy Water Source
- ▨ Dharabuladh Water Source

Surface water sources

Lake Lyell PHES
Groundwater Impact Assessment
Figure 4.2

The majority of the study area (refer Figure 4.1) is located within the Lachlan Fold Belt Greater Metropolitan Groundwater Source, a water source of the *WSP for the Greater Metropolitan Region Groundwater Sources 2023* (Greater Metro GW WSP). A portion of the study area (refer Figure 4.1) is located within the Sydney Basin West Groundwater Source, another water source of the Metro GW WSP.

The Lachlan Fold Belt Greater Metropolitan Groundwater Source comprises all water contained within:

- all rocks of Carboniferous age or older
- Cenozoic sediments directly overlying rocks of Carboniferous age or older.

The Sydney Basin West Groundwater Source comprises all water contained within:

- all rocks of Tertiary to Permian age
- Cenozoic sediments except Cenozoic sediments within the following groundwater sources:
 - the Botany Sands Groundwater Source
 - the Hawkesbury Alluvium Groundwater Source
 - the Metropolitan Coastal Sands Groundwater Source.

The long-term average annual extraction limits (LTAAEL) for the Lachlan Fold Belt Greater Metropolitan Groundwater Source and Sydney Basin West Groundwater Source are 133,949 ML/yr and 36,045 ML/yr, respectively. Table 4.2 presents a summary of the total entitlement shares in these two groundwater sources.

Table 4.2 Summary of Lachlan Fold Belt Greater Metropolitan Groundwater Source and Sydney Basin West Groundwater Source

	Lachlan Fold Belt Greater Metropolitan Groundwater Source		Sydney Basin West Groundwater Source	
Entitlement category	Water Sharing Plan ¹	NSW Water Register ²	Water Sharing Plan ¹	NSW Water Register ²
Basic landholder rights (from WSP¹)				
Domestic and stock (ML/yr)	4,083	Not applicable	2,578	Not applicable
Water access licences				
Domestic and stock (ML/yr)	Not applicable	Not applicable	29	29
Aquifer (unit shares)	8,039	7,998.5	26,708	26,706.7
Aquifer (town water supply) (unit shares)	Not specified	100	Not applicable	Not applicable

Notes: 1. Sourced from the Greater Metro GW WSP.

2. Total share components were obtained from NSW water register (WaterNSW) for financial year 2024/25.

A portion of the study area (refer to Figure 4.1) is located within the Lachlan Fold Belt MDB Groundwater Source, a water source of the *WSP for the NSW MDB Fractured Rock Groundwater Sources 2020* (MDB Fractured Rock WSP).

The Lachlan Fold Belt MDB Groundwater Source comprises all water contained within:

- all rocks within the outcropped and buried areas
- all alluvial sediments within the outcropped areas, within its mapped boundaries. However, it does not include water sources as defined in the Lachlan Alluvial WSP.

The LTAAEL for the Lachlan Fold Belt MDB Groundwater Source is 253,788 ML/yr. Table 4.3 presents a summary of the total entitlement shares in the Lachlan Fold Belt MDB Groundwater Source.

Table 4.3 Summary of Lachlan Fold Belt MDB Groundwater Source water requirements and entitlements

Entitlement category	Water Sharing Plan ¹	NSW Water Register ²
Basic landholder rights (from WSP¹)		
Domestic and stock (ML/yr)	74,311 ML/yr	Not applicable
Water access licences		
Local water utility (ML/yr)	3,421	3,370.5
Local water utility (Domestic and commercial) (ML/year)	Not specified	65
Aquifer (unit shares)	68,210	74,174.7
Aquifer (Town water supply) (ML/yr)	Not specified	467.35
Salinity and watertable management (ML/yr)	236	236

Notes: 1. Sourced from the MDB Fractured Rock WSP.

2. Total share components were obtained from NSW water register (WaterNSW) for financial year 2024/25.

4.3 Relevant guidelines

The guidelines used in the GIA are presented in Table 4.4, with additional detail included in Annexure A.

Table 4.4 Relevant guidelines

Guidelines	Developed by
Guidelines for the preparation and review of groundwater assessments for major projects in NSW: • Groundwater Assessment Toolbox (DPE 2022) • Guidelines for Groundwater Documentation for SSD/SSI projects (DPE 2022) • Minimum Requirements for Groundwater Modelling (DPE 2022) • Cumulative Groundwater Impact Assessment Approaches (DPE 2022)	DPE Water 2022
Australian Groundwater Modelling Guidelines	National Water Commission (Barnett, et al. 2012)
Uncertainty analysis – Guidance for groundwater modelling within a risk management framework (IESC explanatory note)	Middlemis and Peeters (2018)
Australian and New Zealand Guidelines for Fresh and Marine Water Quality	ANZG 2018
Risk Assessment guidelines for groundwater dependent ecosystems	NSW DPI Office of Water (Serov P 2012)

5 Baseline investigations and monitoring

5.1 Overview

Baseline investigations and monitoring is essential for characterising the pre-project hydrogeological conditions within the study area. Baseline water level and quality data (baseline data) was used to:

- establish baseline groundwater conditions (i.e. water levels, climatic responses and water quality)
- identify and characterise hydrogeological units within the study area, focussing on characterising groundwater flow and quality
- provide spatial representation and flux (flow) of pressure heads across the study area
- assess hydraulic gradients and connectivity between hydrogeological units
- investigate the potential for surface water–groundwater interaction
- understand and monitor potential sensitive features, including watercourses, landholder bores and GDEs.

The understanding developed from the baseline data assists with the development of a hydrogeological conceptual model (conceptual model) and subsequently, a numerical groundwater flow model (numerical model). The conceptual and numerical models provide the fundamental tools for predicting the potential project induced effects on groundwater.

A summary of the baseline investigations and baseline monitoring network (the baseline network) is provided in Section 5.2 and Section 5.3, respectively.

5.2 Baseline investigations

5.2.1 Geological logging

Drilling investigations provide valuable geological information, including geological unit depth, extent, composition, weathering and fracturing. Geological information is subsequently used to support the hydrogeological understanding of the study area, including permeability and storage potential of intercepted groundwater systems.

A total of 24 boreholes were completed over two drilling investigations and included:

- geological logging via assessment of extracted core or chip fragments
- geophysical logging of boreholes.

A summary of boreholes is provided in Table 5.1 to Table 5.3.

Table 5.1 Baseline network – Groundwater monitoring bores

Bore	Easting (GDA20)	Northing (GDA20)	¹ Elevation (mAHD)	Screen top (² mbgl)	Screen base (² mbgl)	Target/location	Geology	Hydraulic testing	Groundwater monitoring
BH103	229859.9	6290824.9	1084.1	59.0	71.0	Upper reservoir	Gibbons Creek Sandstone	Packer testing	Quality and level
BH107	229031.3	6289890.0	788.7	27.0	39.0	Out-take structure	Rydal Formation	Packer testing	Quality and level
BH201	229776.7	6290976.9	1122.9	61.0	64.0	Upper reservoir	Gibbons Creek Sandstone	-	³ Level
MB2201A	230069.2	6290430.5	1058.0	192.5	198.5	Regional calibration	Gibbons Creek Sandstone	Slug testing	Quality and level
MB2201B	230071.4	6290419.0	1056.4	97.0	110.0	Regional calibration	Gibbons Creek Sandstone	Slug testing	Quality and level
MB2202A	229273.6	6290061.6	904.4	143.0	149.0	Main access tunnel	Rydal Formation	Slug testing	Quality and level
MB2202B	229274.1	6290072.1	905.4	57.0	69.0	Main access tunnel	Rydal Formation	Slug testing	Quality and level
MB2203A	229858.6	6290823.9	1084.1	193.0	199.0	Upper reservoir	Gibbons Creek Sandstone	Slug testing	Quality and level
MB2203B	229860.7	6290817.2	1084.1	62.0	68.0	Upper reservoir	Gibbons Creek Sandstone	Slug testing	Quality and level
MB2204A	229218.3	6290721.1	981.9	186.0	198.0	Headrace tunnel	Rydal Formation	Slug testing	Quality and level
MB2204B	229211.8	6290719.3	981.8	58.0	70.0	Headrace tunnel	Rydal Formation	Slug testing	Quality and level
MB2205A	229186.3	6290444.4	955.8	185.6	197.6	Power station cavern	Rydal Formation	Slug testing	Quality and level
MB2205B	229193.7	6290441.0	955.8	53.0	59.0	Power station cavern	Rydal Formation	Slug testing	Quality and level
MB2206A	229192.9	6289790.9	839.7	89.0	98.0	Regional calibration	Rydal Formation	Slug testing	Quality and level
MB2206B	229179.3	6289776.7	839.2	61.0	73.0	Regional calibration	Rydal Formation	Slug testing	Quality and level

Source: Lake Lyell PHES Geotechnical Investigation Program - Factual Report (GHD 2023); Lake Lyell PHES Interim Phase 2 Geotechnical Investigation Program - Factual Report (GHD 2024)

Notes: 1. Ground surface elevation in metres above Australian Height Datum
2. Metres below ground level
3. Manual level monitoring only

Table 5.2 Baseline network – Vibrating wire piezometers

Bore	Easting	Northing	¹ Elevation (mAHD)	Inclination (°)	Number of sensors	Sensor depths (²mbgl)	Infrastructure target	Geology	Hydraulic testing	Groundwater monitoring
BH202	229438.0	6291037.2	1063.7	69.9	1	66.9	Upper reservoir	Gibbons Creek Sandstone	Packer testing	³ Level
BH203	229422.1	6290792.4	997.6	72.2	3	213.3; 138.0; 47.6	Pressure shaft	Gibbons Creek Sandstone	Packer testing	³ Level

Source: Lake Lyell PHES Geotechnical Investigation Program - Factual Report (GHD 2023); Lake Lyell PHES Interim Phase 2 Geotechnical Investigation Program - Factual Report (GHD 2024)

Notes: 1. Ground surface elevation in metres above Australian Height Datum
2. Metres below ground level
3. Manual level monitoring only

Table 5.3 Baseline drilling investigations - Geotechnical boreholes

Bore	Easting	Northing	¹ Elevation (mAHD)	Inclination (°)	² Drilled length (m)	Infrastructure target	Geology	Hydraulic testing
BH101	229853.2	6290664.2	1076.8	67.0	79.0	Upper reservoir	Gibbons Creek Sandstone	Packer testing
BH102	230074.6	6290416.2	1056.0	65.0	51.2	Upper reservoir	Gibbons Creek Sandstone	Packer testing
BH104	229882.0	6290411.1	1049.8	78.7	386.9	Powerhouse complex	Gibbons Creek Sandstone	-
BH105	229882.4	6290411.5	1049.9	90.0	359.9	Pressure shaft	Gibbons Creek Sandstone	Drill stem testing
BH106	229273.5	6290066.9	904.7	50.0	219.9	Tailrace tunnel	Rydal Formation	Drill stem testing
BH108	229034.0	6289891.0	788.8	31.0	115.5	Out-take	Rydal Formation	-
BH204	229186.8	6290439.3	955.9	67.5	292.0	Powerhouse complex	Rydal Formation	Packer testing

Source: Lake Lyell PHES Geotechnical Investigation Program - Factual Report (GHD 2023); Lake Lyell PHES Interim Phase 2 Geotechnical Investigation Program - Factual Report (GHD 2024)

Notes: 1. Ground surface elevation in metres above Australian Height Datum
2. Length drilled in metres, does not represent depth below ground surface.

5.2.2 Hydraulic testing

i Slug testing

Slug testing was completed in the conventional groundwater monitoring bores, with results analysed to estimate the bulk hydraulic conductivity of the targeted groundwater system.

Slug testing involves instantaneously displacing water in the bore (using compressed air) and measuring the groundwater level response (using an automated pressure transducer data logger (logger)). When the groundwater level decreases (as a result of injecting compressed air into the bore), the change in water level is captured by the data logger and the aquifer response used to calculate horizontal hydraulic conductivity.

A total of 12 slug tests were undertaken in 12 monitoring bores.

ii Packer testing

Packer testing (also known as Lugeon testing) is an in-situ method of testing the average hydraulic conductivity of a rock mass over a selected depth interval. The formation is tested by inflating pneumatic or hydraulic packers and injecting water at a constant pressure into the isolated section of the borehole.

Packer testing is typically completed in five stages, gradually increasing then decreasing injection pressure, averaging the flow and pressure at each stage to estimate average hydraulic conductivity. Results are expressed in Lugeon units (equivalent to the conductivity required to inject 1 litre (L) of water per metre of the test interval under a constant pressure).

A total of 38 packers tests were undertaken across seven boreholes.

iii Drill stem testing

Drill stem tests (DSTs) can be used to estimate the horizontal hydraulic conductivity across an isolated section of a borehole. Similar to a packer test, the test section is isolated using pneumatic or hydraulic inflatable packers that encase a wireline tool. Both the packer and wireline tool are lowered into the drill string which is set at the test depth. The wireline tool is fitted with a series of valves that control the release of fluid and air.

Compressed air is used to push down the groundwater level in the drill string creating a displacement. When the desired displacement is achieved, the compressed air is released, and the test zone allowed to return to equilibrium. The aquifer response after the air is released is measured using an automated pressure transducer data logger and the aquifer response is used to calculate the horizontal hydraulic conductivity of the test section.

A total of six DSTs were undertaken across two boreholes.

5.2.3 Ecological surveys

i Plant community type mapping

As discussed in the biodiversity development assessment report (BDAR), (EMM 2025) PCT mapping surveys were undertaken within the project's proposed construction envelope. Vegetation was mapped in the field and involved the following survey techniques:

- Random surveys on foot to ground-truth PCT boundaries and collect rapid data (or vegetation validation) points.
- Systematic plot-based floristic vegetation survey (i.e. 'BAM plots') consistent with Section 4.2.1 of the Biodiversity Assessment Method (DPIE 2020) to facilitate identification of the most likely PCTs as described in the BioNet Vegetation Classification database.

Occurrence of PCTs across the broader study area has been inferred from the NSW State Vegetation Type Map (SVTM), (DPE 2022). The SVTM dataset utilises various methods (on-ground surveys, existing extant maps segmentation, structural grouping and computer modelling) to infer PCT occurrence across NSW and is considered the most representative dataset for vegetation mapping.

Characterisation of groundwater dependency for PCTs is discussed in Section 6.7.1.

ii Aquatic ecosystems

Field based assessment of aquatic GDEs has not been undertaken as part of this EIS. Further discussion is provided in the surface water impact assessment (EMM 2025).

iii Subterranean ecosystems

Three stygofauna surveys were undertaken at up to six bores within the study area on 3 May 2024, 31 May 2024 and 4 July 2024.

Stygofauna was not recorded in any bore and it is considered unlikely that the project will impact stygofauna associated with the regional groundwater systems.

5.3 Baseline water monitoring

The baseline groundwater monitoring network (the baseline network) includes both background (regional) monitoring locations and targeted monitoring locations near key project infrastructure elements. The baseline network was designed to capture geological, spatial and temporal variations within the study area, supporting a groundwater assessment in accordance with the AIP (DPI 2012).

The baseline network included:

- fifteen (15) conventional groundwater monitoring bores, providing groundwater level and quality data within the regional groundwater systems, located between 50 m and 500 m from the project infrastructure (refer to Table 5.1)
- two (2) boreholes with vibrating wire piezometer (VWP) installations, sited near key infrastructure locations including the power station complex and upper reservoir (refer to Table 5.2).

5.3.1 Groundwater level monitoring

Project specific groundwater level monitoring commenced in September 2022 to inform the conceptual and numerical groundwater models (refer Section 7 and Section 9.2, respectively). The groundwater level monitoring network was progressively expanded over two hydrogeological field investigation programs (GHD 2023); (GHD 2024).

Groundwater levels were measured using:

- a manual dip tape at 15 monitoring bores (refer to Table 5.1) during groundwater quality monitoring (refer to Section 5.3.2)
- automated pressure and temperature loggers (loggers), deployed in 14 monitoring bores (refer to Table 5.1). Loggers record pressure and temperature at a synchronised six-hourly interval. Barometric fluctuations are directly compensated for via a vented tube
- VWPs, comprising four sensors in two boreholes (refer to Table 5.2) that were installed against permeable zones identified during geotechnical drilling. VWPs record water level and temperature every six-hours (synchronised with the loggers).

Groundwater level data is accessed as required, via the project-specific telemetered data portal. The groundwater level monitoring network will be maintained throughout the project approval process.

A summary of groundwater level monitoring is provided on Figure 5.1. Groundwater level hydrographs are attached as Annexure D.

5.3.2 Groundwater quality monitoring

Project specific groundwater quality monitoring commenced in January 2023. The groundwater quality monitoring network was progressively expanded over two hydrogeological field investigation programs (GHD 2023); (GHD 2024).

Dedicated Solinst™ double-valve pumps (DVPs) were installed in 14 monitoring bores to collect groundwater samples using a low-flow methodology. Groundwater quality samples were collected monthly by a third-party consultancy and submitted to a NATA accredited laboratory for analysis.

Monitored groundwater quality analytes are summarised in Table 5.4. A summary of groundwater quality monitoring is provided on Figure 5.1.

Table 5.4 Groundwater analysis methods and parameters

Category	Monitoring analytes	Analysis method
Physico-chemical properties	Temperature, pH, electrical conductivity, total dissolved solids, dissolved oxygen, redox potential, turbidity and total suspended solids	Field based measurement
	Alkalinity (bicarbonate, carbonate, phenolphthalein and total)	Analysis undertaken by a NATA certified laboratory
Major ions	Calcium (Ca), chloride, sodium (Na), potassium (K) and sulphate	
Inorganics	Fluoride and sulfur (S)	
Hydrocarbons	Total petroleum hydrocarbons	
Nutrients	Total nitrogen (N), ammonia, nitrate, nitrite, total phosphorus (P) and reactive phosphorous (P) and total phosphate	
Total metals	Aluminium (Al), Arsenic (As), Boron (B), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Vanadium (V) and Zinc (Zn)	
Dissolved metals	Aluminium (Al), Antimony (Sb), Arsenic (As), Barium (Ba), Beryllium (Be), Boron (B), Cadmium (Cd), Chromium (Cr), Hexavalent Chromium (Cr(VI)), Trivalent Chromium (CR(III)), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Magnesium (Mg), Manganese (Mn), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Silver (Ag), Strontium (Sr), Vanadium (V) and Zinc (Zn)	

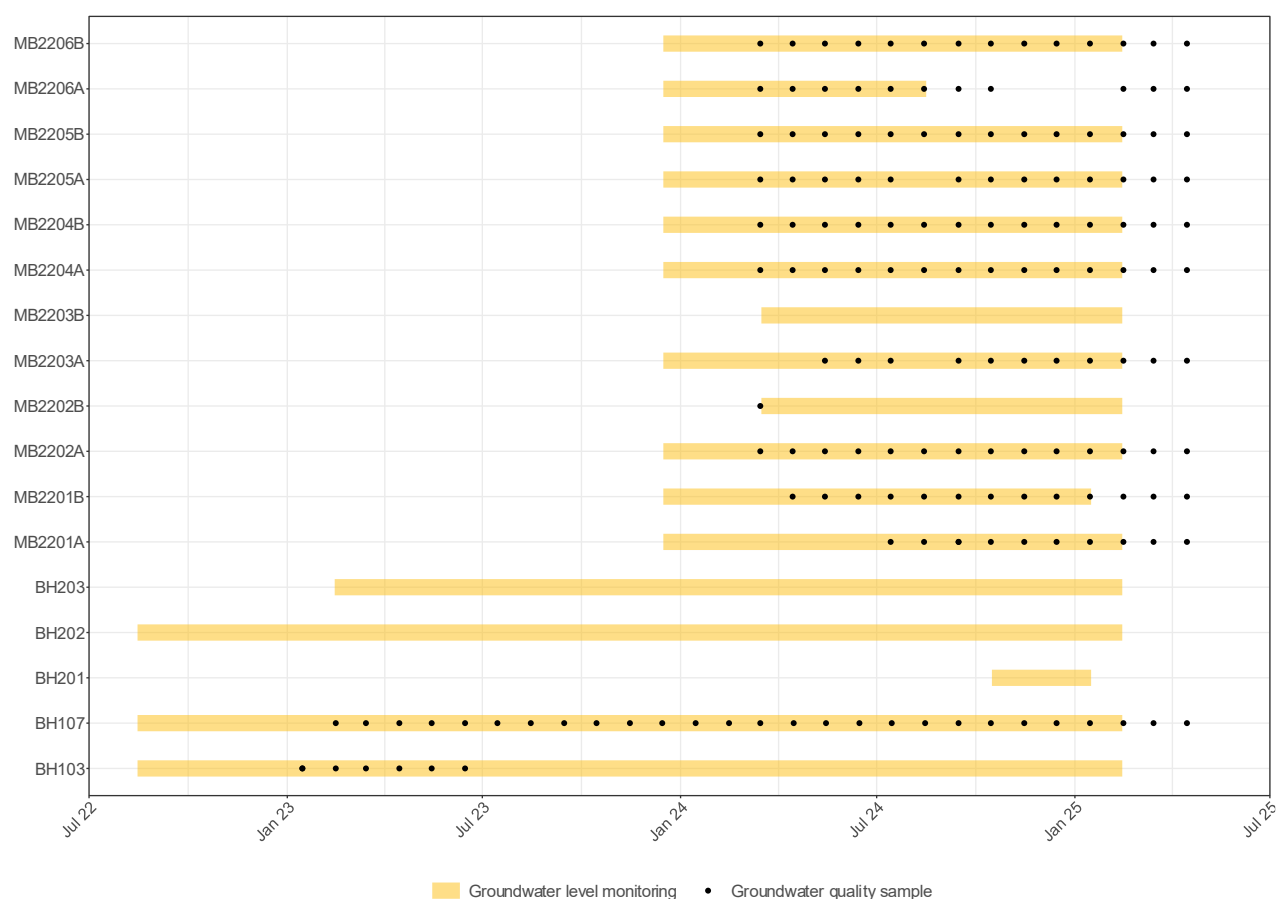


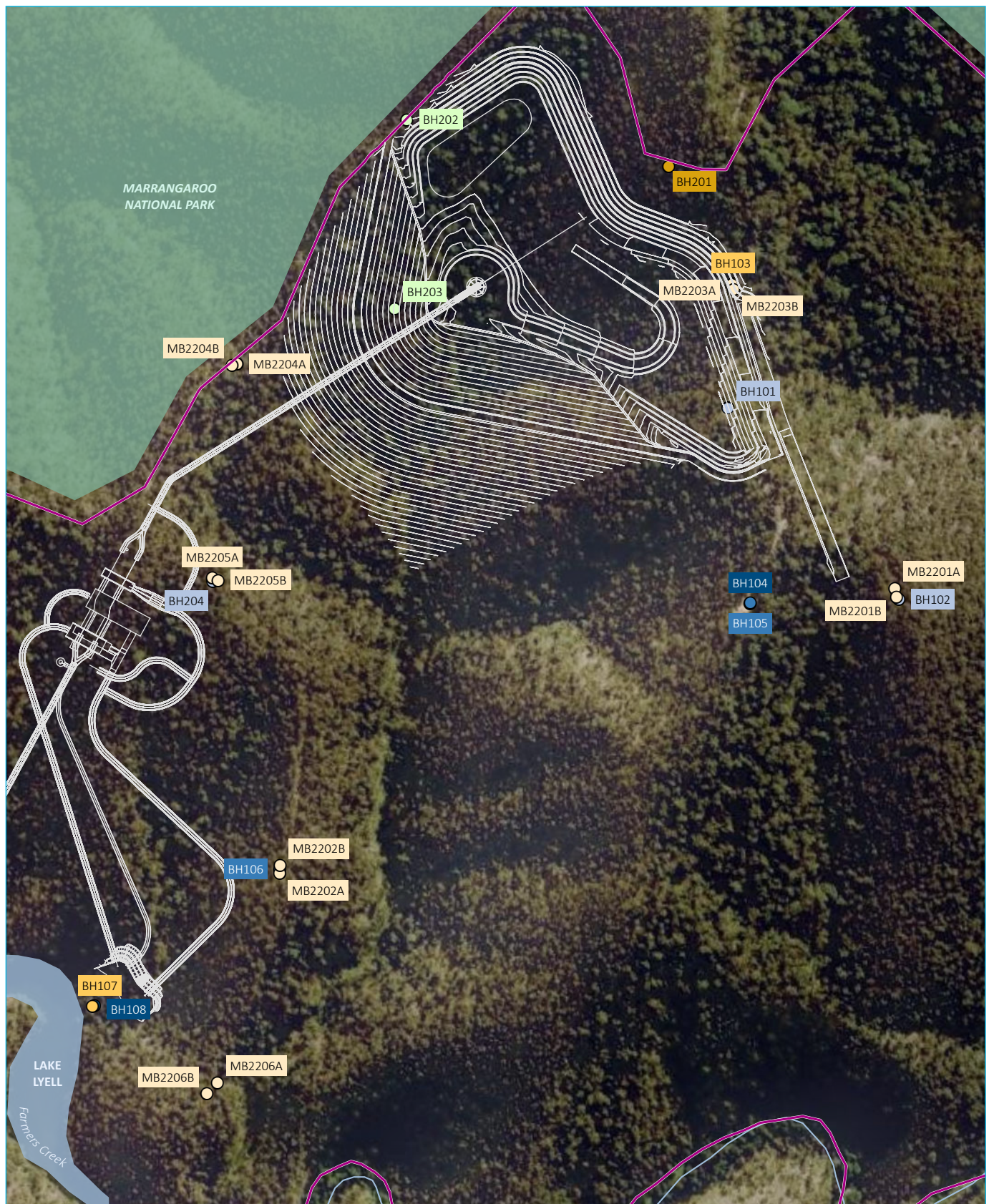
Figure 5.1 Groundwater level and quality monitoring summary

5.3.3 Surface water quality monitoring

Surface water quality monitoring has been made available by EnergyAustralia within the study area. Surface water quality monitoring commenced in February 2016 and is ongoing. A summary of surface water sampling is provided in Table 5.5 and indicated on Figure 5.2.

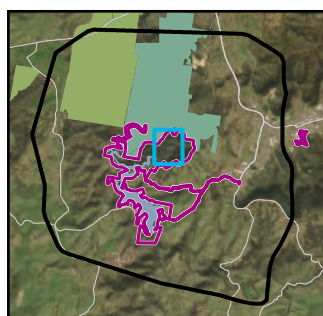
Table 5.5 Baseline surface water monitoring locations and frequency

Watercourse	Site	Easting	Northing	Start of monitoring	Samples analysed
Coxs River	Cox 5	227595	6291191	3/02/2021	122
	Cox 8A	228885	6286494	3/02/2016	94
	Cox 9	229213	6285534	3/02/2016	105
	Cox 10	229225	6285399	3/02/2016	107
Farmers Creek	Cox 6	230355	6289933	3/02/2016	121



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)

0 100 200
m
GDA2020 MGA Zone 56



KEY

- Project area
- Model extent
- Key project infrastructure
- Baseline investigation and monitoring location
- Geotechnical borehole
 - No testing
 - Drill stem testing
 - Packer testing
- Monitoring bore
 - No testing

- Packer testing
- Slug testing
- VWP
 - Packer testing
- Existing environment
 - Major road (refer to inset)
 - Named watercourse
 - Named waterbody
 - NPWS reserve
 - State forest (refer to inset)

Baseline investigation and monitoring locations

Lake Lyell PHES
Groundwater Impact Assessment
Figure 5.2



\\emmm.local\drive\2022\E221111 - Lake Lyell PHES EIS\GIS\02_Maps_GIA\GIA013_BaselineInvestigation_20250626_03.aprx 7/08/2025

6 Groundwater characterisation

6.1 Overview

This section describes the local hydrogeological setting, including groundwater levels and flow, hydraulic properties, groundwater quality and interaction between surface water and groundwater associated with the groundwater systems within the study area.

6.2 Hydrostratigraphic units

The study area is divided into stratigraphic units, generally constrained by similar geological origin and expected hydraulic characteristics (i.e. groundwater quality, hydraulic conductivity, storage and potential yield). These are the:

- Gibbons Creek Sandstone
- Rydal Formation
- Bathurst Batholith
- Sydney Basin.

Each stratigraphic unit is further divided into two hydro-stratigraphic units (HSUs), comprising a connected deep and shallow groundwater system (resulting in eight HSUs). The shallow groundwater system is characterised by higher weathering and fracturing (compared to the deep groundwater system).

Based on baseline investigations (refer to Section 5.2), the upper 120 m of each stratigraphic unit was inferred as the shallow groundwater system, as indicated by:

- noted weathering of the rock matrix (i.e. moderately to extremely weathered)
- consistent fracturing (i.e. rock quality designations generally below 75%).

The shallow groundwater system is unconfined and supports the phreatic watertable. Groundwater receptors at/near surface (i.e. terrestrial and aquatic GDEs, shallow water supply bores and shallow subterranean GDEs) receive groundwater from the shallow groundwater system.

The deep groundwater systems underlie the shallow groundwater system within each stratigraphic unit and are laterally connected (as in the shallow groundwater systems). The deep groundwater systems are unconfined to semi-confined and are intercepted by most of the groundwater affecting project infrastructure (i.e. the powerhouse complex and power waterways).

6.3 Groundwater mechanisms

6.3.1 Groundwater flow

The HSUs within the study area are considered secondary porosity groundwater systems, whereby groundwater flows through inter-connected discontinuities within the rock matrix (such as fractures, joints, bedding planes, fault gouges etc). Primary porosity flow (i.e. flow through pore spaces within the rock matrix) is negligible in the Lambie Group and Bathurst Batholith rock units, considering low porosity is a common characteristic of the associated igneous and metamorphic rock units. Minor primary porosity flow may occur within the Sydney Basin HSUs, however given the proximity to the project (shown in Figure 3.9), is not considered in further detail for this GIA.

Groundwater generally flows from north to south within the study area. Localised flow-paths occur radially from elevated points within the topography (recharge areas) towards surrounding perennial watercourses and Lake Lyell (discharge areas). Vertical flow is predominantly downward within the elevated topography (near Mt Walker) and upward in the lower areas (near Lake Lyell and the perennial watercourses).

Seasonal oscillations of regional groundwater systems typically influence the magnitude of groundwater flow, with greater flow during wet periods compared to dry periods. Rainfall induced groundwater level fluctuations are typically less than 0.5 m and are prominent in the shallow groundwater system.

Groundwater elevation contours are provided on Figure 6.1. Groundwater level hydrographs are provided in Figure 6.3.

6.3.2 Groundwater depth

Groundwater levels are supported by the shallow groundwater systems and generally reflect topography within the study area. The watertable is shallower near Lake Lyell (near ground surface at BH107) and deeper near the topographic high at Mount Walker (~65 metres below ground level (mBGL) at MB2203B).

Depth to groundwater is indicated on Figure 6.2.

6.3.3 Groundwater recharge

Recharge to the shallow groundwater system occurs through:

- direct recharge via rainfall infiltration
- indirect recharge via surface water infiltration through streambeds in losing streams.

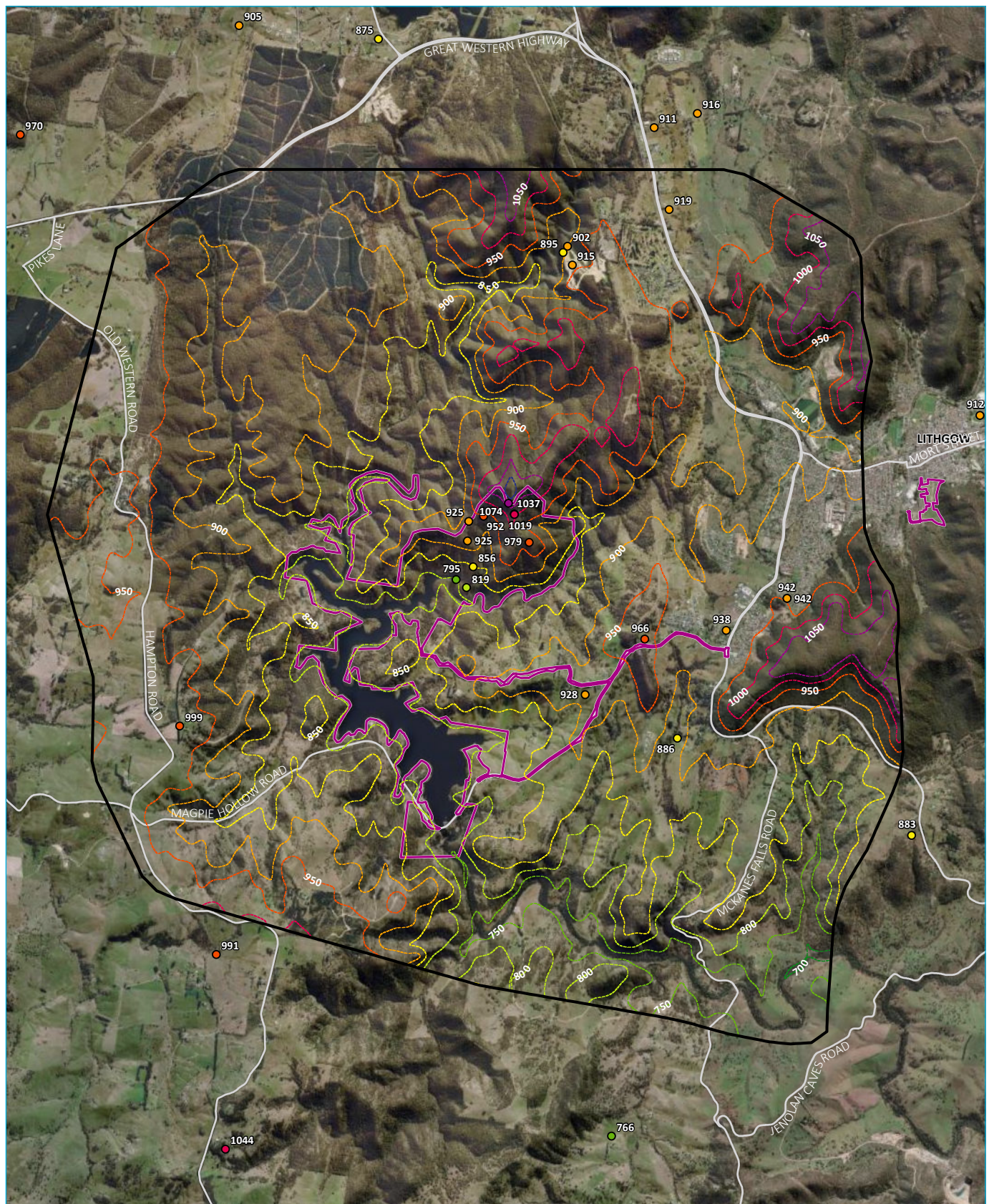
The deep groundwater system is recharged by localised infiltration from the overlying shallow groundwater system, typically at topographic high points where vertical groundwater flow is downward.

6.3.4 Groundwater discharge

Discharge from the shallow groundwater system occurs through:

- baseflow contributions to connected, gaining watercourses and Lake Lyell
- evapotranspiration in areas where vegetation can access groundwater
- intermittent discharge to springs when the watertable is elevated, typically following wet periods.

The deep groundwater system discharges to the shallow groundwater system, typically at topographic low points where vertical groundwater flow is upward.



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)

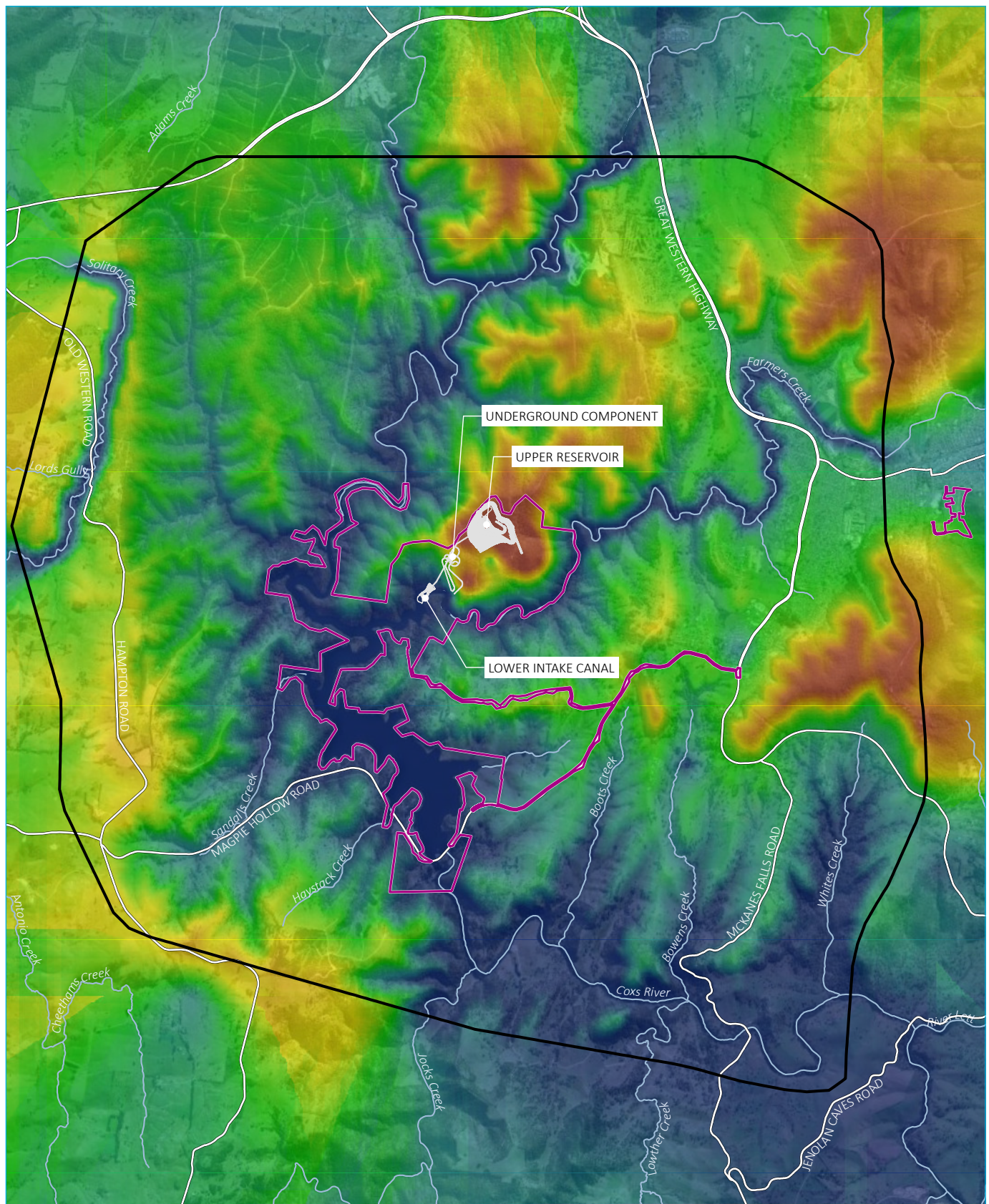
0 2.5 5 km
GDA2020 MGA Zone 56

KEY

 Project area	● 900 - 950	--- 850
 Study area	● 950 - 1000	--- 900
Existing environment	● 1000 - 1050	--- 950
Major road	● 1050 - 1100	--- 1000
Regional water level (mAHD)	Groundwater elevation (mAHD)	--- 1050
● 750 - 800	--- 700	--- 1100
● 800 - 850	--- 750	
● 850 - 900	--- 800	

Groundwater elevation contours

Lake Lyell PHES
Groundwater Impact Assessment
Figure 6.1



Source: EMM (2024); EnergyAustralia (2024); DCSSS (2023); ESRI (2024); GA (2009)

KEY

 Project area

 Study area

Key project infrastructure

Depth to groundwater (mbgl)



Existing environment

Major road

Named watercourse

Groundwater depth

Lake Lyell PHES
Groundwater Impact Assessment
Figure 6.2

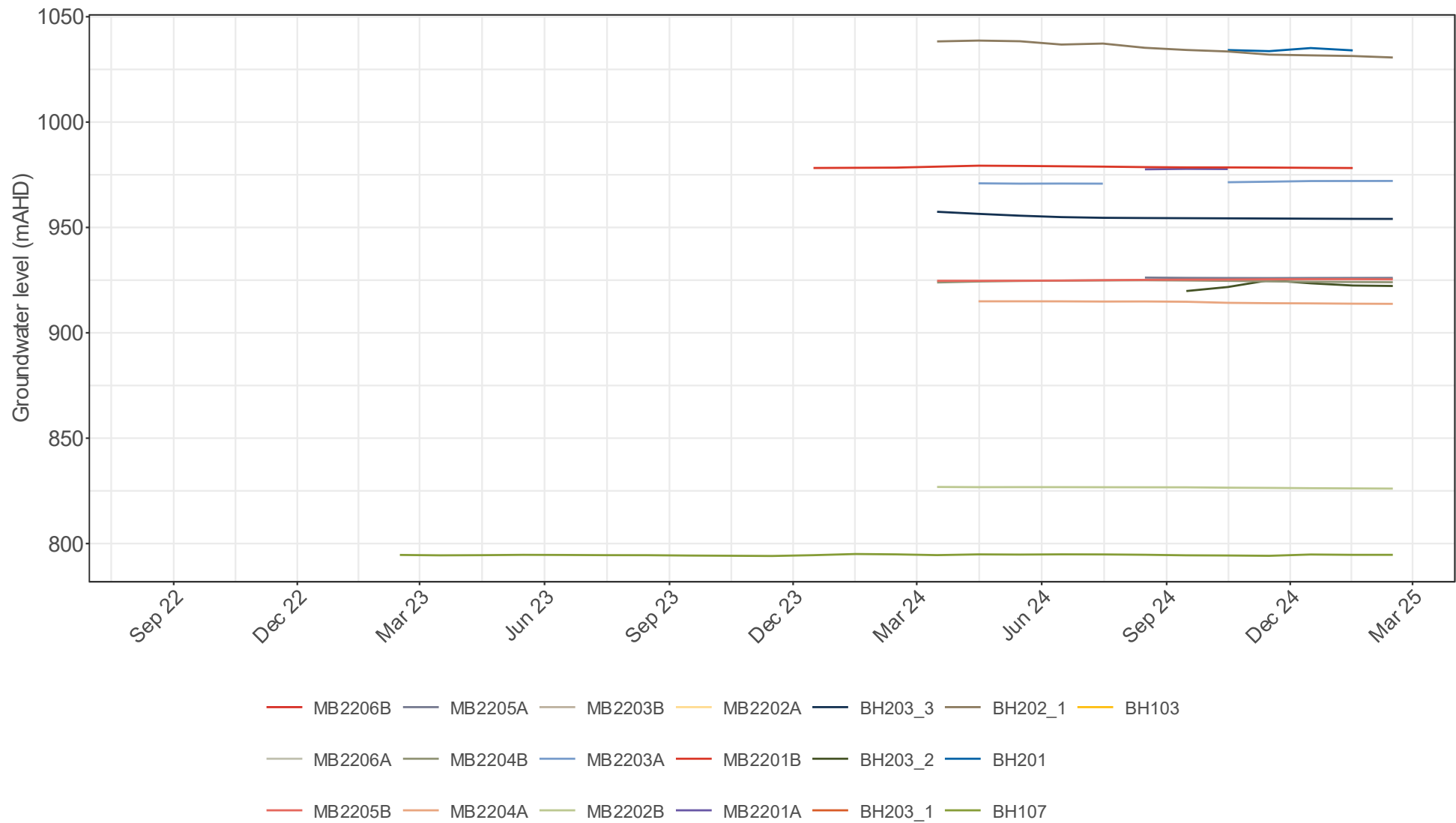


Figure 6.3 Groundwater level hydrographs

6.4 Hydraulic parameters

Hydraulic testing results undertaken during baseline investigations (refer Section 5) were combined with literature values (refer Section 3.6.2) to infer hydraulic parameters across the broader study area. The Gaussian distributions for hydraulic conductivity by HSU provided on Figure 6.4 indicates that the:

- Sydney Basin exhibits the highest potential for groundwater flow, as expected for predominantly sedimentary sequences of Triassic sandstone
- Lambie Group (i.e. the Gibbons Creek Sandstone and Rydal Formation) exhibits a moderate potential for groundwater flow, as expected for highly deformed, metamorphic rock units
- Bathurst Batholith exhibits the lowest potential for groundwater flow, as expected for predominantly igneous rock units.

The hydraulic properties of the geology intercepted by the project is generally interpreted to have a low hydraulic conductivity, consistent with lower bound values reported in literature for fractured rock geological units (Domenico and Schwartz 1990).

The Gaussian distributions provide an indication of the hydraulic conductivity between shallow and deep groundwater systems, whereby the shallow and deep groundwater systems are expected to be within the upper and lower range of the relevant stratigraphic unit, respectively.

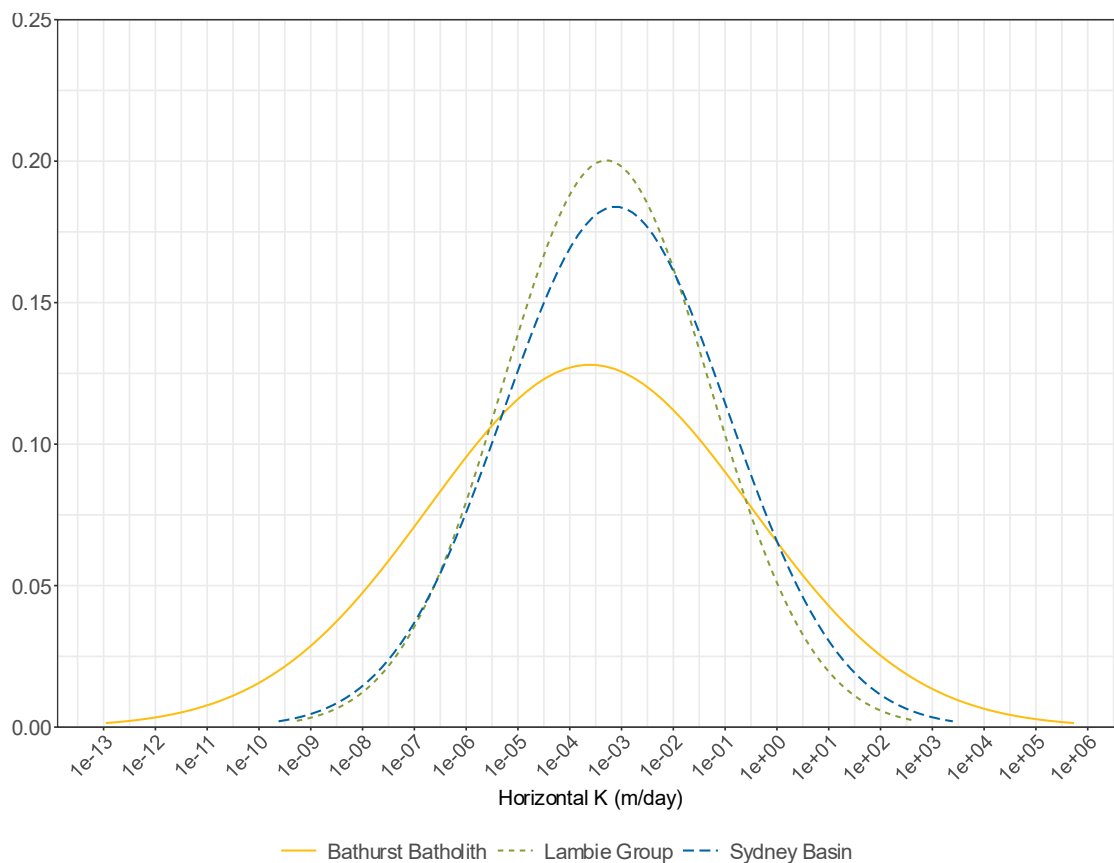


Figure 6.4 Hydraulic conductivity

6.5 Water chemistry

Based on average concentrations of physico-chemical parameters (i.e. pH, electrical conductivity and alkalinity) measured during baseline monitoring, water quality is generally:

- higher alkalinity within the groundwater systems (compared to surface watercourse)
- fresh in groundwater and surface water systems, indicated by an average electrical conductivity of less than 500 $\mu\text{S}/\text{cm}$
- more acidic within the groundwater systems, compared to the surface watercourse.

Groundwater quality box and whisker plots are provided on Figure 6.5.

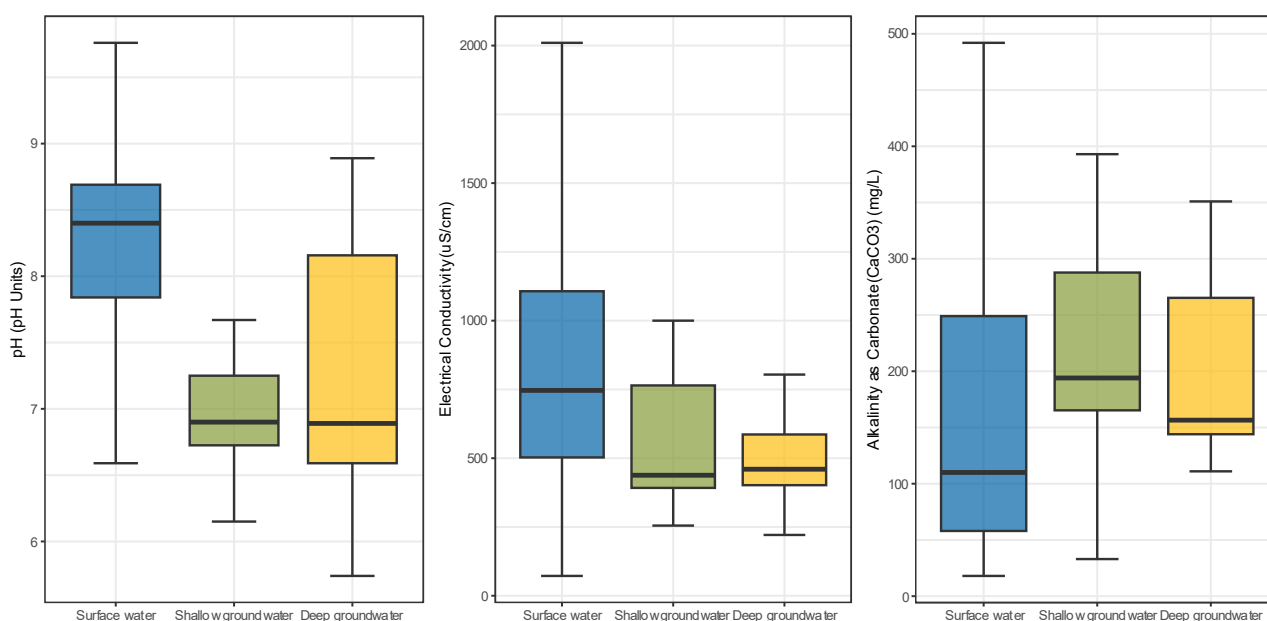


Figure 6.5 Box and whisker plots for pH, electrical conductivity and alkalinity

Box and whisker plots for the filtered metals, shown in Figure 6.6 provide a useful indication of natural concentrations within the groundwater systems. It is noted that the surface watercourses may be impacted by upstream activities associated with coal extraction and power generation.

For all metals except iron, concentrations were compared to the ANZECC & ARMCANZ (2018) default guideline values for 95% of species protection in freshwater. As iron does not currently have an ANZECC & ARMCANZ guideline value, the Australian Drinking Water Guidelines value of 0.3 mg/L (NHMRC & NRMCC 2011, 183) was used. The provided guideline values do not serve as triggers for the system and are provided only to contextualise existing conditions.

Baseline monitoring indicated average dissolved metal concentrations were generally below the 95% guideline limit for all analytes, with the exception of iron in the shallow groundwater system.

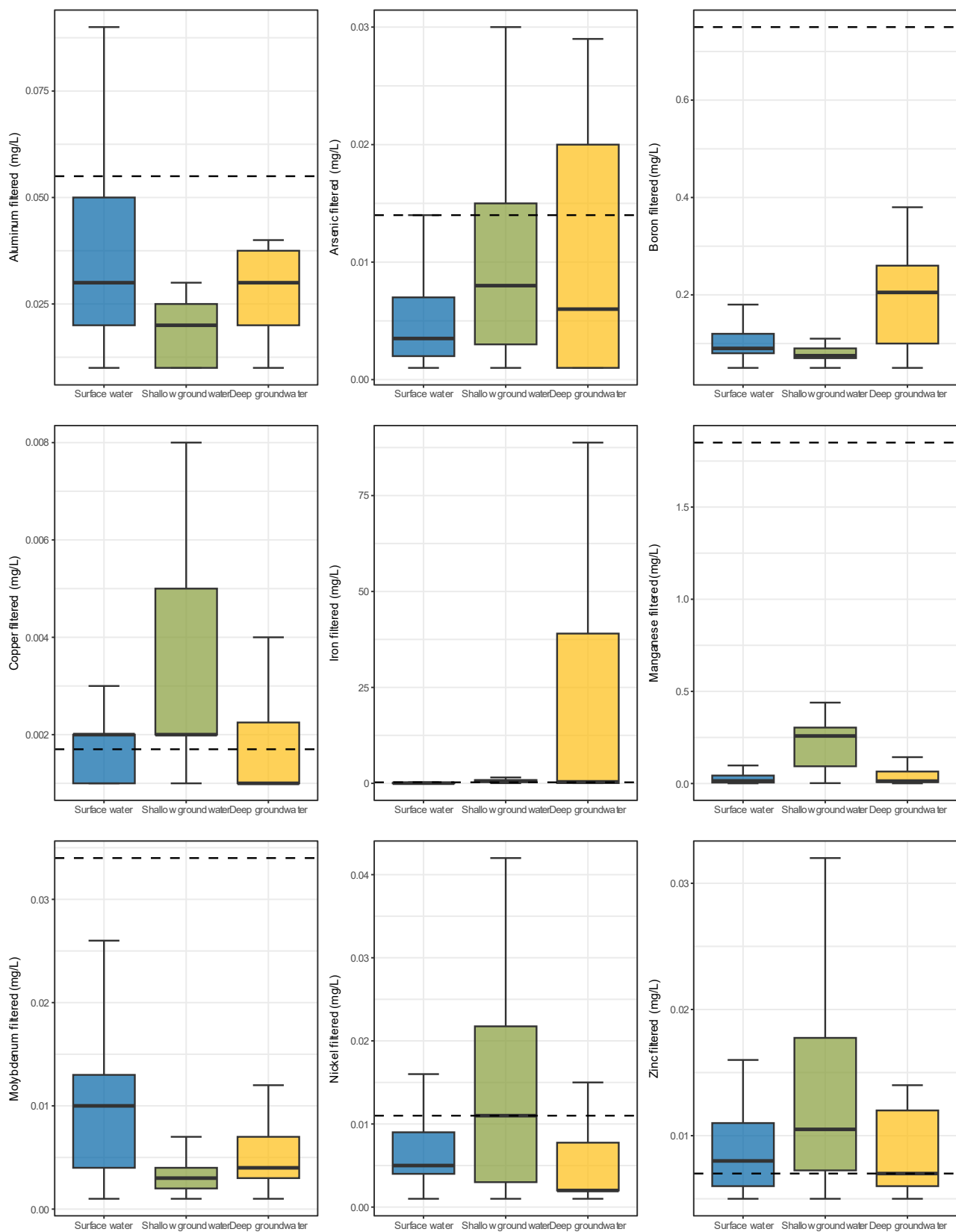


Figure 6.6 Box and whisker plots for filtered metal analytes

6.6 Surface water and groundwater interaction

Surface water features that interact with groundwater include:

- perennial watercourses (refer to Section 3.4) which:
 - receive baseflow from the shallow groundwater system during dry periods
 - discharge to the shallow groundwater system during wet periods
- ephemeral streams, receiving groundwater during periods when water levels in the shallow groundwater system are high (i.e. during and immediately after wet periods).

6.7 Groundwater dependent ecosystems

6.7.1 Terrestrial

In accordance with the Risk Assessment Guidelines for Groundwater Dependant Ecosystems (Serov, Kuginis and Williams 2012), terrestrial GDEs have been identified as:

- **Obligate**, represented by PCTs with an entire dependency on groundwater for ecosystem sustainment, typically occurring in areas with a consistently shallow (<0.5 m) watertable and comprising vegetation within swamps, fens and bogs. Obligate GDEs are considered at high risk of ecosystem degradation following watertable drawdown
- **Facultative**, represented by PCTs that have adapted to access groundwater when available however, are not entirely dependent on the presence of groundwater for ecosystem sustainment. Facultative dependence is sub-categorised by a:
 - high level of facultative dependence, relying on groundwater semi-regularly; considered at moderate risk of impact in the event of watertable drawdown
 - opportunistic level of facultative dependence, accessing groundwater when the watertable is elevated after flooding (i.e. vegetation within ephemeral watercourses and drainage lines); considered at low risk of impact in the event of watertable drawdown
 - proportional level of facultative dependence, remaining resilient in the absence of groundwater yet reflected as a proportional change in ecosystem prevalence and health; considered at low risk of impact in the event of watertable drawdown
- **Non dependant**, represented by PCTs that do not require groundwater for ecosystem sustainment, typically occurring in areas with a relatively deep watertable (i.e. vegetation along elevated ridgelines) and considered at negligible risk of impact in the event of watertable drawdown.

To infer dependence, baseline groundwater level monitoring data (refer to Section 5) was used to infer the depth to watertable across the study area. Table 6.1 provides the characterisation matrix for groundwater dependence. Table 6.2 shows the areas of each PCT (refer to Section 5.2.3i), respective of the depth to watertable, to characterise groundwater dependence in accordance with the characterisation matrix.

Seven PCTs were identified as groundwater dependant and are presented in Table 6.2. The locations of these GDEs are shown on Figure 6.7. Remaining PCTs were inferred as non-dependant on groundwater.

Table 6.1 Characterisation matrix for terrestrial groundwater dependant ecosystems

Groundwater dependence	Criteria	Risk of impact
Obligate	- more than 50% of the PCT is mapped in areas with groundwater at 0.5 mBGL or less, or - more than 75% of the PCT is mapped in areas with groundwater at 2 mBGL or less.	High
Facultative – high	- more than 50% of the PCT is mapped in areas with groundwater at 2 mBGL or less, and - more than 75% of the PCT is mapped in areas with groundwater at 5 mBGL or less.	Moderate
Facultative – proportional	- more than 75% of the PCT is mapped in areas with groundwater at 5 mBGL or less, but - less than 50% of the PCT is mapped in areas with groundwater at 2 mBGL or less.	Low
Facultative – opportunistic	- more than 50% of the PCT is mapped in areas with groundwater at 5 mBGL or less, but - less than 75% of the PCT is mapped in areas with groundwater at 2 mBGL.	Low
Non-dependent	- evenly distributed across groundwater levels, and - less than 50% of the PCT mapped in areas with groundwater at 5 mBGL or more.	Negligible

Table 6.2 Terrestrial groundwater dependant ecosystem characterisation

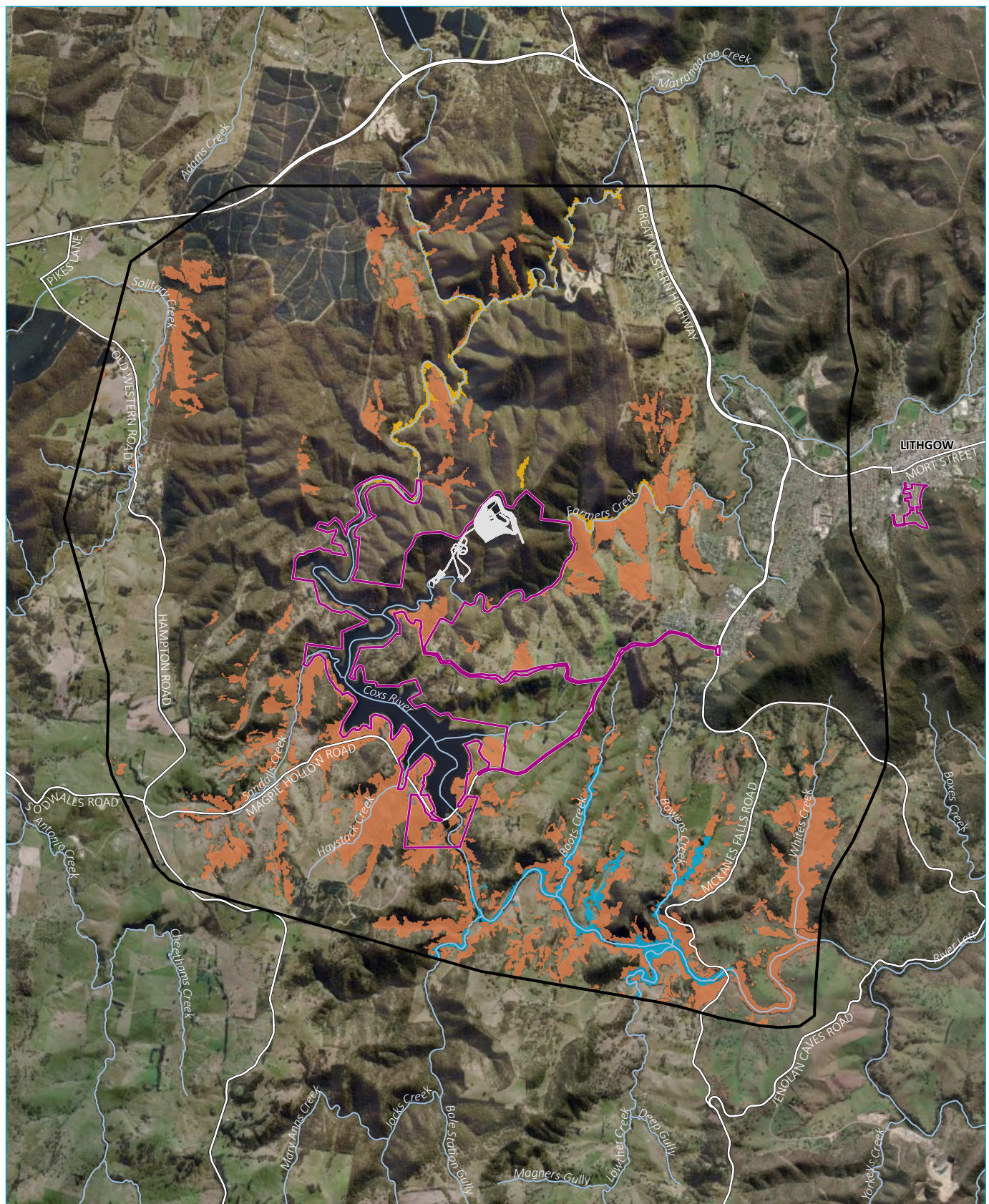
PCT	Percentage of PCT overlying groundwater depth				Groundwater dependence
	<0.5 m	<2 m	<5 m	>5 m	
3483	100%	100%	100%	0%	Obligate
3948	100%	100%	100%	0%	Obligate
4063	82%	93%	100%	0%	Obligate
4064	29%	83%	100%	0%	Obligate
3303	17%	61%	92%	9%	Facultative-High
3367	30%	41%	54%	46%	Facultative-Opportunistic
3738	12%	27%	51%	49%	Facultative-Opportunistic

6.7.2 Aquatic

As provided in Section 6.6, aquatic GDEs comprise habitats associated with the watercourses receiving groundwater within the study area. Potential impacts may arise through the reduction in habitat, caused by a reduction of groundwater baseflow to watercourses. Impacts are further discussed in Section 9.5.

6.7.3 Subterranean

Stygofauna sampling did not indicate the presence of subterranean GDEs; however, stygofauna are assumed to exist within some parts of the groundwater system and are inferred to be similar to those encountered in other fractured rock systems in NSW. Stygofauna are likely to be more common in bogs, hyporheic zones and shallow fractured rock groundwater systems due to the greater availability of dissolved oxygen and nutrients. Impacts are further discussed in Section 9.3.4ii.



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)

KEY

- | | |
|--|--|
| Project area | Existing environment |
| Model extent | Major road |
| Key project infrastructure | Named watercourse |
| Terrestrial GDE- study trued | |
| Facultative- high | |
| Facultative- opportunistic | |
| Obligate | |

Terrestrial groundwater dependent ecosystems- Study trued

Lake Lyell PHES
Groundwater Impact Assessment
Figure 6.7

7 Conceptual model

This section discusses the extent of local and regional groundwater systems of relevance to the study area, including the mechanisms by which groundwater is recharged, transmitted and discharged, as well characterising the dependency of access to relevant systems.

A graphical depiction of the conceptual hydrogeological understanding for the project is shown on Figure 7.1.

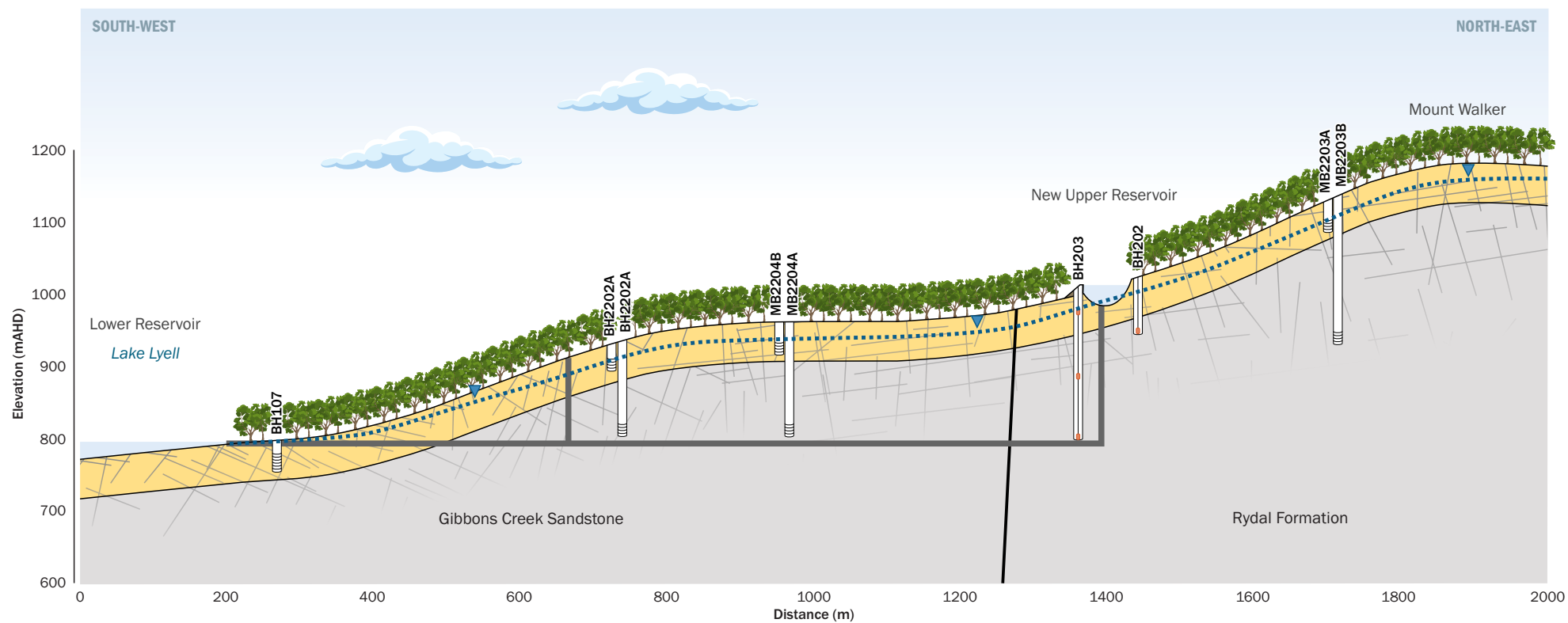


Figure 7.1 Lake Lyell hydrogeological conceptualisation

This section summarises the local hydrogeological setting, including groundwater levels and flow, hydraulic properties, groundwater system chemistry and surface water-groundwater interaction of the hydrogeological units in the project area.

The conceptual water model is provided in Table 7.1 and Figure 7.1.

Table 7.1 Conceptual water model

Component	Description	Reference
Topography	- Three distinct topographic areas, including: - steep ridges and valleys (at the project) - escarpments (eastern extent of the study area) - rolling foothills (remainder of study area).	Section 3.2
Climate	- Temperate, with no dry-season and a mild summer. - Typically wetter periods between May and August, drier periods between September and April. - Wet and dry periods both observed over the monitoring period. - Predicted increase in temperature and decrease in rainfall due to climate change.	Section 3.3
Hydrology	- Study area predominantly within Hawkesbury-Nepean/Sydney drinking water catchment, partly within the Macquarie-Bogan catchment. - Coxs River is the main receiving watercourse for surface water. - Perennial watercourses include Farmers Creek, Sandalls Creek, Coxs River, Bowens Creek, Jocks Creek, Lowther Creek, Whites Creek, Marangaroo Creek and Solitary Creek. - Multiple ephemeral watercourses discharging to higher order, perennial watercourses.	Section 3.6 Section 6.5
Geology	- Study area comprises rock units associated with the: - lower permeability Lachlan Fold Belt (deformed metamorphic, volcanic and sedimentary rocks) - higher permeability Sydney Basin (sedimentary rocks). - Structures associated with synclines and anticlines forming topographic deformation near the project. - Shallow (<2 m) and generally low permeability soils overlying hard-rock units.	Section 3.5 Section 6.2
Hydrostratigraphic units	- Shallow fractured rock groundwater system supported in shallow (<120 m), weathered and fractured Lachlan Fold Belt and Sydney Basin rock units. - Deep fractured rock groundwater system underlying shallow fractured rock groundwater system, supported in deeper Lachlan Fold Belt and Sydney Basin rock units.	Section 6.2
Hydraulic properties	- Relatively low hydraulic conductivity in Lachlan Fold Belt compared to Sydney Basin. - Higher hydraulic conductivity in shallow groundwater system, compared to deeper groundwater system (irrespective of geological province).	Section 6.4
Groundwater levels and flow	- Deeper watertable near high points in topography (~46 metres below ground level near Mt Walker) and shallower (near ground level) at perennial watercourses. - Regional groundwater flow direction is generally north to south. - Local flow occurs radially from high points in landscape towards watercourses.	Section 6.3
Water quality	- Relatively fresh (<500 µs/cm) and neutral pH. - Detections of dissolved metals generally below guideline values (with the exception of iron).	Section 6.5

Component	Description	Reference
Groundwater recharge	• Direct rainfall recharge to soil profile (where present) or shallow groundwater system, percolating downward to deeper groundwater systems. • In-direct recharge via leakage at losing watercourses. • Recharge volumes dependant on rainfall duration and magnitude, increasing during wet periods. • Generally low infiltration across elevated areas and high infiltration within valleys and foothills.	Section 9.2
Groundwater discharge	• Receiving perennial watercourses including Farmers Creek, Sandalls Creek, Coxs River, Bowens Creek, Jocks Creek, Lowther Creek, Whites Creek, Marangaroo Creek and Solitary Creek. • Ephemeral watercourses during wet periods. • Evapotranspiration where the watertable is sufficiently shallow to be intercepted by vegetation.	Section 6.3.4
Groundwater and surface water interaction	• Continuous hydraulic connection to perennial watercourses, with alternating gaining and losing relationship along streamline. • Intermittent hydraulic connection to ephemeral watercourses during periods of high rainfall and elevated groundwater levels.	Section 3.6 Section 6.5
Groundwater receptors	• Aquatic GDEs, comprising habitats associated with receiving perennial watercourses (Farmers Creek, Sandalls Creek, Coxs River, Bowens Creek, Jocks Creek, Lowther Creek, Whites Creek, Marangaroo Creek and Solitary Creek). • Terrestrial GDEs, comprising plant communities with a dependence on groundwater (PCTs 3483, 3948, 4063, 4064, 3303, 3367 and 3738). • Landholder bores accessing regional groundwater for supply.	Section 6.7

8 Assessment approach

8.1 Potential impacts

8.1.1 Overview

The assessment of project-related impacts to water resources, water users and the resultant water licensing needs to consider the requirements of the WM Act, the relevant WSPs and the AIP.

The assessment methodology that has been used to characterise impact is modelled on the National Water Commission's (NWC) risk framework (NWC 2010). The Framework uses a source-pathway analysis model that describes how water affecting activities might impact groundwater receptors, referred to as a source-pathway-receptor model in this GIA.

This GIA quantifies the risk of project related water affecting activities which are predicted to alter baseline groundwater conditions (if left unmitigated/managed), by identifying direct impacts (discussed in Section 8.1.2) and indirect impacts at identified groundwater receptors (discussed in Section 3.7).

8.1.2 Direct impacts

Direct impacts refer to a disruption of the physical water system and behaviour, linked directly to a specific project activity. Types of direct impacts may include:

- changes to surface water or groundwater quantity (e.g. watertable drawdown or aquifer depressurisation, reduced baseflow to gaining watercourses)
- changes to surface water or groundwater quality (e.g. potential leaching of solutes or oxidation of acid-generating elements, uncontrolled release of contaminated water intercepting during construction)
- changes to the physical aquifer medium (e.g. aquifer impoundment generating groundwater mounding, excavation below watertable resulting in depressurisation).

A summary of the relevant water affecting activities, their associated direct impacts, potential effects and the assessment criteria that have been used to quantify the significance of the impact is provided in Section 9 and Section 10.

An expansive description of the water affecting activity (i.e. pumped hydro generation components) related to the project is provided in Section 2.

8.1.3 Indirect impacts

i Overview

Indirect impacts represent the final link in the source-pathway-receptor chain. An indirect impact is resultant of direct impact (i.e. a change in water quality, quantity or the aquifer medium). Types of indirect impacts may include the following:

- Altered groundwater quantity or quality available for terrestrial, aquatic or subterranean ecosystems that potentially rely on groundwater. This may be caused by a direct impact which has resulted in reduced water availability or altered water chemistry, exceeding the tolerance or limits of the groundwater supported species.

- Reduced water availability or altered water chemistry which has impacted the functioning of nearby third-party users that rely on groundwater, including landholders who rely on:
 - groundwater supply bores, and/or
 - surface water extraction from nearby groundwater dependent watercourses.
- Reduced water availability or altered water chemistry which alters the cultural/spiritual amenity of declared culturally and/or spiritually significant sites.

The significance of an indirect impact is a function of the impact magnitude, receptor sensitivity and receptor resilience to changing groundwater conditions. The assessment of indirect impacts, and particularly the significance of the impact, requires an understanding of the relevant sensitive receptors. Principally these include:

- location within the landscape, particularly in relation to the receivers' proximity to water affecting activities
- reliance on water (e.g. depth to watertable, groundwater flux to baseflow-fed streams, water quality to meet beneficial purposes)
- capacity to adapt to altered surface water and/or groundwater regimes (resilience and resistance)
- an understanding of the scale of direct impacts
- the EV of the receptor, as discussed below.

ii Environmental values

Environmental values (EVs) establish a level of significance for groundwater receptors, providing an understanding of the importance for maintaining baseline water conditions at the groundwater receptor during Project construction and operation. EVs are dependent on the intrinsic value of an ecosystem (i.e. distribution of plant communities and category of endangerment) and the beneficial use of the source water system (i.e. water intended for drinking water supply or agricultural purposes).

Definitions of EVs relevant to the project are provided in Table 8.1.

Table 8.1 Summary of environmental values and definitions

Environmental value	Definition
Cultural/spiritual areas	The requirement to sustain water available to features of cultural or spiritual significance (i.e. watercourses attached to dreaming stories).
Aquatic ecosystems	The intrinsic value of aquatic ecosystems, habitat and species supported by perennial watercourses, waterholes and riparian areas (i.e. floodplain wetlands and fish).
Terrestrial ecosystems	The intrinsic value of terrestrial ecosystems, habitat and species supported by near surface groundwater (i.e. plant communities with a dependence on groundwater, potentially providing a habitat for animal species).
Subterranean ecosystems	The intrinsic value of subterranean ecosystems supported by subsurface groundwater (i.e. stygofauna).
Irrigation water	The suitability of water to support irrigation of crops, gardens and recreational areas.
Stock water	The suitability of water to support drinking water for livestock.
Domestic water	The suitability of water to support domestic supply (i.e. household use for laundry, bathing and washing).

Environmental value	Definition
Recreation water	The suitability of water to support recreational use (i.e. swimming and boating).
Drinking water supply	The suitability of water to support drinking water for households, requiring relatively minimal water treatment (such as water softening or disinfection).

Although the sensitivity of the EV will not change (i.e. it is generally determined qualitatively by the interaction of the receptor's condition, adaptive capacity, and resilience), the magnitude of the potential impact is variable and may be categorised quantitatively (i.e. via numerical modelling of groundwater drawdown) to facilitate the prediction of impact likelihood and significance.

iii Groundwater receptors within the project area

Project relevant EVs have been identified in Table 8.2, providing a basis for assessing the significance of impact to receptors.

Table 8.2 Environmental values and identified groundwater receptors

Environmental value	Groundwater receptor
Cultural/spiritual areas	Platypus Dreaming story associated with Coxs River.
Aquatic ecosystems	The intrinsic value of aquatic ecosystems, habitat and species supported by perennial watercourses, waterholes and riparian areas (i.e. floodplain wetlands and fish).
Terrestrial ecosystems	Plant communities with a dependence on groundwater.
Subterranean ecosystems	Stygofauna.
Irrigation water	Coxs River, supporting downstream unregulated river water access licenses used for irrigation.
Stock water	Coxs River, supporting downstream landholders utilising the river for stock watering.
Domestic water	- Coxs River and Farmer Creek, supporting domestic water access licenses. - Water supply bores.
Recreation water	Lake Lyell and the Coxs River, supporting water sports, fishing and camping.
Drinking water supply	Coxs River, downstream enters the northern arm of Lake Burragorang (also known as Warragamba Dam), a major water supply dam for the Sydney metropolitan region.

iv Summary of project sources, pathways and receptors

Table 8.3 presents a summary of project water affecting activities (sources), direct impacts (pathways) and indirect impacts (receptors).

Table 8.3 Direct and indirect impacts: water affecting activities and assessment criteria

Water affecting activity (source)	Potential effects	Direct impact (pathway)	Indirect impact (receptor)	Assessment criteria
Subsurface excavation (drill and blast)	• Watertable drawdown • Aquifer depressurisation • Modified groundwater flow paths	Changes to groundwater quantity	Reduced water availability and habitat for EVs	AIP
	• Contamination of groundwater (from chemical spills or materials used in activity)	Changes to groundwater quality	Altered water chemistry for EVs	AIP WQO
	• Modified baseflow to watercourses	Changes to surface water – groundwater interaction	Reduced water availability and habitat for EVs	AIP WQO
	• Physical removal of part or whole of aquifer • Modified groundwater flow paths	Aquifer disruption	Reduced water availability and habitat for EVs	AIP
Stockpiling of generated spoil and wastewater ponds/storage	• Modified recharge • Hydraulic loading on aquifer • Project induced perched groundwater system	Changes to groundwater quantity	Altered water availability and habitat for EVs	AIP
	• Acid spoil drainage • Metalliferous spoil drainage	Changes to groundwater quality	Altered water chemistry for EVs	AIP WQO
Operation of the project	• Watertable drawdown • Watertable mounding • Aquifer depressurisation	Changes to groundwater quantity	Altered water availability and habitat for EVs	AIP
	• Modified groundwater flow paths	Aquifer disruption	Reduced water availability and habitat for EVs	AIP
Dewatering for maintenance purposes	• Watertable drawdown • Aquifer depressurisation	Changes to groundwater quantity	Reduced water availability and habitat for EVs	AIP
	• Modified groundwater flow paths	Aquifer disruption	Reduced water availability and habitat for EVs	AIP
Groundwater supply for construction	• Watertable drawdown • Aquifer depressurisation	Changes to groundwater quantity	Reduced water availability and habitat for EVs	AIP

8.1.4 Cumulative impacts

Cumulative water-related impacts have been assessed for the project within the following context, considering nearby dewatering activities associated with Marangarro Quarry:

- existing pre-project water quality
- project-induced drawdown, baseflow reduction and surface water quality during the construction phase of the project
- the ongoing influence of drawdown, baseflow increase and surface water quality during the operational phase of the project.

8.2 Risk based assessment approach

Impacts will be assessed in accordance with a risk-based approach, comprising:

- identification of relevant water effecting project activities (during construction and operational phases)
- assessment of EVs (including location, sensitivity, resilience and resistance)
- assessment of the risk of potential impacts to EVs, including the:
 - significance of potential impacts
 - likelihood of potential impacts
- recommendation of mitigation measures, with an assessment of the effectiveness of mitigation options
- assessment of the residual impact.

Further discussion of assessed impacts is provided in Section 11.

9 Groundwater level and flow assessment

9.1 Overview

This section provides a summary of the numerical groundwater model (the model) and the predicted, project induced, impacts to groundwater flow and level (in accordance with the AIP).

Discussion regarding the model is presented as a summary of information relevant to this GIA. Further discussion of the model, such as calibration performance and detailed model design, is presented in the groundwater modelling report attached as Annexure C.

The groundwater level and flow assessment presented in this section also considers the cumulative impacts associated with nearby water affecting activities (i.e. Marangaroo Quarry) and the effects of climate change.

9.2 Numerical groundwater model

9.2.1 Overview

The model and groundwater modelling report (refer Annexure C) was developed in accordance with the Australian groundwater modelling guidelines (AGMG) (B. T. Barnett 2012) and the *Minimum Groundwater Modelling Requirements for SSD/SSI projects* (DPE 2022).

The numerical groundwater model was built using MODFLOW-USG Transport, version 2.4.0 (Panday, Langevin, et al. 2013); (Panday, USG-Transport Version 1.10.0 2023). Custom Python scripts were utilised to assist with building model packages and processing outputs. History-matching was carried out using PEST++ IES, version 5.2.11 (White 2018), including development of a parameter ensemble for predictive uncertainty analysis.

9.2.2 Model objectives

The model objectives were developed to quantify potential local-scale and/or regional-scale changes to the groundwater system, resulting from construction and operation of the project. Specifically, the objectives are to predict:

- watertable drawdown due to project-only and cumulative impacts
- potential impacts (drawdown/mounding) caused by the project at identified sensitive receivers such as landholder bores and groundwater-dependent ecosystems
- groundwater inflows to the project infrastructure during construction and operation
- changes to the water balance (with regards to both groundwater and surface water source areas) to inform water licensing as a result of the project
- watertable drawdown due to project-only impacts taking into consideration potential future long term rainfall changes under a climate change scenario.

The model was not designed to explicitly simulate soil water, surface water, perched groundwater or water quality/solute transport. It also does not explicitly simulate fractures or secondary porosity, instead taking an approach whereby equivalent porous medium (EPM) properties are modelled.

9.2.3 Design

As provided on Figure 9.1, the model domain (also the study area) encompasses all groundwater and water features within approximately 6 km of the project, including:

- nearby watercourses (refer to Section 3.4)
- GDEs (refer to Section 6.7)
- landholder bores (refer to Section 3.7.1)
- nearby groundwater affecting activities (refer to Section 3.8).

The model domain was sufficiently large to encompass the maximum extent of drawdown and mounding induced by the project (refer to Section 9.3).

The model mesh was designed using a Voronoi polygon mesh with up to 20,686 cells per layer and a total of 145,194 active cells. The MODFLOW-USG option to pinch out cells was used, resulting in some layers having less than 20,686 cells.

A total of 20 model layers were used to represent the hydrogeological conceptualisation and the geometry of the project. The four regional HSUs (refer to Section 6.2) combine to a total of eight considering their respective regolith, with the eight units used to discretise the model layers. Additionally, 10 m thick horizontal layers were used within a 100 m buffer from the project tunnels, which combined with the 2D mesh produce 3D cells small enough to allow for a detailed representation of tunnel features in the model. Outside of the 100 m buffer, 30 m thick horizontal layers were extended to a buffer of 2,000 m around the tunnels (outside of the 100 m buffer).

The model design is further discussed in the groundwater modelling report (refer to Annexure C).

9.2.4 History-matching

The model was history-matched to water level targets derived from the baseline groundwater monitoring data (refer Section 5.3.1). Erroneous data (i.e. recovering from installation or disturbed by sampling events) was removed, ensuring the targets were representative of the groundwater system. The data was simplified to monthly averages (matching monthly stress periods during the history-matching period), at each target location.

The history-matching dataset included 38 monitoring locations, including:

- 15 monitoring locations from within the baseline network (refer to Section 5.3.1)
- 23 theoretical monitoring locations, with calibration targets derived from the conceptual water table dataset (refer to Figure 6.1).

Stream-gauging data (refer Section 3.4) was used as an input to the model at the Coxs River and Marrangaroo Creek, where the respective drainage lines enter the model boundary. These were selected in the model design considering their location and the magnitude of flow rates, to allow for a more accurate representation of fluxes entering the model and a better replication of streamflow water balances.

The parameter estimation software PEST++ version 4.2.16 (USGS 2019) was employed to automate the history-matching process. The resulting base case parameterisation achieved scaled root mean squared (SRMS) errors of 1.4%. The history-matched model was considered to sufficiently represent available groundwater level measurements, gradients and dynamic responses to climate stresses.

History-matching is further discussed in the groundwater modelling report (refer to Annexure C).

9.2.5 Predictions

i Approach

Three main predictive model scenarios were developed to produce the outputs listed in the model objectives, including a:

- null scenario where no projects are active, allowing the model to run with climatic fluctuations
- cumulative scenario where the project and Marrangaroo Quarry (refer to Section 3.8) are active
- no project scenario where only Marrangaroo Quarry (refer to Section 3.8) is active.

Additionally, the null and cumulative scenarios were simulated under a climate change scenario, considering reduced rainfall-recharge predictions (refer to Section 3.3.5).

Multiple realisations of individual, plausible parameter sets for the model were run to estimate the uncertainty of the predictions. For each realisation a null scenario (i.e. no project) and project scenario were run. Project-related changes (e.g. drawdown/mounding or change in water balance components) were calculated as the difference between the null scenario and the project scenario for each realisation. In this way non-project related effects (such as response to seasonal climate) were removed.

Despite the anticipated low groundwater risk posed by the project, a type 3 “stochastic modelling with Bayesian probability quantification” predictive uncertainty analysis approach, as defined in *Uncertainty analysis – guidance for groundwater modelling within a risk management framework* (Middlemis and Peeters 2018) was implemented.

Following history-matching, from the 283 history-matched realisations, an accepted assemble of 104 realisations (including the base case (best-matched)) with individual parameter sets was used to produce a range of predictions. The ensemble is considered history-matched, and accordingly model predictions are presented as percentiles across the ensemble of 104 accepted realisations.

ii Scenario definition

A predictive model was developed including the history-matching period, and extending it for the duration of the project and post-project. The predictive model was run under the scenarios listed above, covering the duration of project construction, operation and post-closure in accordance with the project schedule (as provided by EnergyAustralia). The various project phases were discretised as follows:

- Historical phase: Starts with a steady state stress period representing average “pre project” conditions. Four quarterly stress periods follow, introducing seasonal climate variations during the year 2022. Between January 2023 and the end of September 2024, where monitoring data is available, monthly stress periods were used.
- Construction phase: Quarterly (three-month) stress periods between October 2024 and December 2030.
- Operation phase: Five-yearly stress periods for the initial 20 years (2030 to 2050) and 10-yearly stress periods for the remaining 60 years (2050 to 2110).
- Closure phase: Five 10-yearly stress periods, followed by a 50-year stress period, four 100-year stress periods, and a final steady-state stress period (covering 2110 to 2610, and long-term equilibrium).

Boundary conditions were employed to simulate seasonal climate variations as well as construction of the project.

During construction:

- the upper reservoir, headrace, tailrace, penstock tunnels, access portals and power station were represented using the Drain (DRN) package of MODFLOW, allowing for the simulation of groundwater inflow during excavation
- dam walls were represented using the Time-Variant Materials (TVM) package, allowing for the model to change the hydraulic properties of the material, simulating the retention of water upstream of the dam wall following construction.

During operation:

- the upper reservoir was represented using the River (RIV) package, allowing for the model to simulate water in the reservoir (to the average operating water level) and predict the resultant infiltration losses to the underlying groundwater system
- the headrace and tailrace were represented using the General Head Boundary (GHB) package of MODFLOW, allowing for the model to simulate the water losses or gains to/from the surrounding groundwater systems when conveying water between the project reservoirs.

The penstock tunnels are to be partly steel lined (impermeable) and within those lengths are assigned no boundary conditions during operation. Remaining lengths are concrete lined (permeable) and assigned under the GHB package. Following project closure:

- the upper reservoir was represented using the DRN package, as it is intended to remain dry, draining freely through a purpose-built drain placed in its base.

9.2.6 Confidence

The AGMG provides a classification system, whereby models can be categorised as either class 1, class 2 or class 3 (in order of increasing confidence). The class assigned to a model is generally based on:

- data availability (i.e. groundwater level data, stream gauge data and climate data was/was not available over a suitable spatial and temporal distribution)
- calibration performance (i.e. the difference between real and simulated data is acceptable/unacceptable or the model does/does not suitably represent groundwater stressors)
- inferred predictions (i.e. the predictive period of the model is not excessive, compared to the calibration period).

Different aspects of the model meet various AGMG classifications, including:

- the spatial distribution of geological information is sufficient to define aquifer geometry, representative of a class 3 model
- streamflow data and baseflow estimates are available at few data points, representative of a class 2 model
- the predictive phase exceeds the calibration phase, representative of a class 1 model (noting the predictive phase runs for approximately 500 years).

The model is considered to largely align with class 2 and class 1 classifications. Additional information is provided in the groundwater modelling report (refer to Annexure C).

The modelling report was peer reviewed by Chris Nicol of Groundwater Logic and found to be fit for purpose. All modelling objectives were satisfied and the model generally complies with current best practise with regards to design, calibration and prediction. Additional information is provided in the groundwater modelling report (refer Annexure C).

9.2.7 Conservatism

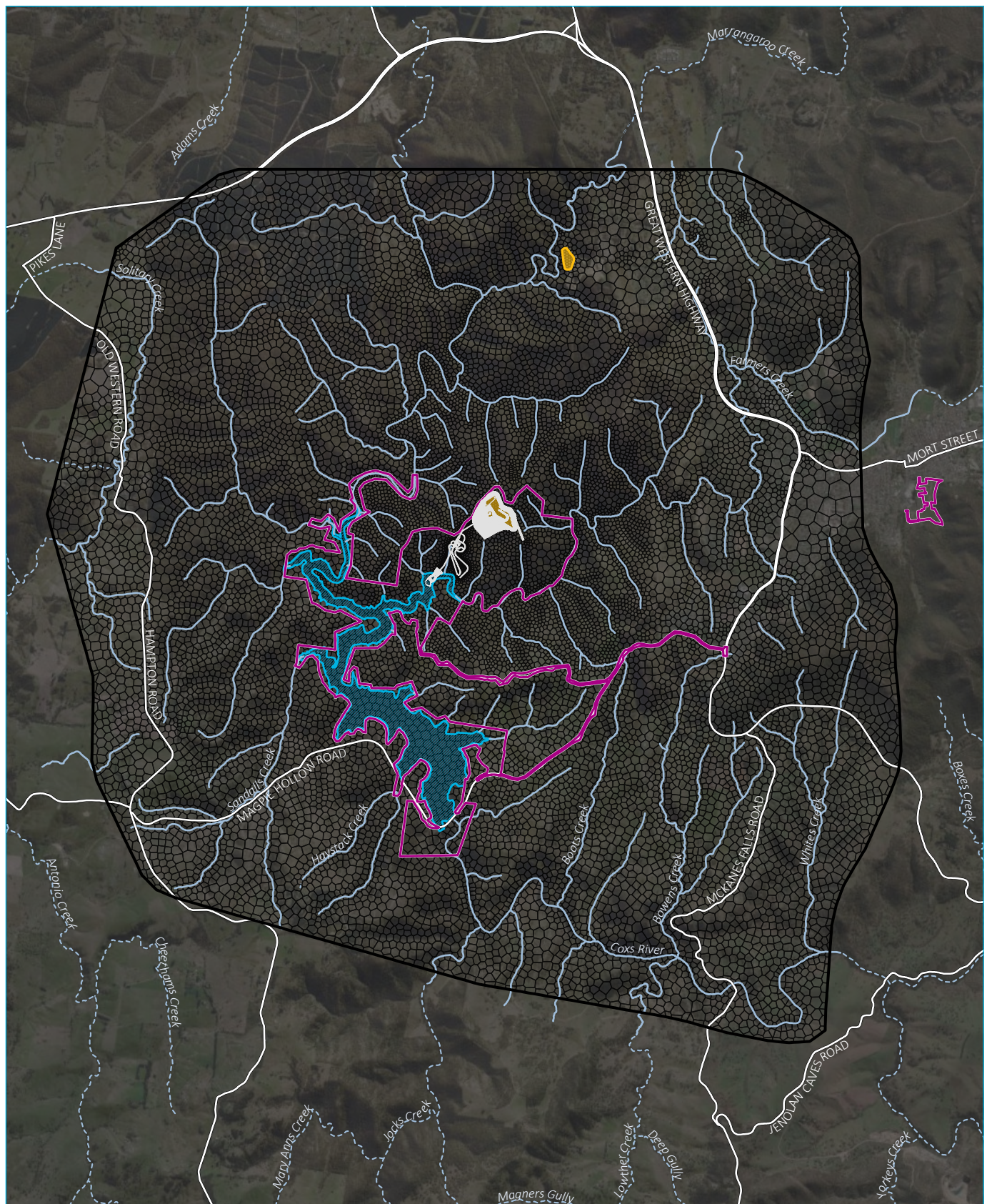
Watertable drawdown is caused by groundwater flow to project elements constructed below the watertable. Inflow is expected to occur mainly via fractures (secondary porosity) (refer to Section 6.3.1), whereby flow volumes increase in proportion to the degree and frequency of intercepted fractures during excavation.

The model cannot simulate individual fractures as fractured rock groundwater systems are highly complex, leading to an inherent uncertainty around occurrence, location and hydraulic conductivity of individual fractures. Attempts to 'constrain' the model to simulate unknown geological occurrences (i.e. fractures interspersed with low hydraulic conductivity zones) or design elements, is not in-line with the Australian Groundwater Modelling Guidelines (Barnett et al 2012) and has, therefore, not been undertaken.

To compensate for the uncertainty, the model is designed to be conservative as follows:

- Modelling does not consider project activities that reduce groundwater inflow (i.e. grouting or slurry injections) or management and mitigation measures (refer Section to 11.3).
- The model assumes an equivalent porous media approach (i.e. the HSU is similarly fractured across the entire model domain). Hydraulic parameters constraining the model are within the upper portion of values indicated by field testing (refer Section to 5.2.2) and literature (refer to Section 3.6.2), resulting in increased inflow and connectivity. The conservative assumptions may not represent the entire groundwater system, with the majority of the system expected to be less permeable.
- Ninety percent of the modelling ensemble results indicated watertable drawdown and groundwater inflows are predicted to be less than what is presented in this GIA, noting this GIA presents the 90th percentile PUA results (refer to Section 9.3) for project only related watertable drawdown.

The modelled predictions of groundwater inflow and drawdown are likely overestimated, resulting in conservative impacts and licensing requirement predictions. The results of this conservative modelling approach need to be considered within this overall context to accurately assess the project on its true merits.



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)

KEY

- | | |
|--|---|
| Project area | Existing environment |
| Key project infrastructure | Major road |
| Model extent | Named watercourse |
| Model mesh | |
| Major feature | |
| Modelled drainage line | |
| Lake Lyell waterbody extent | |
| Marrangaroo Quarry | |

Model domain and major features

Lake Lyell PHES
Groundwater Impact Assessment
Figure 9.1

9.3 Groundwater level impact assessment

9.3.1 Project construction

Drawdown progressively increases over the construction phase of the project. Maximum watertable drawdown is realised in the final year of construction, when the project is nearing completion and generating inflow over the greatest excavated area.

Based on the 90th percentile of prediction results, maximum watertable drawdown during construction is generally predicted to:

- extend up to 1.1 km from the project
- encompass approximately 112 ha (considering the 0.2 m drawdown contour, the practical accuracy of the model).

The predicted watertable drawdown during construction of the project is presented in Figure 9.2.

9.3.2 Project operation

During operation, the project induces watertable drawdown near project elements continually intercepting the watertable (i.e. the drained MAT, ECVT and upper reaches of the lower and upper reservoir), similar to the construction phase. Conversely, infiltration occurs from the water held in the reservoirs and power waterway induces watertable mounding (raising of the watertable) extending radially (and predominantly down-slope) of the upper and lower reservoir.

Based on the 90th percentile of prediction results:

- watertable drawdown during operation is predicted to:
 - extend up to 1.1 km from the project
 - encompass approximately 173 ha (considering the 0.2 m drawdown contour, the practical accuracy of the model)
- watertable mounding is predicted to:
 - extend up to 1.8 km from the project
 - encompass approximately 121 ha (considering the 0.2 m drawdown contour, the practical accuracy of the model).

The predicted watertable drawdown and mounding during operation of the project is presented in Figure 9.3.

9.3.3 Post project closure

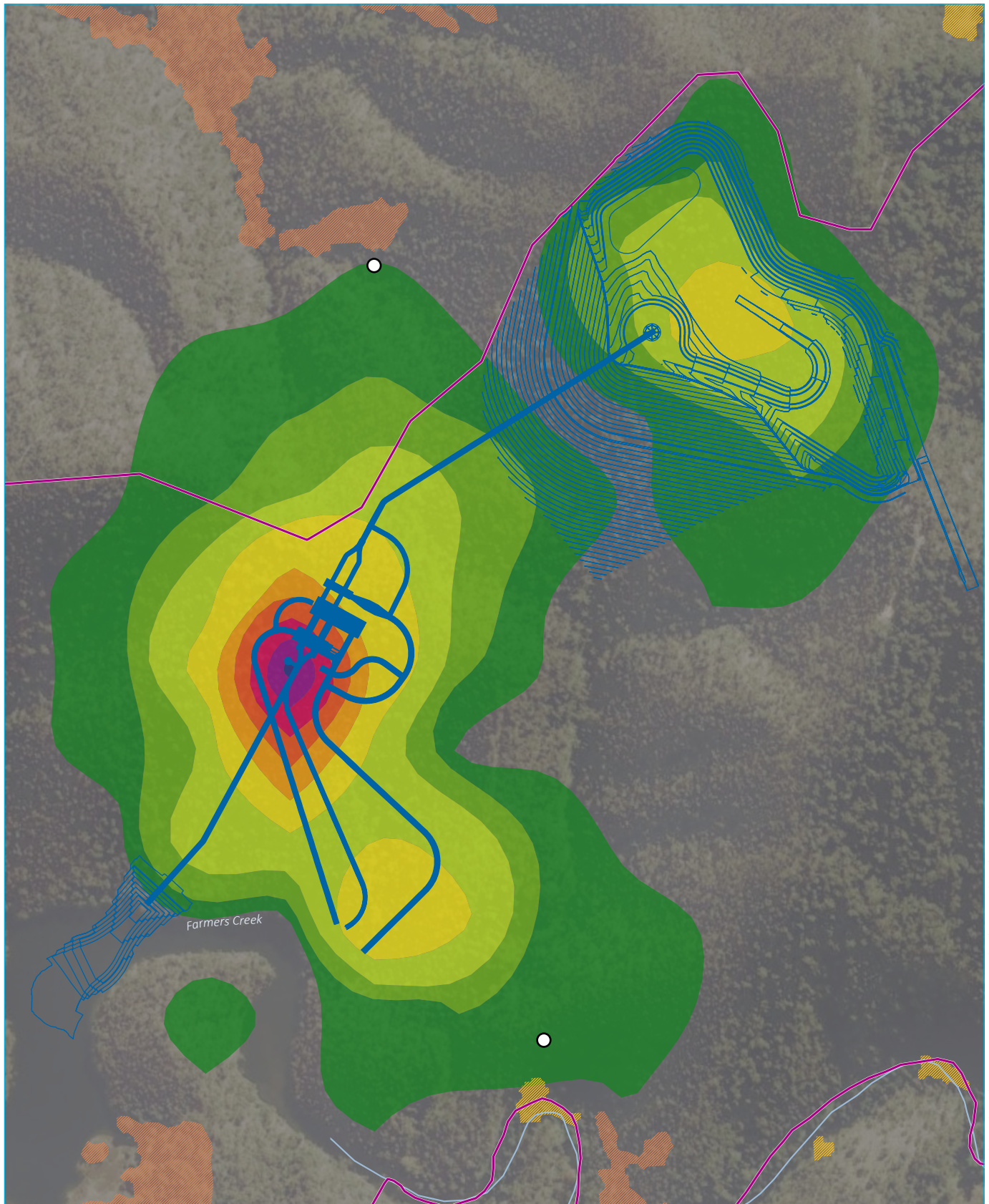
Following closure, the project induces watertable drawdown near project elements continually intercepting the groundwater table (i.e. the upper reaches of the upper reservoir), similar to the construction and operation phase. The remainder of the project reaches an equilibrium with the surrounding groundwater system.

Based on the 90th percentile of prediction results:

- watertable drawdown following project closure is predicted to:
 - extend up to 1.1 km from the project

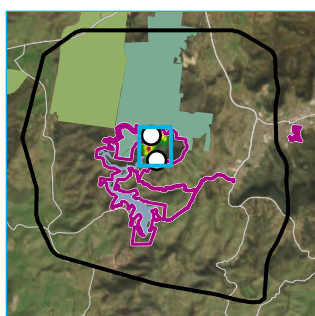
- encompass approximately 170 ha (considering the 0.5 m drawdown contour, the practical accuracy of the model).

The predicted watertable drawdown and mounding following project closure is presented on Figure 9.4.



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)

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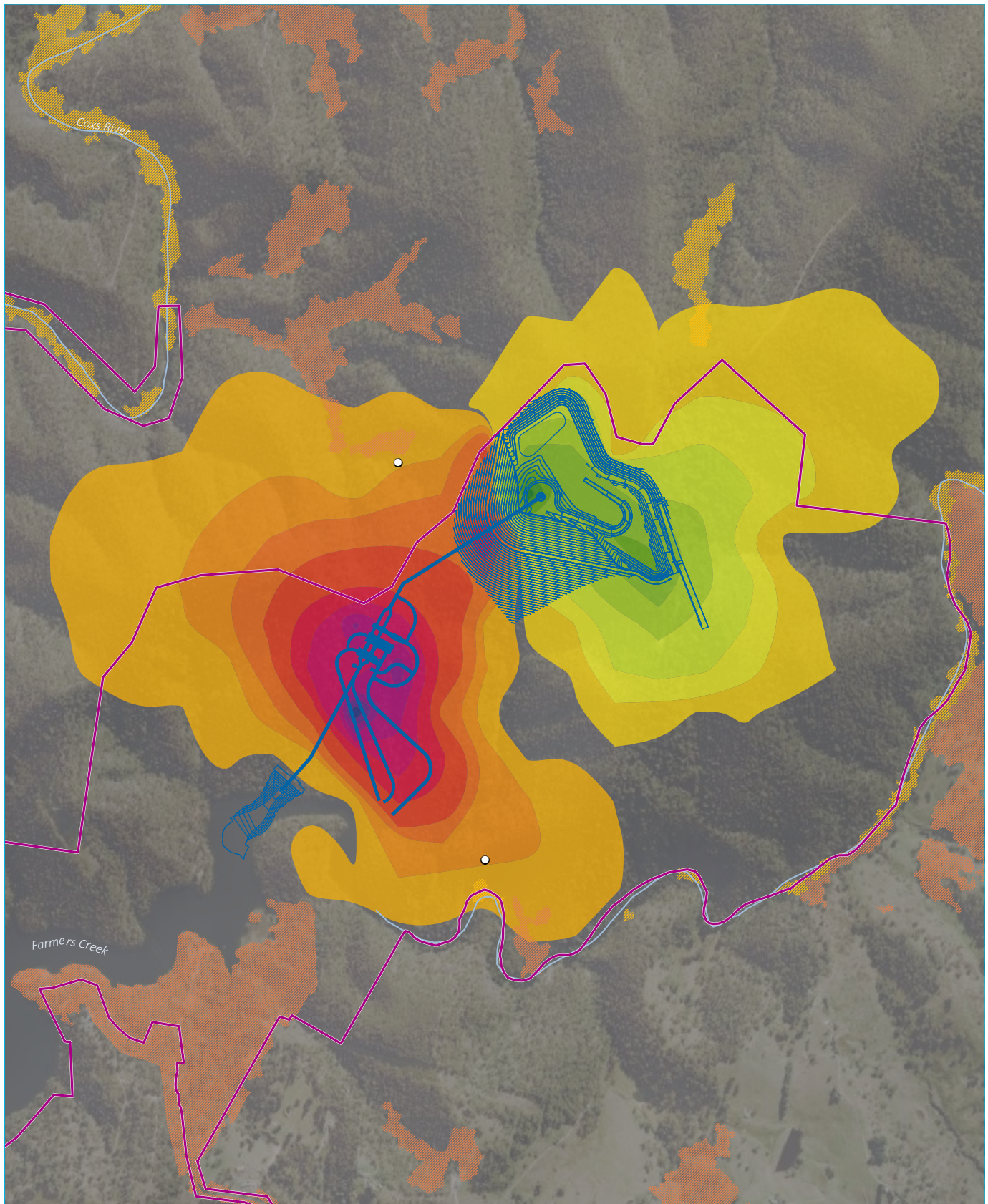
- KEY**
- Project area
 - Study area
 - Key project infrastructure
 - Hydrograph location
 - Terrestrial GDE - study truthed
 - Facultative- high
 - Facultative- opportunistic
 - Existing environment
 - Named watercourse

Maximum predicted watertable drawdown (m)

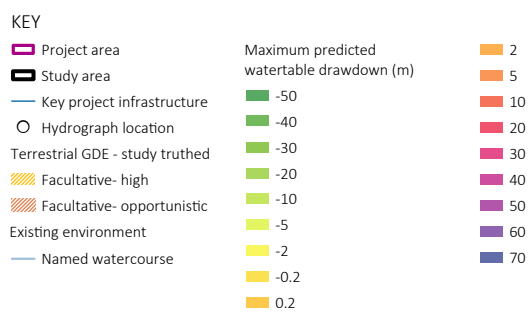
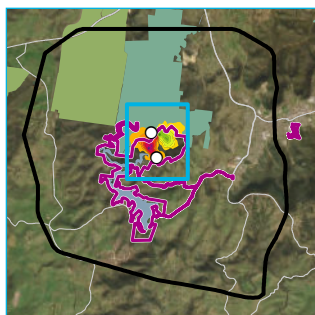
- 0.2
- 2
- 5
- 10
- 20
- 30
- 40
- 50
- 60

Maximum predicted watertable drawdown- Project construction

Lake Lyell PHES
Groundwater Impact Assessment
Figure 9.2



Source: EMM (2024); EnergyAustralia (2024); DCSSS (2023); ESRI (2024); GA (2009)

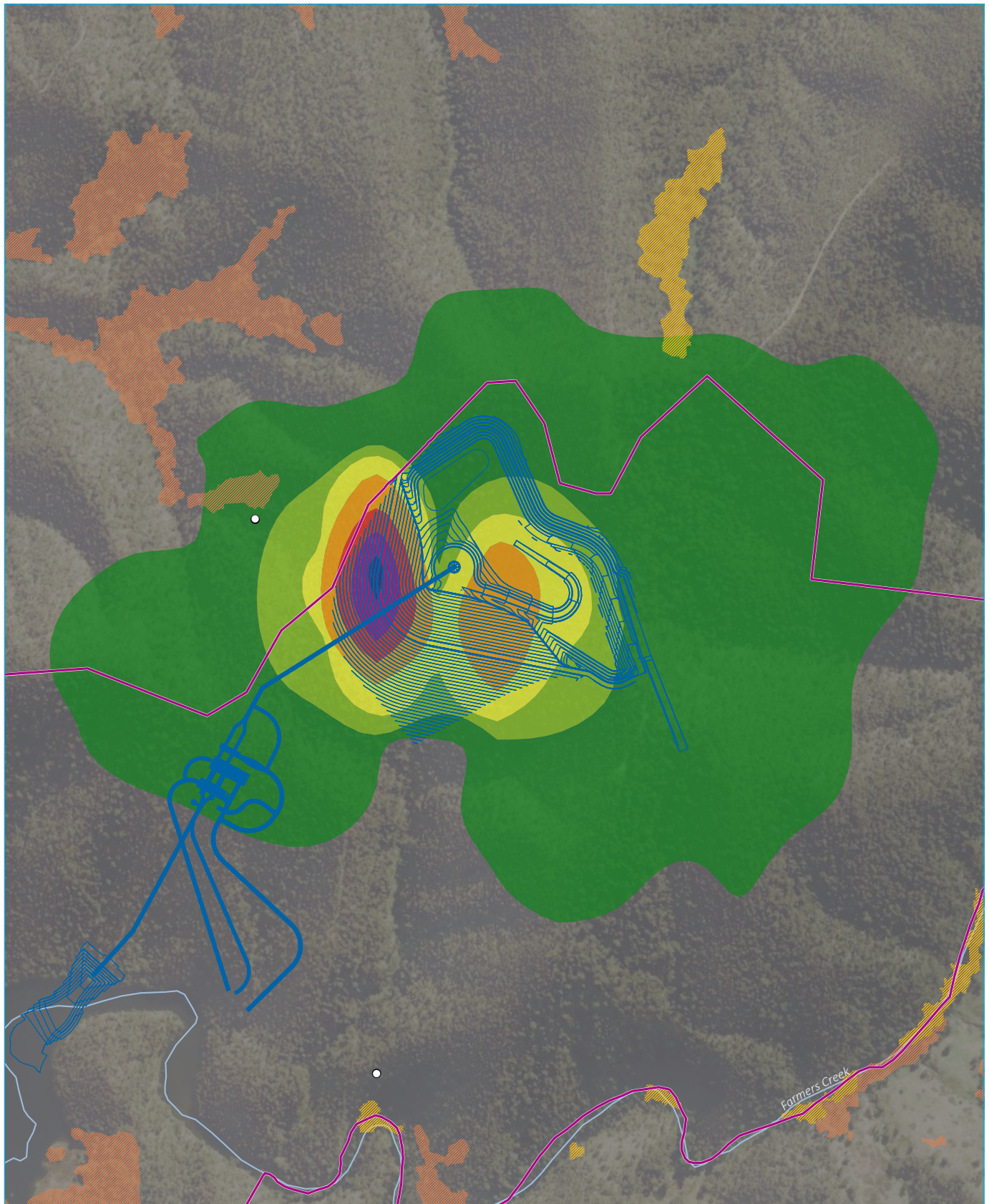


Predicted watertable drawdown
project operation

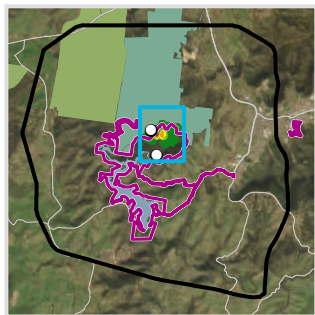
Lake Lyell PHES
Groundwater Impact Assessment
Figure 9.3



\\emm.local\drive\2022\E221111 - Lake Lyell PHES EIS\GIS\02_Maps\GIA\GIA018_PredictedWTDDO_Operation\GIA018_PredictedWTDDO_Operation_20250701_03.aprx 8/08/2025



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2024); GA (2009)



- KEY**
- Project area
 - Study area
 - Hydrograph location
 - Key project infrastructure
 - Terrestrial GDE- study truthed
 - Facultative- high
 - Facultative- opportunistic
 - Existing environment
 - Major road
 - Named watercourse
 - Maximum predicted watertable drawdown (m)
 - 0.2
 - 2
 - 5
 - 10
 - 20
 - 30
 - 40

Predicted watertable drawdown-
post project closure

Lake Lyell PHES
Groundwater Impact Assessment
Figure 9.4



\\emm.local\drive\2022\E221111- Lake Lyell PHES EIS\GIS\02_Maps_GA\GIA019_PredictedWTDD_Closure_20250701_03.aprx 8/08/2025

9.3.4 Predicted drawdown impacts

i Terrestrial groundwater dependent ecosystems

Watertable drawdown is predicted to intercept two terrestrial GDEs (refer to Figure 9.2 and Figure 9.3), comprising:

- one mapped community of PCT3303 (Central Tableland Ribbon Gum Sheltered Forest), located along Farmers Creek and approximately 750 m south-east of the project power station. The entirety of PCT3303 was inferred to have a facultative-high dependence on groundwater (refer Section 6.7.1). The Greater Metropolitan Region Groundwater Sources 2023 indicates this GDE is high priority
- one mapped occurrence of PCT3367 (Central Tableland Granites Grassy Box Woodland), located on an ephemeral watercourse approximately 550 m north-west of the project power station. The entirety of PCT3367 was inferred to have a facultative-opportunistic dependence on groundwater. This GDE is not listed as high priority under The Greater Metropolitan Region Groundwater Sources 2023.

Watertable drawdown hydrographs have been extracted from the model and are provided on Figure 9.5. The locations for plotting have been assigned in accordance with the AIP (i.e. approximately 40 m from the respective GDEs, towards the project). Watertable drawdown is predicted to steadily increase over the construction and operations phases of the project, reaching a maximum value of approximately:

- 3.6 m at PCT3303
- 1.1 m at PCT3367.

As discussed in Section 6.7.1, PCT3303 and PCT 3367 are considered at moderate and low risk of watertable induced impact, respectively. It is also considered that the adjacent watercourses (i.e. the ephemeral watercourse at PCT3367 and Farmers Creek at PCT3303) support the majority of the plant communities water requirements. Noting there is minimal impact to baseflow (refer to Section 9.4.2) in the afore-mentioned watercourses, impacts to terrestrial GDEs is considered negligible.

Management and mitigation measures that will be implemented to further reduce risk of impact to terrestrial GDEs is provided in Section 11.3 and Section 11.4.

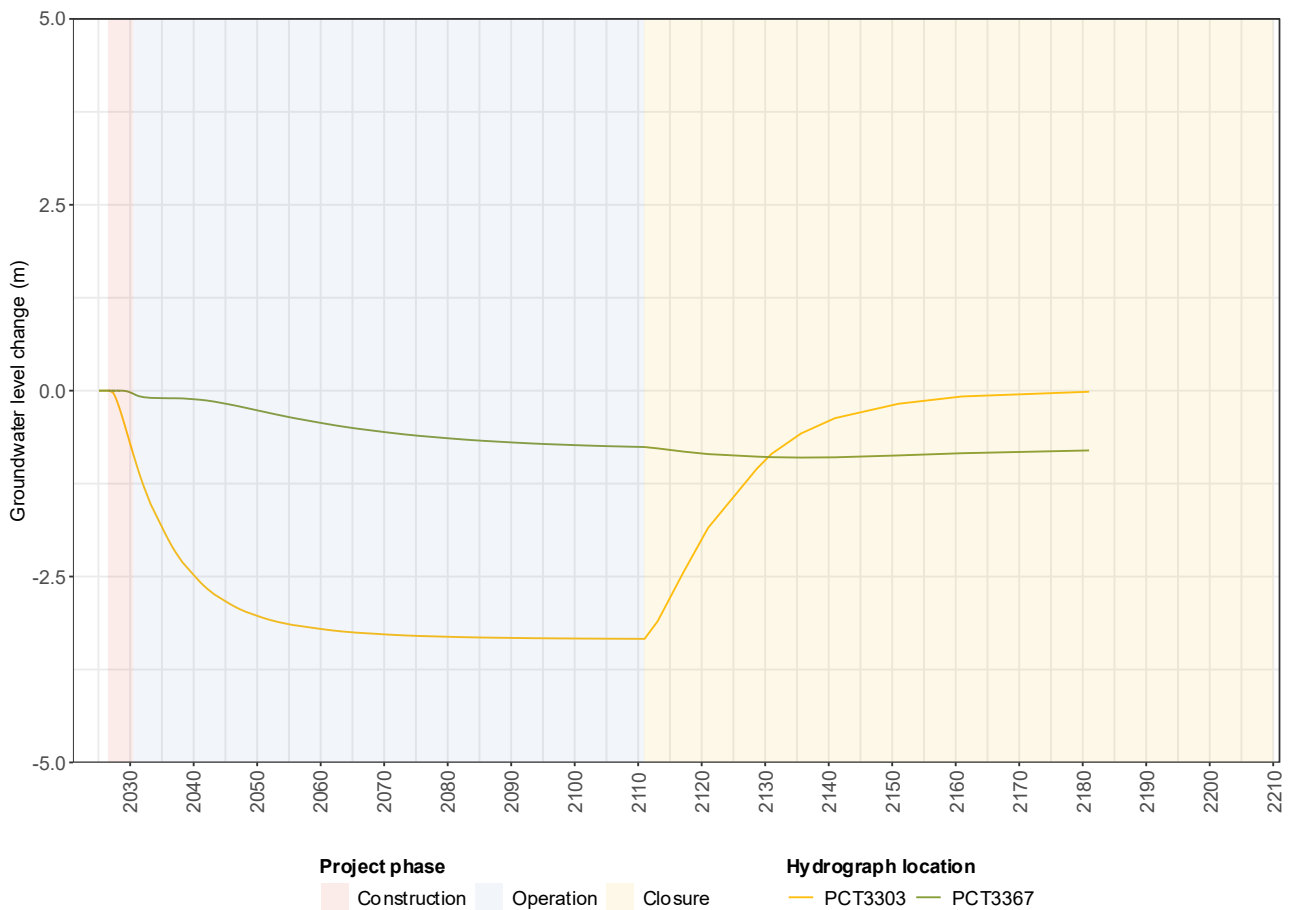


Figure 9.5 Watertable drawdown time series

ii Subterranean groundwater dependent ecosystems

The predicted drawdown will reduce the extent of habitat available to stygofauna. Drawdown of less than 20 m is considered unlikely to affect many stygofauna species, given the ability of these species to relocate within the saturated zone as groundwater level declines, e.g. drawdown of 5 m would be unlikely to have any significant effect.

Stygofauna communities are considered to be at high risk (Serov, Kuginis and Williams 2012). However, only a small area (approximately 173 ha) of habitat is predicted to be affected by drawdown during construction, and species of stygofauna have not been identified during site investigations (refer to Section 6.7.3). Therefore, it is anticipated that the risk of impact to stygofauna communities is low. It is again noted that the drawdown predictions are worst case based on conservative hydraulic conductivity values in the model and unmitigated tunnel construction methods.

iii Groundwater users

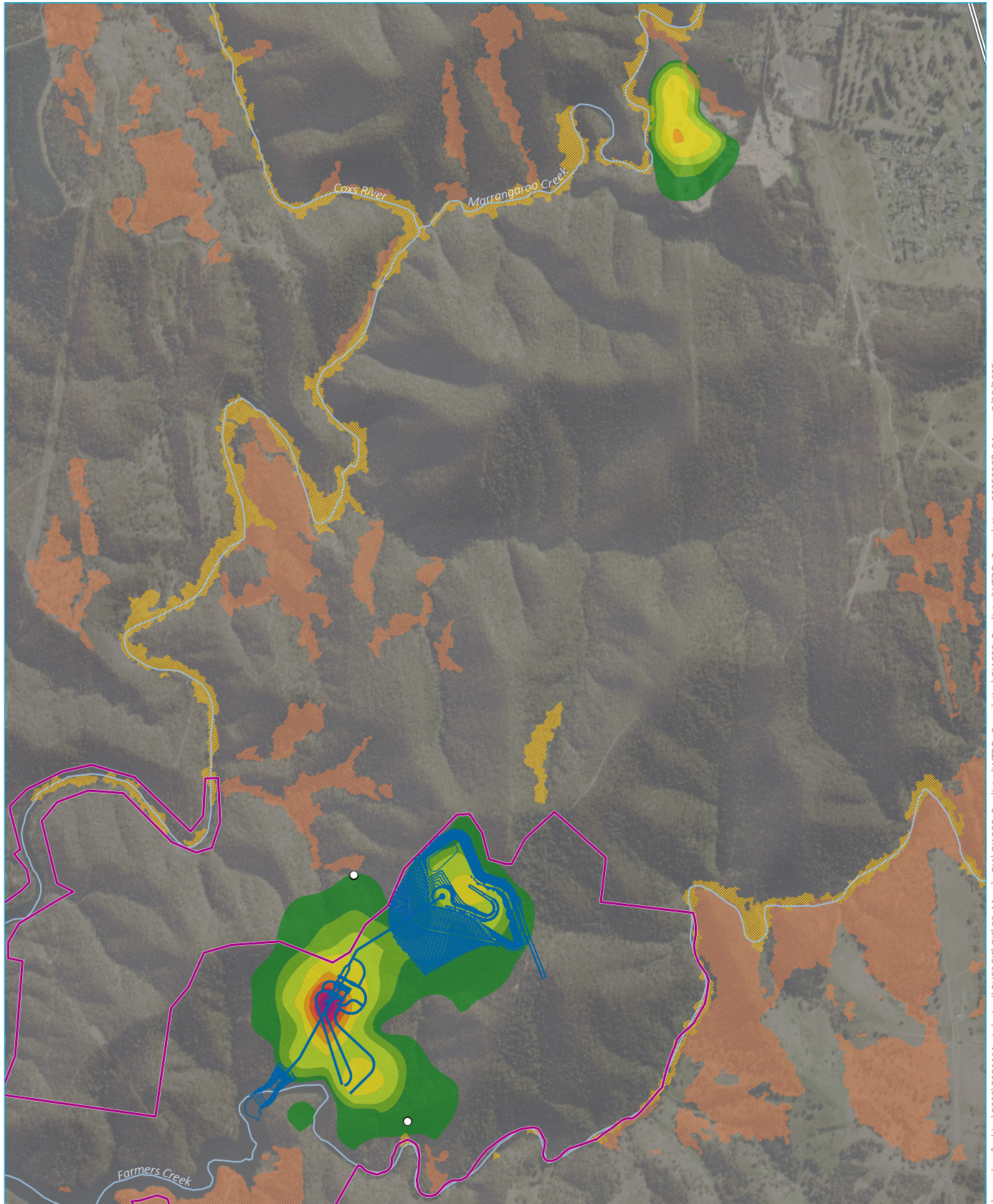
Based on the model predictions, drawdown is not predicted at any registered water supply works. project induced impacts to groundwater users is considered negligible.

9.3.5 Cumulative impacts

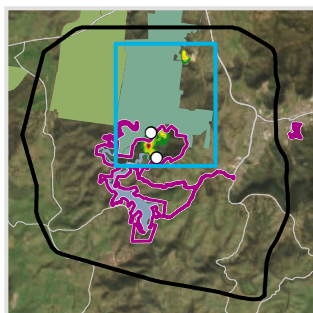
Cumulative watertable drawdown resulting from the project and the nearby Marangaroo Quarry (refer to Section 3.7.2iii) has been assessed during project construction. As discussed in Section 9.3.1, maximum watertable drawdown occurs during construction of the project, providing the greatest potential for groundwater relevant impacts.

As provided on Figure 9.6, the base case model predicts watertable drawdown above 0.2 m (the practical limit of the model accuracy) as isolated areas (separated by approximately 3 km) around the project and Marangaroo Quarry.

The potential for cumulative impacts resulting from the project and Marangaroo Quarry is considered negligible.



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2024); GA (2009)



KEY

- ▬ Project area
- ▬ Study area
- Hydrograph location
- ▬ Key project infrastructure
- Terrestrial GDE - study truthed
- ▨ Facultative- high
- ▨ Facultative- opportunistic
- Existing environment
- ▬ Major road
- ▬ Named watercourse

Predicted watertable drawdown (m)

- 0.2
- 2
- 5
- 10
- 20
- 30
- 40
- 50
- 60

Predicted watertable drawdown - cumulative impacts

Lake Lyell PHES
Groundwater Impact Assessment
Figure 9.6

9.3.6 Climate change effects

Watertable drawdown has been assessed resulting from the project, considering climate change effects (refer to Section 3.3.5). Watertable drawdown hydrographs extracted from the model, simulating average climate and climate change effects, are presented on Figure 9.7.

Noting the similarity (<0.1 m difference) between average climate and climate change simulations, and noting the accuracy of the model (~0.5 m), enhanced drawdown impacts resulting from climate change is considered negligible.

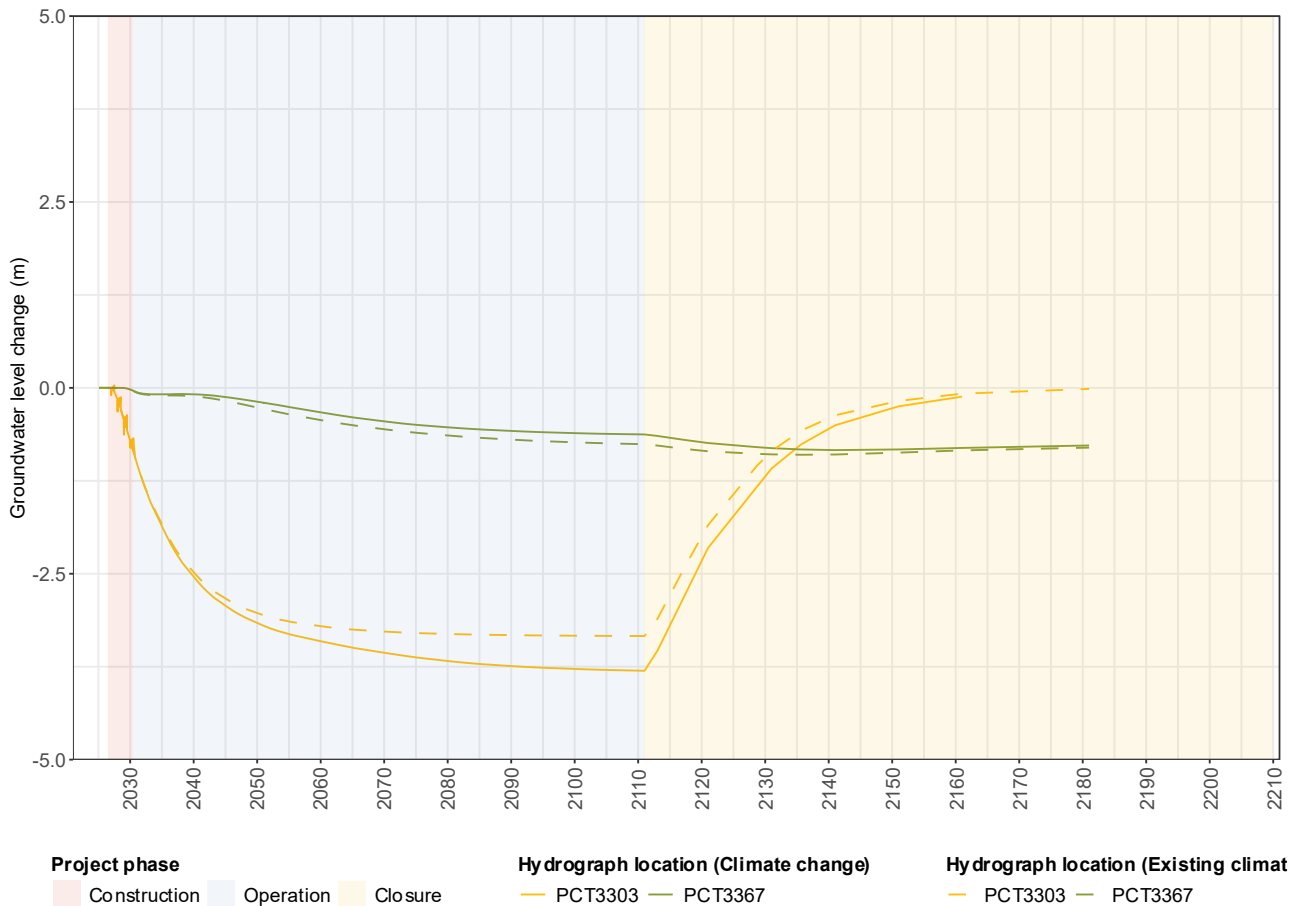


Figure 9.7 Drawdown (P90) at groundwater receptors – Comparison with climate change effects

9.4 Groundwater flow impact assessment

9.4.1 Groundwater inflow

Groundwater take (i.e. inflow to excavated components) and infiltration (i.e. losses from water retained in reservoirs) will occur as follows:

- During project construction, groundwater inflow will occur to project elements excavated below the watertable, prior to the installation of impermeable liners at selected project elements (i.e. the penstock shafts).
- During project operation, water losses will occur from pressurised project elements (i.e. the headrace tunnel and upper reservoir), contributing to the groundwater system.
- Following project closure, the sub-surface components of the project will reach equilibrium with the surrounding groundwater system (i.e. no net change) and the upper reservoir will receive groundwater inflow.

Water supply for construction may be accessed from groundwater supply bores, forming another component of groundwater inflow (or direct take). Water supply bores would likely target the LFB Greater Metropolitan Groundwater Source. Noting the conservatism of the numerical model inflow predictions and reducing water take over subsequent construction years, this will likely be captured under the peak construction groundwater take allocation however, a pathway for assessment of groundwater supply bore impacts is provided in Section 11.4.3.

Groundwater inflow predictions are summarised in Table 9.1.

Table 9.1 Groundwater inflow during project life-span

Project phase	Year	Groundwater inflow (1ML/yr)	Water losses (1ML/yr)
Construction	1	22.4	0
	2	31.9	0
	3	61.9	0
	4	56.6	0
Operation	-	25.8	66.1
Post-operation	-	3.1	0

Notes: 1. Megalitres per year, based on the 90th percentile results

9.4.2 Baseflow reduction and leakage

The groundwater model predicts effects on watercourses as a result of groundwater inflow to the project. The predicted baseflow reductions are restricted to localised areas near the project.

The reductions to baseflow are considered over time and the source of this water has also been considered in accordance with the AIP. The AIP requires the peak baseflow reductions to be considered for licensing purposes from each source of the water. Groundwater inflow peaks in the third year of construction (61.9 ML/yr).

Reductions in groundwater available for baseflow to watercourses was considered from the ultimate source perspective, as per a legal interpretation of the AIP, and in accordance with how the AIP has been implemented for other major project assessments. Reductions in streamflow (from a licence perspective) are either:

- reduced groundwater available for baseflow contributions (i.e. less gaining stream – but ultimately still a gaining stream) – this is licensed as groundwater, and/or
- induced losses from the surface water system to the underlying groundwater system (i.e. induced leakage from the surface water source) – this is licensed as surface water.

A summary of the predicted baseflow reduction and surface water leakage is provided in Table 9.2 and Table 9.3, respectively.

Table 9.2 Baseflow changes during project life-span

Watercourse/waterbody	Baseflow change (¹ ML/yr)					
	² Construction year				Operation phase	Post-closure
	1	2	3	4	-	-
Farmers Creek	0.0	0.0	0.0	0.0	+0.8	+0.5
Coxs River	0.0	0.0	0.0	0.0	-0.1	-0.1
Lake Lyell	-0.9	-2.4	-3.4	-3.8	-4.2	-2.1
³ Ephemeral watercourses	-20.7	-17.9	-20.0	-19.2	-3.8	-3.2
Marrangaroo Creek	0.0	0.0	0.0	0.0	0.0	0.0
Whites Creek	0.0	0.0	0.0	0.0	0.0	0.0
Lowther Creek	0.0	0.0	0.0	0.0	0.0	0.0
Jocks Creek	0.0	0.0	0.0	0.0	0.0	0.0
Bowens Creek	0.0	0.0	0.0	0.0	0.0	0.0
Sandalls Creek	0.0	0.0	0.0	0.0	0.0	0.0
Solitary Creek	0.0	0.0	0.0	0.0	0.0	0.0

Notes: 1. Megalitres per year, based on 90th percentile results
2. Divided by water year to support water licensing
3. Representing unnamed, ephemeral watercourses within the study area.

Table 9.3 Watercourse leakage during project life-span

Watercourse/waterbody	Watercourse leakage (¹ ML/yr)					
	² Construction year				Operation phase	Post-closure
	1	2	3	4	-	-
Farmers Creek	0.0	0.0	0.0	0.0	0.1	0.0
Coxs River	0.0	0.0	0.0	0.0	0.0	0.0
Lake Lyell	0.0	0.2	0.5	0.6	0.4	0.2
Ephemeral watercourses	0.0	0.0	0.0	0.0	0.0	0.0
Marrangaroo Creek	0.0	0.0	0.0	0.0	0.0	0.0

Watercourse/waterbody	Watercourse leakage (¹ ML/yr)					
	² Construction year				Operation phase	Post-closure
	1	2	3	4	-	-
Whites Creek	0.0	0.0	0.0	0.0	0.0	0.0
Lowther Creek	0.0	0.0	0.0	0.0	0.0	0.0
Jocks Creek	0.0	0.0	0.0	0.0	0.0	0.0
Bowens Creek	0.0	0.0	0.0	0.0	0.0	0.0
Sandalls Creek	0.0	0.0	0.0	0.0	0.0	0.0
Solitary Creek	0.0	0.0	0.0	0.0	0.0	0.0

Notes: 1. Megalitres per year, based on 90th percentile results
2. Divided by water year to support water licensing
3. Representing unnamed, ephemeral watercourses within the study area.

9.5 Predicted impacts on aquatic groundwater dependent ecosystems

Baseflow reduction to the perennial, receiving watercourses within the study area is predicted during construction of the project, with the maximum reduction realised in the fourth year of construction at approximately 3.8 ML/yr. Following construction of the project, ongoing losses are predicted at Lake Lyell (4.2 ML/yr) and Coks River (0.1 ML/yr).

Project induced leakage is predicted from Lake Lyell, with maximum leakage predicted in the fourth year of construction (0.6 ML/yr). Following construction of the project, leakage is predicted from Farmers Creek (0.1 ML/yr) and Lake Lyell (0.4 ML/yr).

Given the relatively low reduction in baseflow and increased leakage, reduced water availability is not anticipated to have a significant impact on aquatic GDE habitats.

10 Water quality assessment

10.1 Overview of water affecting activities

As discussed in Section 8.1.3iv, project activities that could be considered a potential water affecting activity include:

- stockpiling of spoil (i.e. excavated waste rock and soils), potentially providing a source of:
 - acid drainage, potentially associated with the oxidisation of sulphides contained within the spoil
 - metals and metalloids, potentially associated with the mobilisation of metals contained within the spoil when exposed to oxygen or differing pH levels
- storage of surplus or construction water, potentially infiltrating to the groundwater system or spilling to nearby watercourses and altering water quality
- drilling and blasting for tunnel excavation, potentially introducing nutrients (typically ammonium and nitrate contained within the blasting chemicals) to the groundwater system
- machine operation, potentially introducing hydrocarbons (fuels and oils) to the groundwater system in the event of a spill.

10.2 Water quality objectives and environmental values

The NSW Water Quality and River Flow Objectives (DECCW 2006) provides WQOs that are consistent with ANZECC/ARMCANZ water quality guidelines for the protection of the aquatic environment (ANZECC & ARMCANZ 2018). The WQOs are “primarily aimed at maintaining and improving water quality, for the purposes of supporting aquatic ecosystems, recreation and where applicable water supply and the production of aquatic foods suitable for consumption and aquaculture activities” (DECCW 2006).

WQOs are provided for catchments throughout NSW, with waterbodies potentially impacted by the project contained within the Cocks River catchment.

Ecological values (EV) are values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health, and which require protection from the effects of contamination, waste discharges and deposits. In general accordance with the National Water Quality Management Strategy (NWQMS), EVs for groundwater include (ANZECC & ARMCANZ 2000):

- aquatic ecosystems
- primary industries, comprising:
 - irrigation and general water users
 - stock drinking water
 - aquaculture
 - human consumption of aquatic foods
- recreation and aesthetics
- drinking water

- industrial water
- cultural and spiritual values.

Groundwater provides baseflow to watercourses (including the Cocks River, supporting ecosystems and Sydney water supply) within the study area. The primary ecological value for this groundwater is aquatic ecosystems and drinking water.

Water quality objectives (WQO) provide guideline values to mitigate potential impacts to EVs, the following WQO values have been referenced to characterise groundwater quality within the study area:

- Physical and chemical stressors – default trigger values for upland rivers in south-eastern Australia (ANZECC & ARMICANZ 2000).
- Toxicant trigger values for the protection of 95% of freshwater aquatic species (ANZECC & ARMICANZ 2000).
- Health based guideline values for physical and chemical characteristics in drinking water (NHMRC & NRMIC 2011).

Baseline characterisation of water quality is provided in Section 6.5.

10.2.1 Aquatic ecosystem protection

The ANZECC/ARMICANZ (2000) guidelines present default trigger values for the protection of 99%, 95%, 90%, and 80% of aquatic species. The guidelines also present default trigger values for the protection of slightly–moderately disturbed ecosystems that are based on the default trigger values for the protection of 95% of species, but which use the lower default trigger values for the protection of 99% of species for chemicals for which possible bioaccumulation and secondary poisoning effects should be considered.

10.2.2 Protection of systems supporting drinking water

The ADWG (NHMRC & NRMIC 2011) present default trigger values for the protection of receiving waters that may be utilised for human consumption. In this regard, ADWG trigger values apply more conservative values for certain contaminants than ANZECC/ARMICANZ (2000) default guideline values. Given this, this assessment conservatively assumes that ADWG default criteria supersedes ANZECC/ARMICANZ (2000) guideline criteria for certain analytes where applicable.

10.2.3 Summary of water quality objectives

Water quality objectives (WQOs) for watercourses and reservoirs are based on the NSW Water Quality and River Flow Objectives (DECCW 2006) and are presented in Table 10.1. WQOs are assigned based on the type of waterbody, the existing ecosystem condition and the potential receptors to any discharged water.

There is currently insufficient data to prepare site specific trigger values (SSTVs) for all monitoring locations, streamflow conditions and operating regimes (in the case of reservoirs). Hence, the default guideline values presented in Table 10.2 have been applied to characterise and assess water quality. These values are referred to as WQO values throughout the water assessment. SSTVs can be prepared during construction phase monitoring if sufficient data is available.

Table 10.1 **Summary of water quality objective values**

Water component	Ecosystem condition/beneficial use	Ecosystem condition justification	Proposed WQO approach	Default WQO values
Watercourses (ephemeral and perennial streams)	Slightly–moderately disturbed	Upstream impacts to watercourses associated with historical coal mining, treated effluent discharge and power generation	Physical and chemical stressors (some change due to natural variability acceptable)	Default trigger values for upland rivers in south-east Australia (ANZECC & ARMCANZ 2018)
			Toxicant trigger values for slightly–moderately disturbed ecosystems	Toxicant trigger values for slightly–moderately disturbed ecosystems (ANZECC & ARMCANZ 2018)
Reservoirs	- Slightly–moderately disturbed - Recreational	Lower reservoir (i.e. Lake Lyell) is man made and utilised for power generation and receives discharge from coal mines and Lithgow Sewage treatment plant	Physical and chemical stressors (some change due to natural variability acceptable)	Default trigger values for freshwater lakes and reservoirs in south-east Australia (ANZECC & ARMCANZ 2018)
			Toxicant trigger values for slightly–moderately disturbed ecosystems	Toxicant trigger values for slightly–moderately disturbed ecosystems (ANZECC & ARMCANZ 2018)
Discharge from project	- Slightly–moderately disturbed - Downstream water supply	Upstream impacts to watercourses associated with discharge from coal mines and Lithgow Sewage treatment plant	Physical and chemical stressors (some change due to natural variability acceptable)	Default trigger values for freshwater lakes and reservoirs in south-east Australia (ANZECC & ARMCANZ 2018)
			Toxicant trigger values for slightly–moderately disturbed ecosystems	Toxicant trigger values for slightly–moderately disturbed ecosystems (ANZECC & ARMCANZ 2018)
			Guideline values for physical and chemical characteristics of drinking water (where not presented in ANZECC guidelines, (ANZECC & ARMCANZ 2018))	Guideline values for physical and chemical characteristics (NHMRC & NRMCC 2011)

Table 10.2 **Water quality objectives – default trigger values**

Indicator	Units	Aquatic ecosystem ¹	Visual amenity	Secondary contact	Primary contact	Livestock water supply	Irrigation water supply	Aquatic foods (cooked)	ADWG (health)	ADWG (aesthetic)
Physico-chemical										
pH	-	6.5–7.5	-	-	5.0–9.0	-	6.5–8.5	-	-	6.5–8.5
Temperature	°C	-	-	-	15–35	-	-	<2°C change over one hour	-	-
Dissolved oxygen	%	90–110	-	-	-	-	-	-	-	>85
Electrical conductivity	µS/cm	30–350 ²	-	-	-	3,582 ³	<950 ⁴	.	<896 ³	-
Turbidity	NTU	2–25	-	-	6	-	-	-	-	5
Nutrients										
Oxidised nitrogen	µg/L	40	-	-	-	-	-	-	-	-
Ammonia	µg/L	20	-	-	-	-	-	-	-	500
Total nitrogen	µg/L	350	-	-	-	-	25,000–125,000	-	-	-
Reactive phosphorus	µg/L	20	-	-	-	-	-	-	-	-
Total phosphorus	µg/L	25	-	-	-	-	800–12,000	-	-	-
Chemical contaminants/toxicants										
Aluminium	µg/L	55	-	As per ADWG aesthetic	As per ADWG health	5,000	5,000	-	-	200
Arsenic	µg/L	13 ⁵	-			500	100	-	10	-
Antimony	µg/L	9 ⁶	-			-	-	-	3	-
Cadmium	µg/L	0.2	-			10	10	-	2	-

Indicator	Units	Aquatic ecosystem ¹	Visual amenity	Secondary contact	Primary contact	Livestock water supply	Irrigation water supply	Aquatic foods (cooked)	ADWG (health)	ADWG (aesthetic)
Chromium	µg/L	1.0 ⁷	-			1,000	100	-	50	-
Copper	µg/L	1.4	-			1,000	200	5	2,000	1,000
Iron	µg/L	-	-			2,000	200	-	-	300
Lead	µg/L	3.4	-			100	2,000	-	10	-
Manganese	µg/L	1900	-			-	200	-	500	100
Mercury	µg/L	0.06	-			2	2	1	1	-
Nickel	µg/L	11	-			1,000	200	-	20	-
Zinc	µg/L	8	-			20,000	2,000	5	-	3,000
Other chemical contaminants/toxicants	-	As per ANZG (2018)	-			As per Table 4.3.2 ANZECC	As per Table 4.2.10 ANZECC	-	As per ADWG (2011)	As per ADWG (2011)
Biological										
Chlorophyll-a	µg/L	5	-	-	-	-	-	-	-	-
Algae & blue-green algae	Cells/mL	-	-	<15,000	<15,000	<11,500	Not visible	-	<2,000	-
Faecal coliforms	Col./100 mL	-	-	<1,000	<150	<100	<10	2.3 MPN/g	0	0
Enterococci	Ent. /100 mL	-	-	<230	<35	-	-	-	-	-

Notes:

1. Contaminant/toxicant DGVs for slightly to moderately disturbed ecosystems as per ANZG (2018). All other indicators for upland (>150 m AHD) rivers as per DECCW (2006)
2. Values typical of NSW upland rivers as described in Table 3.3.3 of ANZECC (2000)
3. Derived from a total dissolved solids concentration by using the following equation electrical conductivity x 0.67 = total dissolved solids (ANZECC 2000)
4. For sensitive crops as defined in Table 4.2.4 of ANZECC (2000)
5. As for Arsenic (V)
6. Unknown reliability value
7. As for Chromium (VI)

10.3 Groundwater quality

10.3.1 Contaminant mobilisation

The geological units intercepted by the project have a low potential to induce metalliferous drainage. In the event that groundwater flow were increased (i.e. by infiltration from the power waterway and reservoirs), it would be unlikely to practically increase contaminant loading to receiving watercourse. The risk of contaminant mobilisation during operation of the project is considered negligible.

10.3.2 Material stockpiling

Spoil material will be stockpiled as project construction progresses. Stockpiles of excavated rock may mobilise minor concentrations of contaminants (i.e. metals, nitrates, etc.); however, the risk of leachate contamination within groundwater system is considered low, noting:

- Infiltration impacts would be highly localised and limited by the low permeability of the prepared stockpile pads / underlying groundwater system.
- Infiltrated water would predominantly flow down-gradient towards Lake Lyell, where dilution would result in low overall contaminant concentrations.

Noting that access constraints limit the potential for down-gradient monitoring bores or engineered design solutions (i.e. interception trenches), seepage sampling will provide an understanding of potential impacts, as further discussed in the Surface Water Impact Assessment (EMM 2024) and to be detailed in the water management plan (refer to Section 11.4.1).

10.3.3 Storage and transportation of chemicals and fuels

There is the potential for the project construction works to cause contamination to the groundwater resource. This predominately encompasses either spills of hazardous materials/chemicals and/or the generation of solid or liquid waste. Examples of this include spills of hydrocarbons while refuelling or lubricants used by machinery, and generation of solid construction waste or liquid waste during tunnelling. All scenarios have the potential to impact human and environmental health depending on the type of contaminant if not managed accordingly.

11 Impact summary and risk assessment

11.1 Risk assessment and management framework

An evaluation of project activities and potential impacts to groundwater, surface water and GDEs associated with these activities has been completed. The project activities are discussed in Section 2, with potential groundwater impacts arising from these impacts (and nearby water affecting activities) discussed in Section 8.1.

A risk assessment matrix has been used to quantify the level of environmental risk based on:

- likelihood of a potential impact occurring
- consequence of a potential impact, in line with the AIP (DPI 2012).

The definition of likelihood and the consequences are defined in Table 11.1 and Table 11.2 respectively. Based on the likelihood and consequence of project activity inducing impact, an overall risk score has been developed and is presented in Table 11.3.

Table 11.1 Classification of likelihood

Likelihood category	Description of qualitative likelihood (water chemistry)	Description of quantitative likelihood (based on groundwater modelling of watertable drawdown)
Almost Certain (AC)	A recurring event during the lifetime of an operation or project.	i.e. the P10 (refer Annexure C) results predict drawdown.
Likely (L)	An event that will probably occur during the lifetime of an operation or project.	i.e. the P33 (refer Annexure C) results predict drawdown.
Possible (P)	An event that may occur during the lifetime of an operation or project.	i.e. the P67 (refer Annexure C) results predict drawdown.
Unlikely (U)	An event that is unlikely to occur during the lifetime of an operation or project.	i.e. the P90 (refer Annexure C) results predict drawdown.
Rare (R)	An event with a low probability to occur during the lifetime of an operation or project.	No predicted drawdown.

Table 11.2 Classification of significance

Significance category	Description of impact	Minimal impact considerations (DPI 2012)
Severe (5)	• Considered critical to the decision-making process. • Permanent and irreversible impacts to EVs or areas of cultural/spiritual significance. • Occurring over a large area.	Level 2 – requires modification of project activity
High (4)	• Considered important to decision-making process. • Long-term and reversible (>5-year recovery period) impacts to EVs or areas of cultural/spiritual significance. • Occurring over medium–large areas.	Level 2 – requires modification of project activity

Significance category	Description of impact	Minimal impact considerations (DPI 2012)
Moderate (3)	- Considered relevant to the decision-making process. - Short-term to long-term and reversible (1-to-4-year recovery period) impacts to EVs or areas of cultural/spiritual significance. - Highly localised to the project area.	Level 2 – requires consideration when developing mitigation measures
Minor (2)	- Considered relatively minor in the decision-making process. - Short-term and reversible (<12-month recovery period). - Highly localised to the water affecting source.	Level 2 – requires consideration when developing mitigation measures
Negligible (1)	- Minimal change to the existing environment. - Allowable under relevant assessment criteria. - Results in a negligible change to sensitive receptors and therefore does not impact EV.	Level 1 – considered minimal impact

Table 11.3 **Classification of risk**

Likelihood	Significance				
	Negligible (1)	Minor (2)	Moderate (3)	High (4)	Severe (5)
Rare (R)	Low (R1)	Low (R2)	Low (R3)	Medium (R4)	High (R5)
Unlikely (U)	Low (U1)	Low (U2)	Medium (U3)	Medium (U4)	Critical (U5)
Possible (P)	Low (P1)	Medium (P2)	Medium (P3)	High (P4)	Critical (P5)
Likely (L)	Low (L1)	Medium (L2)	High (L3)	Critical (L4)	Critical (L5)
Almost Certain (AC)	Medium (AC1)	High (AC2)	Critical (AC3)	Critical (AC4)	Critical (AC5)

11.2 Unmitigated risk evaluation

This section provides a risk assessment based on the project construction and operation without mitigation measures. As such, the risks identified within this section should be considered an initial assessment to inform the development of mitigation measures and subsequent residual risks.

The risks of potential impacts caused by project activities, assuming no controls are in place are summarised in Table 11.4. Potential impacts identified as having a medium or above risk classification may be downgraded if appropriate controls and management measures are implemented and maintained. The commitments to the implementation of management measures and residual risk levels are provided in Section 11.3.

Table 11.4 **Assessment of unmitigated potential impacts**

Potential impact mechanism	Potential impact	Risk analysis (likelihood and consequence)			
		Low	Medium	High	Critical
Changes to groundwater quantity (flow/levels)	Localised drawdown – construction			L3	
	Localised drawdown – operation			L3	
	Regional drawdown – construction		L2		
	Regional drawdown – operation		L2		
Changes to groundwater quality	Localised quality impacts – construction		P3		
	Localised quality impacts – operation		P3		
	Regional quality impacts – construction	R2			
	Regional quality impacts – operation	R2			

11.3 Environmental management measures

11.3.1 Management of groundwater

The objectives of environmental management measures, as they relate to water resources, are to minimise and/or mitigate the potential for environmental impacts arising from project activities.

If required, it is proposed to implement:

- pre-grouting (i.e. grouting through pilot holes at the excavation face if inflows are un-manageable via pumping)
- post-grouting (i.e. following excavation and installation of any structural liners).

Whilst this construction methodology hasn't been considered in the project groundwater model, these management controls are likely to restrict groundwater inflows during construction and operation of the project, subsequently reducing impact to water resources. Peer reviewed referenced journal articles on inflow reductions from pre-or-post-grouting in other fractured rock tunnel environments are quoted as reducing inflows to manageable levels (Wannenmacher, Entfellner and Hauer 2022).

The residual risk levels, which are presented in Section 11.3.2, reflect the outcomes of management and mitigation measures.

11.3.2 Residual risk levels and environmental management measures

Specific management measures to address the requirements relating to water and the unmitigated potential impacts identified in Table 11.4 have been broadly outlined in Section 11.3. In addition, the residual risk associated with each potential impact has been reassessed.

While the control measure(s) focus on lowering the likelihood of an impact occurring, typically the consequence will remain unchanged, except where the risk control measure applied directly reduces the impact/consequence (e.g. pre-or-post grouting). Mitigated (or residual) impacts are assessed in Table 11.5.

Table 11.5 Assessment of mitigated (residual) potential impacts

Potential impact mechanism	Potential impact	Risk analysis (likelihood and consequence)			
		Low	Medium	High	Critical
Changes to groundwater quantity (flow/levels)	Localised drawdown – construction	P1			
	Localised drawdown – operation	P1			
	Regional drawdown – construction	U1			
	Regional drawdown – operation	U1			
Changes to groundwater quality	Localised quality impacts – construction	U2			
	Localised quality impacts – operation	U2			
	Regional quality impacts – construction	R1			
	Regional quality impacts – operation	R1			

Following the implementation of control and mitigation management measures, the residual risk of the potential impacts has reduced for all impact mechanisms.

Table 11.6 lists potential risks to the project where potential deviations from the model predictions and identified impacts may occur. Proposed management measures are also provided.

Table 11.6 Potential risks to the project and management measures from potential deviations

Potential impact deviation	Management measure
Groundwater drawdown (levels and extent) is significantly larger than predicted.	Groundwater monitoring to provide early indication of potential change in predicted impacts. Reconciliation of groundwater model predictions against groundwater monitoring data, e.g. increased drawdown, verified by groundwater monitoring, can be mitigated with further grouting treatments.
Groundwater inflow rates are higher than predicted to the tunnel, affecting water management system and project licensing (compliance).	Metering and monitoring will be in place to record the volume of water removed from the tunnel. Notify regulators. Standby pumps to increase volume removed from the underground for safe operation. Review of groundwater model.
Impacts on baseflow are greater than predicted.	Monitoring during operations to provide indication of impact. Triggers and trigger action response plans (TARPs), detailing potential mitigation measures, to be assigned within a water management plan (WMP). Notify relevant regulators in accordance with management measures.
Groundwater quality sampling indicates changes from baseline conditions	Monitoring during operations to provide indication of impact. Triggers and TARPs, detailing potential mitigation measures, to be assigned within a WMP. Notify relevant regulators in accordance with management measures.

11.4 Water management strategy and plans

11.4.1 Management Plan

Two water management plans (WMP) will be developed for the project to support construction and operational activities. The WMP will be a sub-plan of the construction environmental management plan (CEMP) and operational environment management plan (OEMP), respectively. The WMPs will document the proposed mitigation and management measures for the approved project, and will include the surface and groundwater monitoring program, reporting requirements, spill management and response, water quality trigger levels, corrective actions, contingencies, and responsibilities for all management measures.

The WMPs will be prepared in consultation with DCCEEW, the EPA and key local stakeholders, and would consider concerns raised during the exhibition and approvals process for the project.

The WMPs will include details of the surface water and groundwater monitoring program, which will incorporate and update the existing monitoring network, monitoring frequencies and water quality constituents, and physical water take and pumping volumes between water storage structures. Reporting frameworks for the above will be prepared in accordance with licensing and agency requirements. Trigger levels for water quality parameters will be developed as part of the WMPs to assist in early identification of water quality trends. The monitoring program will be prepared in accordance with the approved project's EPL, once enacted.

11.4.2 Monitoring and thresholds

The baseline monitoring network provides spatial coverage across the project area and targets key hydrological and hydrogeological features. Groundwater level and quality data will be collected throughout the project approval phase.

The baseline monitoring network also allows for data collection throughout project construction and operation, allowing for validation of the predicted:

- project induced groundwater drawdown and mounding
- seasonal groundwater level and quality variations in response to climatic stresses.

The baseline monitoring network will be expanded to include:

- water metering from excavations, allowing for validation of numerical model inflow predictions (as per commitments made in Section 11.4.3)
- water quality sampling from captured groundwater, ensuring releases to nearby watercourses from the WTP (if required) are in accordance with the WMP.

The suite of water quality analytes to be sampled and the frequency of sampling will be reviewed and updated in the WMP developed for the project. Data loggers that currently monitor water levels in the baseline monitoring network will continue to operate. Any required ongoing development and expansion of the monitoring network will occur in consultation with NSW DCCEEW.

11.4.3 Model validation

The groundwater model predictions would be validated by installing groundwater monitoring sites at selected, virtual monitoring sites simulated in the model. Should sites be unsuitable (i.e. access restrictions), then the model will be re-run with additional, virtual monitoring sites.

Model recalibration will be considered every two years (based on analysis of predicted versus actual impacts) and completed as required to:

- incorporate groundwater supply bores, following completion of water supply prospectivity investigations
- incorporate deep layer measurements (parameters and observed heads)
- consider all remaining comments from the independent peer review in the future models
- check model validity using recently collected data
- refine and/or recalibrate the model if needed
- revise predictions if needed, including uncertainty analysis.

Significant deviations from the predicted impacts will be investigated and reported on annually.

12 Water licensing

12.1 NSW water legislation and policies for licensing water

EnergyAustralia is required to licence water that is either taken or intercepted in accordance with the WM Act and the AIP. This includes water taken for use as well as water intercepted and managed as a result of project activities. EnergyAustralia is required to hold WALs in each affected water source to account for all water extracted and intercepted.

In accordance with the AIP, the project is required to licence both the direct and indirect take from adjacent and overlying water sources. The volume of water to be licensed for the project is defined as:

- groundwater inflow to the project that is physically handled by the water management system
- groundwater inflow to the project that is evaporated and thereby lost from the system
- reduced baseflow to overlying water sources
- increases in induced leakage from overlying water sources.

The results of the groundwater modelling have been used to estimate the required groundwater licence entitlements for the project, based on the predicted total groundwater inflow rates to the project and baseflow changes in permanent stream flows in the vicinity of the subsurface infrastructure.

The WALs and associated shares need to be held for the water year in which the impact occurs. All shares and WALs do not need to be held prior to the project approval, as some effects do not occur for years after construction and operation commences. A pathway to acquire sufficient water allocation is provided in the project water licensing strategy (EMM 2025).

12.2 Predicted water take

Based on the volumetric take predictions (refer to Section 9.4), water allocations required for licensing are provided in Table 12.1.

Table 12.1 Predicted water take during project construction

Water take	AIP classification	Maximum water take per source (ML/year)			
		LFB Greater Metropolitan Groundwater Source	Sydney Basin West Groundwater Source	Wywandy Water Source	Fish River Water Source
Groundwater inflow to excavated/tunnelled infrastructure	Direct take	62	0	-	-
Reduced baseflow for connected watercourses	Indirect take	24	0	-	-
Leakage via watercourse streambed	Indirect take	-	-	1	0
Total take (ML/yr)		86	0	1	0

Notes: 1. Megalitres per year, based on the 90th percentile results, values are rounded up to the nearest megalitre per year.

13 AIP assessment framework

This section reproduces the AIP assessment framework with commentary to assist NSW DCCEW with the assessment.

Table 13.1 Does the activity require detailed assessment under the AIP?

#	Consideration	Proponent response
1	Is the activity defined as an aquifer interference activity?	Yes
2	Is the activity a defined minimal impact aquifer interference activity according to Chapter 3.3 of the AIP?	Yes

13.1 Accounting for, or preventing the take of water

Table 13.2 Accounting for, or preventing the take of water, has the proponent:

#	AIP requirement	Proponent response
1	Described the water source(s) the activity will take water from?	Yes, this information is provided in Section 4.2.2
2	Predicted the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity?	Yes, this information is provided in Section 9.4
3	Predicted the total amount of water that will be taken from each connected groundwater or surface water source after the closure of the activity?	Yes, this information is provided in Section 9.4
4	Made these predictions in accordance with Section 3.2.3 of the AIP?	Yes, this information is provided in Section 9
5	Described how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources?	Yes, this information is provided in Section 12.2
6	Described how any licence exemptions might apply?	Yes, this has been described in the project water licensing strategy (EMM 2025)
7	Described the characteristics of the water requirements?	Yes, this information is provided in Section 4
8	Determined if there are sufficient water entitlements and water allocations that are able to be obtained for the activity?	Yes, this has been described in the project water licensing strategy (EMM 2025)
9	Considered the rules of the relevant water sharing plan and if it can meet these rules?	Yes, this has been described in the project water licensing strategy (EMM 2025)
10	Determined how it will obtain the required water?	Yes, this has been described in the project water licensing strategy (EMM 2025)
11	Considered the effect that activation of existing entitlement may have on future available water determinations?	Yes, this has been described in the project water licensing strategy (EMM 2025)
12	Considered actions required both during and post-closure to minimize the risk of inflows to a mine void as a result of flooding?	Yes, this has been described in the project water licensing strategy (EMM 2025)
13	Developed a strategy to account for any water taken beyond the life of the operation of the project?	Yes, this has been described in the project water licensing strategy (EMM 2025)
Will uncertainty in the predicted inflows have a significant impact on the environment or other authorised water users?		No
If yes , items 14–16 must be addressed.		

#	AIP requirement	Proponent response
14	Considered any potential for causing or enhancing hydraulic connections, and quantified the risk?	-
15	Quantified any other uncertainties in the groundwater or surface water impact modelling conducted for the activity?	-
16	Considered strategies for monitoring actual and reassessing any predicted take of water throughout the life of the project, and how these requirements will be accounted for?	-

Table 13.3 Determining water predictions in accordance with Section 3.2.3

#	AIP requirement	Proponent response
1	For the Gateway process, is the estimate based on a simple modelling platform, using suitable baseline data, that is, fit-for-purpose?	Yes, this information is provided in Section 5.3.1 and Section 9.2
2	For State Significant Development or mining or coal seam gas production, is the estimate based on a complex modelling platform that is: • Calibrated against suitable baseline data, and in the case of a reliable water source, over at least two years? • Consistent with the Australian Modelling Guidelines? • Independently reviewed, robust and reliable, and deemed fit-for-purpose?	The project is Critical State Significant Infrastructure. Numerical modelling has been calibrated to a reliable baseline data record, described in detail in Section 5.3.1 The model has been developed in accordance with the requirements of the <i>Australian Groundwater Modelling Guidelines</i> (Barnett et al 2012).
3	In all other processes, estimate based on a desk-top analysis that is: • Developed using the available baseline data that has been collected at an appropriate frequency and scale. • Fit-for-purpose?	The frequency of monitoring is adequate for the assessment. Details of which have been provided in Section 5.3.1

Table 13.4 Other requirements to be reported on under Section 3.2.3 of the AIP

#	AIP requirement	Proponent response
1	Establishment of baseline groundwater conditions?	Yes, this information is provided in Section 5
2	A strategy for complying with any water access rules?	Yes, this has been described in the project water licensing strategy (EMM 2025)
3	Potential water level, quality or pressure drawdown impacts on nearby basic landholder rights water users?	Yes, this information is provided in Section 9.3.4iii
4	Potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources?	Yes, this information is provided in Section 9.3.4
5	Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems?	Yes, this information is provided in Section 9.3.4
6	Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems?	Yes, this information is provided in Section 10
7	Potential to cause or enhance hydraulic connection between aquifers?	Yes, this information is provided in Section 11
8	Potential for river bank instability, or high wall instability or failure to occur?	Not applicable

#	AIP requirement	Proponent response
9	Details of the method for disposing of extracted activities (for coal seam gas activities)?	Not applicable

13.2 Addressing the minimal impact considerations

One groundwater source is impacted – the Lachlan Fold Belt Greater Metropolitan Groundwater Source. This water source is defined as a ‘less productive’ groundwater system in the fractured rock sub-grouping.

Table 13.5 Minimal impact considerations

Aquifer Category	Fractured rock Less productive
Level 1 Minimal Impact Consideration	Assessment
Watertable Less than or equal to a 10% cumulative variation in the watertable, allowing for typical climatic ‘post-water sharing plan’ variations, 40 m from any: - 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 watertable decline cumulatively at any water supply work.	No. Predicted impacts have been presented in Section 9.3.4
Water pressure A cumulative pressure head decline of not more than a 2 m decline, at any water supply work.	No. Predicted impacts have been presented in Section 9.3.4
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. Predicted impacts have been presented in Section 10

13.3 Proposed remedial actions where impacts are greater than predicted

Table 13.6 Proposed remedial actions where impacts are greater than predicted, has the proponent

#	AIP requirement	Proponent response
1	Considered types, scale, and likelihood of unforeseen impacts <i>during operation</i> ?	Yes, this information is provided in Section 9.3.2
2	Considered types, scale, and likelihood of unforeseen impacts <i>post closure</i> ?	Yes, this information is provided in Section 9.3.3
3	Proposed mitigation, prevention or avoidance strategies for each of these potential impacts?	Yes, this information is provided in Section 11.3 and Section 11.4
4	Proposed remedial actions should the risk minimization strategies fail?	Yes, this information is provided in Section 11.3 and Section 11.4
5	Considered what further mitigation, prevention, avoidance or remedial actions might be required?	Yes, this information is provided in Section 11.3 and Section 11.4
6	Considered what conditions might be appropriate?	Yes, this information is provided in Section 11.3 and Section 11.4

13.4 Other considerations

Table 13.7 Other considerations, has the proponent

#	AIP requirement	Proponent response
1	Addressed how it will measure and monitor volumetric take? (Page 4 of the AIP).	Yes, this information is provided in Section 11.3 and Section 11.4
2	Outlined a reporting framework for volumetric take? (Page 4 of the AIP).	Yes, this information is provided in Section 11.3 and Section 11.4

14 Conclusions

This GIA forms part of the EIS for the project and considers the changes to groundwater flow, level and quality that could impact nearby:

- environmental users, such as terrestrial, aquatic and subterranean GDEs
- watercourses receiving groundwater as baseflow contributions
- landholders accessing groundwater for supply.

This GIA has been collated to consider the WM Act, the POEO Act the EPBC Act. The AIP has provided the framework to establish the criteria for impact assessment of the project when intercepting groundwater and requirements for licensing.

The groundwater resources for the project are managed under the Greater Metropolitan Region Groundwater Sources 2023 and the NSW Murray–Darling Basin Fractured Rock Groundwater Sources 2020. Surface water resources (as assessed in the Surface Water Impact Assessment (EMM 2024)) within the project area are managed under the Greater Metropolitan Region Unregulated River Water Sources 2023 (forming part of the Sydney drinking water catchment) and the Macquarie Bogan Unregulated and Alluvial Water Sources 2012.

Extensive baseline investigation and monitoring works were undertaken to characterise the existing environment near the project. Works included geological borehole drilling, hydraulic testing, groundwater monitoring bore/vibrating wire piezometers installation and water quality sampling from groundwater and surface water.

The network covers 17 monitoring locations providing ongoing water quality and/or water level data, the majority of which will continue to provide data throughout post-approval. The extent, duration and frequency of baseline monitoring, for which this GIA has been based on, is considered fit for purpose. Additional data will continue to be gathered at key locations to further understand and monitor potential project impacts at a more local scale and verify model predictions and provide recalibration targets over time.

Groundwater modelling predicts localised watertable drawdown in the vicinity of the project throughout construction and operation. Maximum watertable drawdown, once the project has advanced into operations, is predicted to extend up to approximately 1.1 km from the centre of the project (near the power station complex), over approximately 173 ha.

Based on the groundwater modelling, drawdown is not predicted at any private groundwater users and watertable drawdown is predicted to have negligible impacts on terrestrial GDEs. There will be a minor reduction in baseflow available to rivers and creeks, however impacts are predicted to discrete stream-lengths only and residual impact are predicted to be negligible.

Water quality objectives have been provided to develop an indicative standard for project related water quality. These objectives will be monitored throughout the construction and operation of the project to ensure discharged water is of sufficient quality to meet this standard.

The peak groundwater inflow, impacts and take are considered for each groundwater source. The peak, cumulative take (including direct take, arising from inflow to project components and indirect take, arising from reduced baseflow to watercourses) occurs over the third year of construction (85.3 ML). Water allocation will be obtained to sufficiently license the groundwater take induced by the project.

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Abbreviations

Abbreviation	Meaning
AGMG	Australian groundwater modelling guidelines
AIP	Aquifer interference policy
BDAR	Biodiversity Development Assessment Report
BoM	Bureau of Meteorology
CLP	China Light and Power
CSSI	critical State significant infrastructure
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DPE	Department of Planning and Environment
DPHI	Department of Planning, Housing and Infrastructure
DST	drill stem test
DVP	double valve pump
ECVT	emergency, cable, and ventilation tunnel
EIS	Environmental Impact Statement
EP&A Act	<i>Environmental Planning and Assessment Act 1979</i>
EV	environmental value
GDE	groundwater dependant ecosystem
GIA	groundwater impact assessment
GL	gigalitre
Ha	hectare
HEVAE	high ecological value aquatic ecosystems
HGL	hydrogeological landscape
HV	high voltage
K	hydraulic conductivity
km	kilometre
kV	kilovolt
L	litre
LFB	Lachlan Fold Belt
LTAAEL	long-term average annual extraction limit
m	metre
m AHD	metres above Australian Height Datum
MAT	main access tunnel
mbgl	metre below ground level

Abbreviation	Meaning
MDB	Murray Darling Basin
ML	megalitre
MW	megawatt
MWh	megawatt hour
NSW	New South Wales
NWC	National Water Commission
PCT	plant community type
PHES	Pumped Hydro Energy Storage
POEO Act	<i>Protection of the Environment Operations Act 1997</i>
s	second
SEARs	Secretary's Environmental Assessment Requirements
SPAL	specific purpose access license
VWP	vibrating wire piezometer
WAL	Water access license
WM Act	<i>Water Management Act 2000</i>
WSP	water sharing plan
μs/cm	microsiemen per centimetre

Annexure A

Regulatory overview

A.1 Relevant legislation

A.1.1 Water Management Act 2000

The WM Act is the primary legislation governing water management and licensing in NSW.

The WM Act is based on the principles of ecologically sustainable development and the need to share and manage water resources for future generations. The WM Act recognises that water management decisions must consider economic, environmental, social, cultural and heritage factors. In addition, the WM Act recognises that sustainable and efficient use of water delivers economic and social benefits to the state of NSW.

The WM Act provides for water sharing between different water users, including environmental, basic rights or existing WAL holders and provides security for licence holders.

The licensing provisions of the WM Act become effective for any water source once a WSP for that water source commences; it has progressively been enacted across NSW since July 2004.

One of the key components of the WM Act is the separation of the water licence from the land; this facilitates opportunities for licence holders to trade water. The WM Act outlines the requirements for taking and trading water through WALs, water supply works, and water use approvals.

The WM Act is replacing the *Water Act 1912*. This transition occurs for particular water sources when a water sharing plan which applies to those water sources commences. This transition process is largely complete.

i Water Sharing Plans

WSPs are statutory documents that apply to one or more water source areas. They contain the rules for sharing and managing the water resources within water source areas. WSPs are designed to establish sustainable use and management of water resources and are periodically reviewed (every 10 years).

WSPs describe the basis for water sharing, and document the water available and how it is shared between environmental, extractive, and other uses. The WSPs then outline the water available for extractive uses within different categories, such as local water utilities, domestic and stock, basic rights, and access licences. Long-term average annual extraction limits (LTAAELs) are set by WSPs to define the limit of water that can sustainably be taken for all purposes. Sharing of water is prioritised for the environment, with planned environmental water prescribed under the rules of a WSP to protect the fundamental health of a river or aquifer and the ecosystems that depend on it. Requirements for basic landholder rights and licensed water users are also provided within WSPs. Amongst licensed water users, priority is given to water utilities and licensed stock and domestic use, ahead of commercial purposes such as irrigation and mining.

A.1.2 NSW Protection of the Environment Operations Act

The POEO Act is the key piece of environment protection legislation administered by the NSW EPA. The POEO Act enables the government to set protection of the environment policies that provide environmental standards, goals, protocols, and guidelines. It also establishes a licensing regime for pollution generating activities in NSW. Under sections 47 and 48 of the POEO Act, an environment protection licence (EPL) is required for 'scheduled development work' and 'scheduled activities', respectively, which include electricity generation and wastewater treatment. Accordingly, an EPL for the project will be applied for.

In accordance with section 5.24 of the EP&A Act, an EPL cannot be refused if it is necessary for carrying out approved SSI (and CSSI, by extension) and is to be consistent with the approval, should it be granted by the NSW Minister for Planning. The POEO Act also includes a duty to notify relevant authorities of pollution incidents where material harm to the environment is caused or threatened.

A.1.3 Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities, and heritage places, which are defined as matters of national environmental significance (MNES).

On 27 February 2023, EnergyAustralia submitted a referral for a proposed action to the Commonwealth DCCEEW under the EPBC Act for the project (EPBC Ref: 2022/09445). This referral considered impacts to matters of MNES and the environment generally and detailed that the project would potentially have a significant impact on MNES, including listed threatened species and ecological communities and listed migratory species.

Due to the potential impacts of the project on MNES and the environment, an accredited assessment process was sought under section 87(4) of the EPBC Act, where the Commonwealth accredits the assessment process under division 5.2 of the EP&A Act. On 3 April 2023, the Commonwealth DCCEEW Assistant Secretary provided notification of its referral decision and designated proponent, determining that the project's action was a controlled action and is to be assessed by accredited assessment process under part 5, division 5.2 of the EP&A Act.

As part of the accredited assessment process, Commonwealth DCCEEW assessment requirements have been included in the SEARs.

A.1.4 NSW Biodiversity Conservation Act 2016

Under the BC Act, any activities assessed under Part 5 of the EP&A Act must apply the test of significance to determine whether the proposed activity is likely to significantly impact threatened species or ecological communities. If a significant impact is likely, the proponent may choose to opt into the Biodiversity Offsets Scheme (BOS) or undertake a species impact statement (SIS). These are included elsewhere in the BDAR.

A.1.5 NSW Fisheries Management Act 1994

The FM Act is the principal piece of legislation protecting aquatic habitat in NSW. The FM Act aims to conserve fish stocks, key fish habitat, aquatic vegetation, and threatened species, populations and communities. Threatened aquatic species, populations and communities are listed under schedules 4, 4A and 5 of the FM Act, while key threatening processes are listed under schedule 6. Any impact to groundwater level or quality needs to be considered under the FM Act for groundwater dependent rivers if it has the potential to reduce streamflow and block fish passage.

A.2 Relevant policies

A.2.1 Aquifer Interference Policy

i Overview

The AIP was released by the NSW Government in September 2012. The purpose of the AIP is to explain the water licensing and assessment processes for aquifer interference activities under the WM Act and other relevant legislative frameworks.

The dictionary to the WM Act (under section 91) defines an 'aquifer interference activity' as an activity involving any of the following:

- penetration of an aquifer
- interference with water in an aquifer

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

The AIP clarifies the requirements for obtaining water licences for aquifer interference activities and defines considerations in assessing and providing advice on whether more than minimal impacts might occur to a key water-dependent asset.

The AIP defines water sources as being either ‘highly productive’ or ‘less productive’ based on levels of salinity and average yields from bores. The AIP then further defines water sources by their lithological character, being one of: alluvium, coastal sand, porous rock, or fractured rock.

The key requirements of the AIP are to:

- account for, or prevent, the take of water. Where a proposed activity will take water from an aquifer or connected surface water source, adequate arrangements must be in place to account for this water. It is the proponent’s responsibility to enable this to be estimated to a suitable level of accuracy, and to ensure necessary WALs are obtained and held
- address the ‘minimal impact considerations’. Aquifer interference activities can adversely impact groundwater and connected surface water sources by decreasing groundwater pressure and/or lowering the watertable; deteriorating groundwater and surface water quality either due to pollution or increases in salinity; by affecting the health or viability of a groundwater dependent ecosystem; or impacting on a culturally significant site. The AIP provides objective, measurable thresholds for considering the degree of impact an activity may have on the watertable, groundwater pressure and water quality changes. The assessment criteria differ between aquifer types (for example alluvial, porous, fractured) and whether the aquifer is deemed ‘highly’ or ‘less’ productive on the basis of natural water quality and extraction yields
- propose remedial actions. Where impacts are greater than those that were predicted as part of the relevant approval, proposed remedial actions shall be specified to manage those impacts.

ii AIP assessment process

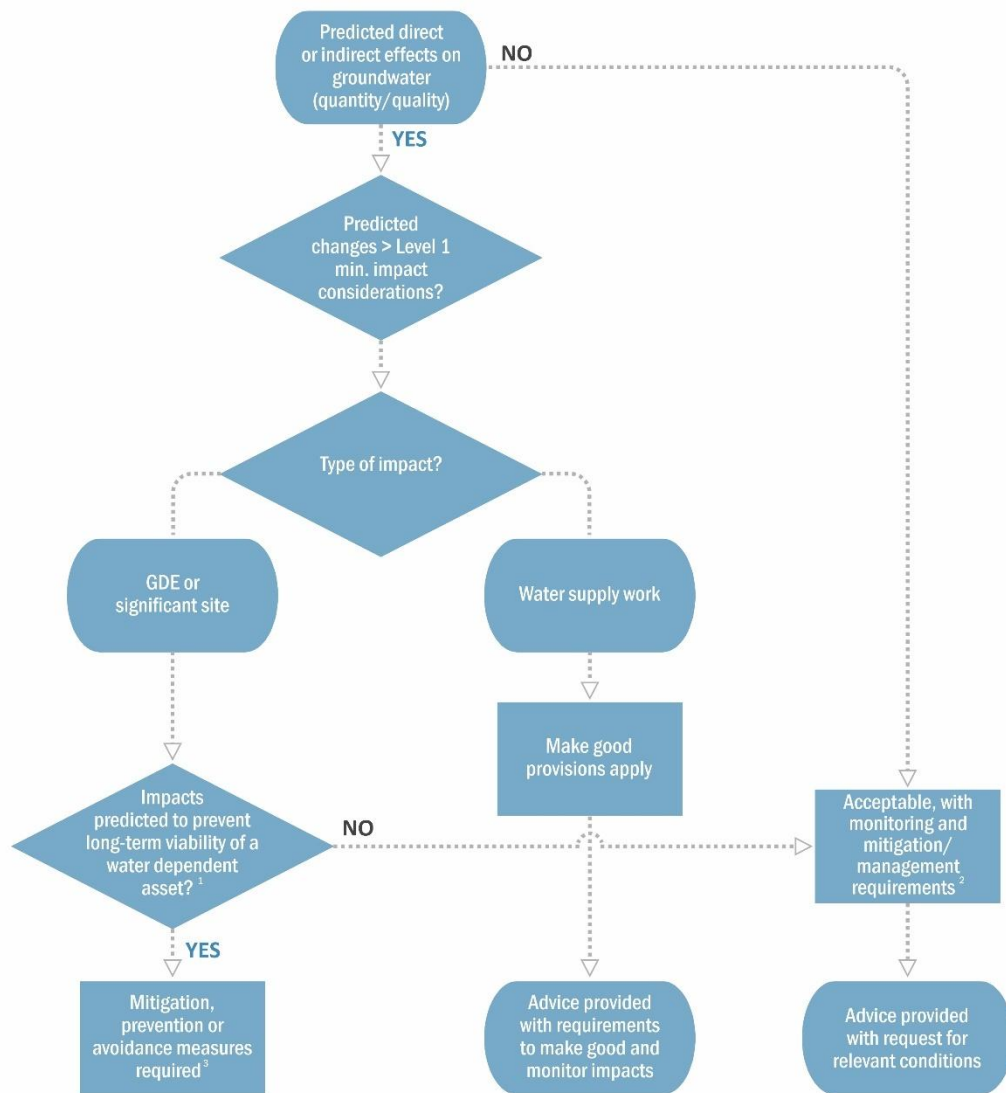
As part of the NSW Government’s role in water management, including assessing development proposals and providing advice to the DPE Planning and Assessment Group, DPE Water’s approach is based on the principles of “account for, mitigate, avoid/ prevent, and remediate”.

The Aquifer Interference Assessment Framework is a step-by-step guide that DPE Water use to assess project proposals against the AIP. The framework has been considered in this assessment and is provided in Section 13.

a Minimal impact considerations

The WM Act includes the concept of ensuring “no more than minimal harm” for both the granting of WALs and the granting of approvals.

The minimal impact considerations have been developed for impacts on groundwater sources, connected water sources, and their dependent ecosystems, culturally significant site and water users. The AIP minimal impact considerations process is shown in Figure A.1.



- 1 Assessment as per Serov et al 2012, with consideration of uniqueness, ecological/cultural value and timeframe of the impact.
- 2 Conditions of approval may include requirements for adaptive management to monitor and mitigate or remediate impacts that exceed level 1 thresholds.
- 3 Where there are no suitable or practical mitigation or prevention options, the proponent may be asked to avoid impacts by modifying the proposed activity.

Adapted from DPI Water 2012a

Figure A.1 AIP minimal impact considerations process

b Make good provisions

AIP Fact Sheet 4 outlines how a minimal impact is to be considered. It describes how the minimal impact criteria are applied to both a water supply work and a groundwater dependent ecosystem or culturally significant site defined in a WSP.

The WM Act requires water users or landholders to hold:

- a WAL to take water from a river, lake, dam or groundwater for irrigation, industrial, or commercial purposes
- a water supply work approval to construct and use a water supply work, such as a pump, dam, channel or bore
- a water use approval for a specific purpose at a particular location
- a flood work approval for works on floodplain that divert floodwaters
- a controlled activity approval to carry out work in a watercourse or within 40 m of the bank of a river, lake or estuary, such as extracting material from a river bed, constructing a creek crossing or residential developments.

However, under clause 4.41(1)(g) of the EP&A Act, SSD projects are exempt from requiring:

- a water use approval under section 89 of the WM Act
- a water management work approval under section 90 of the WM Act, or
- an activity approval (other than an aquifer interference approval) under section 91 of the WM Act.

As the project is an CSSI, there is no requirement to obtain approvals under the WM Act.

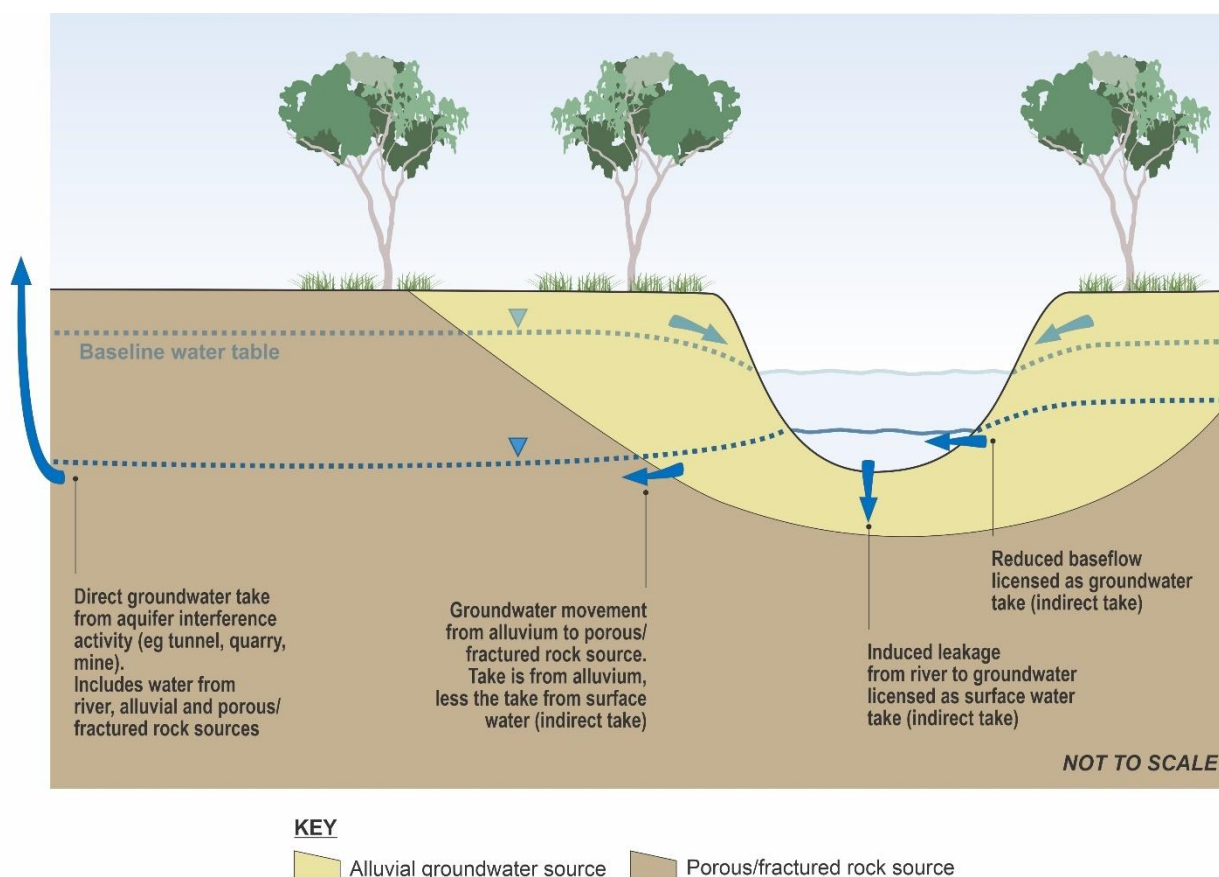
AIP Fact Sheet 3 and the DPE Water (2022b) guidelines provides guidance regarding licensing and accounting for water. Water can be taken directly from a groundwater or surface water source, usually via a pump (in a river or an excavated area) or bore. It can also be taken indirectly when an aquifer interference activity causes water to flow from another connected groundwater or surface water source. Flows induced from other water sources also constitute take of water. In all cases, separate WALs are required to account for the take from all individual water sources.

Take of water is licensed by the source from where the water is taken.

For example, where an aquifer interference activity is taking water from a groundwater source, and this take is causing the movement of water from a connected surface water source into the groundwater source, then an access licence in the regulated or unregulated river water source is required to account for the take of water from that water source and another access licence in the groundwater source is required for the remainder of the take. This is illustrated in Figure A.2.

The DPE Water (2022b) guidelines note the total volume of water to be taken from each water source as a result of an aquifer interference activity needs to be estimated before project approval can be granted. A proponent is not required to hold sufficient entitlement prior to project approval; however, the proponent is required to demonstrate the licensing pathway to secure sufficient entitlement for the peak take (including documenting the proposed mechanisms to secure the entitlement, for example trade or controlled allocation orders). A proponent is required to hold sufficient entitlement prior to the take occurring (DPE Water 2022b).

Once the activity commences, the take must be measured and reported (DPE Water 2022b).



Source: DPE Water 2022b

Figure A.2 Licensing requirements by source (surface water vs groundwater)

iv **NSW State Groundwater Dependent Ecosystems Policy**

This policy aims to protect the ecological processes and biodiversity of ecosystems that depend on groundwater. The GDE policy was developed in 2002, and outlines the following principles for managing GDEs:

- The scientific, ecological, aesthetic and economic values of GDEs, and how threats to them may be avoided, should be identified and action taken to ensure the most vulnerable and valuable ecosystems are protected.
- Groundwater extractions should be managed sustainably so that ecological processes and biodiversity are maintained and/or restored.
- Priority should be given to ensuring enough groundwater of a suitable quality is available when needed for:
 - protecting ecosystems which are known to be, or most likely to be, groundwater dependent
 - GDEs which are under immediate or high degree of threat from groundwater-related activities.
- Where scientific knowledge is lacking, the precautionary principle should be applied to protect GDEs.
- Planning, approval and management should aim to minimise adverse impacts on GDEs by:
 - maintaining natural patterns of groundwater flow and not disrupting groundwater levels that are critical for ecosystems

- not polluting or causing adverse changes in groundwater quality
- rehabilitating degraded groundwater systems where practical.

A.3 Relevant guidelines

A.3.1 Groundwater Assessment Toolbox for Major Projects in NSW

DPE Water has developed a Groundwater Assessment Toolbox for Major Projects in NSW (Groundwater Assessment Toolbox) (DPE Water 2022a), which aims to create a collaborative, transparent and enabling environment for the preparation and review of groundwater assessments for major projects in NSW. The documents provide a framework to investigate, assess the impacts on, manage and monitor groundwater resources and their interaction with surface water resources within the footprint of a major project.

The Groundwater Assessment Toolbox is a complementary guidance document that comprises the following documents:

- *Guidelines for Groundwater Documentation for SSD/SSI Projects* (DPE Water 2022b)
- *Minimum Requirements for Groundwater Modelling* (DPE Water 2022c)
- *Cumulative Groundwater Impact Assessment Approaches* (DPE Water 2022d).

These documents denote the role of the NSW Government in project assessment, and the continuation of guidance on and review of post-approvals monitoring and management plans, and compliance reporting.

The GIA has been prepared in accordance with the above guidance documentation.

A.3.2 Australian Groundwater Modelling Guidelines

The Australian Groundwater Modelling Guideline (B. T. Barnett 2012) provide a consistent and sound approach for the development of groundwater flow models in Australia. The guidelines ‘propose a point of reference and not a rigid standard’ and provide direction on scope and approaches while acknowledging that techniques are continually evolving, and innovation is to be encouraged.

The guidelines provide information on the data requirements for models (depending on complexity and level of potential risk and scale), such as spatial distribution of bores and temporal groundwater level data.

The numerical groundwater model for the project has been prepared in accordance with the Australian Groundwater Modelling Guidelines and peer reviewed using the structure of the ‘review checklist’ as per the guidelines.

A.3.3 Uncertainty analysis – Guidance for groundwater modelling within a risk management framework

The IESC published guidelines on undertaking uncertainty analysis in March 2018 (Middlemis and Peeters 2018). The guidelines recommend different levels of uncertainty analysis for various project complexities and risks, with the most robust and detailed option being ‘stochastic modelling with Bayesian probability quantification’. This detailed uncertainty analysis produces “an ensemble of model predictions ... based on a large number of model evaluations with different parameter values that are all consistent with the observations” (Middlemis and Peeters 2018).

Annexure C details the approach taken for the uncertainty analysis completed as part of the groundwater modelling for the project.

A.3.4 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) provides guidance on monitoring, assessing and managing ambient water quality in a wide range of water resource types and according to specified environmental values, such as aquatic ecosystems, primary industries, recreation and drinking water. The guidelines provide a framework for:

- establishing water quality objectives
- assessing and managing water quality for environmental values
- establishing protection levels, water quality indicators and trigger values.

A.3.5 Risk assessment guidelines for groundwater dependent ecosystems

The Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Serov P 2012) (GDE Risk Assessment Guidelines) are the NSW requirements for assessment and management of GDEs under the WM Act.

The GDE Risk Assessment Guidelines provide that GDEs:

explicitly include any ecosystem that uses groundwater at any time or for any duration in order to maintain its composition and condition.

An ecosystem's dependence on groundwater can be variable, ranging from partial and infrequent dependence, i.e. seasonal or episodic (facultative), to total continual dependence (entire/obligate) (refer Figure A.3).

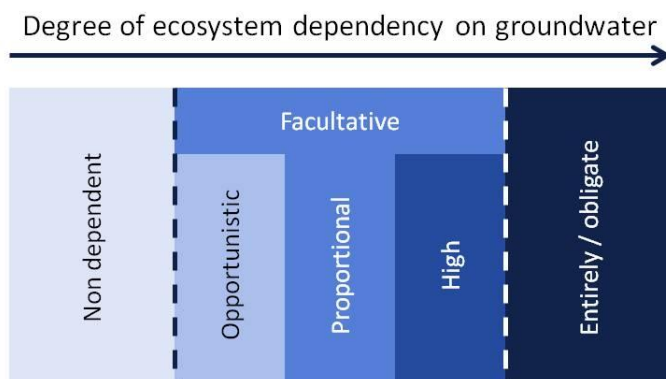


Figure A.3 Groundwater dependent ecosystem level of dependence on groundwater

Serov *et al* (2012) has developed a risk assessment approach, documented in the *Risk Assessment Guidelines for Groundwater Dependent Ecosystems*. The following risk factors are required to be considered in the assessment:

- Impacts to groundwater quantity: reductions in fluctuations in groundwater levels and/or pressure, reductions in seasonal baseflow conditions.
- Impacts to water quality: changes in water quality that may impacts any beneficial uses of the system.
- Impacts to aquifer integrity: changes to geological structure supporting a GDE, including timeframe and severity of impacts.
- Impacts to the biological integrity of the GDE: species diversity or composition, dieback of vegetation, increased exotic species or removal/alteration of habitat.

The risk assessment approach considered the risk of impact (low, medium or high) as well as the ecological value of the GDE (low, medium or high) to determine the overall risk.

Annexure B

NSW Groundwater Guidelines (DPE 2022)

B.1 NSW Groundwater Guidelines (DPE 2022)

Project setting (If any 'no' answers are recorded, then proponent to provide explanation)	
<i>Scope of the project described (including construction, operation and closure)?</i> Sections 1 and 2; and EIS.	☒ Yes ☐ No
<i>Location of project clearly identified (address and real property description, and/or lot and plan information)?</i> Section 2.1 and EIS.	☒ Yes ☐ No
<i>Environmental setting described (including topography, climate, the location of surface water features, biodiversity values and land use)?</i> Section 3.	☒ Yes ☐ No
<i>Appreciation of regional and local geological setting clearly stated?</i> Section 3.2.	☒ Yes ☐ No
<i>Geological structural features potentially affecting groundwater behaviour identified?</i> Section 3.6.1.	☒ Yes ☐ No
<i>Will any project related excavation remain above the watertable?</i> Yes.	☒ Yes ☐ No
<i>Have baseline groundwater field investigations been conducted and report provided?</i> Section 5.	☒ Yes ☐ No
<i>Have the relevant Water Sharing Plans and relevant water sources been identified?</i> Section 4.2.2	☒ Yes ☐ No
<i>Has the proponent consulted with the local community, local Aboriginal community, council, DPE-Water, EPA, WaterNSW and Environment, Energy and Science group within DPE (where relevant) to establish cultural and environmental values of the water sources?</i> Consultation requested however, response preferred formally through submission of this document.	☐ Yes ☒ No
Receptors (If any 'no' answers are recorded, then proponent to provide explanation)	
<i>Have mapped high priority groundwater dependent ecosystems, listed in the relevant Water Sharing Plans, been identified?</i> Section 3.7.2.	☒ Yes ☐ No
<i>Has the proponent reviewed the GDE Atlas to identify any other mapped potential groundwater dependent ecosystems in the project area?</i> Section 3.7.2 and Section 6.7.	☒ Yes ☐ No

<i>Has the proponent identified other potential groundwater dependent ecosystems out of other technical specialist analysis? Have the technical specialists used outputs from the GIA for their ecological assessment?</i> Section 6.7.	☒ Yes ☐ No
<i>Has the proponent considered and identified potential culturally significant sites listed in the relevant Water Sharing Plans been identified?</i> None are listed in the WSPs.	☒ Yes ☐ No
<i>Has the proponent identified third-party users in the vicinity that might be impacted identified (Registered/unregistered)?</i> Section 3.7.1.	☒ Yes ☐ No
Groundwater investigations and groundwater impact assessment (If any 'no' answers are recorded, then proponent to provide explanation)	
Groundwater elevation and flow	
<i>Are monitoring bore locations and depths provided and appropriate based on depth and scale of proposed development?</i> Section 5.	☒ Yes ☐ No
<i>Are measurements recorded at a frequency suitable to detect potential changes (EIS or post-approval)?</i> Section 5.3.	☒ Yes ☐ No
<i>Has a bore census of existing third-party bores in the project area been completed?</i>	☐ Yes ☒ No
<i>Is the groundwater baseline provided sufficient (AIP requires 2 years)?</i> Considered fit for purpose, with monitoring ongoing and model validation commitments made.	☐ Yes ☒ No
<i>Has the proponent assessed vertical gradients between overlying water sources?</i> Section 7	☒ Yes ☐ No
<i>Has the proponent provided watertable elevation and potentiometric surface contour plans for water sources pre-development (including consideration of wet/winter and summer/dry seasonal variations), supported by points labelled with measured groundwater elevation?</i> Figure 6.1	☒ Yes ☐ No
<i>Has the proponent provided evidence of spatial and temporal assessment of groundwater elevation and flow (that is, vertical and lateral with time and seasons)?</i> Figure 6.3	☒ Yes ☐ No

Hydraulic properties	
<i>Has the proponent conducted hydraulic tests at various locations across the project area? For example, slug tests, pumping tests, packer tests, core tests.</i> Section 5.2.2	☒ Yes ☐ No
<i>Has the proponent conducted a literature review of potential hydraulic properties for the water sources in the project area? For example, other projects in the area or textbook values.</i> Section 3.6.2	☐ Yes ☒ No
Groundwater quality	
<i>Has the proponent included sufficient spatial & temporal variation in groundwater quality data?</i> Section 6.5	☒ Yes ☐ No
<i>Was the potential for cross contamination of aquifers assessed sufficiently?</i> Section 7	☒ Yes ☐ No
<i>Is the baseline groundwater quality defined and described sufficiently with respect to the cultural and environmental values and the development?</i> Section 8.1.3ii	☒ Yes ☐ No
<i>Is quality assurance data provided?</i> To be made available electronically.	☒ Yes ☐ No
Conceptual hydrogeological model	
<i>Has the proponent described the hydrostratigraphic units in the project area?</i> Section 6.2 and Section 7	☒ Yes ☐ No
<i>Has the proponent assessed and described potential surface water-groundwater interaction?</i> Section 6.6 and Section 7	☒ Yes ☐ No
<i>Has the proponent considered existing water use in the area?</i> Section 3.7.1 and Section 6.7	☒ Yes ☐ No
<i>Has the proponent provided a graphical representation of the conceptual hydrogeological model (cross section or three dimensional block model) to show hydrostratigraphy and other groundwater processes described above?</i> Figure 7.1	☒ Yes ☐ No
<i>Has the proponent provided a graphical representation of potential groundwater dependence of GDEs within the project area?</i> Section 6.7	☒ Yes ☐ No

Impact assessment (If any 'no' answers are recorded, then proponent to provide explanation)	
<i>Is the assessment methodology commensurate with the risk and as agreed with DPE Water? For example, analytical model versus simple numerical model vs complex numerical model?</i> Section 9.2	☒ Yes ☐ No
<i>Has the proponent completed the Aquifer Interference Assessment Framework form?</i> Section 13	☒ Yes ☐ No
<i>Has the proponent assessed the predicted impacts against the Aquifer Interference Policy “minimal impact considerations”?</i> Section 13	☒ Yes ☐ No
<i>Has the proponent assessed the predicted impacts during construction, operations and post-development?</i> Section 9.3, Section 9.4 and Section 10.3	☒ Yes ☐ No
<i>Have the potential impacts from changes in water quality, water quantity, aquifer integrity and biological integrity of groundwater dependent ecosystems been identified and quantified?</i> Section 10.3	☒ Yes ☐ No
<i>Has the proponent assessed the potential presence of acid sulfate soils?</i> Considered but not applicable.	☒ Yes ☐ No
<i>Has the proponent assessed the potential for generation of acid metalliferous drainage?</i> Section 10.3.2	☒ Yes ☐ No
<i>Has the proponent documented the predicted annual water take (per water source) on an annual basis?</i> Section 12.2	☒ Yes ☐ No
<i>Has the proponent documented the licensing pathway proposed to secure the required water entitlement for water access licence(s) for the predicted take?</i> Refer to Lake Lyell Water Licensing Strategy (EMM 2025)	☒ Yes ☐ No
Has the proponent assessed impacts on the groundwater dependent ecosystems and culturally significant sites in accordance with the Aquifer Interference Policy considerations? Section 9.3	☒ Yes ☐ No
Management and mitigation measures (If any 'no' answers are recorded, then proponent to provide explanation)	
<i>Are the documented management and mitigation measures practical and measurable?</i> Section 11.3	☒ Yes ☐ No

Has the proponent documented the approach to the proposed monitoring program during construction and operations?

Section 11.4

☒ Yes ☐ No

Annexure C

Groundwater modelling report

Lake Lyell Pumped Hydro Energy Storage Project

Groundwater modelling report

Prepared for Lake Lyell Project Pty Ltd

November 2025

Lake Lyell Pumped Hydro Energy Storage Project

Groundwater modelling report

Lake Lyell Project Pty Ltd

E221111 RP14

November 2025

Version	Date	Prepared by	Reviewed by	Comments
1	7 November 2024	Juan Berrio	Tom Neill	Draft for peer review
2	27 November 2024	Juan Berrio	Tom Neill	Draft for client review
3	20 June 2025	Cristina Solorzano	Tom Neill	Draft for client review
4	15 August 2025	Cristina Solorzano	Katharine Bond/Henry Noakes	Draft for peer review
5	21 November 2025	Cristina Solorzano	Chris Nicol (Groundwater logic)	Final

Approved by



Tom Neill

Associate Groundwater Modeller

21 November 2025

Level 10 201 Pacific Highway

St Leonards NSW 2065

ABN: 28 141 736 558

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ABN: 28 141 736 558

Executive Summary

EnergyAustralia Portfolio Holdings Pty Ltd (EnergyAustralia) in partnership with EDF power solutions Australia (EDFA), referred to as Lake Lyell Project Pty Ltd (LLP) as trustee, is developing the Lake Lyell Pumped Hydro Energy Storage (PHES) Project (the project). The project that is anticipated to store up to 3,080 megawatt hours (MWh) of energy and generate at 385 megawatts (MW) for 8 hours or generate up to 440 MW for a shorter period.

At a basic level, the project will consist of upper and lower water reservoirs, an underground waterway connecting them, and a hydro-electric power station connected to the national electricity market that is capable of generating or consuming electricity.

The project has been declared by the NSW Government to be critical State significant infrastructure (CSSI) under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). Infrastructure projects are declared to be CSSI if, in the opinion of the NSW Minister for Planning, they are essential to the State for economic, environmental, or social reasons.

The purpose of this groundwater modelling report is to support the groundwater impact assessment (GIA) for the project. The report documents the groundwater modelling design, history-matching and predictions (resulting from groundwater-affecting project activities).

Modelling objectives were developed to quantify potential local-scale and/or regional-scale changes to the groundwater system resulting from construction and operation of the project. Specifically, the objectives are to predict:

- watertable drawdown due to project-only and cumulative impacts
- potential impacts (drawdown/mounding) of the project at identified sensitive receivers such as landholder bores and groundwater-dependent ecosystems
- groundwater inflows to the project infrastructure during construction and operation
- changes to the water balance (with regards to both groundwater and surface water source areas) as a result of the project to inform water licensing
- watertable drawdown due to project-only impacts taking into consideration potential climate change prediction rainfall.

The groundwater modelling workflow was developed to meet the *Minimum Groundwater Modelling Requirements for SSD/SSI projects* (DPE, 2022).

A numerical groundwater flow model was built using the MODFLOW-USG simulation code. This model employs a Voronoi polygon mesh across an irregularly shaped domain to follow hydrogeological, hydrological and project features. The model covers an area that spans a diameter of approximately 12 kilometres (km) across 20 model layers.

Model history-matching included both steady-state and transient stress periods to allow matching to heads and changes in head as a result of recharge-discharge processes. The model employs a highly parameterised approach via pilot points deployed in every model layer to allow for spatially distributed hydraulic parameters. The ensemble of accepted realisations was deemed to be appropriately history-matched, and generally aligns with attributes of a Class 2 model.

Following history-matching, an accepted ensemble of 221 realisations with individual parameter sets was used to produce a range of predictions. Three main predictive model scenarios were developed to meet the modelling objectives:

- a “cumulative” scenario where the project and nearby projects (Metromix Quarry) are active
- a “no project” scenario where only nearby projects (Metromix Quarry) are active
- a “null” scenario where no projects are active, allowing the model to run with climatic fluctuations.

“Project-related” drawdown and water balance impacts were calculated as the difference between the “cumulative” and “no project” scenarios. “Cumulative” drawdown and water balance impacts were calculated as the difference between the “cumulative” and the “null” scenarios.

An additional version of the “cumulative” scenario was developed to assess the long-term impact of climate change on the model predictions.

The groundwater flow model predictions include:

- drawdown at the end of construction is confined to the immediate surroundings of the project, with the 0.2 metres (m) drawdown contour no more than 1,000 m from the centre of the project
- at the end of operations a maximum of 60 m mounding is predicted immediately below the upper reservoir, with the 0.2 m mounding contour extending approximately 1.8 km north-east from the centre of the project
- drawdown / mounding associated with the project is not predicted to interact with drawdown from Metromix Quarry, indicating that cumulative impacts on groundwater are very unlikely
- inflows to underground excavations, excluding the upper reservoir, are expected to peak approximately 0.16 megalitres per day (ML/d) (approximately 58.4 megalitres per year (ML/yr)) in 2029
- a net increase in leakage from surface water features is predicted, reaching nearly 0.7 ML/yr by 2030
- a net decrease in baseflow of approximately 4 ML/yr to perennial watercourses is expected during construction and operation.

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1 Introduction

1.1 Project background and context

EnergyAustralia Portfolio Holdings Pty Ltd (EnergyAustralia) in partnership with EDF power solutions Australia (EDFA), referred to as Lake Lyell Project Pty Ltd (LLP) as trustee, is developing the Lake Lyell Pumped Hydro Energy Storage (PHES) Project (the project). The project that will have the capacity to store up to 3,080 megawatt hours (MWh) of energy and generate at 385 megawatts (MW) for 8 hours or generate up to around 440 MW for a shorter period. At a basic level, it will consist of upper and lower water reservoirs, a pipeline connecting them, and a hydro-electric power station connected to the national energy grid that is capable of generating or consuming electricity.

The project is located approximately 5 kilometres (km) west of Lithgow and 110 km west of the Sydney central business district, shown in Figure 1.1. The project takes advantage of existing infrastructure (i.e. Lake Lyell) associated with Mt Piper power station which will be decommissioned in the coming decades and allows Lake Lyell to continue to serve a specific purpose in electricity generation (consistent with its existing use).

In June 2024, the Minister for Planning and Public Spaces declared the project to be critical State significant infrastructure (CSSI). Accordingly, approval for the project is required under Part 5, Division 5.2 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). This requires the preparation of an environmental impact statement (EIS) for the project in accordance with Secretary's environmental assessment requirements (SEARs) and the approval of the Minister. EMM Consulting Pty Limited (EMM) has been engaged by EnergyAustralia to prepare the EIS.

1.2 Groundwater-affecting activities

The project involves the following groundwater-affecting activities, which are described in detail in Chapter 3 and Appendix B of the overarching EIS:

- The upper reservoir.
- The headrace and tailrace tunnels.
- Ancillary access tunnels and adits.
- Surge shafts.

Other infrastructure components (refer to the overarching EIS) will be designed to mitigate permanent interception of the regional groundwater table. Temporary de-watering may be required for footing or trench excavations; however, potential impacts are considered minor and temporary and are not considered as part of the numerical groundwater model.

1.3 Purpose of this report

This report is a supporting appendix to the groundwater impact assessment (GIA) and documents the groundwater modelling design, history-matching and predictions (resulting from the groundwater-affecting project activities). Predictions include:

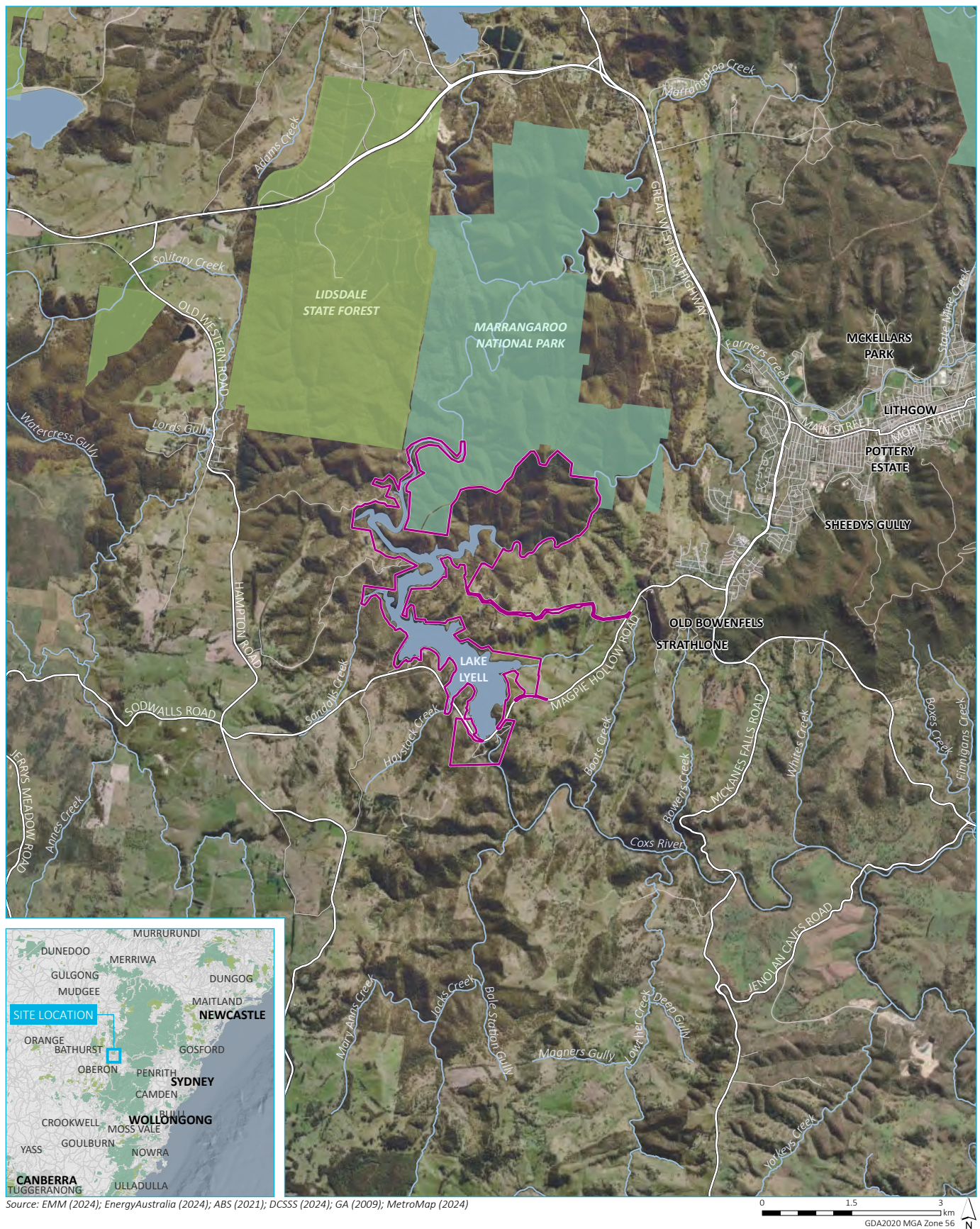
- groundwater head and drawdown
- groundwater inflow rates to the tunnels and excavations
- the baseflow component of streamflow.

The groundwater modelling workflow was developed to meet the *Minimum Groundwater Modelling Requirements for SSD/SSI projects* (DPE, 2022) and this report is presented in a sequential manner that is consistent with those guidelines.

1.4 Study area

The study area relevant to the GIA (and hence this supporting groundwater modelling report) aligns with the numerical groundwater model boundary, shown in Figure 4.1. The study area, which is larger than the project area, encompasses the:

- project-related sub-surface excavations
- project-related water monitoring network
- nearby licensed groundwater bores
- nearby high potential groundwater dependant ecosystems (GDEs) and surface water features
- other groundwater-affecting activities (i.e. Marrangaroo Quarry).



KEY

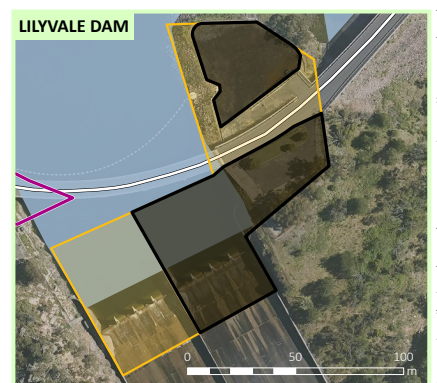
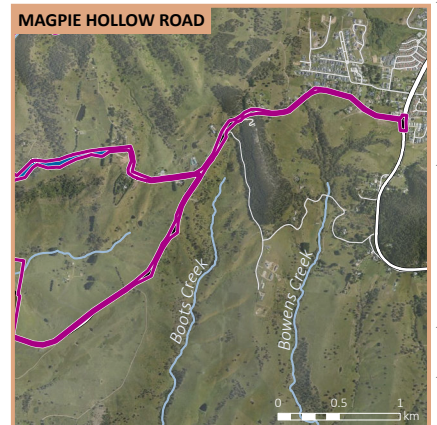
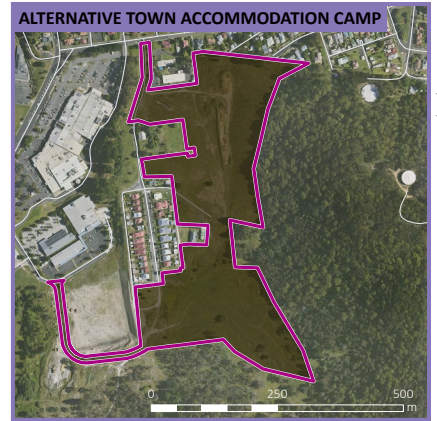
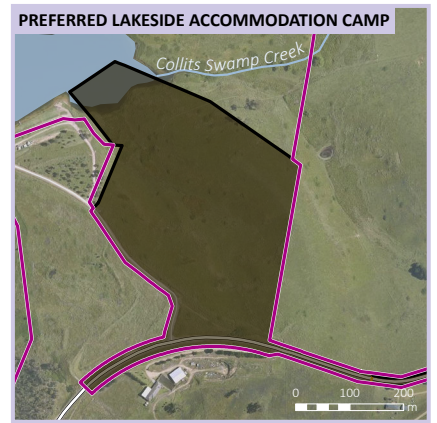
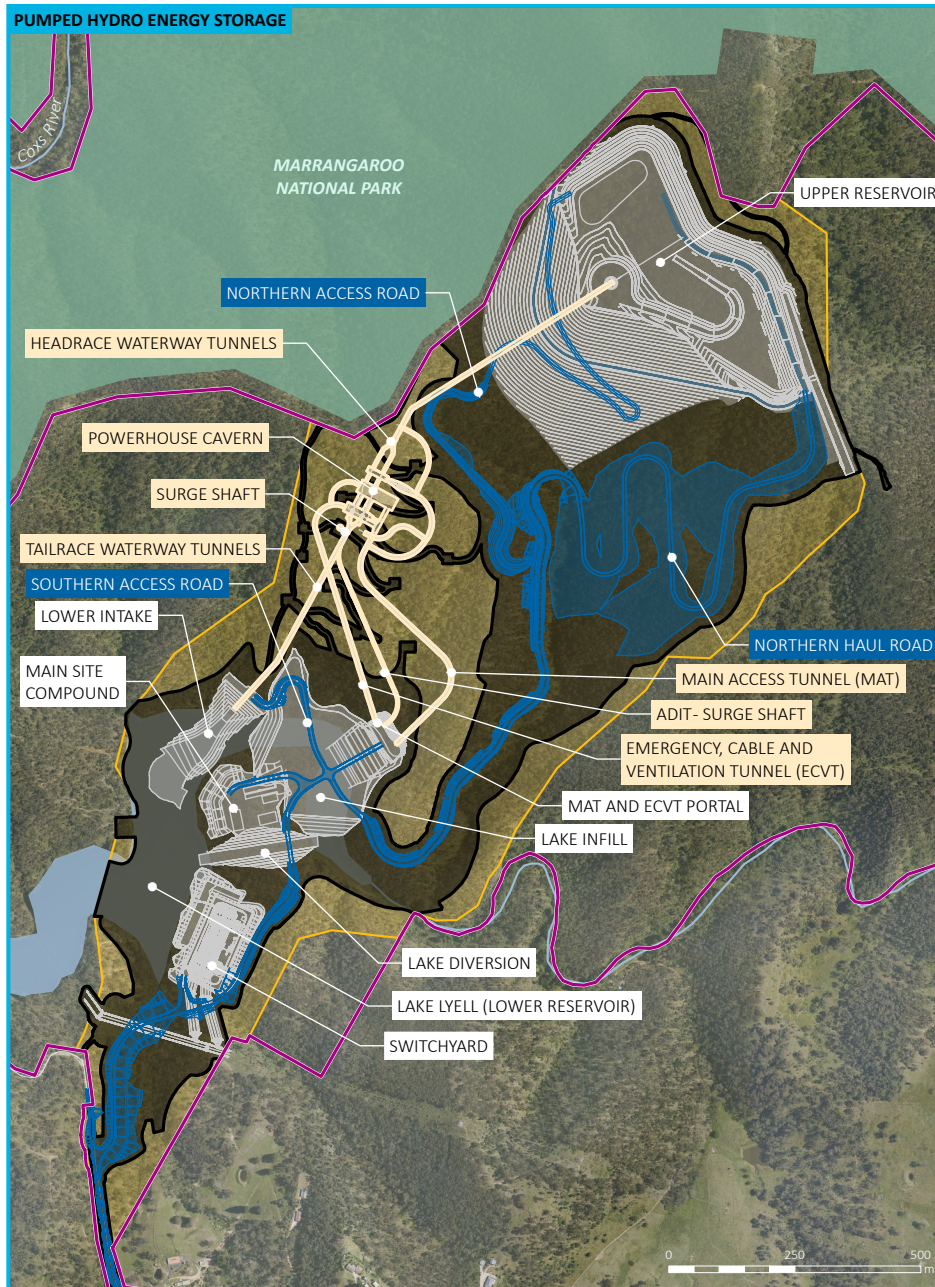
- Project area
- Existing environment
- Major road
- Minor road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest

INSET KEY

- Major road
- NPWS reserve
- State forest

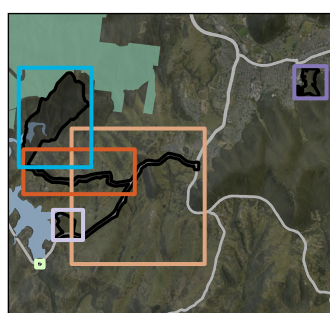
Regional setting

Lake Lyell PHES
Groundwater Modelling Report
Figure 1.1



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2024); GA (2009); MetroMap (2025)

GDA2020 MGA Zone 56



KEY

- | | |
|--|--|
| Project area | Existing environment |
| Permanent road | Major road |
| Above ground design | Minor road |
| Underground design | Named watercourse |
| Construction envelope | Named waterbody |
| Disturbance footprint | NPWS reserve |

Project overview

Lake Lyell PHES
Groundwater Modelling Report
Figure 1.2

2 Groundwater modelling overview

The model was developed in accordance with the Australian groundwater modelling guidelines (AGMG) (Barnett et al. 2012), and in accordance with the requirements of the Aquifer Interference Policy (AIP) (DPI Water, 2012) and Minimum groundwater modelling requirements for SSD/SSI projects (DPE 2022). Details on the AGMG model confidence classification are provided below.

2.1 Groundwater modelling objectives

The modelling objectives were developed to quantify potential local-scale and/or regional-scale changes to the groundwater system resulting from construction and operation of the project. Specifically, the objectives are to predict:

- watertable drawdown due to project-only and cumulative impacts
- potential impacts (drawdown/mounding) of the project at identified sensitive receivers such as landholder bores and GDEs
- groundwater inflows to the project infrastructure during construction and operation
- changes to the water balance (with regards to both groundwater and surface water source areas) to inform water licensing as a result of the project
- watertable drawdown due to project-only impacts taking into consideration potential climate change prediction rainfall.

The Lake Lyell numerical groundwater flow model was not designed to explicitly simulate soil water, surface water or perched groundwater nor water quality / solute transport. It also does not explicitly simulate fractures or secondary porosity, instead taking an approach whereby equivalent porous medium (EPM) properties are modelled.

2.2 Model confidence classification

The AGMG (Barnett et al. 2012) provides a confidence-based classification schema to set the context for identifying where more effort may be required on data acquisition and/or sensitivity and uncertainty analysis. Although the classification scheme has been made somewhat redundant by advances in software tools and guidance for uncertainty analysis, developed since the guidelines were written, DPE (2022) refers to the classification system and, for that reason, this report provides an assessment against it. The schema defines three classes of model:

- Class 1 – low confidence in model predictions, suitable for use in low value resource or low risk developments
- Class 2 – medium confidence in model predictions, suitable for use in projects with medium to high-risk developments
- Class 3 – high confidence in model predictions, suitable for use in high value resources and projects such as regional sustainable yield assessments.

The guidelines provide information on the data requirements for each model class, such as spatial distribution of bores and temporal groundwater level data. Ideally, groundwater resource assessments at major development sites would employ a Class 2 or 3 model. The onerous data requirements to achieve a Class 3 model (e.g. reliable metered extraction and the duration of the prediction to be not more than three times the history-matching period) mean that for most major projects in NSW, a Class 3 model is practically unattainable at approval stage.

A table comparing the attributes of the Lake Lyell model against the Class 1, 2 and 3 criteria included in the AGMG (Barnett et al. 2012) is included in Attachment A.

The model and associated predictions meet many of the criteria outlined in the AGMG for Class 3, 2 and 1 models, with the primary limitations related to the duration of the groundwater level dataset, and the limited availability of regional groundwater level monitoring locations. Additionally, due to the greenfield nature of the project, there are no observations of impact (drawdown, water take) in response to construction and operation of the project that could be used to inform the model forecasts. For that reason, the model is considered to mostly be aligned with Classes 2 and 1. A key limitation is the history-matching dataset, of which the duration and magnitude does not allow for the constraint of parameters that are pertinent to predictions.

Where assumptions were required, these were made conservatively such that modelling would tend towards over-predicting effects. A predictive uncertainty analysis was conducted, and the model capabilities and limitations are documented.

2.3 Peer review

In line with the AGMG (2012) and the minimum requirements outlined for SSD/SSI projects in NSW (DPE 2022), the model was peer reviewed by an experienced hydrogeologist and groundwater modeller, Chris Nicol, who considered the model fit-for-purpose in meeting the modelling and project objectives.

A document detailing the outcome of the peer review is included in Attachment D.

3 Monitoring data and conceptual water model

3.1 Groundwater monitoring network

The baseline groundwater monitoring network (the baseline network) includes both background (regional) monitoring locations and targeted monitoring locations near key project infrastructure elements. The baseline network was designed to capture geological, spatial and temporal variations within the study area, supporting a groundwater assessment in accordance with the AIP (DPI, 2012).

The baseline network included:

- fifteen conventional groundwater monitoring bores, providing groundwater level and quality data within the regional groundwater systems, located between 50 metres (m) and 500 m from the project infrastructure (refer to Table 3.1)
- two boreholes with vibrating wire piezometer (VWP) installations, sited near key infrastructure locations including the power station complex and upper reservoir (refer to Table 3.2).

The location of the baseline groundwater monitoring network is shown in Figure 3.1.

Table 3.1 Baseline network – groundwater monitoring bores

Bore	Easting (GDA20)	Northing (GDA20)	¹ Elevation (mAHD)	Screen top (² mbgl)	Screen base (² mbgl)	Target/ location	Geology	Hydraulic testing	Groundwater monitoring
BH103	229859.9	6290824.9	1084.1	59.0	71.0	Upper reservoir	Gibbons Creek Sandstone	Packer testing	Quality and level
BH107	229031.3	6289890.0	788.7	27.0	39.0	Out-take structure	Rydal Formation	Packer testing	Quality and level
BH201	229776.7	6290976.9	1122.9	61.0	64.0	Upper reservoir	Gibbons Creek Sandstone	-	³ Level
MB2201A	230069.2	6290430.5	1058.0	192.5	198.5	Regional calibration	Gibbons Creek Sandstone	Slug testing	Quality and level
MB2201B	230071.4	6290419.0	1056.4	97.0	110.0	Regional calibration	Gibbons Creek Sandstone	Slug testing	Quality and level
MB2202A	229273.6	6290061.6	904.4	143.0	149.0	Main access tunnel	Rydal Formation	Slug testing	Quality and level
MB2202B	229274.1	6290072.1	905.4	57.0	69.0	Main access tunnel	Rydal Formation	Slug testing	Quality and level
MB2203A	229858.6	6290823.9	1084.1	193.0	199.0	Upper reservoir	Gibbons Creek Sandstone	Slug testing	Quality and level
MB2203B	229860.7	6290817.2	1084.1	62.0	68.0	Upper reservoir	Gibbons Creek Sandstone	Slug testing	Quality and level
MB2204A	229218.3	6290721.1	981.9	186.0	198.0	Headrace tunnel	Rydal Formation	Slug testing	Quality and level
MB2204B	229211.8	6290719.3	981.8	58.0	70.0	Headrace tunnel	Rydal Formation	Slug testing	Quality and level

Bore	Easting (GDA20)	Northing (GDA20)	¹ Elevation (mAHD)	Screen top (² mbgl)	Screen base (² mbgl)	Target/ location	Geology	Hydraulic testing	Groundwater monitoring
MB2205A	229186.3	6290444.4	955.8	185.6	197.6	Power station cavern	Rydal Formation	Slug testing	Quality and level
MB2205B	229193.7	6290441.0	955.8	53.0	59.0	Power station cavern	Rydal Formation	Slug testing	Quality and level
MB2206A	229192.9	6289790.9	839.7	89.0	98.0	Regional calibration	Rydal Formation	Slug testing	Quality and level
MB2206B	229179.3	6289776.7	839.2	61.0	73.0	Regional calibration	Rydal Formation	Slug testing	Quality and level

Source: Lake Lyell PHES Geotechnical Investigation Program – Factual Report (GHD, 2023); Lake Lyell PHES Interim Phase 2 Geotechnical Investigation Program – Factual Report (GHD, 2024).

Notes:

1. Ground surface elevation in metres above Australian Height Datum.
2. Metres below ground level.
3. Manual level monitoring only.

Table 3.2 Baseline network – vibrating wire piezometers

Bore	Easting	Northing	¹ Elevation (mAHD)	Inclination (°)	Number of sensors	Sensor depths (² mbgl)	Infrastructure target	Geology	Hydraulic testing	Groundwater monitoring
BH202	229438.0	6291037.2	1063.7	69.9	1	66.9	Upper reservoir	Gibbons Creek Sandstone	Packer testing	³ Level
BH203	229422.1	6290792.4	997.6	72.2	3	213.3; 138.0; 47.6	Pressure shaft	Gibbons Creek Sandstone	Packer testing	³ Level

Source: Lake Lyell PHES Geotechnical Investigation Program – Factual Report (GHD, 2023); Lake Lyell PHES Interim Phase 2 Geotechnical Investigation Program – Factual Report (GHD, 2024)

Notes:

1. Ground surface elevation in metres above Australian Height Datum.
2. Metres below ground level.
3. Manual level monitoring only.

3.1.1 Geotechnical boreholes

In addition to the baseline groundwater monitoring network detailed above, geological information from seven geotechnical boreholes was also used to support the hydrogeological understanding of the study area. These boreholes are detailed in Table 3.3.

Table 3.3 **Baseline drilling investigations - geotechnical boreholes**

Bore	Easting	Northing	¹ Elevation (mAHD)	Inclination (°)	² Drilled length (m)	Infrastructure target	Geology	Hydraulic testing
BH101	229853.2	6290664.2	1076.8	67.0	79.0	Upper reservoir	Gibbons Creek Sandstone	Packer testing
BH102	230074.6	6290416.2	1056.0	65.0	51.2	Upper reservoir	Gibbons Creek Sandstone	Packer testing
BH104	229882.0	6290411.1	1049.8	78.7	386.9	Powerhouse complex	Gibbons Creek Sandstone	-
BH105	229882.4	6290411.5	1049.9	90.0	359.9	Pressure shaft	Gibbons Creek Sandstone	Drill stem testing
BH106	229273.5	6290066.9	904.7	50.0	219.9	Tailrace tunnel	Rydal Formation	Drill stem testing
BH108	229034.0	6289891.0	788.8	31.0	115.5	Out-take	Rydal Formation	-
BH204	229186.8	6290439.3	955.9	67.5	292.0	Powerhouse complex	Rydal Formation	Packer testing

Source: Lake Lyell PHES Geotechnical Investigation Program – Factual Report (GHD, 2023); Lake Lyell PHES Interim Phase 2 Geotechnical Investigation Program – Factual Report (GHD, 2024).

Notes:

1. Ground surface elevation in metres above Australian Height Datum.
2. Length drilled in metres, does not represent depth below ground surface.

3.1.2 Groundwater level monitoring

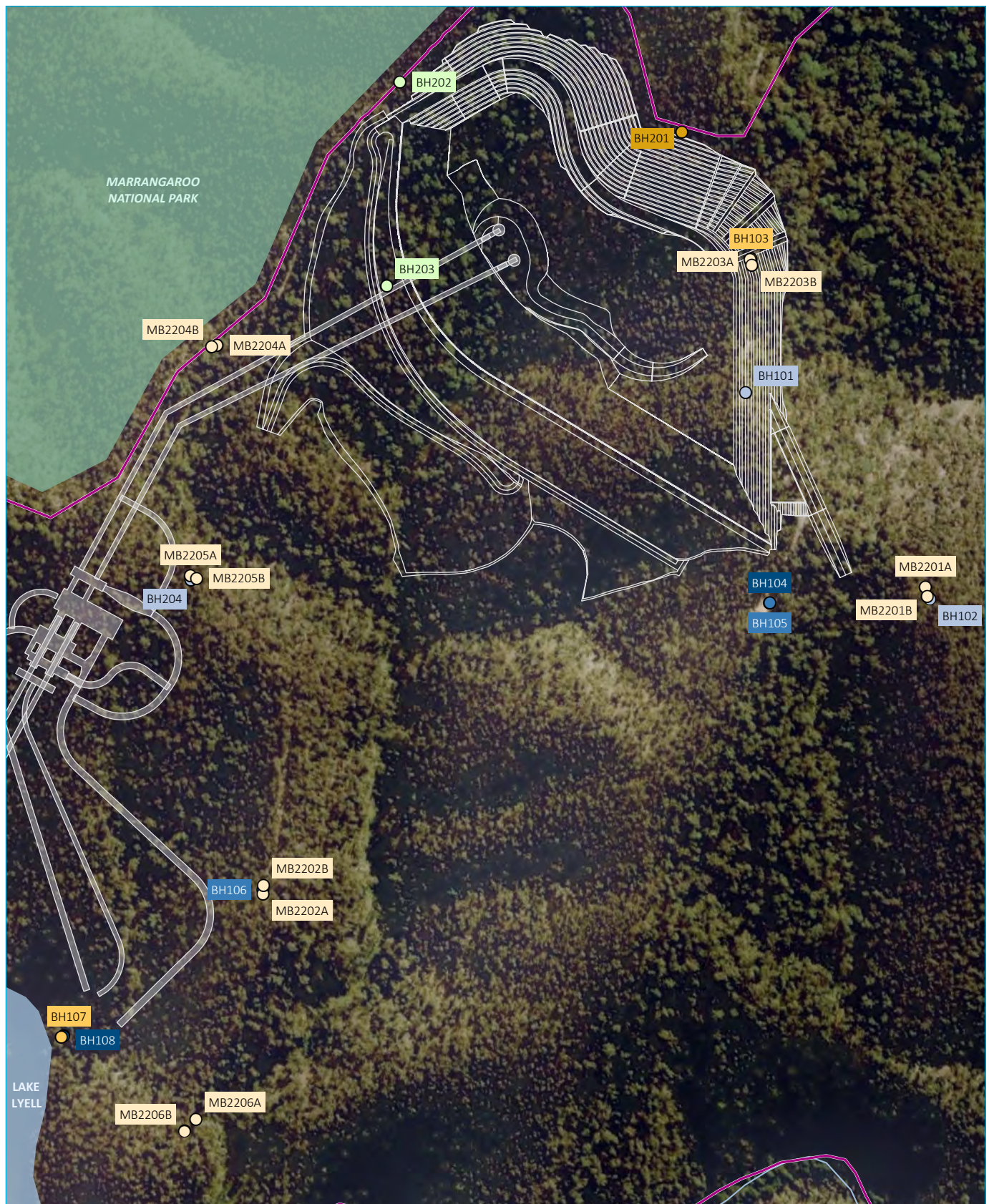
Project specific groundwater level monitoring commenced in September 2022 to inform the conceptual and numerical groundwater models. The groundwater level monitoring network was progressively expanded over two hydrogeological field investigation programs (GHD, 2023); (GHD, 2024).

Groundwater levels were measured using:

- a manual dip tape at 15 monitoring bores (refer to Table 3.1) during groundwater quality monitoring
- automated pressure and temperature loggers (loggers), deployed in 14 monitoring bores (refer to Table 3.1). Loggers record pressure and temperature at a synchronised six-hourly interval. Barometric fluctuations are directly compensated for via a vented tube
- VWP, comprising four sensors in two boreholes (refer to Table 3.2) that were installed against permeable zones identified during geotechnical drilling. VWPs record water level and temperature every six hours (synchronised with the loggers).

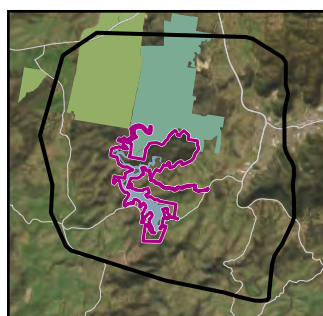
Groundwater level data is accessed as required, via the project-specific telemetered data portal. The groundwater level monitoring network will be maintained throughout the project approval process.

A summary of groundwater level monitoring is provided on Figure 3.2.



Source: EMM (2024); EnergyAustralia (2024); DCSSS (2023); ESRI (2024); GA (2009)

0 100 200
m
GDA2020 MGA Zone 56



KEY

- Project area
- Study area
- Key project infrastructure
- Baseline investigation and monitoring location**
- Geotechnical borehole
 - No testing
 - Drill stem testing
 - Packer testing
- Monitoring bore
 - No testing

- Packer testing
- Slug testing
- VWP
- Packer testing
- Existing environment
- Named watercourse
- Named waterbody
- NPWS reserve

Baseline investigation and monitoring locations

Lake Lyell PHES
Groundwater Modelling Report
Figure 3.1



\\emm.local\drive\2022\E221111 - Lake Lyell PHES EIS\GIS\02_Maps\GIA\GIA013_BaselineInvestigation\GIA013_BaselineInvestigation_01.aprx 5/11/2024

3.1.3 Groundwater quality monitoring

Project specific groundwater quality monitoring commenced in January 2023. The groundwater quality monitoring network was progressively expanded over two hydrogeological field investigation programs (GHD, 2023); (GHD, 2024).

Dedicated Solinst™ double-valve pumps (DVPs) were installed in 14 monitoring bores to collect groundwater samples using a low-flow methodology. Groundwater quality samples were collected monthly by a third-party consultancy and submitted to a NATA accredited laboratory for analysis.

Monitored groundwater quality analytes are summarised in Table 3.4. A summary of groundwater quality monitoring is provided on Figure 3.2.

Table 3.4 Groundwater analysis methods and parameters

Category	Monitoring analytes	Analysis method
Physico-chemical properties	Temperature, pH, electrical conductivity, total dissolved solids, dissolved oxygen, redox potential, turbidity and total suspended solids.	Field based measurement
	Alkalinity (bicarbonate, carbonate, phenolphthalein and total).	Analysis undertaken by a NATA certified laboratory
Major ions	Calcium (Ca), chloride, sodium (Na), potassium (K) and sulphate.	
Inorganics	Fluoride and sulfur (S).	
Hydrocarbons	Total petroleum hydrocarbons.	
Nutrients	Total nitrogen (N), ammonia, nitrate, nitrite, total phosphorus (P) and reactive phosphorous (P) and total phosphate.	
Total metals	Aluminium (Al), Arsenic (As), Boron (B), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Vanadium (V) and Zinc (Zn).	
Dissolved metals	Aluminium (Al), Antimony (Sb), Arsenic (As), Barium (Ba), Beryllium (Be), Boron (B), Cadmium (Cd), Chromium (Cr), Hexavalent Chromium (Cr(VI)), Trivalent Chromium (CR(III)), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Magnesium (Mg), Manganese (Mn), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Silver (Ag), Strontium (Sr), Vanadium (V) and Zinc (Zn).	

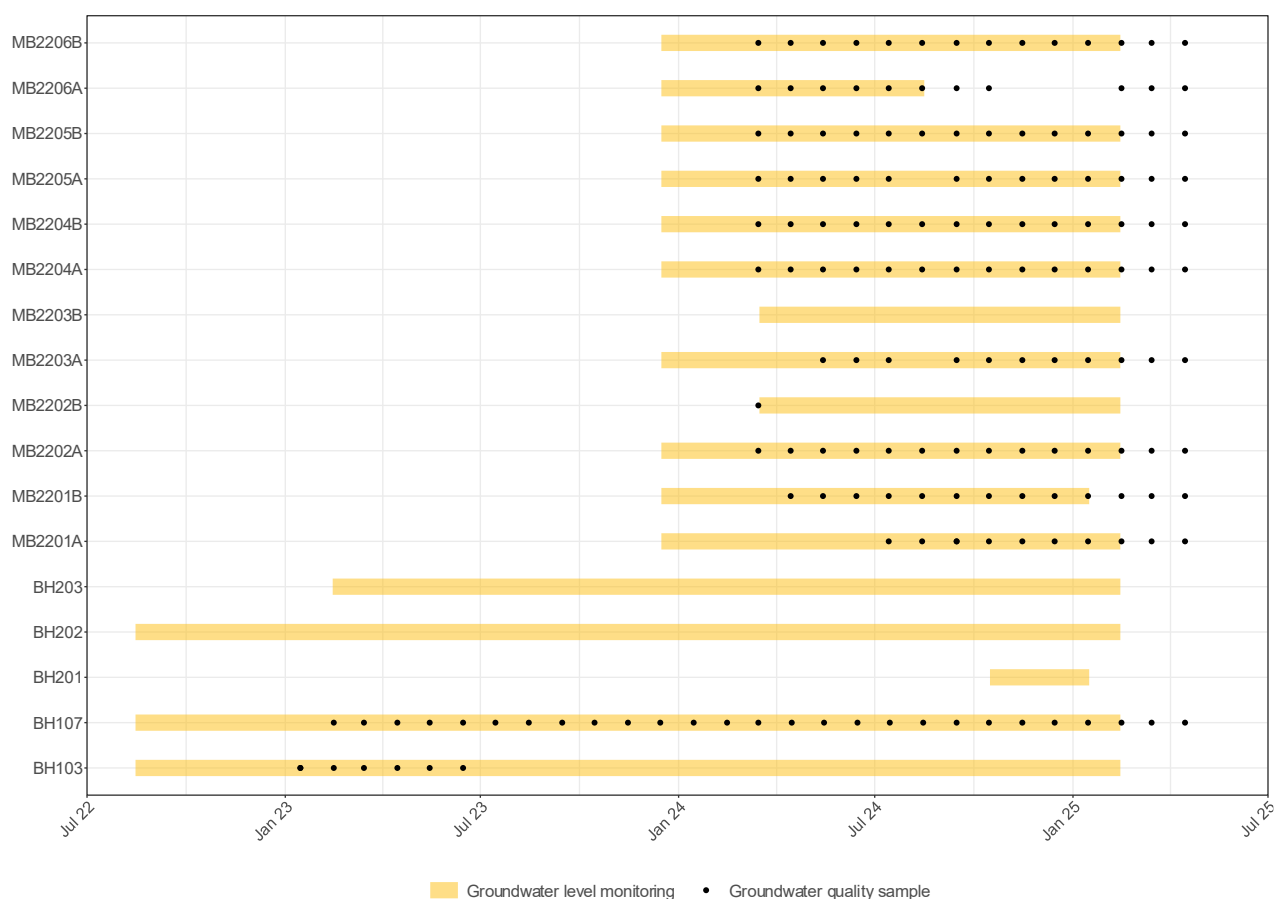


Figure 3.2 Groundwater level and quality monitoring summary

3.2 Conceptual water model

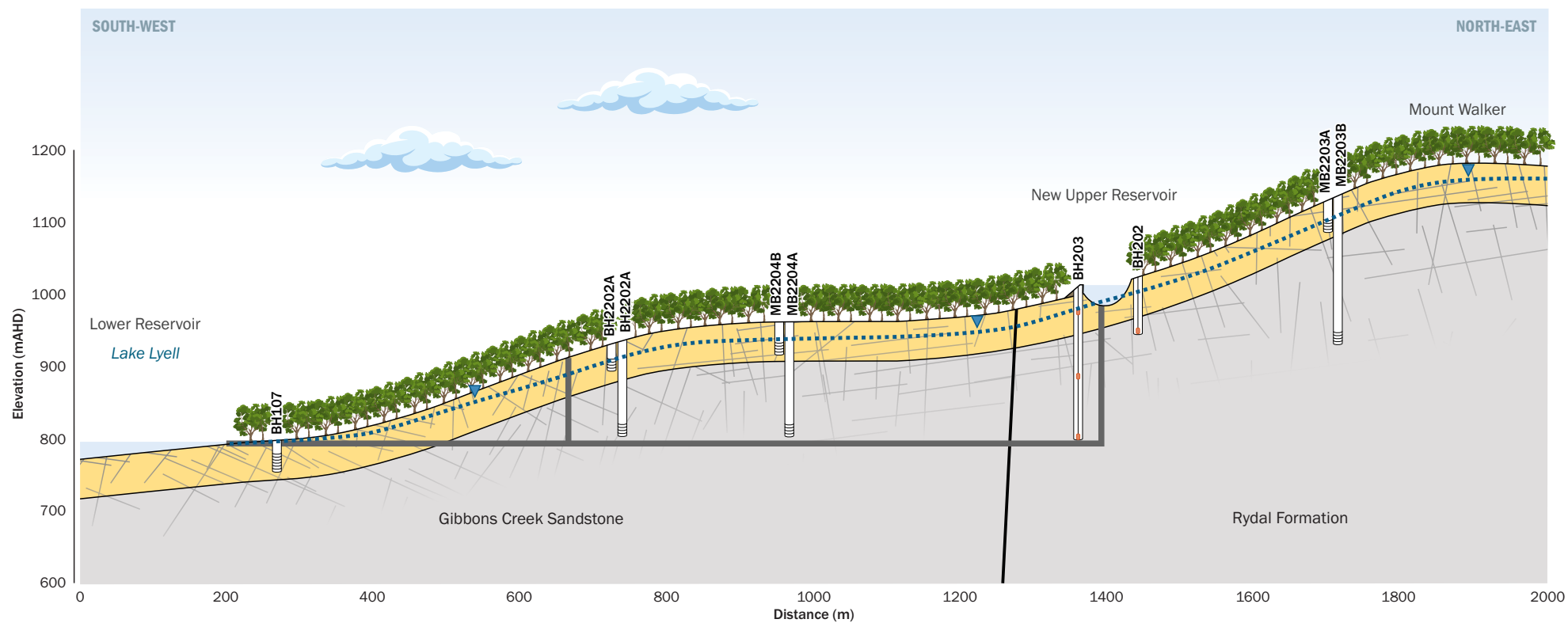
This section summarises the local hydrogeological setting, including groundwater levels and flow, hydraulic properties, groundwater system chemistry and surface water-groundwater interaction of the hydrogeological units in the project area. Further details of the conceptualisation that supports this groundwater model report are provided in the body of the main GIA report of this study.

The conceptual water model is provided in Table 3.5 and Figure 3.3.

Table 3.5 Conceptual water model

Component	Description
Topography	- Three distinct topographic areas, including: - steep ridges and valleys (at the project) - escarpments (eastern extent of the study area) - rolling foothills (remainder of study area).
Climate	- Temperate, with no dry-season and a mild summer. - Typically wetter periods between May and August, drier periods between September and April. - Wet and dry periods both observed over the monitoring period. - Predicted increase in temperature and decrease in rainfall due to climate change.

Component	Description
Hydrology	- Study area predominantly within Hawkesbury-Nepean / Sydney drinking water catchment, partly within the Macquarie-Bogan catchment. - Coxs River is the main receiving watercourse for surface water. - Perennial watercourses include Farmers Creek, Sandalls Creek, Coxs River, Bowens Creek, Jocks Creek, Lowther Creek, Whites Creek, Marangaroo Creek and Solitary Creek. - Multiple ephemeral watercourses discharging to higher order, perennial watercourses.
Geology	- Study area comprises rock units associated with the: - lower permeability Lachlan Fold Belt (deformed metamorphic, volcanic and sedimentary rocks) - higher permeability Sydney Basin (sedimentary rocks). - Structures associated with synclines and anticlines forming topographic deformation near the project. - Shallow (<2 m) and generally low permeability soils overlying hard-rock units.
Hydrostratigraphic units	- Shallow fractured rock groundwater system supported in shallow (<120 m), weathered and fractured Lachlan Fold Belt and Sydney Basin rock units. - Deep fractured rock groundwater system underlying shallow fractured rock groundwater system, supported in deeper Lachlan Fold Belt and Sydney Basin rock units.
Hydraulic properties	- Relatively low hydraulic conductivity in Lachlan Fold Belt compared to Sydney Basin. - Higher hydraulic conductivity in shallow groundwater system, compared to deeper groundwater system (irrespective of geological province).
Groundwater levels and flow	- Deeper watertable near high points in topography (~46 metres below ground level (mbgl) near Mount Walker) and shallower (near ground level) at perennial watercourses (refer to Figure 3.4). - Regional groundwater flow direction is generally north to south. - Local flow occurs radially from high points in landscape towards watercourses.
Water quality	- Relatively fresh (<500 microsiemens per centimetre (µs/cm)) and neutral pH. - Detections of dissolved metals generally below guideline values (with the exception of iron).
Groundwater recharge	- Direct rainfall recharge to soil profile (where present) or shallow groundwater system, percolating downward to deeper groundwater systems. - In-direct recharge via leakage at losing watercourses. - Recharge volumes dependant on rainfall duration and magnitude, increasing during wet periods. - Generally low infiltration across elevated areas and high infiltration within valleys and foothills.
Groundwater discharge	- Receiving perennial watercourses including Farmers Creek, Sandalls Creek, Coxs River, Bowens Creek, Jocks Creek, Lowther Creek, Whites Creek, Marangaroo Creek and Solitary Creek. - Ephemeral watercourses during wet periods. - Evapotranspiration where the watertable is sufficiently shallow to be intercepted by vegetation.
Groundwater and surface water interaction	- Continuous hydraulic connection to perennial watercourses, with alternating gaining and losing relationship along streamline. - Intermittent hydraulic connection to ephemeral watercourses during periods of high rainfall and elevated groundwater levels.
Groundwater receptors	- Aquatic GDEs, comprising habitats associated with receiving perennial watercourses (Farmers Creek, Sandalls Creek, Coxs River, Bowens Creek, Jocks Creek, Lowther Creek, Whites Creek, Marangaroo Creek and Solitary Creek). - Terrestrial GDEs, comprising plant communities with a dependence on groundwater (plant community types (PCTs) 3483, 3948, 4063, 4064, 3303, 3367 and 3738). - Landholder bores accessing regional groundwater for supply.

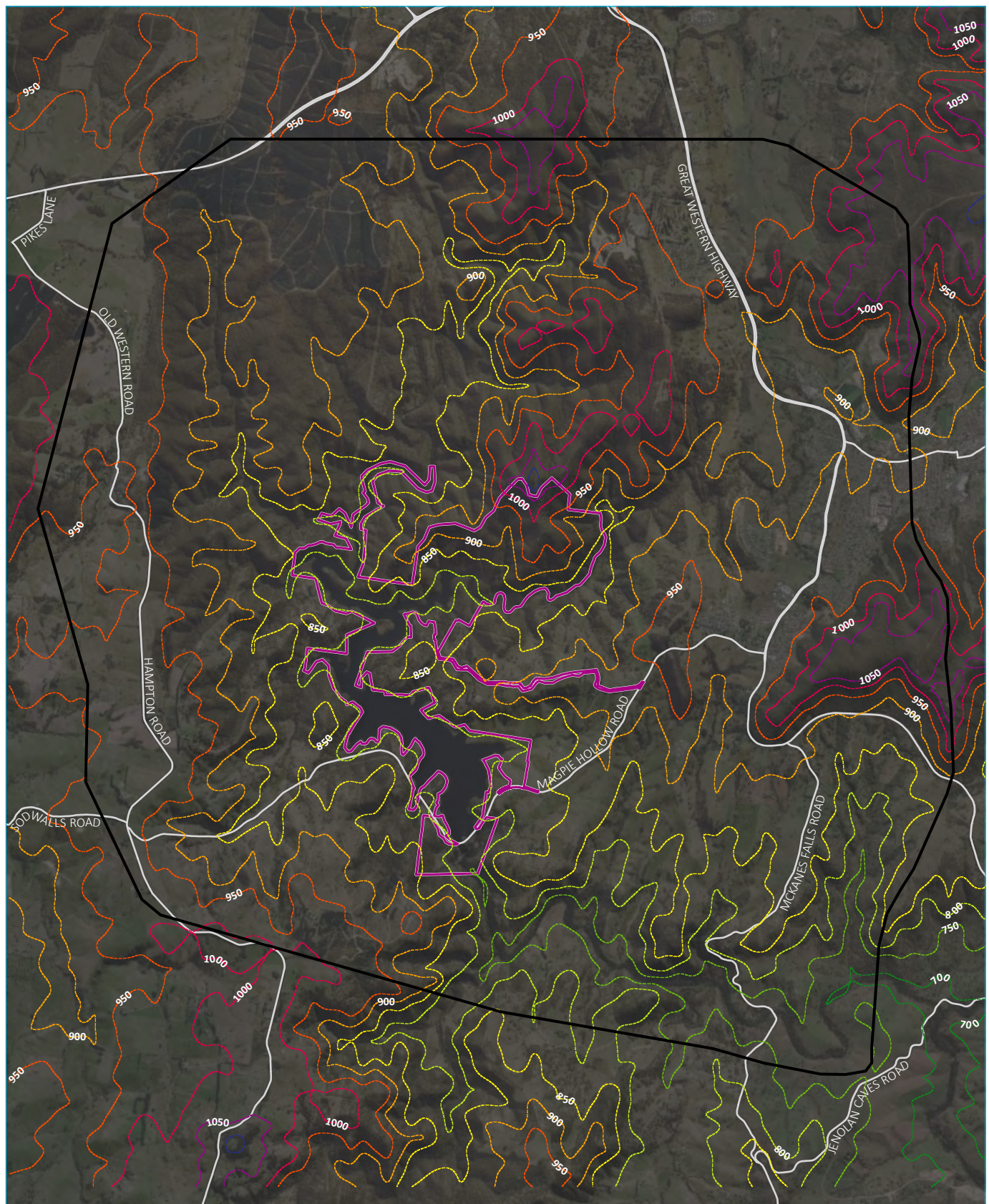


LEGEND

- | | |
|----------------------------|---------------------------|
| Shallow groundwater system | Monitoring bore |
| Deep groundwater system | Vibrating wire piezometer |
| Fracturing | Water level |
| Rock unit boundary | |
| PHES underground workings | |



Figure 3.3 Lake Lyell hydrogeological conceptualisation



Source: EMM (2024); EnergyAustralia (2024); DCSSS (2023); ESRI (2024); GA (2009)

KEY

- ▬ Project area
- ▬ Study area
- Existing environment
- ▬ Major road
- Groundwater elevation (mAHD)
 - ▬ 800
 - ▬ 850
 - ▬ 900
 - ▬ 950
 - ▬ 1000
 - ▬ 1050
 - ▬ 1100

Measured groundwater
elevation contours

Lake Lyell PHES
Groundwater Modelling Report
Figure 3.4

\\emm.local\drive\2022\E221111- Lake Lyell PHES EIS\GIS\02_Maps_GIA\Modelling\GWM020_GroundwaterElevContours\GWM020_GroundwaterElevContours_20241105_01.aprx 5/11/2024

4 Model design

4.1 Software

The numerical groundwater model was built using MODFLOW-USG Transport version 2.4.0 (Panday et al. 2013; Panday, 2024) using custom Python code to build the packages and process the outputs.

History-matching was carried out using PESTpp-IES version 5.2.19 (White 2018), including development of a parameter ensemble for predictive uncertainty analysis.

4.2 Model extent

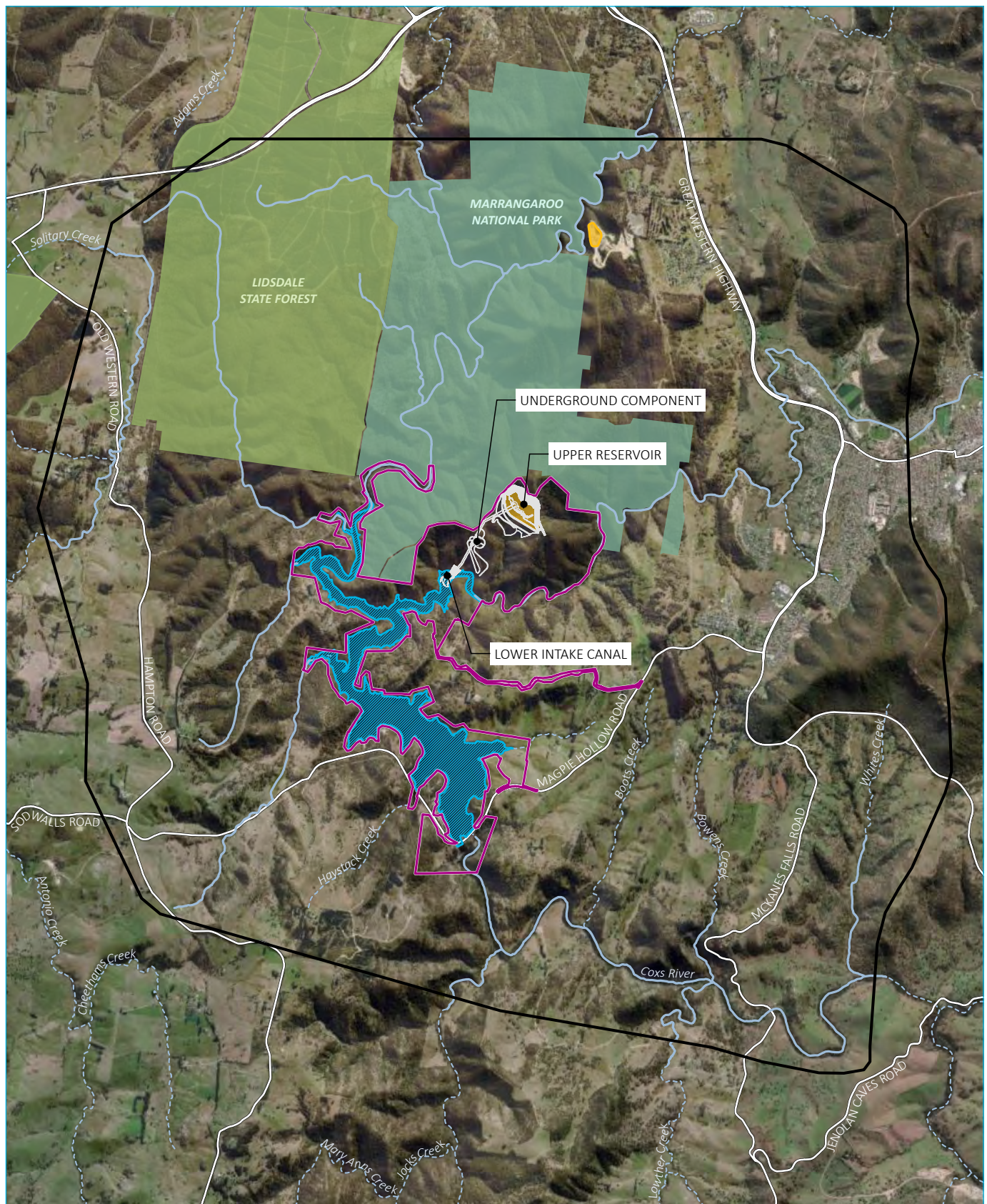
The full extent of the groundwater model domain for the project is shown in Figure 4.1. The model area is irregularly shaped to follow hydrogeological boundaries and features, and covers a north—south and an east—west distance of approximately 12 km.

The eastern and a portion of the northern boundaries align with topographic highs that correspond to groundwater catchment divides. The general position of the northern boundary was planned to allow sufficient space to account for predicting cumulative impact from the Metromix Quarry, and to include a generous segment of the south-east boundary representing the Coxs River and Marrangarro Creek for setting the regional context of the groundwater system and prevent influence from the model extent into the simulated impact. The southern boundary was traced including the Coxs River downstream as well as Sandalls Creek, also setting the regional context of the system and allowing any potential impact to the south, if present. The western segment of the boundary was traced including a portion of Solitary Creek, which also helps setting the regional context of the groundwater system for the project.

The model domain covers an area of approximately 125 kilometres squared (km²), with the outline of the model always at a distance greater than 5 km from the project.

This extent allows the model to:

- encompass the main identified groundwater receptors
- include the main hydrogeological boundary conditions influencing groundwater flow
- encompass changes to the groundwater system related to excavation of tunnels and construction of the upper reservoir
- include potential cumulative impact from the Metromix Quarry
- prevent undue influence of boundary conditions on model predictions.



Source: EMM (2024); EnergyAustralia (2024); DCSGS (2023); ESRI (2024); GA (2009)

KEY

- | | |
|--|---|
| Project area | Existing environment |
| Model extent | Major road |
| Key project infrastructure | Named watercourse |
| Major feature | NPWS reserve |
| Main drainage line | State forest |
| Project tunnel | |
| Lake Lyell waterbody extent | |

Model domain and major features

Lake Lyell PHES
Groundwater Modelling Report
Figure 4.1

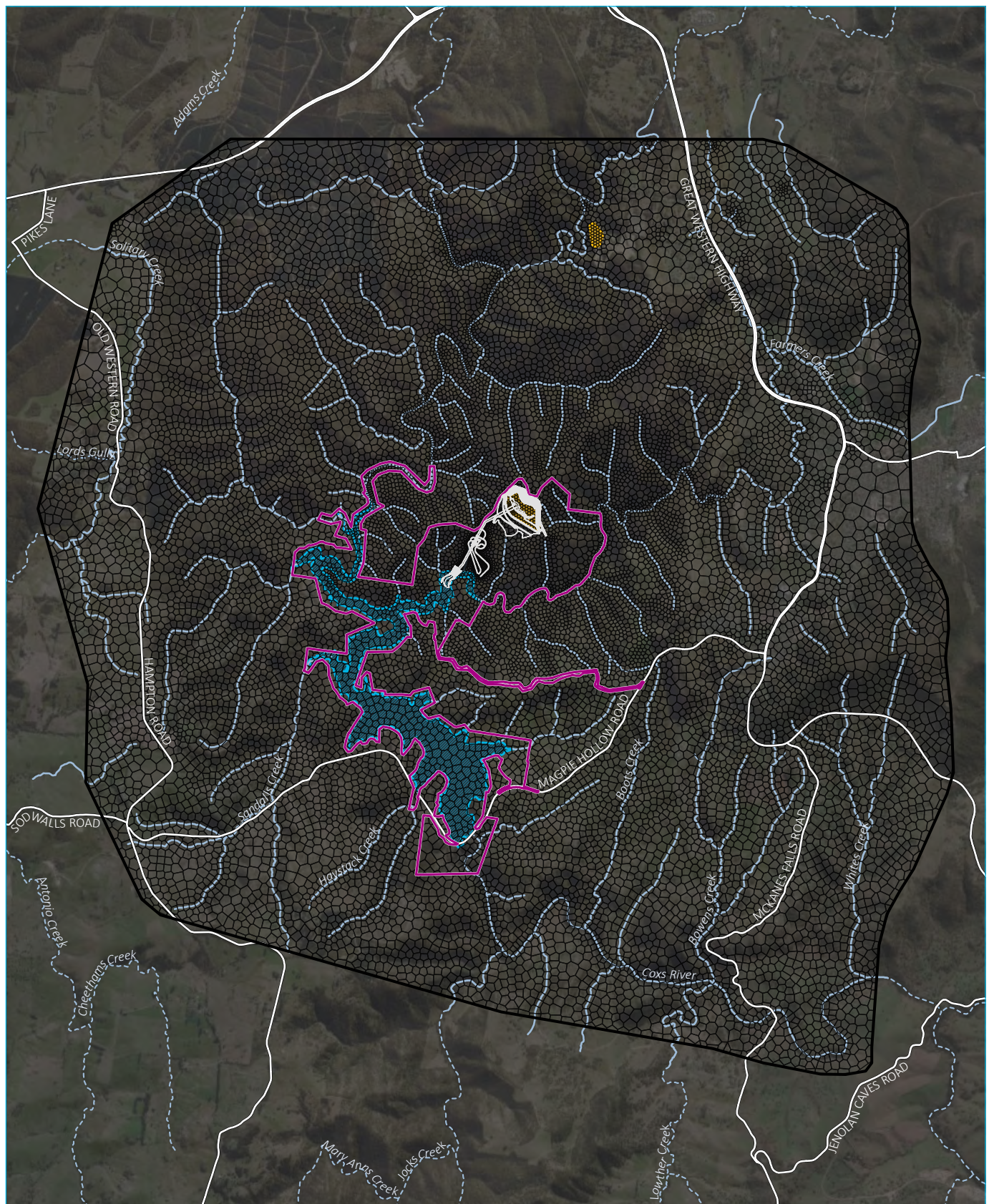
4.3 Spatial discretisation

4.3.1 Mesh

The Voronoi polygon mesh created to spatially discretise the model domain is presented in Figure 4.2 and Figure 4.3. The mesh was designed using a feature of MODFLOW-USG which allows cells to be “pinched out” where a layer is not present or is less than 2 m thick. The resulting 3D mesh contains up to 20,686 active cells in each layer, 20 layers, and a total of 145,194 active cells.

The Voronoi mesh was generated using a combination of Python scripting and AlgoMesh 2.0 (HydroAlgorithmics 2020), which provides significant control over the mesh generation process. The following general approach was taken when defining the size and alignment of the cells (in chronological order):

1. Cells aligned to the project tunnels were generated first. Some of these cells are drained during construction (representing drained tunnels), so the cell size replicates the width of each tunnel for an accurate representation of the process. Tunnel cell sizes vary between 5.5 and 8 m in diameter, matching tunnel construction plans.
2. Cells aligned to mapped GDEs vary between 30 m (for GDEs within 4 km from the project) and 60 m in diameter for other GDEs within the model extent.
3. Cells representing the upper reservoir and the Metromix Quarry were generated using regular hexagonal polygons of 40 m in diameter.
4. Cells representing rivers and streams were generated using three sizes: stream segments within a 2 km buffer using 50 m in diameter, then within a 4 km buffer using 80 m, and the rest were created using 100 m.
5. Cells representing monitoring bores were generated using a 50 m diameter.
6. Cells representing the outline of Lake Lyell were generated using an 80 m diameter.
7. Cells aligned with geological contacts were generated using a 100 m diameter.
8. Empty spaces in between features were filled out by AlgoMesh using its optimised algorithm for generation of Voronoi polygons. The largest resulting cells were 300 m in diameter.



Source: EMM (2024); EnergyAustralia (2024); DCSSS (2023); ESRI (2024); GA (2009)

KEY

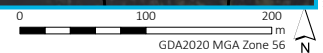
- | | |
|--|---|
| Project area | Existing environment |
| Key project infrastructure | Major road |
| Model mesh | Named watercourse |
| Model extent | |
| Major feature | |
| Modelled drainage line | |
| Project tunnel | |
| Lake Lyell waterbody extent | |

Model mesh

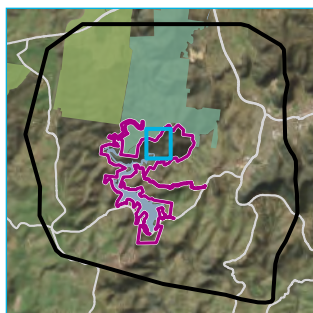
Lake Lyell PHES
Groundwater Modelling Report
Figure 4.2



Source: EMM (2024); EnergyAustralia (2024); DCSSS (2023); ESRI (2024); GA (2009)



Model mesh (detail)



- KEY**
- Project area
 - Key project infrastructure
 - Model mesh
 - Model extent
 - Major feature**
 - Modelled drainage line
 - Project tunnel
 - Lake Lyell waterbody extent

- INSET KEY**
- Major road

4.3.2 Layers

Three-D views of the model layers are presented in Figure 4.4 to Figure 4.7, and a description of each layer is presented in Table 4.1.

Table 4.1 **Model layer summary**

Layer	Hydrostratigraphic unit	Comments
1	Regolith	3 m thick, multiple regolith units.
2	Shallow hard rock, multiple HSUs	Base 120 m deep from top of the model.
3	Multiple HSUs	Any other hard rock above 830 metres Australian Height Datum (mAHD).
4	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 820 mAHD within 100 m buffer.
5	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 810 mAHD within 100 m buffer. 30 m thick, base at 790 mAHD within 2,000 m buffer.
6	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 800 mAHD within 100 m buffer.
7	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 790 mAHD within 100 m buffer.
8	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 780 mAHD within 100 m buffer.
9	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 770 mAHD within 100 m buffer.
10	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 760 mAHD within 100 m buffer.
11	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 750 mAHD within 100 m buffer.
12	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 740 mAHD within 100 m buffer.
13	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 730 mAHD within 100 m buffer.
14	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 720 mAHD within 100 m buffer.
15	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 710 mAHD within 100 m buffer.
16	Multiple HSUs	Refined layer around tunnels. 10 m thick, base at 700 mAHD within 100 m buffer.
17	Shallow hard rock	Base 120 m deep from top of the model.
18	Rydal Formation	Base of layer matches the base of the HSU unit.

Layer	Hydrostratigraphic unit	Comments
19	Gibbons Creek Sandstone	Base of layer matches the base of the HSU unit. Capped at a minimum of 300 mAHD.
20	Hartley Suite Pluton	Flat base of model set at 300 mAHD.

The total thickness of the model ranges between 385 and 880 m, with the top elevation matching the topography of the area and the base of the model set flat at 300 mAHD.

A total of 20 model layers were used to represent the hydrogeological conceptualisation and the geometry of the project. The four regional hydrostratigraphic units (HSUs) combine to a total of eight considering their respective regolith, with the eight units used to discretise the model layers. Additionally, 10 m thick horizontal layers were used within a 100 m buffer from the project tunnels, which combined with the 2D mesh produce 3D cells small enough to allow for a detailed representation of tunnel features in the model. Outside of the 100 m buffer, 30 m thick horizontal layers were extended to a buffer of 2,000 m around the tunnels (outside of the 100 m buffer), to allow the simulated impact to propagate freely.

Special consideration was given to the design of the upper reservoir, where part of the mountain will be removed and a dam constructed to shape the reservoir. To represent this change in the area's topography, two MODFLOW models were created: one for history-matching, representing the current conditions of the mountain, and a second model for the predictive stage, incorporating the planned dam's upper surface into the topography and using the modelled heads from the end of the history-matching model as initial conditions. As detailed in Section 4.6.7, the portion of the model representing the future dam, i.e. the area above the current topography, was initially assigned hydraulic properties corresponding to "air", which later change to "dam/ground" during the simulation. Conversely, the portion of the topography that will be removed to create the reservoir was used as base of layer 1 in the relevant area, allowing change of the modelled hydraulic properties from "ground" to "lake".

All model layers were set to MODFLOW layer type 4 (variably confined/unconfined upstream watertable). This allows each layer to simulate confined or unconfined conditions, depending on the simulated elevation of the watertable at each point in time.

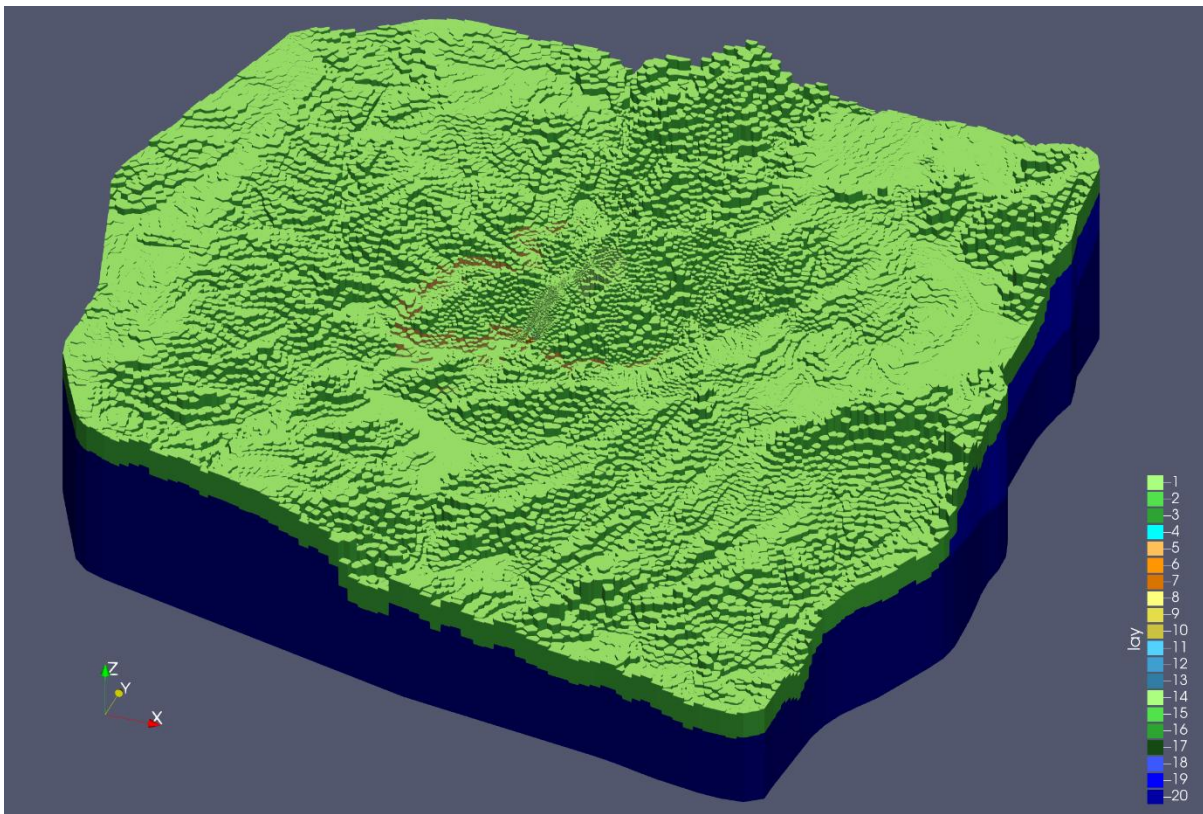


Figure 4.4 3D view of the model mesh, coloured by layer



Figure 4.5 3D view of the model mesh, coloured by layer, sliced to show details in the project area

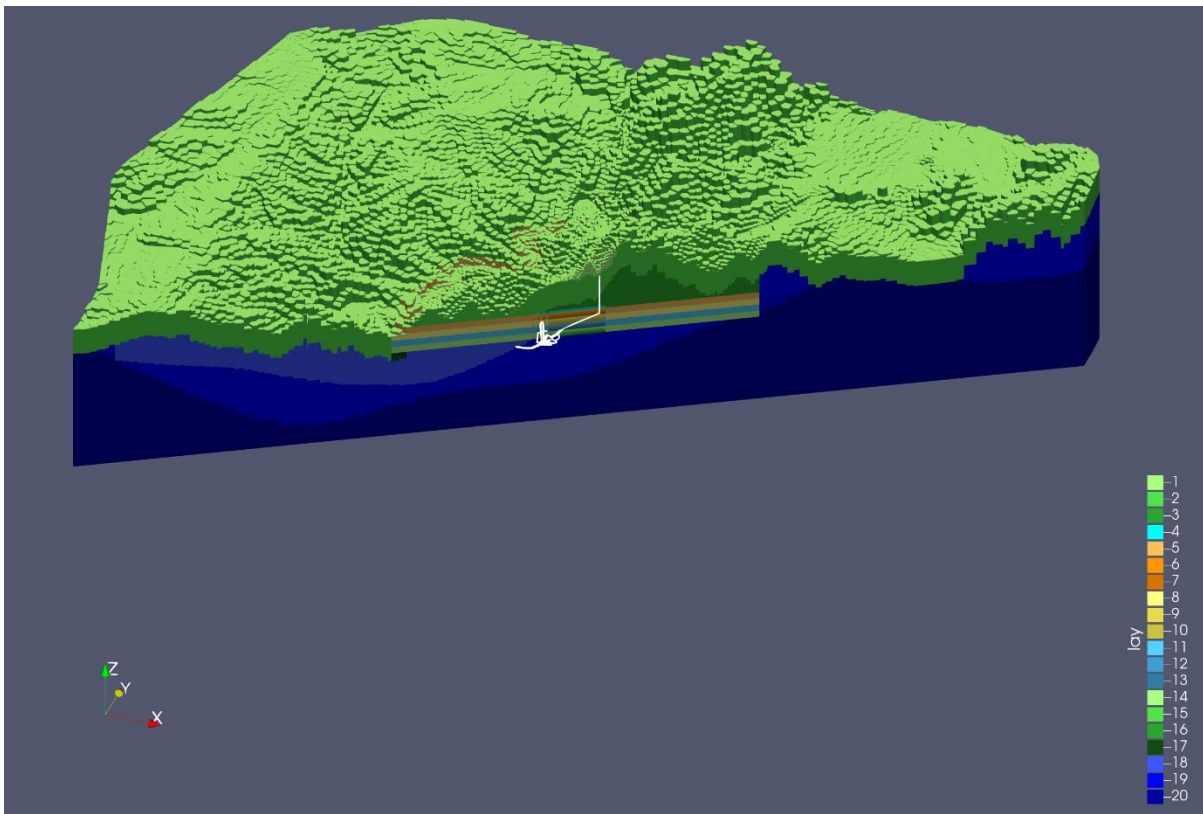


Figure 4.6 3D view of the model mesh, coloured by layer, sliced to show details in the project area and layers/HSUs to the west

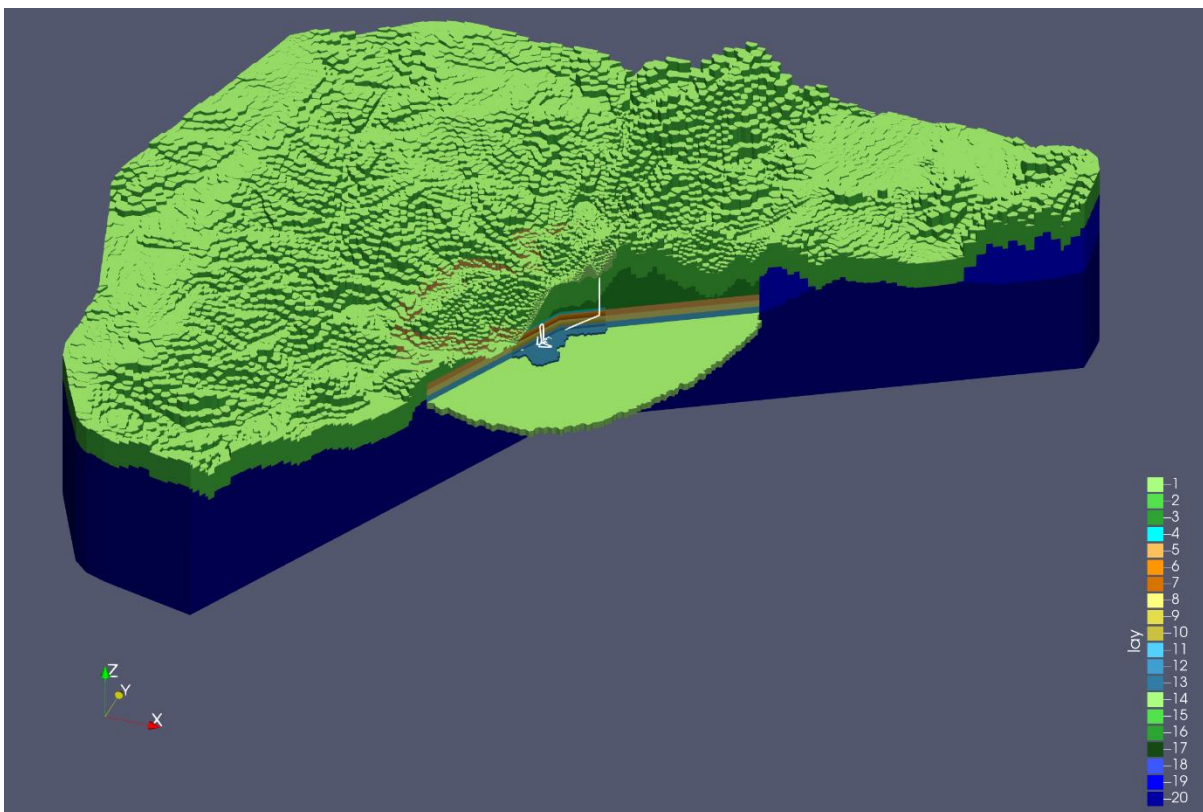


Figure 4.7 3D view of the model mesh, coloured by layer, sliced to show details in the project area, also showing extent of 10 m thick and 30 m thick layer refinements

4.4 Temporal discretisation

Considering the timing of the monitoring data and the construction and operation of the project, the model was split into four periods: historical, construction, operation and post-operation. A summary of the date range of these periods and the model timing is presented in Table 4.2.

A long initial transient stress period was used to “warm up” the numerical solution, helping with numerical convergence at the beginning of the model. This stress period covers between 1 January 1900 and 31 December 2021. Then the historical period starts with a steady state stress period representing average “pre-project” conditions. Four quarterly stress periods follow, introducing seasonal climate variations during the year 2022. Between January 2023 and the end of January 2025, where monitoring data is available, monthly stress periods were used allowing the model to replicate water level changes that respond to monthly climatic variations.

For the purposes of the model, the construction period was represented using quarterly stress periods, running from February 2025 to June 2030, with construction activities simulated to commence in July 2025.

The operation period lasts 80 years, covering the years 2031 to 2110. It was represented using four stress periods of five years and six stress periods of 10 years.

Lastly, the post-operation stress period lasts 500 years, covering between 2111 and 2610. A steady state stress period was used at the end of this period, to simulate the post-project equilibrium of the system.

Regarding time steps, an initial time step of one day was used for all stress periods, except during the construction period – when major stresses occur – where a shorter initial time step of 0.1 day was applied to aid numerical convergence. The time step length was allowed to increase using a multiplier of two for subsequent time steps within each stress periods, provided convergence was achieved within one-third of the total number of iterations (Panday, 2024).

Table 4.2 **Model timing summary**

Period	Stress period	Date range	Comment
Warm up	1	01/01/1900 to 30/12/2021	Transient, numerical warm-up
Historical	2	31/12/2021	Steady state
	3 to 6	01/01/2022 to 31/12/2022	Transient, quarterly
	7 to 31	01/01/2023 to 31/01/2025	Transient, monthly
Construction	32 to 33	01/02/2025 to 31/03/2025	Transient, monthly
	34 to 54	01/04/2025 to 30/06/2030	Transient, quarterly
Operation	55 to 56	01/07/2030 to 31/12/2031	Transient, quarterly
	57 to 60	01/01/2031 to 31/12/2050	Transient, 5 yearly
	61 to 66	01/01/2051 to 31/12/2110	Transient, 10 yearly
Post-operation	67 to 71	01/01/2111 to 31/12/2160	Transient, 10 yearly
	72	01/01/2161 to 31/12/2210	Transient, 50 yearly
	73 to 76	01/01/2211 to 31/12/2610	Transient, 100 yearly
	77	01/01/2611 to infinity	Steady state

4.5 Numerical solution

The MODFLOW-USG SMS solver was employed to solve the series of differential equations generated by the model. Head closure criteria of 1×10^{-2} m and 1×10^{-2} m were employed for outer iterations (HCLOSE) and inner iterations (HICLOSE) respectively, with the Delta-Bar-Delta/Newton Raphson nonlinear method and the Unstructured Pre-conditioned conjugate gradient (PCGU) linear method.

4.6 Boundary conditions

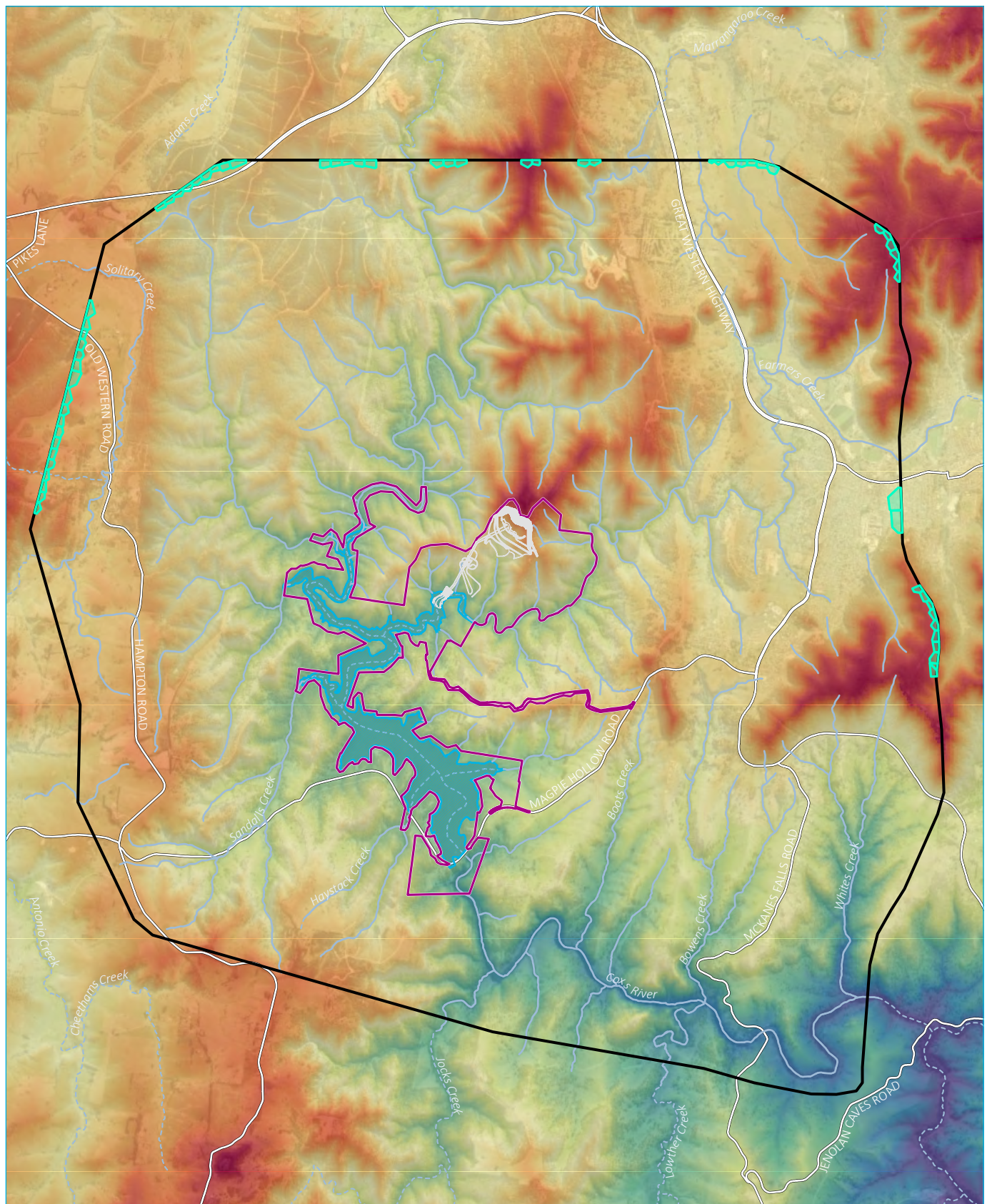
4.6.1 Regional groundwater flow

As described in previous sections of this report, and the main GIA report it forms part of, the groundwater system within the model extent is generally conceptualised as comprising four main hydrostratigraphic units, all behaving mainly as fractured rock aquifers. A relatively thin (3 m) regolith layer covers these units, with no significant alluvial units mapped in the area. Within the hard rock units, groundwater is recharged via rainfall and flows radially outward from elevated topography and discharges to ephemeral streams as baseflow/interflow and also is lost to the atmosphere via evapotranspiration processes.

To replicate this flow system water enters the model as rainfall-derived recharge and exits the model along surface water features that drain the elevated ridgelines as well as discharge to the low-lying alluvium, rivers, lakes and lost to the atmosphere as evapotranspiration. The model domain has been specifically aligned with as many topographic (and groundwater) divides as feasible to capture the regional flow system recharge and throughflow processes. Along some of the topographical ridge lines, in areas where the topographic elevation is somewhat uniform, a general head boundary (GHB) was specified on Layer 1 along the relevant model edge to allow for throughflow to occur. In areas with steep topographic changes, or to the south-west, south and south-east of the model, far from the project, no GHB cell conditions were used, as they would be redundant and/or numerically problematic.

To define the elevation of each GHB cell along the edge of the model, a regional interpolation of measured water levels was used, and read for each cell centre. This interpolation considered the topography and depth to water around topographic highs and lows, making it as meaningful and realistic as possible, and adjusted to the conceptual understanding of the system. Time-invariant heads were used for these regional GHB cells, since they are far enough from the project that this is considered a simple, useful assumption taking into account the model objectives.

The GHB cells defined around the perimeter of the model are displayed on Figure 4.8.

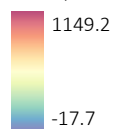


Source: EMM (2024); EnergyAustralia (2024); DCSGS (2023); ESRI (2024); GA (2009)

KEY

- Project area
- Key project infrastructure
- Model extent
- General head boundary cell
- Major feature
- Modelled drainage line
- Lake Lyell waterbody extent

Conceptual water table (mAHd)



Existing environment

- Major road
- Named watercourse

Regional general head boundary (GHB) cells

Lake Lyell PHES
Groundwater Modelling Report
Figure 4.8

4.6.2 Rainfall-derived recharge

The MODFLOW Recharge (RCH) package was used to simulate diffuse rainfall-derived recharge, applied directly to the watertable.

Rainfall recharge was imposed as a percentage of actual rainfall, with spatially and temporally variable recharge rates applied. The recharge factors applied per the HSU zone were optimised during history-matching, with prior values defined per outcropping HSU (refer to Figure 4.9):

- Sedimentary: 20% of rainfall.
- Pluton: 9% of rainfall.
- Gibbons Creek Sandstone: 6% of rainfall.
- Rydal Formation: 6% of rainfall.

Temporal variation to recharge during transient simulation periods was calculated using daily rainfall data from SILO at location 33.30°S, 150.06°E (DES 2023). Spatial variability is achieved by applying factors to the base timeseries of rainfall.

A flat recharge rate equivalent to the long-term average between January 1960 and January 2025 was used for future predictions.

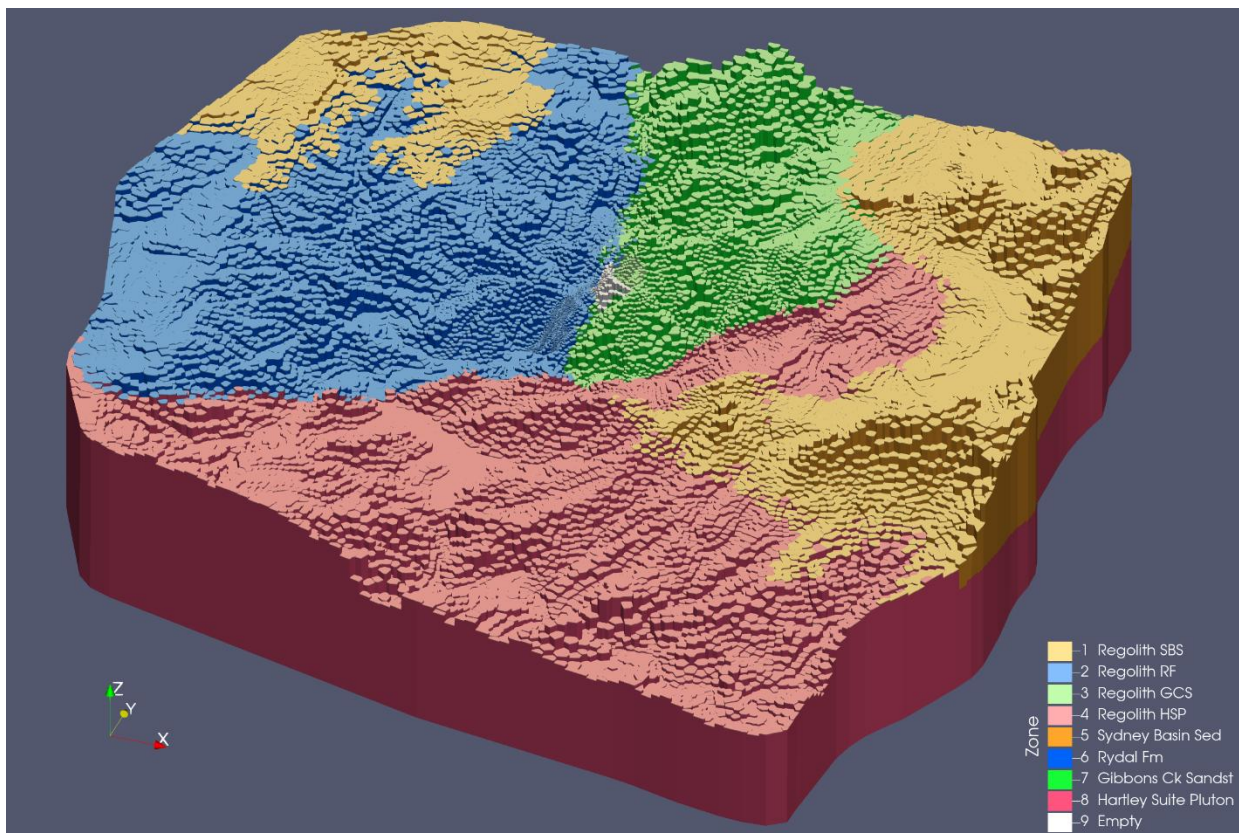


Figure 4.9 Outcropping HSUs

4.6.3 Evapotranspiration

The MODFLOW evapotranspiration (EVT) package was used to simulate evapotranspiration from the groundwater system. One evapotranspiration zone was defined per outcropping HSU, with the maximum rate set as 100% of potential evapotranspiration according to Penman-Monteith (short crop) sourced from SILO (DES 2023) with an extinction depth of 2 m.

4.6.4 Lakes and reservoirs

The river package of MODFLOW (RIV) was used to represent Lake Lyell. Lake level data available between January 2019 and January 2025 were used to define the stage levels for the RIV package during history matching, varying between 782.3 and 786.7 mAHD. The river bottom elevation was set as the topographic elevation minus a constant depth of 1.5 m (half of top layer thickness). For the predictive models, a constant average value of 785.5 mAHD – corresponding to the last stress period stage value of the history-matching stage (and the full supply level of Lake Lyell) – was used. This river boundary was applied only in Layer 1 and only within the defined extent of the lake (refer to Figure 4.10).

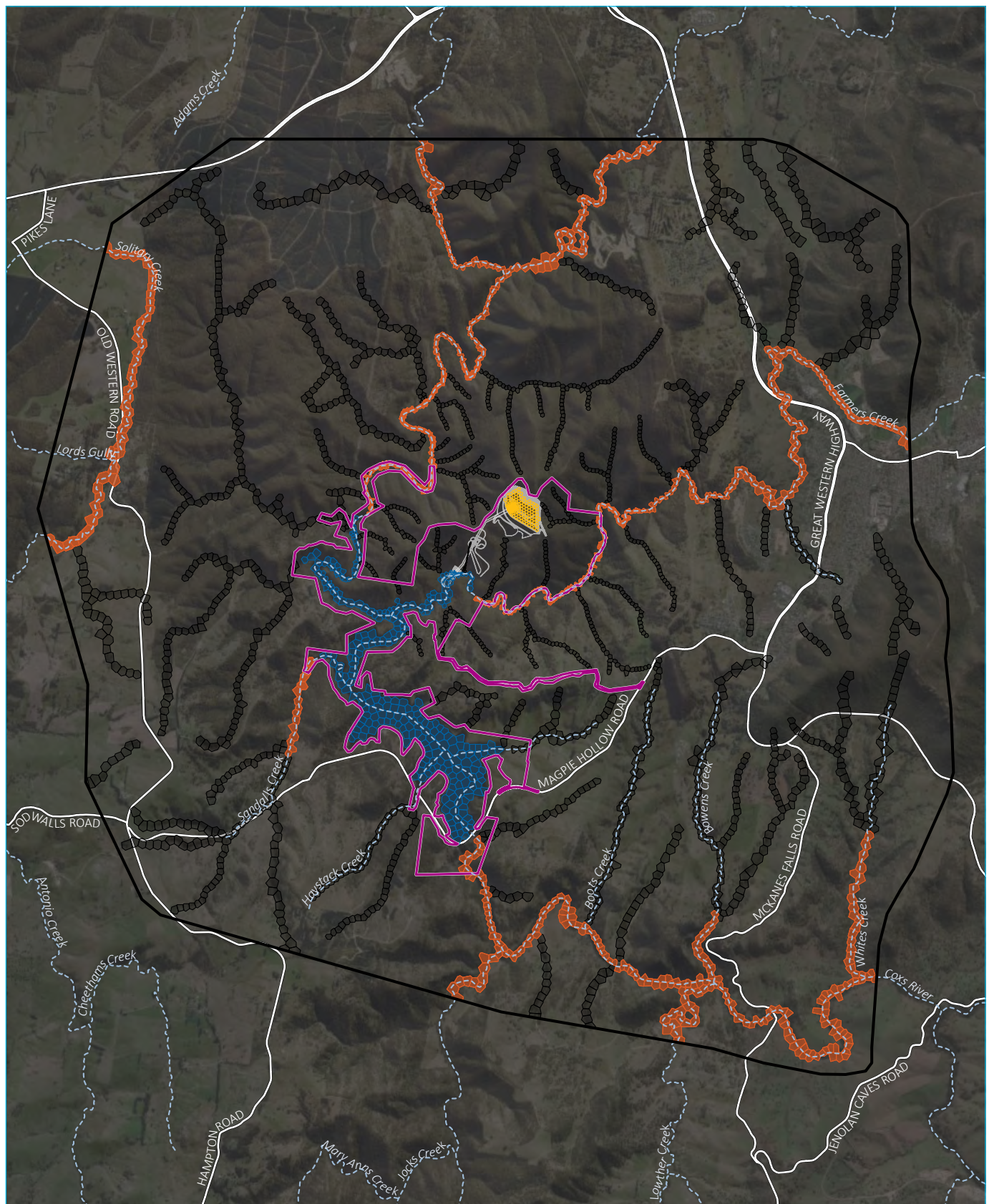
For the upper reservoir, a similar approach was adopted, with the RIV boundary condition applied during stress periods 55 to 66 (inclusive), covering the period from July 2030 to December 2110. A fixed water level stage elevation of 1,035 mAHD (representing the median operating level of the upper reservoir) was used, along with a bottom elevation determined by the design reservoir bottom levels. Considering the early stage of the project and the objectives of the groundwater model, representing an instant creation of the upper reservoir (dam and lake) was considered a valid simplification for modelling purposes.

The streambed conductance of each cell was calculated individually in both cases, based on the hydraulic conductivity of the river/lakebed, the area of the cell, and a nominal bed thickness of 1 m, assumed to simplify the calculation. A lakebed hydraulic conductivity value of 0.1 metre per day (m/d) – corresponding to clay or sandy silts – was assumed for the upper reservoir (fixed parameter), while a value of 7.1 m/d was obtained through history matching for Lake Lyell (variable parameter – Base realisation). The formula used to calculate the conductance per cell was:

$$C = K \frac{A}{d} = \frac{lw}{d}$$

where:

- C = conductance (m^2/d)
- K = hydraulic conductivity of river/lakebed (m/d)
- A = area covered by the river within the cell (or area of the cell if fully covered) (m^2)
- d = thickness of the riverbed (m)
- l = length of the river segment within the cell (m)
- w = width of the river segment within the cell (m).



Source: EMM (2024); EnergyAustralia (2024); DCSSS (2023); ESRI (2024); GA (2009)

0 2.5 5 km
GDA2020 MGA Zone 56

KEY

- Project area
- Model extent
- Key project infrastructure
- River drainage segment
- Stream drainage segment
- RIV cells
- Lake Lyell
- Upper reservoir
- Existing environment
- Major road
- Named watercourse

RIV boundary condition in Lake Lyell and the Upper Reservoir

Lake Lyell PHES
Groundwater Modelling Report
Figure 4.10

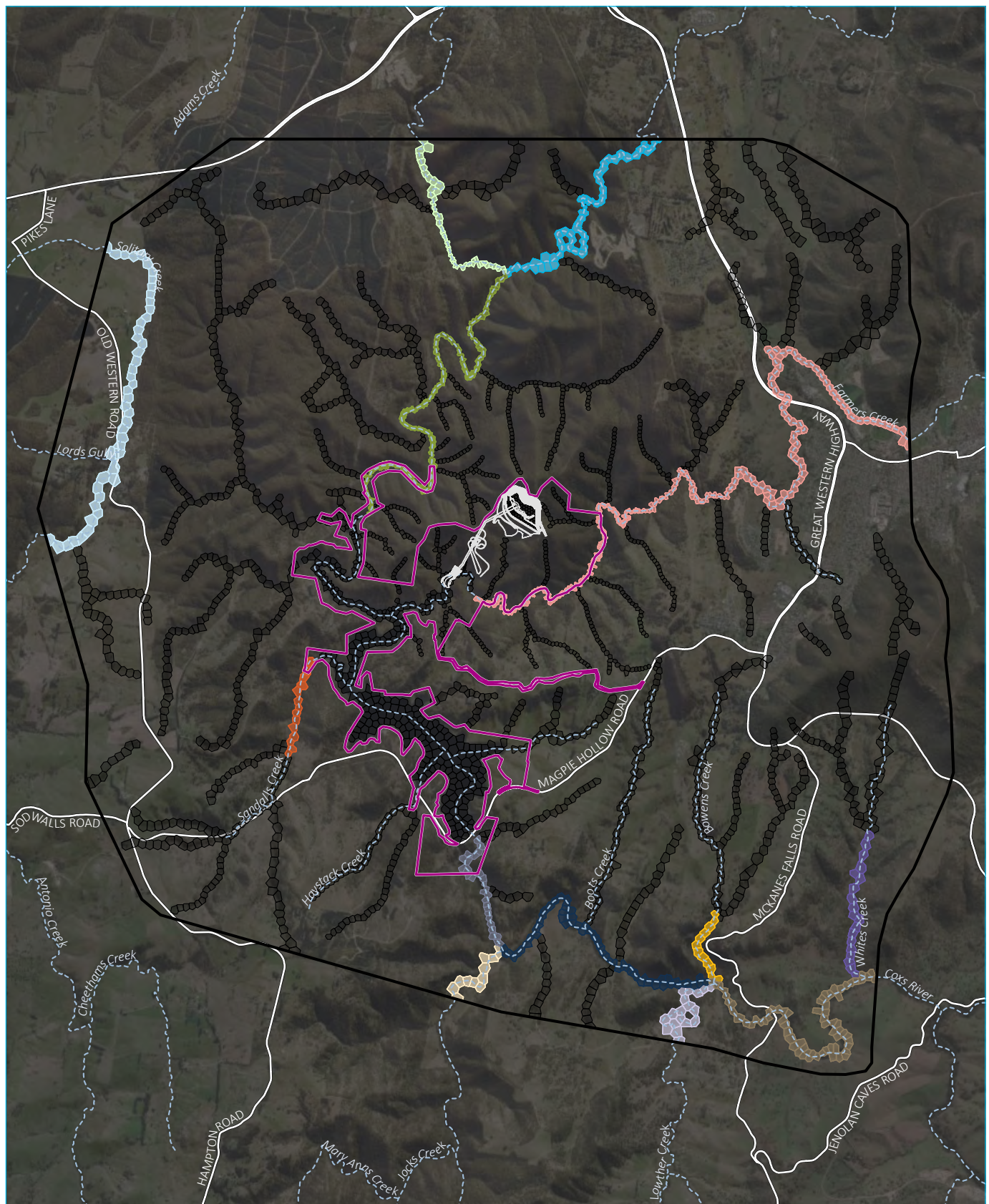
4.6.5 Watercourses

The river (RIV) package of MODFLOW was used to model both perennial and ephemeral watercourses. To differentiate between them, a defined water stage was used in the RIV package for perennial streams, whereas ephemeral streams were simulated using a river stage equal to the riverbed elevation (both set at the elevation of topography). This approach allows water to flow unrestricted into the drainage from the aquifer when the groundwater level reaches the surface but prevents leakage from the channels into the groundwater system, causing the creeks to effectively act as “drains”. This configuration is considered appropriate, as the creeks at higher elevations often traverse fresh rock. While there may be some pooling and local recharge where water is captured in streams, most stream flow is expected to be rapidly conveyed downslope. Although the downstream transfer of water is not explicitly simulated in the model, the volumes captured by the ephemeral streams are included in the estimated baseflow volumes for the model domain.

The perennial drainage features represented by the RIV package (refer to Figure 4.11) include:

- Coxs River (upstream and downstream Lake Lyell)
- Marrangaroo Creek
- Solitary Creek
- Farmers Creek
- Sandalls Creek (downstream segment)
- Jocks Creek
- Lowther Creek
- Bowens Creek (downstream segment)
- Whites Creek (downstream segment).

The elevation along each drainage feature was derived for each relevant model cell using publicly available LiDAR imagery of 5 m resolution (obtained from ELVIS, <https://elevation.fsdf.org.au>). Along drainages, LiDAR imagery represents the elevation of the water stage; for that reason, for each drainage segment a defined depth was subtracted from the LiDAR reading in each cell to estimate the elevation of the streambed. The depths used were defined based on analysis of satellite images and EMM’s field staff knowledge of the area. The bed thickness for all of the drainage systems was set at a constant thickness of 1 m to simplify internal model calculations of streambed conductance. Historical data on water depth are available for some sections of the Coxs River (since 1951) and for Farmers Creek (since 1980). The other creeks were simulated using constant water depths, ranging from 0.25 m (for Sandalls Creek, Jocks Creek, Bowens Creek, Lowther Creek, and Whites Creek) to 1 m for Solitary Creek. Given the large number of drainage lines to be represented with the RIV package, their properties were not assigned individually. To simplify the assignment of RIV segment properties, a number of zones were defined, each with uniform properties. The zones are displayed in Figure 4.11, and their properties including the history matched riverbed conductance for the base parameter set are listed in Table 4.3.



Source: EMM (2024); EnergyAustralia (2024); DCSSS (2023); ESRI (2024); GA (2009)

0 2.5 5 km
GDA2020 MGA Zone 56

KEY

 Project area	 4 Cocks River	 12 Cox River
 Model extent	 5 Farmers Creek	 13 Farmers Creek
 Key project infrastructure	 6 Sandalls Creek	 Existing environment
 River drainage segment	 7 Jocks Creek	 Major road
Stream drainage zone	 8 Bowens Creek	 Named watercourse
 1 Solitary Creek	 9 Lowther Creek	
 2 Marrangaroo Creek	 10 Whites Creek	
 3 Cocks River	 11 Cocks River	

STR boundary condition and
drainage segments

Lake Lyell PHES
Groundwater Modelling Report
Figure 4.11



\\emm.local\drive\2022\E221111 - Lake Lyell PHES EIS\GIS\02_Maps_GIA\Modelling\GWM007_STRBoundaryCondition_2024\018_01.aprx 5/11/2024

Table 4.3 RIV package – zone properties

River zone	Drainage name	Vertical conductivity (m/d)	Drainage width (m)	Streambed depth (below LiDAR elevation) (m)	Streambed thickness (m)	Water depth (m)
1	Centre	2.6×10^{-2}	5	1.5	1.0	-
2	North-east	9.1	5	1.5	1.0	-
3	South-east	2.0	5	1.5	1.0	-
4	South	56	5	1.5	1.0	-
5	Far west	11	5	1.5	1.0	-
6	North west	3.4	5	1.5	1.0	-
7	Lake Lyell	7.1	-	1.5	1.0	*
8	Solitary Creek	8.8×10^{-3}	5	1.5	1.0	1.0
9	Coxs River (upstream)	1.2×10^{-3}	5	1.5	1.0	variable
10	Marrangaroo Creek	1.5×10^{-5}	5	1.5	1.0	0.25
11	Coxs River	2.2×10^{-3}	6	1.5	1.0	variable
12	Farmers Creek	1.1×10^{-3}	10	1.5	1.0	variable
13	Sandalls Creek	3.9×10^{-3}	5	1.5	1.0	0.25
14	Jocks Creek	3.1×10^{-2}	10	1.5	1.0	0.25
15	Bowens Creek	1.4×10^{-1}	5	1.5	1.0	0.25
16	Lowther Creek	8.4×10^{-3}	10	1.5	1.0	0.25
17	Whites Creek	3.5×10^{-2}	10	1.5	1.0	0.25
18	Coxs River	4.0×10^{-4}	20	1.5	1.0	0.25
19	Coxs River	1.7×10^{-1}	20	1.5	1.0	variable
20	Coxs River (downstream)	1.3×10^{-3}	20	1.5	1.0	0.25

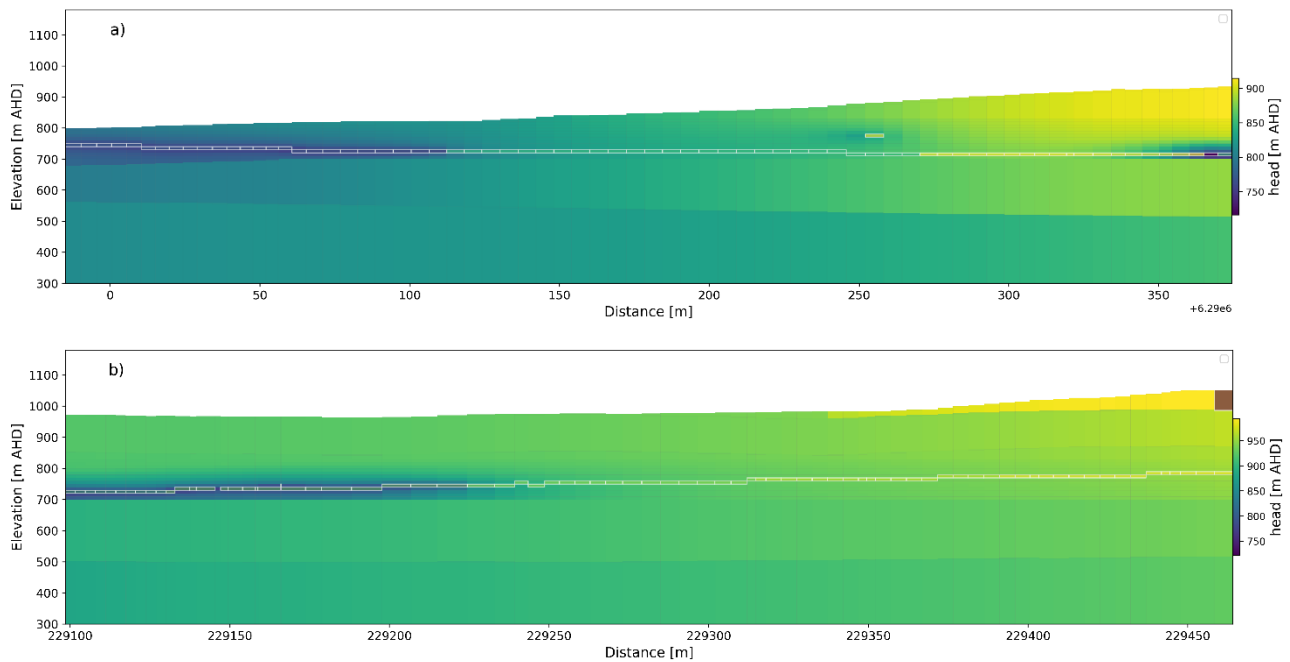
Notes: The vertical conductivity presented in the table corresponds to the base realisation. The parameter was allowed to vary during the estimation of model uncertainty.

* A constant water stage of 785.54 mAHD was used.

4.6.6 Representation of project tunnels

During construction, the project tunnels were simulated using the drain (DRN) package of MODFLOW. This allows representation of freely drained tunnels, with no mitigation measures, which is a conservative representation from an impact prediction perspective. The drain elevation for each individual cell was set to the bottom of the tunnel at its lowest position within the cell.

The first drain cells representing tunnels were applied to the model in stress period 39, corresponding to July 2026. Additional drains representing tunnels were progressively added in each subsequent stress period, following the excavation progress as specified in the project design documents supplied to EMM. Figure 4.12 shows cross-sections of the tailrace and headrace tunnels at stress periods 45 and 47, respectively. The cross-sections are coloured by base realisation modelled heads, with active dewatering visible in blue. The active drain shown at the right boundary of Figure 4.12(a) represents the drainage at the Pressure shaft (Figure 6.9 shows details of the tunnel structures).

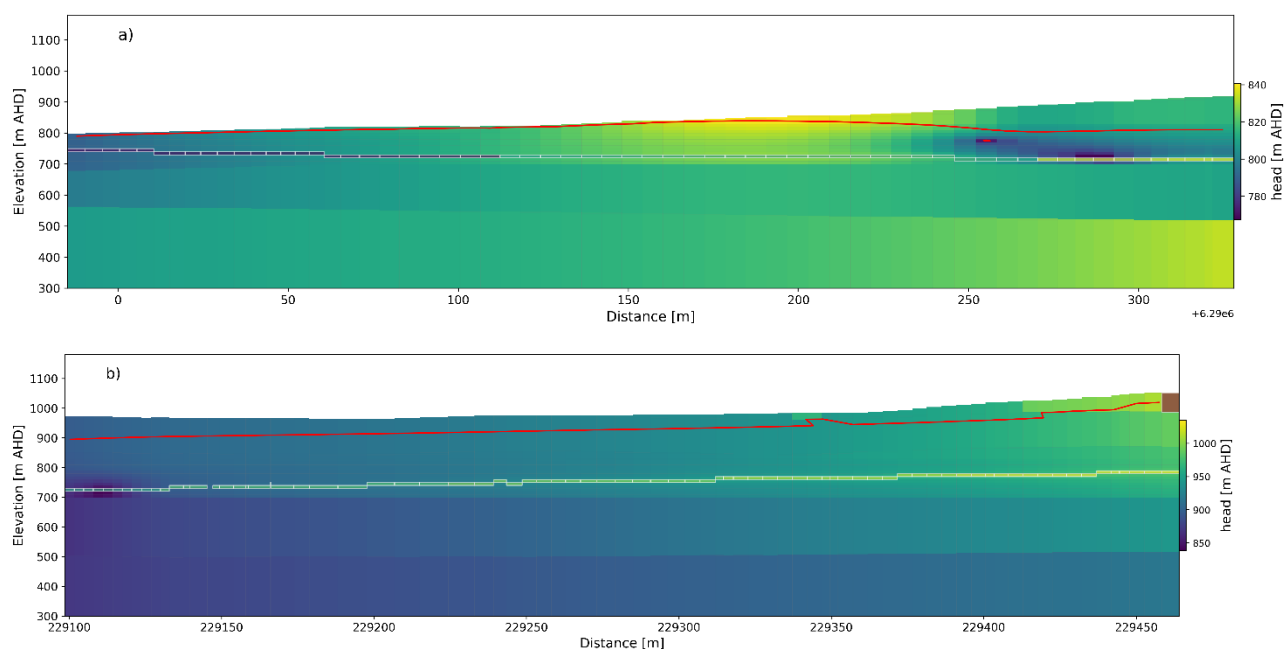


Notes: Thin white lines represent the set of tunnels to be excavated (DRN package cells).
Modelled heads correspond to the base realisation

Figure 4.12 DRN cells representing the tailrace and headrace tunnels

The drains remain active throughout the construction phase of the project, which in the model extends until the end of stress period 54, corresponding to the end of June 2030.

The operation phase of the project is represented in the model from stress periods 56 to 66, corresponding to the period between July 2030 and the end of 2110. During this time, the headrace and tailrace tunnels, as well as the powerhouse are planned to carry water under pressure, with a head gradient ranging between the elevations of the water levels in the upper and lower reservoirs (1,035 to 785.54 mAHD respectively). This pressure gradient was simulated using GHB cells along the tunnel alignment, with stage elevation linearly interpolated along the tunnel chainage. The shaft and surge pressure towers are also planned to be filled with water during the operation phase. To simulate these under pressure conditions, the GHB package was used with a head of 1,035 mAHD, representing the upper reservoir level. Additionally, during this phase, the drains representing underground structures to be kept dry were kept active until the end of operations (i.e. stress period 66). For simplicity, a constant GHB conductance was used. Figure 4.13 shows cross-sections of the tailrace and headrace tunnels at stress period 62 (i.e. during the operation phase), with model cells coloured by modelled hydraulic head, and the modelled watertable elevation presented as a red line. The higher modelled head along the tunnel relative to the surrounding rock is evident.



Notes: The white squares represent the tunnel cells.
The red line represents the modelled watertable.
Modelled heads correspond to the base realisation.

Figure 4.13 GHB cells representing the tailrace and headrace tunnels during the operation phase of the project

The post-operation phase of the project is represented from stress period 67 and onwards, corresponding in the model to the year 2111 and beyond. This phase spans 500 years in the model and ends in steady state for the representation of long-term equilibrium. During this phase, the tunnels are planned to be closed, allowing them to naturally fill as the watertable rises. No induced drainage or pumping is planned to occur during this phase of the project. For this reason, this phase was represented by removing all previously acting boundary conditions on the tunnel cells, allowing them to equilibrate with the surrounding formation.

4.6.7 Representation of the upper reservoir

The simulation of the upper reservoir in the model includes the simulation of three main components: building the earth dam that will give shape to the reservoir, excavating a small portion of the mountain to enlarge the volume of the reservoir, and creating the reservoir lake.

The upper reservoir was represented only in the predictive model, as the current state of the mountain was used during history matching. In the predictive model, the DISU package was modified to reflect the geometry of the model cells surrounding the upper reservoir area. For these cells, the model allows properties to be “swapped” — from “air” to “dam” for the dam scenario, or to assign a RIV boundary condition extending vertically to the appropriate depth for the mountain scenario. For cells in the dam area, the top of model layer 1 was set at the elevation of the planned dam, while its bottom was the current surface elevation. For the cells in the mountain excavation area, the top of layer 1 was set at ground level, but its bottom was set at the base of the planned reservoir excavation. That way, when swapped, the 3D geometry of the materials where the hydraulic properties change match the planned 3D geometry of the project.

The starting hydraulic properties of the portion of the dam corresponding to “air” before construction, were represented with a horizontal and vertical hydraulic conductivity of 10,000 m/day, and a specific yield of 1.0 (or 100%), using the time-variant materials (TVM) package of MODFLOW. These properties are modified starting in stress period 39, or since July 2030 in the model, using the same TVM package, assigning a horizontal and vertical hydraulic conductivity of 1×10^{-5} m/d to the dam material. The specific yield and specific storage of the material were not modified to avoid an issue where MODFLOW sharply raises the water level in cells where the volume of water is maintained but the storage capacity drops.

In the same stress period, a RIV boundary condition was applied to the cells representing the reservoir, with a head of 1,035.0 mAHD. The streambed conductance of the cells was calculated individually using a vertical hydraulic conductivity of 0.1 m/day and streambed thickness of 1 m. The RIV boundary condition remained active until the end of stress period 66, or modelled end of 2110. In stress period 67, or beginning of 2111, the reservoir is planned to remain dry, opening a drain at the bottom that will allow it to freely evacuate any runoff. This condition was represented in the model placing DRN cells at the base of the reservoir.

4.6.8 Representation of the Metromix Quarry

The Metromix Quarry was represented using a DRN boundary condition, with estimates of pit depths, extent and duration based on publicly available information. The base of the pit was represented with stage at 905 mAHD from the beginning of the historical period of the numerical model (including the initial steady state in stress period 2), up to the end of the year 2026. Since the beginning of 2027, the base of pit was set to decrease linearly over time, down to 885 mAHD at the end of 2028. Since the beginning of 2029, the base of the pit remained unchanged at 885 mAHD, with the quarry conservatively assumed to remain drained at this level in perpetuity.

4.7 Hydrostratigraphy

The study area is divided into three stratigraphic units, generally constrained by similar geological origin and expected hydraulic characteristics (i.e. groundwater quality, hydraulic conductivity, storage and potential yield). These are:

- Lambie Group
- Bathurst Batholith
- Sydney Basin.

Each stratigraphic unit is further divided into two HSUs, comprising a connected deep and shallow groundwater system (resulting in six HSUs). The shallow groundwater system is characterised by higher weathering and fracturing (compared to the deep groundwater system).

Based on baseline investigations, the upper 120 m of each stratigraphic unit was inferred as the shallow groundwater system, as indicated by:

- noted weathering of the rock matrix (i.e. moderately to extremely weathered)
- consistent fracturing (i.e. rock quality designations generally below 75%).

The shallow groundwater system is unconfined and supports the phreatic watertable. Groundwater receptors at/near surface (i.e. terrestrial and aquatic GDEs, shallow water supply bores and shallow subterranean GDEs) receive groundwater from the shallow groundwater system.

The deep groundwater systems underlie the shallow groundwater system within each stratigraphic unit and are laterally connected (as in the shallow groundwater systems). The deep groundwater systems are unconfined to semi-confined and are intercepted by most of the groundwater affecting project infrastructure (i.e. the powerhouse complex and power waterways).

The modelled HSU zones are shown 3-dimensionally in Figure 4.14 to Figure 4.15. The zones are as follows:

- Zone 1: Sydney Basin Sedimentary regolith.
- Zone 2: Rydal Formation regolith.
- Zone 3: Gibbons Creek Sandstone regolith.
- Zone 4: Hartley Suite Pluton regolith.
- Zone 5: Sydney Basin Sedimentary.
- Zone 6: Rydal Formation.
- Zone 7: Gibbons Creek Sandstone.
- Zone 8: Hartley Suite Pluton.

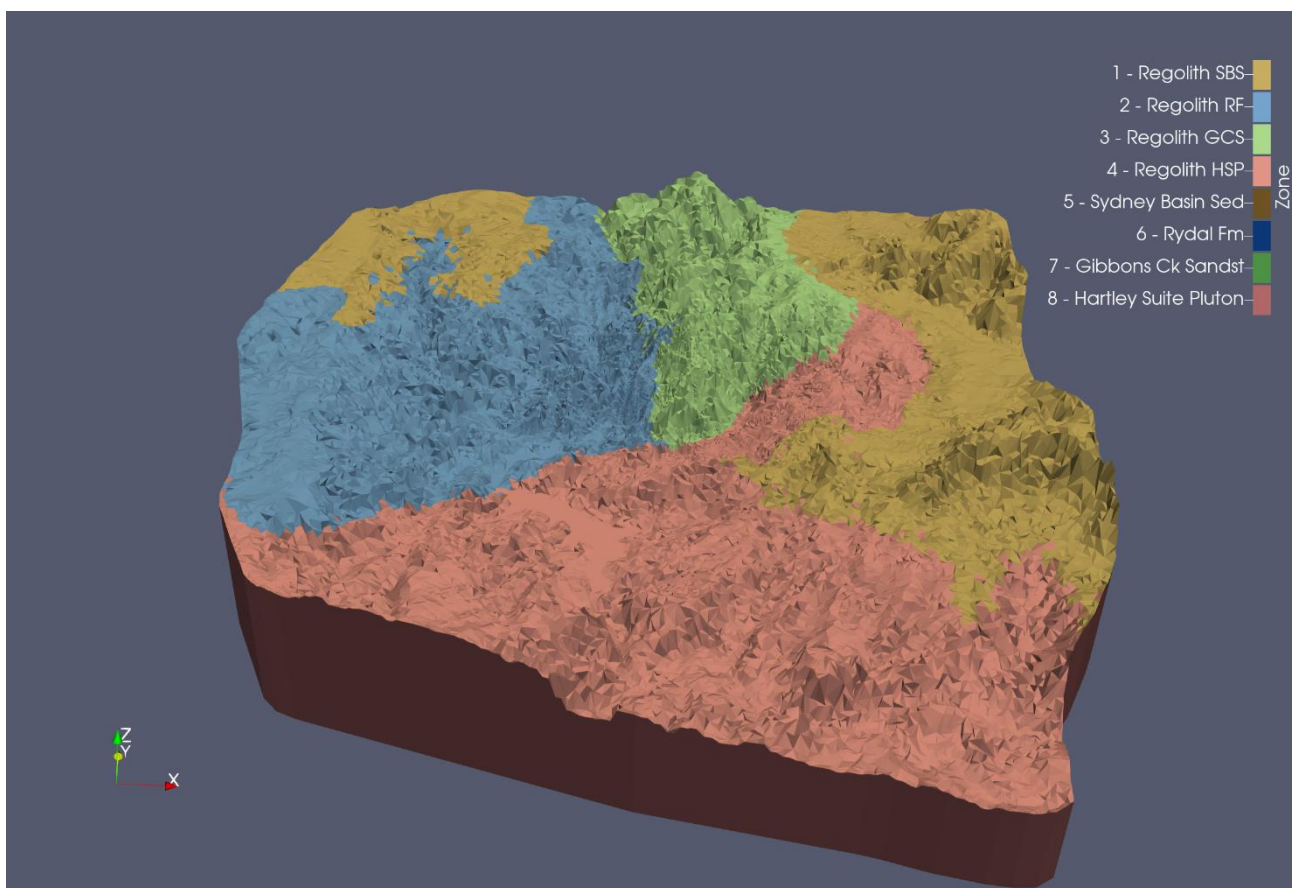
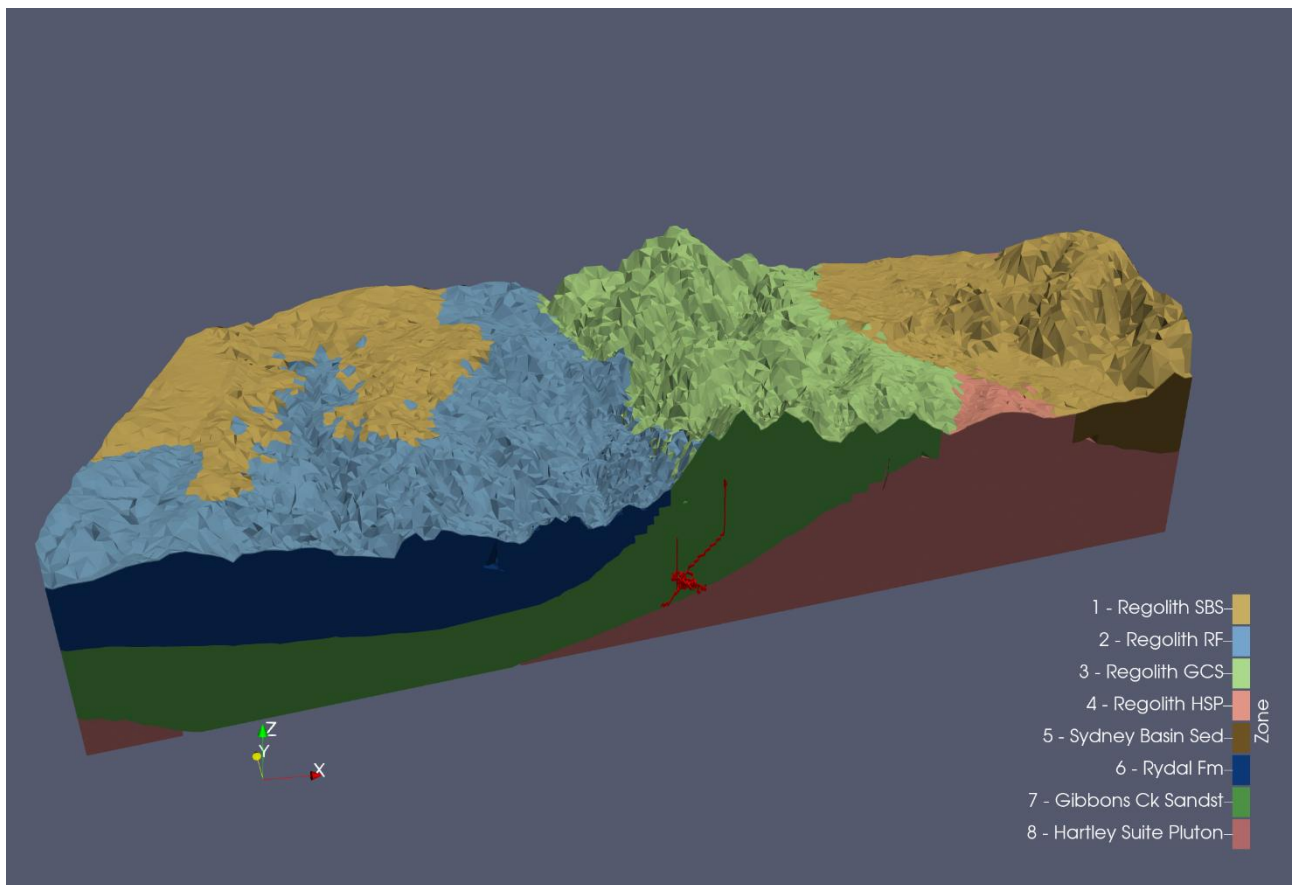


Figure 4.14 Geological parameter zones (all layers)



Notes: The red figure represents the tunnel structures.

Figure 4.15 Geological parameter zones (all layers), sliced vertically

5 History-matching

5.1 Approach and targets

Monitoring of hydraulic heads (see Chapter 3) were used to create a set of “targets” for the history-matching process (refer to Figure 5.1). Hydraulic head data were simplified to monthly averages, with the average groundwater head at each location used as an “absolute head” value. Additionally, each point of the series at each location was also converted to “head change” relative to the average, allowing the assignment of independent weights to the “absolute head” and the magnitude of oscillations for each location. The weights of absolute heads and head change were assigned based on preliminary estimations of contribution to the objective function and adjusted during the history matching process based on preliminary results.

Additional history-matching targets were adopted. These included:

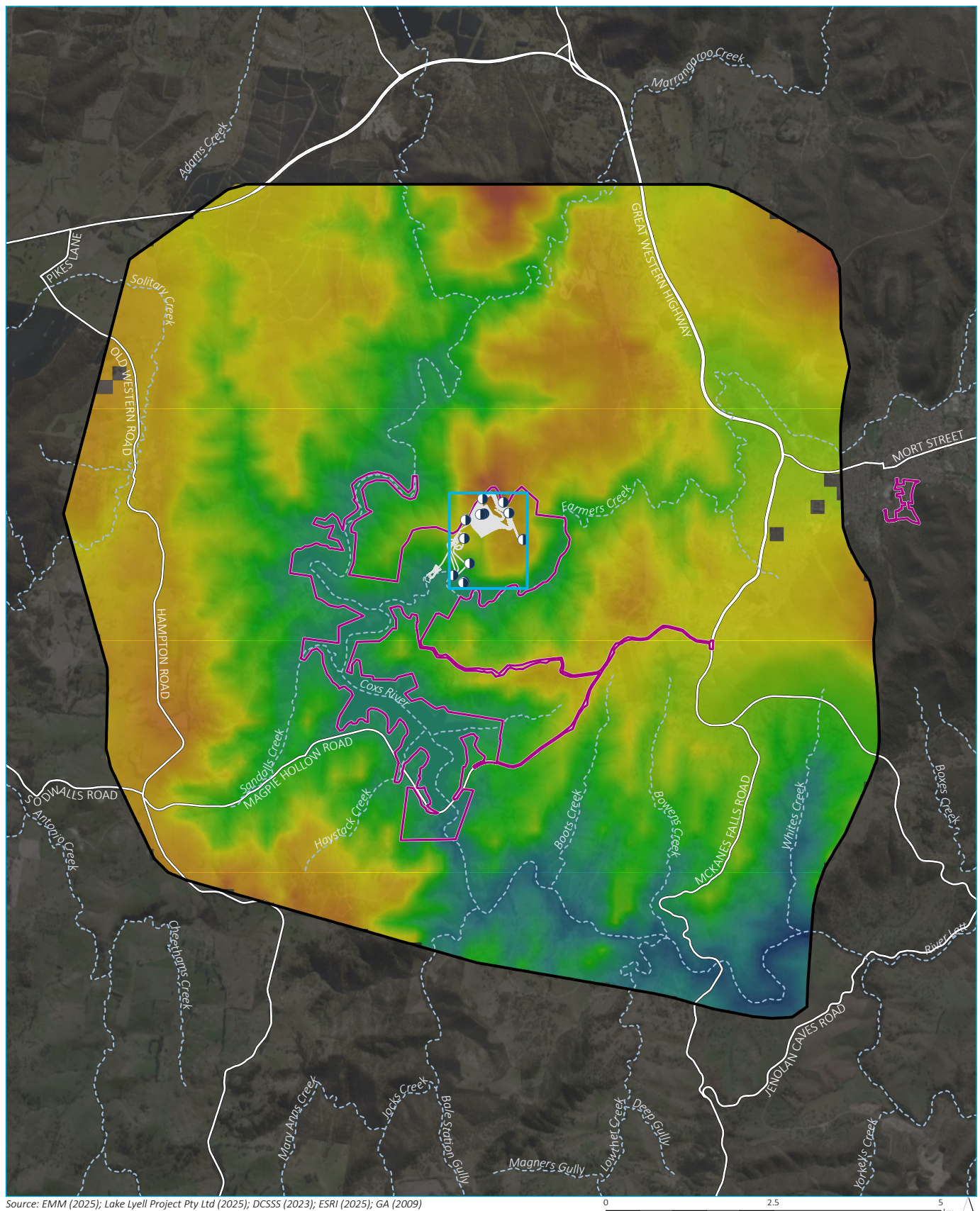
- vertical head differences at nested monitoring locations
- stream flow and level data (soft targets, only qualitatively assessed).

No measurement noise was included.

PESTpp-IES was used to automate the history-matching process. An ensemble of 300 parameter realisations was employed to address non-uniqueness with regard to input parameters and the resulting model uncertainty. The realisation whose calibrated parameters were closest to the mean parameter vector of the ensemble is referred to as the base realisation.

Prior distributions of HSU parameters were informed by available field testing results (including slug tests, drill stem tests and packer tests) and literature values. Further discussion is presented in Chapter 5 of the GIA.

The history-matching period was designed such that it would commence at the beginning of 2022, one year prior to the earliest monitoring data available. A steady-state stress period was defined at the beginning of this period using averaged recharge rainfall and evapotranspiration between the beginning of 1960 and the end of 2021. This provides a stable, internally consistent, initial set of hydraulic heads for the subsequent transient stress periods. Four transient quarterly stress periods were then simulated during the year 2022, providing a year of transient simulation prior to the first groundwater monitoring data available for history-matching, in 2023.

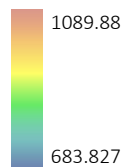


Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)

KEY

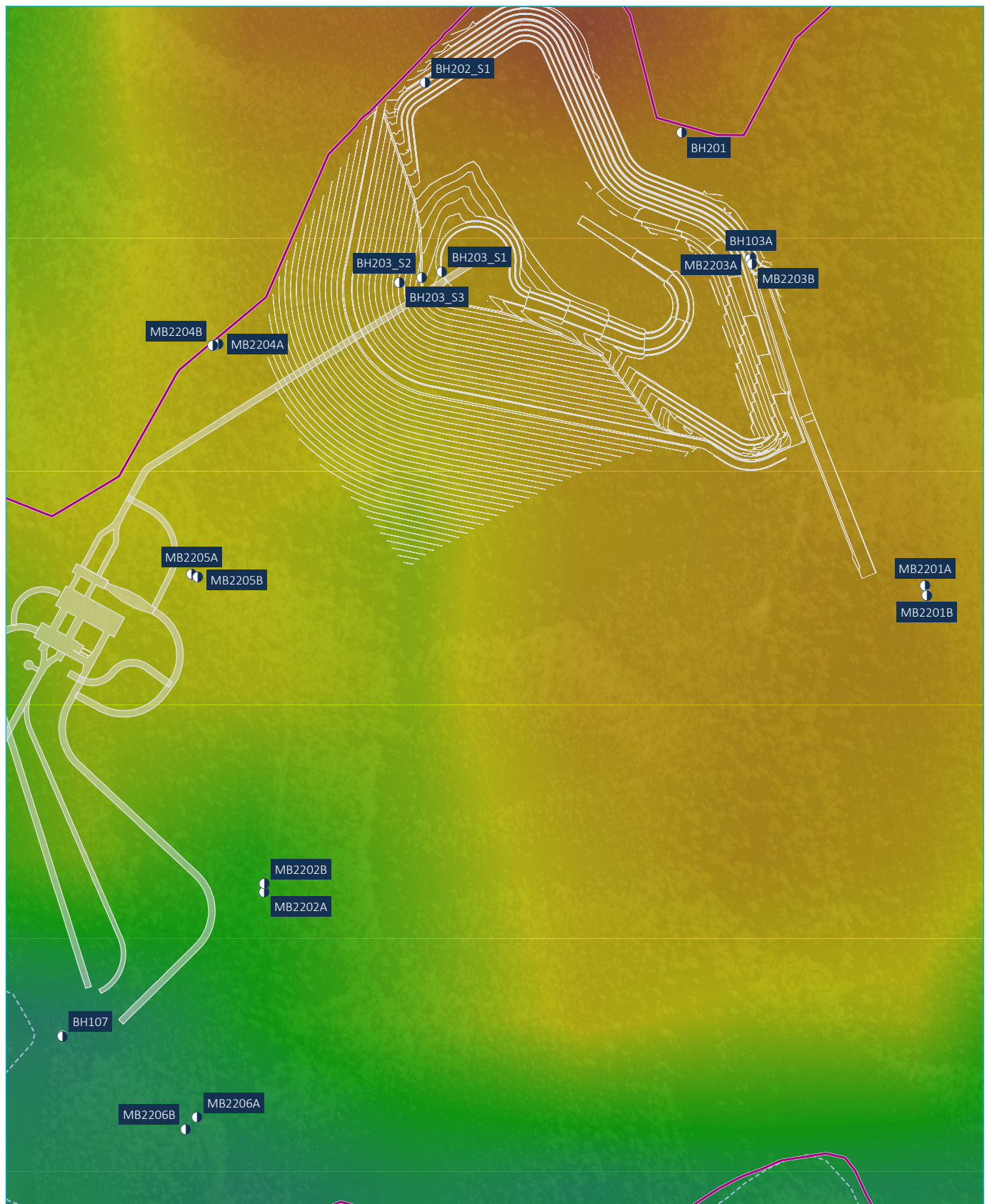
- Project area
- Site target
- Key project infrastructure
- Model extent
- Existing environment
- Major road
- Named watercourse

Water table elevation (m AHD)



History-matching targets

Lake Lyell PHES
Groundwater Modelling Report
Figure 5.1a

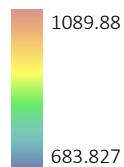


Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)

KEY

- Project area
- Key project infrastructure
- Site target
- Existing environment
- Named watercourse

Water table elevation (m AHD)



History-matching targets

Lake Lyell PHES
Groundwater Modelling Report
Figure 5.1b

5.2 Parameterisation

5.2.1 Hydraulic parameters

To parameterise the model, a stochastic but spatially invariant property field for each HSU was generated based on the parameter ranges presented in Table 5.1. This field was combined with a spatially variant field generated with kriging interpolation of pilot points to introduce heterogeneity. In this approach, the values assigned to the pilot points acted as multipliers rather than direct hydraulic property values. These multipliers are applied to the hydraulic parameters derived from the stochastic property field.

Pilot points were uniformly distributed across each HSU for all hydraulic properties. Each point was assigned a lower multiplier bound of 0.1, an upper bound of 10, and an initial value of 1. These pilot points were positioned at the top layer of each HSU (refer to Figure 5.2) and were then extrapolated laterally in the X–Y plane. As a result, no vertical variation was applied within each HSU. Pilot point covariance was applied in field generation, with spatial correlation length of 2,000 m. Uncorrelated parameter standard deviations were assigned based on conceptual bounds.

Eight “geological parameter zones” were established across the model domain, as shown on Figure 4.14 to Figure 4.15. The zones were based on a 3D geological model prepared for this purpose by EMM, which was created based on drilling investigations (refer Chapter 5 of the GIA) and the NSW seamless geology dataset (Colquhoun et al. 2022).

Each geological zone was simulated with a different set of hydraulic properties (horizontal hydraulic conductivity [Kh], vertical hydraulic conductivity [Kv], specific storage [Ss], and specific yield [Sy]). The geological zones are as follows:

- Zone 1: Sydney Basin Sedimentary regolith.
- Zone 2: Rydal Formation regolith.
- Zone 3: Gibbons Creek Sandstone regolith.
- Zone 4: Hartley Suite Pluton regolith.
- Zone 5: Sydney Basin Sedimentary.
- Zone 6: Rydal Formation.
- Zone 7: Gibbons Creek Sandstone.
- Zone 8: Hartley Suite Pluton.

Zones 5 to 8, which represent consolidated sediments or hard rock, were simulated with depth-dependent Kh and Kv . An exponential equation whereby Kh linearly decreases with depth was used to represent the tightening of fracture apertures with depth. The equation for depth-dependence was:

$$Kh = Kh_0 \times e^{slope \times depth}$$

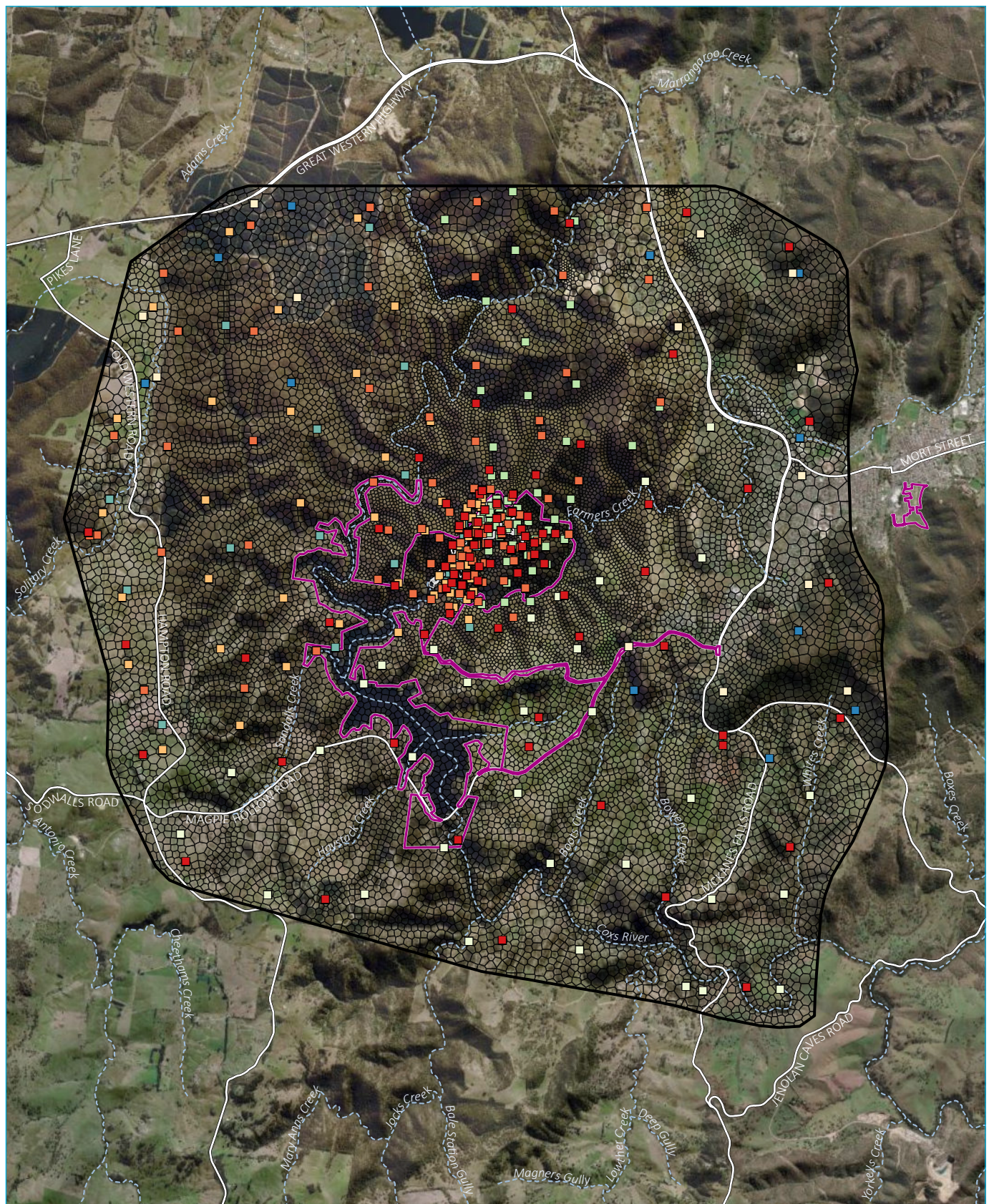
Where Kh_0 is Kh at ground surface. The equation was used in a way that allows Kh to decrease linearly adopting a constant slope coefficient equal to -1%.

Vertical hydraulic conductivity (K_v) was setup as a multiplier of the K_h value for each cell, with a multiplier factor for each geological zone. The K_v factor for each geological zone was allowed to vary within narrow bounds. The simple formula used to calculate actual K_v (per cell) is:

$$K_v = K_h \times K_{v_factor}$$

Table 5.1 Mean hydraulic parameter of the history-matched ensemble

Zone	Name	Single value or depth-dependent	K_h (m/day)	K_v (factor of K_h)	S_y	S_s (m ⁻¹)
1	Sydney Basin Sedimentary regolith	Single value	2.6	1.1	9.7×10^{-2}	4.7×10^{-2}
2	Rydal Formation regolith	Single value	1.1	0.77	9.1×10^{-2}	1.2×10^{-2}
3	Gibbons Creek Sandstone regolith	Single value	1.1	1.1	4.4×10^{-2}	2.3×10^{-2}
4	Hartley Suite Pluton regolith	Single value	5.4×10^{-2}	1.5	3.9×10^{-2}	2.4×10^{-3}
5	Sydney Basin Sedimentary	Depth-dependent	2.0×10^{-2}	5.7	6.0×10^{-2}	2.5×10^{-4}
6	Rydal Formation	Depth-dependent	1.1×10^{-2}	3.4	3.1×10^{-2}	2.0×10^{-6}
7	Gibbons Creek Sandstone	Depth-dependent	1.1×10^{-3}	0.62	2.0×10^{-2}	1.3×10^{-6}
8	Hartley Suite Pluton	Depth-dependent	3.3×10^{-5}	0.38	5.4×10^{-2}	2.3×10^{-7}



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)

KEY

- Project area
- Key project infrastructure
- Model mesh
- Model extent
- Existing environment
- Major road
- Named watercourse

Pilot point zone

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8

History-matching pilot points

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Figure 5.2

5.2.2 Watercourses

Streambed (riverbed) conductance for the RIV package representing natural drainages and classified by zones (refer to Table 4.3) was included in the set of parameters allowed to vary during history-matching. The resulting properties for the base parameter set are listed in Attachment C of this report.

5.3 Performance

PESTpp-IES was run several times during the history-matching process, with manual modification and resampling parameters to ensure consistency with the hydrogeological conceptual model. A final IES run was performed to obtain a history-matched parameter ensemble; this was filtered to remove poorly performing realisations. The final ensemble comprises 283 realisations.

5.3.1 Statistical measures

History-matching performance was evaluated using several metrics, including the mean residual, $\frac{1}{n} \sum_{i=1}^n (h_m - h_s)_i$; the mean absolute residual, $\frac{1}{n} \sum_{i=1}^n |(h_m - h_s)_i|$; the minimum residual, $\min \left(\frac{1}{n} \sum_{i=1}^n (h_m - h_s)_i \right)$; the maximum residual, $\max \left(\frac{1}{n} \sum_{i=1}^n (h_m - h_s)_i \right)$; and the scaled root mean square (SRMS) error, given as a percentage, $\frac{100}{\Delta h} \sqrt{\frac{1}{n} \sum_{i=1}^n [w_i (h_m - h_s)_i]^2}$.

Where:

- h_m is the measured hydraulic head at location/time i .
- h_s is the modelled hydraulic head at location/time i .
- n is the number of measurements used in the history-matching dataset.
- Δh is the range of measured hydraulic heads across the model domain.
- w_i is the statistical weighting applied to measurement i . In this project, a value of 1 was applied to all measurements.

The base realisation performance statistics of the targets formulated as transient head, average head and head-change are presented in Table 5.2. For the site bores, unweighted hydraulic head SRMS is ~1.4%, with an average absolute residual of under 1.4 m. Transient model performance is shown in Section 5.3.2.

Table 5.2 Base realisation history-matching performance statistics

	Average residual (m)	Average absolute residual (m)	Minimum residual (m)	Maximum residual (m)	SRMS
Transient head	0.33	1.37	-5.18	4.74	0.74%
Mean head	0.39	1.15	-2.07	4.03	0.61%

Figure 5.3 shows a histogram of SRMS values for transient head targets from the ensemble of calibrated models. The SRMS distribution is approximately normal, centred around 1.0%, with most ensemble realisations falling between 0.8% and 1.2%, confirming the overall good fit of the ensemble to the measured heads. The dashed blue line indicates the SRMS of the base realisation (0.74%), which is lower than the ensemble mean. This suggests the base realisation provides a slightly better fit to measured heads than the average ensemble member.

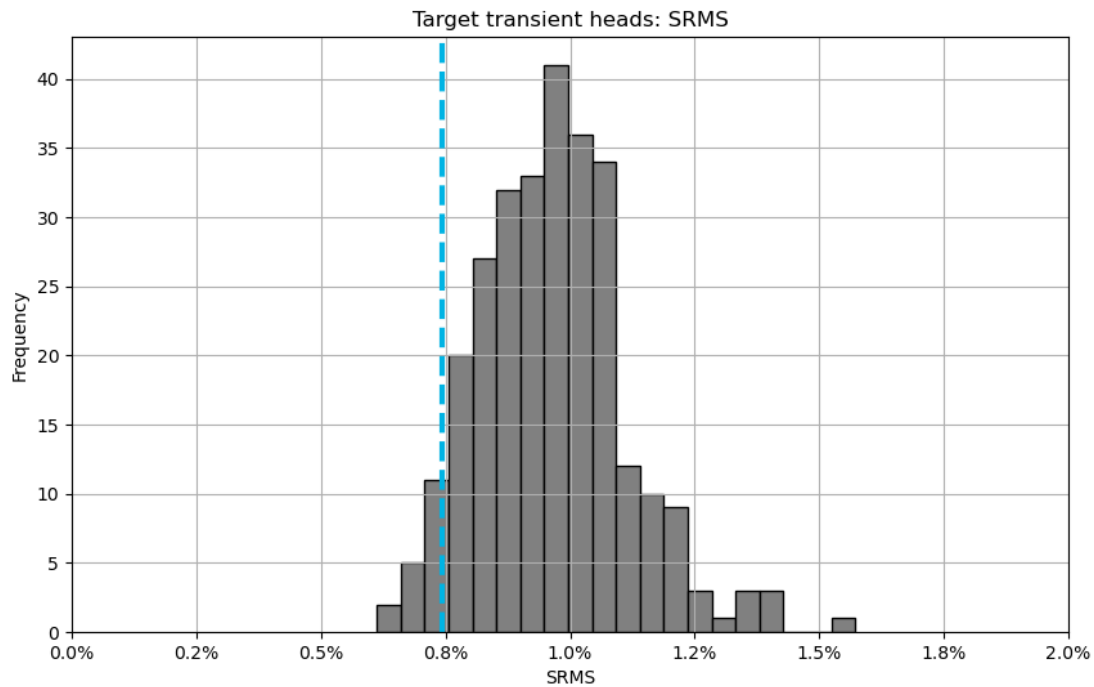


Figure 5.3 SRMS distribution for hydraulic head calibration

A scatter plot of modelled versus measured transient head targets is presented in Figure 5.4. The data show no systemic bias and exhibits a strong correlation for both the base realisation and the ensemble, with values generally clustering near the 1:1 line of perfect fit. This indicates that the model effectively captures regional groundwater levels across the full range of observations.

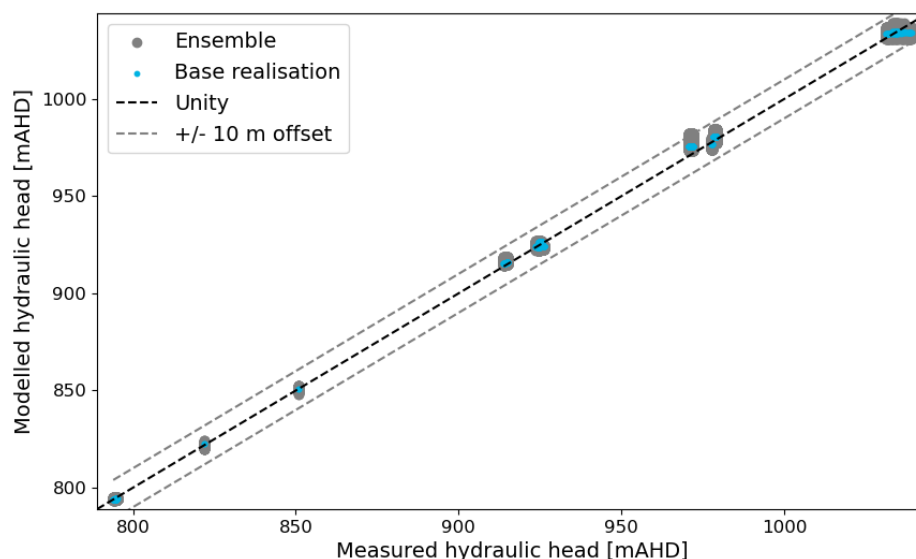


Figure 5.4 Transient hydraulic head scatter plot

5.3.2 Transient hydraulic heads

Hydrographs for selected locations, displaying both modelled and measured hydraulic head, are illustrated in Figure. A comprehensive set of hydrographs, for all the site monitoring locations, is provided in Attachment B. Only a relatively short period of monitoring is available from the site monitoring bores due to their recent installation.

Monitoring bore BH107 is the monitoring bore with the longest data record; it is located very close to Lake Lyell, down slope from the project site. The bore lies within a model cell adjacent to a lake cell (represented with the river boundary condition), and a relatively good match, with replication of seasonal variations, is believed to have been achieved considering its location.

Bore BH201 is located near the proposed upper reservoir. The ensemble simulation results for observation point BH201 show good agreement with the measured groundwater head data. The measured values generally fall within the range of the ensemble realisations, indicating that the model captures the observed variability and trends. The base realisation tracks slightly below the measured heads in the latter part of the simulation period but remains well within the ensemble spread, suggesting no significant bias. The narrow ensemble spread in the early simulation period reflects low predictive uncertainty, while the broader spread toward the end (2024 to 2025) likely reflects increased uncertainty associated with future conditions. Overall, the ensemble provides a credible representation of model uncertainty, and the base realisation offers a reasonable approximation of measured heads.

Bores MB2203a and MB2205b exhibit a less satisfactory match between measured and simulated heads compared to BH107. For MB2203a, measured groundwater levels consistently fall below the ensemble spread throughout the observation period. This discrepancy may be attributed to local-scale heterogeneities, such as preferential flow paths, that are not captured by the regional-scale model. In contrast, for MB2205b, the simulated values initially deviate from the measured heads but begin to fall within the ensemble range toward the latter part of the observation period (October 2024 to January 2025). This may indicate a temporal overestimation of recharge in the vicinity of the bore.

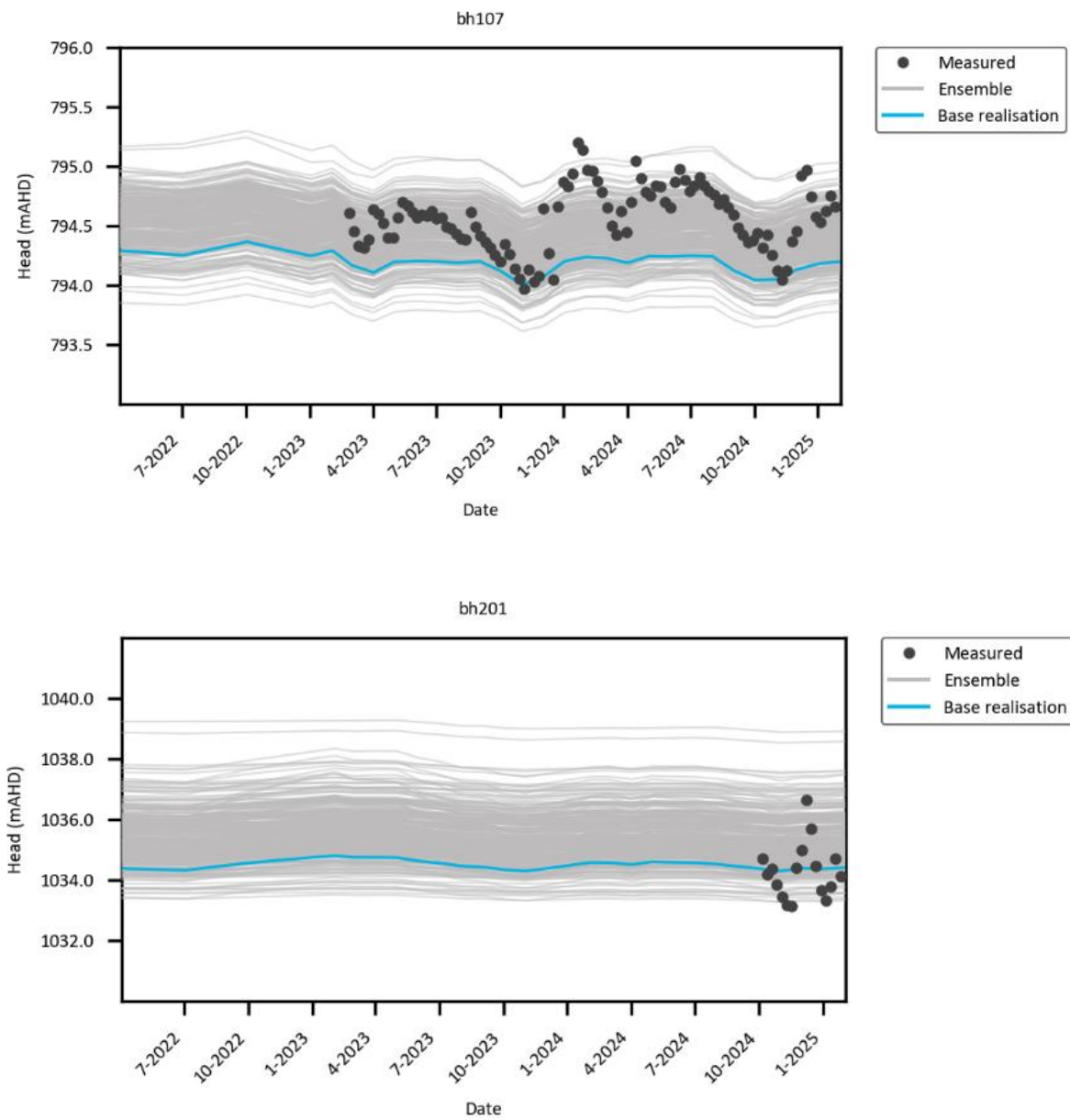


Figure 5.5 Selected hydrographs over the history-matching period

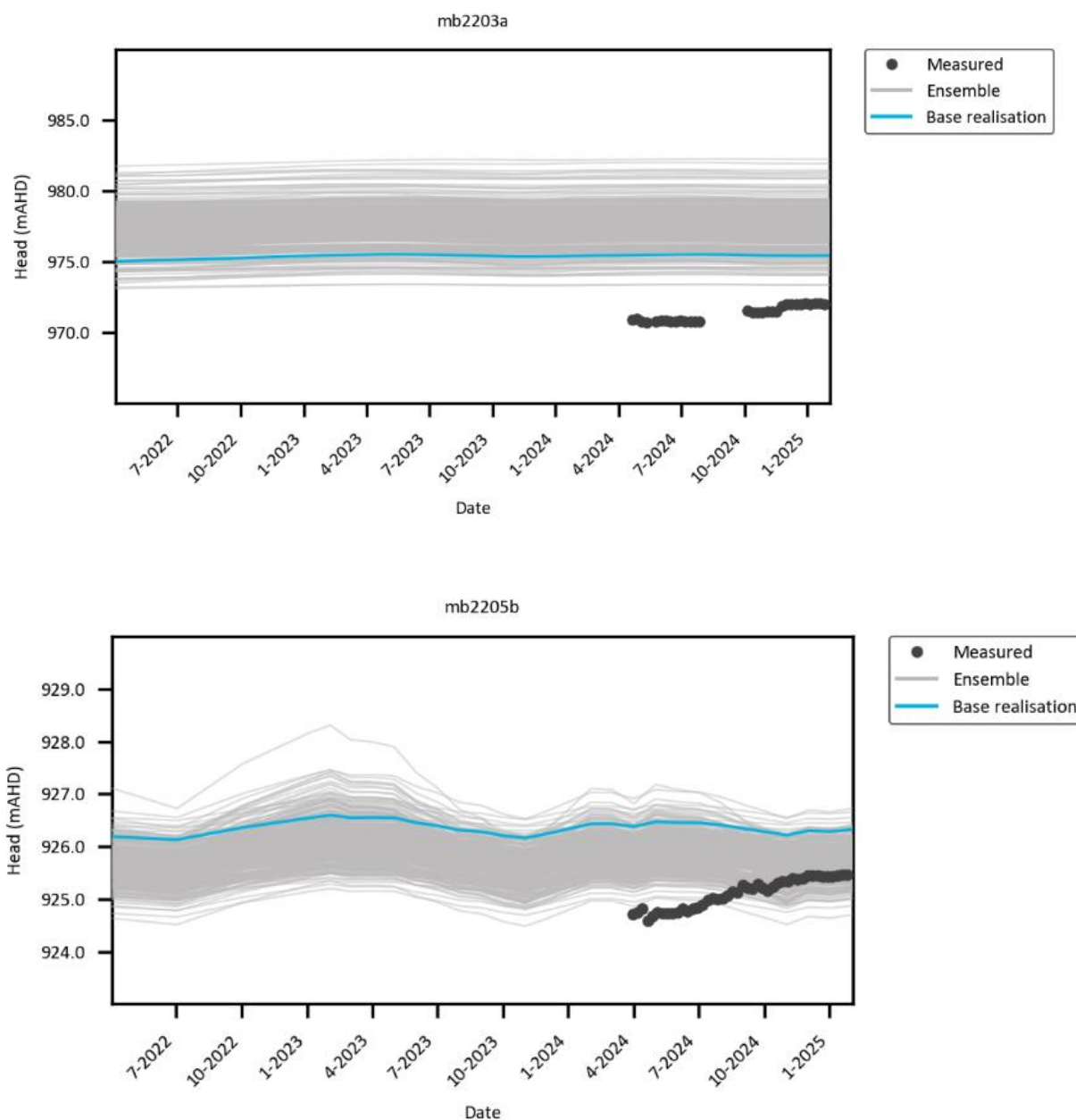
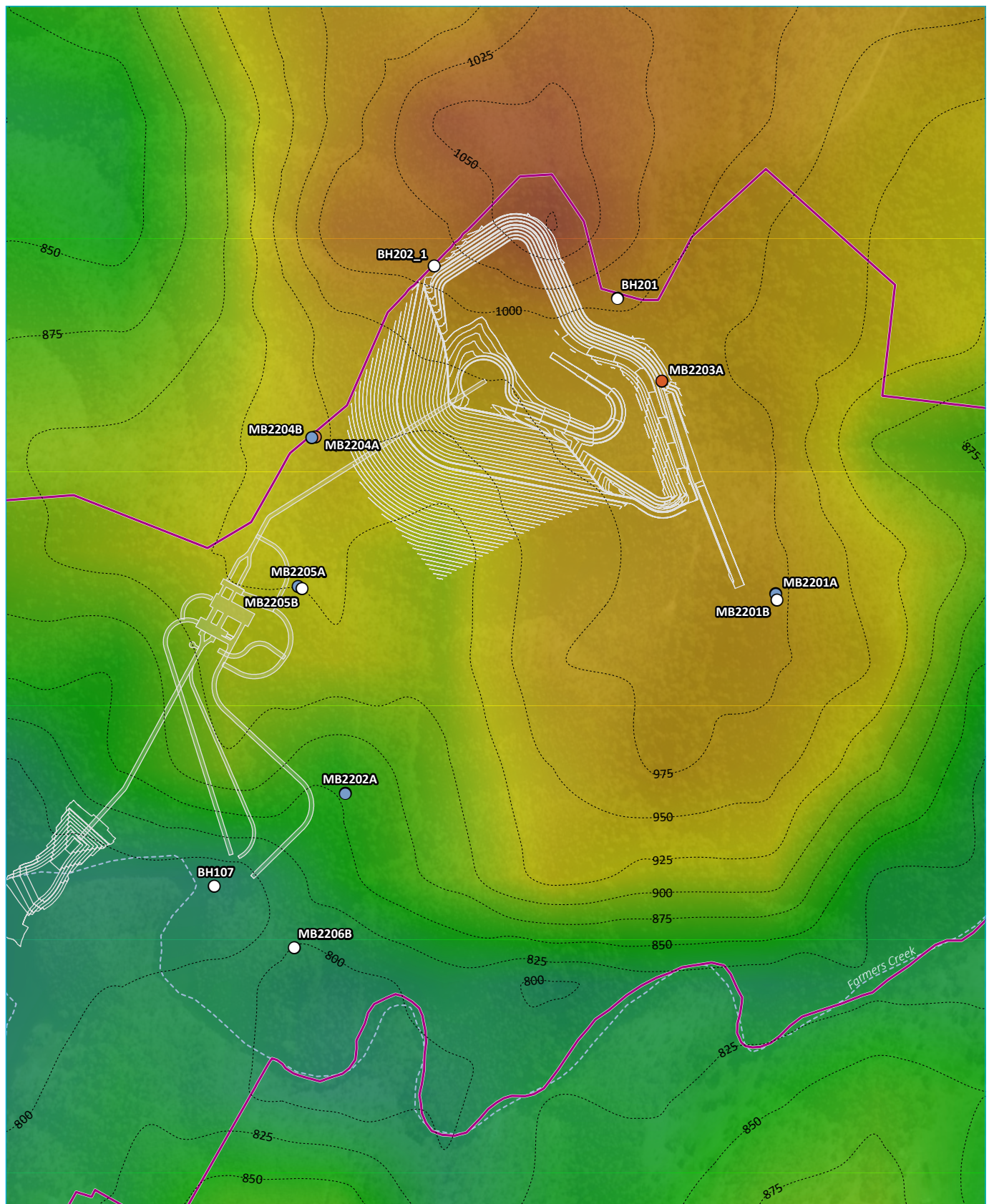


Figure 5.5 Selected hydrographs over the history-matching period

5.3.3 Regional watertable

Figure 5.6 illustrates the modelled pre-project watertable for the base realisation, with target residuals coloured by value. The inferred groundwater flow direction within the model extent is locally away from topographic highs, and overall in a south-easterly direction, following the flow direction of Cocks River. The lowest watertable level is 689 mAHD, located where Cocks River exits the model.

The model replicates the limited available measured groundwater levels (as shown in Figure 5.6). Average residuals per bore range from -5.7 to 6.0 m. As seen in Figure 5.6, there are no visible spatial trends in the distribution of residuals, indicating no or minimal spatial bias.



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)

KEY

Project area

Key project infrastructure

Water table contour (25 m interval)

Water table elevation (m AHD)

1089.88

683.827

Target residual (m)

-5--1

-1- 1

1- 5

5- 10

Existing environment

Named watercourse

Modelled pre-project steady state water table elevation and target residuals (base realisation)

Lake Lyell PHES
Groundwater Modelling Report
Figure 5.6

5.4 Water balance

Table 5.3 presents the modelled pre-project steady state water balance of the base realisation as representative of the average behaviour of the water system prior to 2022. Rainfall recharge is the dominant input flux to the model, with only a very minor contribution from through flow at the boundaries (GHB package) and from lake leakage to the shallow groundwater system. Discharge occurs mainly through the ETS package in the model, representing evapotranspiration or minor drainage lines that were not explicitly simulated. Discharge to ephemeral and perennial watercourses (RIV package) also form part of the main discharge mechanisms in the simulation. Discharge to the Metromix Quarry via pit inflow is present but minimal in the context of the model's water balance.

The transient water balance for the “net” (in minus out) value from each of the water balance components in the model is displayed in Figure 5.7, at different vertical scales to account for variability in flux magnitude. As can be seen in the figure, recharge varies along time and relatively low in the middle of 2023. In response, evapotranspiration decreases (with less water available), along with stream and river leakage. Water being taken out of the model through GHB cells is relatively minor, but responds with the same trend as EVT, RIV and STR. Groundwater being removed from the model via DRN cells in the Metromix Quarry is relatively minor compared to the rest of the water balance components.

Table 5.3 Modelled steady state water balance (base realisation)

Component	In (ML/d)	Out (ML/d)
Rainfall recharge (RCH package)	23.5	-
Evapotranspiration (ETS package)	-	18.4
Drainage leakage and lake (RIV package)	1.15	8.10
General head boundary (GHB package)	2.50	0.65
Pit inflow to Metromix (DRN)	-	0.00487
Storate	0	0
Total	33.4	33.4

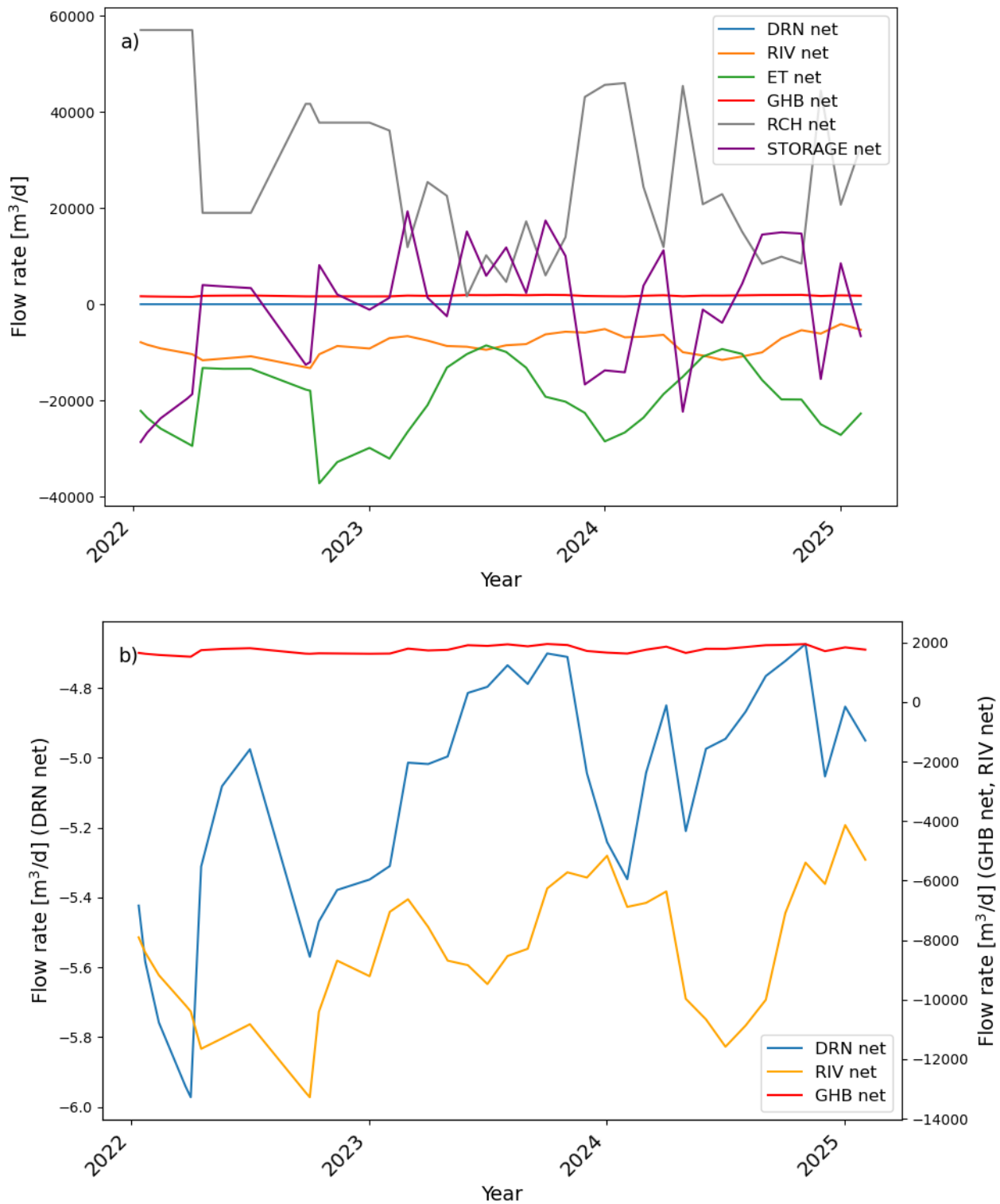


Figure 5.7 Transient water balance during the history-matching period; (a) shows all the water balance components, and (b) shows only DRN, RIV and GHB to appreciate better the fluctuation of the DRN fluxes

5.5 Numerical convergence

Figure 5.8 presents the numerical convergence performance of the transient model, excluding the warm-up period, by showing cumulative water balance error through the history-matching period. The mass balance closure error remains below 0.6% across the history-matching simulation. This is well within the <1.0% threshold recommended in Table 2-1 of the Australian Groundwater Modelling Guidelines (Barnett et al. 2012) for a Class 2 confidence level model, suggesting appropriate numerical convergence.

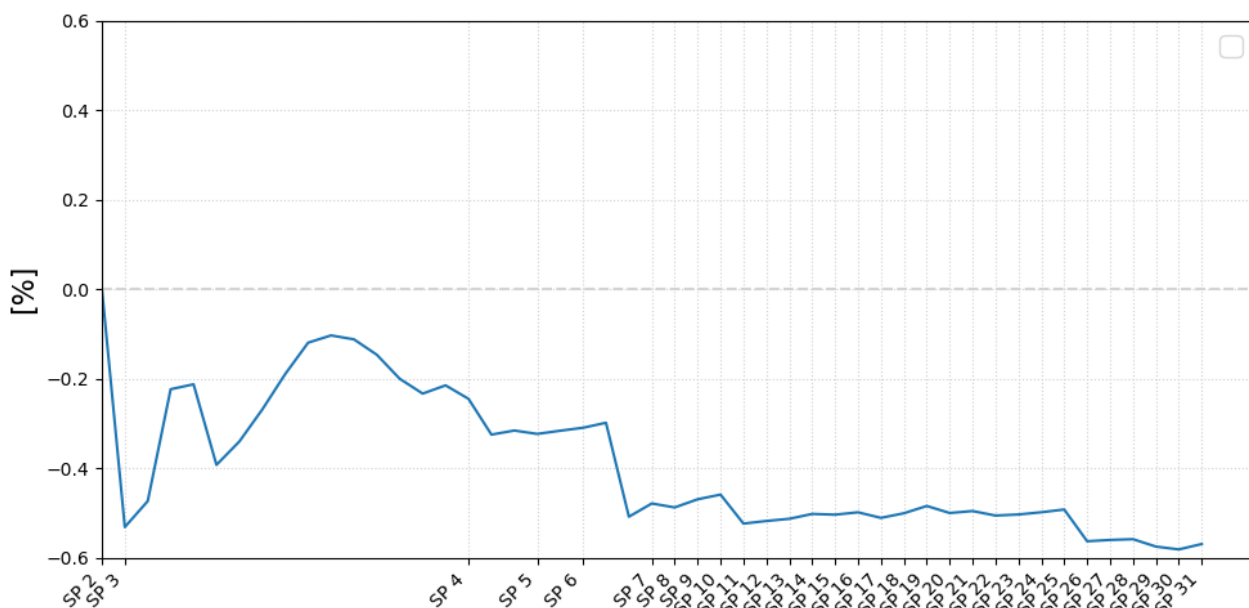


Figure 5.8 Transient model convergence performance

5.6 Adopted hydraulic properties

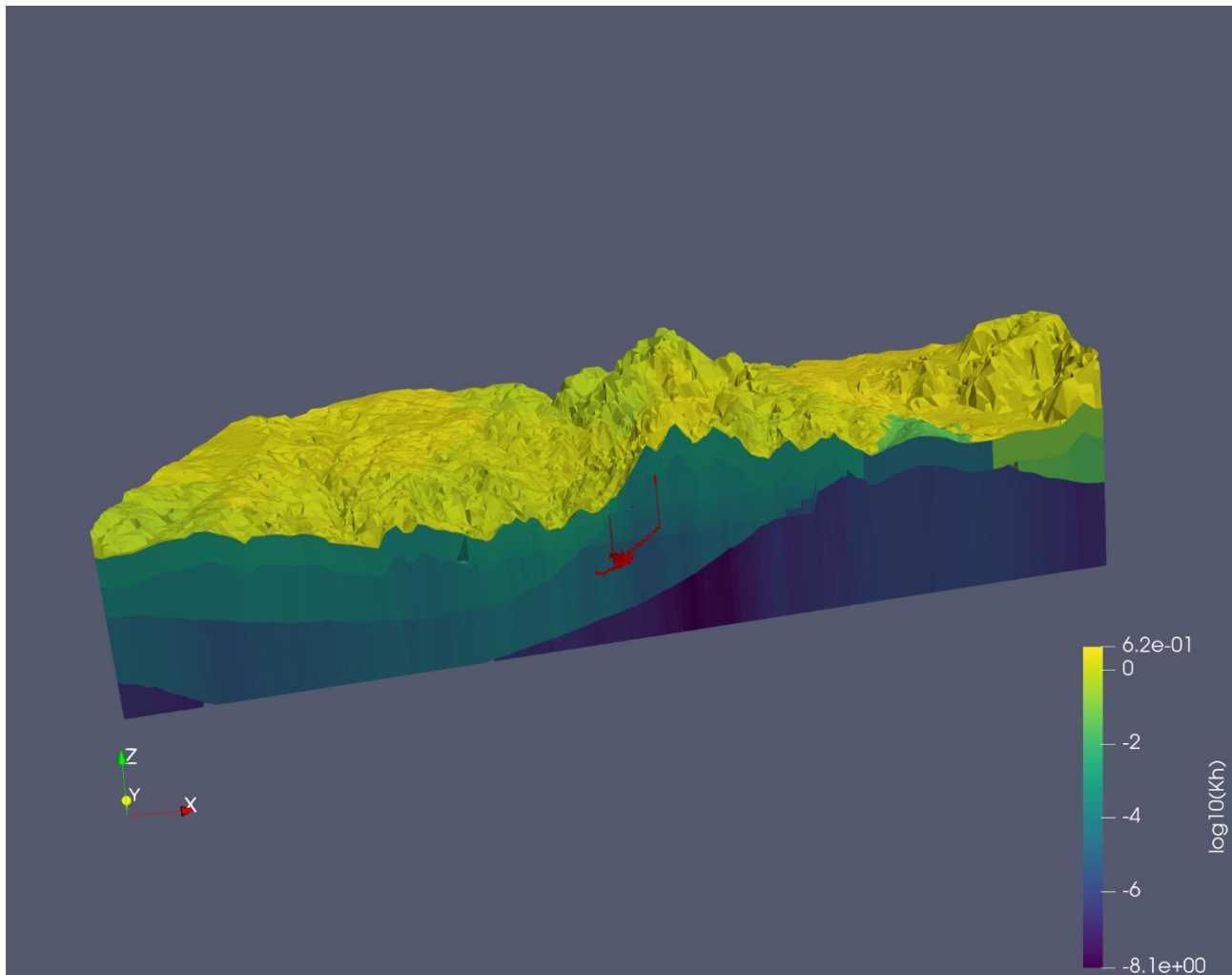
The PESTpp-IES history-matching process involves algorithmically assigning a value to each varied parameter for each realisation, running all realisations for one iteration, and then assigning new values to improve the match between modelled values and targets. In this case, an initial set of iterations was run first for a base set of parameters without pilot points (Kh , Kv , Sy , Ss , recharge, streambed conductance) finding a “calibrated” set of values for these parameters. This was followed by a set of iterations where base Kh , Kv , Sy and recharge were fixed, and replaced instead for pilot point multipliers for the properties. PESTpp-IES was run several times, with manual adjustment of parameters to assist with performance and consistency with the hydrogeological conceptualisation. A final iteration of IES was selected for the parameter ensemble, with the poorest performing realisations filtered out, resulting in an accepted ensemble of 104 realisations.

Histograms of values assigned to each of the history-matched model parameters are presented in Attachment C. To interpret the histograms, the parameter values assigned to each individual pilot point are tallied by frequency for three series:

- The ‘prior’ series is shown as a black outline, and shows the pre-history-matching property distribution, which was created by randomly sampling from the initial mean and standard deviation for the property and restricted by the allowed maximum and minimum values.
- The ‘posterior’ series is shown in grey, and shows the post history-matching property distribution, across all accepted realisations.

- The 'base realisation' series is shown in blue, and shows the distribution for the base realisation only, with the frequency on the right axis. This series gives an indication of heterogeneity per group, rather than the Gaussian distribution of an ensemble.

The spatial distribution of horizontal hydraulic conductivity is presented in Figure 5.9. Ensemble standard deviations are presented in Figure 5.10; these present a proxy for a history-matching sensitivity analysis. Smaller values show areas where hydraulic conductivity is constrained by the history-matching dataset; pilot points where history-matching is sensitive to this parameter. Conversely, larger standard deviations mean less history-matching parameter sensitivity.



Notes: The red figure represents the tunnel structures.

Figure 5.9 3D representation of the horizontal hydraulic conductivity (history-matched mean of $\log_{10}(Kh)$ (m/day), vertically sliced across the project area

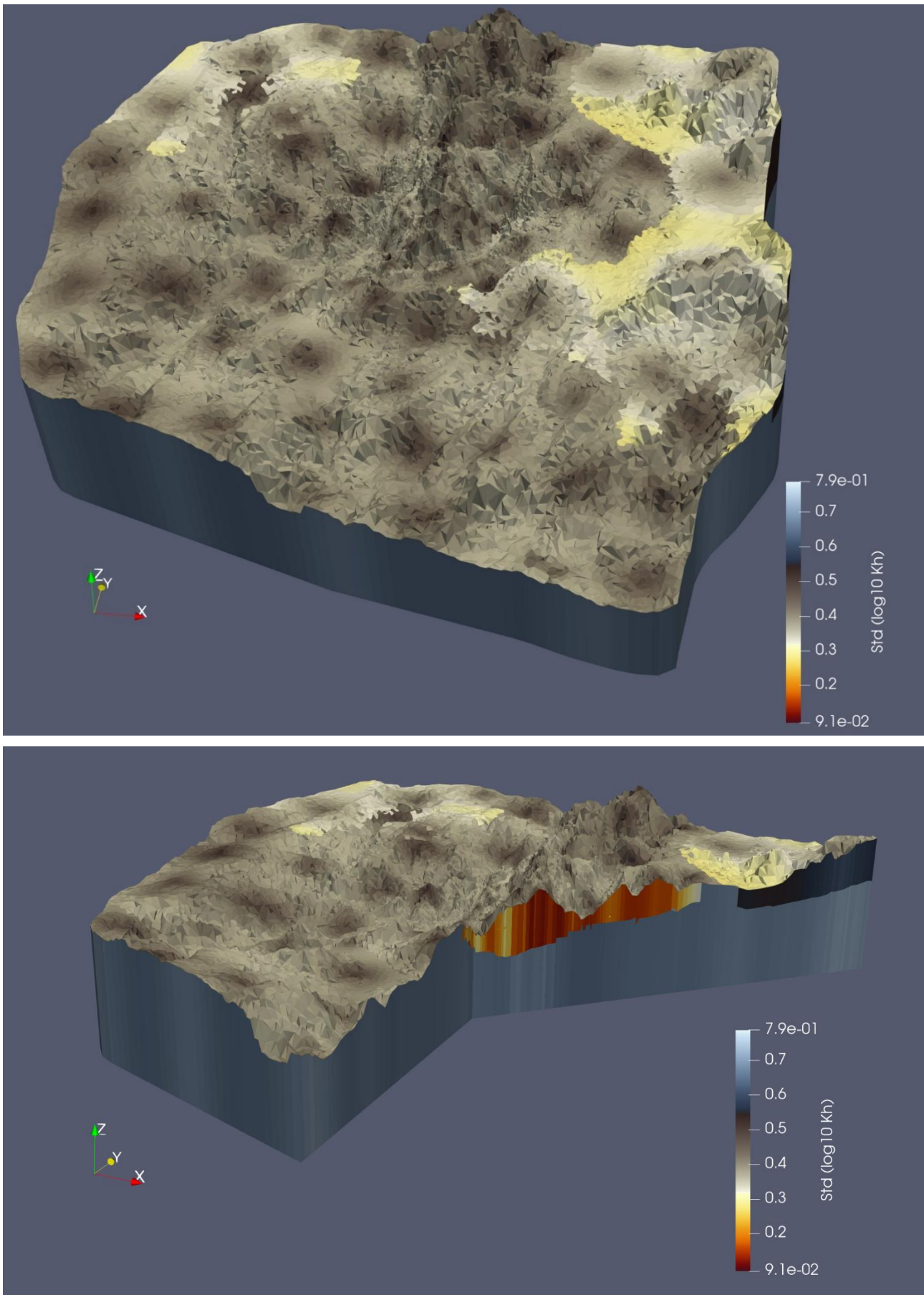


Figure 5.10 3D representation of horizontal hydraulic conductivity standard deviations

6 Predictive modelling

6.1 Overview

As outlined in Section 2.1, the objectives of the modelling are to predict:

- watertable drawdown due to project-only and cumulative impacts
- potential impacts (drawdown/mounding) of the project at identified sensitive receivers such as landholder bores and GDEs
- groundwater inflows to the project infrastructure during construction and operation
- changes to the water balance (with regards to both groundwater and surface water source areas) as a result of the project to inform water licensing
- watertable drawdown due to project-only impacts taking into consideration potential climate change prediction rainfall.

The sections below present details on the set of predictive scenarios developed to address these modelling objectives.

6.2 Scenario definition and representation

Following history-matching, from the 283 history-matched realisations, an accepted ensemble of 104 realisations with individual parameter sets was used to produce a range of predictions. The ensemble is considered history-matched, and accordingly model predictions are presented as percentiles across the ensemble.

Three main predictive model scenarios were developed to produce the outputs listed in the model objectives:

- a “project” scenario where the project and nearby projects (Metromix Quarry) are active
- a “no project” scenario where only nearby projects (Metromix Quarry) are active
- a “null” scenario where no projects are active, allowing the model to run with climatic fluctuations.

“Project-related” drawdown and water balance impacts were calculated as the difference between the “project” and “no project” scenarios. “Cumulative” drawdown and water balance impacts were calculated as the difference between the “project” and the “null” scenarios.

The set of scenario-defined boundary conditions for each scenario, previously described in Chapter 4, are summarised below in Table 6.1. Other boundary conditions, including climatic variability, were kept consistent across all the realisations.

6.2.1 Climate change

An additional version of the “project” scenario was developed to assess the long-term impact of climate change on the model predictions.

A rainfall reduction scenario presented in the NARCLIM dataset (DCCEEW, 2024) was selected for this purpose. A graph of the reduction in rainfall varying in time under this scenario is presented in Figure 6.1. For simplicity, the presented reduction in rainfall was applied linearly to the recharge rates used in the main model scenario to assess the impact of climate change on the predictions. The expected reduction in rainfall, as a percentage, was applied as a reduction in recharge as a percentage, to simplify the assumptions used for predictions. This scenario allows the reader to compare the estimated drawdown impact under such circumstances; and understand the expected magnitude of change it creates. The actual relationship between future changes of rainfall and recharge is unlikely to be linear and may be influenced by other factors such as seasonality and potential evaporation, with future estimations of recharge believed to remain highly uncertain.

Comparative results from this simulation are presented in Section 9.3.3 of the GIA.

Table 6.1 Model scenarios and scenario-defined boundary conditions

	Calibration stage (31/12/2021 to 31/12/2024)	Construction stage (to 31/12/2030)	Operation stage (to 31/12/2110)	Post-operation stage (to 31/12/2610 and infinity)
“Project” scenario				
Power waterway – DRN	-	Active (as construction progresses)	-	-
Power waterway – GHB	-	-	Active	-
Adits and powerhouse - DRN	-	Active (as construction progresses)	Active	-
Upper reservoir – RIV	-	-	Active	-
Upper reservoir – DRN	-	-	-	Active
Upper reservoir dam – TVM	-	Active	Active	Active
Upper reservoir – RCH	(Normal)	(Normal)	Removed	Active
Upper reservoir – EVT	(Normal)	(Normal)	Removed	Active
Metromix – DRN	Active	Active	Active	Active
“No project” scenario				
Project tunnels – DRN	-	-	-	-
Project tunnels – GHB	-	-	-	-
Upper reservoir – RIV	-	-	-	-
Upper reservoir – DRN	-	-	-	-
Upper reservoir dam – TVM	-	-	-	-
Upper reservoir – RCH	(Normal)	(Normal)	(Normal)	(Normal)
Upper reservoir – EVT	(Normal)	(Normal)	(Normal)	(Normal)

	Calibration stage (31/12/2021 to 31/12/2024)	Construction stage (to 31/12/2030)	Operation stage (to 31/12/2110)	Post-operation stage (to 31/12/2610 and infinity)
Metromix – DRN	Active	Active	Active	Active
“Null” scenario				
Project tunnels – DRN	-	-	-	-
Project tunnels – GHB	-	-	-	-
Upper reservoir – RIV	-	-	-	-
Upper reservoir – DRN	-	-	-	-
Upper reservoir dam – TVM	-	-	-	-
Upper reservoir – RCH	(Normal)	(Normal)	(Normal)	(Normal)
Upper reservoir – EVT	(Normal)	(Normal)	(Normal)	(Normal)
Metromix – DRN	-	-	-	-

Notes: A dash on a boundary condition that was active previously in time means the boundary condition was removed.

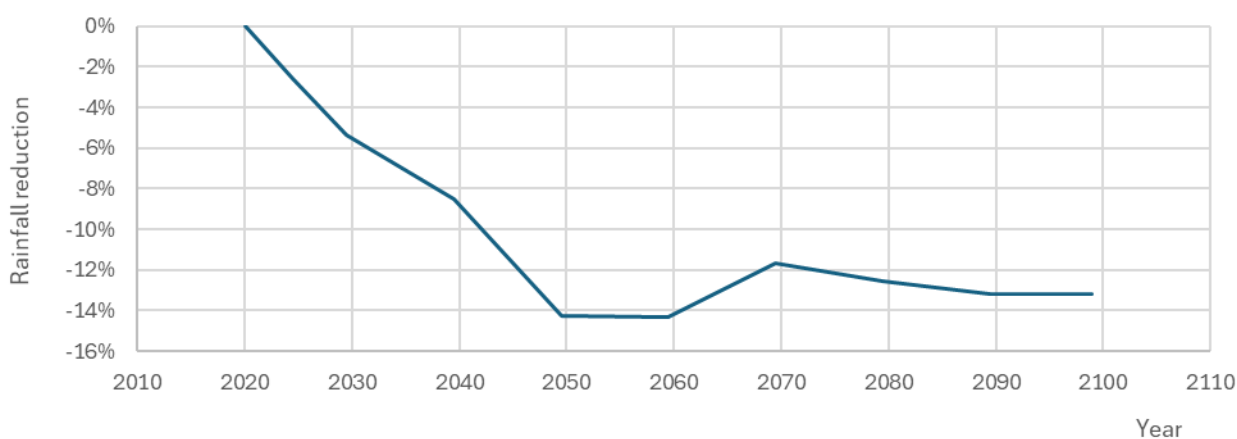


Figure 6.1 Rainfall reduction over time presented in the NARCLIM climate change scenario (DCCEEW, 2024)

6.3 Results

Model results are presented, where appropriate, as percentiles across the ensemble of realisations. The rationale for the percentile approach to presenting predicted drawdown and mounding is based on Table 2 of the model uncertainty guidelines by Middlemis and Peeters (2018). Those guidelines describe the importance of calibrated language and having a consistent and precise language to communicate impacts to decision makers. Table 6.2 provides a summary of the combined numeric, narrative and visual approach to describe likelihood of drawdown and mounding occurring as a result of the project.

Table 6.2 Combined numeric, narrative and visual approach for assessing the likelihood of head and flux changes resulting from the project

Percentile band	Colour code	Outcomes, ranked from small to large
<P10		It is very likely that drawdown/flux change will exceed this value.
P10 to P33		It is likely that drawdown/flux change will exceed this value.
P33 to P67		It is as likely as not that drawdown/flux change will exceed this value.
P67 to P90		It is unlikely that drawdown/flux change will exceed this value.
>P90		It is very unlikely that drawdown/flux change will exceed this value.

6.3.1 Drawdown

i Project-related drawdown and mounding

Drawdown and mounding predicted for the watertable during construction and operation are presented in Figure 6.2 to Figure 6.5. Each map shows the drawdown and mounding contours for a given likelihood of occurrence, based on all accepted model realisations, including the base realisation (104 realisations). In these figures, negative contours indicate mounding, while positive contours represent drawdown.

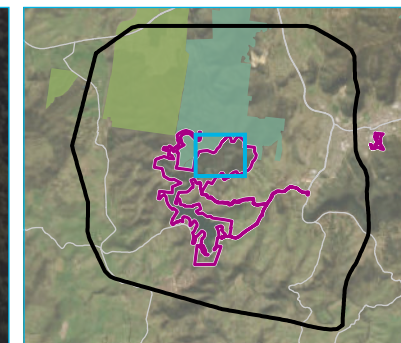
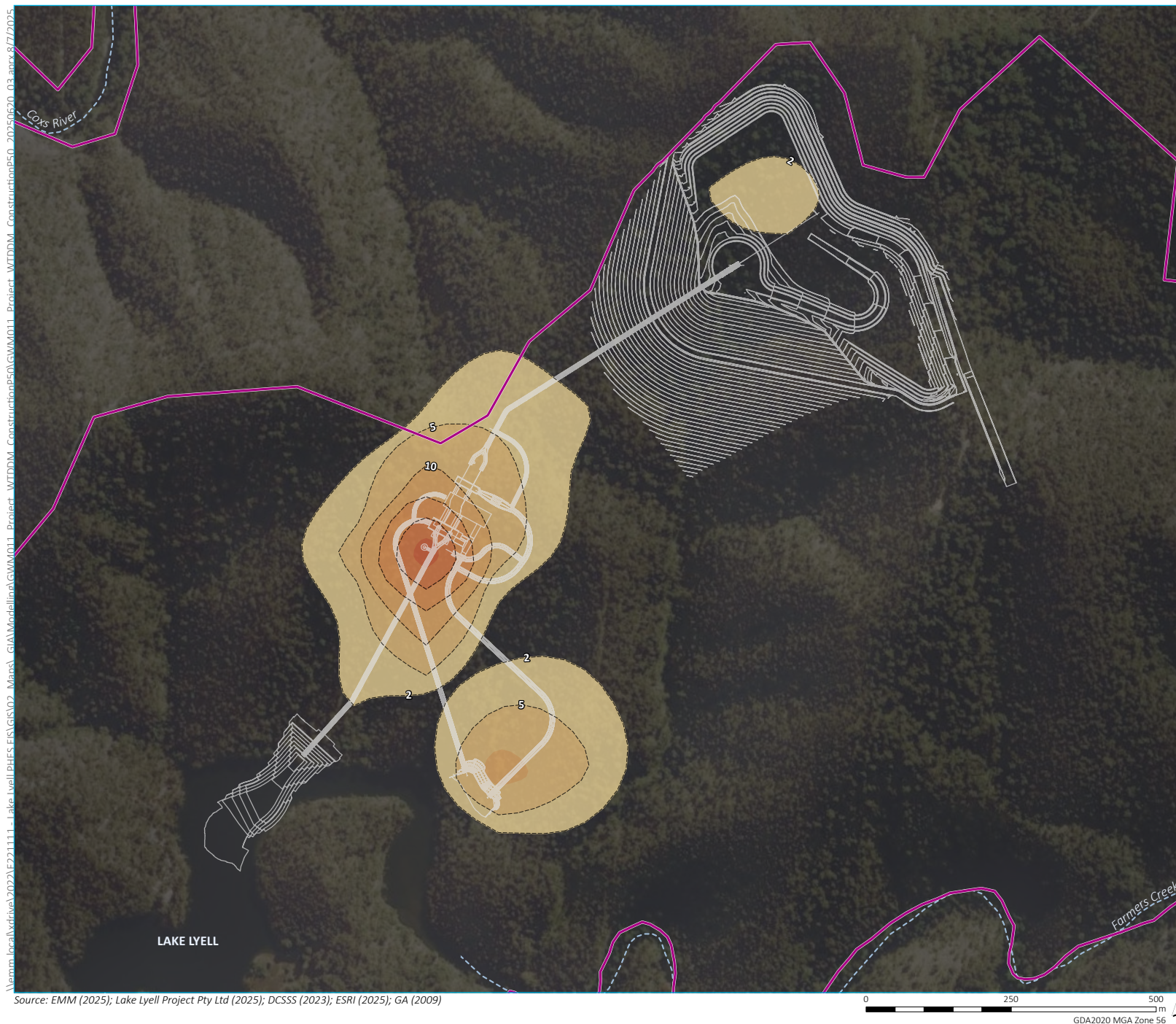
As shown in Figure 6.2 to Figure 6.5, predicted drawdown at these two moments is confined to the immediate surroundings of the project, with the 0.2 m drawdown contour contained within a 1,000 m radius from the centre of the project. The maximum drawdown caused by infrastructure drainage occurs at the pressure shaft, with a P90 value of 96 m and a P50 value of 82 m.

At the end of construction in June 2030 no mounding is predicted, as expected. The impact of the project at that moment is mainly caused by tunnel drainage, causing drawdown and not mounding. During operations the upper reservoir gets filled with water which seeps into the watertable generating mounding, as seen in the figures presented for the year 2110. 60 m of mounding is predicted immediately under the upper reservoir, with the 0.2 m mounding contour extending approximately 1,800 m north-east from the centre of the project. At this point in time, drawdown caused by tunnel drainage and mounding caused by seepage in the upper reservoir coexist together, with drawdown extending south-west from the project (around the tunnels) and mounding extending north-east of the project around the upper reservoir.

ii Cumulative drawdown

Cumulative watertable drawdown and mounding predicted at the end of construction and operations for the base realisation are presented in Figure 6.6 and Figure 6.7. Again, negative contours indicate mounding while positive contours indicate drawdown.

As seen in the figures, the maximum mapped drawdown extent (the 0.2 m drawdown contour) around the project and the Metromix Quarry remains separate, well confined to the immediate vicinity of each of the projects. There is no predicted intersection of 0.2 m drawdown contours from both projects, indicating that cumulative impacts on groundwater are very unlikely.



KEY

- Project area
- Key project infrastructure
- Watertable drawdown (m)
- 50
- 70
- Drawdown contour
- Existing environment
- Major road
- Named watercourse

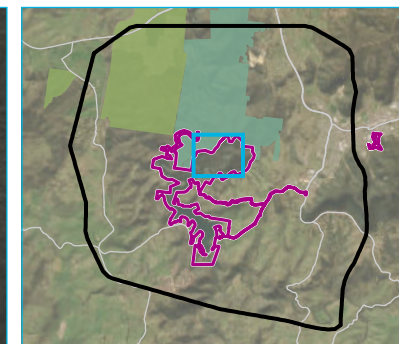
INSET KEY

- Model extent
- Major road
- State forest
- NPWS reserve

Project-related watertable drawdown and mounding at the end of construction (June 2030), P50

Lake Lyell PHES
Groundwater Modelling Report
Figure 6.2

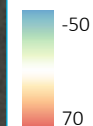




KEY

- Project area
- Key project infrastructure

Watertable drawdown (m)



Drawdown contour

- Drawdown contour
- Major road
- Named watercourse

EXISTING ENVIRONMENT

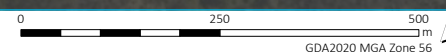
- Model extent
- Major road
- State forest
- NPWS reserve

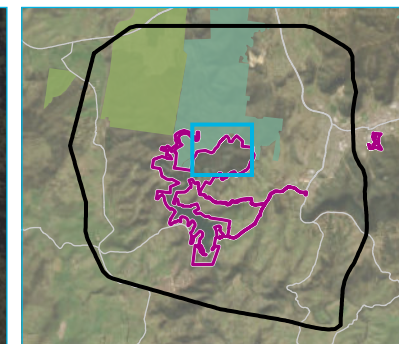
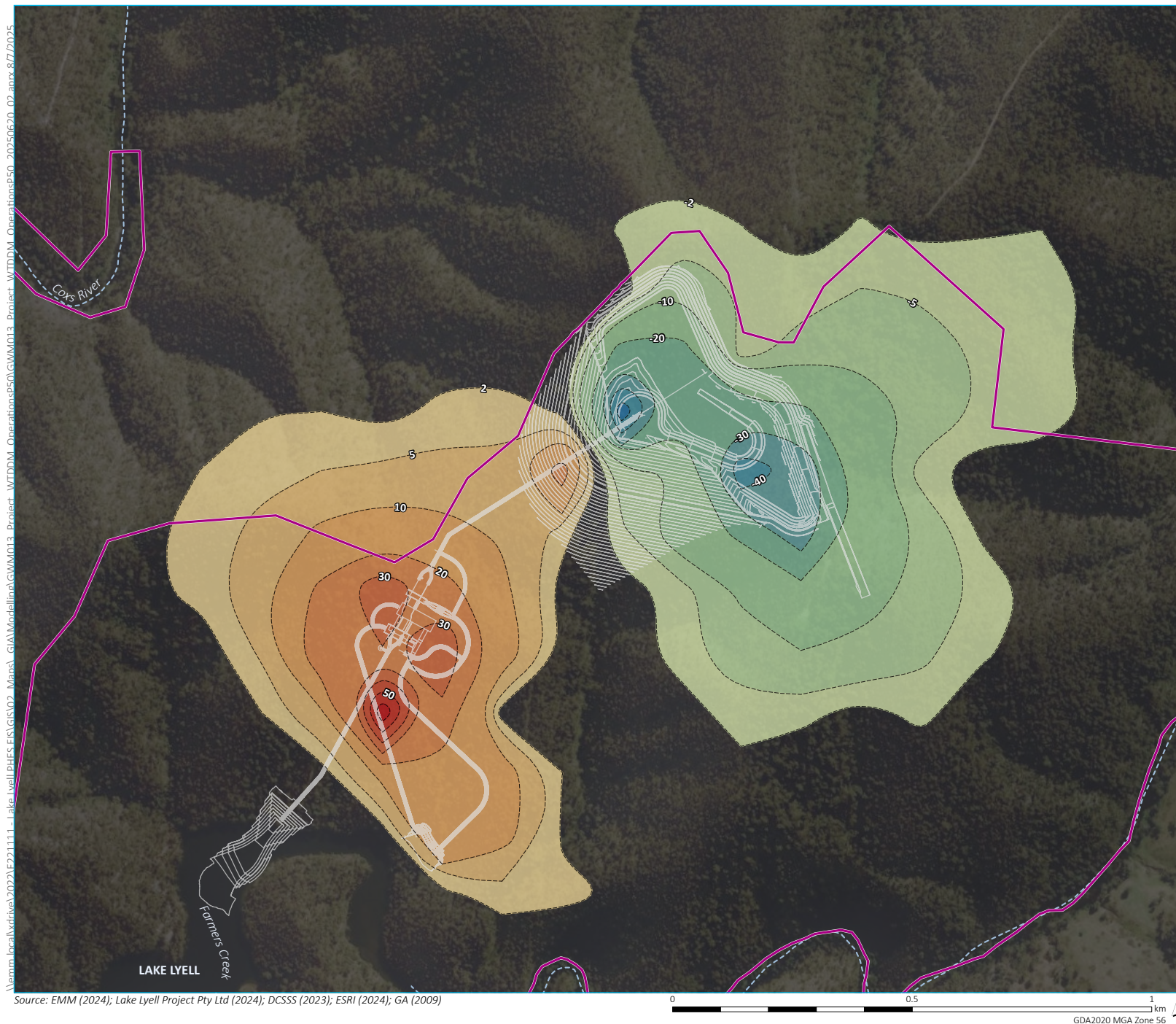
Project-related watertable drawdown and mounding at the end of construction (June 2030), P90

Lake Lyell PHES
Groundwater Modelling Report
Figure 6.3



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)

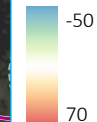




KEY

- Project area
- Key project infrastructure

Watertable drawdown (m)



Existing environment

- Major road
- Named watercourse

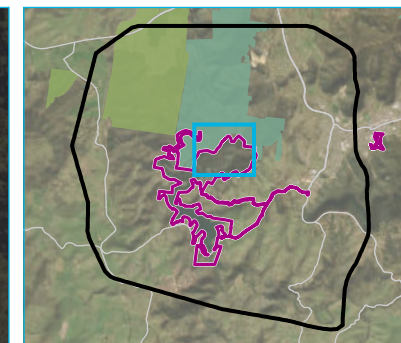
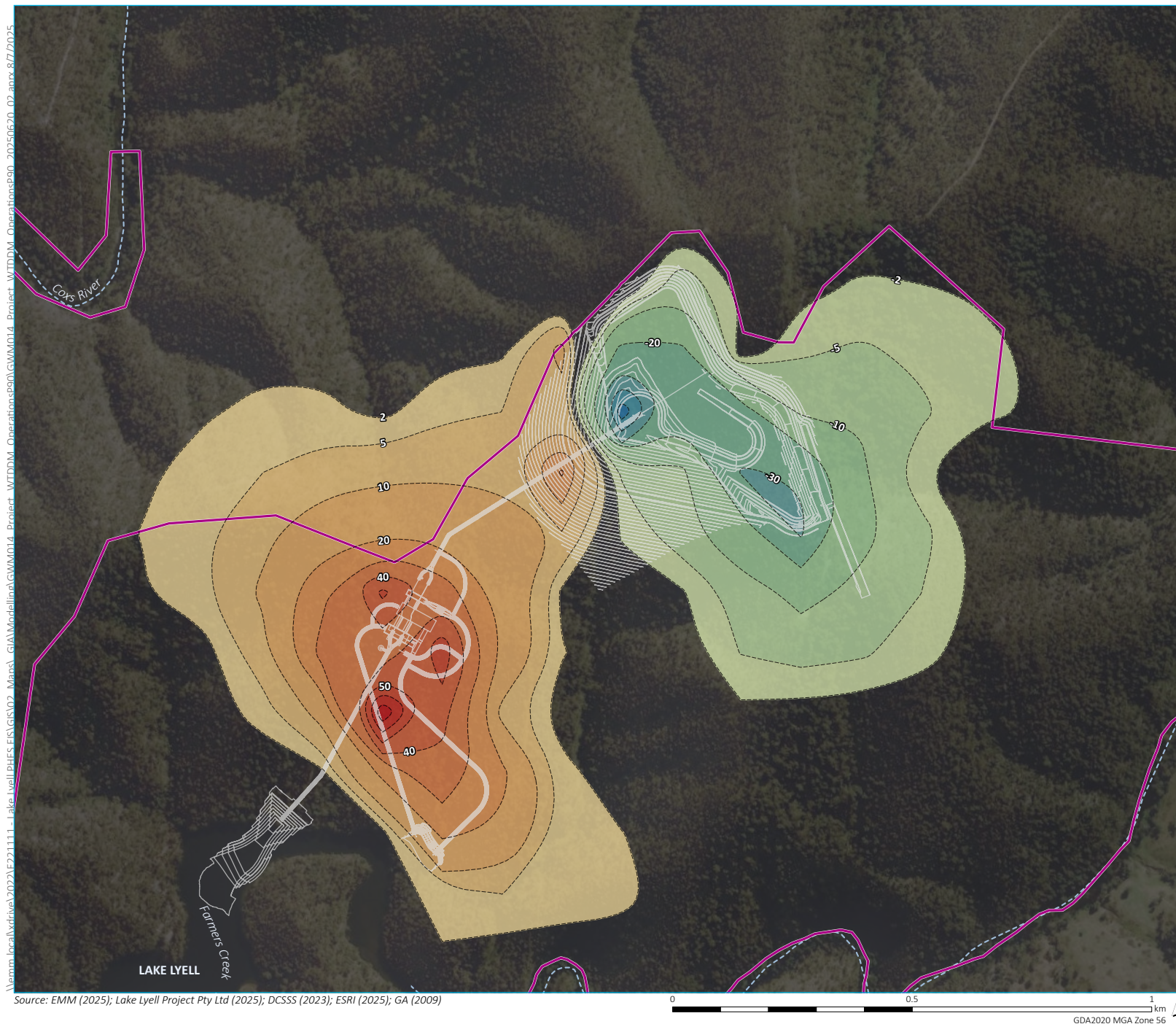
INSET KEY

- Model extent
- Major road
- State forest
- NPWS reserve

Project-related watertable drawdown and mounding at the end of operations (year 2110), P50

Lake Lyell PHES
Groundwater Modelling Report
Figure 6.4

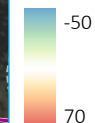




KEY

- Project area
- Key project infrastructure

Watertable drawdown (m)



Drawdown contour

- Existing environment
- Major road
- Named watercourse

INSET KEY

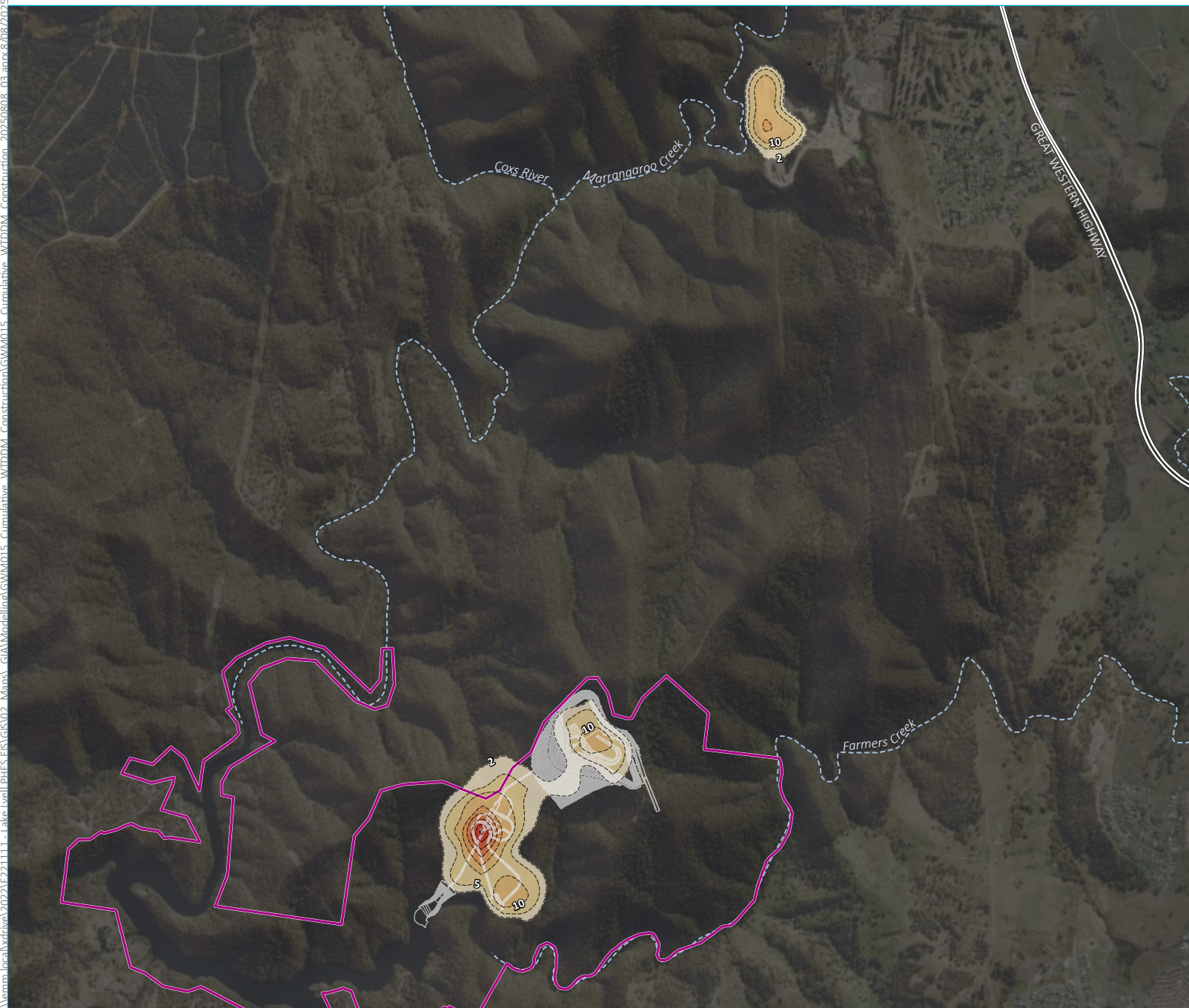
- Model extent
- Major road
- State forest
- NPWS reserve

Project-related watertable drawdown and mounding at the end of operations (year 2110), P90

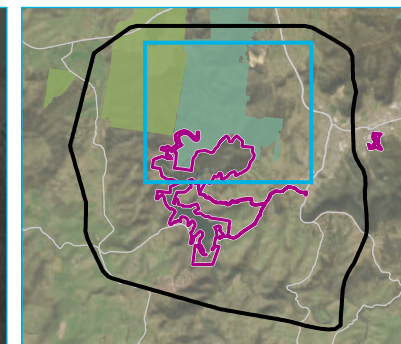
Lake Lyell PHES
Groundwater Modelling Report
Figure 6.5



\\lemm.local\drive\2025\F221111 - Lake Lyell PHES FIS\GIS\02 Maps\ GIA\Modelling\GWM\015 Cumulative_WTDDM_Construction_20250808_03.aprx.8/08/2025



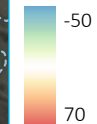
Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)



KEY

- Project area
- Key project infrastructure

Watertable drawdown (m)



--- Drawdown contour

Existing environment

— Major road

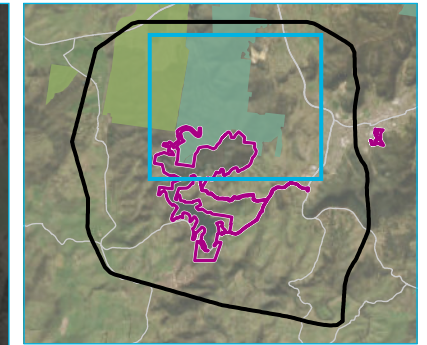
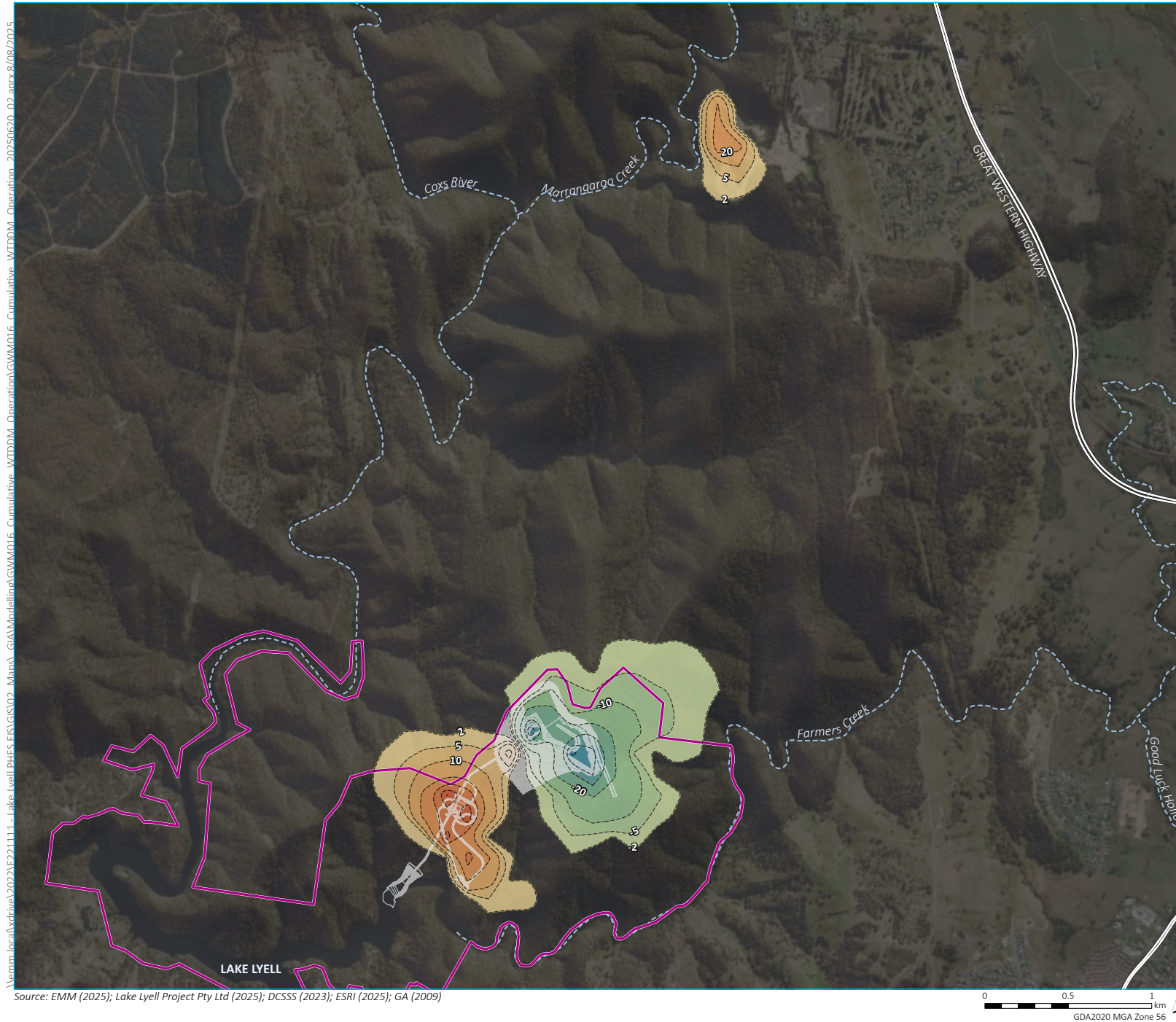
--- Named watercourse

INSET KEY

- Model extent
- Major road
- State forest
- NPWS reserve

Cumulative watertable drawdown
and mounding at the end of
construction (June 2030),
base realisation

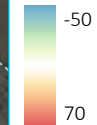
Lake Lyell PHES
Groundwater Modelling Report
Figure 6.6



KEY

- Project area
- Key project infrastructure

Watertable drawdown (m)



Drawdown contour

- Major road
- Named watercourse

INSET KEY

- Model extent
- Major road
- State forest
- NPWS reserve

Cumulative watertable drawdown
and mounding at the end of
operations (year 2110),
base realisation

Lake Lyell PHES
Groundwater Modelling Report
Figure 6.7

6.3.2 Water balance

i Inflow to underground excavations

Figure 6.8 shows the predicted groundwater inflow to the underground excavations associated with the tunnel infrastructure over time, including key percentiles and the base realisation. The underground excavations considered are detailed in Figure 6.9.

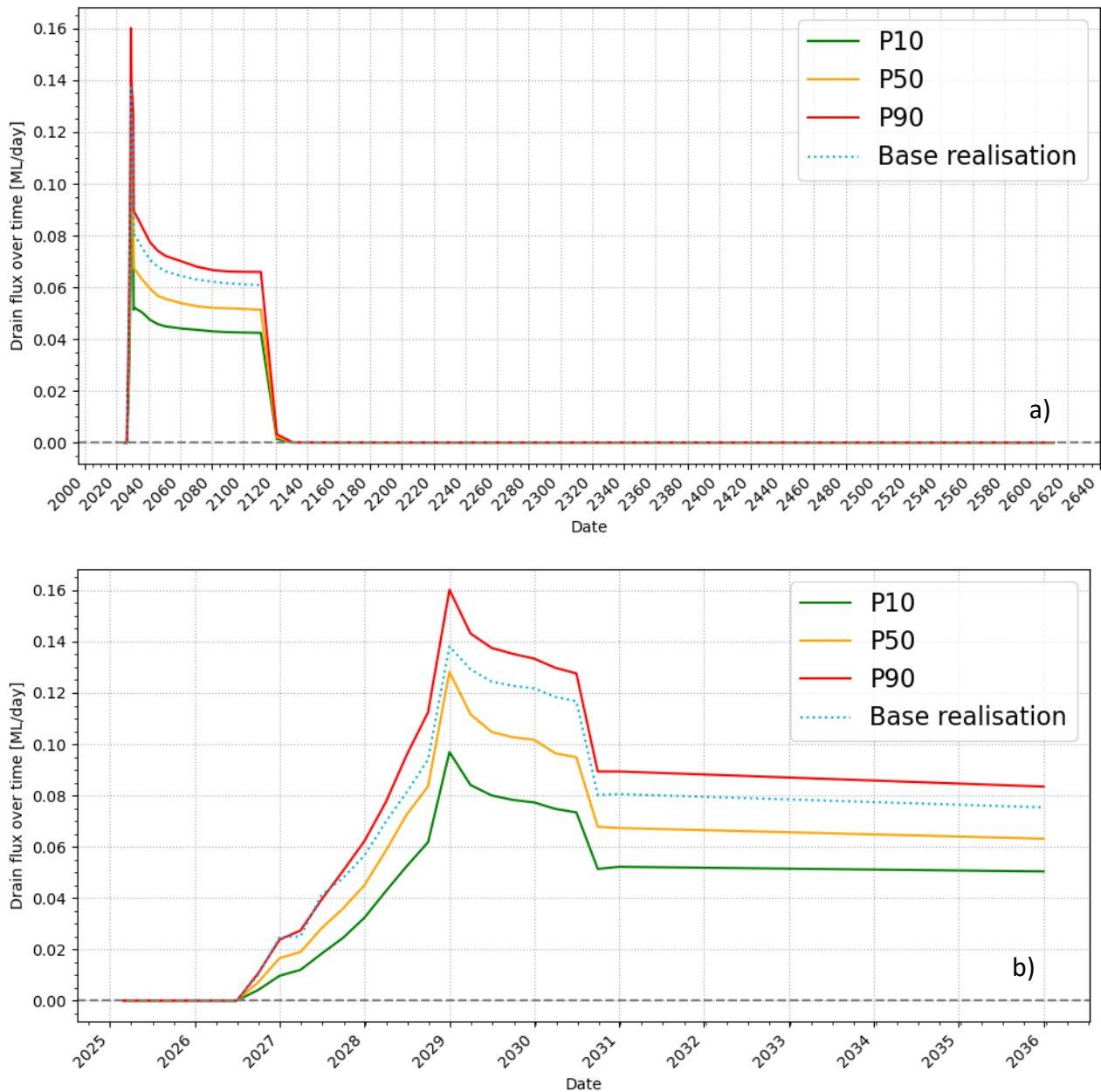


Figure 6.8 Predicted total inflow to underground excavations, excluding the upper reservoir. a) Full simulation period; b) Zoomed-in view of peak inflow period

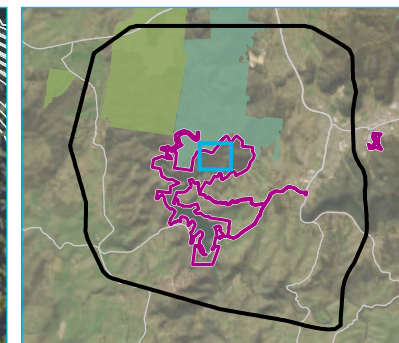
The predicted P90 inflows during the construction period (July 2026 to June 2030) range from 0.05 to 0.71 megalitres per day (ML/d), with lower inflows occurring at the start of excavation works and peaking in early 2027. The P10 scenario follows a similar trend, with peak inflows approximately 0.25 ML/d lower than P90 in 2027. During the operations period, relatively constant inflows ranging from approximately 0.01 to 0.1 ML/d (P10 to P90) are predicted, reflecting the planned continuous drainage from the adits and powerhouse structures (refer to Table 6.1). After closure, a similar sustained inflow is simulated, representing the drainage required to keep the upper reservoir dry.

The predicted inflows separated by underground excavation component for P90 are presented in Table 6.3, with a map showing the naming convention of the underground excavations in Figure 6.9. The high dewatering rates early in the simulation occur at the upper reservoir, and reflect removal of entrained water, with later passive inflows being much lower. Note that the abrupt change in flux for the upper reservoir between 01/01/2121 and 01/01/2131, marking the transition from operation to closure, reflects the dewatering of the upper reservoir.

Table 6.3 Predicted groundwater inflows (ML/d) (P90) separated by underground excavation

Date (model stress periods)	Head- race	Tailrace	MAT	ECVT	Adit4	Power- house	Ancillary	Pressure shaft	Surge shaft	Upper reservoir
01/10/2026	-	-	0.005	0.003	0.004	-	-	-	-	0.055
01/01/2027	-	-	0.014	0.005	0.006	-	-	-	-	0.041
01/04/2027	-	-	0.011	0.009	0.009	-	-	-	-	0.027
01/07/2024	-	-	0.028	0.006	0.007	-	-	-	-	0.013
01/10/2027	-	-	0.028	0.013	0.009	0.003	-	-	-	0.014
01/01/2028	-	0.011	0.028	0.014	0.012	0.004	-	-	-	0.006
01/04/2028	0.005	0.018	0.033	0.012	0.014	0.004	-	-	-	0.006
01/07/2028	0.008	0.019	0.030	0.025	0.013	0.006	0.007	-	-	0.006
01/10/2028	0.015	0.018	0.029	0.034	0.013	0.005	0.015	-	-	0.009
01/01/2029	0.017	0.017	0.028	0.032	0.012	0.005	0.023	0.027	0.025	0.008
01/04/2029	0.017	0.017	0.028	0.031	0.012	0.008	0.024	0.015	0.013	0.006
01/07/2029	0.018	0.017	0.027	0.030	0.012	0.008	0.021	0.013	0.012	0.006
01/10/2029	0.018	0.016	0.027	0.029	0.012	0.008	0.021	0.012	0.010	0.006
01/01/2030	0.017	0.016	0.026	0.028	0.011	0.012	0.021	0.012	0.010	0.006
01/04/2030	0.017	0.016	0.026	0.028	0.011	0.008	0.020	0.012	0.009	0.006
01/07/2030	0.017	0.016	0.026	0.027	0.011	0.008	0.020	0.011	0.009	0.006
01/10/2030	-	-	0.025	0.028	0.013	0.011	0.022	-	-	0.000
01/01/3031	-	-	0.025	0.029	0.013	0.011	0.022	-	-	0.000
01/01/2036	-	-	0.023	0.026	0.012	0.010	0.020	-	-	0.000
01/01/2041	-	-	0.021	0.024	0.011	0.010	0.019	-	-	0.000
01/01/2051	-	-	0.020	0.022	0.010	0.010	0.019	-	-	0.000
01/01/2061	-	-	0.019	0.022	0.010	0.009	0.019	-	-	0.000

Date (model stress periods)	Head- race	Tailrace	MAT	ECVT	Adit4	Power- house	Ancillary	Pressure shaft	Surge shaft	Upper reservoir
01/01/2071	-	-	0.018	0.021	0.009	0.009	0.018	-	-	0.000
01/01/2081	-	-	0.018	0.020	0.009	0.009	0.018	-	-	0.000
01/01/2091	-	-	0.018	0.019	0.008	0.009	0.018	-	-	0.000
01/01/2101	-	-	0.018	0.019	0.008	0.009	0.018	-	-	0.000
01/01/2111	-	-	0.018	0.019	0.008	0.009	0.018	-	-	0.000
01/01/2121	-	-	-	-	-	-	-	-	-	0.000
01/01/2131	-	-	-	-	-	-	-	-	-	0.432
01/01/2141	-	-	-	-	-	-	-	-	-	0.009
01/01/14	-	-	-	-	-	-	-	-	-	0.008
01/01/2161	-	-	-	-	-	-	-	-	-	0.008
01/01/2211	-	-	-	-	-	-	-	-	-	0.007
01/01/2311	-	-	-	-	-	-	-	-	-	0.007
01/01/2411	-	-	-	-	-	-	-	-	-	0.006
01/01/2511	-	-	-	-	-	-	-	-	-	0.006
01/01/2611	-	-	-	-	-	-	-	-	-	0.006



KEY

- Project area
- Key project infrastructure

Underground design

- Headrace waterway tunnel
- Tailrace waterway tunnel
- MAT
- EVCT
- Powerhouse cavern
- Ancillary tunnel
- Adit
- Pressure shaft

Existing environment

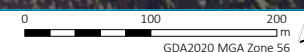
- Major road
- Named watercourse
- Named waterbody

INSET KEY

- Model extent
- Major road
- State forest
- NPWS reserve

Names of underground excavations

Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009)



ii Project-related changes to baseflow and leakage in surface water features

For regulatory purposes, project-related impact to the modelled surface water drainages and lakes (also called water take) within the study area was split into:

- increase of leakage from surface water features into the formation
- reduction of groundwater baseflow from the formation to surface water features.

The increase of modelled surface water leakage was separated by water source and/or management zones, as indicated in the water sharing plans for the Greater Metropolitan Region Unregulated River Water Sources 2023 and Macquarie Bogan Unregulated and Alluvial Water Sources 2012 (Wywandy Management Zone and Dharabuladh Management Zone). The reduction of groundwater baseflow was separated by groundwater source, based on the groundwater sharing plans for the Greater Metropolitan Region Groundwater Sources 2023 and the NSW Murray–Darling Basin (MDB) Fractured Rock Groundwater Sources 2020 (Lachlan Fold Belt (LFB) Greater Metropolitan Groundwater Source and the Sydney Basin West Groundwater Source, respectively). Graphed water takes for P10, P50 and P90 are provided in Figure 6.10 and Figure 6.11, with summarised yearly takes provided in Table 6.4 to Table 6.6. Maps of drainage names and zones matching the data presented in the graphs and tables are included in Figure 6.12 and Figure 6.13.

Increased leakage is predicted within the Wywandy Management Zone (Greater Metropolitan Region Unregulated River Water Sources 2023). The predicted increase in leakage peaks in the middle of 2030, with a P90 value of nearly 0.7 megalitres per year (ML/yr). The increase in leakage from natural drainage lines decreases sharply after the construction phase of the project is completed, offset by mounding generated by the upper reservoir and its associated artificially sourced leakage.

The predicted reduction in baseflow in the LFB Groundwater Source is expected to peak during construction in 2030, with a P90 value of approximately 3.9 ML/yr. This reduction initially decreases at the start of the operations phase but subsequently increases, reaching a second peak of approximately 4.2 ML/yr by the end of operations in 2111. The baseflow reduction gradually declines thereafter, persisting until around 2320, beyond which it stabilises at low levels (less than 0.2 ML/yr) and remains nearly constant over the long term.

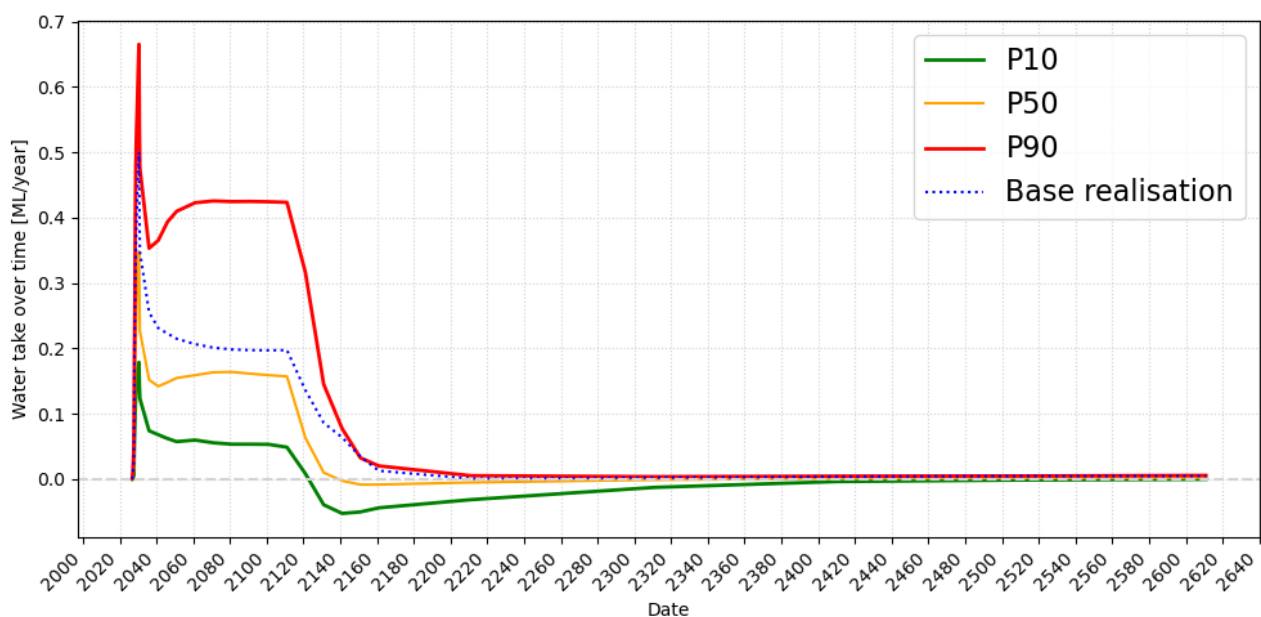


Figure 6.10 Predicted increase of leakage from surface water features from the Wywandy Management Zone into the rock formations

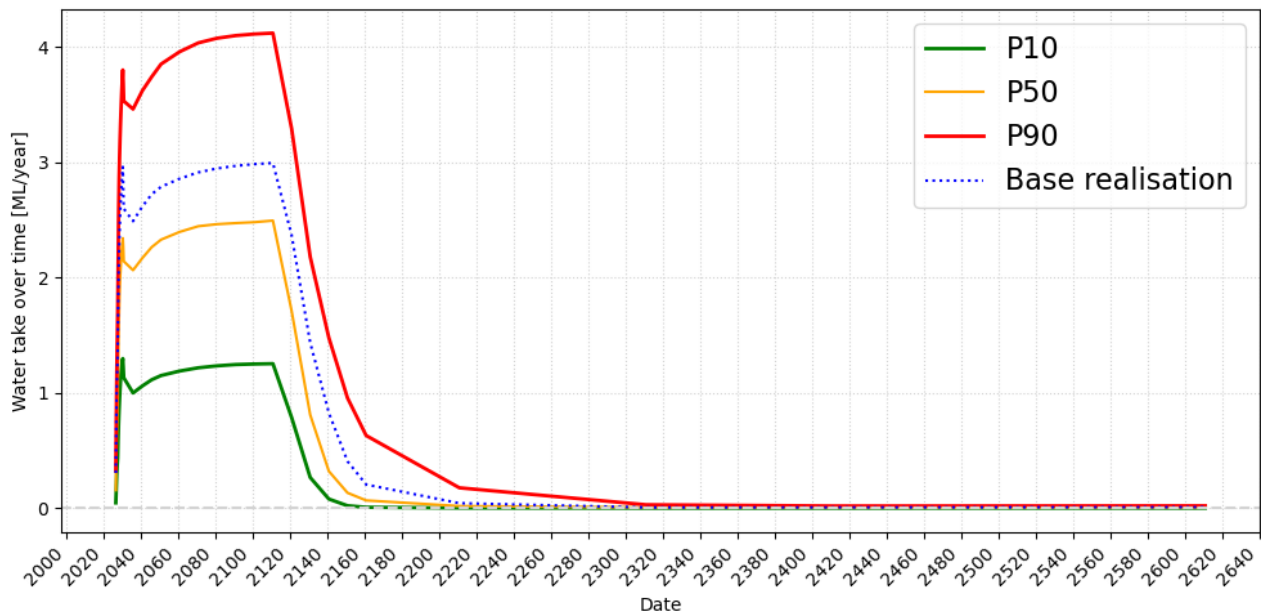


Figure 6.11 Predicted reduction of groundwater baseflow from the rock formations into the perennial watercourses within the LFB Groundwater Source, during construction and long term

Table 6.4 Predicted reduction of groundwater baseflow (ML/d) from the rock formations into surface water features (P50)

Date (model stress periods)	LFB Greater Metropolitan Groundwater Source						Sydney Basin West Groundwater Source		
	Farmers Creek	Coxs River	Marra Creek	Sandals Creek	Other	Lake Lyell	Farmers Creek	Marra Creek	Other
01/10/2026	0.000	0.00	0.00	0.00	0.003	0.000	0.00	0.00	0.00
01/01/2027	0.000	0.00	0.00	0.00	0.002	0.001	0.00	0.00	0.00
01/04/2027	0.000	0.00	0.00	0.00	0.003	0.002	0.00	0.00	0.00
01/07/2027	0.000	0.00	0.00	0.00	0.006	0.002	0.00	0.00	0.00
01/10/2027	0.000	0.00	0.00	0.00	0.003	0.002	0.00	0.00	0.00
01/01/2028	0.000	0.00	0.00	0.00	0.006	0.003	0.00	0.00	0.00
01/04/2028	0.000	0.00	0.00	0.00	0.008	0.004	0.00	0.00	0.00
01/07/2028	0.000	0.00	0.00	0.00	0.010	0.004	0.00	0.00	0.00
01/10/2028	0.000	0.00	0.00	0.00	0.010	0.005	0.00	0.00	0.00
01/01/2029	0.000	0.00	0.00	0.00	0.011	0.005	0.00	0.00	0.00
01/04/2029	0.000	0.00	0.00	0.00	0.010	0.005	0.00	0.00	0.00
01/07/2029	0.000	0.00	0.00	0.00	0.009	0.006	0.00	0.00	0.00
01/10/2029	0.000	0.00	0.00	0.00	0.012	0.006	0.00	0.00	0.00
01/01/2030	0.000	0.000	0.000	0.000	0.013	0.006	0.000	0.000	0.000
01/04/2030	0.000	0.000	0.000	0.000	0.012	0.006	0.000	0.000	0.000

Date (model stress periods)	LFB Greater Metropolitan Groundwater Source						Sydney Basin West Groundwater Source		
	Farmers Creek	Coxs River	Marra Creek	Sandals Creek	Other	Lake Lyell	Farmers Creek	Marra Creek	Other
01/07/2030	0.000	0.000	0.000	0.000	0.011	0.006	0.000	0.000	0.000
01/10/2030	0.000	0.000	0.000	0.000	-0.013	0.006	0.000	0.000	0.000
01/01/3031	0.000	0.000	0.000	0.000	0.002	0.006	0.000	0.000	0.000
01/01/2036	0.000	0.000	0.000	0.000	0.011	0.005	0.000	0.000	0.000
01/01/2041	0.000	0.000	0.000	0.000	0.010	0.006	0.000	0.000	0.000
01/01/2046	0.000	0.000	0.000	0.000	0.011	0.006	0.000	0.000	0.000
01/01/2051	0.000	0.000	0.000	0.000	0.011	0.006	0.000	0.000	0.000
01/01/2061	0.000	0.000	0.000	0.000	0.012	0.006	0.000	0.000	0.000
01/01/2071	0.000	0.000	0.000	0.000	0.012	0.006	0.000	0.000	0.000
01/01/2081	0.000	0.000	0.000	0.000	0.011	0.006	0.000	0.000	0.000
01/01/2091	0.000	0.000	0.000	0.000	0.011	0.006	0.000	0.000	0.000
01/01/2101	0.000	0.000	0.000	0.000	0.011	0.006	0.000	0.000	0.000
01/01/2111	0.000	0.000	0.000	0.000	0.011	0.007	0.000	0.000	0.000
01/01/2121	0.000	0.000	0.000	0.000	0.009	0.005	0.000	0.000	0.000
01/01/2131	0.000	0.000	0.000	0.000	0.006	0.002	0.000	0.000	0.000
01/01/2141	0.000	0.000	0.000	0.000	0.003	0.001	0.000	0.000	0.000
01/01/2151	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000
01/01/2161	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000
01/01/2211	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
01/01/2311	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000
01/01/2411	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000
01/01/2511	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000
01/01/2611	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000

Table 6.5 Predicted reduction of groundwater baseflow (ML/d) from the rock formations into surface water features (P90)

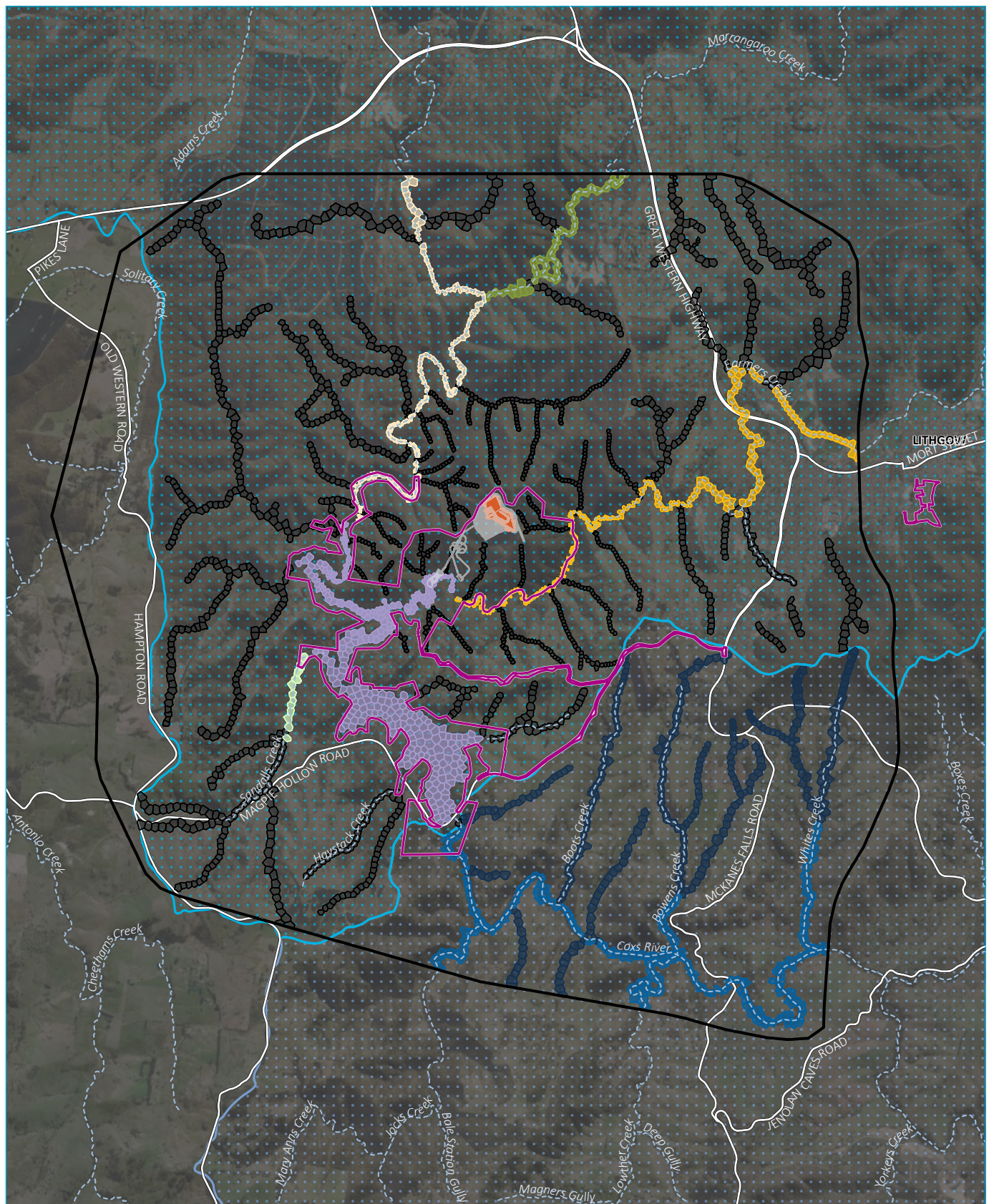
Date (model stress periods)	LFB Greater Metropolitan Groundwater Source						Sydney Basin West Groundwater Source		
	Farmers Creek	Coxs River	Marra Creek	Sandals Creek	Other	Lake Lyell	Farmers Creek	Marra Creek	Other
01/10/2026	0.000	0.000	0.000	0.000	0.058	0.001	0.000	0.000	0.000
01/01/2027	0.000	0.000	0.000	0.000	0.056	0.002	0.000	0.000	0.000
01/04/2027	0.000	0.000	0.000	0.000	0.049	0.003	0.000	0.000	0.000
01/07/2024	0.000	0.000	0.000	0.000	0.070	0.004	0.000	0.000	0.000
01/10/2027	0.000	0.000	0.000	0.000	0.067	0.005	0.000	0.000	0.000
01/01/2028	0.000	0.000	0.000	0.000	0.045	0.006	0.000	0.000	0.000
01/04/2028	0.000	0.000	0.000	0.000	0.049	0.007	0.000	0.000	0.000
01/07/2028	0.000	0.000	0.000	0.000	0.050	0.008	0.000	0.000	0.000
01/10/2028	0.000	0.000	0.000	0.000	0.059	0.008	0.000	0.000	0.000
01/01/2029	0.000	0.000	0.000	0.000	0.062	0.009	0.000	0.000	0.000
01/04/2029	0.000	0.000	0.000	0.000	0.049	0.009	0.000	0.000	0.000
01/07/2029	0.000	0.000	0.000	0.000	0.068	0.009	0.000	0.000	0.000
01/10/2029	0.000	0.000	0.000	0.000	0.058	0.010	0.000	0.000	0.000
01/01/2030	0.000	0.000	0.000	0.000	0.040	0.010	0.000	0.000	0.000
01/04/2030	0.000	0.000	0.000	0.000	0.058	0.010	0.000	0.000	0.000
01/07/2030	0.000	0.000	0.000	0.000	0.083	0.010	0.000	0.000	0.000
01/10/2030	0.000	0.000	0.000	0.000	0.030	0.010	0.000	0.000	0.000
01/01/3031	0.000	0.000	0.000	0.000	0.053	0.010	0.000	0.000	0.000
01/01/2036	0.000	0.000	0.000	0.000	0.031	0.009	0.000	0.000	0.000
01/01/2041	0.000	0.000	0.000	0.000	0.041	0.010	0.000	0.000	0.000
01/01/2046	0.000	0.000	0.000	0.000	0.038	0.010	0.000	0.000	0.000
01/01/2051	0.000	0.000	0.000	0.000	0.036	0.011	0.000	0.000	0.000
01/01/2061	0.000	0.000	0.000	0.000	0.031	0.011	0.000	0.000	0.000
01/01/2071	0.000	0.000	0.000	0.000	0.026	0.011	0.000	0.000	0.000
01/01/2081	0.000	0.000	0.000	0.000	0.022	0.011	0.000	0.000	0.000
01/01/2091	0.000	0.000	0.000	0.000	0.021	0.011	0.000	0.000	0.000
01/01/2101	0.000	0.000	0.000	0.000	0.020	0.011	0.000	0.000	0.000
01/01/2111	0.000	0.000	0.000	0.000	0.019	0.011	0.000	0.000	0.000
01/01/2121	0.000	0.000	0.000	0.000	0.019	0.009	0.000	0.000	0.000

Date (model stress periods)	LFB Greater Metropolitan Groundwater Source						Sydney Basin West Groundwater Source		
	Farmers Creek	Coxs River	Marra Creek	Sandals Creek	Other	Lake Lyell	Farmers Creek	Marra Creek	Other
01/01/2131	0.000	0.000	0.000	0.000	0.013	0.006	0.000	0.000	0.000
01/01/2141	0.000	0.000	0.000	0.000	0.011	0.004	0.000	0.000	0.000
01/01/2151	0.000	0.000	0.000	0.000	0.009	0.003	0.000	0.000	0.000
01/01/2161	0.000	0.000	0.000	0.000	0.008	0.002	0.000	0.000	0.000
01/01/2211	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000
01/01/2311	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000
01/01/2411	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000
01/01/2511	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000
01/01/2611	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000

Table 6.6 Predicted increase of leakage (ML/d) from surface water features into the rock formations

Date (model stress periods)	Wywandy Management Zone	
	P50	P90
01/10/2026	0.000	0.000
01/01/2027	0.000	0.000
01/04/2027	0.000	0.000
01/07/2024	0.000	0.000
01/10/2027	0.000	0.000
01/01/2028	0.000	0.001
01/04/2028	0.000	0.001
01/07/2028	0.000	0.001
01/10/2028	0.001	0.001
01/01/2029	0.001	0.001
01/04/2029	0.001	0.001
01/07/2029	0.001	0.002
01/10/2029	0.001	0.002
01/01/2030	0.001	0.002
01/04/2030	0.001	0.002
01/07/2030	0.001	0.002
01/10/2030	0.001	0.001
01/01/3031	0.001	0.001

Date (model stress periods)	Wywandy Management Zone	
	P50	P90
01/01/2036	0.000	0.001
01/01/2041	0.000	0.001
01/01/2046	0.000	0.001
01/01/2051	0.000	0.001
01/01/2061	0.000	0.001
01/01/2071	0.000	0.001
01/01/2081	0.000	0.001
01/01/2091	0.000	0.001
01/01/2101	0.000	0.001
01/01/2111	0.000	0.001
01/01/2121	0.000	0.001
01/01/2131	0.000	0.000
01/01/2141	0.000	0.000
01/01/2151	0.000	0.000
01/01/2161	0.000	0.000
01/01/2211	0.000	0.000
01/01/2311	0.000	0.000
01/01/2411	0.000	0.000
01/01/2511	0.000	0.000
01/01/2611	0.000	0.000



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009); DPIE (2021)

KEY

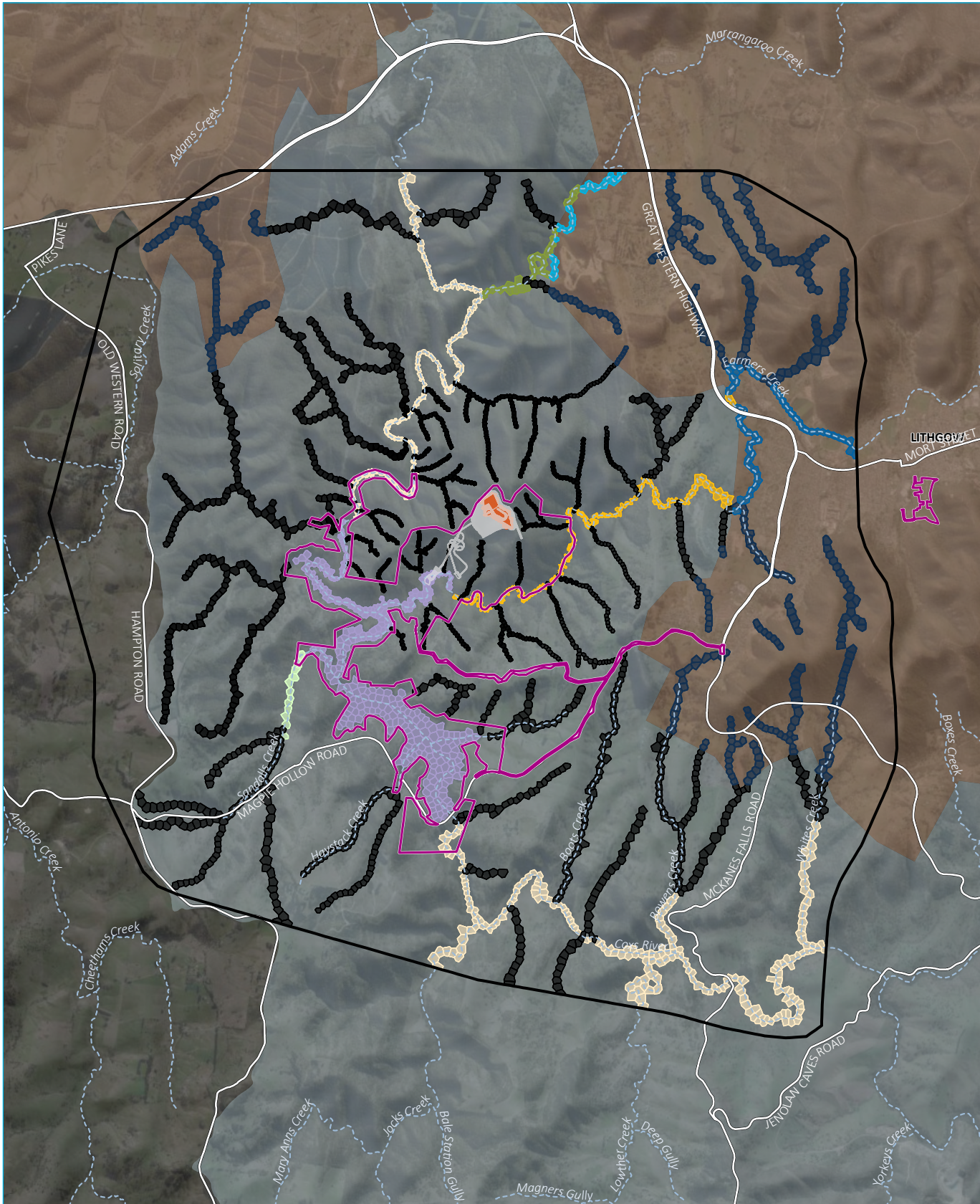
- ▬ Project area
- Model extent
- Key project infrastructure
- Existing environment
- Major road
- Named watercourse
- Surface water management zone
- Dharabuladh

- ▬ Wywanddy
- Surface water drainage budget zone**
- ▬ Dharabuladh management zone
- ▬ Farmers Creek
- ▬ Coxs River
- ▬ Marra Creek
- ▬ Sandalls Creek
- ▬ Other drainage

- ▬ Lake Lyell
- ▬ Upper reservoir
- ▬ Wywanddy management zone
- ▬ Coxs River
- ▬ Other drainage

Surface water management zones and drainage budget zones

Lake Lyell PHES
Groundwater Modelling Report
Figure 6.12



Source: EMM (2025); Lake Lyell Project Pty Ltd (2025); DCSSS (2023); ESRI (2025); GA (2009); DPIE (2021)

KEY

- Project area
- Model extent
- Key project infrastructure
- Existing environment
- Major road
- Named watercourse
- Greater Metropolitan Region Groundwater Sources 2023
 - Lachlan Fold Belt Greater Metropolitan Groundwater Source
 - Sydney Basin West Groundwater

- Groundwater drainage budget zone**
- Lachlan Fold Belt Greater Metropolitan Groundwater Source
 - Farmers Creek
 - Coxs River
 - Marra Creek
 - Sandalls Creek
 - Lake Lyell
 - Upper reservoir
 - Other drainages

- Sydney Basin West Groundwater Source
- Farmers Creek
 - Marra Creek
 - Other drainages

Groundwater management zones and drainage budget zones

Lake Lyell PHES
Groundwater Modelling Report
Figure 6.13



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7 Summary, model limitations and recommendations

The project is a PHES system located approximately 5 km west of Lithgow and 110 km west of the Sydney central business district. The project consists of upper and lower water reservoirs, a pipeline connecting them, and a hydro-electric power station connected to the national energy grid that is capable of generating or consuming electricity.

The construction and operation of the project will potentially impact on groundwater levels due to tunnelling and reservoir construction activities and associated works. To support the GIA, a three-dimensional numerical groundwater flow model was developed to quantify groundwater level and flow impacts due to construction and throughout the operation phase. The modelling objectives included predictions of:

- watertable drawdown due to project-only and cumulative impacts
- potential impacts (drawdown/mounding) at identified sensitive receivers such as landholder bores and GDEs, under long-term average and climate change prediction rainfall scenarios
- groundwater inflows to the project infrastructure during construction and operation
- changes to the water balance (with regards to both groundwater and surface water source areas) as a result of the project to inform water licensing.

An EPM sitewide numerical groundwater flow model was built using the MODFLOW-USG simulation code. This model employs a Voronoi polygon mesh across an irregularly shaped domain to follow hydrogeological, hydrological and project features. The model covers an area that spans a diameter of ~12 km across 20 model layers. Model history-matching included both steady-state and transient stress periods to allow matching to heads and changes in head as a result of recharge-discharge processes. The model employs a highly parameterised approach via pilot points deployed in every model layer to allow for spatially distributed fields for K_h , K_v , S_s , S_y , and recharge. The ensemble of accepted realisations was deemed to be appropriately history-matched and generally aligns with attributes of a Class 2 model.

Three predictive scenarios were developed; cumulative, no project, and null, allowing for prediction of changes to groundwater conditions associated with the project and the nearby Metromix Quarry individually, and separated from climatic variability. A parameter ensemble of 104 realisations was employed to allow for a range of drawdown, mounding and water balance change predictions.

The groundwater flow model predictions include:

- drawdown at the end of construction is confined to the immediate surroundings of the project, with the 0.2 m drawdown contour no more than 1,000 m from the centre of the project
- at the end of operations a maximum of 60 m mounding is predicted immediately below the upper reservoir, with the 0.2 m mounding contour extending approximately 1.8 km north-east from the centre of the project
- drawdown / mounding associated with the project is not predicted to interact with drawdown from Metromix Quarry, indicating that cumulative impacts on groundwater are very unlikely
- inflows to underground excavations, excluding the upper reservoir, are expected to peak approximately 0.16 ML/d (~58.4 ML/yr) in 2029
- a net increase in leakage from surface water features is predicted, reaching nearly 0.7 ML/yr by 2030

- a net decrease in baseflow of approximately 4 ML/yr to perennial watercourses is expected during construction and operation.

The conceptual and numerical models are supported by a dataset that is concentrated around the immediate project area; away from these areas there is limited hydrogeological information. The record from the monitoring network is quite short, with at most 22 months' monitoring for a single observation well.

The monitoring record available to support history-matching contains only climate stresses. These are small in both magnitude and duration relative to the stresses imposed during the predictive scenarios. In order to address the limited dataset available to constrain model parameters, a probabilistic uncertainty analysis was implemented. Parameters were allowed to adopt values from within plausible ranges, however structural controls such as fractures and faults were not modelled explicitly. Due to the limited history-matching dataset available, the parameters adopted for the predictive uncertainty analysis (and the resultant quantification of uncertainty) is not well constrained. Predictive uncertainty would be reduced through the collection and history-matching to additional groundwater data.

The model is not intended to simulate unsaturated zone or geotechnical processes, nor is it designed to simulate solute transport. Additionally, the EPM approach used to build the model was selected to estimate the mid to regional impact of the project on the groundwater system; actual tunnel inflows observed during excavation works may vary locally within excavations due to the heterogeneous nature of the fractured rock media.

Despite these limitations, given the risk profile of the project the model is considered fit-for-purpose in meeting the modelling and project objectives.

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Attachment A

Australian Groundwater Modelling Guidelines (2012) model
confidence criteria

	Class 3	Class 2	Class 1	Comment
Data	Spatial and temporal distribution of groundwater head observations adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported.	Groundwater head observations and bore logs are available but may not provide adequate coverage throughout the model domain.	Few or poorly distributed existing wells from which to obtain reliable groundwater and geological information.	
	Spatial distribution of bore logs and associated stratigraphic interpretations clearly define aquifer geometry.		Observations and measurements unavailable or sparsely distributed in areas of greatest interest.	
	Reliable metered groundwater extraction and injection data is available.	Metered groundwater-extraction data may be available but spatial and temporal coverage may not be extensive.	No available records of metered groundwater extraction or injection.	Not applicable.
	Rainfall and evaporation data is available.		Climate data only available from relatively remote locations.	
	Aquifer-testing data to define key parameters.			
	Streamflow and stage measurements are available with reliable baseflow estimates at a number of points.	Streamflow data and baseflow estimates available at a few points.		
	Reliable land-use and soil-mapping data available.		Little or no useful data on land-use, soils or river flows and stage elevations.	
	Reliable irrigation application data (where relevant) is available.	Reliable irrigation-application data available in part of the area or for part of the model duration.		Not applicable.
	Good quality and adequate spatial coverage of digital elevation model to define ground surface elevation.			
Calibration	Adequate validation* is demonstrated.	Validation* is either not undertaken or is not demonstrated for the full model domain.	No calibration is possible.	
	Scaled RMS error (refer Chapter 5) or other calibration statistics are acceptable.	Calibration statistics are generally reasonable but may suggest significant errors in parts of the model domain(s).		

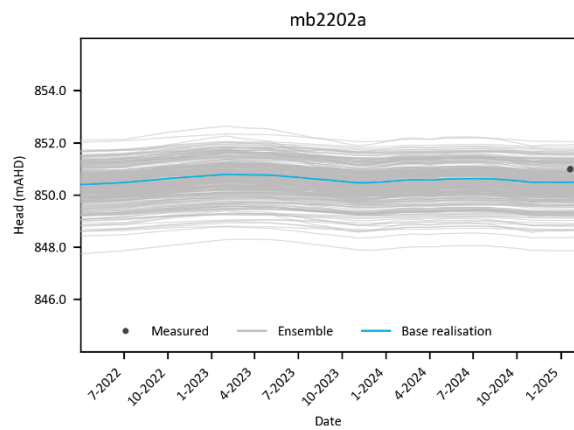
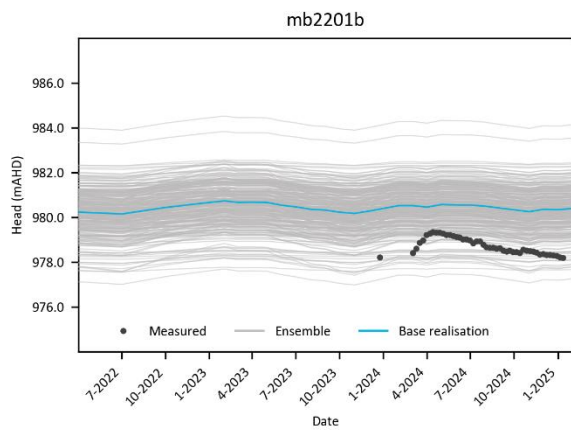
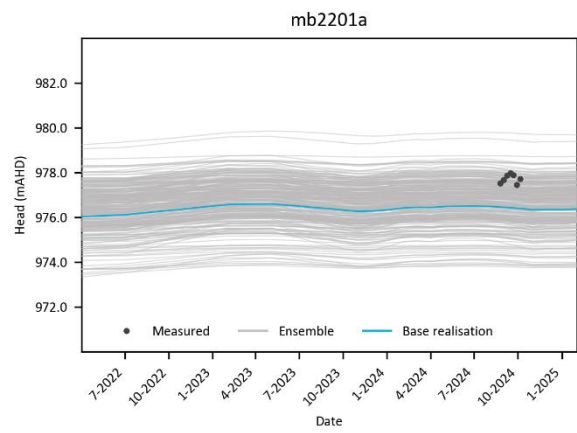
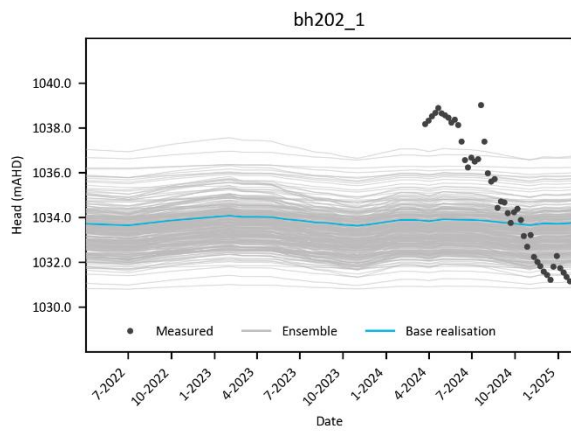
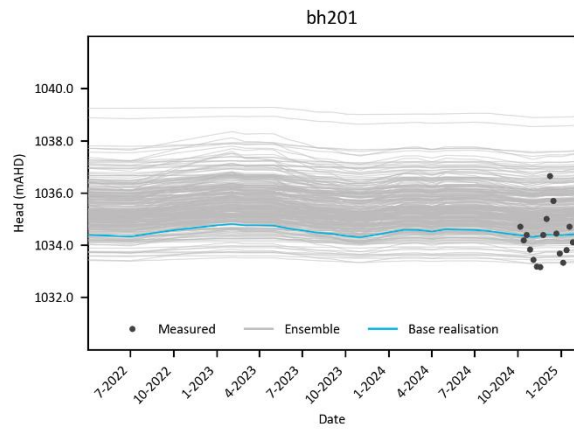
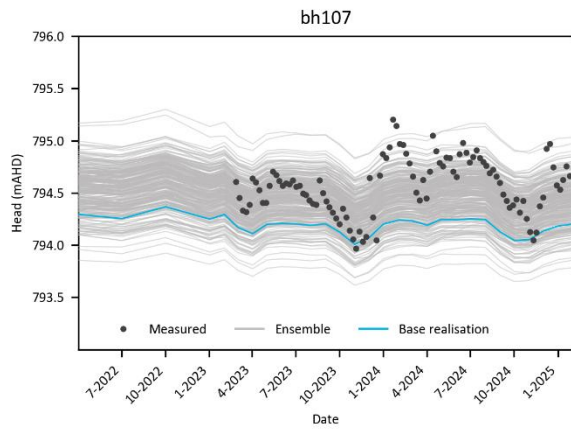
	Long-term trends are adequately replicated where these are important.	Long-term trends not replicated in all parts of the model domain.	Calibration illustrates unacceptable levels of error especially in key areas.	Not applicable.
	Seasonal fluctuations are adequately replicated where these are important.	Seasonal fluctuations not adequately replicated in all parts of the model domain.		
	Transient calibration is current, i.e. uses recent data.	Transient calibration to historic data but not extending to the present day.	Calibration is based on an inadequate distribution of data.	
	Model is calibrated to heads and fluxes.	Model is calibrated to heads only.		
	Observations of the key modelling outcomes dataset is used in calibration.	Observations of the key modelling outcome data set are not used in calibration.	Calibration only to datasets other than that required for prediction.	
Prediction	Length of predictive model is not excessive compared to length of calibration period.	Transient calibration over a short timeframe compared to that of prediction.	Predictive model timeframe far exceeds that of calibration.	
	Temporal discretisation used in the predictive model is consistent with the transient calibration.	Temporal discretisation used in the predictive model is different from that used in transient calibration.	Temporal discretisation is different to that of calibration.	
	Level and type of stresses included in the predictive model are within the range of those used in the transient calibration.	Level and type of stresses included in the predictive model are outside the range of those used in the transient calibration.		
	Model validation* suggests calibration is appropriate for locations and/or times outside the calibration model.	Validation* suggests relatively poor match to observations when calibration data is extended in time and/or space.	Model validation* suggests unacceptable errors when calibration dataset is extended in time and/or space.	Not applicable.
	Steady-state predictions used when the model is calibrated in steady-state only.		Transient predictions are made when calibration is in steady-state only.	Not applicable.
Key indicator	Key calibration statistics are acceptable and meet agreed targets.	Key calibration statistics suggest poor calibration in parts of the model domain.	Model is uncalibrated or key calibration statistics do not meet agreed targets.	
	Model predictive time frame is less than 3 times the duration of transient calibration.	Model predictive timeframe is between 3 and 10 times the duration of transient calibration.	Model predictive time frame is more than 10 times longer than transient calibration period.	

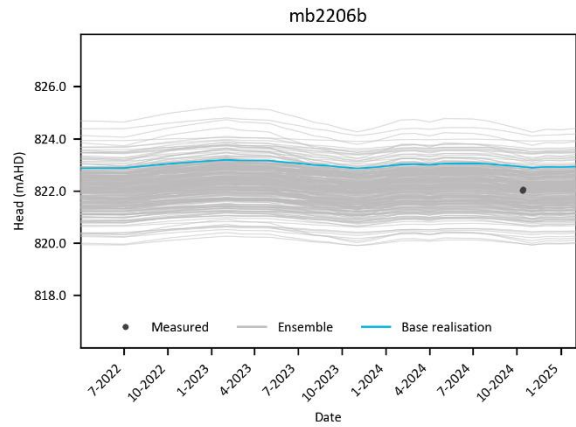
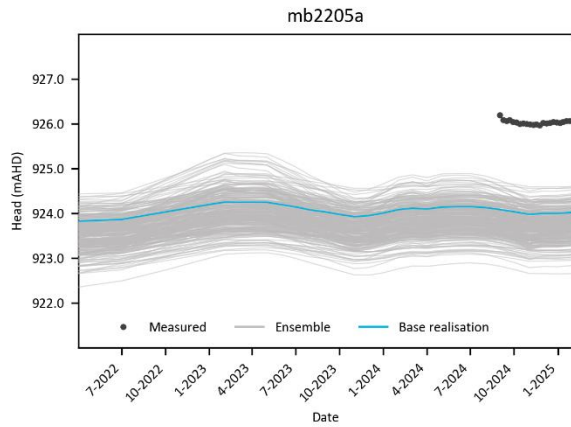
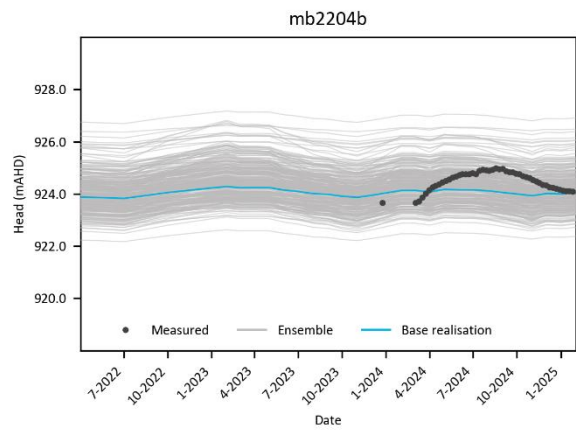
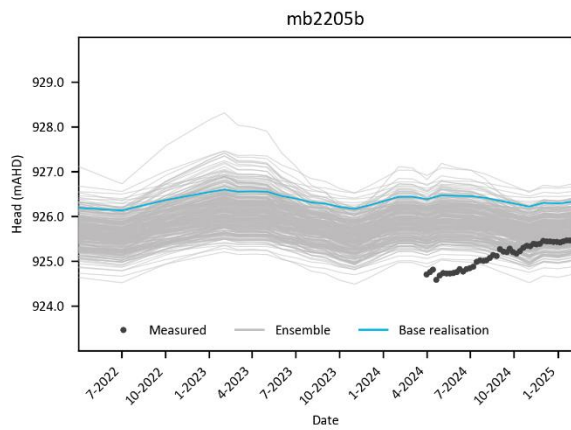
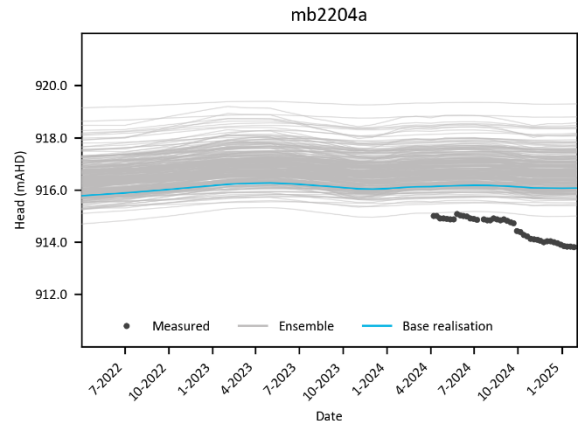
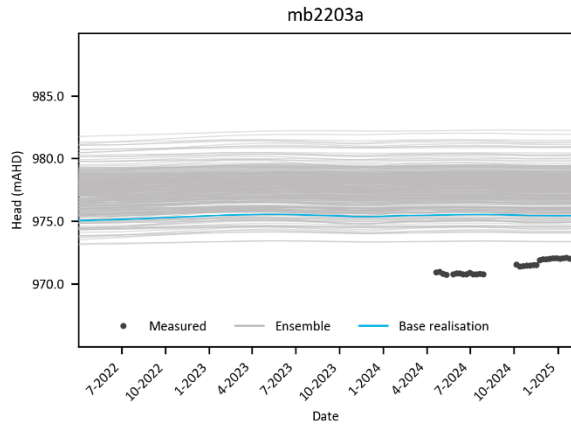
	Stresses are not more than 2 times greater than those included in calibration.	Stresses are between 2 and 5 times greater than those included in calibration.	Stresses in predictions are more than 5 times higher than those in calibration.	
	Temporal discretisation in predictive model is the same as that used in calibration.	Temporal discretisation in predictive model is not the same as that used in calibration.	Stress period or calculation interval is different from that used in calibration.	
	Mass balance closure error is less than 0.5% of total.	Mass balance closure error is less than 1% of total.	Cumulative mass-balance closure error exceeds 1% or exceeds 5% at any given calculation time.	
			Transient predictions made but calibration in steady state only.	Not applicable.
	Model parameters consistent with conceptualisation.	Not all model parameters consistent with conceptualisation.	Model parameters outside the range expected by the conceptualisation with no further justification.	
	Appropriate computational methods used with appropriate spatial discretisation to model the problem.	Spatial refinement too coarse in key parts of the model domain.	Unsuitable spatial or temporal discretisation.	
	The model has been reviewed and deemed fit for purpose by an experienced, independent hydrogeologist with modelling experience.	The model has been reviewed and deemed fit for purpose by an independent hydrogeologist.	The model has not been reviewed.	
Examples of specific uses	Suitable for predicting groundwater responses to arbitrary changes in applied stress or hydrological conditions anywhere within the model domain.	Prediction of impacts of proposed developments in medium value aquifers.	Design observation bore array for pumping tests.	
	Provide information for sustainable yield assessments for high-value regional aquifer systems.	Evaluation and management of medium risk impacts.	Predicting long-term impacts of proposed developments in low-value aquifers.	
	Evaluation and management of potentially high-risk impacts.	Providing estimates of dewatering requirements for mines and excavations and the associated impacts.	Estimating impacts of low-risk developments.	

	Can be used to design complex mine dewatering schemes, salt interception schemes or water allocation plans.	Designing groundwater management schemes such as managed aquifer recharge, salinity management schemes and infiltration basins.	Understanding groundwater flow processes under various hypothetical conditions.	
	Simulating the interaction between groundwater and surface water bodies to a level of reliability required for dynamic linkage to surface water models.		Developing coarse relationships between groundwater extraction locations and rates and associated impacts.	
	Assessment of complex, large-scale solute transport processes.	Estimating distance of travel of contamination through particle-tracking methods. Defining water source protection zones.	As a starting point on which to develop higher class models as more data is collected and used.	
			Provide first-pass estimates of extraction volumes and rates required for mine dewatering.	
	Legend:			
	Blue shading: This item describes this model.			
	Grey: Not applicable to this model.			

Attachment B

History-matching hydrographs (full PUA ensemble)



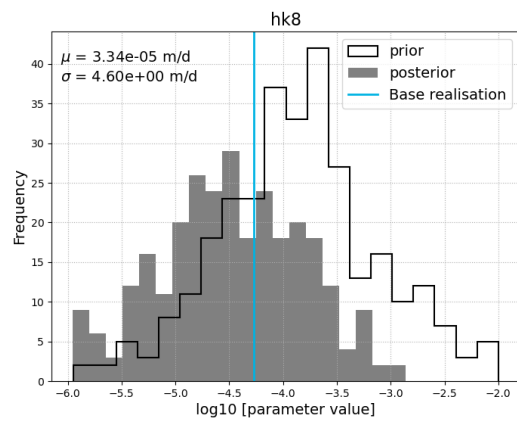
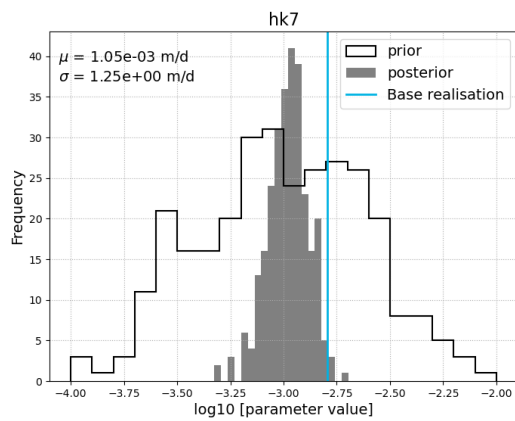
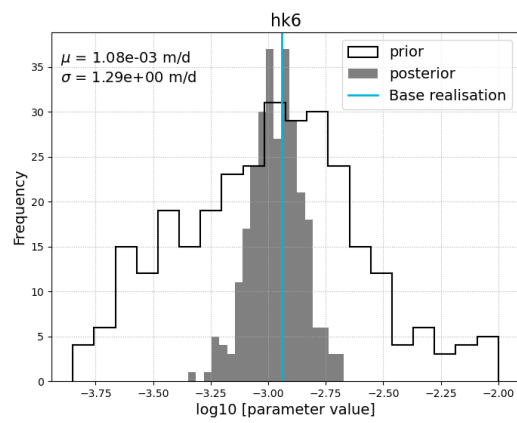
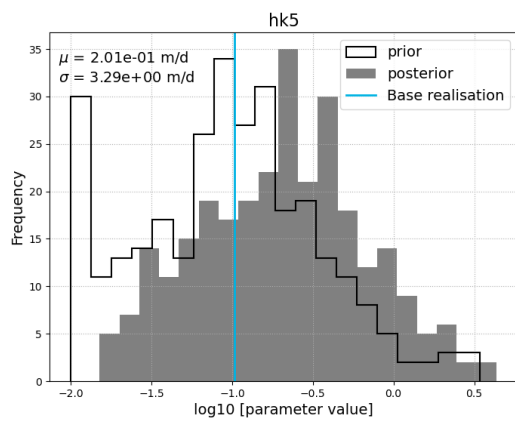
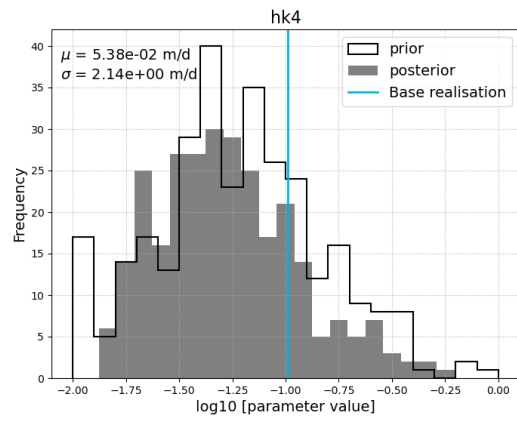
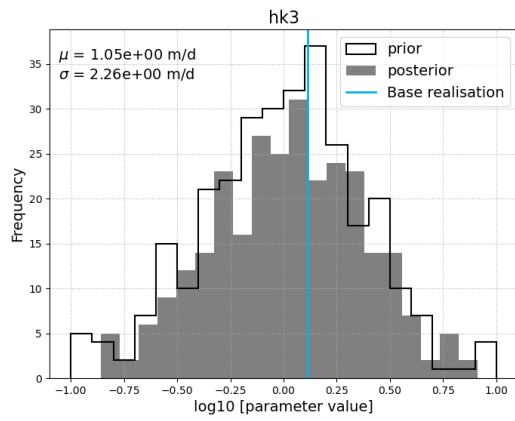
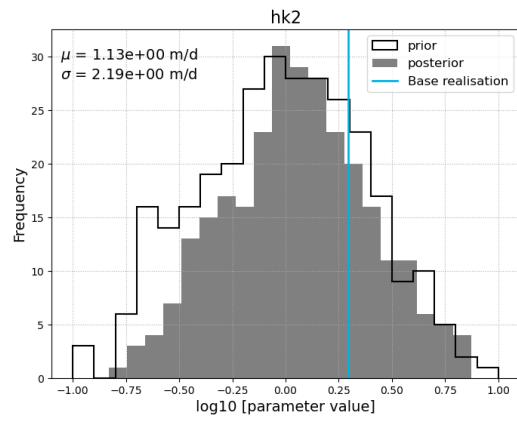
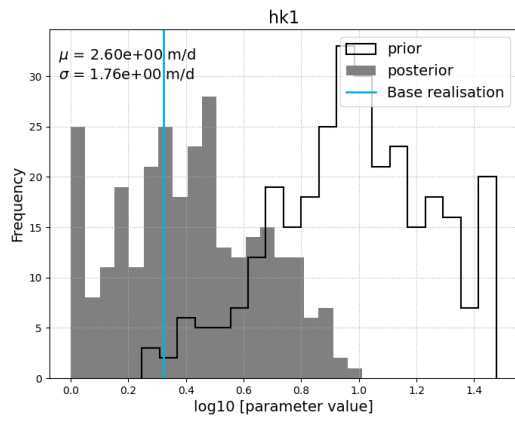


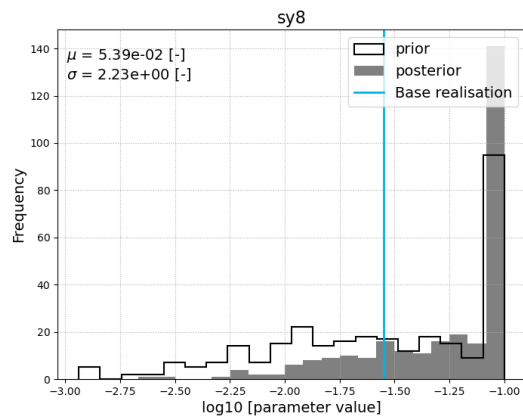
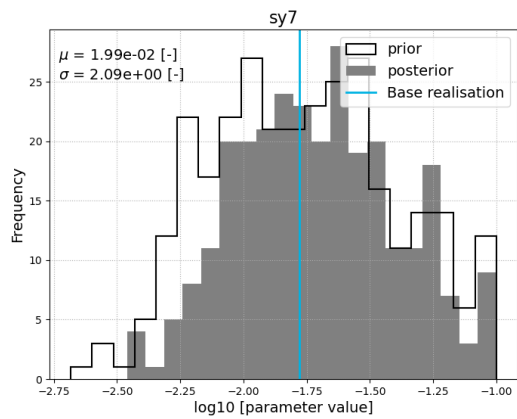
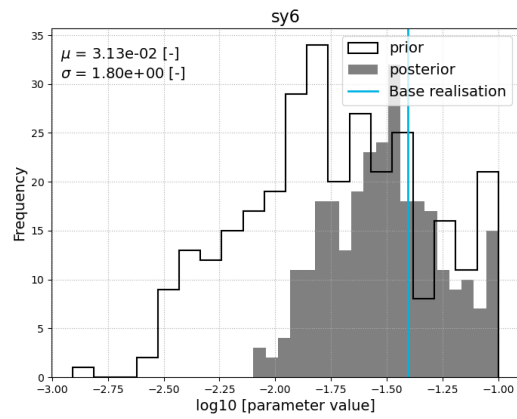
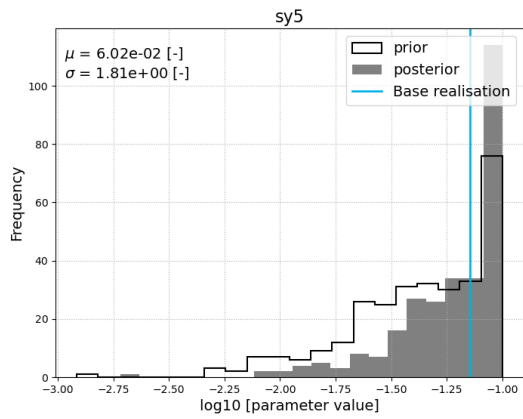
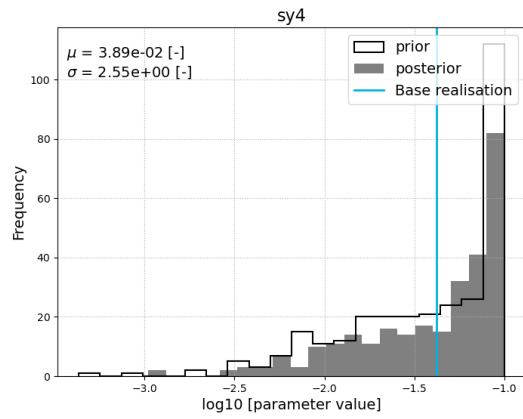
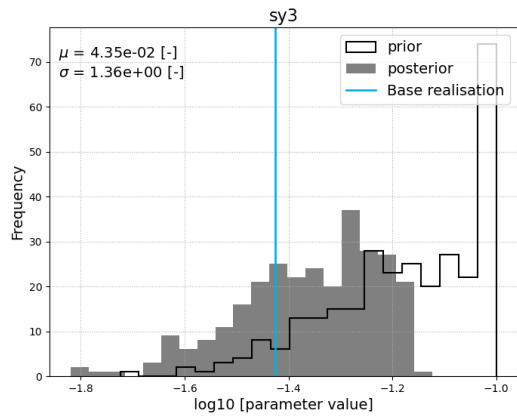
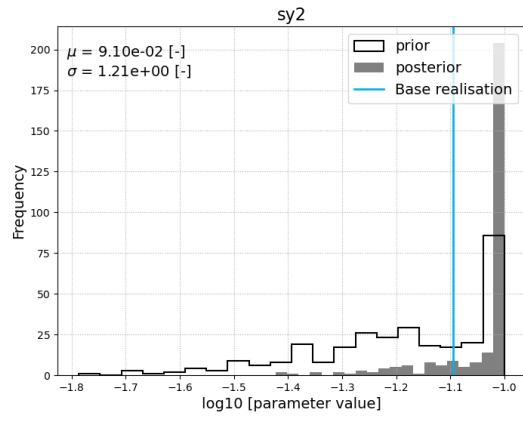
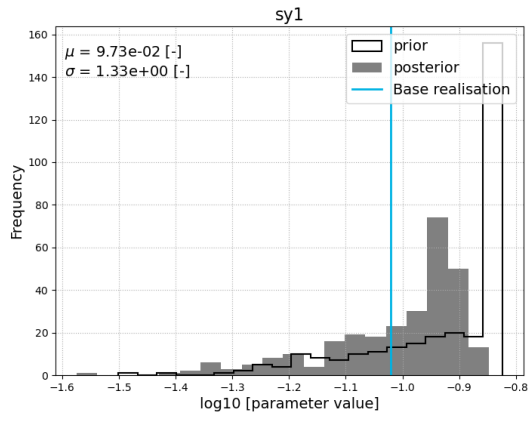
Attachment C

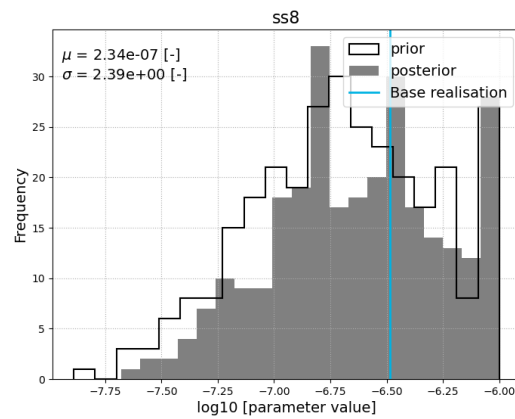
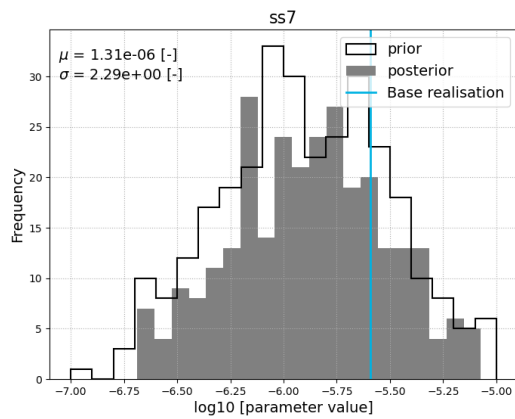
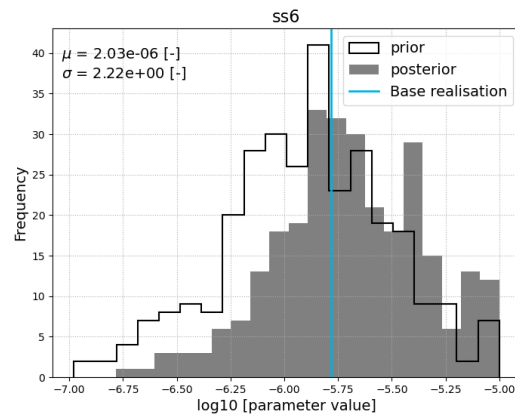
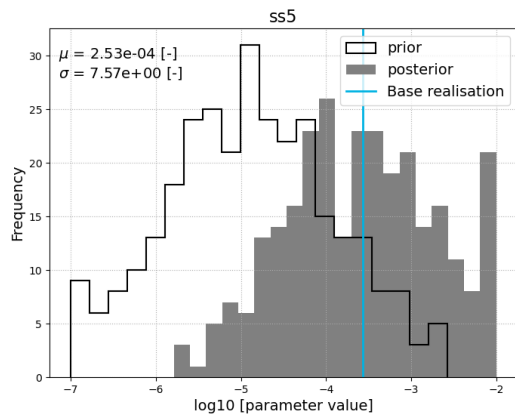
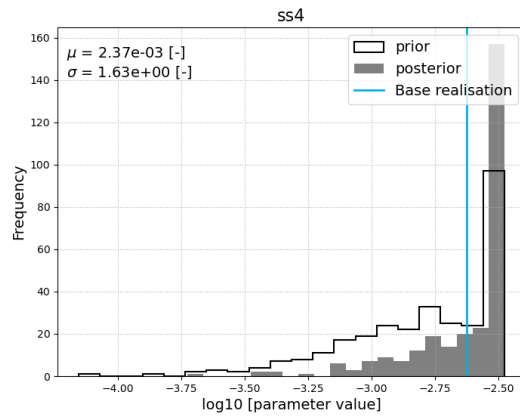
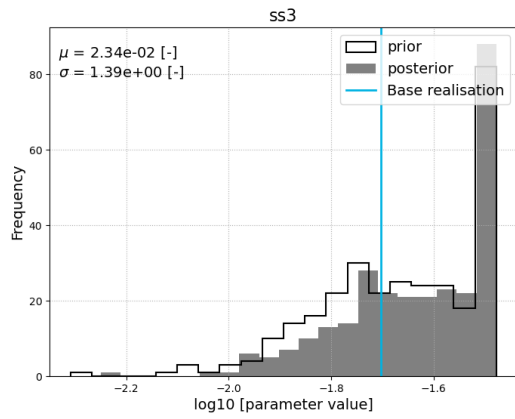
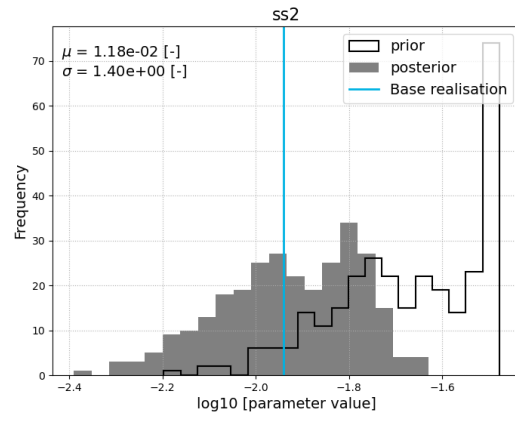
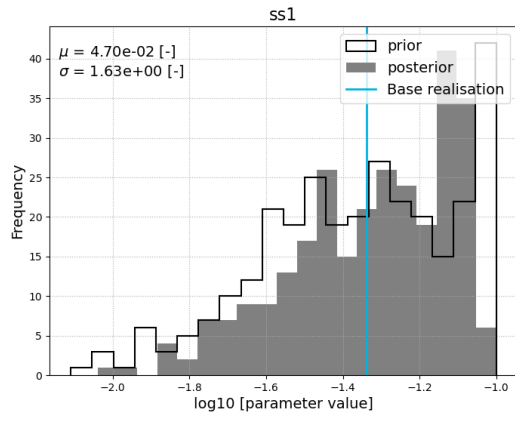
History-matched parameter histograms

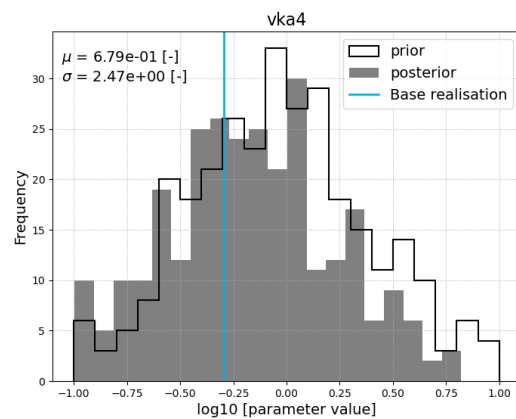
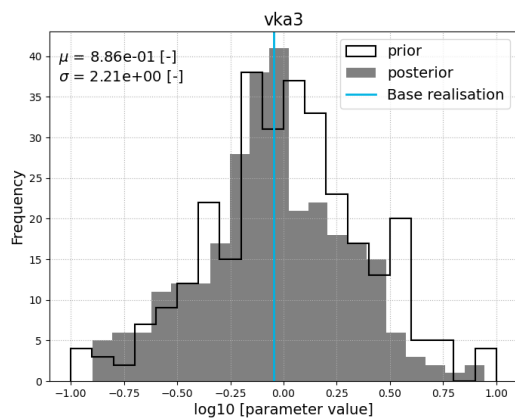
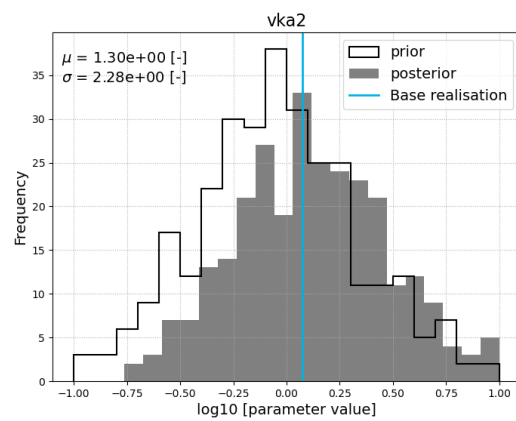
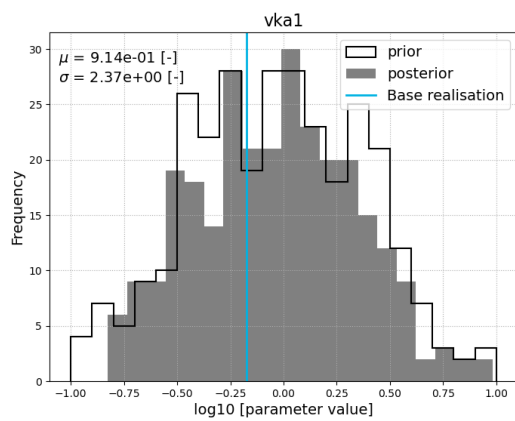
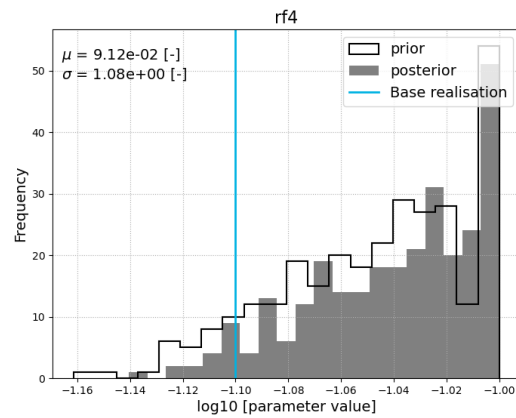
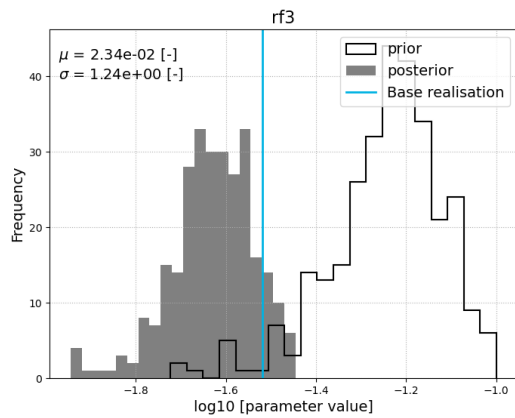
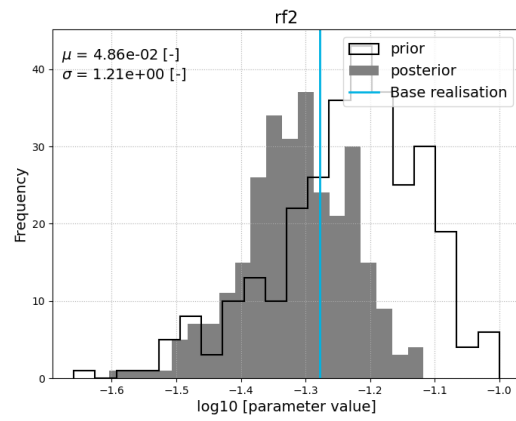
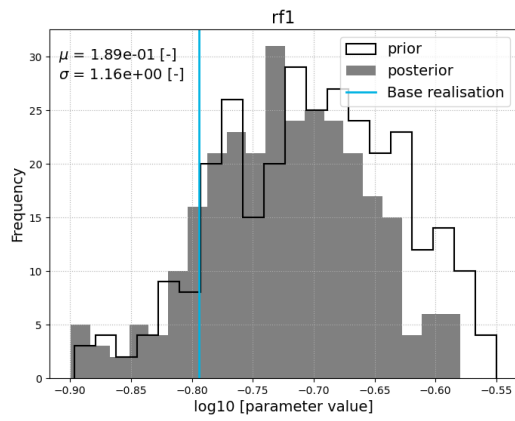
Table C.1 **Parameter naming convention**

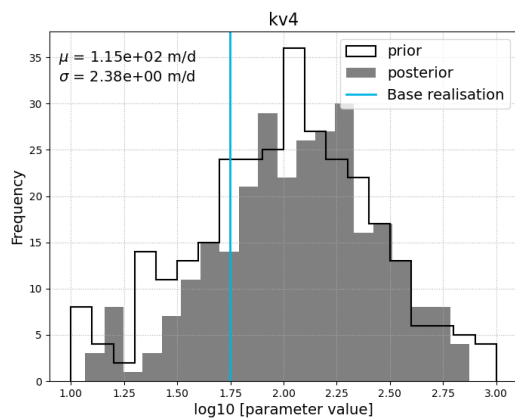
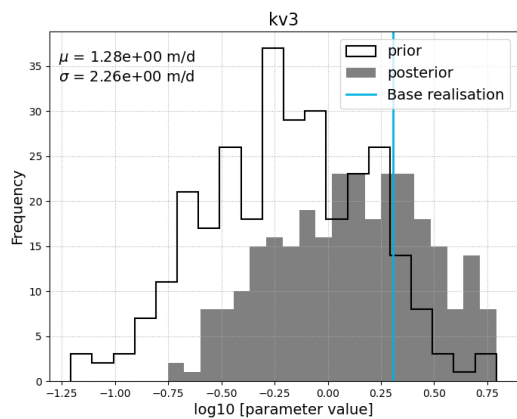
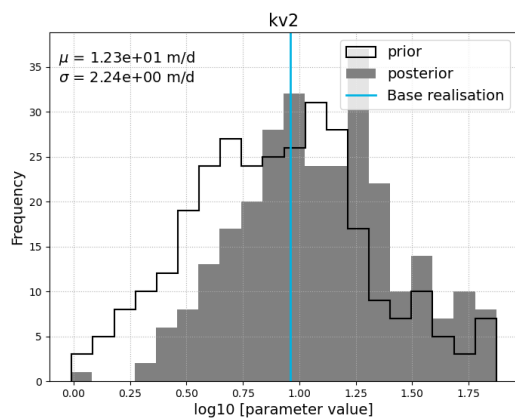
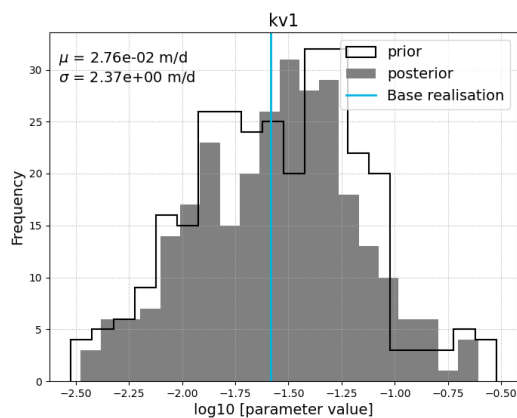
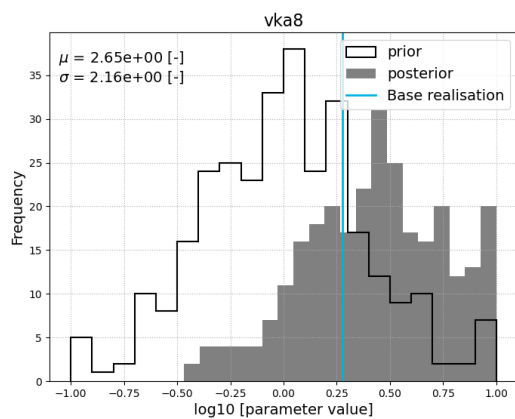
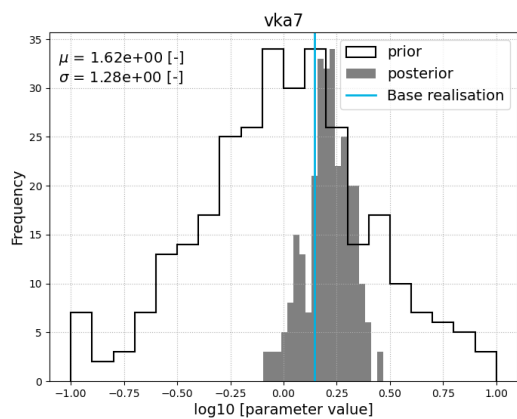
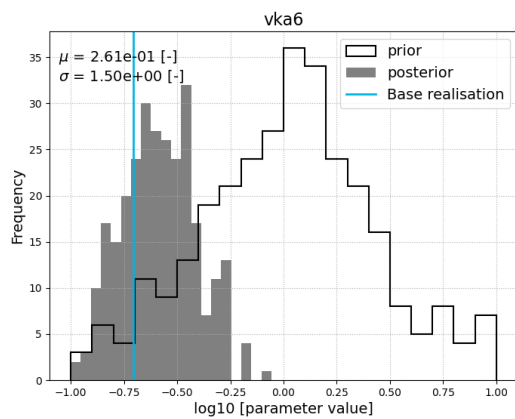
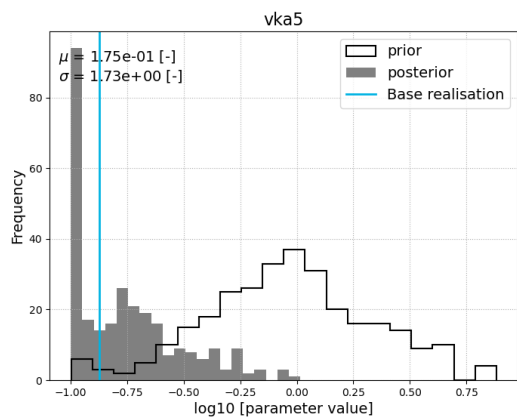
Name snippet	Explanation	Unit
hk	Horizontal hydraulic conductivity, zone-based	-
sy	Specific yield, zone-based	-
sy	Specific storage, zone-based	-
rf	Recharge-rainfall ratio (multiplier factor)	-
vka	Anisotropy ratio (horizontal-vertical hydraulic conductivity ratio), zone-based	-
kv	RIV package – hydraulic conductivity value used for the calculation of the riverbed conductance, zone-based	m/d

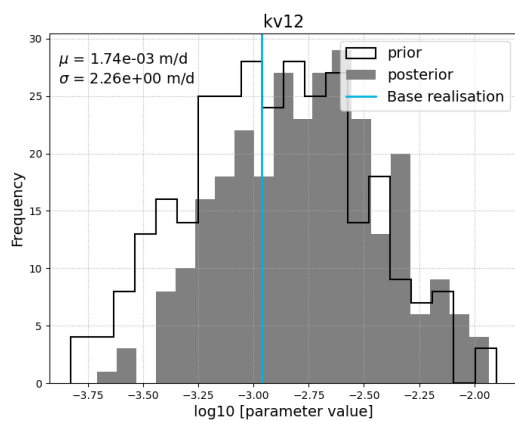
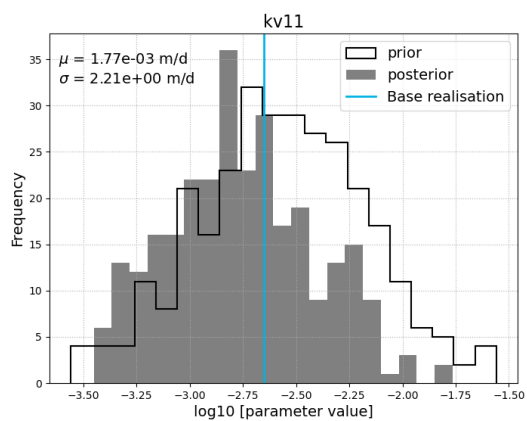
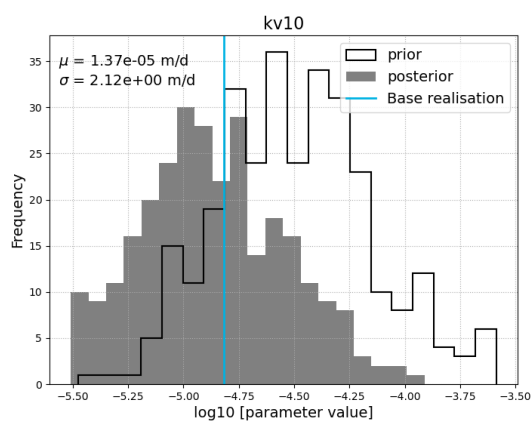
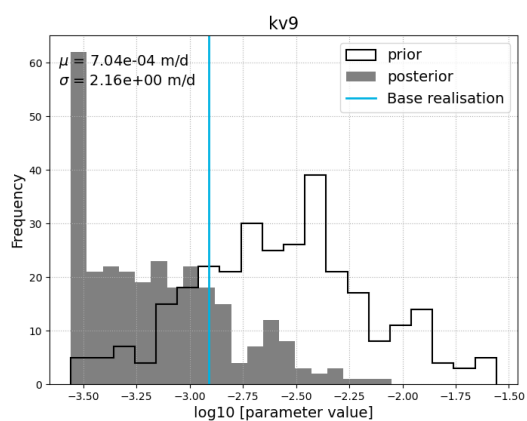
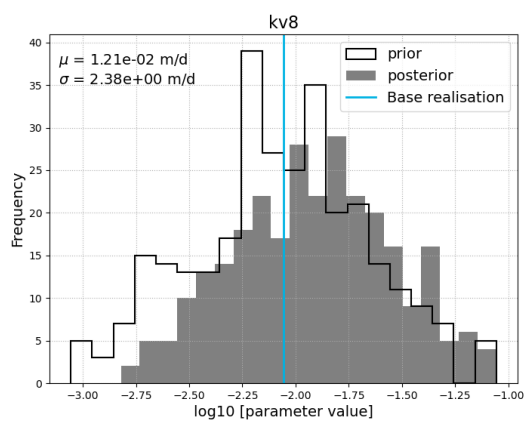
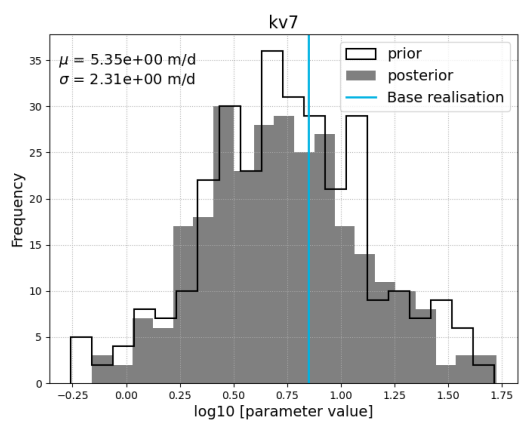
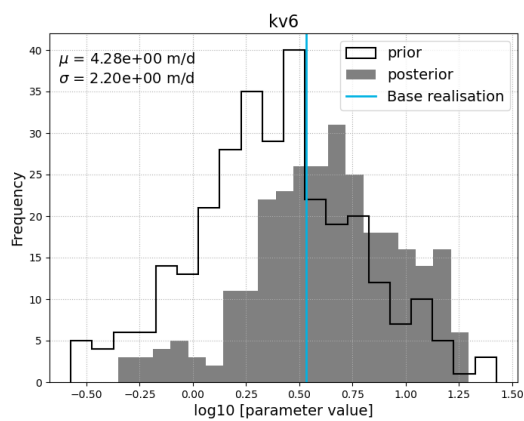
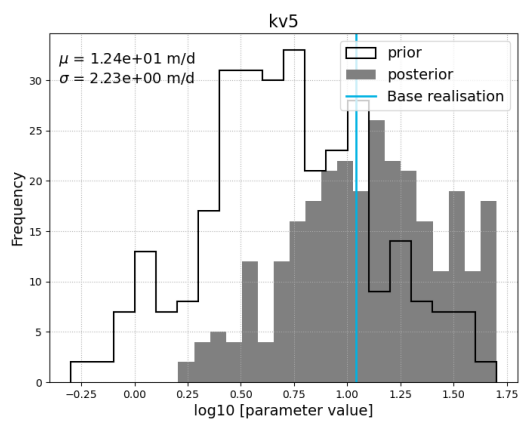


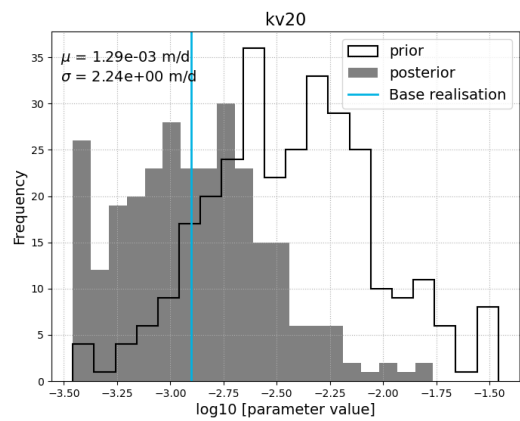
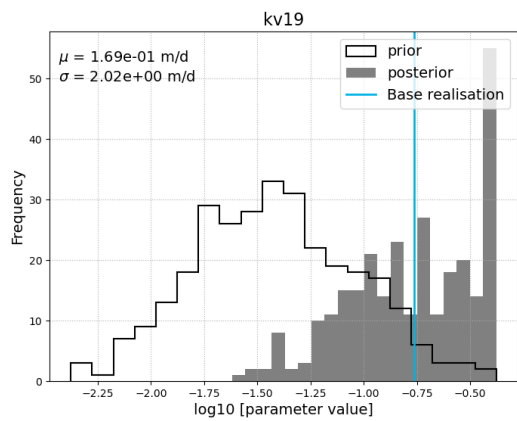
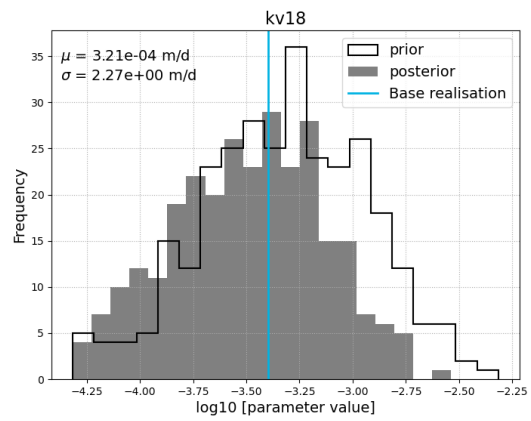
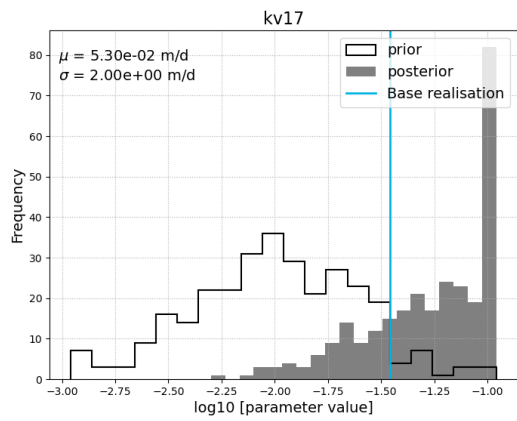
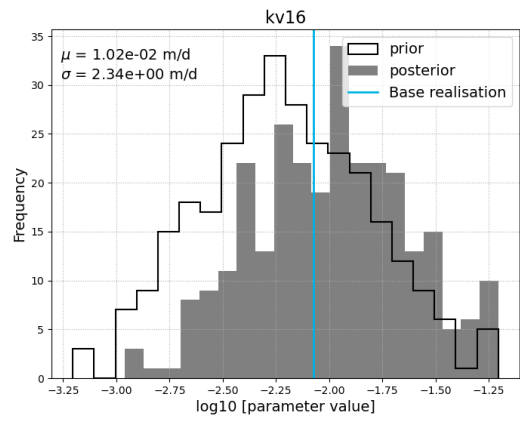
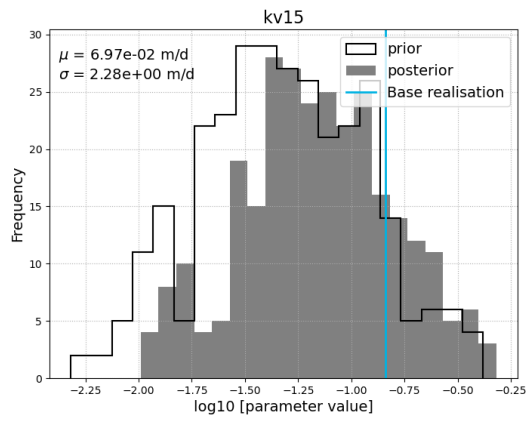
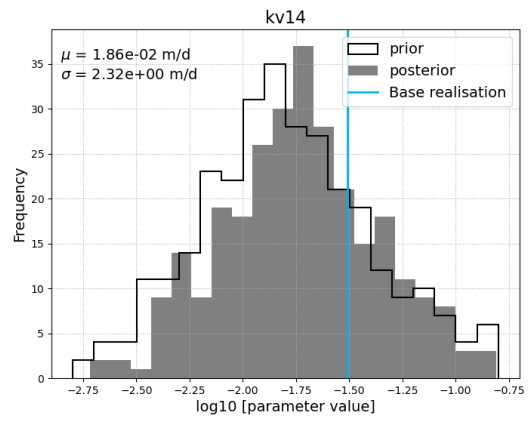
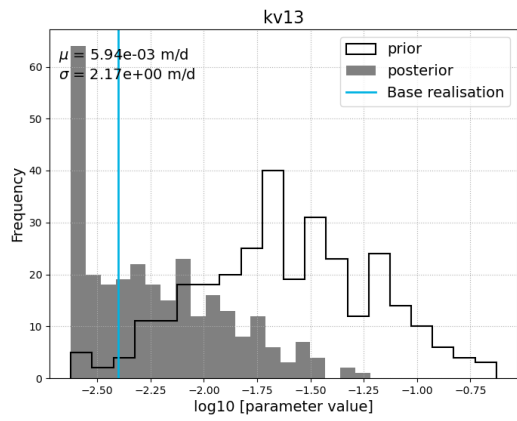












Attachment D

Peer review

DATE: 7th October 2025

TO: EMM
Henry Noakes

FROM: Chris Nicol, Hydrogeologist

RE: Peer review: Lake Lyell Pumped Hydro Energy Storage (PHES)
Groundwater Modelling

OUR REF: EMM004/c002_rev2

1. Introduction

This brief report summarises the primary findings of an independent technical review of a numerical groundwater flow model developed by EMM for the Lake Lyell Pumped Hydro Energy Storage (PHES) project (herein “the Project”), as described by EMM (2025a).

The Project involves a range of groundwater-affecting activities, including construction and operation of an upper reservoir, headrace and tailrace tunnels, ancillary access tunnels and adits, and surge shafts. The reader is referred to EMM (2025a) for a detailed summary of the Project. The tunnel, shaft and adit components may result in groundwater depressurisation as they are constructed to depths below the watertable, whilst the new reservoir is likely to cause local groundwater mounding. There is the possibility of cumulative impact due to the nearby Marangarro Quarry.

EMM (2025a) describes the basis, development, and application of numerical groundwater flow modelling used to assess potential effects arising from the identified groundwater-affecting activities. This information is used in a separate Groundwater Impact Assessment (GIA) report (EMM, 2024b), which translated the modelling outcomes to impact receptor risks.

The objective of the groundwater modelling is to assess the locations, magnitude and timing of potential direct and indirect effects of construction and operation of the Project on groundwater and connected surface water systems, including Groundwater Dependent Ecosystems (GDEs). The GIA (EMM, 2024b) describes the risk assessment basis for the defined model objectives. Potential groundwater effects arising from Project development centre around groundwater depressurisation during tunnelling and dam construction, followed by ongoing operational period depressurisation around certain scheme features, and potential groundwater mounding around the scheme’s upper surface water storage. EMM (2025a) explicitly specifies the modelling objectives, as designed in support of the GIA (EMM, 2024b):

- watertable drawdown due to Project-only and cumulative impacts
- potential impacts (drawdown/mounding) caused by the Project at identified sensitive receivers such as landholder bores and groundwater dependent ecosystems
- groundwater inflows to the Project infrastructure during construction and operation
- changes to the water balance (with regards to both groundwater and surface water source areas) to inform water licensing requirements for the Project

- watertable drawdown due to Project-only impacts taking into consideration potential future long term rainfall changes under a climate change scenario.

EMM (2025a) also specifies a series of exclusions from the modelling objectives and hence its design and application. Also transparently described are several limiting assumptions underpinning the modelling. These are not described here.

2. Review Methodology

The evidentiary basis of this review is limited to: “*Lake Lyell Pumped Hydro Groundwater Modelling Report Version 5*” (EMM, 2025a). This includes a summary of the conceptual hydrogeological model that is used as a basis model design and end use. More detailed conceptual hydrogeological assessment was provided in the GIA (EMM, 2024b; only cursorily reviewed). The modelling review was conducted after all modelling and associated reporting were completed. The reviewer was not involved during the modelling process, aside from a single meeting prior to model history-matching, in which EMM presented a summary overview of the conceptualisation, modelling design and supporting data for cross-discussion. Model files were not inspected for this review.

This review of the Lake Lyell groundwater model was undertaken in broad alignment with the principles of the Australian Groundwater Modelling Guidelines (AGMG; Barnett et al., 2012). The AGMG are referred to under the Minimum groundwater modelling requirements for SSD/SSI Projects (DPE 2022) and hence are used as a basis for this review. However, reference was also made to:

- The body of work surrounding development of PEST and related codes (see Doherty, 2022 and works cited therein).
- The Independent Expert Scientific Committee’s (IESC’s) uncertainty analysis guidance (Middlemis and Peeters, 2023).

In conjunction with the above guidance documents, my experience in the modelling industry was used to assess the following broad aspects of the modelling process:

- Planning – the intended use of the model, the questions to be answered, the modelling objectives and the type of model needed to meet the project objectives.
- Conceptualisation – the development of an objective-relevant conceptual model through analysis of available data and knowledge.
- Design and construction – representation of the conceptualisation in the numerical model, and the representation of key hydrological processes, as of greatest relevance to model end use - specifically, the simulation of quarrying and quarry expansion activities, and their potential effects on groundwater and surface water systems, features, and behaviour.
- History-matching – the process of assimilating historical observation data into the model by informing and constraining model parameters and processes. Incorporated observation data should, where possible, be of direct import to model parameters that affect key model outputs, thereby reducing their uncertainty (Doherty, 2022).
- Forecasts and their uncertainty – how the model has been used to provide outputs that address the questions defined in the modelling objectives, in consideration of model uncertainty and its implications.
- Model reporting – clear communication of the conceptualisation, model development and outputs. This should allow stakeholders and reviewers to understand the process and key outcomes of the assessment, to enable assessment of model fitness for satisfying modelling and project objectives.

Review checklist Table 9-2 of the AGMG (Barnett et al., 2012) forms the detailed framework for this review, to assess alignment with industry standards and best practice. This, as pertaining to review of the Project groundwater model, is provided as Attachment 1; aside from providing useful structured

reviewer prompts, it forms a basis for recording reviewer questions and answers from the modelling team and recording detailed points arising from the review process. The modelling team is specifically referred to the key questions and items identified in column D (“suggested actions”); a level of importance is assigned to each of these items in column E.

3. Review Outcomes Summary

The hydrogeological conceptualisation and associated model planning and design are generally thorough and well thought-out, with a focus on model end use in meeting the Project objectives and the needs of dependent study disciplines.

There are no historical observation data relating to the anthropogenic depressurisation- and mounding-related aquifer stress responses that the model is ultimately used to forecast. This is a commonly encountered situation, because the very nature of these greenfield projects means that it cannot be overcome until the project (or a nearby similar project) is built and effects are monitored. However, the potential future effects of these project-related stresses are well thought through and conceptualised and are ultimately used to inform an appropriate model design, including code selection, layering, boundary conditions, mesh, and temporal discretisation.

It is worth noting here that EMM conducted a revised model history-matching and scenario modelling process approximately one year after an initial effort and associated report was reviewed (in late 2024). The revised modelling is significantly improved, particularly in terms of history matching; this appears driven by more available data with which to train the models, and several improvements and simplifications made to the modelling design and workflows.

The modelling workflow of EMM (2025a) follows current best practice approaches and includes a reasonable assessment of forecast model uncertainty. Most if not all parameters and boundary conditions are treated as uncertain, and many are spatially variable; this is a solid approach. Some documentary omissions from an early modelling report draft were addressed by EMM following an initial review process, and these are addressed in EMM (2025a; see Attachment 1).

EMM’s report quality is generally high, and there are a range of useful depictions of model history-match quality and parameterisation, including uncertainty. Some suggestions for report improvement and clarification are provided in Attachment 1, as are some recommendations for future modelling efforts.

One primary area for potential future improvement is more thought around designing history-matching targets (from the limited observation data) that are of greater direct relevance to the key predictions of interest, i.e., lowering of the watertable by Project construction features. It is noted that vertical hydraulic gradients at nested sites are used, which addresses this to some degree, but a thought that occurred to me as I undertook this review is that standing water level above the invert of the nearest future construction (depressurisation) feature is probably one of the few observation types of direct relevance to modelling objectives that one could develop given the data to hand. Others may exist, and additional thought on this for future model updates is encouraged.

Similarly, if there are other similar infrastructure in a similar and relevant hydrogeological environment, which are in operation and for which groundwater inflow data are available, then it could be worth considering inclusion of “soft” (large error range) inflow observations from such projects in the Lake Lyell model history matching (noting then that the history matching workflow would need to include the forecast model period as well, which may or may not be practical). Whilst very approximate, this or a similar approach may serve to overcome the issue of site-specific prediction-related observation data shortage, which has a direct bearing on how reliable model forecasts can possibly be.

Model forecasts of potential groundwater-related risks arising from the project are nicely presented and suit the specified objectives well. The conclusions made based on modelled impact quantities appear reasonable; a very simple analytical cross-check of construction-related inflows was made under this review, which is in the order of those made by the numerical models. These inflows are the driver of groundwater-related risks, and hence this, along with the conceptually reasonable model parameter values and ranges, implies that those modelled risks are reasonable estimates.

As an overarching comment on EMM's groundwater modelling for Lake Lyell, the reviewer is of the view that there are no critical issues and concludes that the modelling is fit for use in meeting the modelling and project objectives. The modelling has been conducted to a good standard and includes assessment of forecast uncertainty analysis that utilises current best practice principles. This is important in any case, but particularly so for this project given the lack of historical data of direct import to the groundwater stresses that the model is used to forecast, and which inform project-related decision-making and regulation.

4. References

- Barnett B, Townley L, Post V, Evans R, Hunt R, Peeters L, Richardson S, Werner A, Knapton A and Boronkay A., 2012. Australian Groundwater Modelling Guidelines. Waterlines report 82, National Water Commission, Canberra. <http://webarchive.nla.gov.au/gov/20160615064846/http://archive.nwc.gov.au/library/waterlines/82>
- Doherty, J., 2022. Scientifically-Based, Decision-Support Groundwater Modelling: A Conceptual Framework. Draft of Part 1. <https://gmdsi.org/blog/scientifically-based-decision-support-groundwater-modelling/>
- DPE. 2022. Minimum groundwater modelling requirements for Major Projects in NSW. Technical note prepared for the Water Division, NSW Department of Planning and Environment as part of the Groundwater Modelling Toolbox Project.
- EMM, 2025a. Lake Lyell Pumped Hydro Groundwater Modelling Report. Prepared for Energy Australia, August 2025. Version 5 dated 15/8/2025. EMM ref: E221111 RP14
- EMM, 2024b. Lake Lyell Pumped Hydro Groundwater Impact Assessment. Prepared for Energy Australia, November 2024. Version 1 dated 7/11/2024. EMM ref: E221111 RP13
- Middlemis H and Peeters LJM., 2023. Uncertainty analysis - Guidance for groundwater modelling within a risk management framework. Prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development. <http://www.iesc.environment.gov.au/publications/information-guidelines-explanatory-note-uncertainty-analysis>

Regards,



Chris Nicol

Groundwater Logic

Attachments:

1. *c001_EMM001_NWC2012_Review_Oven_Mountain_rev3.xlsx - Review checklist Table 9-2 of the AGMG (Barnett et al., 2012)*

Review questions	Yes / No / N/A ¹ / U ² / C ³	Comment	Suggested Actions	Suggested Action Item Importance / Significance	EMM response	Reviewer issue Closed-out?
1. Planning						
1.1 Are the project objectives stated?	Yes	Yes	-	-	-	-
1.2 Are the model objectives stated?	Yes	Yes	-	-	-	-
1.3 Is it clear how the model will contribute to meeting the project objectives?	Yes	Yes	-	-	-	-
1.4 Is a groundwater model the best option to address the project and model objectives?	Yes	Given the spatially varying nature of topography, scheme construction and operation elements, the temporally variable scheme construction and operation elements, and the variety of modelling objectives (forecasts of various impacts from the project), it is difficult to see a suitable alternative to numerical modelling. This is also supported by the need for breakdown of the various types of impact (cumulative versus project-only), and the need for climate change assessment.	-	-	-	-
1.5 Is the target model confidence-level classification stated and justified?	C	A good justification for the inclusion of this is provided (namely, it is required by DPE (2022)), despite industry moves away from such a classification. An alignment with class1 and 2 is a fair assessment, and the main reasons for this are clearly stated. However, my opinion regarding the "Calibration" criteria of the AGMG is that this model more closely fits a "class 1" classification. This is because "Calibration only to datasets other than that required for prediction" is the case for this model; there are no observations of effects (drawdown, water takes) in response to scheme construction and operation such as that used to make model forecasts. It is however noted that this is mentioned in EMM's Appendix A under the "Prediction" AGMG classification criteria.	Consider my comment re: "class 1" here, amend report if you agree. I think that whilst in practice it doesn't affect anything, it is important that readers are made aware of this key limitation (which, granted, can never be overcome for any greenfields project) - but it is a huge limitation of these assessments. In my mind, this "Calibration only to datasets other than that required for prediction" is probably the most valuable bit of the AGMG classification system.	Moderate	Agree and addressed. -Text updated in Section 2.2 to reflect Class 1 / 2. -AGMG confidence table updated as Attachment A to 'Calibration only to datasets other than that required for prediction'.	Reviewer closed. Appropriately addressed.
1.6 Are the planned limitations and exclusions of the model stated?	C	Mostly yes.	I think that my comment re: item 1.5 above should be considered for inclusion in the limitations section, and in the discussion around AGMG model classification. I would talk around why this limitation is so important - i.e., reducing uncertainty through information of direct relevance to the forecasts made using the model. Without such information, it is difficult to see the point of history matching other than to ensure a broadly reasonable representation of the groundwater flow sytem which is subsequently impacted through project construction and operation (to a largely data-uninformed degree). You've touched on it in an implicit way in section 7 but I think it needs to be spell out.	High	Agree and addressed - edit applied to the AGMG table presented and text in the modelling report, Section 2.2.	Reviewer closed. Appropriately addressed.
2. Conceptualisation						
2.1 Has a literature review been completed, including examination of prior investigations?	Yes	-	-	-	-	-
2.2 Is the aquifer system adequately described?	Yes	-	-	-	-	-
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)	Yes	-	-	-	-	-
2.2.2 lateral extent, boundaries and significant internal features such as faults and regional folds	Yes	-	-	-	-	-
2.2.3 aquifer geometry including layer elevations and thicknesses	Yes	-	-	-	-	-
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?	Yes	-	-	-	-	-
2.3 Have data on groundwater stresses been collected and analysed?	Yes	DSTs, slug tests, packer tests. Discussion around typical bore yields. It is however noted that the permeability data are not presented in the draft GIA or modelling report.	Worth presenting tables and/or graphical statistical depictions of the field perm data. Qualitative discussion of model parameter ensembles with reference to these would be appropriate (noting that model parameters should not reflect these precisely, but the broad range should be covered by the models, unless model structural reasons for disparities exist and can be rationalised).	moderate	Refer to Section 6.4 within the GIA (note, this section was not included in the first round of model review from November 2024).	Yes - sorry I had seen this chart in the modelling report but did not realise it had field data in it. Perfect. Resolved.
2.3.1 recharge from rainfall, irrigation, floods, lakes	Yes	-	-	-	-	-
2.3.2 river or lake stage heights	C	Not explicitly discussed in CSM section but it is considered in the model boundary conditions - time-varying RIV stages used for Lake Lyell. Thought put into different watercourse stage heights ranging from 0 to 2m or so depending on waercourse type.	-	-	-	-
2.3.3 groundwater usage (pumping, returns etc)	Yes	-	-	-	-	-
2.3.4 evapotranspiration	Yes	-	-	-	-	-
2.3.5 other?	N/A	-	-	-	-	-
2.4 Have groundwater level observations been collected and analysed?	Yes	-	-	-	-	-

2.4.1 selection of representative bore hydrographs	Yes	Some in modelling report, not in GIA draft (at time of review)	-	-	-	-
2.4.2 comparison of hydrographs	No	In the draft GIA seen by this reviewer, but no figures were available at the time of review. No discussion conceptually in draft GIA. However this is unlikely to affect model design or application. Hydrographs are used in model calibration, so attempt is made for recharge rates and boundary conditions to (at least by design) be informed by those.	Ensure hydrographs are presented and discussed in terms of stress response cause and effect in your GIA. Maybe worth noting that relative mean head differences along the tunnel alignment are more relevant than fine temporal hydrograph detail however, as those head ranges will be what drives project impacts and inflows etc.	moderate	Agree, hydrographs included as Annexure D within the GIA. A model update is due within the next 24-months, where we would like to present discussion on groundwater levels (noting we would like to include further baseline data before we discuss too much).	Fair call. I think at that later stage a cause-and-effect analysis of the hydrographs is warranted; to better understand key groundwater hydraulic drivers, which could inform the modelling design. E.g., considering rainfall trends vs hydrograph trends. Resolved.
2.4.3 effect of stresses on hydrographs	No	See above	-	-	-	-
2.4.4 water table maps/piezometric surfaces?	Yes	-	-	-	-	-
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?	N/A	-	-	-	-	-
2.5.1 baseflow in rivers	No	-	-	-	-	-
2.5.2 discharge in springs	No	-	-	-	-	-
2.5.3 location of diffuse discharge areas?	Yes	-	-	-	-	-
2.6 Is the measurement error or data uncertainty reported?	No	-	-	-	-	-
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	No	-	-	-	-	-
2.6.2 spatial variability/heterogeneity of parameters	Yes	DST, slug and packer test data analysed	-	-	-	-
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	N/A	-	-	-	-	-
2.7 Have consistent data units and geometric datum been used?	Yes	-	-	-	-	-
2.8 Is there a clear description of the conceptual model?	Yes	-	-	-	-	-
2.8.1 Is there a graphical representation of the conceptual model?	Yes	-	-	-	-	-
2.8.2 Is the conceptual model based on all available, relevant data?	Yes	-	-	-	-	-
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	Yes	-	-	-	-	-
2.9.1 Are the relevant processes identified?	Yes	-	-	-	-	-
2.9.2 Is justification provided for omission or simplification of processes?	Yes	-	-	-	-	-
2.10 Have alternative conceptual models been investigated?	No	-	-	-	-	-

3. Design and construction

3.1 Is the design consistent with the conceptual model?	Yes	-	-	-	-
3.2 Is the choice of numerical method and software appropriate?	Yes	-	-	-	-
3.2.1 Are the numerical and discretisation methods appropriate?	Yes	-	-	-	-
3.2.2 Is the software reputable?	Yes	-	-	-	-
3.2.3 Is the software included in the archive or are references to the software provided?	Yes	Specific release versions used are specified.	-	-	-
3.3 Are the spatial domain and discretisation appropriate?	Yes	Covers sufficient area to include cumulative impacts, likely impacts to 3rd parties, and water takes from specific management units.	-	-	-
3.3.1 1D/2D/3D	Yes	3d - appropriate given nature of the project construction and operation	-	-	-
3.3.2 lateral extent	Yes	-	-	-	-

3.3.3 layer geometry?	Yes	Highly detailed to suit the scheme design details' model representation. A case could be made for simpler discretisation (and EMM suggest this), but in my opinion the fine detail makes model parameterisation of construction elements somewhat easier and more transparent.	-	-	-	-
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	Yes	Absolutely more than enough - extremely fine detail around construction features. A case could be made for simpler discretisation, but in my opinion the fine detail makes model parameterisation of construction elements somewhat easier and more transparent, especially given that there are no observations of direct relevance to the construction-related drawdown forecasts that the model is ultimately used for.	-	-	-	-
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?	Yes	-	-	-	-	-
3.4 Are the temporal domain and discretisation appropriate?	Yes	Efficient design based around monitoring data resolution and periods, and around the construction period (when things are changing rapidly) versus the operational and post-operational periods (when things are changing slowly if at all).	-	-	-	-
3.4.1 steady state or transient	Both	Which is sensible	-	-	-	-
3.4.2 stress periods	Yes	See 3.4 above	-	-	-	-
3.4.3 time steps?	No	Not discussed as far as I can see.	Add brief discussion around time stepping scheme to section 4.4, so that readers can assess whether it is appropriate.	Moderate	Agree and addressed. - Text added to Section 4.4.	Reviewer closed. Appropriately addressed.
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?	Yes	Regional BCs are well away from likely impact area, and most are no flow BCs that are aligned with likely groundwater divides. Internal BCs make sense given both scheme design and the requirement for water takes from specific "water sources".	-	-	-	-
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	Yes	1. RIVs (parameterised as DRNs) used for ephemeral water courses, whilst RIV with varying stage (water depth) is used for perennial watercourses. Lidar is used to define stage elevations. This is a reasonable, simple approach to the different types of features. 2. Regarding conductance of GHBs used for project tunnels, I think this should include the area of both side faces, plus top and bottom faces (assuming inflow from all directions into the tunnel); or, a circular tunnel assumption could be made, with conductance defined using the circumference (5m in your case, giving ~15.7m circumference; for a 5m long cell, that gives ~79m ² face area, as opposed to your ~50m ² face area (on my calculation based on your reported 5m cell length by 10m thickness)). This difference is negligible in the scheme of host rock kh variability (during history matching), so it is unlikely to be important to model predictions.	-	-	Noted. - Amendment will be addressed in future iterations of this numerical model.	Reviewer closed. Appropriately addressed.
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?	Yes	Assigning lateral GHBs only to layer 1 makes sense to me as there would, I think, be minimal regional throughflow/underflow of shallow flow systems. In any case, I think that this is likely conservative from a water take and probably drawdown point of view. Lateral boundaries are so far from likely impact extent that they would not significantly affect key model forecasts in my opinion.	-	-	-	-
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	Yes	Simple, but reasonable given the sparsity of temporal data. The discussion of how the soil moisture balance model is applied should be clarified (see suggested action). I don't think a more detailed recharge estimation approach is warranted in this case given the general sparsity of transient head data, and given the timeframe of model forecasts, i.e., long term average recharge is probably enough for constraining during history matching in this case.	Section 4.6.2: 1. Clarify recharge rates used in the predictive models - assuming these come from the historical model estimates. 2. clarify how GDA was used to "filter out rainfall events that generate groundwater recharge" - presumably a GDA model was run once to estimate a recharge timeseries from rainfall data, and then the nominated (calibratable / adjustable) factors of rainfall are used to generate a recharge timeseries for groundwater modelling, which is itself filtered down to the periods when the GDA model suggested there would be a recharge event. Is that right?	Moderate	Recharge simulation was simplified for the updated model and report updated accordingly. A percentage of actual rainfall was used per outcropping zone, rather than using a soil moisture water balance model. This percentage was then optimised during history-matching by assigning a multiplier as a PEST parameter.	Reviewer closed. Appropriately addressed.
3.5.4 Are lateral boundaries time-invariant?	C	Not explicitly stated, but I think it is implied because of the use of interpolating observed water levels to GHB / no flow cells. In any case, I doubt that they would significantly affect model forecasts given how limited these GHBs are in extent, and their distance from project operations.	Include statement re: GHB time invariance / otherwise	Low	Agree and addressed. -Confirming the GHBs are time-variant. -Text added to Section 4.6.1.	Reviewer closed. Appropriately addressed. (noting that the report states GHBs are time- <i>in</i> variant, which is fine).
3.6 Are the initial conditions appropriate?	Yes	Steady state stress period.	-	-	-	-
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?	Yes	Steady state stress period.	-	-	-	-
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	No	Because a steady stress period is used, it theoretically shouldn't affect outcomes.	-	-	-	-
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?	Yes	Yes, 1E-2 hclose	-	-	-	-
3.7.1 Solution method/solver	Yes	SMS	-	-	-	-
3.7.2 Convergence criteria	Yes	Yes, 1E-2 hclose	-	-	-	-
3.7.3 Numerical precision	Yes	-	-	-	-	-

4. Calibration and sensitivity

4.1 Are all available types of observations used for calibration?	C	Mostly. One additional suggestion is made in 4.1.1 below. Also worth noting again that importantly there are no observations of direct relevance to the model forecasts (i.e., project-related drawdowns).	See 4.1.1 below	-	-	-
4.1.1 Groundwater head data	C	Vertical head differences are also included, as are head changes relative to the average (over time, i.e., oscillations).	In future, I think a good additional observation type that could be added to the model is head difference from nearest construction/operational-related boundary condition (eg tunnel DRNs). This way, pest is asked to focus on the (pre-project) local head gradient of most importance to the forecasts you use the model for.	Moderate	Noted. - Amendment will be addressed in future iterations of this numerical model.	Reviewer closed. Appropriately addressed.
4.1.2 Flux observations	C	Soft stream flow targets qualitatively assessed, which is fine given objectives.		-	-	-
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	No	-		-	-	-
4.2 Does the calibration methodology conform to best practice?	Yes	-		-	-	-
4.2.1 Parameterisation	Yes	1. I like the adjustable linear Kh decay with depth approach - nice, and sits well conceptually. 2. Section 5.2.1: It is unclear how the use of HSU-wide "base parameters" from an initial PEST run were used in the subsequent pest run with pilot point multipliers of those base values. Importantly: were the HSU-wide "base parameters" also adjusted during the pilot point based pest run? If not, their exclusion could artificially narrow down the range of model uncertainty. Their inclusion is the "best practice" approach recommended by GMSI for example. 3. Good that STR and RIV BC conductances are made adjustable / uncertain. 4. There is no description of how (or if) parameter uncertainty structures (e.g., pilot point covariance matrices and uncorrelated parameter standard deviations) are defined in PESTP-IES. This should be included. Parameter mapping suggests pilot point covariance is applied, but it is not clear.	Clarify query [2] to left. If this was not done, it would be best that next time it is done the way I suggest (base HSU parameters are included in pest along with pilot point scaling factors), to minimise underestimation of parameter non-uniqueness and forecast uncertainty. Address [4] to left.	High	Updated history-matching used HSU-wide "base parameters" and pilot points as multipliers. This has been clarified in Section 5.2.1, along with mention of pilot point covariance and uncorrelated parameter standard deviations.	Reviewer closed. Appropriately addressed.
4.2.2 Objective function	Yes	Contributions of the various obs types described above are adjusted to define phi as desired by the modellers.		-		
4.2.3 Identifiability of parameters	No	-		-	-	-
4.2.4 Which methodology is used for model calibration?	Yes	PESTPP-IES, which is fine for this purpose		-	-	-
4.3 Is a sensitivity of key model outcomes assessed against?	Yes	These are all yes because an ensemble method is applied, and most parameters, boundary conditions etc are allowed to vary - so results reflect sensitivity and (posterior) uncertainty in these.		-	-	-
4.3.1 parameters	Yes	-		-	-	-
4.3.2 boundary conditions	Yes	-		-	-	-
4.3.3 initial conditions	Yes	Steady state stress period used - good. Models are stochastic so in effect a sensitivity analysis to these is conducted.		?	?	?
4.3.4 stresses	Yes	-		-	-	-
4.4 Have the calibration results been adequately reported?	Yes	-		-	-	-
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	C	The big scale on the obs vs modelled scatter is driven by the head range (/topographic range). This is probably the primary control on inflows to the project, and associated impacts, so is largely ok, however see comment to right. The hydrograph scales are finer and so I am ok with this for now.	However, for future work the recommendation in 4.1.1 could improve the metrics used for history matching quality, and with the presentation of those results - eg a map showing head error relative to nearest project-construction/operation BC, and/or head scatter plot presented on those local scale pre-project head difference terms. This way the model will be trained to the key driver of construction inflows and hence impact (standing head above tunnel centre for example). With this, we can for example see where the model may be under estimating heads to the point that they are below the construction boundary locally; in practice however, this is probably not a control on forecasts, because of the steep topo gradients - the modelled head at a given location, despite being locally under-estimated relative to the BC, is likely still higher than the BC head a little further down the tunnel.	Low	Noted. - Amendment will be addressed in future iterations of this numerical model.	Reviewer closed. Appropriately addressed.
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	Yes	Appendix C shows these, and they are generally reasonable for bores with more than one observation.		-	-	-
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	C	Yes, although see 4.4.1 and 4.4 above.		-	-	-
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?	C	Hydrographs, scatter plot and map of residuals for heads only. But nested sites are presented in Appendix C too, which is great.		-	-	-
4.5.1 spatially	Yes	Local to project head matches are mostly well within 5m, and the error is generally consistent.		-	-	-

4.5.2 temporally	Yes	Hydrographs in Appendix C and in the main report body show decent coverage of average heads by the model ensemble; this is an improvement on the first iteration for the model which suffered from severe prior data conflict. This revised calibration effort is much improved. However, it is worth noting that transient hydrograph responses are generally not well simulated by the models; these are fair in only one or two bores. I would disagree with the statement made in section 5.3.2 that "the model captures the observed variability and trends". Given that transient water level behaviour is unlikely to affect model predictions significantly - my view is that driving static heads are the primary driver, which appear reasonably well simulated - , this is considered to be of unlikely importance in this case.	Fuure calibration efforts should try to improve upon the model's simulation of observed transient groundwater level variability. Maybe head differences over time need higher weight than currently applied? A longer monitoring record would also help with this, and make the effort more worthwhile in terms of better constraining model parameters and so predictive uncertainty.	Low	-	-
4.6 Are the calibrated parameters plausible?	Yes	The spatial parameter standard deviation plots are also useful, making sense given obs locations. Appendix D histograms are valuable too. Parameter values and distributions appear reasonable.	See suggestion to left, for later history matching attempts.	Low	Noted. - Amendment will be addressed in future iterations of this numerical model.	Reviewer closed. Appropriately addressed.
4.7 Are the water volumes and fluxes in the water balance realistic?	Yes	-	-	-	-	-
4.8 has the model been verified?	N/A	-	-	-	-	-

5. Prediction

5.1 Are the model predictions designed in a manner that meets the model objectives?	Yes	-	-	-	-	-
5.2 Is predictive uncertainty acknowledged and addressed?	Yes	-	-	-	-	-
5.3 Are the assumed climatic stresses appropriate?	C	The approach taken to assigning recharge to the predictive models is not documented. For example, for the base climate case, is it simply a repeat of the transient historical period's mean recharge, or something else? It is unclear because it is not documented, and the timeframes of the historical and forecast models are markedly different. The assumptions made to develop the climate change scenario from NARCLIM climate models' rainfall estimates is not quite right. A 1:1 rainfall to recharge reduction (eg 10% less rainfall means 10% less recharge); in practice, I think that if EMM check this assumption with their soil moisture balance model for example, they might see recharge reductions more along the lines of 1:2 or 1:3 (so in the 10% rainfall reduction example, a 20-30% reduction in recharge). Lower recharge under climate change than that modelled would "possibly" serve to reduce groundwater inflows to project infrastructure, and hence associated drawdown extents. I am not too concerned by this because in the GIA document reviewed, the base climate case is primarily used for "water take" (licensing requirements), and impact assessment. Climate change drawdown estimates are given only a cursory review.	Maybe just expand on the "simple assumption" part of Section 6.2.1, to include discussion of the myriad climate change uncertainties, including non-linear relationships between rainfall and recharge changes, the impact of changes in seasonality (which is probably important to recharge rates), and simply the wide margin of error around future rainfall estimates.	Low	Agree and addressed. - Text added to Section 6.2.1	Reviewer closed. Appropriately addressed.
5.4 Is a null scenario defined?	Yes	-	-	-	-	-
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?	Yes	-	-	-	-	-
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?	No/Yes	Here, "pumping stresses" are taken to mean construction dewatering/depressurisation stresses. This issue, a feature of most infrastructure projects, is acknowledged in EMM's report.	-	-	-	-
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 confidence?	No/Yes	This issue, a feature of most infrastructure projects, is acknowledged in EMM's report.	-	-	-	-
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?	Yes	They are conservative in some ways because controls such as grouting are ignored in the modelling, assuming free-flowing tunnels etc.	-	-	-	-
5.6 Do the prediction results meet the stated objectives?	Yes	-	-	-	-	-
5.7 Are the components of the predicted mass balance realistic?	Yes	I did a cursory analytical cross check of the estimated inflows and the numerical model's estimates appear reasonable on that basis.	-	-	-	-
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?	No	4ML/year max - well below flow rates across the domain, as offset by upper reservoir mounding	-	-	-	-

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)?	No	Nothing appears unusual or unexpected in the reporting.	-	-	-	-
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	Yes	-	-	-	-	-
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?	No	-	-	-	-	-
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	N/A	-	-	-	-	-

6. Uncertainty

6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	Yes	P90 inflows are primarily used in the GIA. P90 project-only drawdowns are mapped. It is noted that cumulative drawdown mapping is only provided for the "base realisation". However, the project-only drawdown extents are larger than the cumulative maps due to offset by upper reservoir mounding.	-	-	-	-
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	C	See above - for some. For others, the P90 estimate is utilised.	-	-	-	-
6.3 Are the sources of uncertainty discussed?	C	Generally yes - uncertainty in parameters is the main focus. However, I think that in the limitations section (see points 1.5/1.6 above), that discussion around the lack of observation data that is of direct relevance to model forecasts is warranted.	See 1.5/1.6 above.	-	Agree and addressed. -See Review Question 1.5 and 1.6 above.	Reviewer closed. Appropriately addressed.
6.3.1 measurement of uncertainty of observations and parameters	C	No observation noise included in the history matching, but this is not uncommon or, in my view, necessarily a problem given the sparsity of data available, and given the ensemble's range of residual uncertainty - the models are not overfit. Parameter variance figures are presented, along with PDFs of all spatially varying parameters, so the reader can see the spread across the ensemble.	-	-	-	-
6.3.2 structural or model uncertainty	No	No noise used in PEST, which can accomodate some of this; however, see 6.3.1 above.	-	-	-	-
6.4 Is the approach to estimation of uncertainty described and appropriate?	Yes	-	-	-	-	-
6.5 Are there useful depictions of uncertainty?	Yes	-	-	-	-	-

7. Solute transport

7.1 Has all available data on the solute distributions, sources and transport processes been collected and analysed?	N/A	-	-	-	-	-
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?	N/A	-	-	-	-	-
7.3 Is the choice of numerical method and software appropriate?	N/A	-	-	-	-	-
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?	N/A	-	-	-	-	-
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?	N/A	-	-	-	-	-
7.6 Are the solver and its parameters appropriate for the problem under consideration?	N/A	-	-	-	-	-
7.7 Has the relative importance of advection, dispersion and diffusion been assessed?	N/A	-	-	-	-	-
7.8 Has an assessment been made of the need to consider variable density conditions?	N/A	-	-	-	-	-
7.9 Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?	N/A	-	-	-	-	-

7.10 Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?	N/A	-	-	-	-	-
7.11 Is the calibration based on meaningful metrics?	N/A	-	-	-	-	-
7.12 Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?	N/A	-	-	-	-	-
7.13 Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?	N/A	-	-	-	-	-
7.14 Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?	N/A	-	-	-	-	-
7.15 Does the report address the role of geologic heterogeneity on solute concentration distributions?	N/A	-	-	-	-	-

8. Surface water–groundwater interaction

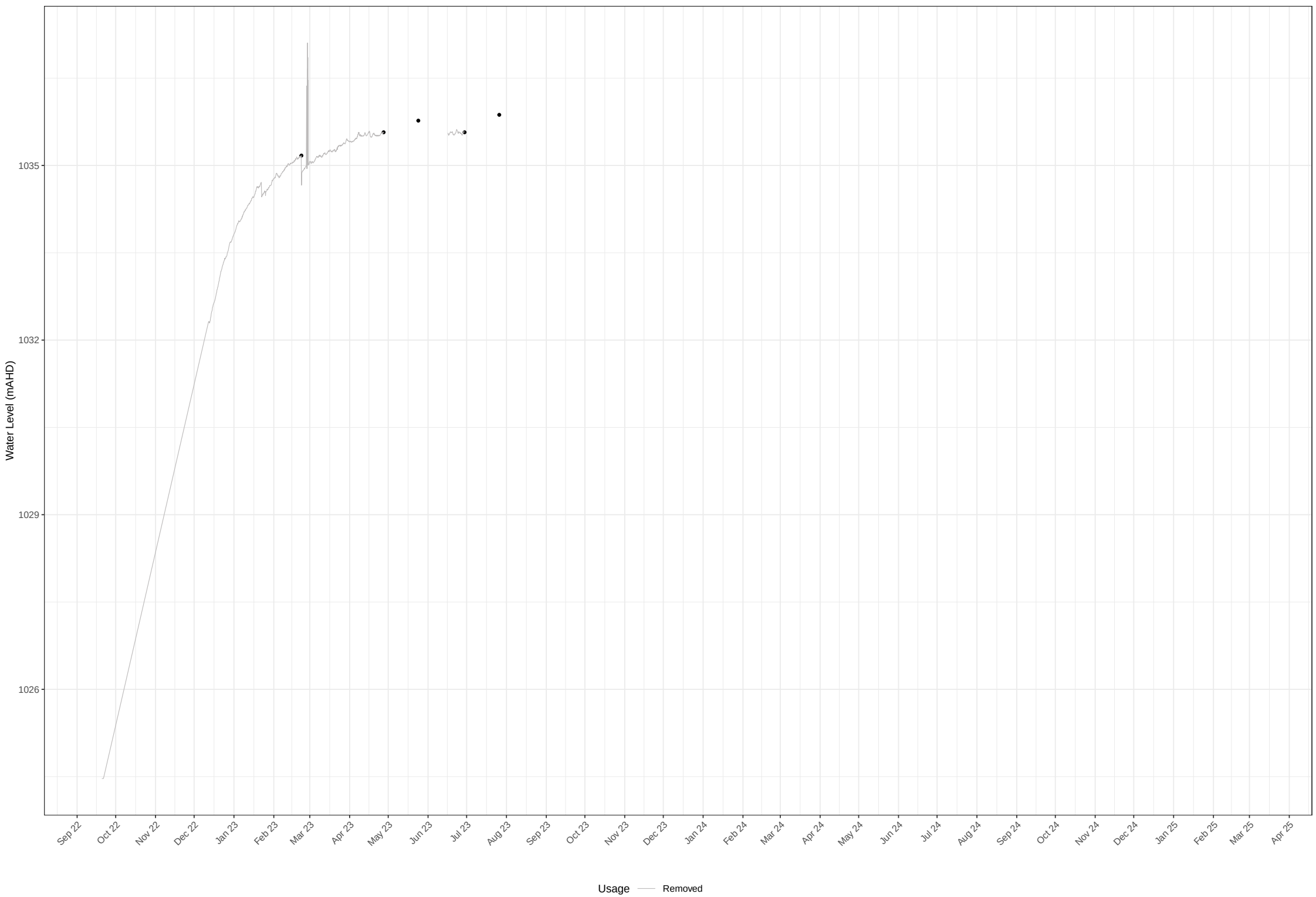
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	Yes	-	-	-	-	-
8.2 Is the implementation of surface water–groundwater interaction appropriate?	Yes	RIV boundary combination are reasonable choices given the CHM and objectives. RIVs set up as drains (no leakage) in relevant upper watercourses				
8.3 Is the groundwater model coupled with a surface water model?	N/A	-	-	-	-	-
8.3.1 Is the adopted approach appropriate?	Yes	-	-	-	-	-
8.3.2 Have appropriate time steps and stress periods been adopted?	Yes	-	-	-	-	-
8.3.3 Are the interface fluxes consistent between the groundwater and surface water models?	N/A	-	-	-	-	-

NOTES		
1	N/A	Not applicable
2	U	Unknown
3	C	Comment

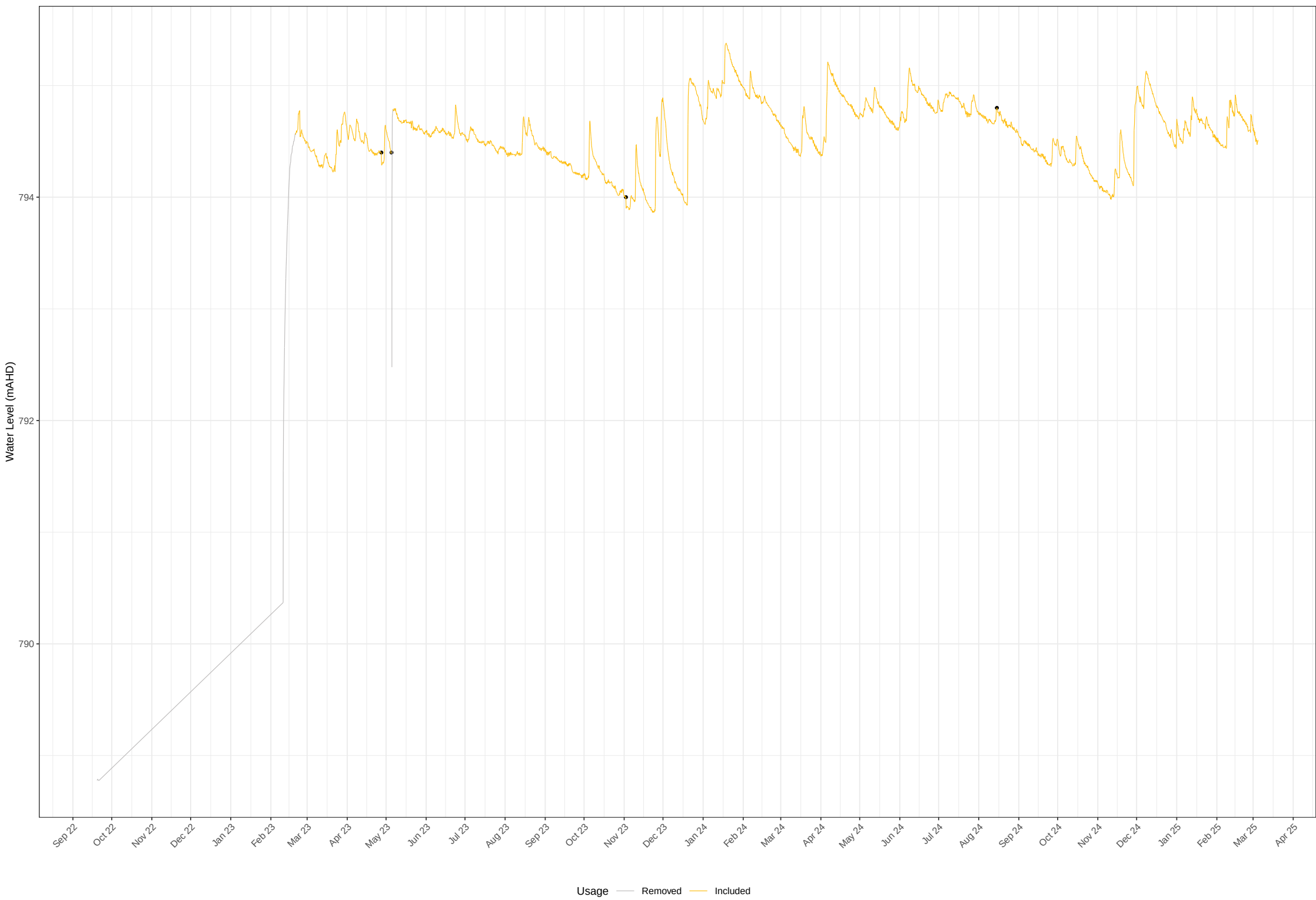
Annexure D

Groundwater level hydrographs

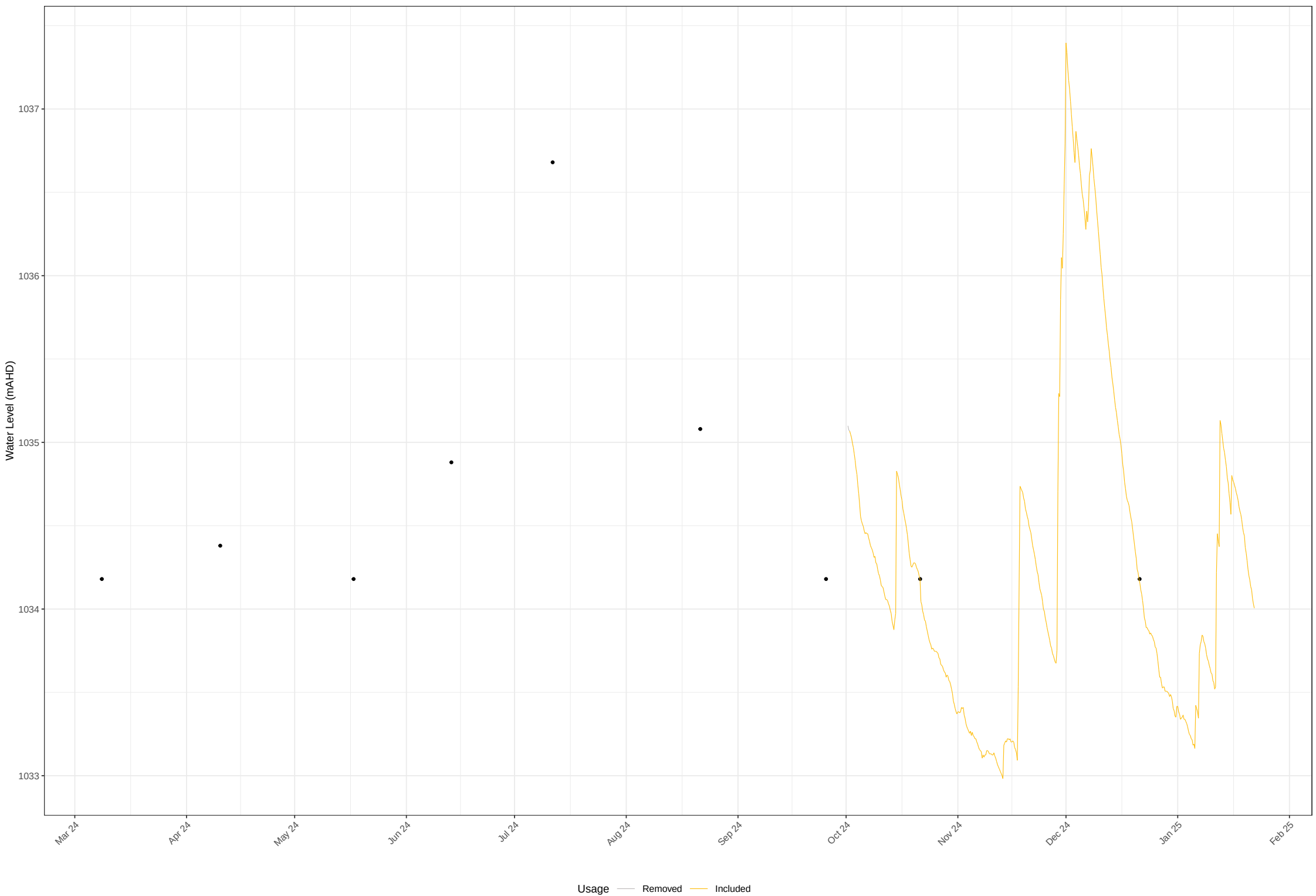
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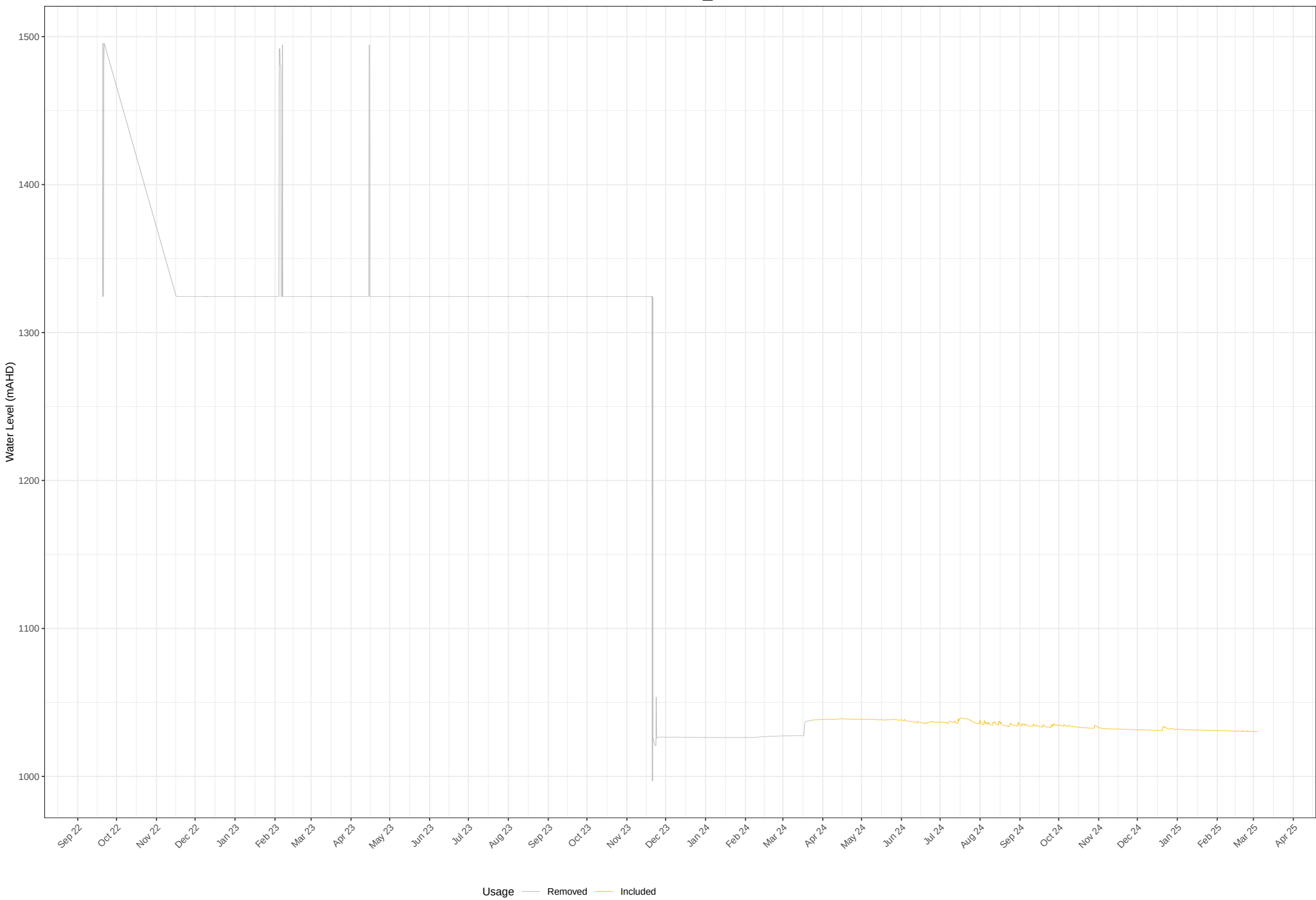
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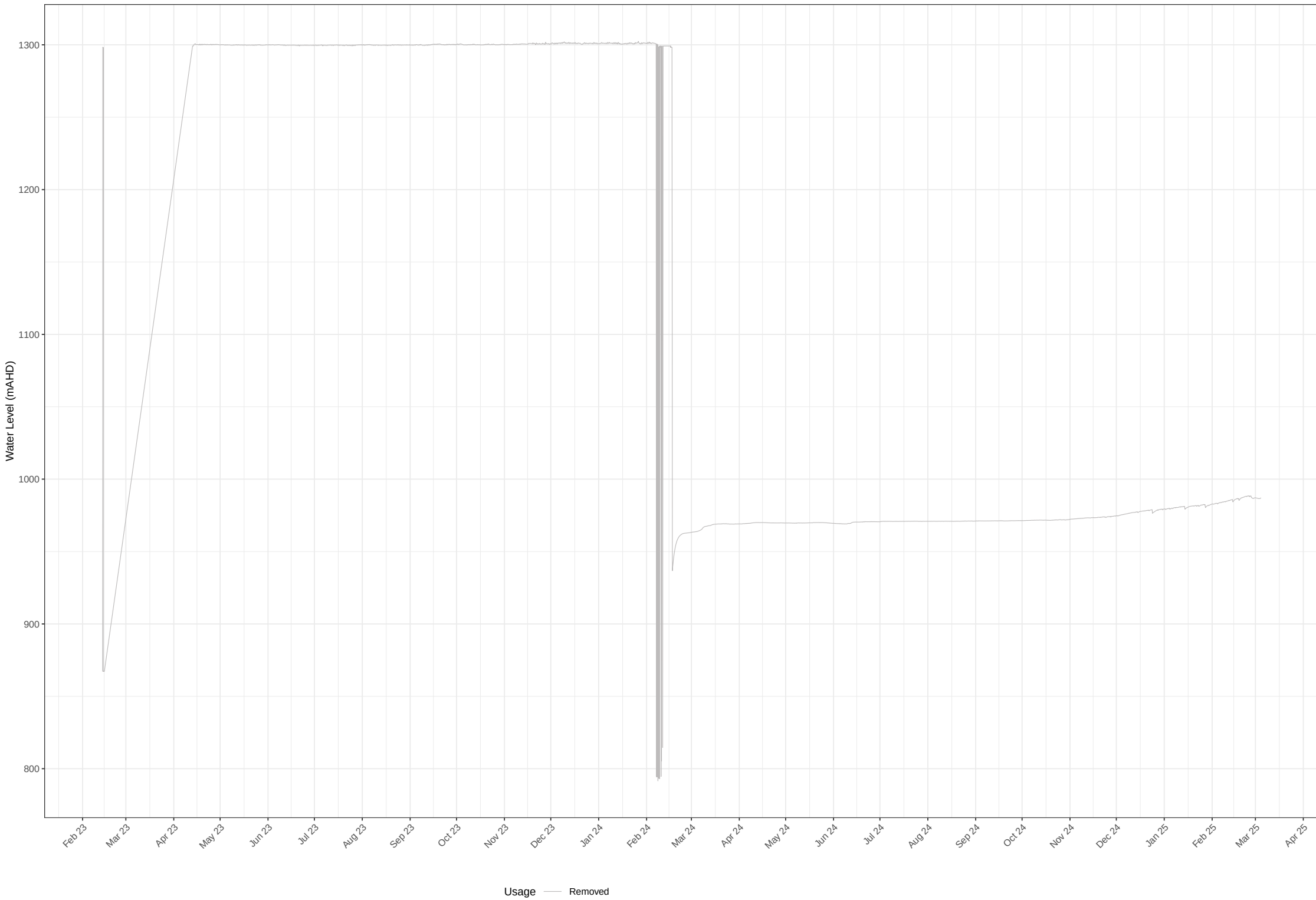
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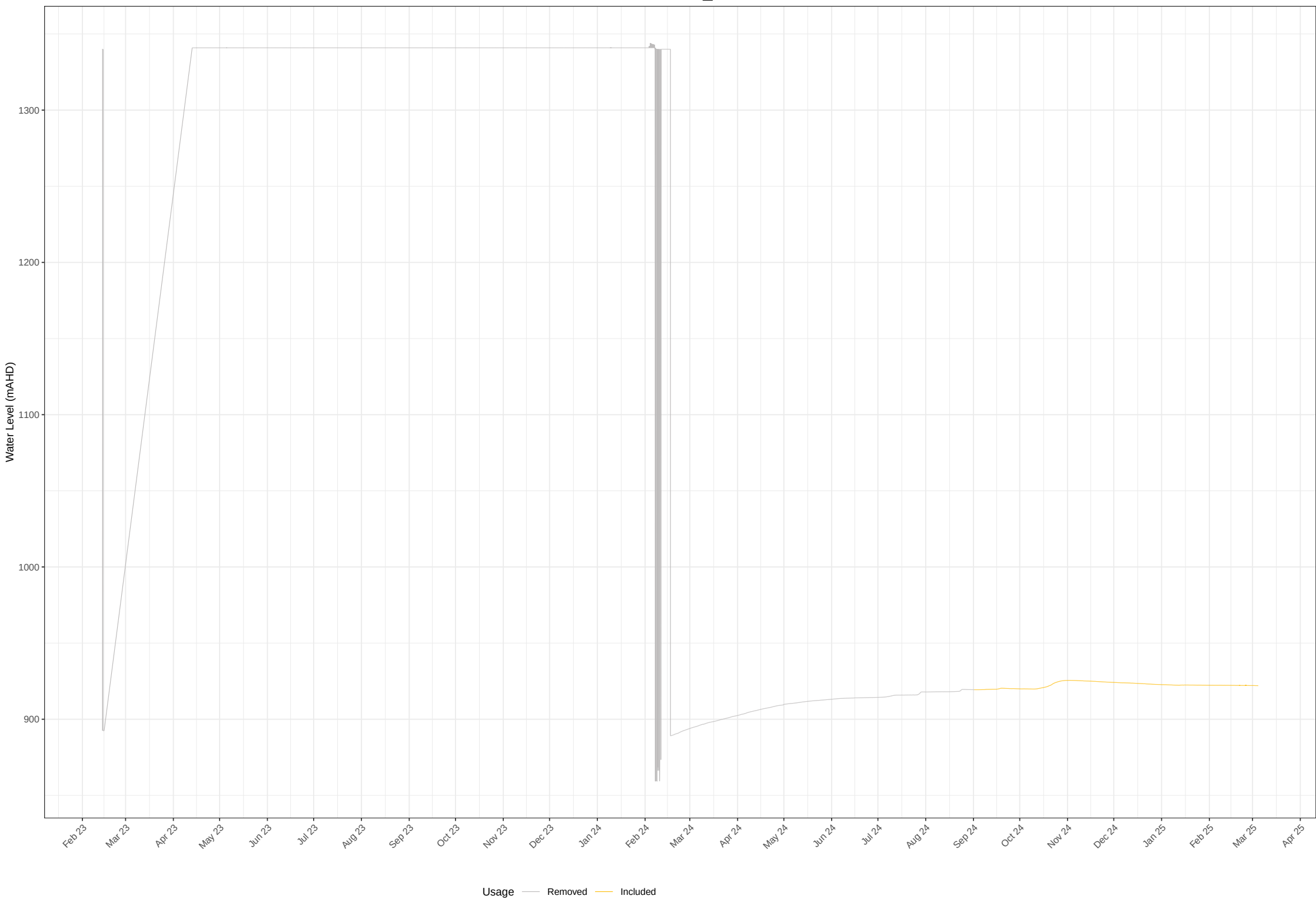
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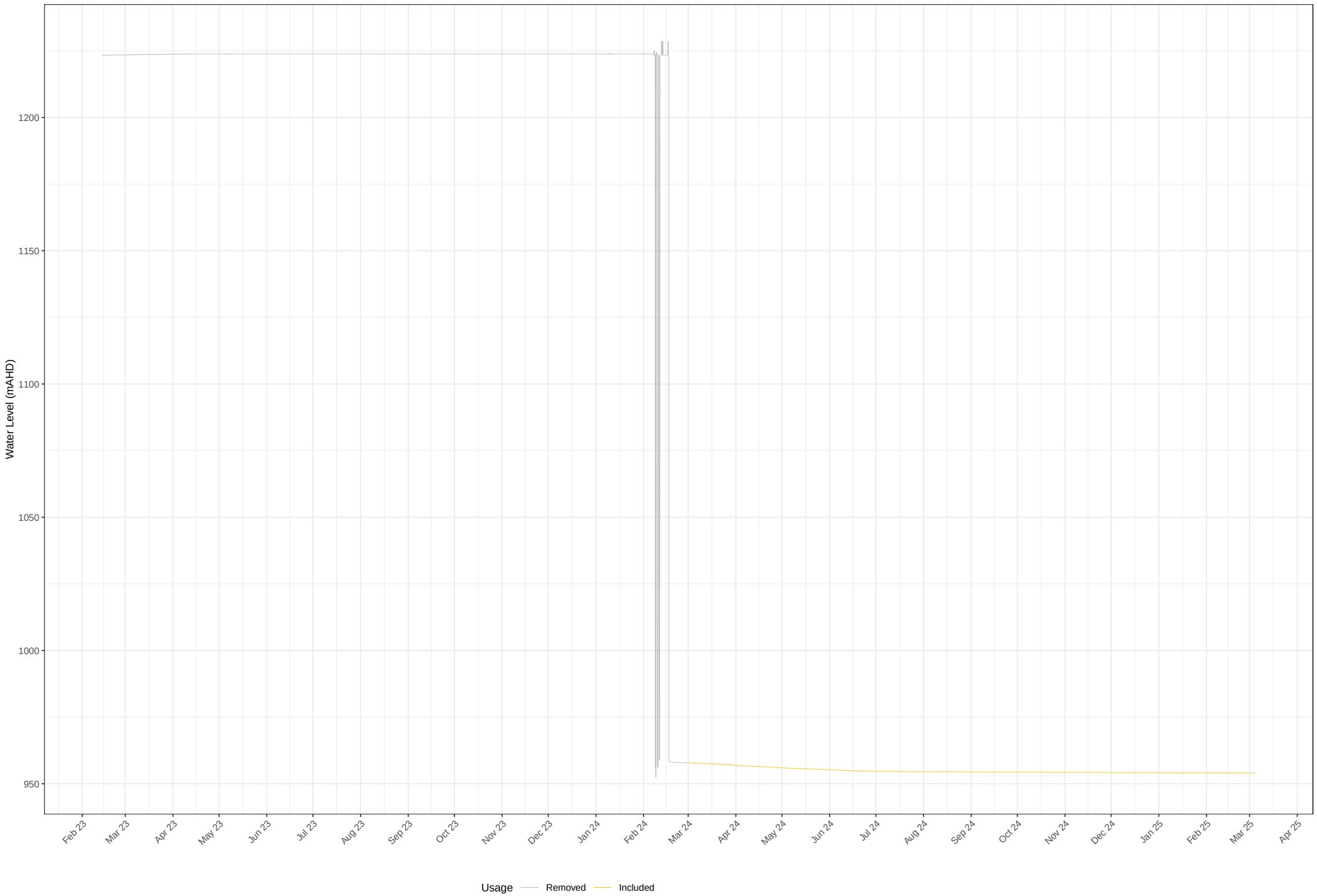
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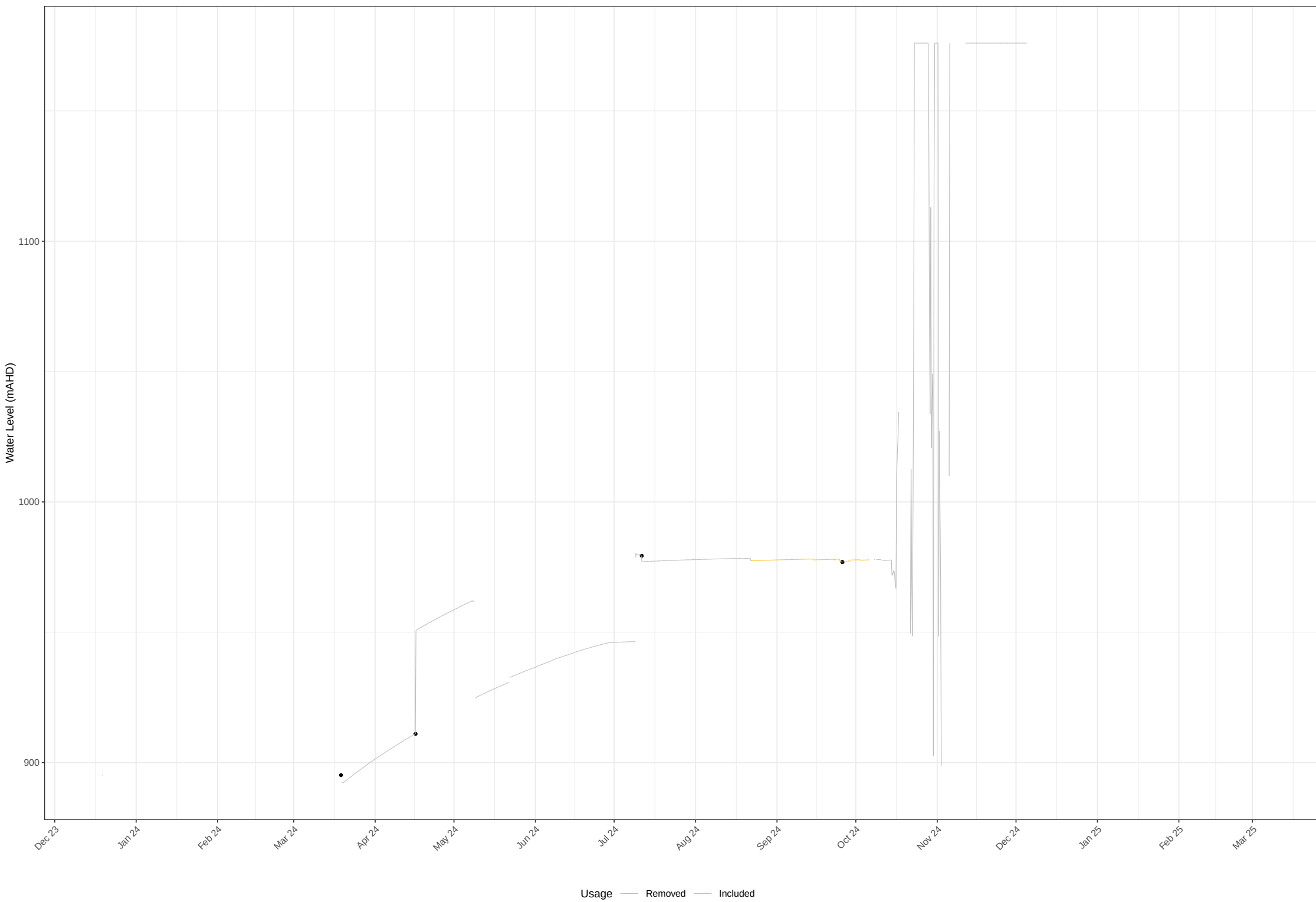
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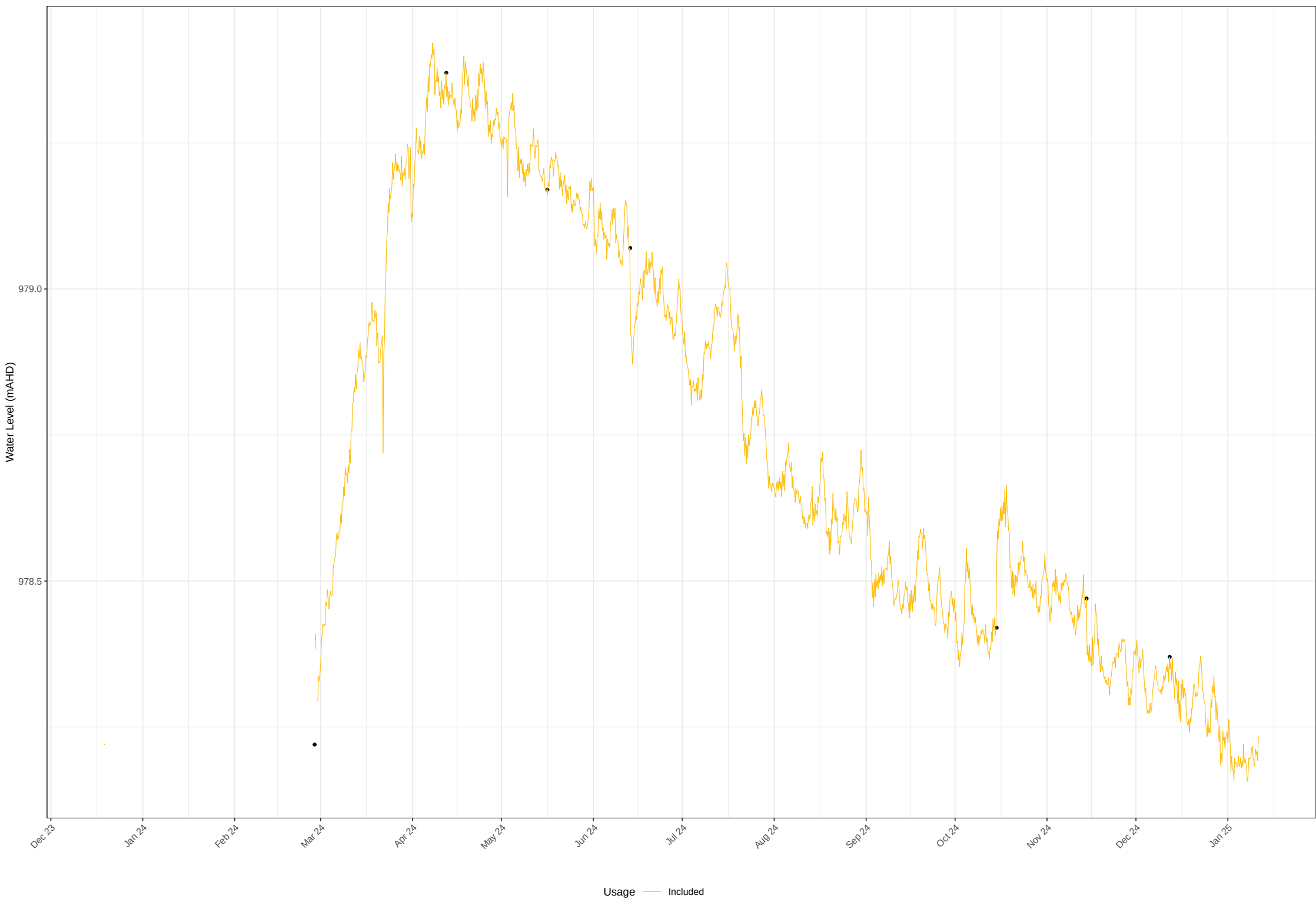
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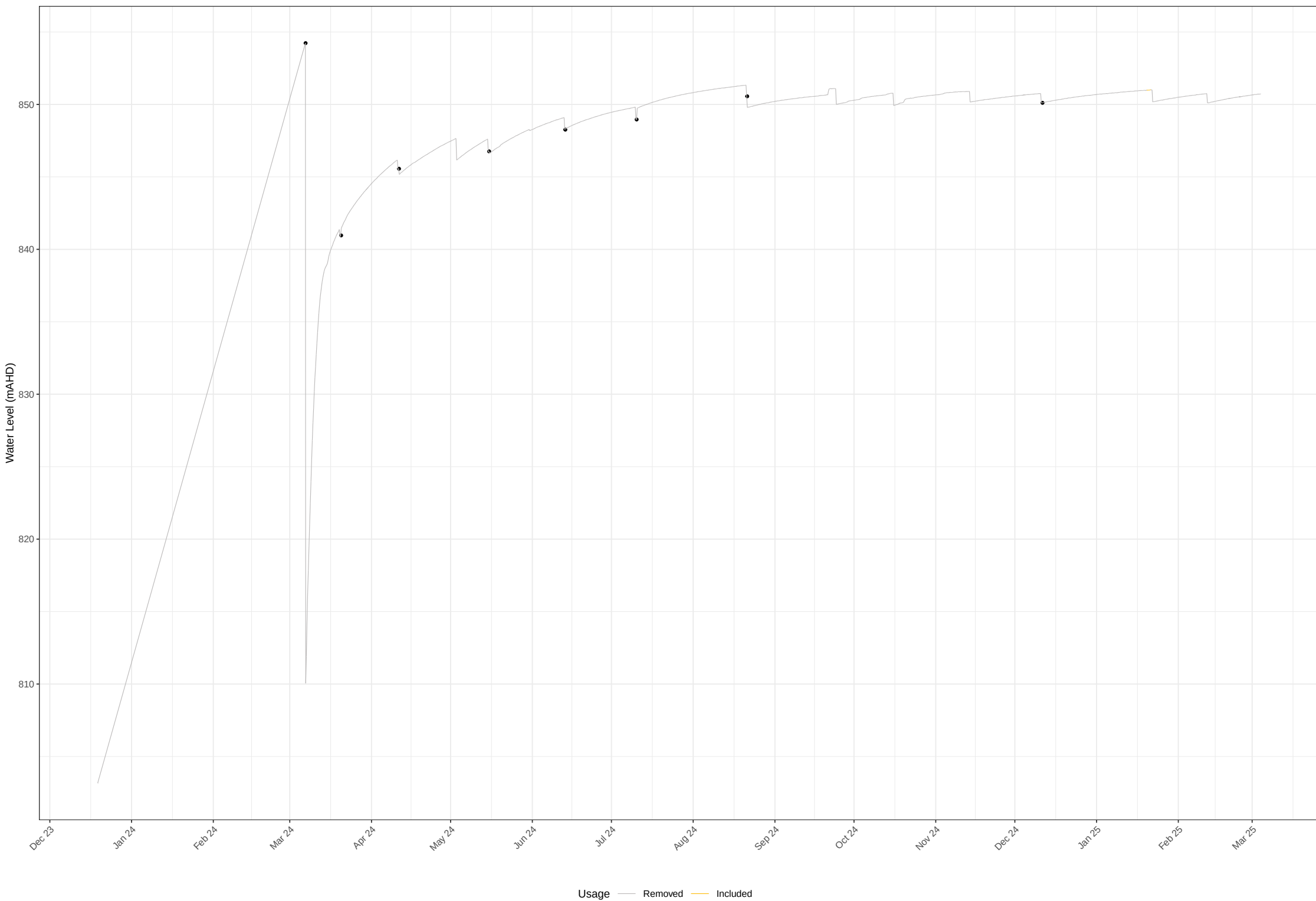
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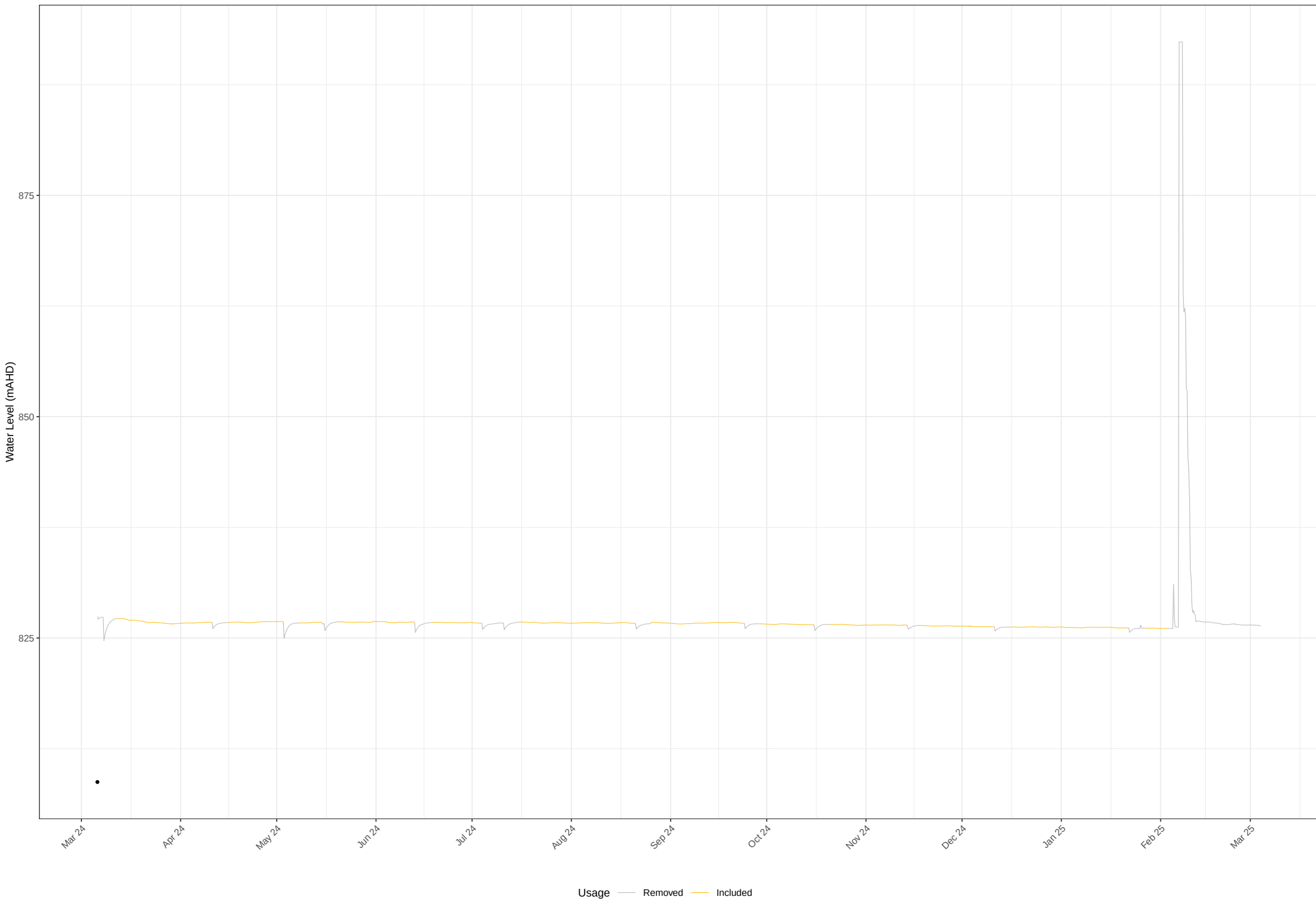
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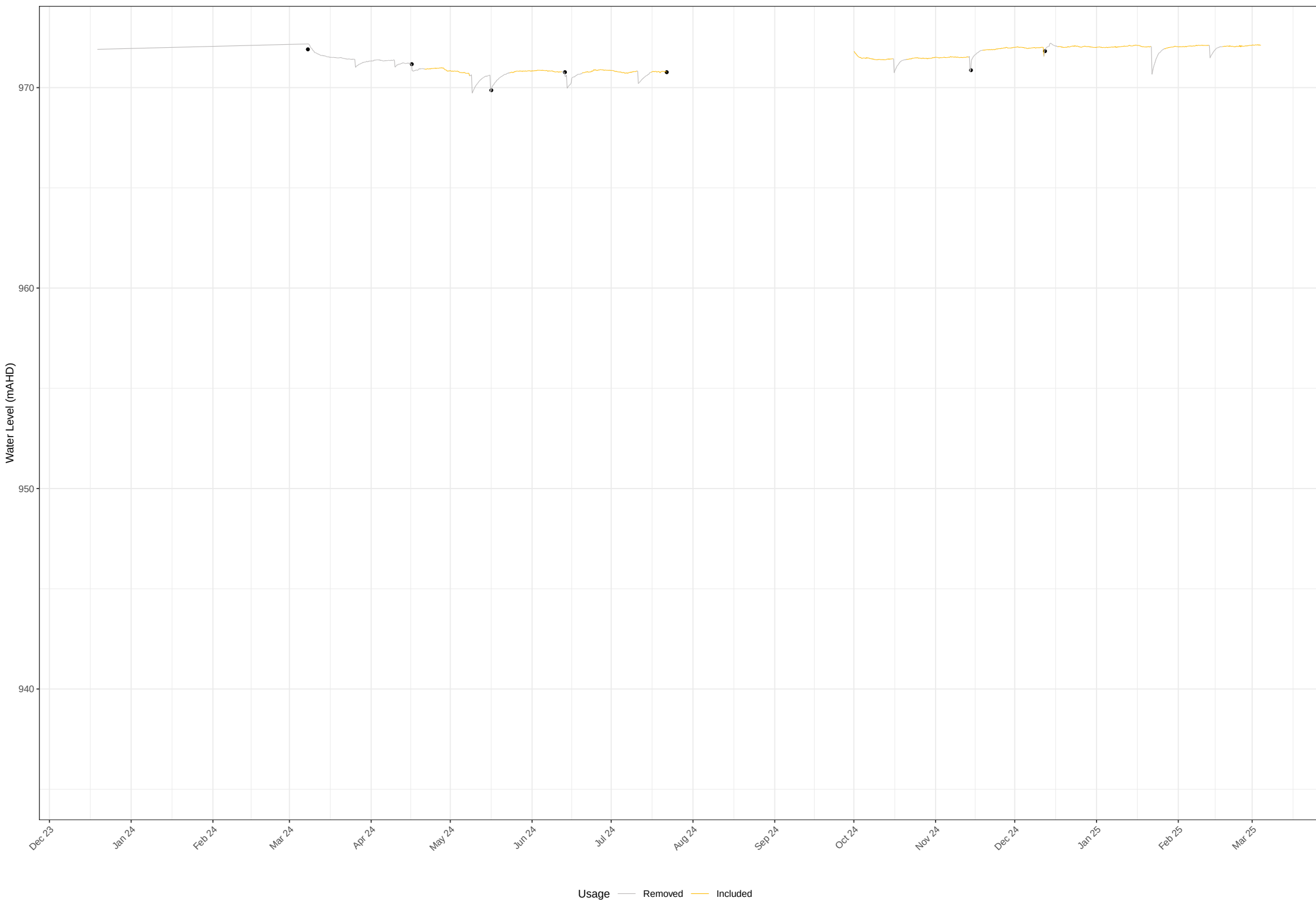
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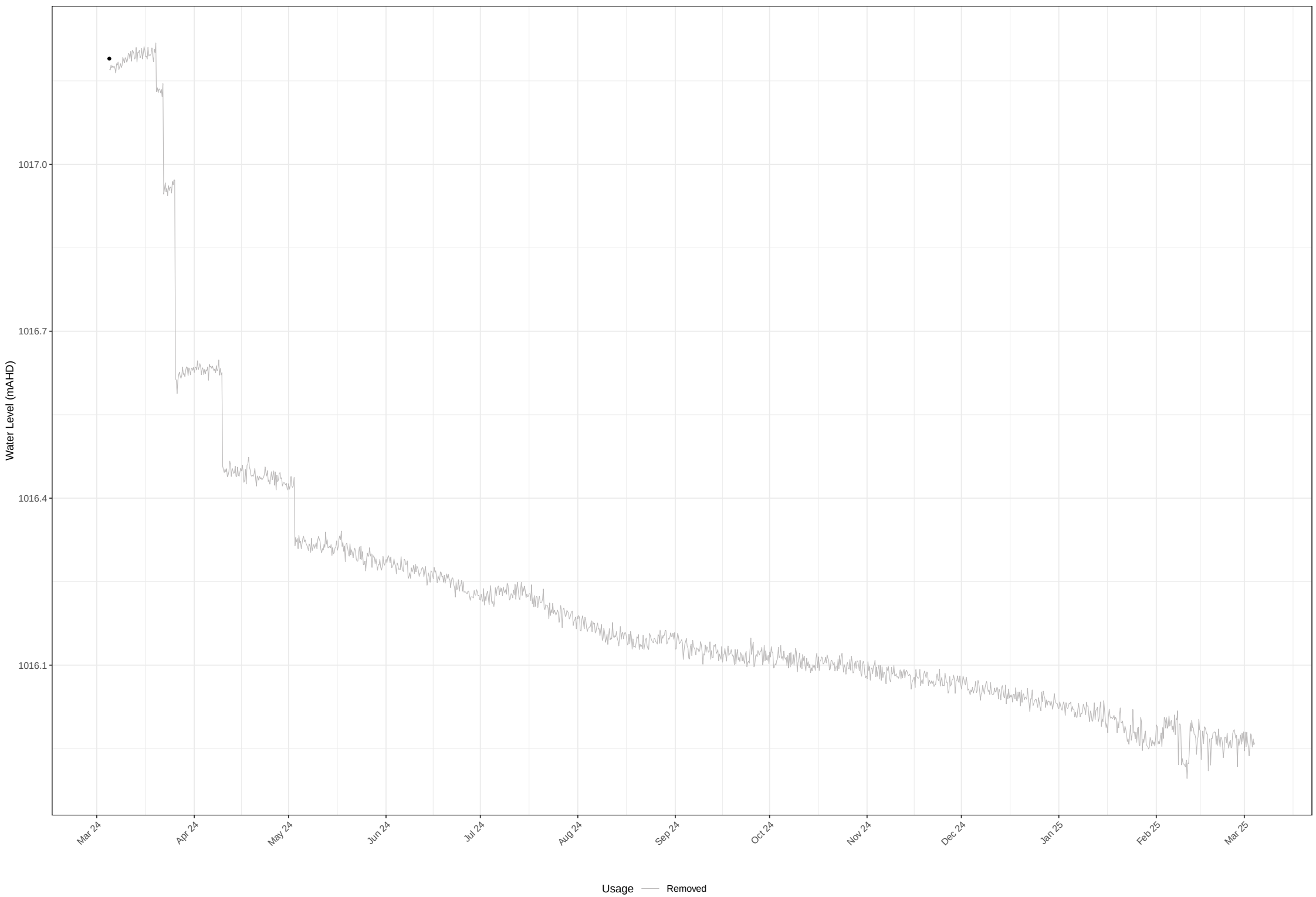
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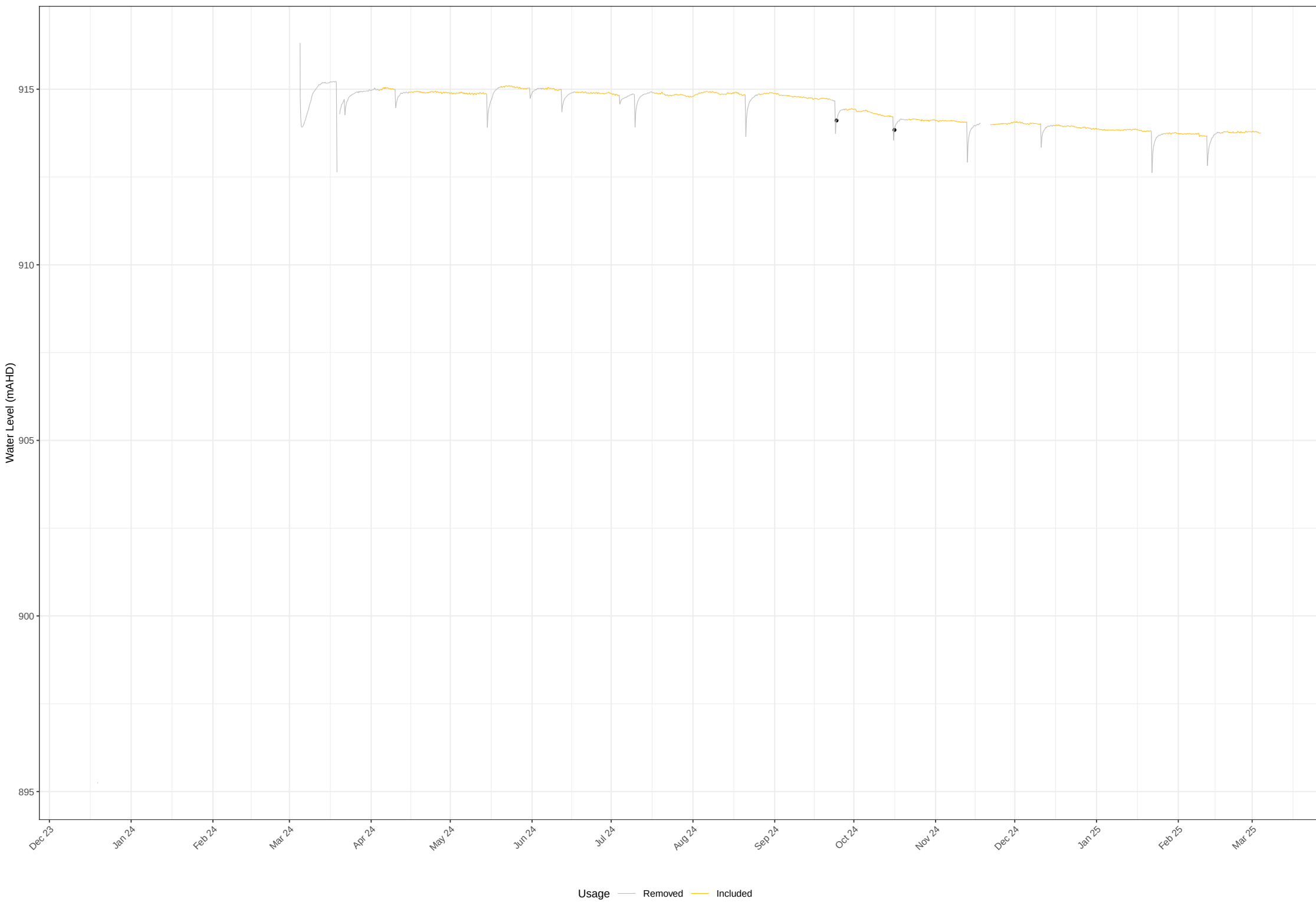
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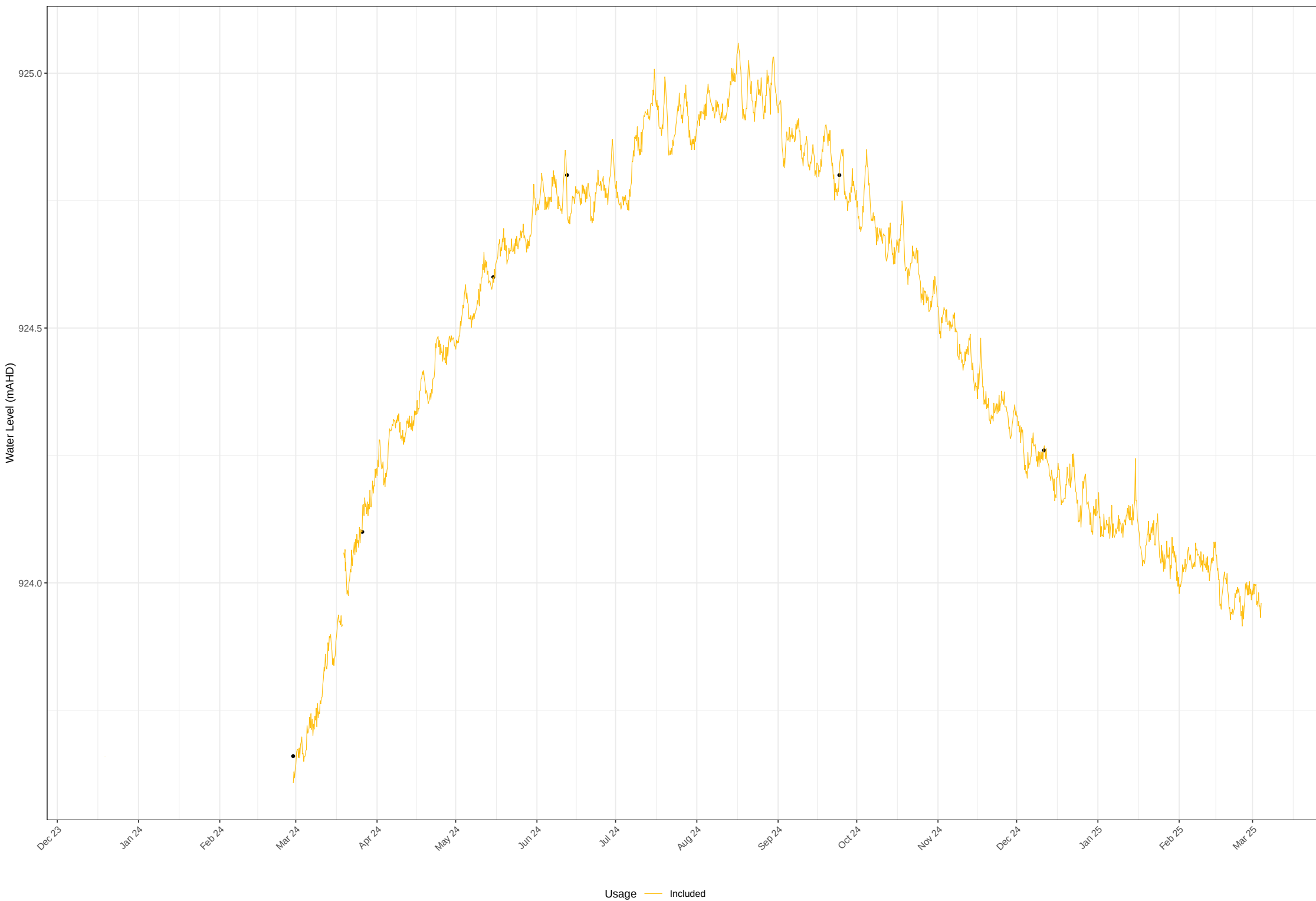
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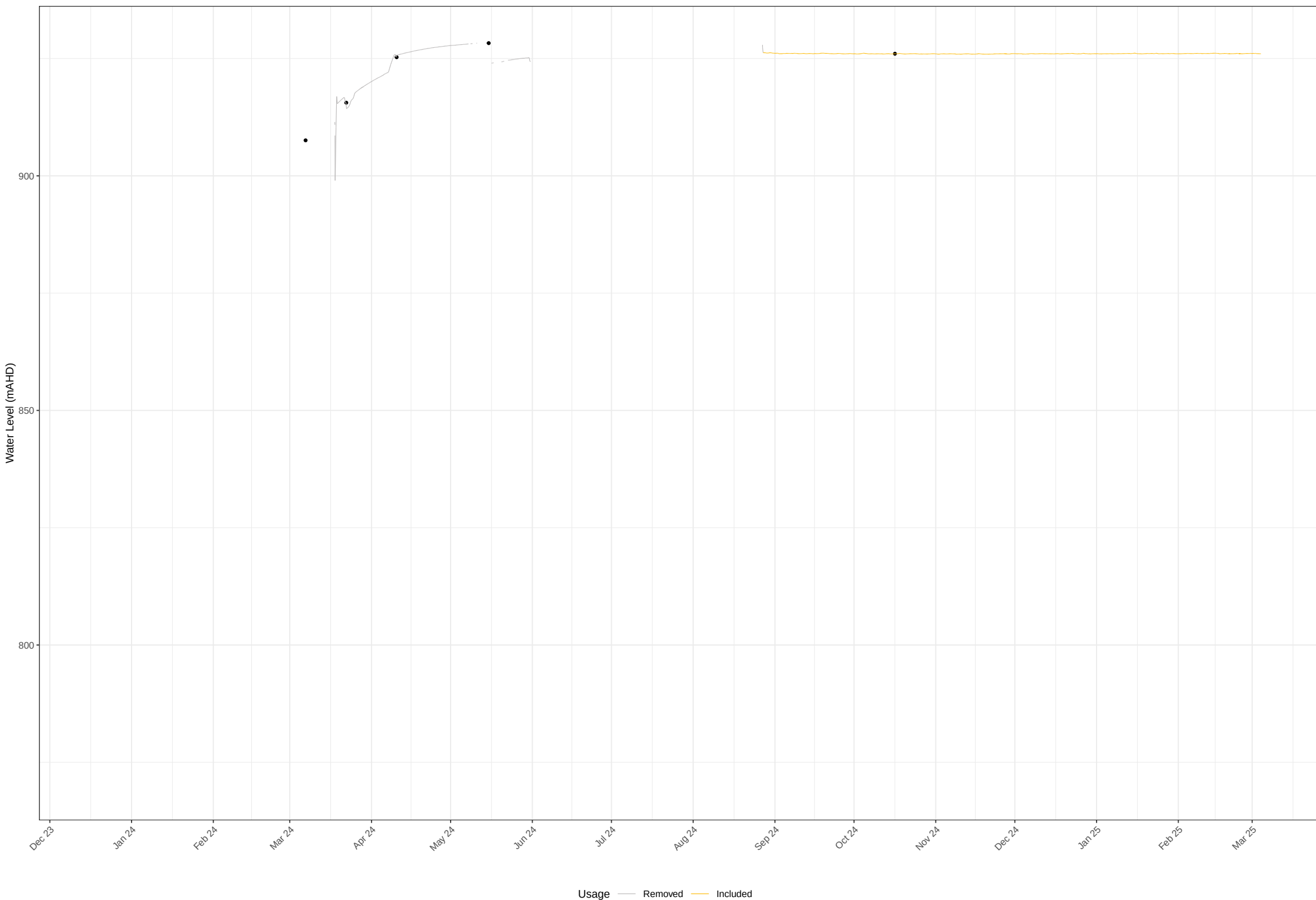
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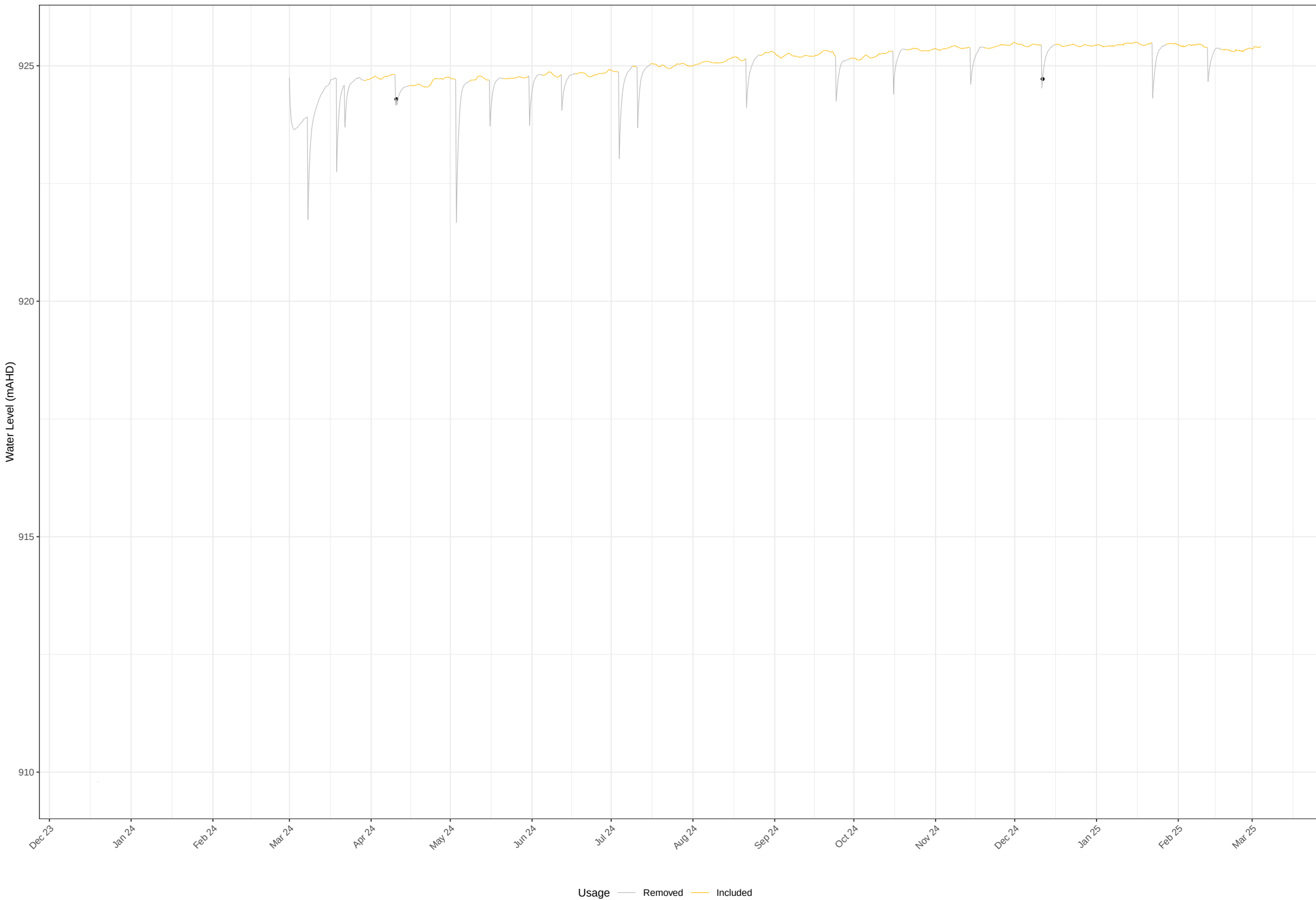
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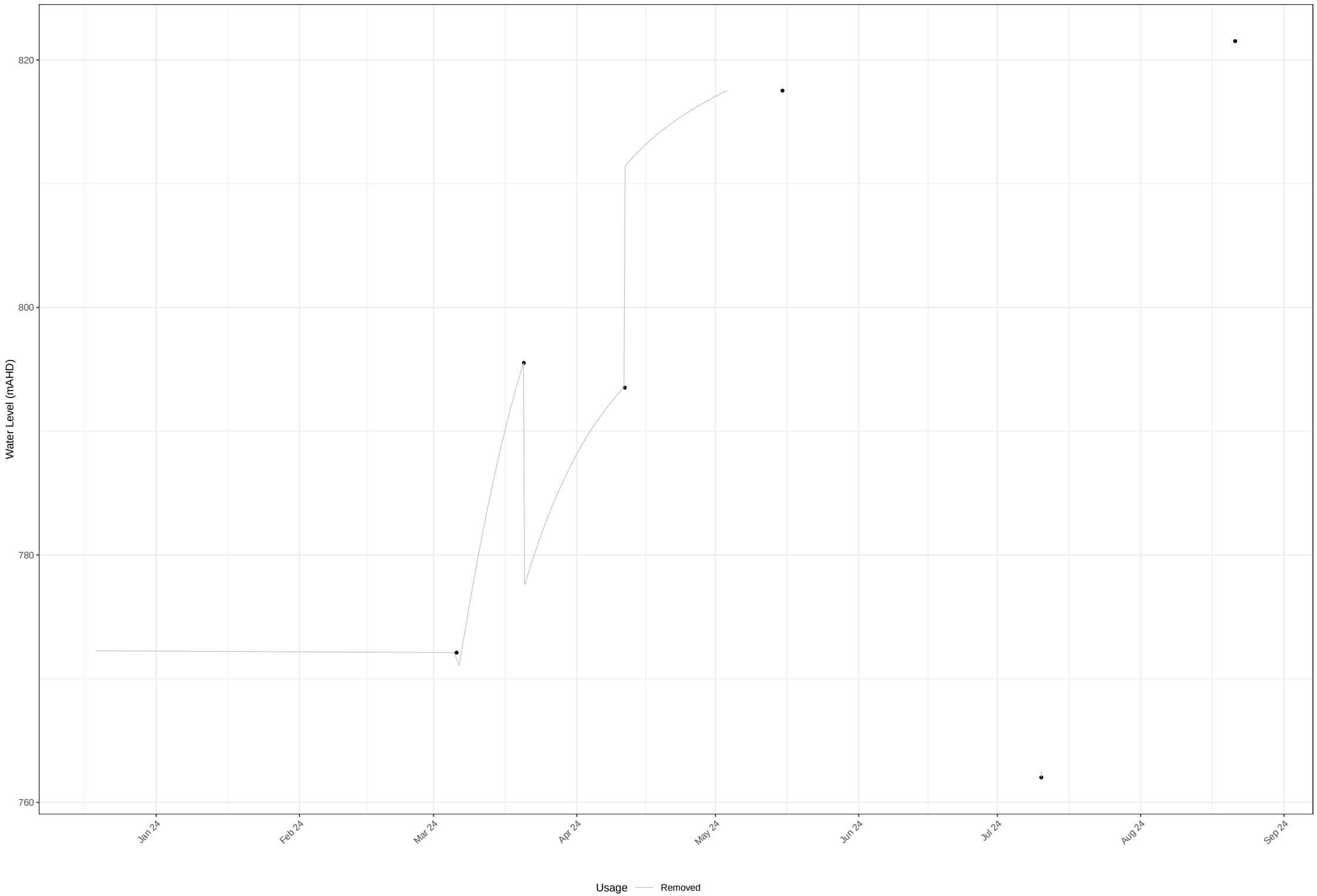
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