Appin Mine Area 7

Longwalls 712 to 716

Water Management Plan

5 August 2026

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DOCUMENT CONTROL

Applicant:	Illawarra Coal Holdings Pty Ltd
Mine:	Appin Mine
Name of operator:	Gear M Illawarra Met Coal Pty Ltd trading as GM^3
Project approval:	MP08_0150
Mining leases:	Consolidated Coal Lease 767, Mine Lease 1698, Mine Lease 1433, Mine Lease 1832, Mine Lease 1847 and Mine Lease 1874
Document Title:	Appin Mine Area 7 Longwalls 712 to 716 Extraction Plan Water Management Plan

NAME OF PERSONS AUTHORISING THIS PLAN

NAME	TITLE	DATE
Bruce Blunden	Manager Approvals	August 2026

DOCUMENT REVISIONS

REVISION	DESCRIPTION OF CHANGES	DATE
1	New document for consultation	December 2025
2	Document revised following consultation	February 2026
3	Document revised following DPHI consultation with agencies	April 2026
4	Document revised following DPHI review and feedback	July 2026
5	Document revised updating Trigger Action Response Plan.	August 2026

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1 INTRODUCTION

1.1 Project Background

Illawarra Coal Holdings Pty Ltd (ICHPL) operates the Bulli Seam Operations (BSO) Appin Mine extracting hard coking coal used for steel production. On 22 December 2011 the Planning and Assessment Commission (PAC), under delegation of the Minister for Planning, approved BSO (MP 08_0150) under Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act) to continue mining operations until 2041.

This Water Management Plan (WMP) supports the Longwalls 712 to 716 Extraction Plan for mining of coal in Appin Area 7 (AA7) mining domain. The WMP describes the monitoring and management of surface water and groundwater within the Extraction Plan Study Area. The relationship between this WMP and the other components of the Extraction Plan is shown in Figure 3 of the Extraction Plan Main Document.

1.2 Scope

The scope of the WMP includes the proposed program of monitoring of surface water and groundwater features within the Longwall 712 to 716 Study Area and a trigger action response plan that includes management actions to be taken upon reaching a specified trigger level.

The Study Area for the Extraction Plan is defined in accordance with MSEC (2025) as the surface area predicted to be affected by the proposed mining of Longwalls 712 to 716 and encompasses the areas bounded by the following limits (Figure 1):

- A 35° angle of draw line from the maximum depth of cover, which equates to a horizontal distance varying between 555 m and 800 m around the limits of the proposed extraction areas for Longwalls 712 to 716, and
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of the proposed Longwalls 712 to 716.

Additionally, features potentially sensitive to far field movements, which includes horizontal, valley closure and upsidence movements that may be outside the 20 mm subsidence zone or 35° angle of draw line have been assessed (600 m boundary around Longwalls 712 to 716).

1.3 Objectives

The objectives of this WMP are to identify at risk surface water and groundwater features and characteristics within the Longwalls 712 to 716 Study Area and to manage the potential impacts and/or environmental consequences of the proposed workings on watercourses and aquifers.

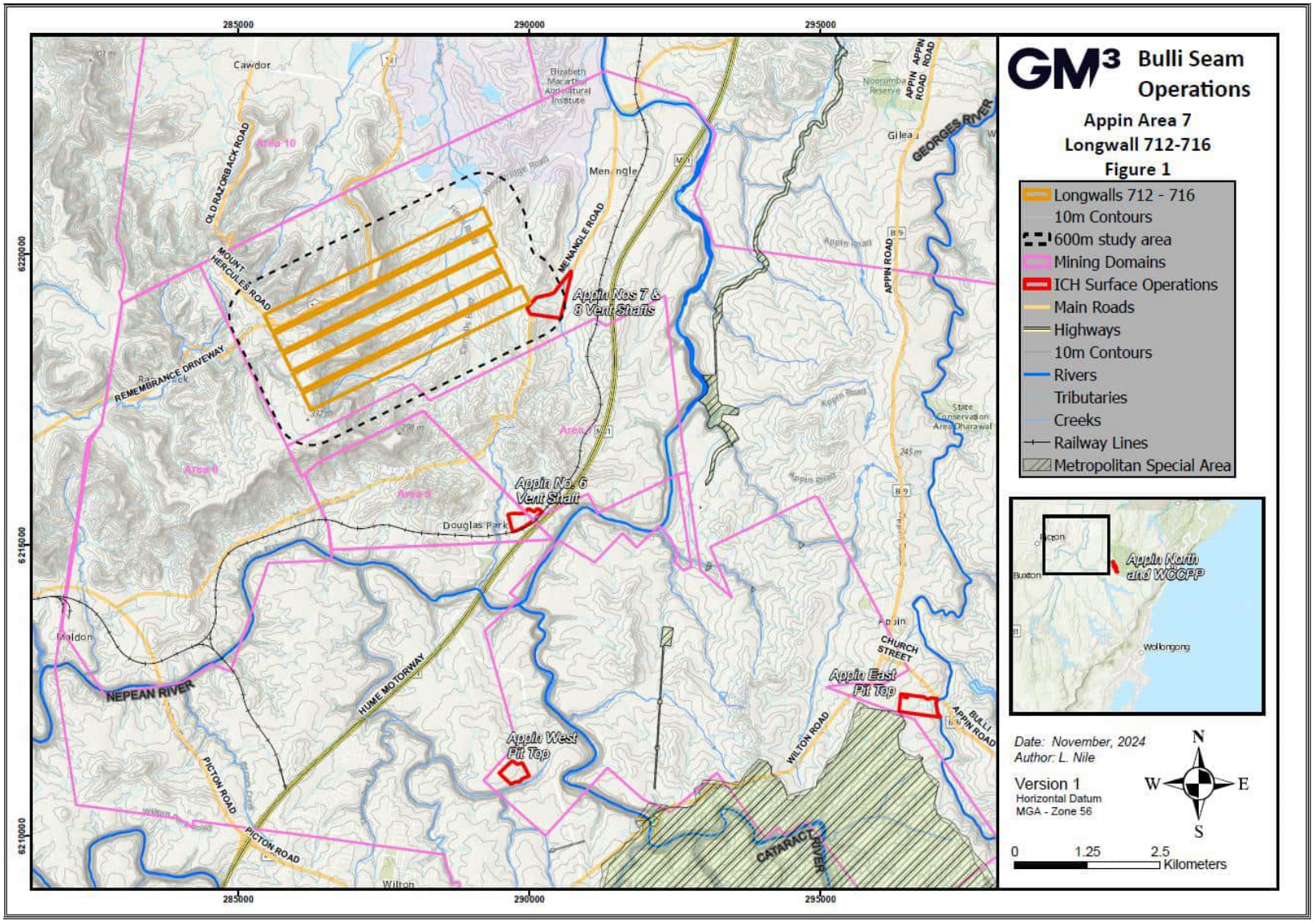
1.4 Consultation

This WMP will be developed in consultation with:

- Department of Planning, Housing and Infrastructure (DPHI);
- Conservation Programs, Heritage, and Regulation Group (CPHR) of the Department of Climate Change, Energy, the Environment and Water (DCCEEW);
- WaterNSW; and
- NSW DCCEEW – Water Group.

ICHPL will make the WMP and associated documentation publicly available on the GM^3 website in accordance with Condition 11, Schedule 6 of the BSO Approval.

Figure 1 Appin Area 7 (Longwalls 712 to 716) Study Area



2 STATUTORY REQUIREMENTS

Extraction of coal from Longwalls 712 to 716 will be in accordance with the conditions set out in the BSO Approval, applicable legislation and the requirements of relevant licences and permits, including conditions attached to mining leases.

2.1 BSO Approval

Condition 5 (h), Schedule 3 of the BSO Approval requires the preparation of a WMP to manage the potential impacts and/or environmental consequences of the proposed second workings on groundwater and surface water features in the Study Area as shown in Table 1.

Table 1: Key Conditions of the BSO Approval MP 08_0150

No.	Condition Requirement	Section
C3.5(h)	The Proponent shall prepare and implement an Extraction Plan for first and second workings within each longwall mining domain to the satisfaction of the Planning Secretary. Each extraction plan must:	This plan
	include a Water Management Plan, which has been prepared in consultation with BCS, WaterNSW and NSW DCCEEW – Water Group, which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on watercourses and aquifers, including:	Section 1.4
	– Surface and groundwater impact assessment criteria, including trigger levels for investigating any potentially adverse impacts on water resources or water quality;	Section 7.1
	– a program to monitor and report stream flows and assess any changes resulting from subsidence impacts;	Section 6
	– a program to monitor and report ground water inflows to underground workings; and	Section 6
	– a program to predict, manage and monitor impacts on groundwater bores on privately owned land.	Section 6

This WMP also addresses the requirements detailed in Condition 6 Schedule 3 and Condition 2, Schedule 6 of the BSO Approval as shown in

Table 2.

Due consideration has been given to all the BSO Approval Conditions in the preparation of this WMP, including those relating to auditing, rehabilitation and environmental management.

Table 2 Management Plan Requirements

Project Approval Conditions	Section
Condition 6, Schedule 3 The Proponent shall ensure that the management plans required under Condition 5 (g)-(l) above include: a) an assessment of the potential environmental consequences of the Extraction Plan, incorporating any relevant information that has been obtained since this approval; b) a detailed description of the measures that would be implemented to remediate predicted impacts.	 Section 3 and 4 Section 8
Condition 2, Schedule 6 The Proponent shall ensure that the management plans required under this approval are prepared in accordance with any relevant guidelines, and include: (a) detailed baseline data; (b) a description of: - the relevant statutory requirements (including any relevant approval, licence or lease conditions); - any relevant limits or performance measures/criteria; - the specific performance indicators that are proposed to be used to judge the performance of, or guide the implementation of, the project or any management measures; (c) a description of the measures that would be implemented to comply with the relevant statutory, limits, requirements or performance measures/criteria; (d) a program to monitor and report on the: - impacts and environmental performance of the project; - effectiveness of any management measures (see c above); (e) a contingency plan to manage any predicted impacts and their consequences and to ensure that ongoing impacts reduce to levels below relevant impact assessment criteria as quickly as possible; (f) a program to investigate and implement ways to improve the environmental performance of the project over time; (g) a protocol for managing and reporting any: - incidents; - complaints; - non-compliances with statutory requirements; and - exceedances of the impact assessment criteria and/or performance criteria; and (h) a protocol for periodic review of the plan.	 Section 3 Section 2 Section 5 Section 5 to 8 Section 5 to 8 Section 6 Section 8 Section 6 Section 9 Section 10

2.2 Legislation and Guidelines

Legislation applicable to water, erosion and sediment control management may include but is not limited to:

- Protection of the Environment Operations Act 1997 (POEO Act);
- Protection and the Environment Operations (Underground Petroleum Storage Systems) Regulation 2014;
- Environmental Planning and Assessment Act 1979 (EP&A Act);

- Water Act 1912;
- Water Management Act 2000;
- Water Management (General) Regulation 2018;
- Mining Act 1992;
- Water NSW Act 2014;
- Sydney Water Regulation 2017;
- Soil Conservation Act 1938; and
- National Environment Protection (National Pollutant Inventory) Measure 1998.

2.3 Relevant Leases and Licences

The following licences or permits may be applicable to ICHPL operations in AA7:

- Mining Leases as per Table 3.
- Environment Protection Licence (EPL) 2504 which applies to BSO, including Appin and West Cliff Mines. A copy of the licence can be accessed at the NSW EPA website.
- Water Access Licences (WALs) issued by the NSW DCCEEW – Water Group (formerly the Department of Industry - Water) under the NSW Water Management Act, 2000, including WAL 36481, 36477 and 37464 under the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 and WAL 30145 and 35519 under the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011.
- All relevant Occupational Health, Safety, Environment and Community approvals.
- Any additional leases, licences and approvals resulting from the BSO Approval.

Table 3: Appin Mine Leases

MINING LEASE – DOCUMENT NUMBER	START	FINISH
CCL 767	29 OCT 1991	08 JUL 2029
ML 1433	24 JULY 1998	24 JULY 2043
ML 1698	26 JUN 2014	26 JUN 2035
ML 1832	9 AUG 2022	9 AUG 2043
ML 1874	20 FEB 2020	20 FEB 2045
ML 1892	4 SEP 2025	4 SEP 2046

3 BASELINE ASSESSMENT

Baseline groundwater (Heritage Computing, 2009) and surface water assessments (Gilbert and Associates, 2009) were undertaken in support of the BSO Environmental Assessment (EA). The Study Area for these assessments included the Longwalls 712 to 716 Study Area.

Supplementary Assessments for groundwater (HGEO 2025a) (refer Appendix A) and surface water (HGEO 2025b) (refer Appendix B) were undertaken for the purposes of this Extraction Plan.

The rivers within the Appin Mine area generally flow in a northerly direction and have perennial flows influenced by dam releases, catchment runoff and baseflow contributions from the incised Hawkesbury Sandstone. There are no drinking water catchment areas, or declared special areas within the Study Area. The Hawksbury-Nepean Catchment covers approximately 21,400 km^2.

Error! Reference source not found. shows the location of the existing and proposed surface water monitoring sites for Longwalls 712 to 716.

3.1 Nepean River

The closest river is the Nepean River, which is located to the over two kilometers to the south and east of the Longwalls 712 to 716 (MSEC, 2025) and well outside the Study Area. The Longwalls 712 to 716 Study Area includes drainage lines which predominately flow into the Nepean River.

Water flows from the Nepean River are derived from a number of sources and include flows from catchment areas, licensed discharges, including Appin and Tahmoor Mines, and runoff from agricultural and urban areas.

Water flows in the Nepean River:

- Vary greatly and are highly responsive to rain events due to the significant areas of catchment.
- Regulated flows from upstream dams and baseflow contributions where incised into Hawkesbury Sandstone.
- Natural flow within the Nepean River and its associated watercourses have been significantly altered by water storages such as dams and weirs. Some natural catchment flows are retained by large storage dams upstream of Appin Mine for the purpose of the Sydney water supply system. Water is also retained by numerous farm dams within the local part of the Nepean River catchment.
- Flows in a northerly direction, with flow of around 310 ML/day (Maldon Weir) since 2010.

Surface water monitoring is conducted at the main rivers at government stream gauges (Maldon, Menangle and Broughtons Weirs). The Maldon, Menangle and Broughtons Pass gauging sites are located on the Cataract or Nepean River, being directly upstream and downstream of the

approved BSO footprint. Flow monitoring on the Cataract River at Broughtons Pass Weir measures the flow of the major tributary input to Nepean River between the two Nepean River flow stations.

Daily flow records for Maldon, Menangle and Broughtons Pass weirs from 1990 have been assessed in order to study the dry weather recessions in the Nepean River adjacent to the proposed mining areas. The difference in flows should be equivalent to runoff from all catchments between these two weirs responding to local rainfall minus any abstractions by licensed pumps in the River.

The Nepean River is a 'gaining river' in terms of surface water - groundwater interaction. The potential for infiltration of water into the groundwater system is very low as the Nepean River lies in a well incised gorge which represents the regional low point in the piezometric surface (SLR 2021). The potential for sub-bed diversion of surface water from Longwalls 712 to 716 is very low as the Nepean River is flooded and the gradient is very flat, significantly removing the effects of gravity to force surface flow through any fracture network that develops. The thalweg (i.e. centreline) of the Nepean River is 2.2 km south of the commencing (i.e. western) end of Longwall 712 and 2.5 km east of the finishing (i.e. eastern) end of Longwall 712 at its closest points to the longwalls. As such, no surface water flow or quality monitoring is proposed in the Nepean River for the Longwall 712 to 716 Extraction Plan, although two years of post-mining monitoring will be undertaken in accordance with the Longwall 709 to 711 and 905 Extraction Plan.

3.2 Watercourses within the Study Area

Minor creeks and tributaries of the Nepean River are present across the Study Area. This includes Navigation Creek, four Tributaries of Navigation Creek, and upstream tributaries of Apps Gully and Foot Onslow Creek within the Study Area.

Watercourses within the Study Area have upper reaches with shallow incisions into the surface soils, which have been derived from the Wianamatta Group, and steep natural gradients ranging from 2-40%. The lower reaches of these creeks have substantial incisions into the surface soils, with exposed sandstone platforms in the bases and rock outcropping in the valley sides. Natural gradients of third order streams range from 0.5-4%.

Watercourses within the Study Area contribute to a small portion of the total Hawkesbury-Nepean Catchment (<0.2%) with runoff from predominately cleared, agricultural land with small pockets of remnant vegetation. The creeks are largely ephemeral, but pools have naturally formed in some areas. Like the receiving Nepean River, flows within ephemeral creeks have been altered by farm dams which intersect the drainage lines at a number of locations. Runoff from within the catchments is influenced by input of nutrients from adjacent farmland and salinity from the marine sediments of the Wianamatta Shale (HGEO 2025b).

The creeks that have first to third order sections located within the Study Area or within 600 m of Longwalls 712 to 716 are Foot Onslow Creek, Navigation Creek and four tributaries of Navigation

Creek and Apps Gully. A fourth order section of Navigation Creek is located within the Study Area directly above Longwalls 715 and 716.

A summary of the third order (or above) creeks that are located within the Study Area are provided in Table 4 and monitoring locations are shown in Figure 2.

Table 4 Third order (or above) creeks located within the Study Area (MSEC, 2025)

Name	Location	Total length of third order section above the mining area (km)	Total length of third order section within the Study Area (km)
Navigation Creek	Fourth order section of creek directly above Longwalls 715 and 716. Third order section directly above Longwalls 712 to 714.	3.0 (3rd order) 1.4 (4th order)	3.0 (3rd order) 2.1 (4th order)
Tributary to Navigation Creek (NavC14.5)	200 m north of LW716	-	1.3
Tributary to Navigation Creek (NavC16)	Directly above Longwalls 710B and 716.	1.9	3.7
Tributary to Navigation Creek (NavC17)	Directly above Longwall 715.	0.27	0.27
Tributary to Navigation Creek (NavC20)	Directly above Longwall 713-714	1.1	1.1
Apps Gully	Located 250 m west of Longwall 715	-	0.39
Foot Onslow Creek	Located 560 m south east of Longwall 712	-	0.29
Total		7.7	12.1

Baseline water quality data has been collected within minor creeks and tributaries within the Study Area as summarised in Table 5 and Table 6. New water quality and flow site monitoring sites on Navigation Creek were established in March 2024 which will provide in excess of two years pre-mining baseline data. Additional surface water quality data for creeks and tributaries in the vicinity of the Study Area is provided in Appendix B (HGEO 2025b).

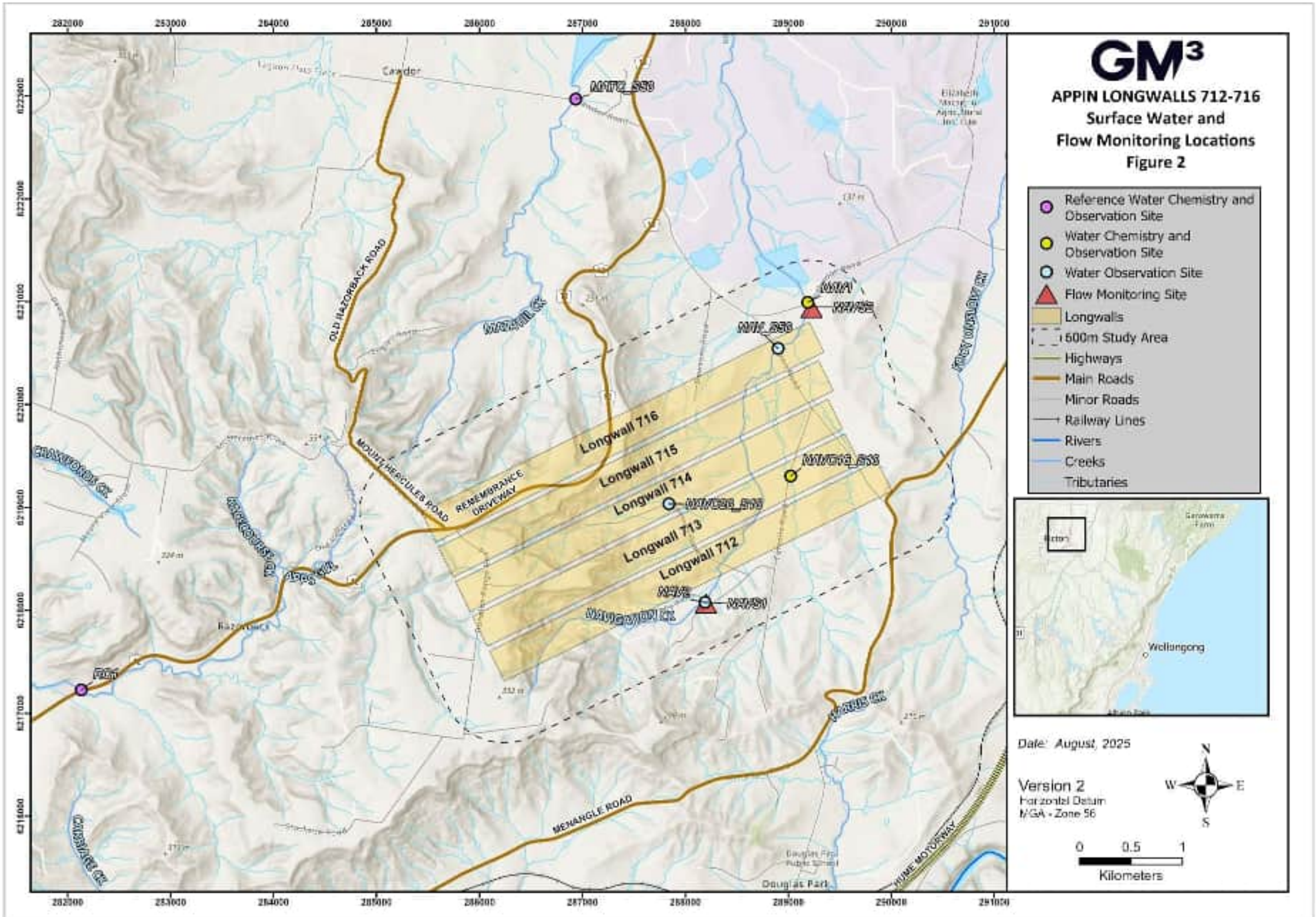
Table 5 Field water quality data (medians)

Stream		Navigation Creek and tributaries			Racecourse Creek
Parameter	Units	NAV1	NAV_S50	NAVC16_S10	RC1
Number of samples	n	77	1	1	47
Electrical Conductivity	µS/cm	1955	2210	315	1105
pH	pH units	7.5	7.7	8.16	7.5
Redox potential	mV	98	121	135	195
Dissolved Oxygen	%	43.7	29.1	76.5	46.0
Temperature	°C	16.3	22.1	22.51	16.0

Table 6 Laboratory data (medians)

Stream		Navigation Creek and tributaries		Racecourse Creek
Parameter	Units	NAV1	NAVC16_S10	RC1
Electrical Conductivity	µS/cm	2099	329	1107
Total Dissolved Solids	mg/L	1214	381	611
pH	pH units	7.8	7.7	7.7
Suspended Solids	mg/L	44.3	156	11.2
Dissolved Organic Carbon	mg/L	12.0	17.0	5.8
Aluminium	mg/L	0.074	0.560	0.062
Arsenic	mg/L	<0.001	<0.001	<0.001
Barium	mg/L	0.076	na	0.166
Boron	mg/L	0.050	na	0.050
Copper	mg/L	<0.001	0.003	<0.001
Iron	mg/L	0.734	0.430	0.104
Lead	mg/L	<0.001	<0.001	<0.001
Lithium	mg/L	0.002	<0.001	<0.001
Manganese	mg/L	0.991	0.325	0.453
Nickel	mg/L	<0.001	0.003	<0.001
Selenium	mg/L	<0.010	<0.01	<0.01
Strontium	mg/L	0.280	na	0.201
Zinc	mg/L	0.008	<0.005	0.012
Aluminium	mg/L	0.389	4.170	0.423
Iron	mg/L	2.920	6.800	0.606
Manganese	mg/L	1.309	0.656	0.542
Total Nitrogen as N	mg/L	1.660	na	na
Total Phosphorus as P	mg/L	0.278	0.370	0.043

Figure 2 Surface Water Monitoring Locations



3.3 Groundwater

The primary hydro stratigraphic units within the Appin Mine area are:

- Quaternary alluvium – localised along rivers and creeks, likely unconfined and recharged from rainfall and surface water flow. Discharge to surface water (baseflow contributions) possible where gradients enable this, with potential for downward seepage where unconformity overlies HBSS. Groundwater flow likely follows topography and streamflow direction towards the north;
- Hawkesbury Sandstone – main groundwater source and widely accessed for groundwater supply and provides baseflow contributions where incised along major rivers (i.e. Cataract River, Nepean River and Georges River). Groundwater flow generally in a northerly direction, and locally influenced where intersected by rivers and private abstraction bores;
- Narrabeen Group – sandstones that can be used for groundwater supply, and low permeability claystones that generally act as aquitards; and
- Illawarra Coal Measures – with groundwater occurrence largely associated with the more permeable coal seams, with confined groundwater conditions. Groundwater flow generally in a northerly direction, and locally depressurised due to current and historical mining and coal seam gas.

3.3.1 Landholder Bores

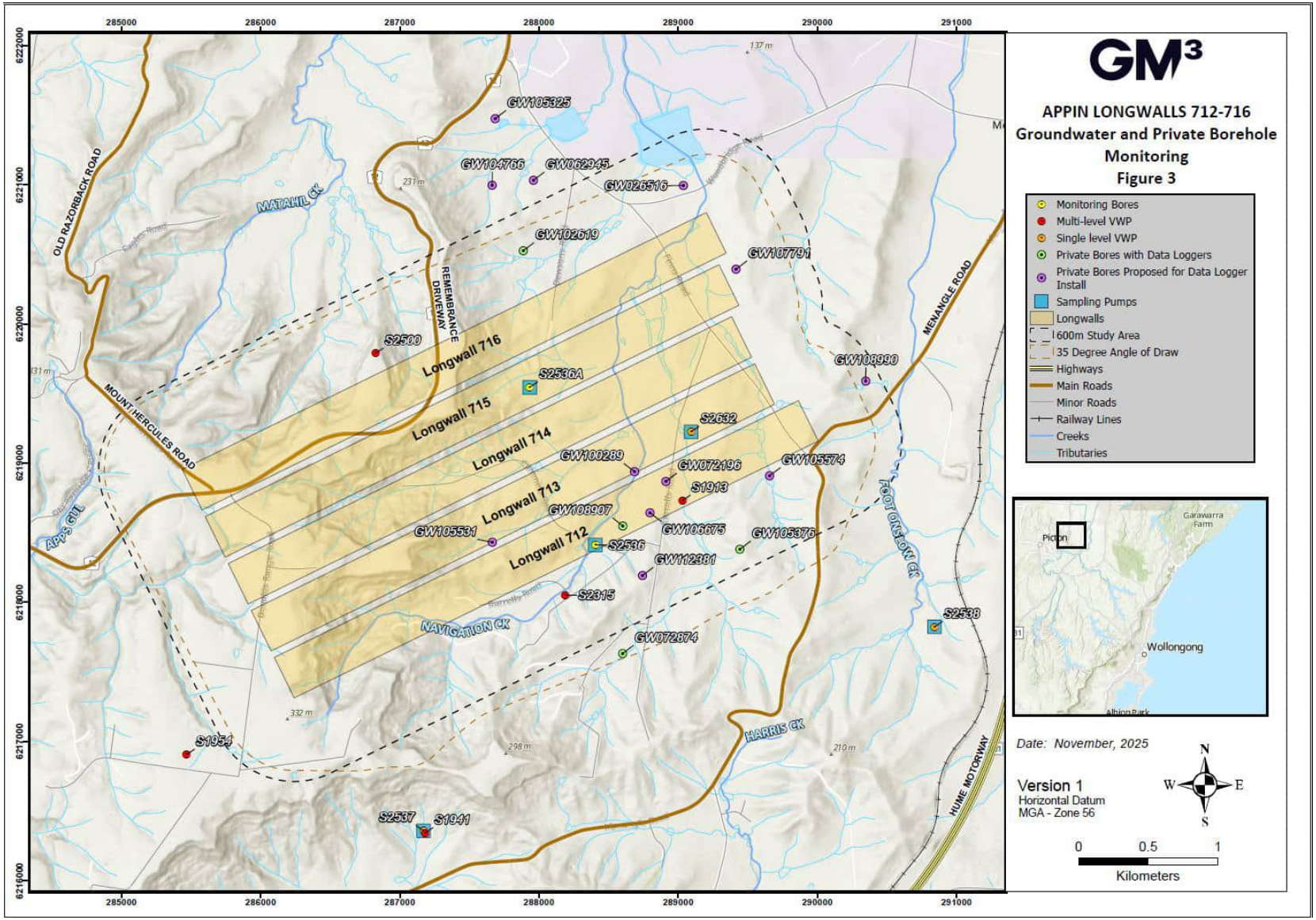
A search of the BoM's National Groundwater Information System (NGIS) was carried out for registered bores within the Study Area (MSEC 2025).

Most groundwater users are located to the north of Appin Mine, within the Wianamatta Group outcrop area, and to the southwest, within the Hawkesbury Sandstone outcrop area. Most landholder bores are located within the Hawkesbury Sandstone and Bulgo Sandstone

There are 16 Registered Bores within the 600 m Study Area for Longwalls 712 to 716 as shown in HGEO 2025a Figure 57 and Figure 3. HGEO 2025a recommended monitoring of the registered bores in the vicinity of Longwalls 712 to 716, four of which have existing data loggers installed, and the remainder are proposed for data logger install and ongoing monitoring. Monitoring and data logger installation is dependent on accessibility and landholder access being granted.

ICHPL have installed 12 groundwater monitoring bores within the Study Area. The proposed groundwater monitoring network for Longwalls 712 to 716 has been presented in Figure 3.

Figure 3 Groundwater Monitoring Locations



4 PREDICTED IMPACTS

In accordance with the findings of the Southern Coalfield Inquiry (2008) and Independent Expert Panel for Mining in the Catchment (2019a), subsidence impacts are defined as:

- **Subsidence effects** are defined as the deformation of ground mass such as horizontal and vertical movement, curvature and strains.
- **Subsidence impacts** are the physical changes to the ground that are caused by subsidence effects, such as tensile and sheer cracking and buckling of strata.
- **Environmental consequences** are then identified, for example, as a loss of surface water flows and standing pools.

4.1 Subsidence Effects

There are no rivers within the 600 m Study Area. The closest river is the Nepean River which is located to the south and to the east of the proposed longwalls. The centreline of the Nepean River is located 2.2 km south of the commencing (i.e. western) end of Longwall 712 and 2.5 km east of the finishing (i.e. eastern) end of Longwall 712, at its closest points to the proposed longwalls. No subsidence impacts are predicted to occur in the Nepean River from Longwalls 712 to 716.

The predicted subsidence movements on the third order creeks that are located within the Study Area is provided in Table 7.

Table 7 Maximum Predicted Subsidence Effects for Creeks and Tributaries located within the Study Area (MSEC 2025)

Name	Maximum predicted total subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Navigation Creek	1450	6.5	0.07	0.14
Navigation Creek (Trib NavC14.5)	90	<0.5	<0.001	<0.01
Navigation Creek (Trib NavC16)	1400	6.5	0.06	0.12
Navigation Creek (Trib NavC17)	1300	5.0	0.06	0.11
Navigation Creek (Trib NavC20)	1350	6	0.06	0.12

Apps Gully	1100	4.0	0.04	0.07
Foot Onslow Creek	100	1.0	<0.01	<0.01

The creeks will also experience valley-related effects. The effective valley-height for the upper reaches (i.e. first and second order) section of Navigation Creek is up to 100 m. The closure for these sections of stream could be greater than that previously measured due to mining in the Bulli Seam, of 640 mm. However, the closure is expected to be less than the maximum measured value due to mining in the shallower and thicker Wongawilli Seam, of 880 mm.

Elsewhere, the effective valley heights for the lower reaches of Navigation Creek and the other streams within the Study Area typically vary between 10 m and 60 m. The predicted closures for these streams range between 125 mm and 500 mm based on the 95 % confidence level.

The compressive strains due to the valley-related effects are expected to be similar to those measured for streams previously mined beneath at Appin and other nearby mines.

The groundwater bores could experience adverse impacts due to the extraction of the proposed Longwalls 712 to 716, particularly the bores located directly above the proposed mining area. Impacts could include lowering of the piezometric surface, blockage of the bores due to differential horizontal displacements at different horizons within the strata, changes to groundwater quality and gas release.

HGEO 2025a models groundwater depressurisation and provides median and 90th percentile drawdown predictions at landholder bores due to mining of Longwalls 712 to 716 as well as the cumulative impact as a result of all mining activities in the region. The drawdown values are obtained from the deepest model layer that the bore intersects, based on published depth, if the depth is unknown it is assigned to the mid-Hawkesbury Sandstone layer. This was considered a conservative approach, since many bores will be screened (or open) over a large depth interval and would experience less drawdown in standing water level than the theoretical maximum at the base of the bore.

A maximum 9.19 m of cumulative drawdown (all mining) and 0.81m of incremental drawdown (Longwalls 712 to 716 only) was precited by HGEO 2025a at any of the registered private use bores, utilising conservative 90th percentile values. Private bores where greater than 2 m of depressurisation (AIP threshold for a highly productive aquifer) as predicted by HGEO 2025a are listed in Table 8.

Table 8 - Predicted Drawdown Greater than 2 m at Privately Owned Boreholes

BORE ID	Median Drawdown (m)	90TH Percentile Drawdown (m)
GW108907	**3.42**	**5.13**
GW105531	**3.52**	**4.22**

GW112381	**2.00**	**2.57**
GW105376	**4.02**	**7.09**
GW072874	**6.74**	**9.19**
GW105376	1.97	**3.69**

While no depressurisation is predicted within the surficial strata (Alluvium/ Wianamatta Group / Weathered Hawkesbury Sandstone) as part of the groundwater assessment, the subsidence assessment (MSEC, 2025) identified potential for surface cracking including along Navigation Creek and other minor tributaries. This has the potential for localised impacts at the surface, including Navigation Creek surface water flow, which may influence recharge to the alluvium in proximity to the Project and potentially landholder bores accessing alluvial groundwater (i.e. GW100289).

This is consistent with Heritage Computing (2009) findings 'for bores located directly above mined longwalls, there is a risk of damage to bore casing from subsidence related movement'.

4.2 Subsidence Impacts

MSEC (2025) predict subsidence effects for the Nepean River, due to the mining of Longwalls 712 to 716, are less than 5 mm vertical subsidence, less than 5 mm upsidence and less than 5 mm closure. While the Nepean River could experience very low levels of vertical subsidence or valley-related effects, it is not predicted to experience measurable tilts, curvatures or strains. It is unlikely, therefore, that the Nepean River would experience adverse physical impacts due to the mining-induced movements from Longwalls 712 to 716. Gas release zones have been observed along the river during the mining of longwalls in Areas 7 and 9. Gas release zones could re-activate due to the mining of the proposed longwalls, however as monitoring and reported for previous Area 7 and 9 Longwalls, these gas releases give rise to temporary and negligible changes in water quality.

MSEC (2025) predict that it is unlikely that there would be large-scale adverse changes in the levels of ponding or scouring of the banks along the creeks and tributaries in the Study Area due to mining-induced tilt. It is possible that localised increased ponding could develop in some isolated sections, where the existing grades are small, and upstream of the chain pillars and the edges of the mining area. Potential impacts of increased ponding and scouring are expected to be minor and localised. Impacts resulting from changes in surface water flows due to mining-induced tilt are expected to be small in comparison to those which occur during natural flooding conditions.

Predictions by MSEC (2025) indicate that fracturing could develop along the creeks and tributaries due to the mining of Longwalls 712 to 716. Fracturing will predominantly occur where the creeks

and tributaries are located directly above the longwalls. Impacts could occur outside the mining area with minor isolated fracturing occurring at distances up to 400 m outside the mining area.

Surface water flow diversions could occur along the creeks and tributaries located directly above the longwalls. In times of heavy rainfall, the majority of the runoff would flow over the fractured bedrock and soil beds and would not be diverted into the dilated strata below. In times of low flow, however, surface water flows can be diverted into the dilated strata below the beds. Most sections of the creeks and tributaries within the Study Area are ephemeral and, therefore, surface water flows only occur during and for short periods after rain events.

There are a limited number of standing pools within the Study Area but some of these pools could experience a reduction or loss of water holding capacity.

ICHPL has previously observed gas and groundwater release impacts in circumstances where a suitable pathway exists to connect the underground fracture network above the longwall panels to the near surface. Unsealed or poorly sealed boreholes can act as a conduit connecting the fracture network to the near-surface allowing pressurised gasses and groundwater to migrate to the surface. The Water Management Trigger Action Response Plan (TARP) incorporated in Section 7.1 includes triggers to reflect this potential and identify mitigation and management measures.

ICHPL implements proactive avoidance measures for gas and groundwater release, conducting reviews of bore construction and site-specific assessment of risk for each borehole. Proactive identification, assessment and, where required, management of boreholes (i.e. grouting) prior to longwall extraction is undertaken. Boreholes under management are reinstated following active mining periods.

5 PERFORMANCE MEASURES AND INDICATORS

The BSO Approval provides subsidence impact performance measures (Condition 1, Schedule 3). Table 9 details the conditions relevant to watercourses within the Study Area.

Performance indicators specific to each performance measure have been developed to judge the performance of, and guide the implementation of, the project or any management measures.

The term 'negligible' is defined within the Project Approval as "s*mall and unimportant, such as not to be worth considering*" or as otherwise defined in Table 9 for the Nepean River and other watercourses.

Table 9 Subsidence Impact Performance Measures (BSO Approval)

Watercourses	Performance Measure	Performance Indicators
Nepean River	Negligible environmental consequences including: • negligible diversion of flows or changes in the natural drainage behaviour of pools; • negligible gas releases and iron staining; and • negligible increase in water cloudiness.	The performance measure would be considered to be exceeded if: • mining results in more than negligible diversion of flows or changes in the natural drainage behaviour of pools in the Nepean River; • mining results in more than negligible gas releases, iron staining or water cloudiness in the Nepean River
Other Watercourses	No greater subsidence impact or environmental consequences than predicted in the EA and PPR.	The performance measure would be considered to be exceeded if: • mining results in more than moderate diversion of flows or changes in the natural drainage behaviour of pools in the watercourse; • mining results in more than negligible gas releases, moderate iron staining or water quality change (±2SD) in the watercourse

In order to assess the potential subsidence impacts and environmental consequences from the mining of Longwalls 712 to 716, monitoring and recording will be undertaken prior to mining, throughout the extraction and at the completion of subsidence (refer Section 6).

In the event that any subsidence impact is recorded, consideration would be given to implementing appropriate management, remediation and/or mitigation measures in

consultation with the relevant stakeholders and with the approval of the landholder (refer Section 7).

If the subsidence impact performance measures are exceeded, ICHPL will notify DPHI, CPHR, Resources Regulator and other key stakeholders and implement the Contingency Plan (Section 8).

6 MONITORING AND REPORTING

6.1 Surface Water Quality Monitoring

There is adequate baseline data to fully characterise water quality conditions prior to the commencement of mining in the Study Area. This includes monitoring locations within the Study Area (Figure 2). There are no watercourses which flow into the Study Area, with the headwaters of Navigation and Foot Onslow Creeks and Apps Gully being within the Study Area.

Locations of water quality monitoring sites are included in Table 11.

6.2 Water Flow Monitoring

6.2.1 Watercourse Flow Sites

Monitoring for surface flows on third and forth order watercourses within the Study Area will be undertaken.

Navigation Creek is ephemeral and only flows during periods of extended, moderate to high rainfall. The headwaters of Navigation Creek are located within the Longwalls 712 to 716 Study Area with first and second order streams within the steep ridgeline of remnant bushland to the northwest of Appin Mine. The majority of the remaining catchment, including that of the third order stream, is comprised of agricultural land. Navigation Creek is predominantly highly disturbed and in poor condition.

Stream banks associated with Navigation Creek are often steep with vegetation often consisting of weeds, and areas of minimal vegetation with evidence of erosion and scouring. Some pools have naturally established along the reaches; however the majority of the upper reaches consist of depressions and minor drainage lines intersected by a number of farm dams with little to no signs of flow. Any surface water flows from the upper reaches are predominantly captured within these established farm dams with runoff likely to only contribute to the downstream Nepean River during periods of extended or significant flow. The predicted influence of this watercourse on flow and water quality within the Nepean River is minimal (HGEO 2025a).

Foot Onslow Creek is ephemeral and likely only flows during periods of extended, moderate to high rainfall. Foot Onslow Creek is a third order creek and only just extends into the Study Area, with some minor first and second order tributaries extending further into the Study Area but not

over the longwall extraction footprint. Within the Study Area the watercourse resides chiefly within agricultural land. Foot Onslow Creek is predominantly highly disturbed and in poor condition.

Apps Gully is ephemeral and likely only flows during periods of extended, moderate to high rainfall. Apps Gully is a third order stream and only just extends into the Study Area, with some minor first and second order tributaries extending further into the Study Area. Within the Study Area the watercourse resides chiefly within agricultural land. Apps Gully is predominantly highly disturbed and in poor condition.

Some minor first and second order tributaries of Matahil Creek extend into the Study Area. These upper tributaries are predominantly highly disturbed and in poor condition.

Stream banks show areas of significant scouring and erosion with steep to near vertical walls. On shallower banks vegetation consist primarily of grassland and weeds. Stream bed material consists of loose sediment with grass and reed growth in some locations. Surface water flows from the upper reaches are predominantly captured within a number of established farm dams with runoff likely to contribute to the Nepean River during periods of extended or significant flow only. The predicted influence of this watercourse on flow and water quality within the Nepean River is minimal (HGEO 2025a).

Monitoring for surface cracking:

ICHPL will monitor and report observable fracturing resulting in loss of surface water flow.

Assessment of cease-to-flow frequency from qualitative observations:

Estimation of cease-to-flow frequency (% of days) at the sites NAV1 and NAV2 for the pre- and post-mining periods will be assessed via comparison of the long record of qualitative flow observations (Surface Flow/No Observable Flow) and pool water observations (Water in Pool/Pool Dry) at these sites with quantitative flow records at suitable Reference sites (e.g. O'Hares at Wedderburn, possibly Stonequarry Creek at Picton).

Installation of flow gauging:

ICHPL inspected locations on Navigation Creek to establish additional (quantitative) flow monitoring sites over the longwall footprint where access was granted by landholders. The majority of these watercourses were determined to be unsuitable by ALS.

Sites NAVS1 and NAVS2 (**Error! Reference source not found.**) were selected based on their existing solid rockbar or potential for engineered control. Other potential locations inspected were of poor quality due to wide downstream controls and sediments banks which already displayed signs of erosion which would likely be exacerbated by the installation of flow monitoring structures. The proposed sites will contain pool water level loggers and the modification of downstream controls, by means of a low-profile plate/weir from which to gauge flow. These gauging stations provide estimates of stream flow via:

- A structure behind which water pools and flows over.

- A sensor and logger that measure and record water level ("stage") in the pool at typically 15-minute intervals.
- A "rating curve" which is a chart or graph of discharge (flow) versus stage for each gauging station. A theoretical rating curve is developed initially following a site survey. This rating is improved using subsequent infield measurements of flow in the channel at a known water level.
- Estimates of mean daily flow are then provided.

ICHPL is in the process of gaining approval to install the Navigation Creek flow site NAVS2 as it is located on private land and subject to install and access agreement. ICHPL will investigate an alternate site if approval cannot be secured.

Assessment of cease-to-flow frequency from flow gauging:

Once site NAVS2 (proposed) has been established and baseline data collected, calculation of cease-to-flow frequency (% of days) at the site for the pre- and post-mining periods will be assessed from this to augment the comparison of qualitative observations and the Reference Sites (above). This is reliant on approval/installation and assessment of the data gathered at these sites.

6.3 Pool Water Level Monitoring

Water levels in the Navigation Creek tributaries at NAV1, NAV2, NAV_S50, NAVC16_S10 and NAVC20_S10 are monitored using observations and measured benchmarks. The water level is recorded before, during and after mining and is assessed against catchment rainfall. This method of monitoring has been used previously for areas AA7 and 9. Pool water level monitoring sites are listed in Table 11. Given the ephemeral nature of the other third order creeks within the Study Area, there is a lack of suitable pool water monitoring sites. No monitoring of pool water levels (other than those shown on Figure 2) is proposed on these creeks and tributaries.

6.4 Groundwater Monitoring

An extension of the current groundwater monitoring program will be used to monitor the subsidence effects from the extraction of Longwalls 712 to 716 on groundwater within the Study Area (refer Table 10).

If significant excursions from the predicted model outcomes occur, this will trigger the need for model re-calibration and/or further investigation.

Consultation with bore owners and the monitoring of bores will be incorporated into the PSMPs for relevant properties and, with the agreement of the landowner would include:

- Interview with landowner before a bore is mined beneath to determine the normal rate and duration of pumping.
- Details obtained on the type and set up of the pump in each bore, if installed.
- Post mining interview to compare rate and duration of pumping.
- Measurement of the bore yield if used and access is available.
- Observations on the presence and quantum of iron hydroxide precipitating from the pumped water before and after mining.
- Observations of any gas in the bores.

A description of the ICHPL piezometers is provided in Table 10.

Table 10 Monitoring in ICHPL Piezometers

Piezometer	Description	Groundwater level (yes/no)	Water quality (yes/no)
S2500W	Full string piezometers. Automated telemetry	Y	N
S2315	Full string piezometers. Automated telemetry	Y	N
S2536	Shallow Groundwater hole. 1 piezometer 15m. Micro purge pump @15m.	Y	N
S2536A	Shallow Groundwater hole. 1 piezometer 135m. Micro purge pump @130m.	Y	N
S1913	Full string piezometers. Automated telemetry	Y	N
S2632	Shallow Groundwater hole. 1 piezometer 15m. Micro purge pump @15m.	Y	Y
S1954	Full string piezometers. Automated telemetry, 4 sampling pump locations	Y	Y
S1936	Full string piezometers. Automated telemetry	Y	N
S1941	Full string piezometers. Automated telemetry	Y	N
S2157	Full string piezometers. Automated telemetry	Y	N

S2537	Single piezometer in the HBSS. Automated telemetry	Y	Y
S2538	Single piezometer in the HBSS. Automated telemetry	Y	Y

Notes: Where a private bore is used and access is granted, monitoring is conducted before and after the site is mined beneath. Monitoring sites which have piezometers and data loggers installed will be measured and data logged at least twice daily in the pre-mining baseline, impact and post-mining period. Monitoring equipment in private bores also varies between sites i.e. water quality data is collected in some but not all boreholes.

6.5 Reporting

Results from the monitoring program will be reported annually in the Annual Review. The Annual Review will detail the outcomes of monitoring undertaken; provide results of visual inspections; and determine whether performance indicators have been exceeded and whether CMAs are required.

Monitoring results will be reviewed monthly in the ICHPL Subsidence Review Meeting. However, if the findings of monitoring are deemed to warrant an immediate response the Principal Approvals will initiate the requirements of the TARP (refer Table 12).

Monitoring results will be made publicly available in accordance with BSO Approval Conditions 8 and 11, Schedule 6 and will also be included in the Annual Review in accordance with Condition 4, Schedule 6.

7 MANAGEMENT AND MITIGATION STRATEGIES

The predicted impacts for the watercourses and drainage lines within the Study Area are minor and no mitigation measures are currently proposed for any of these predicted impacts. Where there are impacts to farm dams these would be repaired utilising standard dam building techniques and/or an alternate water supply would be provided in consultation with and agreement of the landowner.

The main impacts predicted for groundwater are lowering of some groundwater levels due to dilation of the strata above the longwalls. Where this lowering of groundwater level impact the use of landholders bores, the following mitigation measures may be proposed:

- Temporary provision of water from external sources
- Automated and optimised pump system.
- Lowering of the pump intake.
- Establishment of a new bore.

With these mitigation measures in place the impact of lower groundwater levels on landholder bores are predicted to be negligible.

ICHPL will review the need to implement additional management and mitigation measures during routine monitoring (refer Section 6) and during the finalisation of PSMPs with affected landholders.

7.1 WMP Monitoring Plan and Trigger Action Response Plan

The water monitoring program across the Longwalls 712 to 716 Study Area is provided in Table 11. The Trigger Action Response Plan (TARP) for these sites is provided in Table 12.

Table 11 Water Monitoring Program

	MONITORING SITE	MONITORING TYPE	MONITORING FREQUENCY	PARAMETERS
SURFACE WATER				
Area 7	**Surface water quality and observational** **Navigation Creek** NAV1 (Lab, Field, Level, Obs) NAV2 (Obs, Level) NAV_S50 (Obs) NAVC16_S10 (Lab, Field, Obs) NAV20_S10 (Obs) **Matahil Creek** MATC_S50 (Lab, Field, Obs) **Racecourse Creek** RC1 (Lab, Field, Level, Obs) – Reference Site	• Laboratory analysis (Lab) • Field parameters (Field) • Observations (Obs) • Water level (Level) (where a suitable structure exists)	• Monthly baseline monitoring prior to mining • Weekly observations and field analysis during active subsidence • Monthly laboratory analysis during active subsidence • Monthly monitoring for two years post mining • If required as a result of assessment of mining impacts	**Field Parameters:** • Temperature • Dissolved Oxygen (DO) • Electrical Conductivity (EC) • pH • ORP **Laboratory analysis:** • pH and EC • Filtered Na, K, Ca, Mg, Cl, Ni, Zn, Fe, Mn, Al, SO4 • Total Fe, Mn, Al • Total Alkalinity • TKN, TP, NH3-N, NOx-N (TON), FRP, TSS, DOC **Observations:** • Iron or salinity staining (e.g. orange or white staining in water or on banks/seeps) • Visual signs of impacts (i.e. cracking, fracturing, vegetation changes, increased erosion, changes in water colour etc) • Inflow, outflow and Water in Pool observations • Impacts determined from comparing photo points taken prior to, during and post mining
	Flow Monitoring **Navigation Creek** NAVS1 (gauge with logger) NAVS2 (proposed) (gauge with logger)	• Gauged flow site	• Daily flow (logger sites)	• Daily flow results • Inspection for potential fracturing for observable loss of surface water flow

GROUNDWATER				
Area 7	**Private Bores** GW108907 GW105376 GW072874 GW102619 GW072196# GW100289# GW106675# GW112381# GW105574# GW107791# GW105531# GW026516# GW108990# GW062945# GW104766# GW105325# (*in consultation with bore owner and if accessible and access is granted*)	• Lab sample • Field parameters • Water levels • Observations	• Where access is available and granted, water level and water quality monitoring at least once before and once after the bore is mined under	**Field Parameters:** • Electrical conductivity (EC) • pH **Laboratory analysis:** • pH and EC • Filtered, Na, K, Ca, Mg, Cl, Ni, Zn, Fe, Mn, Al, SO4 • Total Fe, Mn, Al • Total Alkalinity • TKN, TP, NH3-N, NOx-N (TON), FRP, TSS, DOC **Lab Sample for Gas Releases**: • CH4 • C2H6 • Trace Phenols • Sulphide **Observations:** • Iron or salinity staining (e.g. orange or white staining in water or around borehole) • Visual signs of impacts (i.e. movement around borehole)
	ICHPL Boreholes S2536 S2536A S1913 S2500 S2315 S1954 S1936 S1941 S2157		• Water levels to be logged at least twice daily in the pre-mining baseline, impact and post-mining period • At least one appropriately purged sample pre-mining and post mining, where access permits, tested for the analytes in the next column	

	S2632 S2537 S2538			

Note: Monitoring of sites which are located on private property is undertaken only with the landowner's permission. Where access cannot be secured or safety is of concern, these sites will not be monitored.

[#] Private bores proposed for data logger installation.

Table 12 Appin Area 7 Longwalls 712 to 716 WMP Trigger Action Response Plan

Performance Measure	Potential Impacts	Monitoring sites	Parameters	Monitoring Frequency	Reporting Trigger	Trigger Response
SURFACE WATER QUALITY MONITORING						

Creeks and Tributaries:
 	
No greater subsidence impact or environmental consequences than predicted in the EA and PPR.
	Potential surface water quality impacts in EA and PPR include:
	• minor change in water quality;
	• localised iron staining
		Creeks and Tributaries
		
		Control Site:
		RC1
		MATC_S50
		
		Impact Sites:
		NAV1
		NAV2
		NAV_S50
		NAVC16_S10 (water chemistry site)
		NAV20_S10(water chemistry site)
			Field Parameters:
			• Temperature
			• Dissolved Oxygen (DO)
			• Electrical Conductivity (EC)
			• pH
			• ORP
			Laboratory analysis:
			• pH and EC
			• Filtered, Na, K, Ca, Mg, Cl, Ni, Zn, Fe, Mn, Al, SO4
			• Total Fe, Mn, Al
			• Total Alkalinity
			• TKN, TP, NH3-N, NOx-N (TON), FRP, TSS, DOC
				Monthly baseline monitoring prior to mining
				
				Weekly field analysis during active subsidence
				
				Monthly laboratory analysis during active subsidence
				
				Monthly monitoring for two years post mining If required as a result of assessment of mining impacts
					Level 1*
					Impact monitoring sites when comparing the baseline period to the mining period for that site:
					• At field parameter monitoring sites, mining results in
					  ○ Dissolved Oxygen reduction
					  ○ Electrical Conductivity increase
					  ○ pH variation
					greater than 1 standard deviation but less than 2 standard deviations from **pre-mining mean** (hereafter defined as the period prior to mining within 400m of a monitoring site) for two consecutive months
					
					• At water chemistry monitoring sites, mining results in:
					  ○ Filtered: Na, K, Ca, Mg, Cl, Ni, Zn, Fe, Mn, Al, SO4
					  ○ Total Fe, Mn, Al;
					  ○ Total alkalinity; or
					  ○ TKN, TP, NH3-N, NO_x-N (TON), FRP, TSS, DOC
					Increasing by greater than 1 standard deviation but less than 2 standard deviations from pre-mining mean for two consecutive months
						• Continue monitoring program
						• Report in End of Panel Report
						• Summarise actions and monitoring in Annual Review

Performance Measure	Potential Impacts	Monitoring sites	Parameters	Monitoring Frequency	Reporting Trigger	Trigger Response

					Level 2*
					Impact monitoring sites when comparing the baseline period to the mining period for that site:
					• At field parameter monitoring sites, mining results in
					  ○ Dissolved Oxygen reduction
					  ○ Electrical Conductivity increase
					  ○ pH variation
					  greater than 2 standard deviations from **pre-mining mean** (hereafter defined as the period prior to mining within 400m of a monitoring site) for two consecutive months
					
					• At water chemistry monitoring sites, mining results in:
					  ○ Filtered: Na, K, Ca, Mg, Cl, Ni, Zn, Fe, Mn, Al, SO4
					  ○ Total Fe, Mn, Al;
					  ○ Total alkalinity; or
					  ○ TKN, TP, NH3-N, NO_x-N (TON), FRP, TSS, DOC
					  Increasing by greater than 2 standard deviations from pre-mining mean for two consecutive months
						• *Actions as stated for Level 1*
						• Review monitoring program
						• Notify relevant technical specialists and seek advice on any CMA required
						• Implement agreed CMAs as approved
						
						Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. water quality changes with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts

					Level 3* Impact monitoring sites when comparing the baseline period to the mining period for that site: • Level 2-type reduction in water quality for six consecutive months as a result of mining.	• *Actions as stated for Level 2* • Notify DPHI, DCCEEW-CPHR, DCCEEW-Water Group, and relevant resource managers and technical specialists and seek advice on any CMA required • Invite stakeholders for site visit • Develop site CMA (subject to stakeholder feedback) • Completion of works following approvals, including monitoring and reporting on success • Review the TARP and Management Plan in consultation with key stakeholders *Note: CMAs are to be proposed based on appropriate management of environmental and*

Performance Measure	Potential Impacts	Monitoring sites	Parameters	Monitoring Frequency	Reporting Trigger	Trigger Response
						other consequences of mining impacts i.e. water quality changes with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts
					Performance Indicator Mining results in impacts greater than Level 3 reduction in water quality for 12 consecutive months	• *Actions stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide environmental offset if CMAs are unsuccessful
SURFACE WATER FLOW MONITORING						
Creeks and Tributaries: No greater subsidence impact or environmental consequences than predicted in the EA and PPR.	Potential surface water quality impacts in EA and PPR include: • Creek bed fracturing leading to loss of flow or pool water loss	**Creeks and Tributaries:** NAVS1 NAVS2 NAV1 NAV2	**Gauged flow site:** • Daily flow **Observations:** • Visual observation of inflow and outflow	**Gauged flow site:** Daily flow (logger sites) **Observations:** Monthly/weekly inspection	***Level 1**** Mining results in: • Change in percentage of cease to flow days between pre- and post-mining, from the date of closest approach after the passage of the longwall, at the logger sites of ≥+5%, recorded over a period of 6 months (determined as part of End of Panel analysis)	• Continue monitoring program • Submit an impact report to DPHI, DCCEEW-CPHR and DCCEEW–Water Group and other relevant stakeholders • Report in the End of Panel Report and Annual Review • Summarise actions and monitoring in Annual Review
					Level 2* Mining results in: • Change in percentage of cease to flow days between pre- and post-mining, from the date of closest approach after the passage of the longwall, at the logger sites of ≥+10%, recorded over a period of 6 months (determined as part of End of Panel analysis)	*Actions as stated for Level 1* • Review monitoring program • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved
					Level 3* Mining results in: • Change in percentage of cease to flow days between pre- and post-mining, from the date of closest approach after the passage of the longwall, at the logger sites of ≥+20%, recorded over a period of 6 months (determined as part of End of Panel analysis)	*Actions stated for Level 2* • Notify DPHI, DCCEEW-CPHR, DCCEEW-Water Group and relevant resource managers and technical specialists and seek advice on any CMA required • Invite stakeholders for site visit • Develop site CMA (subject to stakeholder feedback)

Performance Measure	Potential Impacts	Monitoring sites	Parameters	Monitoring Frequency	Reporting Trigger	Trigger Response
						• Completion of works following approvals, including monitoring and reporting on success • Review the TARP and Management Plan in consultation with key stakeholders
					Performance Indicator Mining results in total loss of surface flow in all sections of a creek or tributary	*Actions stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide environmental offset if CMAs are unsuccessful
SURFACE WATER OBSERVATIONAL MONITORING (Stream Geomorphic, Aesthetic and Riparian Health aspects)						
Creeks and Tributaries No greater subsidence impact or environmental consequences than predicted in the EA and PPR	Fracturing of the beds of some minor streams & diversion of flows Erosion / sedimentation Iron or salinity staining Vegetation changes Visible changes in water quality	**Photo monitoring points:** NAV1 NAV2 NAV_S50 NAVC16_S10 NAV20_S10 MATC_S50 (Lab, Field, Obs) **General observations:** Where access is permitted under an existing access agreement with a private property owner, or, observations are achievable from publicly accessible	**Observations:** • Erosion or sedimentation when compared to baselines. • Signs of impact (e.g. soil cracking in steam banks or beds, riparian vegetation changes, increased erosion in steam banks or beds, changes in water colour). • Impacts determined from comparing photo points taken prior to, during and post mining.	**Photo monitoring points:** • Monthly baseline monitoring prior to mining • Weekly observations and field analysis during active subsidence • Monthly monitoring for two years post mining **General observations:** • Annually where access permits. **LiDAR data collection:** • Baseline survey data collected prior to	***Level 1**** Mining results in: • Crack or fracture up to 100mm width at its widest point with no observable loss of surface water or erosion • Crack or fracture up to 10m length with no observable loss of surface water or erosion • Erosion in a localised area (not associated with cracking or fracturing) which would be expected to naturally stabilise without CMA and within the period of monitoring • Observable release of strata gas at the surface • Localised (<50m total length) observable iron or salinity staining at the monitoring site • Minor (<10m^2 area) localised dieback of riparian vegetation • Erosion within Navigation Creek or Matahil Creek (compared to its pre-mining length) is **2%** of its respective total watercourse length within the LW712-716 600m study area.	• Continue monitoring program • Submit an impact report to DPHI, DCCEEW-CPHR and DCCEEW–Water Group and other relevant stakeholders • Report in the End of Panel Report and Annual Review • Summarise actions and monitoring in Annual Review
					Level 2* Mining results in: • Crack or fracture between 100 and 300mm width at its widest point or any fracture which results in localised observable loss of surface water or erosion • Crack or fracture between 10 and 50m length	*Actions as stated for Level 1* • Review monitoring program • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved

Performance Measure	Potential Impacts	Monitoring sites	Parameters	Monitoring Frequency	Reporting Trigger	Trigger Response
		thoroughfare for Navigation Creek and Tributaries of Navigation Creek and Matahil Creek. **LiDAR observations:** Comparison of pre and post mining LiDAR monitoring results at End of Panel (EoP) for inclusion in EoP report.	• Iron or salinity staining (e.g. orange or white staining in water or on banks/seeps) • Water cloudiness • Evidence of springs. **LiDAR observations:** Raw ground strike LiDAR data will be contoured with a 0.25 m interval after the completion of subsidence at each longwall to provide a new (subsided) baseline surface dataset. Repeat LiDAR datasets and surface modelling will be completed to assess for new or increases in existing erosion. The maximum area/length and depth of any erosion identified by LiDAR will be measured by standard survey methods where	Longwall 712 extraction and repeat LiDAR surveys at EoP	• Soil surface crack that causes erosion that is likely to stabilise within the monitoring period without intervention • >10m^2 area but less than 50m^2 dieback of riparian vegetation • >50m but <100m total length of observable iron or salinity staining at the monitoring site • Erosion within Navigation Creek or Matahil Creek (compared to its pre-mining length) is **3%** of its respective total watercourse length within the LW712-716 600m study area.	
					Level 3 Mining results in: • Crack or fracture over 300mm width at its widest point • Crack or fracture over 50m length • Fracturing observed in the bedrock base of any significant permanent pool which results in observable loss of surface water • Soil surface crack that causes erosion that is unlikely to stabilise within the monitoring period without intervention • Gas release results in vegetation dieback, mortality or loss of aquatic habitat • > 50m^2 area of riparian vegetation dieback in a 1km creek section • >100m total length of observable iron or salinity staining at the monitoring site • Erosion within Navigation Creek or Matahil Creek (compared to its pre-mining length) is 4**%** of its respective total watercourse length within the LW712-716 600m study area.	*Actions stated for Level 2* • Notify DPHI, DCCEEW-CPHR, DCCEEW-Water Group and relevant resource managers and technical specialists and seek advice on any CMA required • Invite stakeholders for site visit • Develop site CMA (subject to stakeholder feedback) • Completion of works following approvals, including monitoring and reporting on success • Review the TARP and Management Plan in consultation with key stakeholders
					Performance Indicator Mining Results in watercourse impacts extending beyond the local area and/or remediation measures implemented are unsuccessful	*Actions stated for Level 3* • Investigate reasons for the exceedance • Update future predictions based on the outcomes of the investigation • Provide environmental offset if CMAs are unsuccessful

Performance Measure	Potential Impacts	Monitoring sites	Parameters	Monitoring Frequency	Reporting Trigger	Trigger Response
			access is permitted.			
PRIVATE BOREHOLE GROUNDWATER LEVEL MONITORING						
No performance measure relevant. <u>TARP Objective:</u> This TARP defines measures to manage potential impacts on groundwater level, and supply. Details actions required to be implemented in response to trigger level conditions being met.	*Potential groundwater drawdown as outlined within the EA and PPR.*	Private Bores GW108907 GW105376 GW072874 GW102619 GW072196 GW100289 GW106675 GW112381 GW105574 GW107791 GW105531 GW026516 GW108990 GW062945 GW104766 GW105325 (**in consultation with bore owner and if accessible and access is granted**)	**Water Level** **Field Parameters:** • Electrical conductivity • pH **Laboratory analysis:** • pH and EC • Filtered Na, K, Ca, Mg, Cl, Ni, Zn, Fe, Mn, Al, SO4 • Total Fe, Mn, Al • Total Alkalinity • TKN, TP, NH3-N, Nox-N (TON), FRP, TSS, DOC • Trace Phenols • Sulphide **Observations:**	**Private Bores:** Where access is available and granted, water level and water quality monitoring at least once before and once after the bore is mined beneath.	***Level 1**** Mining results in: • Reduction in water level between pre- and post-mining observations greater than Level 1 trigger recommendations as presented in Section 7.5 of HGEO 2025a	• Continue monitoring program • Submit an impact report to DPHI, DCCEEW-CPHR and DCCEEW–Water Group and other relevant stakeholders • Report in the End of Panel Report and Annual Review • Summarise actions and monitoring in Annual Review
					Level 2* Mining results in: • Reduction in water level between pre- and post-mining observations greater than Level 2 trigger recommendations as presented in Section 7.5 of HGEO 2025a	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*

Performance Measure	Potential Impacts	Monitoring sites	Parameters	Monitoring Frequency	Reporting Trigger	Trigger Response
			Iron or salinity (e.g. orange or white staining in water or around borehole)		***Level 3**** Mining results in: • Reduction in water level between pre- and post-mining observations greater than Level 3 trigger recommendations as presented in Section 7.5 of HGEO 2025a	**Private Bores** • Actions as stated for Level 2 • Notify DPHI, DCCEEW-CPHR, DCCEEW–Water Group, and relevant resource managers and technical specialists and seek advice on any CMA required • Invite stakeholders for site visit • Develop site CMA (subject to stakeholder feedback). This may include: - Make area safe - Any actions agreed to in the Property Subsidence Management Plan - Provisions of alternate water supply where this has been impacted by mining • Completion of works following approvals (where applicable), including monitoring and reporting on success • Review the Groundwater Model, TARP and Management Plan in consultation with key stakeholders *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*
ICHPL BOREHOLE GROUNDWATER LEVEL AND QUALITY MONITORING						
No performance measure relevant. <u>TARP Objective:</u> This TARP defines measures to	*Potential groundwater drawdown as outlined within the EA and PPR.*	ICHPL Boreholes with pumps: S2536 S2536A S2538 S2537 S2632 ICHPL Boreholes with VWP:	**Water Level and/or Pressure** **Field Parameters:** • Electrical conductivity • pH	**ICHPL Bores:** Water levels to be logged at least twice daily in the pre-mining baseline, impact and post-mining period.	***Level 1**** Mining results in: • Reduction in water level between pre- and post-mining observations greater than Level 1 trigger recommendations as presented in Section 7.5 of HGEO 2025a • pH outside of the 5th and 95th percentile of baseline data at bores S2536A (Hawkesbury Sandstone) and S2632 (Wianamatta Shale Group)	• Continue monitoring program • Submit an impact report to DPHI, DCCEEW-CPHR and DCCEEW–Water Group and other relevant stakeholders • Report in the End of Panel Report and Annual Review • Summarise actions and monitoring in Annual Review

Performance Measure	Potential Impacts	Monitoring sites	Parameters	Monitoring Frequency	Reporting Trigger	Trigger Response
manage potential impacts on groundwater level and quality, and includes actions required to be implemented in response to trigger level conditions being met. Note: all ICHPL bores will be maintained in a safe and serviceable state. Appropriate remedial actions will be undertaken where necessary.		S2536 S2536A S1913 S2500 S2315 S1954 S1936 S1941 S2157 S2632 S2537 S2538	**Laboratory analysis:** • pH and EC • Filtered Na, K, Ca, Mg, Cl, Ni, Zn, Fe, Mn, Al, SO4 • Total Fe, Mn, Al • Total Alkalinity • TKN, TP, NH3-N, Nox-N (TON), FRP, TSS, DOC **Lab Sample for Gas Releases:** • CH4 • C2H6 • Trace Phenols • Sulphide **Observations:** Iron or salinity (e.g. orange or white staining in water or around borehole)	**ICHPL Bores with sampling pumps:** At least four samples pre-mining and annual sampling post mining (for 5 years following completion of mining within 600m of the borehole) and/or one sampling event at the completion of each longwall within 600m of the borehole, whichever occurs first, where access permits for testing. Groundwater samples will be collected following appropriate purging and/or stabilisation (i.e. consecutive readings within acceptable tolerance) of bores.	• EC outside of 95th percentile of baseline data at bores S2536A (Hawkesbury Sandstone) and S2632 (Wianamatta Shale Group)	
					Level 2* Mining results in: • Reduction in water level between pre- and post-mining observations greater than Level 2 trigger recommendations as presented in Section 7.5 of HGEO 2025a • Two consecutive readings for pH outside of the 5th and 95th percentile of baseline data at bores, S2536A (Hawkesbury Sandstone) and S2632 (Wianamatta Shale Group) • Two consecutive readings for EC outside of 95th percentile of baseline data at bores S2536A (Hawkesbury Sandstone) and S2632 (Wianamatta Shale Group)	• *Actions as stated for Level 1* • Review monitoring frequency • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*
					Level 3* Mining results in: • reduction in water level between pre- and post-mining observations greater than Level 3 trigger recommendations as presented in Section 7.5 of HGEO 2025a • Three consecutive pH readings outside of the 5th and 95th percentile of baseline data at S2536A (Hawkesbury Sandstone) and S2632 (Wianamatta Shale Group) • Three consecutive EC readings outside of 95th percentile of baseline data at bores S2536A (Hawkesbury Sandstone) and S2632 (Wianamatta Shale Group)	• Actions as stated for Level 2 • Notify DPHI, DCCEEW-CPHR and DCCEEW-Water Group and relevant resource managers and technical specialists and seek advice on any CMA required • Invite stakeholders for site visit develop site CMA (subject to stakeholder feedback). • Review the Groundwater Model, TARP and Management Plan in consultation with key stakeholders *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*

Performance Measure	Potential Impacts	Monitoring sites	Parameters	Monitoring Frequency	Reporting Trigger	Trigger Response
BOREHOLE SERVICABILITY, GAS AND GROUNDWATER RELEASE						

No performance measure relevant.
 	
<u>TARP Objective:</u>
This TARP defines measures to manage potential impacts due to surficial gas and groundwater releases, and includes actions required to be implemented in response to exceedances of defined trigger levels.
	Potential gas and groundwater releases.
	
	Potential impacts may include:
	• olfactory odours,
	• reduction in surface water quality
	• soil erosion
	• Air quality impacts / risks
		Surface footprint above and adjacent to active mining area (400m from current LW position) and all boreholes within the Study Area.	**Monitoring only when groundwater or gas releases are identified.**
			
			Gas Sample for Lab Analysis:
			• range of analytes including methane and other hydrocarbons
			
			Presence of odour
			
			Observations (water):
			• Turbidity
			• Colour
			
			Field Parameters (water):
			• EC, pH, DO, ORP, Temp.
			
			Lab Sample for Water Releases:
			• pH and EC
			• Filtered Na, K, Ca, Mg, Cl, Ni, Zn, Fe, Mn, Al, SO4
			• Total Fe, Mn, Al
			• Total Alkalinity
				Watercourses:
				Monitoring of creeks and tributaries within the mining area monthly prior to mining, weekly during mining and monthly during the post-mining period (for 2 years following the nearest passing of a longwall)
				
				Private Bores:
				At least one inspection pre-mining and post mining, where access permits.
				
				ICHPL Bores:
				At least one inspection pre-mining and post mining, where access permits.
					Level 1*
					Mining results in
					• gas and/or groundwater release which does not present an environmental or safety hazard and releases decline naturally (<2 months) following depressurisation with no long-term impact predicted or observed
					• Private bores being unserviceable or damaged where remedial action can be implemented within 12 months
						• Routine observations (frequency as determined based on case by case risk) during any identified release
						• Submit an Impact Report to DPHI, NSW EPA, DCCEEW - CPHR, DCCEEW - Water, and other relevant stakeholders
						• Report in the End of Panel Report and Annual Review
						• Summarise actions and monitoring in Annual Review and End of Panel reporting.
						• Manage safety implications with nearby residents
						• Notify relevant technical specialists and seek advice on any CMA required
						• Implement agreed CMAs as approved this may include:
						  • Any actions agreed to in the Property Subsidence Management Plan
						  • Provisions of alternate water supply where this has been impacted by mining
						• Where bores are located on privately owned land, seek establishment of a land access agreement in negotiation with the landowner.

					Level 2* Mining results in: • gas and/or groundwater releases exceeding Level 1 trigger, but able to be made safe through remedial action. No long-term environmental or public safety impacts predicted or observed and/or releases do not decline naturally within 2 months and/or requires intervention (such as, remedial action to seal nearby bores) • Private bores being unserviceable or damaged where remedial action can be implemented within greater than 12 months but less than 36 months	• *Actions as stated for Level 1* • Notify relevant technical specialists and seek advice on any CMA required • Implement agreed CMAs as approved *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*

Performance Measure	Potential Impacts	Monitoring sites	Parameters	Monitoring Frequency	Reporting Trigger	Trigger Response
			• TKN, TP, NH3-N, Nox-N (TON), FRP, TSS, DOC **Where Gas Release Observed in water:** • CH4 • C2H6 • Trace Phenols • Sulphide **Observations:** • Visual signs of impacts (i.e. soil movement around borehole)		**Level 3** Mining results in: • gas and/or groundwater releases unable to be made safe with remedial action, requires emergency services to manage impacts (i.e. establishing public exclusion zones) • Predicted long-term environmental or public safety impacts requiring ongoing management and extensive remedial works • Private bores are unserviceable or damaged where remedial action cannot be implemented	• Actions as stated for Level 2 • Notify CPHR, DPHI - Water, and relevant resource managers and technical specialists and seek advice on any CMA required • Invite stakeholders for site visit (if safely achievable) • Develop site CMA (subject to stakeholder feedback). This may include: - Make area safe - Any actions agreed to in the Property Subsidence Management Plan - Provisions of alternate accommodation where this has been impacted by mining • Completion of works following approvals, including monitoring and reporting on success *Note: CMAs are to be proposed based on appropriate management of environmental and other consequences of mining impacts i.e. cracking at the surface with insignificant consequences may not require specific CMAs other than ongoing monitoring to confirm there are no ongoing impacts*

* These may be revised in consultation with DPHI and other key stakeholders following analysis of natural variability within the pre-mining baseline data.

Note: The NSW Development Coordination Authority (DCA) was established on 1 July 2026 and centralises several NSW Agencies in responses to development applications and post-approval matters. Where agencies that are included within DCA have been listed as stakeholders (or are required to be notified under a TARP trigger response) notifications and impact reports will be provided to the DCA.

8 CONTINGENCY RESPONSE PLAN

Contingency and emergency response options are available and will be implemented if it is demonstrated that environmental consequences are greater than those predicted or authorised by the BSO Consent. This would generally involve:

- Capture photographic record.
- Notify relevant stakeholders soon as practicable.
- Notify relevant agencies and specialists soon as practicable.
- Offer site visits with stakeholders.
- Contract specialists to investigate and report on changes identified.
- Provide incident report to relevant agencies.
- Establish weekly monitoring frequency where appropriate until stabilised.
- Updates from specialists on investigation process.
- Inform relevant agencies and stakeholders of results of investigation.
- Develop site CMA in consultation with key stakeholders if required, (pending stakeholder availability) and seek approvals where necessary.
- Implement CMA as agreed with stakeholders following approvals.
- Conduct initial follow up monitoring and reporting of CMA completion.
- Review Management Plan.
- Report in regular reporting and Annual Review.

ICHPL will consult with appropriate specialists and relevant agencies in order to devise an appropriate response in respect to any identified exceedance.

The development and implementation of contingency measures will be specifically designed to address the circumstances of the exceedance and assessment of environmental consequences.

If the contingency measures implemented by ICHPL fail to remediate the impact or the Secretary determines that it is not reasonable or feasible to remediate the impact, ICHPL will provide a suitable compensatory measure or offset for the impact to the satisfaction of the Secretary in accordance with the BSO Approval Condition 2, Schedule 3 or Condition 14, Schedule 4.

9 COMPLAINTS AND COMPLIANCE MANAGEMENT

9.1 Incidents

An incident is defined in the BSO Approval as "An occurrence or set of circumstances that causes, or threatens to cause, material harm to the environment, and as a consequence of that environmental harm, may cause harm to the safety of human beings, and which may or may not be or cause a non-compliance".

The reporting of incidents will be conducted in accordance with Condition 7, Schedule 6 of the BSO Approval. ICHPL will notify the Secretary of the DPHI via the NSW Planning Portal and any other relevant agencies of any incident associated with the BSO within 24 hours after ICHPL becomes aware of the incident. Within seven days of the date of the incident, ICHPL will provide the Secretary of the DPHI and relevant agencies with a detailed report on the incident.

An Incident Report will be prepared in accordance with Appendix 7 (3) of the BSO Approval and will:

- identify how the incident was detected;
- identify when ICHPL became aware of the incident;
- identify any actual or potential non-compliance with conditions of consent;
- details on the nature of the incident (including survey results, photographs and date of the incident);
- results of investigation(s) to identify/evaluate the contributing factors to and the cause of the incident;
- proposed course of action (including proposed timeline for implementation of corrective and preventative actions to address the incident and prevent recurrence) and development of contingency measures;
- details of any communication with other stakeholders regarding the incident; and
- relevant ICHPL contact details to obtain further information on the incident.

9.2 Complaints and Dispute Resolution

ICHPL has a readily accessible contact point through a 24-hour toll-free Community Call Line (1800 102 210) and email address (community@gm3.au). The number is displayed on the GM^3 website, prominently on ICHPL Projects and Mine sites in a position visible by the public as well as on publications, letters and other correspondence provided to the local community. The call line is for all complaints and general enquiries regarding environmental or community issues associated with ICHPL operations.

Community complaints and enquiries may also be received in person by any employee of ICHPL, with details to be immediately shared with the Community Team for investigation. All complaints

received in relation to Dendrobium Mine will be managed in accordance with the Handling Community Complaints, Enquiries and Disputes Procedure.

Upon receipt of a community complaint, preliminary investigations will commence as soon as practicable to determine the likely cause of the complaint. An initial response will be provided to the complainant within 24 hours of the complaint being made, with a follow up response being provided as soon as practicable once a more detailed investigation is complete.

A summary of all complaints received during the reporting year will be provided as part of the Annual Review. A log of complaints is also maintained on the GM^3 website.

9.3 Non-Compliance, Corrective Action and Preventative Action

Non-compliances will be notified and reported in accordance with Condition 7A of Schedule 6 of the BSO Approval. ICHPL will notify the DPHI in writing via the NSW Planning Portal and will include the following information:

- the development including the development application number and name;
- the condition of consent that the development is non-compliant with and why it does not comply;
- the reasons for the non-compliance (if known);
- what actions have been undertaken or will be undertaken to address the non-compliance.

The BSO Approval states that "a non-compliance which has been notified as an incident does not need to also be notified as a non-compliance.

10 PLAN ADMINISTRATION

This WMP will be administered in accordance with the requirements of the Appin Mine Environmental Management Strategy (EMS) and the BSO Approval Conditions. A summary of the administrative requirements is provided below.

10.1 Roles and Responsibilities

Statutory obligations applicable to this Plan are identified and managed via an online compliance management system (TICKIT).

The overall responsibility for the implementation of this Plan resides with the Manager Approvals who is the Plan's authorising officer.

Parties responsible for environmental management in AA7 and the implementation of the Plan include:

Manager Approvals

- Ensure that the requisite personnel and equipment are provided to enable this Plan to be implemented effectively.
- Authorise the Plan and any amendments thereto.

Principal Approvals

- Document any changes to the Plan, recognising the potential for those changes to affect other aspects of the Plan.
- Provide regular updates to ICHPL on the results of the Plan.
- Arrange information forums for key stakeholders as required.
- Prepare any report in accordance with the Plan.
- Maintain records required by the Plan.
- Organise and participate in assessment meetings called to review mining impacts.
- Within 24 hours, respond to any queries or complaints made by members of the public in relation to aspects of this Plan.
- Organise audits and reviews of the Plan.
- Address any identified non-conformances, assess improvement ideas submitted and implement if considered appropriate.
- Arrange for the implementation of any agreed actions, responses or remedial measures.
- Check surveys required by this Plan are conducted and record details of instances where circumstances prevent these from taking place.

Coordinator Environment

- Instruct suitable person(s) in the required standards for inspections, recording and reporting and be satisfied that these standards are maintained.
- Investigate significant subsidence impacts.
- Identify and report any non-conformances with the Plan.
- Participate in any other assessment meetings called to review subsidence impacts in the area affected by mining.

Survey Coordinator

- Collate survey data and present in an acceptable form for review at assessment meetings.
- Bring to the attention of the Principal Approvals any findings indicating an immediate response may be warranted.
- Bring to the attention of the Principal Approvals any non-conformances identified with the Plan provisions or ideas aimed at improving the Plan.

Technical Experts

- Conduct the roles assigned to them in a competent and timely manner to the satisfaction of the Principal Approvals and formally provide expert opinion as requested.

Person(s) Performing Inspections

- Formally bring to the attention of the Coordinator Environment any nonconformances identified with the Plan, or ideas aimed at improving the Plan.
- Conduct inspections in a safe manner.

10.2 Resources Required

The Manager Approvals provides resources sufficient to support this Plan.

Equipment may be needed for this Plan. Where this equipment is of a specialised nature, it will be provided by the supplier of the relevant service. All equipment is to be appropriately maintained, calibrated and serviced as required in operation manuals.

It is the responsibility of the Manager Approvals to ensure that personnel and equipment are provided as required to allow the provisions of this Plan to be implemented.

10.3 Training

All staff and contractors working on ICHPL sites are required to complete the ICHPL training program which includes:

- An initial site induction (including all relevant aspects of heritage, environment, safety and community).

- Safe Work Methods Statements and Job Safety Analyses, Toolbox Talks and Preshift communications.
- On-going job specific training and re-training (where required).

All training records are maintained by the ICHPL Training Department.

It is the responsibility of the Manager Approvals to ensure that all persons and organisations having responsibilities under this Plan are trained and understand their responsibilities.

The person(s) performing regular inspections will be under the supervision of the Coordinator Environment and be trained in observation and reporting. The Coordinator Environment will be satisfied that the person(s) performing the inspections are capable of meeting and maintaining this standard.

10.4 Review and Update

In accordance with Condition 5 of Schedule 6 of the BSO Approval, the WMP will be reviewed, and if necessary revised, within three months, of:

- the submission of an Annual Review;
- the submission of an incident report;
- the submission of an Independent Environmental Audit (IEA) report; or
- any modification to the conditions of the BSO Approval (unless the conditions require otherwise).

If significant deficiencies in this WMP are identified in the interim period, the Plan will be modified as required. This process has been designed to ensure that documentation continues to meet current requirements, including changes in technology and operational practice, and expectations of stakeholders.

11 REFERENCES

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12 APPENDICES

12.1 Appendix A – Appin Longwalls 712 to 716 Groundwater Impact Assessment (HGEO2025a)

GM3 – Illawarra Coal Holdings

Appin Mine Extraction Plan

Groundwater Assessment
Longwall panels 712 to 716



HGEO Pty Ltd

Date: 27 April 2026
Project number: J21607

Report: D25299 RevC

Hgeo
hgeo.com.au

DOCUMENT REGISTER

Revision	Description	Date	Comments
A	1st Draft	25/11/2025	MS word
B	Final	28/11/2025	Final pdf document
C	Revised Final	27/4/2026	Pdf document

FILE

Https://hgeocomau.sharepoint.com/sites/HGEO/Shared Documents/Files/Client_Site/Appin_A7/Projects/J21607_Appin_LW712_716_Groundwater/D25299_Appin_Mine_Extraction_Plan_Groundwater_Assessment_RevC_v14.docx

QUALITY CONTROL

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ABBREVIATIONS

Abbreviation/Term	Meaning
ACCO	America Creek Coal Seam
AHD	Australian height datum
ANZG	The Australian and New Zealand Guidelines for Fresh and Marine Water Quality
BACO	Balgownie Coal Seam
BGSS	Bulgo Sandstone
BHCL	Bald Hill Claystone
BLR	Basic landholder rights
BUCO	Bulli Coal Seam
BSO	Bulli Seam Operations
CCSS	Coalcliff Sandstone
CHCO	Cape Horn Coal Seam
DGVs	Default guideline values
DO	Dissolved oxygen
EA	Environmental Assessment
EC	Electrical conductivity
EP	Extraction Plan
EV	Environmental value
GM3	Gear M Illawarra Met Coal Pty Ltd
HBSS	Hawkesbury Sandstone
IFOT	Injection fall-off test
IPD	Impact pathway diagram
IPM	Incremental profile method
IESC	Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development
KFH	Key fish habitat
LDSS	Loddon Sandstone
LW	Longwall
ML	Megalitres
NRAR	Natural Resources Access Regulator
ORP	Oxidation reduction potential
PEL	Petroleum Exploration Licence
PPL	Petroleum Production Lease

Abbreviation/Term	Meaning
PPR	Preferred Project Report
RMZ	Risk Management Zone
SBSS	Scarborough Sandstone
SMP	Subsidence Management Plan
SPCL	Stanwell Park Claystone
TGCO	Tongarra Coal Seam
WGSH	Wianamatta Group shales
WWCO	Wongawilli Coal Seam

SUMMARY

Illawarra Coal Holdings Pty Limited (ICHPL), a wholly owned subsidiary of Gear M Illawarra Met Coal Pty Ltd (GM[3]), operates Appin Mine, a longwall coal mine in the Southern Coalfield of New South Wales. ICHPL is preparing an Extraction Plan (EP) Application for Longwalls 712 to 716 (LW712 to LW716) in the Bulli Seam. ICHPL has engaged HGEO to conduct a groundwater impact assessment for the Project involving review of available data to develop a conceptual hydrogeological model and characterise the impacts of mining to date, and numerical groundwater flow modelling to predict impacts associated with the mining of LW712 to LW716.

Longwall mining at Appin Mine has been ongoing for more than 40 years and the impacts are well understood. Longwall mining results in fracturing and deformation of the overburden, providing pathways for the vertical movement of water in the subsurface. Extensive monitoring of surface water and groundwater systems at Appin has shown limited depressurisation of the Hawkesbury Sandstone (HBSS) and Bulgo Sandstone, the main groundwater sources in the region, with no impacts identified to surface water systems. The depths of cover above LW712 to LW716 are greater than or equal to the depths of cover for previous longwalls, and therefore the subsidence impacts and associated impacts on groundwater are expected to be less than or equal to the impacts that have been observed during the mining of previous longwalls at Appin.

The HBSS is the main groundwater source in the Project area and is widely accessed for groundwater supply. The Narrabeen Group underlies the HBSS and is a sequence of interbedded sandstones and low permeability claystones that act as aquitards and limit vertical conductivity between the Bulli Seam and HBSS. The main water bearing unit in the Narrabeen Group is the confined Bulgo Sandstone which produces lower bore yields and poorer water quality than the HBSS. Groundwater flow is generally in a northerly direction, with some influence from mining observed in the lower part of the sequence. There are no major geological structures (faults) intersecting the proposed longwalls and no indication of higher inflows during mining through in-seam zones of geological structure based on mine water balance data and observations from previous longwalls.

Potential receptors include: 221 registered bores within 10 km of the Project, 195 of which access the HBSS; the Nepean River, Cataract River, and Georges River which are gaining streams and receive baseflow from the HBSS where they are incised; and high priority groundwater dependent ecosystems (GDEs) listed in the water sharing plan including Cumberland Red Gum Riverflat Forest, Cumberland Bangalay x Blue Gum Riverflat Forest, and Sydney Hinterland Red Gum Riverflat Forest.

A numerical groundwater flow model was developed using MODFLOW 6 to predict impacts associated with the mining of LW712 to LW716. The model was based on previous models developed for Appin Mine with some improvements. The model extends approximately 42 km from west to east and 35 km from north to south, covering an area of 1,316 km^2. The model includes 17 layers, simulating extraction from the Bulli Seam and potential impacts in the overlying hydrostratigraphy. Fracturing above the longwalls was simulated by varying hydraulic parameters over longwall panels with initial heights of fracturing informed by the empirical models of Ditton and Merrick (2014) and Tammetta (2013). Surface fracturing was simulated in the model by adopting enhanced horizontal and vertical conductivity in the model. History matching was carried out using PEST++ to match observed groundwater levels at Appin Mine.

Three model scenarios were used to simulate the mining of LW712 to LW716 and assess impacts to groundwater, including cumulative impacts. Forecast groundwater drawdown in the lower Hawkesbury

Sandstone System (HBSS) is expected to range from negligible to approximately 17 m directly above the proposed longwalls, with drawdown of 2 m or more extending up to about 430 m from the extraction areas. These forecasts are consistent with the range of responses observed in previously mined areas.

Model results indicate that six private water supply bores may experience more than 2 m of cumulative depressurisation (the threshold applied under the NSW Aquifer Interference Policy), though the incremental effect attributable specifically to Longwalls 712–716 is minor, with a maximum of 0.48 m. Cumulative drawdown exceeding 10 % of natural annual variability is possible at three high-priority GDE sites listed in the Water Sharing Plan. This impact is driven by historical mining, with negligible additional drawdown predicted for the Project. Changes in baseflow to watercourses are forecast to be negligible or very minor for both incremental and cumulative effects during 2026–2035, including the Nepean River which is located more than 2.5 km from the Project.

The rate of groundwater flow into the mine workings is predicted to remain relatively stable during extraction of Longwalls 712–716, within the range 1.4 to 2.8 ML/day (510 to 1,020 ML/year). Practically all of this inflow (99.9%) will be derived from the Sydney Basin Nepean Groundwater Source, with less than 1 ML/year representing induced flow from the adjacent Sydney Basin Central Groundwater Source.

Fracturing of the overburden due to longwall subsidence may result in damage to water supply bores or mobilise methane and other formation gases which may accumulate within bores. Near-surface fracturing may result in minor changes in groundwater quality, including iron staining and changes in colour and odour.

Monitoring of groundwater pressures and quality to verify predicted impacts is recommended in accordance with the Extraction Plan – Water Management Plan. Monitoring results will be compared to assessment criteria developed based on model predictions and baseline conditions. The recommended network includes seven multi-level vibrating wire piezometers (VWPs) that monitor water pressure every 6 to 12 hours and automatically transmit data, providing for early identification of adverse impacts. The network also includes five locations where groundwater pressures are measured, and samples can be collected for water quality analysis. Following a landholder bore survey, monitoring of private water supply bores will be conducted to assess any impacts to bores.

1. Introduction

Appin Mine is an underground mine located approximately 25 kilometres (km) north-west of Wollongong near the township of Douglas Park (Figure 1). The mine extracts hard coking coal for steel production and is owned and operated by Illawarra Coal Holdings Pty Limited (ICHPL), a wholly owned subsidiary of Gear M Illawarra Met Coal Pty Ltd (GM3). Mining operations are undertaken in accordance with Project Approval 08_0150 for the Bulli Seam Operations (BSO), granted on 22 December 2011 and subsequently modified in April 2015 (Mod 1), October 2016 (Mod 2), April 2022 (Mod 3), August 2024 (Mod 5), and October 2024 (Mod 6). Appin Mine has an approved production capacity of up to 10.5 million tonnes per annum of Run of Mine coal until 2041. ICHPL is currently extracting Longwall 711 in Appin Area 7 (Figure 2).

BSO Approval Condition 5 requires that an Extraction Plan (EP) is prepared prior to commencement of secondary extraction. An EP is required to outline the proposed management, mitigation, monitoring, and reporting of potential impacts from the secondary extraction of approved longwalls at Appin Mine. ICHPL are currently seeking EP approval for Longwalls 712 to 716 (LW712 to LW716, the Project) (Figure 2), which are a continuation of the current longwall series in Area 7.

Heritage Computing (2009) conducted the groundwater impact assessment for the approved operations relevant to the Project. HGEO was engaged by ICHPL to complete a technical review of the groundwater impacts for the Project (LW712 to LW716). This report presents the latest groundwater modelling methodology and results, a discussion on the impact predictions for the Project compared to the predictions by Heritage Computing (2009), and recommendations on management, mitigation, and monitoring strategies.

1.1 Appin Mine

Appin Mine is a longwall mine that extracts coal from the Bulli Seam within the Permian aged Illawarra Coal Measures. Mining is currently occurring in Areas 7 and 9. Historically mining at Appin Mine has also occurred at Tower Colliery, Appin Area 1, Area 2, Area 3, and Area 4, and West Cliff Mine (Figure 1). A summary of mining at Appin Mine is provided in Table 1.

Table 1: Summary of mining at Appin Mine

Mine Area	Longwall panels	Period of mining	Status
Tower	1 – 20	1978 – 2002	Historic mining
Appin Area 1	1 – 12	1969 – 1986	Currently used for underground mine water storage, transferred from current mining areas
Appin Area 2	12 – 29	1986 – 1997	Historic mining
Appin Area 3	301 – 302	1998 – 2007	Historic mining
Appin Area 4	401 – 408	1998 – 2007	Currently used for underground mine water storage, transferred from current mining areas
West Cliff Area 5	1 – 138	1983 – 2016	Historic mining, approved to 2041
Appin Area 7	701 - 711	2007 – Present	Active mining, approved to 2041
Appin Area 9	901 – 905	2016 – 2023	Historic mining, approved to 2041

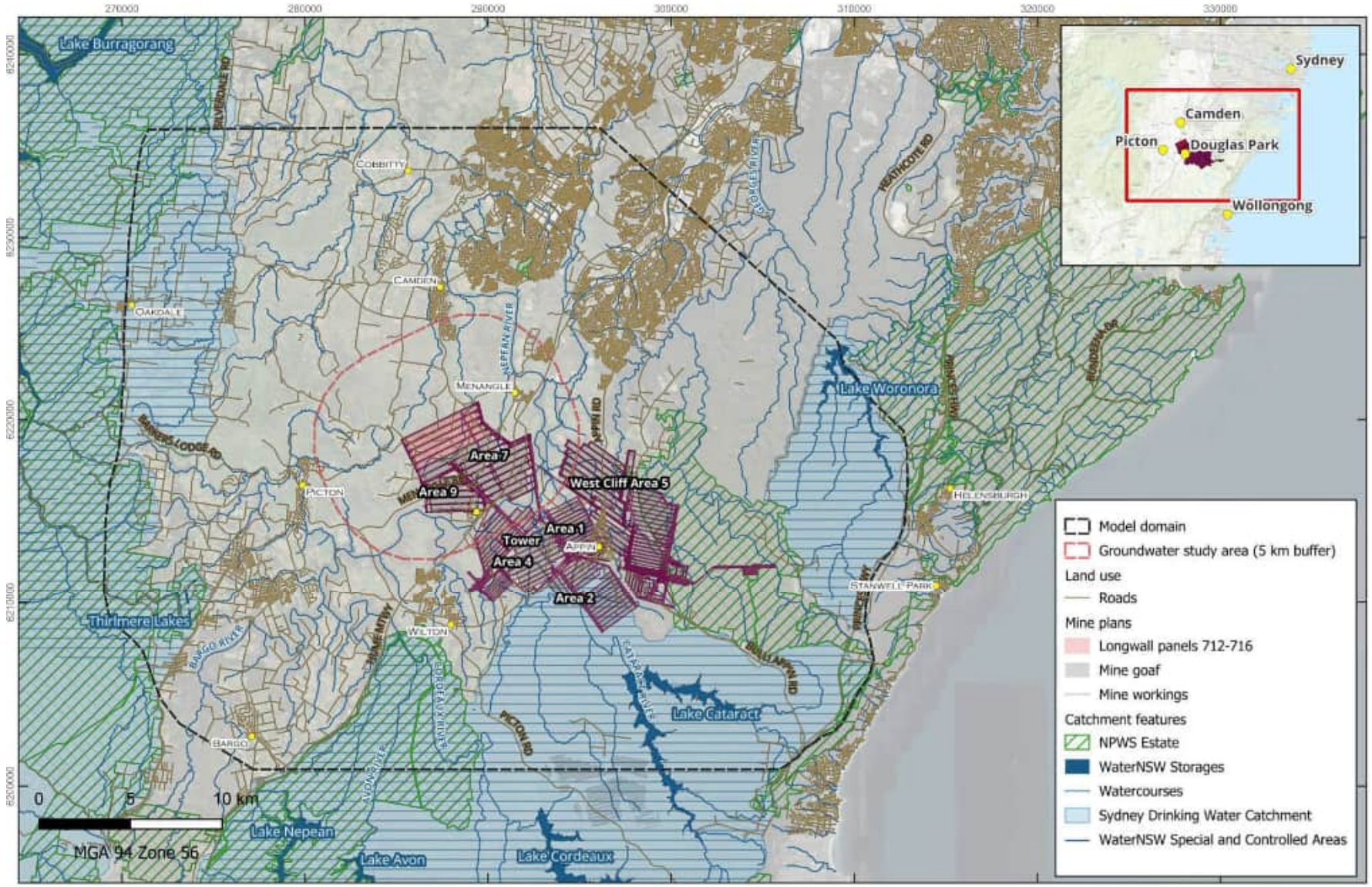

Figure 1: Location map

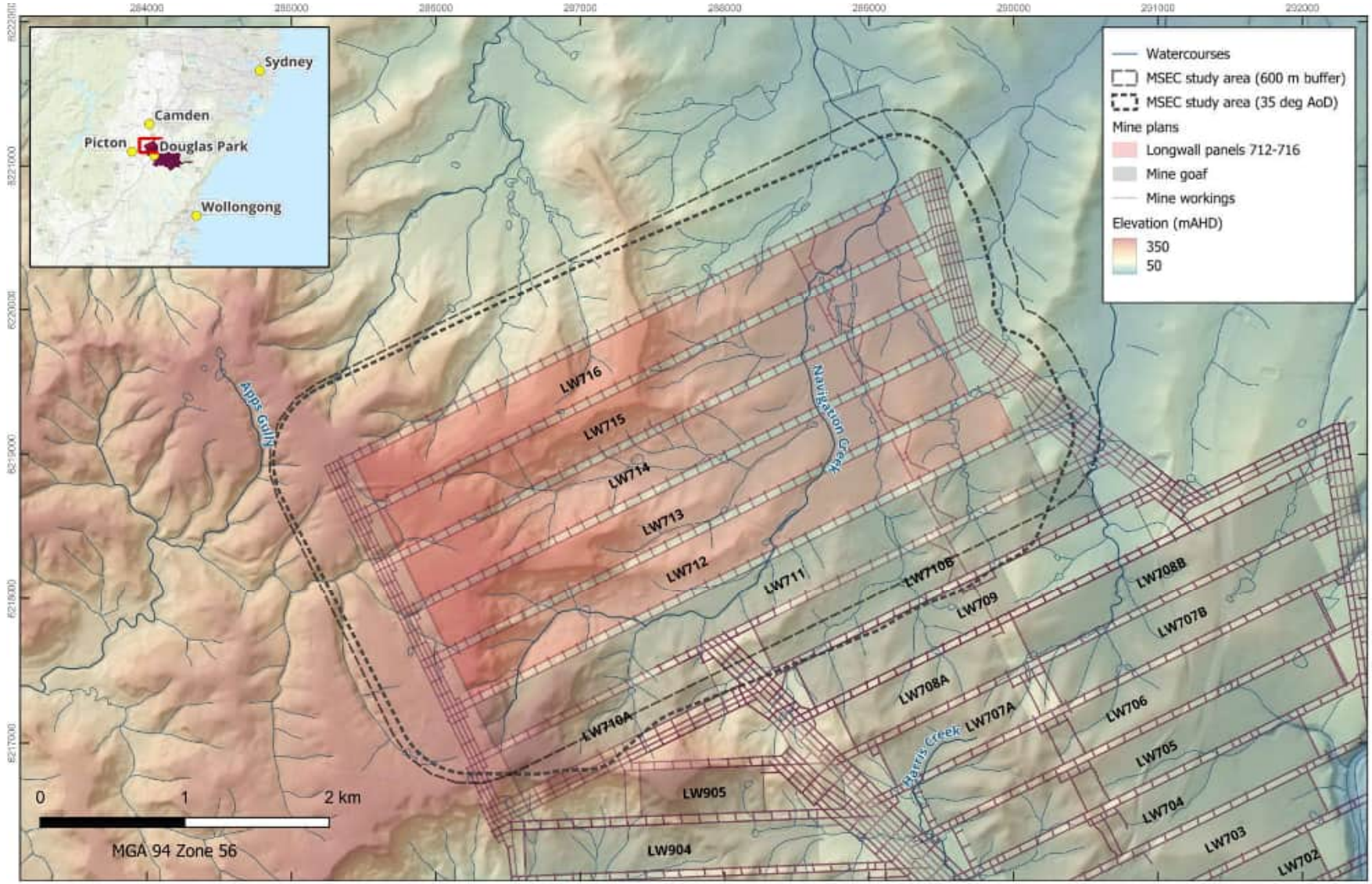

Figure 2 Longwall layout

1.2 Project description

The Project being assessed is the secondary extraction of longwall panels LW712 to LW716 in Appin Area 7 of the approved BSO. The location of the longwalls is shown in Figure 2.

Longwall panels LW712 to LW716 are approximately 4 km in length and 313 m wide (excluding the first workings). The thickness of the Bulli Seam within the extents of the longwalls varies between 3.0 m and 3.6 m. The proposed longwalls will mine the full seam thickness.

The floor of the Bulli Seam generally dips from the south-southeast to the north-northwest with an average grade across the mining area of approximately 3.0 % (i.e. 1 in 33). The proposed longwalls will be extracted towards the main headings, i.e. retreat mining from west to east (MSEC, 2025)

The depth of cover (depth from the surface to the Bulli Seam) in the Project area (LW712 to LW716) ranges between 555 m and 800 m (Figure 3). The minimum depth of cover occurs along a tributary to Navigation Creek above the tailgate of LW712. The maximum depth of cover occurs along the Razorback Range above the western end of LW716 (MSEC, 2025).

The depths of cover in the Project area are greater than or equal to the depths of cover for previous longwalls mined in the area (Figure 3). Therefore, the subsidence impacts and associated impacts on groundwater are expected to be less than or equal to the impacts that have been observed during the mining of previous longwalls at Appin. This is further discussed in Section 4.10.2.

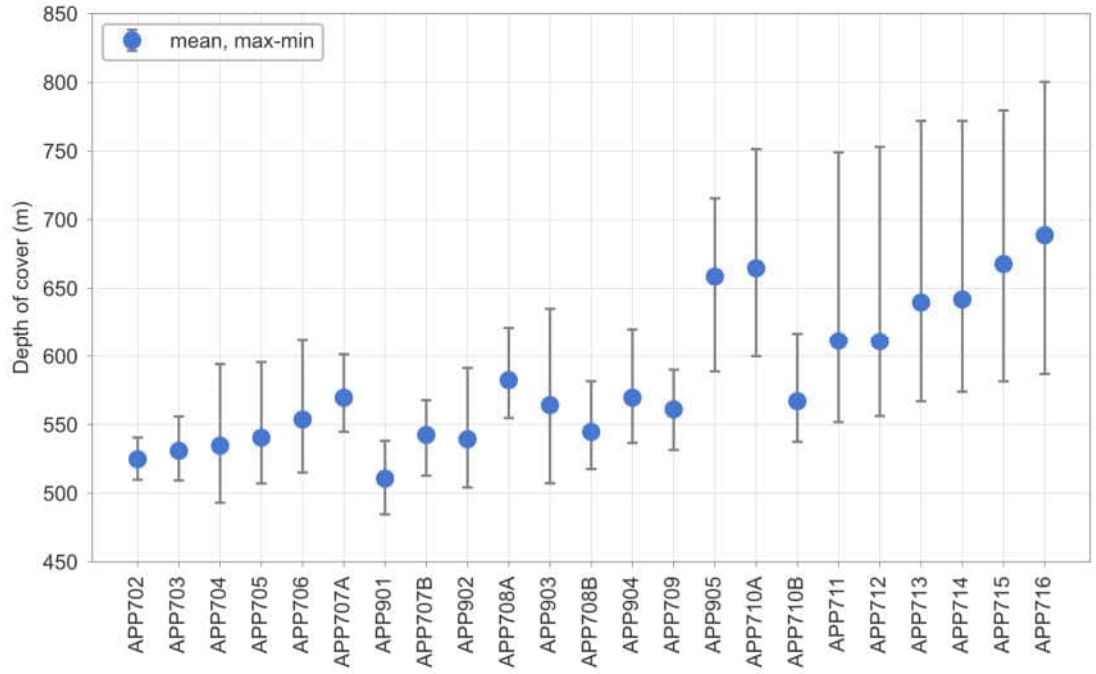

Figure 3 Depth of cover at Appin Mine

1.3 Study area

1.3.1 MSEC study area

MSEC (2025) conducted a subsidence impact assessment for the Project and defined a study area based on two extents: a 35° angle of draw from the longwall extents, and a 600 m boundary around the proposed mine workings.

The study area based on the 35° angle of draw represents the minimum extent for the assessments for the conventional ground movements, i.e. vertical subsidence and its associated effects, as recommended by the Resources Regulator for Subsidence Management Plan applications (Department of Mineral Resources, 2003). It has been calculated by combining the areas bounded by the following limits:

- The 35° angle of draw line from the extents of the proposed LW712 to LW716; and
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour determined using the calibrated Incremental Profile Method (MSEC, 2025).

The study area based on the 600 m boundary is the area within 600 m of the edge of longwall panels (Figure 1). It represents the minimum extent of the assessments for the valley-related effects. This distance is based on the recommendations from the Southern Coalfield Inquiry (Department of Planning, 2008) for the risk management zones.

1.3.2 Groundwater study area

For the purposes of groundwater impact assessment, a study area extending 5 km from the mine workings (Figure 1) has been adopted as depressurisation will occur beyond the extent of subsidence impacts, particularly at depth. This area encompasses the extent of impacts likely to occur based on observations of impacts during the mining of previous longwall panels in Area 7 and the extent of depressurisation predicted by SLR (2021) for longwall panels 710 to 711.

1.3.3 Model domain

The extent of the model domain for the numerical groundwater model is shown on Figure 1. The model extends approximately 42 km from west to east and approximately 35 km from north to south, covering an area of approximately 1,316 km^2. The groundwater model extent was designed to minimise edge effects, allow realistic boundary conditions to be established, be large enough to accommodate future mining at Appin Mine, and to cover any potential associated impacts.

2. Relevant legislation, policy, guidelines, and conditions

2.1 BSO Project Approval

The BSO Project Approval requires preparation of an Extraction Plan (EP) for first and second workings within each longwall mining domain. The EP must incorporate a Water Management Plan which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on surface water and groundwater resources, and includes:

- Surface water and groundwater impact assessment criteria, including trigger levels for investigating any potentially adverse impacts on water resources or water quality; and
- Provisions to predict, manage, and monitor impacts on privately-owned groundwater bores.

The BSO Project Approval also includes subsidence impact performance measures for natural and built features. The performance measures relevant to this groundwater assessment are summarised in Table 2.

Table 2 Subsidence impact performance measures relevant to the groundwater assessment

Built feature	Performance measure
Privately-owned groundwater bores	Always safe. Serviceability should be maintained wherever practicable. Loss of serviceability must be fully compensated. Damage must be fully repaired or fully compensated, or else the damaged built feature or damaged infrastructure component must be replaced.

2.2 Water Sharing Plan

The take of groundwater near Appin Mine is regulated under the water sharing plan for the *Greater Metropolitan Region Groundwater Sources 2023.* Water Sharing Plans are the primary legal framework for managing water access and sharing in NSW and are developed in accordance with the *Water Management Act 2000*. These plans set extraction limits and rules for water access, available water determinations, account management and trading in order to protect water sources and their dependent ecosystems, whilst recognising the social and economic benefits of the sustainable and efficient use of water.

The plan area of the water sharing plan for the *Greater Metropolitan Region Groundwater Sources 2023* manages groundwater contained within 10 groundwater sources that include Cenozoic sediments, porous rock aquifers and fractured rock aquifers. The Project is located within the Sydney Basin Nepean Groundwater Source (Figure 4), which is a porous rock groundwater source. The Sydney Basin Nepean Groundwater Source is subdivided into Management Zones. The Project is located within Nepean Management Zone 2 (Figure 4). Nepean Management Zone 1 occurs in the north of the study area (model domain). The Sydney Basin Central and Sydney Basin South Groundwater Sources also occur within the study area (Figure 4). These are also porous rock groundwater sources.

Water sharing plans set extraction limits and rules for water access, available water determinations, account management and trading in order to protect water sources and their dependent ecosystems, whilst recognising the social and economic benefits of the sustainable and efficient use of water. To

comply with extraction limits set by the water sharing plan, the volumetric take of groundwater for the Project (including for dewatering) must be licensed and accounted for.

Increased losses of surface water from connected streams due to groundwater depressurisation must also be licensed and accounted for. The take of surface water near Appin Mine is regulated under the Water Sharing Plan for the *Greater Metropolitan Region Unregulated River Water Sources 2023*. Surface water overlying the Project is predominantly located within the Mid Nepean River Catchment Management Zone of the Mid Nepean River Weirs Water Source, with the very western extent of the longwall panels located within the Stonequarry Creek Management Zone of the Stonequarry Creek Water Source. The Menangle Weir Management Zone within the Hawkesbury and Lower Nepean Rivers Water Source is located along the Nepean River to the east of the study area upstream of Menangle Weir, and the Camden Weir Management Zone (also within the Hawkesbury and Lower Nepean Rivers Water Source) is located along the Nepean River to the north-east of the study area downstream of Menangle Weir. The numerical groundwater model for the Project is required to predict losses from connected surface water systems and ICHPL are required to hold volumetric licences for the take of water from these water sources.

The *Greater Metropolitan Region Groundwater Sources 2023* contains provision to protect groundwater dependent ecosystems (GDEs) by specifying minimum distance rules for new groundwater works (bores). GDEs are those ecosystems that need access to groundwater to maintain their plant and animal communities and ecological processes. The water sharing plan includes a map of high priority groundwater dependent vegetation communities. The map was developed based on the findings of a program to identify and prioritise vegetation GDEs in NSW (Kuginis, L. et al., 2016).

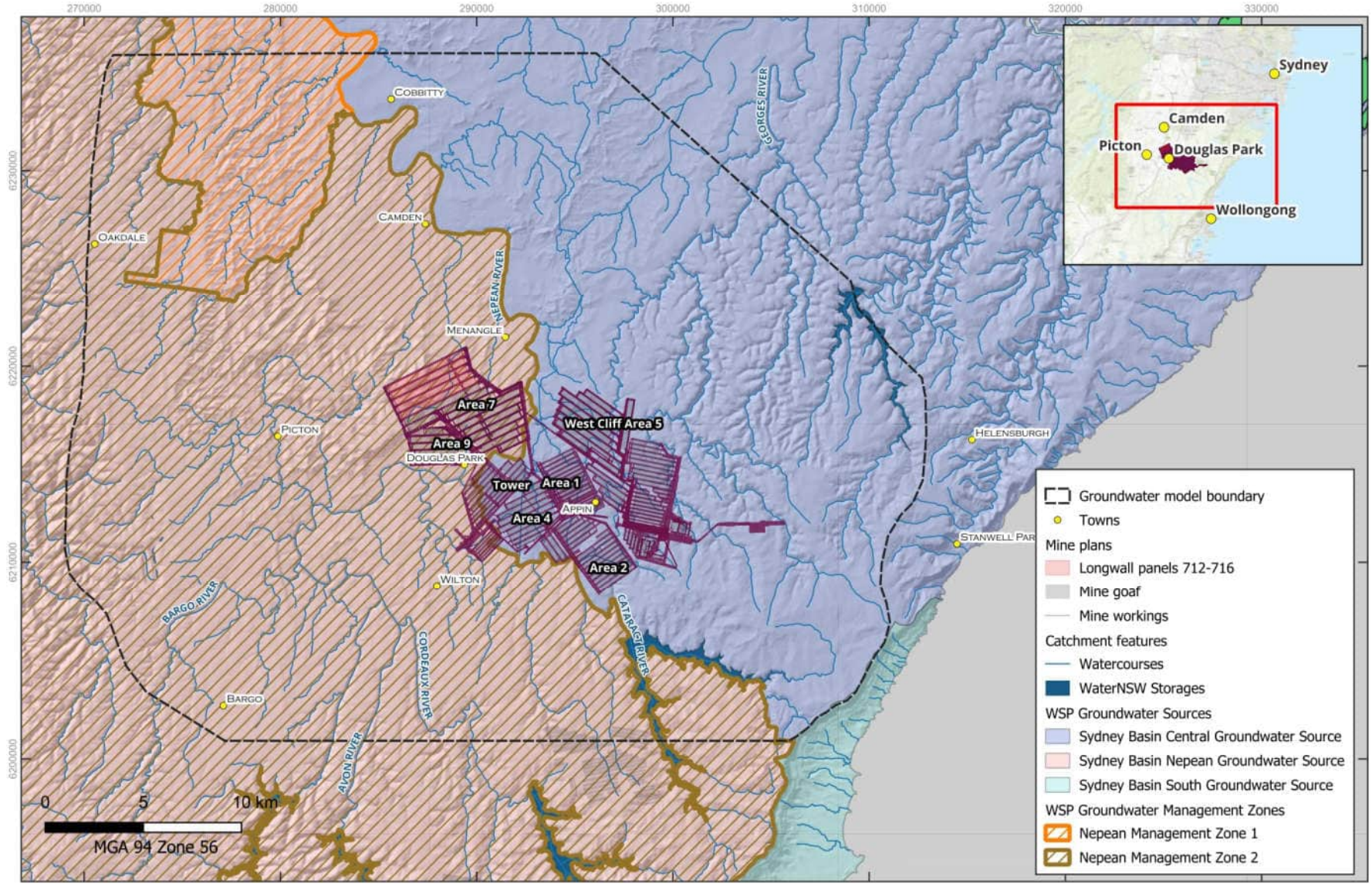

Figure 4 Water Sharing Plan Groundwater Sources

2.3 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy (Department of Primary Industries, 2012) regulates activities that interfere with aquifers managed under the *Water Management Act 2000*. It outlines the requirements for water licensing and assessment processes to minimise the impacts of taking groundwater or interfering with aquifers by developments including mining, extractive, and coal seam gas activities.

The policy requires that all water taken—deliberately or incidentally—must be licensed and accounted for. Proponents are required to predict volumes before approval, measure and report extraction annually, and obtain separate licences for each impacted water source (including groundwater and connected surface water). Activities assessed under the *Environmental Planning and Assessment Act 1979* are required to undertake detailed studies (including numerical groundwater modelling) to demonstrate no more than minimal harm to aquifers and dependent ecosystems.

The policy divides groundwater sources into 'highly productive' and 'less productive' categories based on salinity and aquifer yield. Highly productive groundwater is defined as a groundwater source that is declared in the Regulations, has total dissolved solids of less than 1,500 mg/L, and contains water supply works that can yield water at a rate greater than 5 L/sec. The policy specifies 'minimal impact considerations' for highly productive and less productive groundwater sources. These are thresholds for water table and groundwater pressure drawdown and changes in groundwater and surface water quality.

The groundwater sources at Appin Mine are 'highly productive' porous rock aquifers of the Sydney Basin Nepean Groundwater Source (Nepean Management Zones 1 and 2). The minimal impact considerations for highly productive porous rock groundwater sources are summarised in Table 3.

Table 3 Minimal impact considerations for highly productive porous rock groundwater sources

Water table	Water pressure	Water quality
Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: • High priority groundwater dependent ecosystem; or • High priority culturally significant site; listed in the schedule of the relevant WSP. A maximum of a 2 m water table decline cumulatively at any water supply work.	A cumulative pressure head decline of not more than a 2 m decline, at any water supply work. If the predicted pressure head decline is greater than requirement above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity. If this condition is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

2.4 NSW Groundwater Dependent Ecosystems Policy

The NSW State Groundwater Dependent Ecosystems Policy (Department of Land and Water Conservation, 2002) provides guidelines on how to protect and manage GDEs. The policy applies the following principles to the management of GDEs in NSW:

1. The scientific, ecological, aesthetic and economic values of groundwater-dependent ecosystems, and how threats to them may be avoided, should be identified and action taken to ensure that the most vulnerable and the most valuable ecosystems are protected.

2. Groundwater extractions should be managed within the sustainable yield of aquifer systems, so that the ecological processes and biodiversity of their dependent ecosystems are maintained and/or restored. Management may involve establishment of threshold levels that are critical for ecosystem health, and controls on extraction in the proximity of groundwater dependent ecosystems.

3. Priority should be given to ensuring that sufficient groundwater of suitable quality is available at the times when it is needed:

    - for protecting ecosystems which are known to be, or are most likely to be, groundwater dependent; and,

    - for groundwater dependent ecosystems which are under an immediate or high degree of threat from groundwater-related activities.

4. Where scientific knowledge is lacking, the Precautionary Principle should be applied to protect GDEs. The development of adaptive management systems and research to improve understanding of these ecosystems is essential to their management.

5. Planning, approval and management of developments and land use activities should aim to minimise adverse impacts on GDEs by:

    - maintaining, where possible, natural patterns of groundwater flow and not disrupting groundwater levels that are critical for ecosystems;

    - not polluting or causing adverse changes in groundwater quality; and

    - rehabilitating degraded groundwater systems where practical.

The tools that can be used to manage GDEs should be adapted to suit local conditions. The management tools available to achieve the protection, management and restoration of groundwater dependent ecosystems include environmental planning instruments, monitoring, research, and education.

2.5 Australian and New Zealand Guidelines for Water Quality (ANZG)

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) (DCCEEW, 2018) provide authoritative guidance on the management of water quality for natural and semi-natural water resources in Australia and New Zealand. The guidelines form part of the National Water Quality Management Strategy, which is a national approach to improving water quality in Australian waterways.

The ANZG provide water managers with tools and guidance to assess, manage and monitor the water quality. The ANZG aim to protect ‘environmental values’ (EVs), those values or uses of water that the community believes are important for a healthy ecosystem for public benefit, welfare, safety or health. These include, but are not limited to, protection of aquatic ecosystems, drinking water, primary and secondary recreation, visual amenity, agricultural water for irrigation, livestock and growing aquatic foods, industrial water, and cultural and spiritual values.

The ANZG provide guidance on the derivation of site-specific water quality guideline values, technically-derived numerical measures (e.g. concentrations) or descriptive statements to protect aquatic ecosystems and human water uses and values (e.g. irrigation, stock watering, recreation). The guideline values can be derived for a range of physico-chemical, biological, and habitat indictors.

Each of the EVs requires its own specific set of guideline values because the acceptable guideline values to support one type of EV may not be acceptable to maintain another EV. For example, the guideline values for pesticides required to protect fish and other fauna are usually lower than those required to protect irrigated crops. Another reason is that the indicators relevant to one EV may be different to those used for other EVs.

The ANZG includes default guideline values (DGVs) which can provide a generic starting point for assessing water quality. DGVs can be used for generic applications in the absence of more relevant guideline values (jurisdictional, site specific).

2.6 IESC Information Guidelines Explanatory Note on using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessment

The Explanatory Note on using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessment (IESC, 2024) was developed by the Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development (IESC), a statutory body under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999.

The Explanatory Note provides guidance on the development of impact pathway diagrams (IPDs) to integrate and communicate the diverse information in the documentation of environmental impact assessment. IPDs are a conceptual model that illustrates how impacts of a proposed project are predicted to adversely affect water resources and related assets (receptors), the potential pathways of the impacts from sources to receptors, and how these pathways might interact with each other. When superimposed on maps of the project area, IPDs also indicate where such impacts might occur.

The pathways in IPDs are typically represented as linking consecutive categories of components (Figure 5), starting with drivers and ending in receptors, which in this context are surface water resources. The Explanatory Note presents some examples of IPDs from the mining literature which demonstrate that the terminology used for the different components of IPDs and the representation of IPDs is variable from project to project.

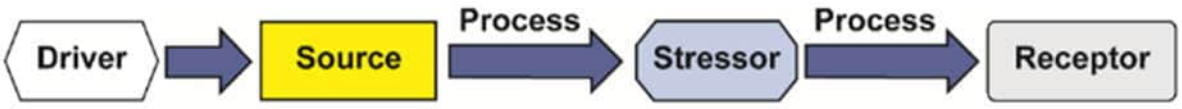

Figure 5 Typical components of an impact pathway diagram

2.7 Bioregional assessment for the Sydney Basin bioregion

The Bioregional Assessment Program was a scientific initiative developed by the Australian Government to evaluate the potential impacts of coal and coal seam gas (CSG) development on water-dependent assets across selected bioregions. The purpose of the program was to integrate data

on geology, hydrology, ecology, and land use and assess the cumulative impacts of coal and CSG resource development on surface water and groundwater systems and their water-dependent assets to support informed decision-making by governments, stakeholders, and communities. The results from each assessment are provided in a series of reports together with a water-dependent asset register and a data register.

The assessment for the Sydney Basin bioregion (Bioregional Assessment Program, 2018), which includes Appin Mine, examined coal mining and CSG operations in the region and their interactions with surface water catchments, many of which provide water supply to Sydney and are protected under NSW State Government legislation, and groundwater systems, including productive aquifers within the Hawkesbury Sandstone and Narrabeen Group.

A key finding of the study was that the flow of water between the porous sandstone aquifers and the underlying coal measures is limited by low permeability claystones that overlie the coal measures throughout the Sydney Basin. The Bald Hill Claystone is particularly important as it occurs below the Hawkesbury Sandstone, the main productive aquifer of the Southern Coalfields. Its presence limits the exchange of groundwater between the Hawkesbury Sandstone and the underlying Bulgo Sandstone, possibly providing some protection against the potential impacts by underground coal mining activities (Bioregional Assessment Program, 2018).

3. Environmental setting

3.1 Climate

ICHPL has been recording daily rainfall observations at Appin East, Appin North, Appin West and Ventilation Shaft No.6 since 2014. Longer term data are available at Bureau of Meteorology (BoM) climate stations in the vicinity of the mine, including Darkes Forest (068024), Cataract Dam (068016), Wedderburn (068159) and Douglas Park (068200). Rainfall data collected at the Douglas Park weather station were used for this assessment. Climate data were also obtained from the Scientific Information for Landowners (SILO) database, which interpolates data from the BoM climate stations for grid cell locations. Data for the grid cell location between Douglas Park and Appin (Latitude -34.20 Longitude 150.75) for the period 1890 to 2025 was used for this assessment.

Appin Mine experiences moderate rainfall, with a mean annual rainfall of approximately 774 mm based on continuous observations from 2001 to 31 July 2025 (Figure 6). Rain can fall year-round with slightly higher monthly average rainfall in late summer months February and March (Figure 7). It is common for a substantial proportion of the annual rainfall to be delivered in one or two large rainfall events, during which significant surface water runoff and groundwater recharge is generated.

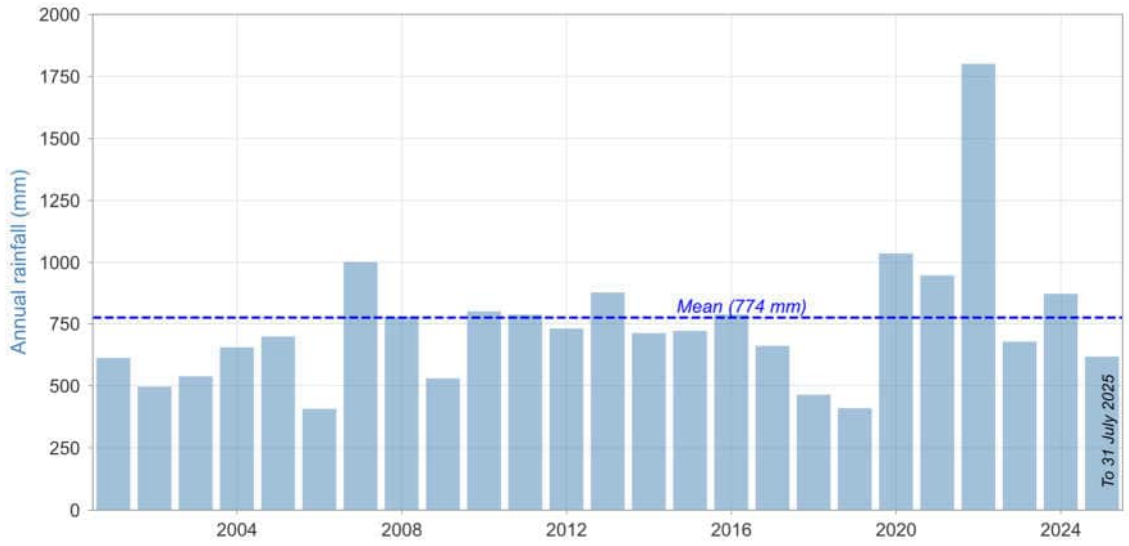

Figure 6 Annual rainfall at Douglas Park since 2010

Daily temperatures in the area range throughout the year from 10 to 46 °C in January and -3.7 and 27 °C in July (at Campbelltown). Potential evapotranspiration varies seasonally in line with temperature and solar radiation, peaking during the summer months (Figure 7). Long-term average annual potential evaporation at Appin is approximately 1422 mm. A comparison of average daily rainfall and potential evapotranspiration for each month shows a rainfall excess in June, with a rainfall deficit in all other months (Figure 7).

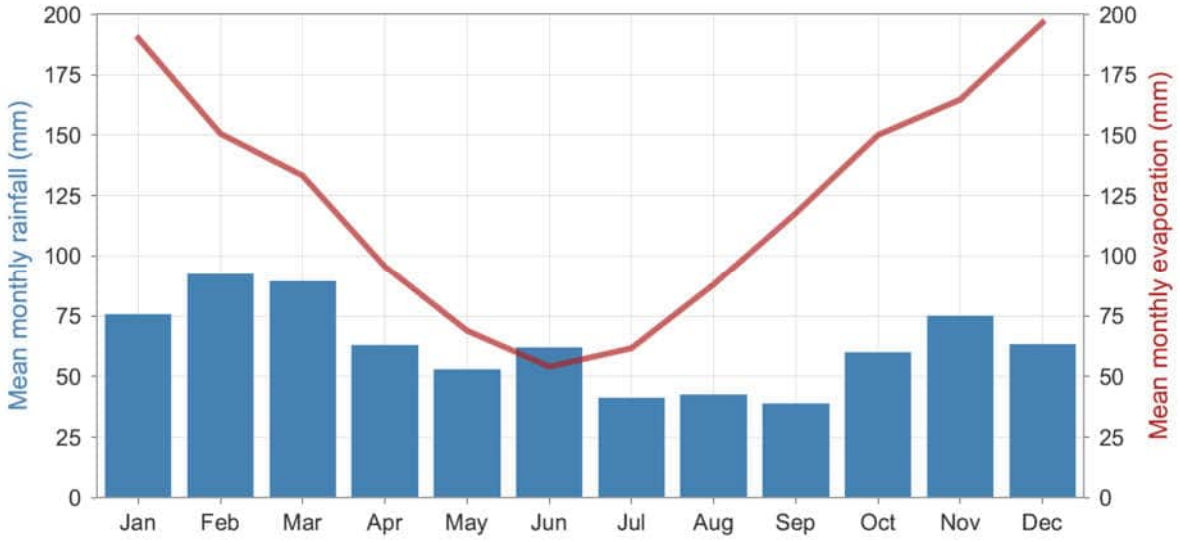

Figure 7 Monthly average rainfall and pan evaporation at Douglas Park

Figure 8 shows the Cumulative Rainfall Residual (CRR) for Douglas Park. The CRR represents long-term rainfall trends by comparing long-term rainfall variability to the climatological mean. A negative slope in the CRR curve indicates a period of below-average rainfall while a positive slope indicates a period of above-average rainfall. Severe drought conditions occurred across much of NSW during 2017 to 2019 including at Appin (Figure 8). The drought was followed by very wet weather from 2020 to 2022 with the development of La Niña conditions, including significant flooding in the South-Western Sydney Region in March and July 2022. Since 2022, seasonal norms and average conditions at Appin have returned with early 2025 slightly wetter than normal (Figure 8).

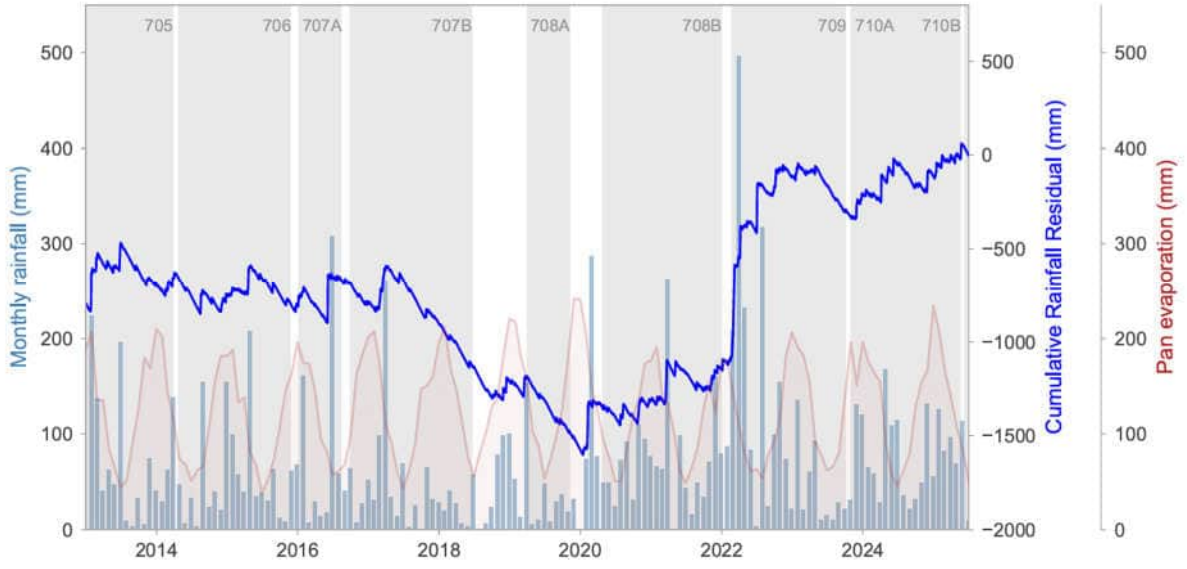

Figure 8: Weather observations at Douglas Park

3.2 Topography

Appin Mine is located at the interface between two distinct physiographic regions within the Sydney Basin. The landscape to the west and north-west of Appin is dominated by the Cumberland Plain, while the landscape to the south and east of Appin marks the transition onto the Woronora Plateau.

The Cumberland Plain is a broad, low-lying region in the western Sydney Basin, characterised by gently undulating plains and hills. The plain encompasses key river systems, including the Nepean and Georges Rivers, and contains numerous ephemeral streams and minor creeks.

The Woronora Plateau is a distinct sub-region of the Illawarra Plateau in the Sydney Basin. It is an elevated landscape (generally 200 to 400 mAHD) that is characterised by broad sandstone ridges and steep, narrow gorges incised by the Woronora, Cataract, and Georges rivers. The eastern extent of the Woronora Plateau is the Illawarra Escarpment, a steep sandstone cliff that occurs along the coastline from Wollongong to Helensburgh and forms the eastern boundary of the model domain.

Elevations above the longwall panels range from approximately 95 m to 310 m AHD (Figure 9). The terrain is characterised by Razorback Range in the west transitioning to flatter plains in the east. Razorback Range is a prominent north-south trending ridge system comprised of Hawkesbury Sandstone and incised by tributaries that form the headwaters of Navigation Creek, Apps Gully, and Matahil Creek. Flatter plains occur in the east with the lowest surface elevation along Navigation Creek where it crosses the finishing (i.e. eastern) end of LW716.

3.3 Surface water and drainage

Appin Mine is located within the Hawkesbury-Nepean and Georges River basins (Figure 9). Major rivers near the mine include the Nepean River, Stonequarry Creek, and the Cataract River in the Hawkesbury-Nepean catchment and Georges River in the Georges River catchment. Summary details for each of the main rivers near the Project are included in Table 4.

Table 4: Major rivers near Appin Mine

River	Appin Mine Area	Catchment	Description
Nepean River	Area 7, Area 9 and Tower	Hawkesbury-Nepean	Flows in a general northerly direction. Flow is regulated by upstream weirs and is approximately 310 ML/day (at Maldon Weir).
Stonequarry Creek	Area 7	Hawkesbury-Nepean	Flows in a general southerly direction and joins the Nepean River near Maldon upstream of Appin Mine. Flow is regulated by upstream Warragamba Dam and is approximately 22 ML/day (at Picton).
Cataract River	Area 4 and Tower	Hawkesbury-Nepean	Flows in a northerly direction and joins the Nepean River between Tower and Area 9. Flow is regulated by upstream Cataract Dam and is approximately 92 ML/day (at Broughton Pass Weir).
Georges River	West Cliff	Georges River	Flows in a northerly direction. Flow is regulated by upstream Brennan's Creek Dam and is around 4.2 ML/day (at Brennans Creek Dam).

ICHPL conduct monitoring of stream flow at Navigation Creek within the Project area and at Foot Onslow Creek just outside the LW712 to LW716 Project area associated with previous Area 7 longwalls (Figure 9). Stream flow is also recorded every 15 minutes at NSW government stream gauges including two on the Nepean River at Maldon and Menangle weirs, one on the Cataract River

at Broughtons Pass Weir, and one on Stonequarry Creek at Picton (Figure 9). Data collected at stream gauging sites are summarised in Table 5.

Table 5 Stream flow at watercourses near Appin Mine

Stream gauge location	Stream gauge no.	Monitoring commenced	Median flow (ML/day)	Mean flow (ML/day)	Average annual no flow days
Navigation Creek^	NAVS1	07/09/2023	0.000	0.073	347
Foot Onslow Creek^	FOS1	06/09/2023	0.079	0.330	16.5
Nepean River at Maldon Weir	212208	26/07/1973	22.5	377	1.68
Nepean River at Menangle Weir	212238	03/07/1990	66.7	556	4.22
Cataract River at Broughtons Pass Weir	212233	31/12/1982	3.19	137	148
Stonequarry Creek at Picton	212053	05/12/1990	2.26	23.2	5.82

^ Data are based on short period of record since Sept 2023

Flows within the Hawkesbury-Nepean and Georges River basins are retained by large dams used to store water for Sydney's water supply. Major storages within the model domain are Lake Cataract and Lake Woronora (Figure 9). Major storages upstream of the Project include Lake Nepean, Lake Avon, Lake Cordeaux, and Lake Burragorang (Figure 9). These storages are located within the declared Sydney Drinking Water Catchment and the areas of land identified as Special or Controlled Areas (in the *Sydney Water Catchment Management Act 1998*) that protect water quality, although the Project itself is outside this area (Figure 1). The Hawkesbury-Nepean and Georges River basins are unregulated systems as while the dams and weirs in the catchment capture water, they are not used to release water into the river downstream for extraction by users and so flows are not regulated.

Nepean River flows in a northerly direction through Appin Mine between Tower and Areas 7 and 9 (Figure 9). Surface water flows in the Nepean River are derived from several sources including:

- Rainfall-runoff from natural, agricultural, and urban catchment areas;
- Baseflow from perched aquifers and the regional Hawkesbury Sandstone groundwater system; and
- Licensed discharges, including from Appin and Tahmoor Collieries.

Nepean River is a 'gaining river' in terms of surface water - groundwater interaction, being situated in a well incised gorge that defines a regional low point in the piezometric surface. Rainfall-runoff from catchment areas contributes most flow in the Nepean River system. Flows vary greatly and are highly responsive to rain events due to the significant areas of catchment. Natural flow within Nepean River and associated watercourses including Stonequarry Creek and Cataract River has been significantly altered by the large upstream storage dams and smaller weirs including Maldon and Menangle weirs on Nepean River and Broughtons Pass Weir on Cataract River (Figure 9).

The upper reaches of the Georges River occur in the West Cliff mining area to the east of the Project. The river flows in a northerly direction through the mining area and then in a north-easterly direction and is primarily fed by rainfall-runoff and tributary inflows in its upper catchment near Appin Mine. In its upper reaches near Appin Mine, Georges River is not incised and may exhibit losing stream behaviour.

Navigation Creek, a tributary of Nepean River, overlies longwall panels LW712 to LW716. The headwaters of Apps Gully, Matahil Creek, and Foot Onslow Creek, also tributaries of the Nepean River, are within the MSEC study area for LW712 to LW716. The streams overlying the longwall panels are ephemeral, but pools have naturally developed along the lengths of these creeks within the surface soils and rock platforms. Flows have been altered by the numerous farm dams which intersect the drainage lines and capture flows (Figure 9) and therefore watercourses within the study area contribute only a small portion of total flows in the Hawkesbury-Nepean basin (<0.2%). Water quality is influenced by the land use and soils in the catchment, with nutrients associated with farming activities and salinity associated with the marine sediments of the Wianamatta Group shales.

ICHPL have historically conducted surface water quality monitoring at numerous sites across the Appin Mine lease on typically a monthly basis. Surface water monitoring for the LW712 to LW716 Extraction Plan is outlined in the Water Management Plan and will include sites within Navigation Creek and its tributaries, Racecourse Creek, and Matahil Creek.

Surface water in the Nepean River both upstream and downstream of the Project is fresh whereas surface water in Navigation Creek, Racecourse Creek, and Foot Onslow Creek is brackish and elevated compared to the default guidelines values for EC for upland river systems in southeast Australia (DCCEEW, 2018). High variation in salinity over time is observed for the tributaries, which is typical of ephemeral creeks with higher salinity generally associated with low flows. The pH of surface waters in the region, including both the Nepean River and tributaries, is elevated compared to the default guidelines values for pH for upland river systems in southeast Australia (DCCEEW, 2018). The pH reflects the land use in the catchment being predominately farmland with inputs of nitrogen and phosphorus related to livestock and fertiliser use. Concentrations of total iron and manganese in surface waters are elevated for the tributaries compared to the Nepean River.

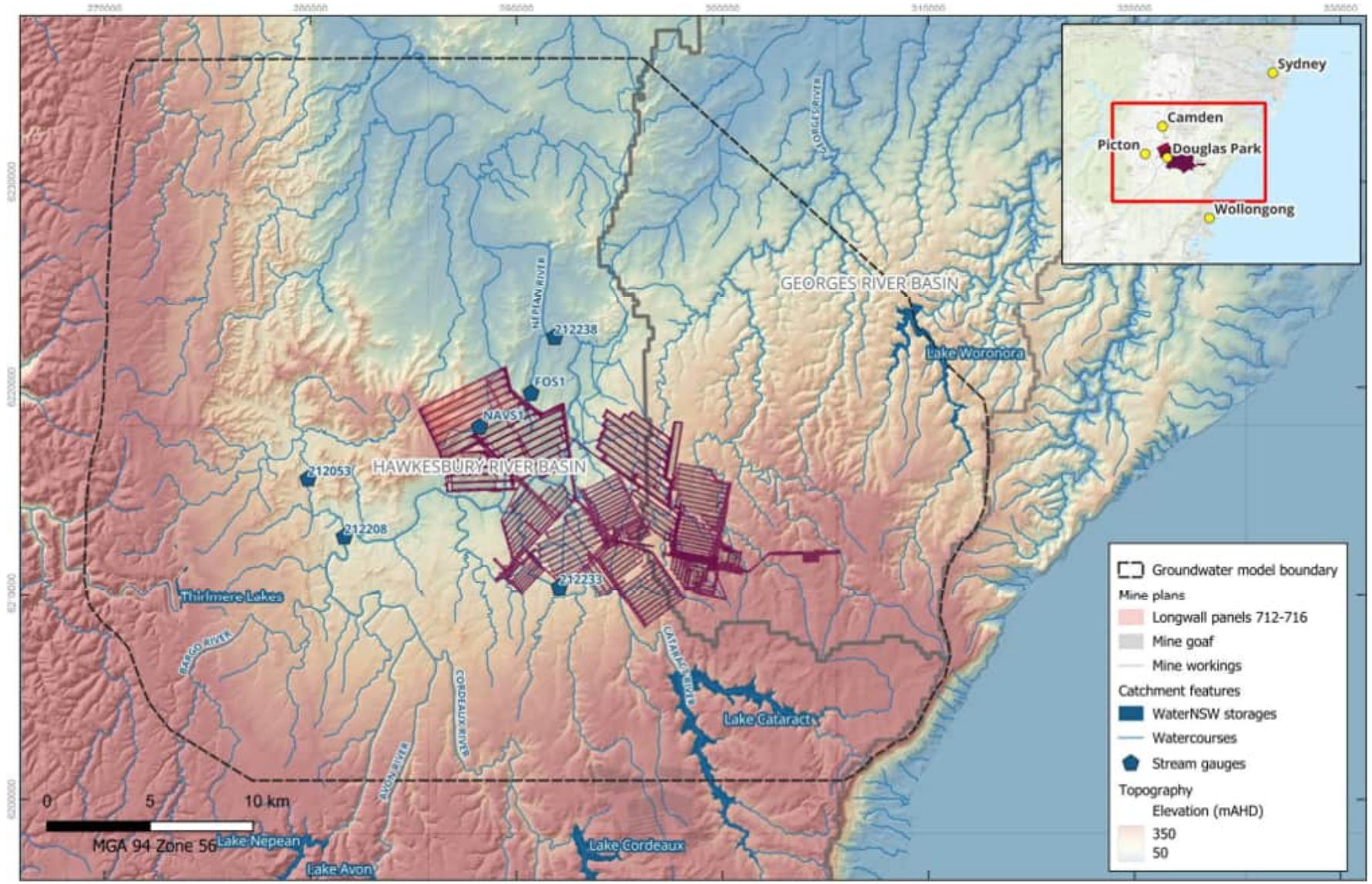

Figure 9 Topography and drainage

3.4 Land use

Most of the region surrounding Appin Mine has a semi-rural character and supports a mix of rural and rural-residential land use. The region also includes expanding urban fringe housing, mining, coal seam gas extraction, and bushland and conservation areas (Figure 1).

Land use in the region is currently dominated by rural-residential and grazing with horticulture also occurring north of Appin Mine where fertile soils associated with the Wianamatta Shale occur. To the north and west of Appin, the region is experiencing a shift from rural-residential and grazing to residential subdivision and infrastructure growth associated with the Greater Macarthur Growth Area and Wilton Growth Area strategic land use and infrastructure planning initiatives.

A significant portion of the region is covered by bushland with large areas protected by National Park Estates, the declared Sydney Drinking Water Catchment, and areas identified as Special or Controlled Areas to protect water quality for the Greater Sydney water supply system (Figure 1). Development is restricted within these areas.

Mining and coal seam gas operations also occur in the region and are discussed in Sections 3.4.1 and 3.4.2.

3.4.1 Nearby mines

Numerous active and historic underground coal mines occur within the study area around Appin Mine (Figure 10). The closest active mine to the Project is Tahmoor Colliery which is a coking (metallurgical) longwall coal mine that targets the Bulli Seam. Mining of the Tahmoor South Domain commenced in October 2022 and is approved to continue until 2033 (Table 6). Metropolitan Mine, also a coking (metallurgical) longwall coal mine, is the only other active mine within the study area. This mine also targets the Bulli Seam and is approved to operate until 2032 (Table 6). Russell Vale Colliery, which mined the Bulli, Balgownie, and Wongawilli seams was closed in February 2024. Details of the mines within the study area are summarised in Table 6.

Table 6 Nearby mines

Mine	Current owner/ operator	Seam	Status	Distance from Appin Mine
Tahmoor Colliery	SIMEC Mining	Bulli Seam	Active	Located approximately 7 km west of the proposed longwall panels. In operation since 1975 and approved until 2032. Mining of the Tahmoor South Domain commenced in October 2022 and is approved to continue until 2033. Historical inflows to mine workings have been reported between 0.3 ML/day and 5 ML/day (SLR, 2022).
Metropolitan Mine	Peabody Energy (owner), Metropolitan Collieries (operator)	Bulli Seam	Active	Located approximately 7.2 km east of Appin Mine. In operation since 1886 and approved to operate until 2032. The most recent Project Approval 08_0149 covers underground coal extraction from Longwalls 20–27 and 301–317. A recent modification to allow continued extraction from Longwalls 311–316 is still under assessment with

Mine	Current owner/ operator	Seam	Status	Distance from Appin Mine
				approval hinging on resolving environmental conditions for swamps that overlie the panels. Measured mine inflows generally less than 1 ML/day (Peabody 2019 referenced in SLR, 2022).
Russell Vale Colliery	Wollongong Resources	Bulli Seam, Balgownie Seam, and Wongawilli Seam	Closed	Located approximately 2.5 km south of Appin Mine. Bulli Seam and Balgownie Seam mined from 1887 to 1950 as bord and pillar. Mining restarted in 1960s as continuous miners then from 1970 to 1982 as longwall. Gibson Colliery then in operation between 2001 to 2003 within Bulli and Balgownie seams, using continuous miner and longwall methods. From 2007 to 2024 in Wongawilli Seam. The mine was closed in February 2024. Historical inflows have been reported between 0.05 to 0.7 ML/day (SLR 2020) and around 1.1 ML/day for current (NRE 2019, Umwelt 2020 referenced in SLR, 2022).
Cordeaux Colliery	n/a	Bulli Seam	Care and maintenance	Located approximately 6.9 km south of Appin Mine. In operation from 1979 to 2001.
Old Bulli Colliery	n/a	Bulli Seam, with some workings in the Balgownie Seam	Closed	Located approximately 4 km south-east of Appin Mine. In operation from 1863 to 1987.
Excelsior Colliery (No. 1 and No.2)	n/a	Bulli Seam, with later development into the Balgownie Seam	Closed	Located approximately 7.5 km south-east of Appin Mine. In operation from 1900 to 1962.
Coalcliff Colliery (Darkes Forest)	n/a	Bulli Seam	Closed	Located approximately 5 km east of Appin Mine. In operation from 1877 to 1992.
South Clifton Colliery	n/a	Bulli Seam	Closed	Located approximately 7 km south-east of Appin Mine. In operation from 1883 to 1983.
North Bulli Colliery	n/a	Bulli Seam	Closed	Located approximately 8.3 km south-east of Appin Mine. In operation from 1878 to 1973.
Bulli Main Colliery	n/a	Bulli Seam	Closed	Located approximately 10.5 km south-east of Appin Mine. In operation from 1842 to 1974.

3.4.2 Camden Gas Project

The AGL Camden Gas Project is located at the northern end of Appin Mine on Petroleum Production Lease (PPL) 1 to 6 and Petroleum Exploration Licence (PEL2) and overlaps with the Longwall 712-716 Study Area. The Camden Gas Project commenced operations in 2001 and over the life of the project comprised 144 wells targeting the Bulli and Balgownie coal seams. AGL is currently in the process of ceasing production and decommissioning wells, with 134 wells reported to be decommissioned as of mid-2025.

The extraction of coal seam gas (CSG) for the Camden Gas Project involves abstraction of water to induce gas flow. Data provided by AGL indicate a total recorded produced water of 31.1 ML for the period 2010 to 2024, with an average annual production of approximately 2.2 ML/year. Water production peaked in the first few years at approximately 4.8 ML/year and then declined over time to approximately 1 ML/year. The volumes of produced water are significantly lower than the authorised extraction. AGL are authorised to extract groundwater for gas production in accordance with Water Access Licenses 24856 and 24736 and Works and Use Approvals 10WA112288 and 10WA112294 up to 30 ML/year (with 15 ML allocated from the Sydney Basin Central Groundwater Source and 15 ML allocated from the Sydney Basin Nepean Groundwater Source) (SLR, 2021). The Camden Gas Project wells that produced more than 25 kL of water during the period 2010 to 2024 are shown in Figure 10.

CSG production for the Camden Gas Project has resulted in a reduction in groundwater pressures in the target coal seams. Monitoring of groundwater levels in alluvium and the Hawkesbury Sandstone does not show any evidence of long-term effects other than seasonal/climatic variations (EMM, 2024).

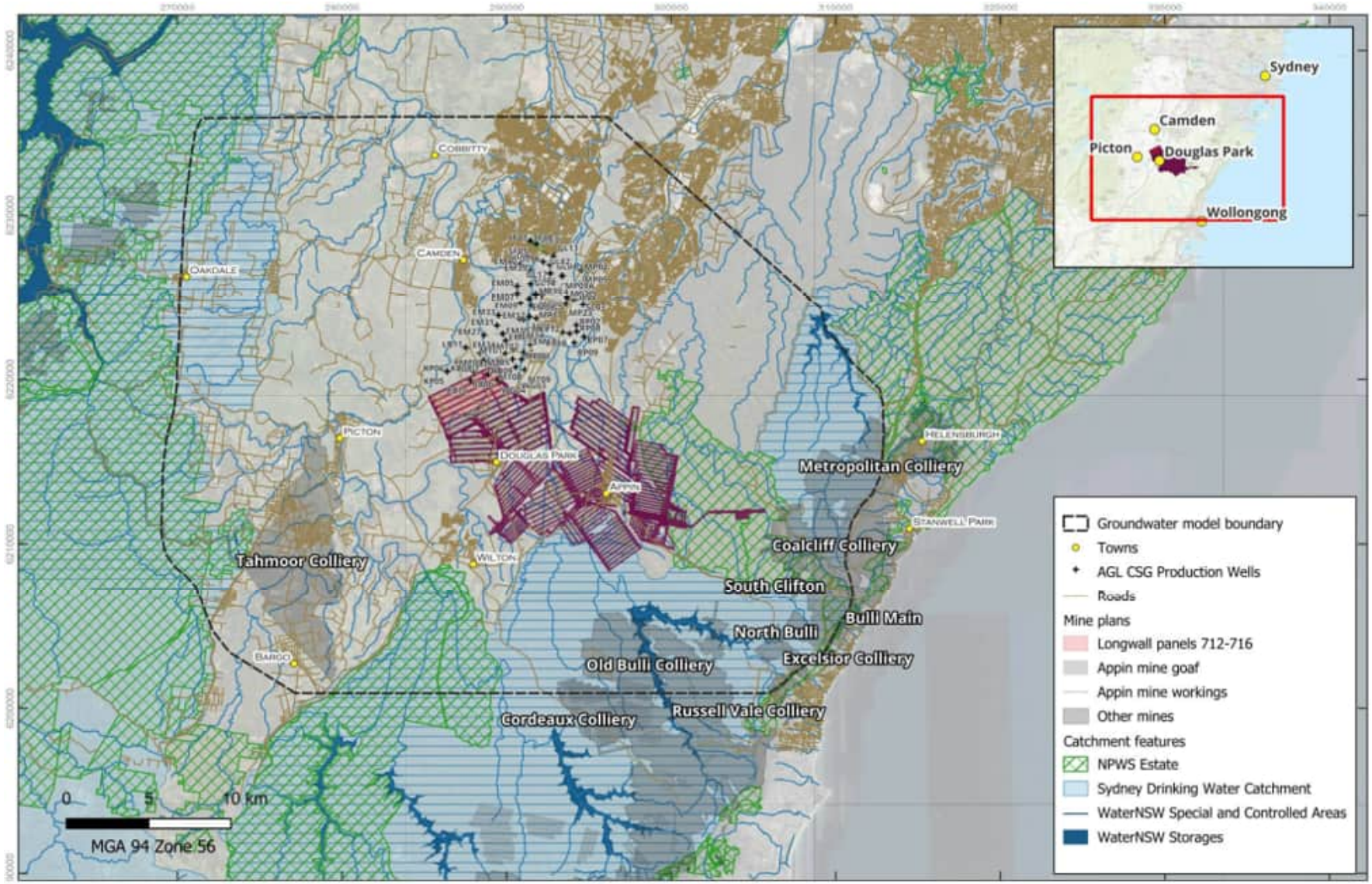

Figure 10 Land use

3.5 Geology

Appin Mine is located within the Southern Coalfield of the Sydney Basin. The stratigraphy of the Southern Sydney Basin is shown in Figure 11, based on the Southern Coalfield 1:100,000 geological map (Moffitt, 1999).

3.5.1 Quaternary and Triassic sediments

Quaternary floodplain alluvium is mapped at the surface overlying LW712 to LW716 along Navigation Creek and its tributaries. Extensive alluvial deposits are also mapped along the Nepean River and its tributaries to the north of the Project (Figure 12).

The Triassic Wianamatta Group is present at the surface above the longwall panels and across most of the central and northern parts of the study area. It predominantly comprises shale, claystone, siltstone and sandstone and includes the Bringelly Shale, Minchinbury Sandstone, Razorback Sandstone, and Ashfield Shale. Within the study area, the Wianamatta Group ranges in thickness from less than 10 m to 200 m at Razorback Range.

The Hawkesbury Sandstone (HBSS) underlies the Wianamatta Group and occurs at the surface in the eastern, southern and western parts of the study area. The HBSS comprises bedded sandstone units around 170 m thick (MSEC, 2025), which are incised along the Nepean River. The HBSS is underlain by the Triassic sandstones, siltstones and claystones of the Narrabeen Group. This includes the Bulgo Sandstone, Scarborough Sandstone and Coal Cliff Sandstone, as well as the Bald Hill Claystone, Stanwell Park Claystone and Wombarra Claystone.

3.5.2 Permian sediments

Permian aged Illawarra Coal Measures underlie the Narrabeen Group. The Illawarra Coal Measures comprise interbedded sandstone, shale and coal seams, with a thickness of approximately 200 m to 300 m. The Bulli Seam is the primary economic sequence of interest at Appin Mine. Within the study area the Bulli Seam is around 3.0 m to 3.6 m thick and around 555 m to 800 m below surface (MSEC, 2025).

3.5.3 Structural geology

Geological structures have been mapped in studies at a variety of scales, e.g. regional mapping (Moffitt, 1999), high level mapping using remote methods, and local-scale drilling (from surface and underground) by ICHPL, and interpretation and mapping by ICHPL geologists that evolves with mine development.

3.5.3.1 Regional structure

Figure 12 presents regional structure, as mapped on the Southern Coalfield geology map (Moffitt, 1999). The mapping indicates there are no major geological structures (faults) intersecting the proposed longwalls. Major geological structures in the surrounding region include the fault zone to the east which includes Four Mile Fault, Stokes Fault, and Pig Farm Fault, and the fault zone to the west which includes Bargo Fault, Moore Fault, and Oakdale Fault. The nearest mapped faults to the Project are 3.8 km to the south, 5.0 km to the west, and 5.7 km to the east.

The Permian coal measures dip approximately 3 % in a north north-westerly direction, towards the Douglas Park syncline.

3.5.3.2 In-seam faults and dykes

Structures identified at seam level by ICHPL geologists are shown in Figure 13. There are two NNW-SSE orientated zones of geological structure within the Project area that cross the western ends of LW712 to LW716 and the eastern end of LW712 and possibly extend through the eastern ends of the other proposed longwalls. These zones comprise series of dykes with thicknesses up to approximately 3.5 m and minor faults with displacements up to approximately 3 m (MSEC, 2025). Increased vertical subsidence is not anticipated at the zones of geological structure, as it was not observed when LW703 to LW706, LW709 and LW901 to LW904 previously mined through these zones (MSEC, 2025).

Elsewhere, minor faults with displacements up to approximately 1 m cross the proposed LW712 to LW716. Increased subsidence or localised irregular movements are not anticipated in these locations, as this was not observed when longwalls previously mined through similar geological structures in Appin Areas 7 and 9 (MSEC, 2025).

3.5.3.3 Structures interpreted from aeromagnetic survey

An aeromagnetic survey was conducted by ICHPL in 2022. Analysis of data from the survey by geophysicists identified anomalies that were interpreted to be faults ranging in confidence from low to high (Figure 13). There is no significant surface expression of these potential faults, and their presence has not been confirmed.

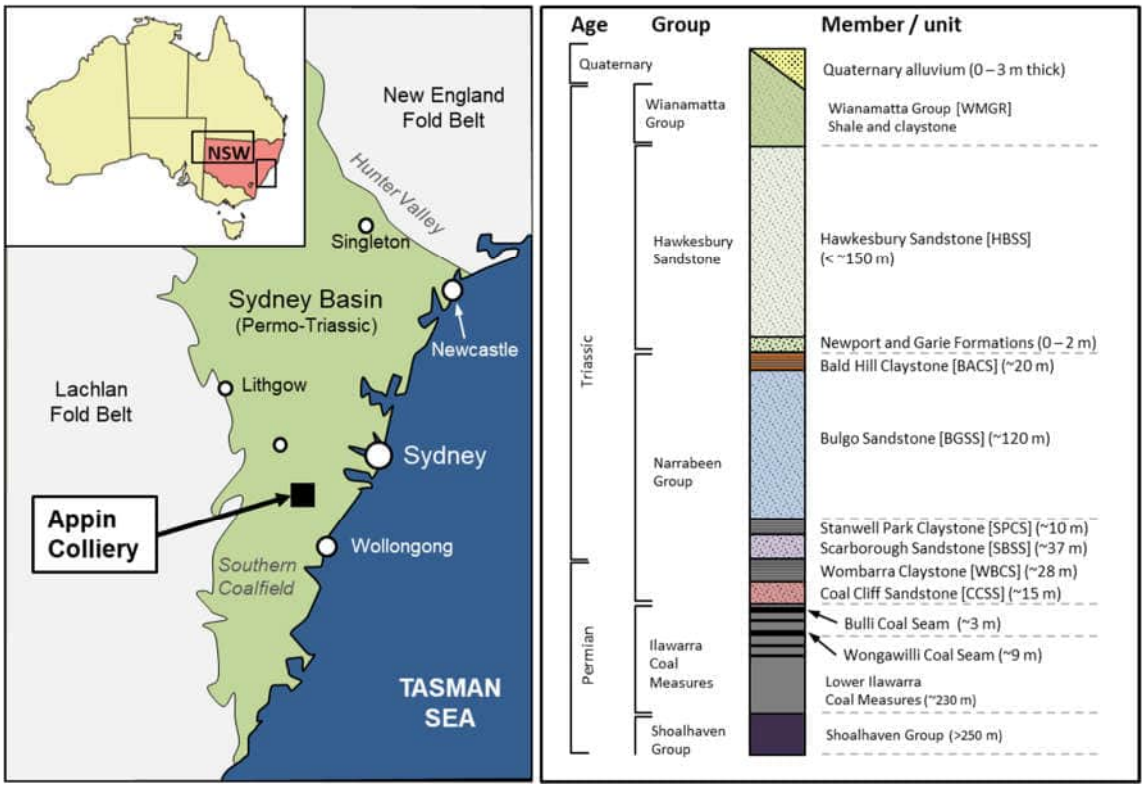

Figure 11 Stratigraphy

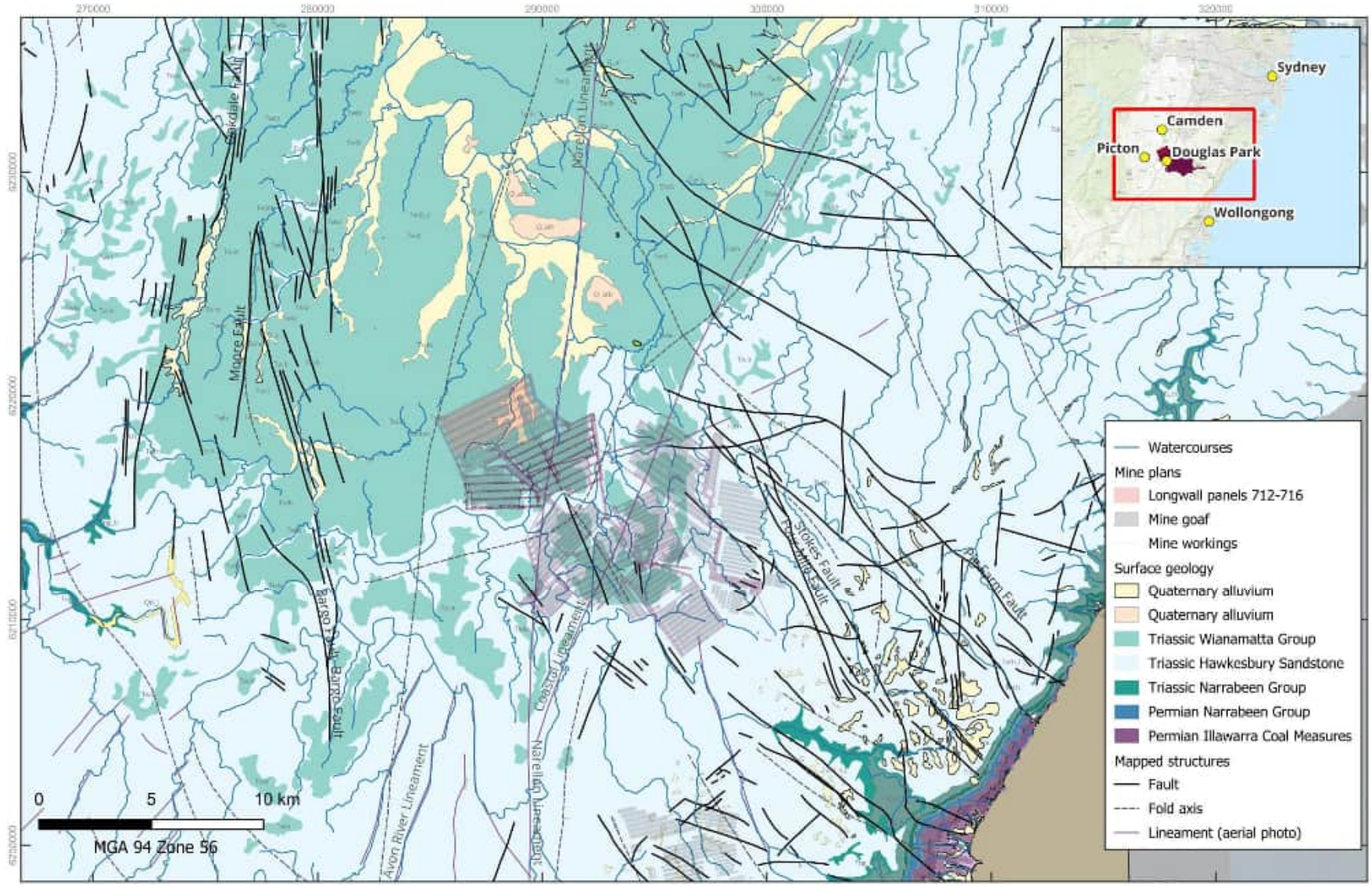

Figure 12 Geology

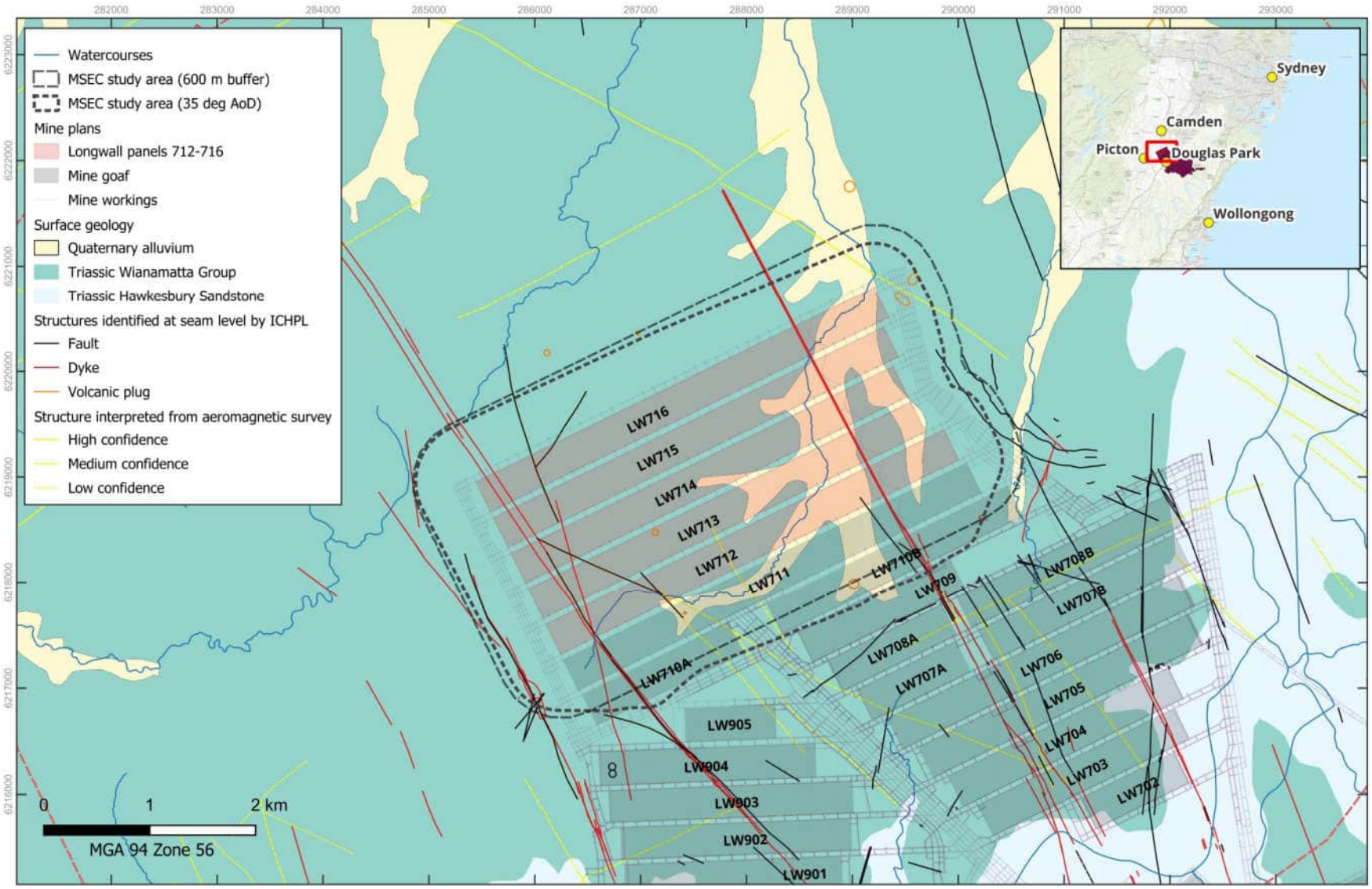

Figure 13 Faults and dykes in the Project area

4. Hydrogeology

4.1 Hydrogeological setting

The study area is located within the southern part of the Sydney Basin, an asymmetrical structural basin which includes coal measures, shales and sandstones and extends from Port Stephens in the north to Bateman's Bay in the south (Department of Planning and Environment, 2023).

The Sydney Basin is primarily Permian-Triassic sedimentary rock sequence underlain by undifferentiated sedimentary rocks of Carboniferous and Devonian age (Figure 11). Locally there are important aquifers within the Hawkesbury Sandstone and Narrabeen Group and unconsolidated alluvial aquifers associated with present-day drainage networks and coastal deposits (Bioregional Assessment Program, 2018). Bore depths within the basin are variable, ranging from 20 to 200 metres with most bores less than 60 metres deep. Groundwater quality, in particular salinity, in several areas may limit its potential uses (Department of Planning and Environment, 2023).

The Illawarra Coal Measures are the main coal-bearing rocks in the southern coalfield where Appin Mine is located. Coal production from underground mines in the region has been occurring since the mid-1800s. There is also coal seam gas production at Camden (Bioregional Assessment Program, 2018).

4.2 Hydrostratigraphy

The hydrostratigraphy of the study area comprises interbedded sandstone, claystone, and shale units and is illustrated in the north-south cross section in Figure 14. The sandstone units behave as porous and fractured rock aquifers while the claystones and shales behave as aquitards. The main groundwater systems are associated with the following geological features:

- Unconsolidated Cenozoic alluvial deposits along river floodplains
- Upper Triassic Wianamatta Group rocks where minor aquifers and aquitards occur (Bringelly Shale, Minchinbury Sandstone, and Ashfield Shale)
- Middle Triassic Hawkesbury Sandstone aquifers (including Newport and Garie formations of the Narrabeen Group)
- Lower Triassic Narrabeen Group sandstone aquifers (Bulgo and Scarborough sandstones)
- Permian water-bearing units (Illawarra Coal Measures) (Bioregional Assessment Program, 2018).

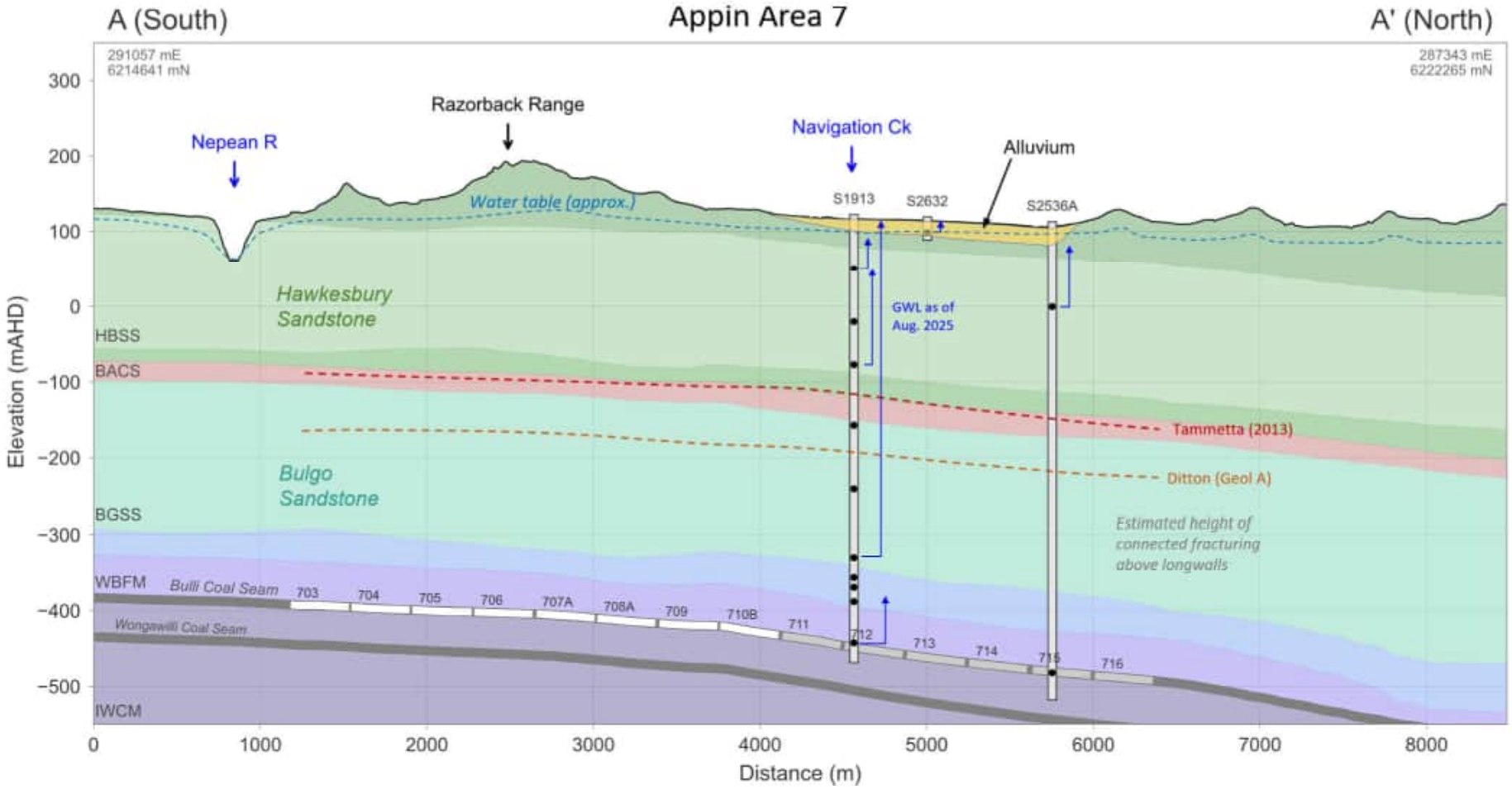

Figure 14 Hydrogeological cross section (N-S) through Appin Area 7

4.2.1 Alluvium

The 1:100,000 Southern Coalfield geology mapping (Moffitt, 1999) indicates Quaternary floodplain alluvium occurs at the surface of the proposed longwalls along Navigation Creek. Alluvium is also mapped along the Nepean River and its tributaries to the north of the Project (Figure 12).

The alluvium is unconsolidated and comprises a heterogenous distribution of clay, silt, sand and gravel. CSIRO (2015) regolith mapping indicates that alluvium in the vicinity of the Project is typically less than 10 m thick and increases in thickness to around 20 m along the Nepean River in the north of the study area.

Groundwater resources in the unconfined alluvial systems near the Project are limited in extent and flow likely follows topography and streamflow in a general northerly direction. Water levels in alluvium are likely responsive to rainfall recharge, interactions with streams, and abstraction.

4.2.2 Wianamatta Group

The Triassic Wianamatta Group outcrops in the Project area (Figure 12), underlying the alluvium where it occurs. It comprises Bringelly Shale (BrSh), Minchinbury Sandstone and Ashfield Shale (AsSh) and thickens with distance to the north-west of the Project where it can be up to 100 m thick.

Groundwater in the Wianamatta Group occurs in perched water table zones associated with bedding planes and fractures. These zones are understood to be ephemeral, have limited vertical flow, and be hydraulically disconnected from the deeper groundwater systems. Monitoring data indicate differences in head between perched water tables in the Wianamatta Group and the regional water table in the Hawkesbury Sandstone of around 50 m in Area 7.

Groundwater in the Wianamatta Group is moderately saline (median electrical conductivity 4,750 µS/cm) and suitable for short term irrigation and water for some stock (i.e. sheep and dairy cattle). Due to low yields the Wianamatta Group is not considered a productive groundwater source.

4.2.3 Hawkesbury Sandstone

The Hawkesbury Sandstone underlies the Wianamatta Group and is the main groundwater source in the Project area due to its regional extent and exposure at the surface outside the Project area (Figure 12) that enables rainfall recharge and easy access for private water supply bores. It is a thick aquifer (approximately 155 m) with numerous high and low permeability horizons and provides baseflow contributions where incised along major rivers including the Nepean River.

Due to the stratification of the sandstone sequences, groundwater flow is primarily horizontal, with minor vertical leakage. Monitoring data indicate a general downward head gradient within the Hawkesbury Sandstone in the study area. Groundwater flow is generally in a northerly direction and locally influenced where intersected by rivers that are deeply incised into the sandstone (i.e. Nepean River) and private abstraction bores.

Within the Appin Mine area, the Hawkesbury Sandstone has been described as having generally low groundwater yields (~0.2 to 1 L/s) but good groundwater quality (Heritage Computing, 2009). The shallow depths make the aquifer ideal for private water supply bores, with the highest yielding bores associated with coarse sandstone units and/or fracture networks. The quality of groundwater in the Hawkesbury Sandstone is variable but in general brackish (median electrical conductivity 2,060

µS/cm) with a neutral pH (median pH of 7.5) and suitable for short-term irrigation (due to elevated iron concentrations) and stock water.

4.2.4 Narrabeen Group

The Narrabeen Group underlies the Hawkesbury Sandstone and is a sequence of interbedded sandstone, claystone, and siltstone. The main water bearing unit is the confined Bulgo Sandstone. This unit is typically of much lower permeability than the Hawkesbury Sandstone and produces lower bore yields and poorer water quality. The Bald Hill Claystone at the top of the Bulgo Sandstone limits vertical groundwater flow from the Hawkesbury Sandstone. The aquitard is present across the Appin Mine and has a thickness of approximately 25 m.

Groundwater flow in the Bulgo Sandstone is in a north-westerly direction through bedding planes, joints and fractures. Groundwater quality is moderately saline (median electrical conductivity 4,950 µS/cm), neutral (median pH 7.2) and suitable for short term irrigation and water for some stock (i.e. sheep and dairy cattle).

The Stanwell Park Claystone, which is approximately 20 m thick in Area 7, underlies the Bulgo Sandstone and limits the interaction of groundwater between the Bulgo Sandstone and the Scarborough Sandstone. The Wombarra Claystone, which forms the base of the Narrabeen Group, is approximately 32 m thick in the study area and impedes vertical flow to the Illawarra Coal Measures.

Groundwater monitoring data indicate that groundwater heads at depth within the Narrabeen Group tend to be higher than those observed in the HBSS.

4.2.5 Illawarra Coal Measures

Groundwater occurrence within the Illawarra Coal Measures is associated with the more permeable coal seams. Groundwater is confined and flow is generally in a northerly direction. The coal seams outcrop to the east of Appin Mine, where coal seams are truncated along the Illawarra Escarpment (Figure 12).

Prior to mining, heads in the Wongawilli Seam were around 1 to 5 m higher than the heads in Bulli Seam. On a regional scale, groundwater in the Bulli and Wongawilli seams flowed towards the north. Groundwater in the Narrabeen Group and Illawarra Coal Measures has been locally depressurised due to current and historical mining at Appin Mine and coal seam gas extraction for the Camden Gas Project (Figure 10).

4.3 Groundwater monitoring network

Appin Mine has an extensive groundwater monitoring network (Figure 15). The network comprises:

- Single and multi-level vibrating wire piezometer (VWP) installations with sensors that measure groundwater pressures at discrete depths through the profile
- Shallow screened bores and open standpipes that measure groundwater levels in upper formations including along the Nepean River, Georges River and Cataract River
- Monitoring locations with in-built borehole pumps that can be used to sample groundwater for water quality analyses

- Monitoring locations within the mine workings that can be used to sample goaf seep for water quality analyses.

Groundwater monitoring locations within the study area include ICHPL installations (for Appin and Dendrobium), private bores monitored by ICHPL, government monitoring bores, and monitoring locations installed by other mines including Tahmoor.

A review of available data has identified 84 monitoring locations with 362 individual VWP sensors that have pressure head data. Water level data are also available for 36 private water supply bores targeting the Hawkesbury Sandstone. The groundwater monitoring locations are shown on Figure 15 (model domain) and Figure 16 (study area). Target formations for the monitoring locations are summarised in Table 7.

Monitoring of the Hawkesbury Sandstone, the main aquifer in the area, is comprehensive with time series data available for 166 sensors/bores. Monitoring of the Bulgo Sandstone, the main water bearing unit in the Narrabeen Group, is also comprehensive with data available for 91 sensors/bores.

The groundwater monitoring program includes hourly readings of pressure head at VWPs and quarterly sampling for groundwater quality at the monitoring bores. Details of the monitoring locations are provided in Appendix A.

Table 7 Monitoring locations by target formation

Group	Hydrostratigraphic unit	Number of sensors/monitoring bores
Wianamatta Group	Wianamatta Group shale (WMGR)	22
Hawkesbury Sandstone (HBSS)	Upper Hawkesbury Sandstone	61
	Mid Hawkesbury Sandstone	61
	Lower Hawkesbury Sandstone	44
Narrabeen Group	Newport Formation (NPFM)	1
	Bald Hill Claystone (BACS)	10
	Bulgo Sandstone (BGSS)	91
	Stanwell Park Claystone (SPCS)	5
	Scarborough Sandstone (SBSS)	43
	Coalcliff Sandstone (CCSS)	5
Illawarra Coal Measures	Bulli Coal Seam (BUCO)	40
	Loddon Sandstone (LDSS)	2
	Other coal seams	6
	Wongawilli Coal Seam (WWSM)	6
	American Creek Coal Seam (ACCO)	1
TOTAL		**398**

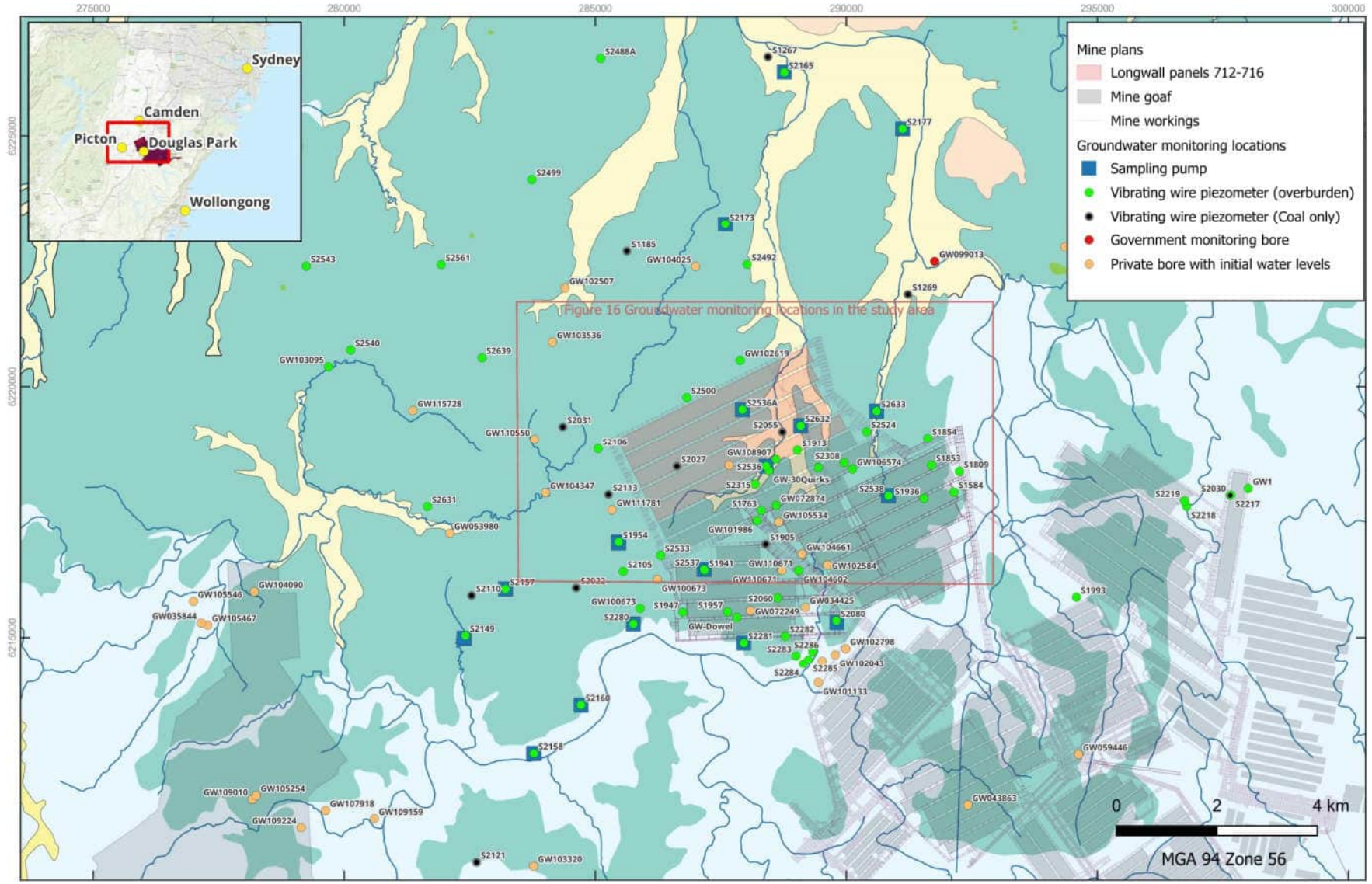

Figure 15: Groundwater monitoring network

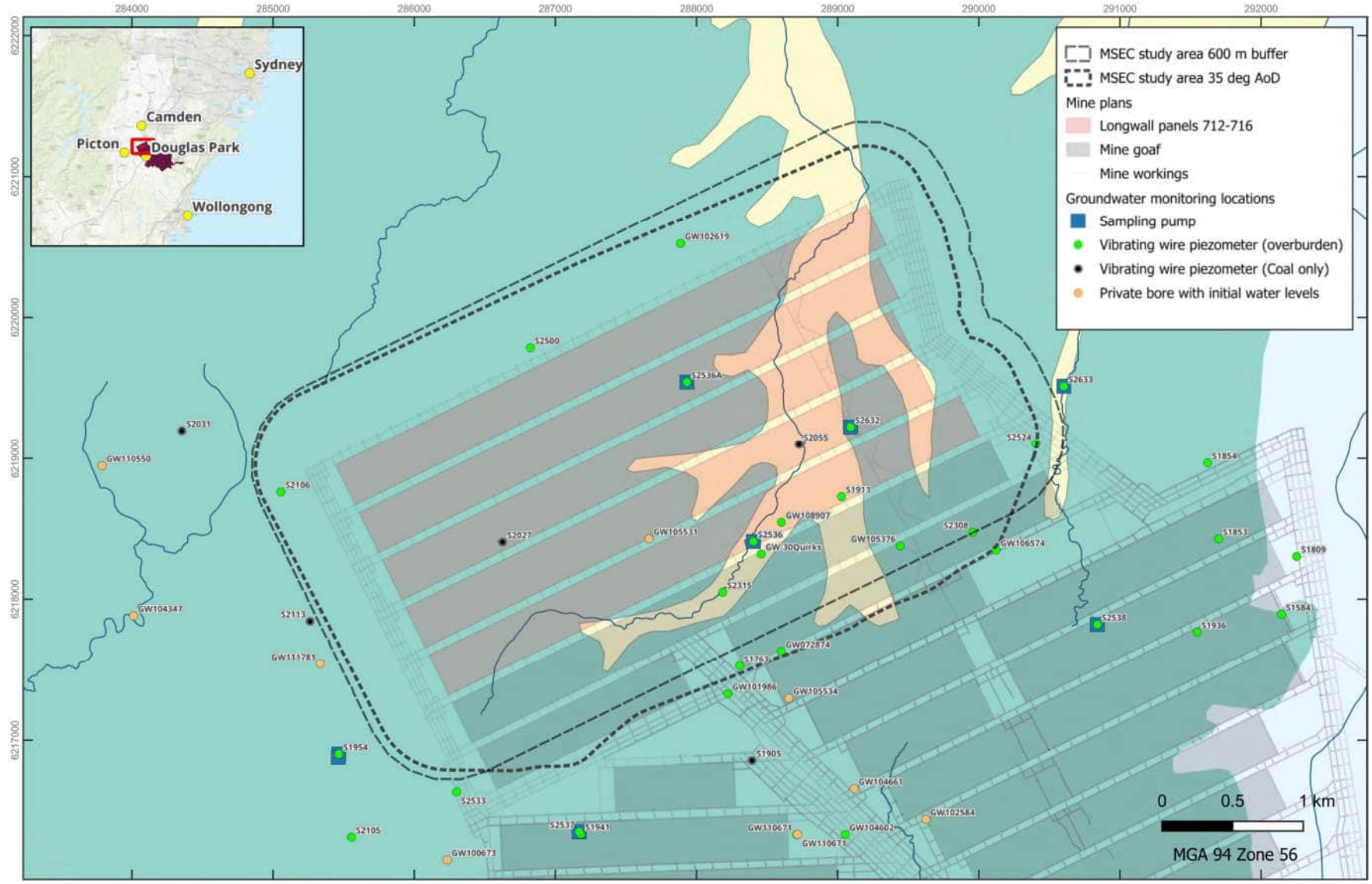

Figure 16 Groundwater monitoring locations in the study area

4.4 Groundwater levels and flow direction

Groundwater level hydrographs for monitoring locations with continuous data are in Appendix B. Selected hydrographs are also provided below to show the main trends in water levels for each of the hydrostratigraphic units.

4.4.1 Alluvium

There are registered bores within alluvium along Navigation Creek and Nepean River (and its tributaries) to the north of the Project area. Data from these registered bores indicates groundwater is present within the alluvium around 5 to 8 m below surface (SLR, 2022). Alluvial groundwater flow likely follows topography and streamflow, flowing in a general northerly direction.

4.4.2 Wianamatta Group

Figure 17 shows groundwater levels at S2632 which overlies longwall 713 (Figure 16) and constructed in the Wianamatta Group shales. Groundwater levels during the period of monitoring ranged between approximately 109 and 113 m RL. Figure 18 shows groundwater levels at S2536 which overlies longwall 715 (Figure 16) and is constructed in the Wianamatta Group shales. Groundwater levels during the period of monitoring ranged between approximately 121 and 125 m RL.

The Wianamatta Group outcrops across the Project area (Figure 12) and the observed variations in water levels are understood to be related to variation in recharge associated with climatic conditions.

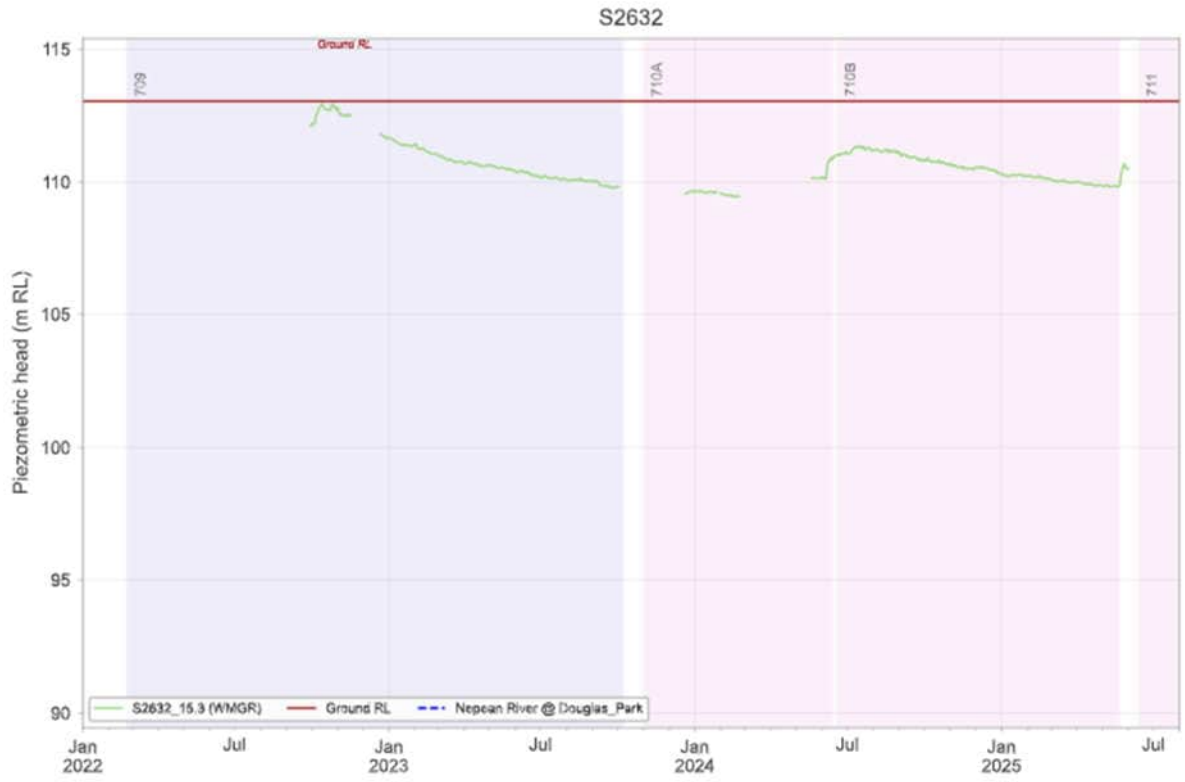

Figure 17 Hydrograph – S2632

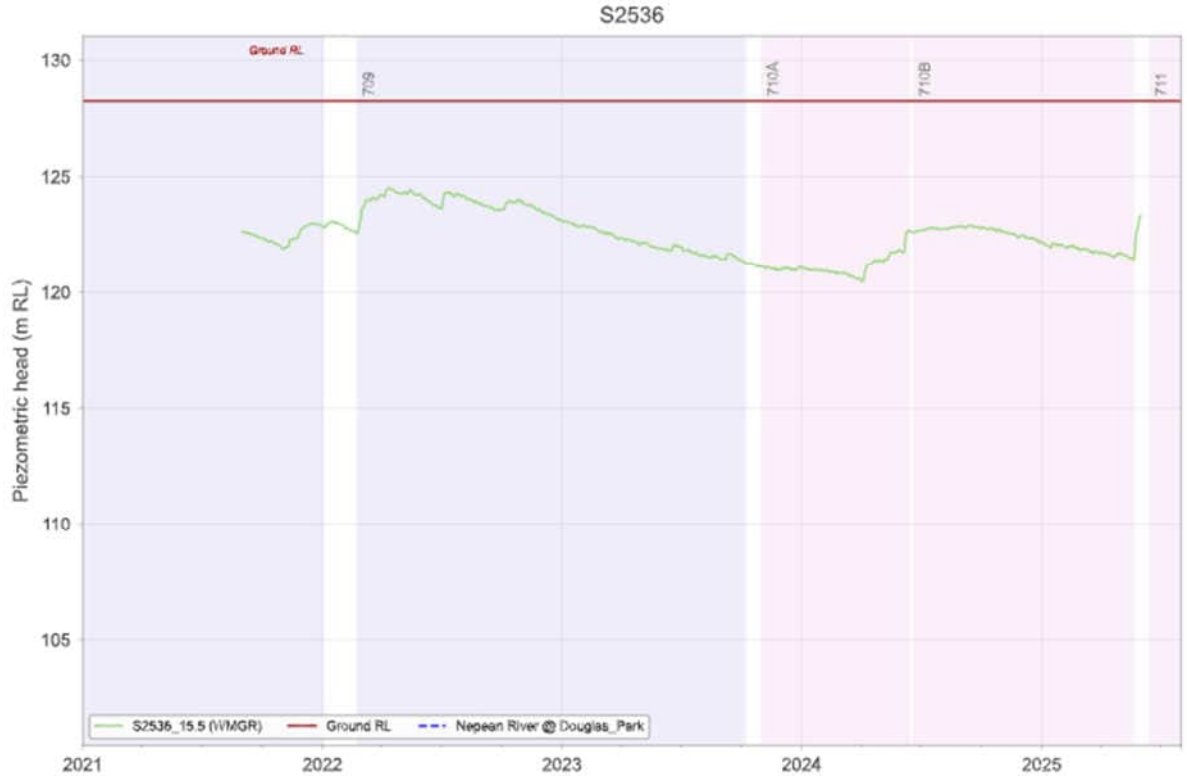

Figure 18 Hydrograph – S2536

Figure 19 shows groundwater levels at S2500 to the north of longwall 716. S2500 is a multi-level VWP with sensors at three different depths in the Wianamatta Group shales, as well as sensors in the underlying Hawkesbury Sandstone, Bulgo Sandstone, and Scarborough Sandstone. Over the period of monitoring (following stabilisation), groundwater levels ranged from a minimum of 153 m to a maximum of 155 m RL in the upper Wianamatta Group, while in the lower Wianamatta Group levels ranged from 123 m to 125 m RL.

Data for S2500 show a downward head gradient within the Wianamatta Group shales. Comparison of water levels in the Wianamatta Group to water levels in the underlying Hawkesbury Sandstone (Figure 19) show a head difference of approximately 50 m, indicating groundwater in the Wianamatta Group is perched above the regional water table.



Figure 19 Hydrograph – S2500

4.4.3 Hawkesbury Sandstone

The Hawkesbury Sandstone is the main water bearing unit in the Project area. Figure 20 shows piezometric heads at S2536A constructed in the upper Hawkesbury Sandstone (HBSS) and overlying LW715. Piezometric levels during the period of monitoring ranged between ~73 m and 77 m RL. Piezometric heads at GW108907 constructed in the mid HBSS and overlying LW712 ranged between ~75 and 87 m RL (Figure 21). The observed variations in water levels are understood to be related to variation in recharge associated with climatic conditions and pumping at nearby private water supply bores which access groundwater from the HBSS.

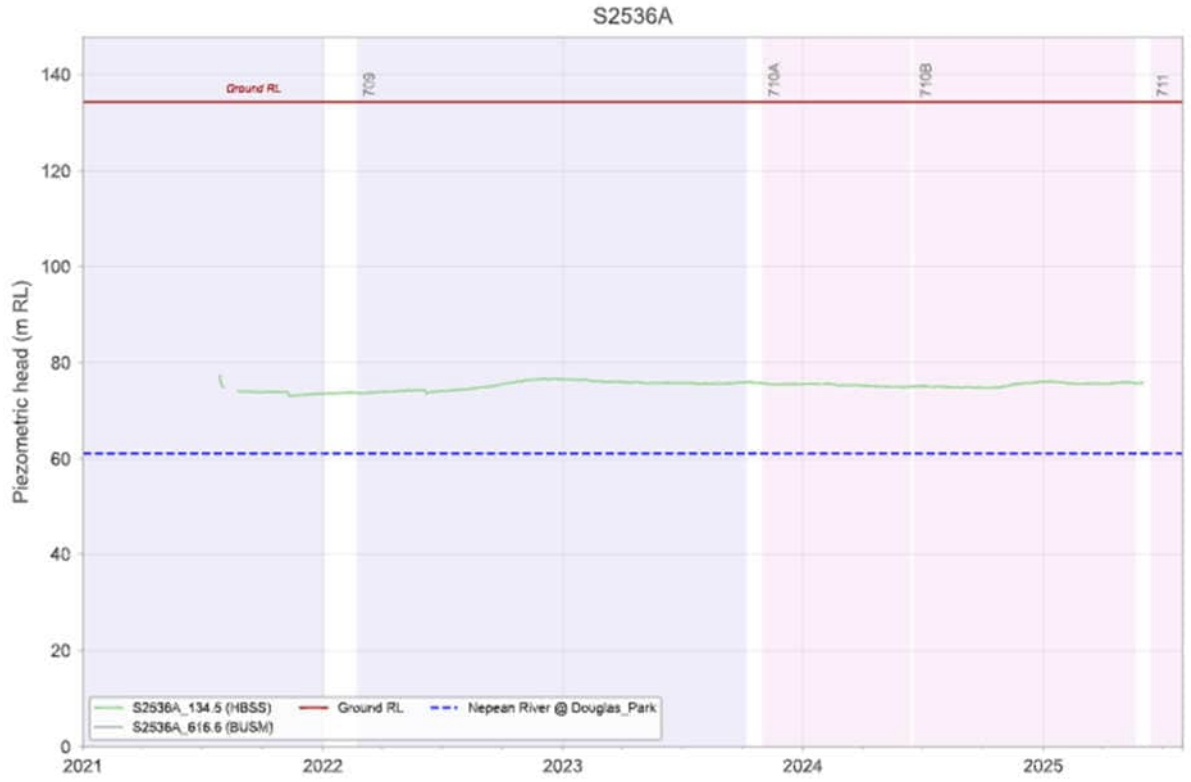

Figure 20 Hydrograph – S2536A

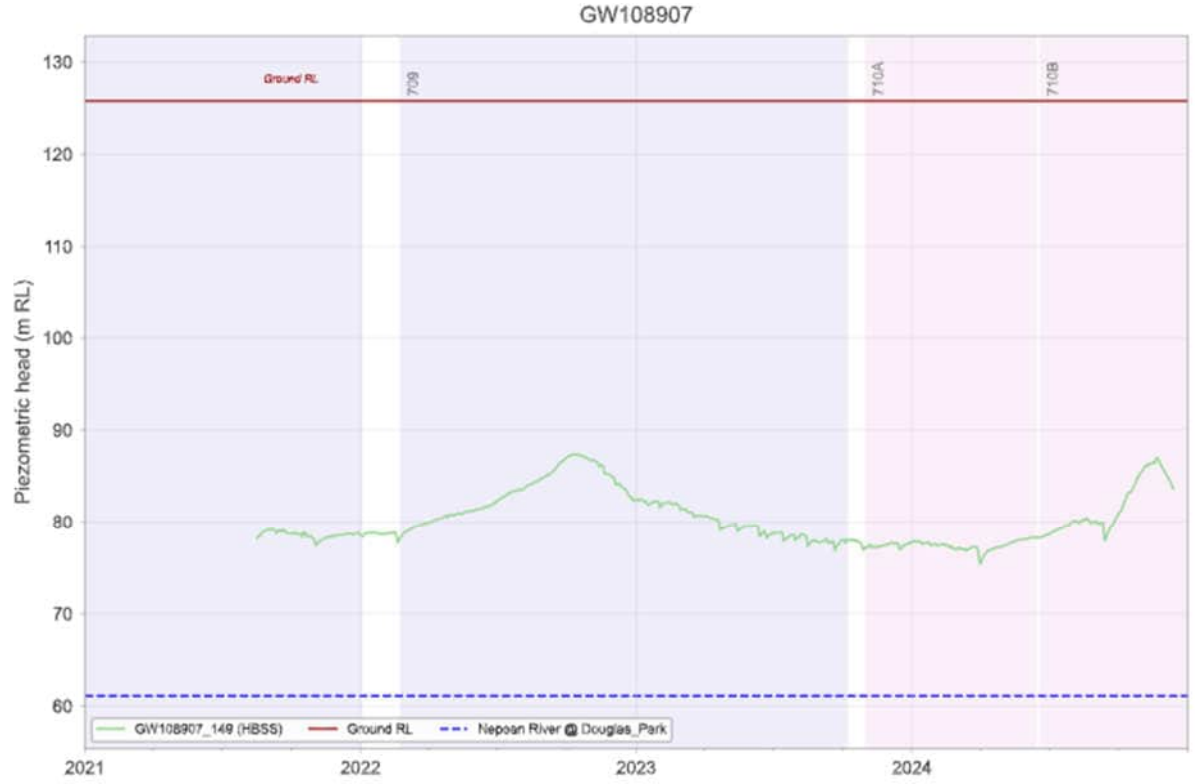

Figure 21 Hydrograph – GW108907

Figure 22 shows piezometric heads at S1913 which overlies LW712. S1913 is a multi-level VWP with sensors at three different depths in the HBSS, as well as sensors in the underlying Bulgo Sandstone, Scarborough Sandstone, and Bulli Coal Seam. Over the period of monitoring, piezometric heads ranged from 70 m to 92 m RL in the upper HBSS, and from 43 to 129 m RL in the lower HBSS (noting data are missing during the period April 2018 and August 2020). SLR (2022) report the declining trend in piezometric levels observed from 2017 to 2018 was likely a combination of response to drought (including reduced recharge and increased pumping) and mining activities in Area 9 (longwalls 901 and 902).

The data for S1913 (Figure 22) and S2500 (Figure 19) show a downward head gradient within the Hawkesbury Sandstone. Piezometric levels in the mid to upper HBSS are higher than Nepean River (which is incised into the HBSS) and indicate Nepean River is a 'gaining river' in terms of surface water - groundwater interaction. Heads within the underlying Narrabeen Group and Illawarra Coal Measures are higher than those observed in the HBSS indicating an upward head gradient.

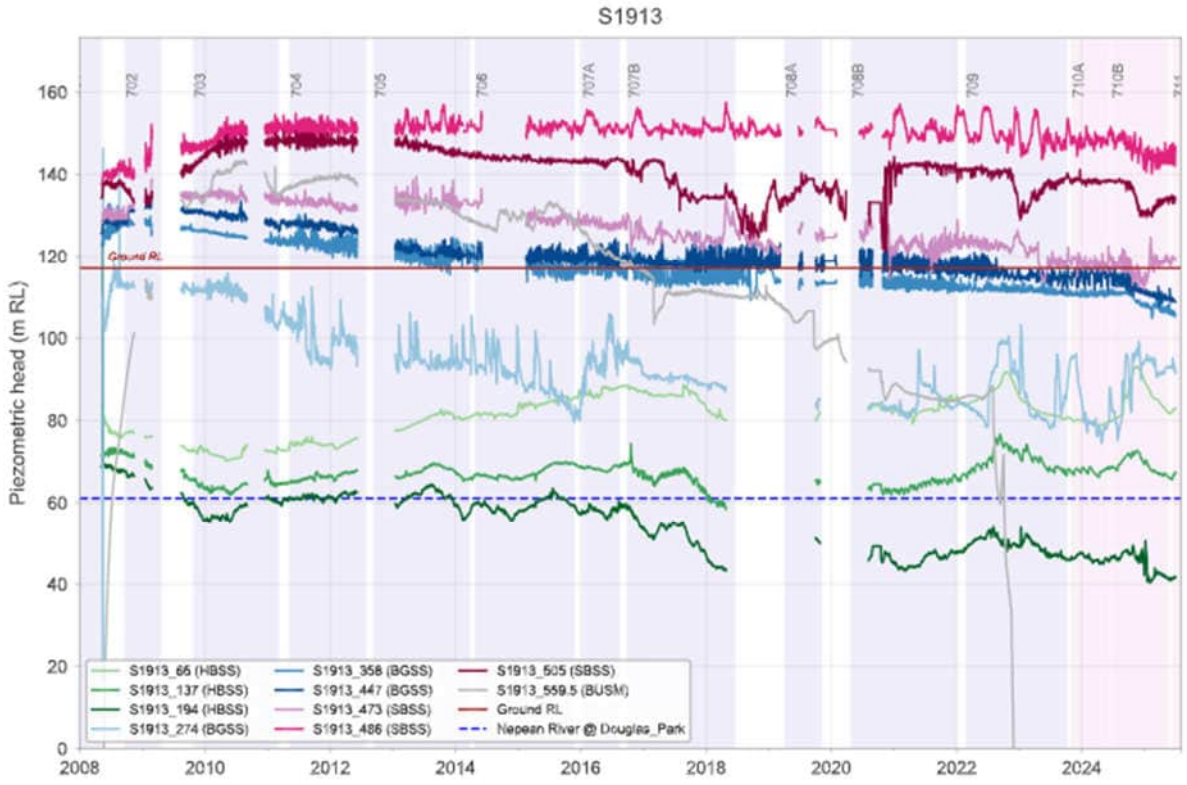

Figure 22 Hydrograph – S1913

Monitoring locations overlying and nearby longwall panels have shown evidence of drawdown in the HBSS. HGEO (2025d) report that piezometric heads in the HBSS were slightly lower during LW710 compared with the previous 12 months, with an average change of ~0.5 m and most (>92%) piezometers remaining within ±5 m of the pre-longwall median.

Changes greater than 10 m were observed in the mid and lower HBSS at two locations during LW710: S2315 and S2537 (HGEO, 2025d). Figure 23 shows piezometric head data for S2315 located 226 m north of LW710B. This VWP has sensors at three different depths in the HBSS. Mining passed closest to this VWP on 5 July 2024. More than 15 m of decline in piezometric head was observed in the lower HBSS (224.5 m) and more than 10 m of decline was observed in the mid HBSS (144.8 m) at this location. No significant change was observed in the upper HBSS piezometer at 65 m depth.

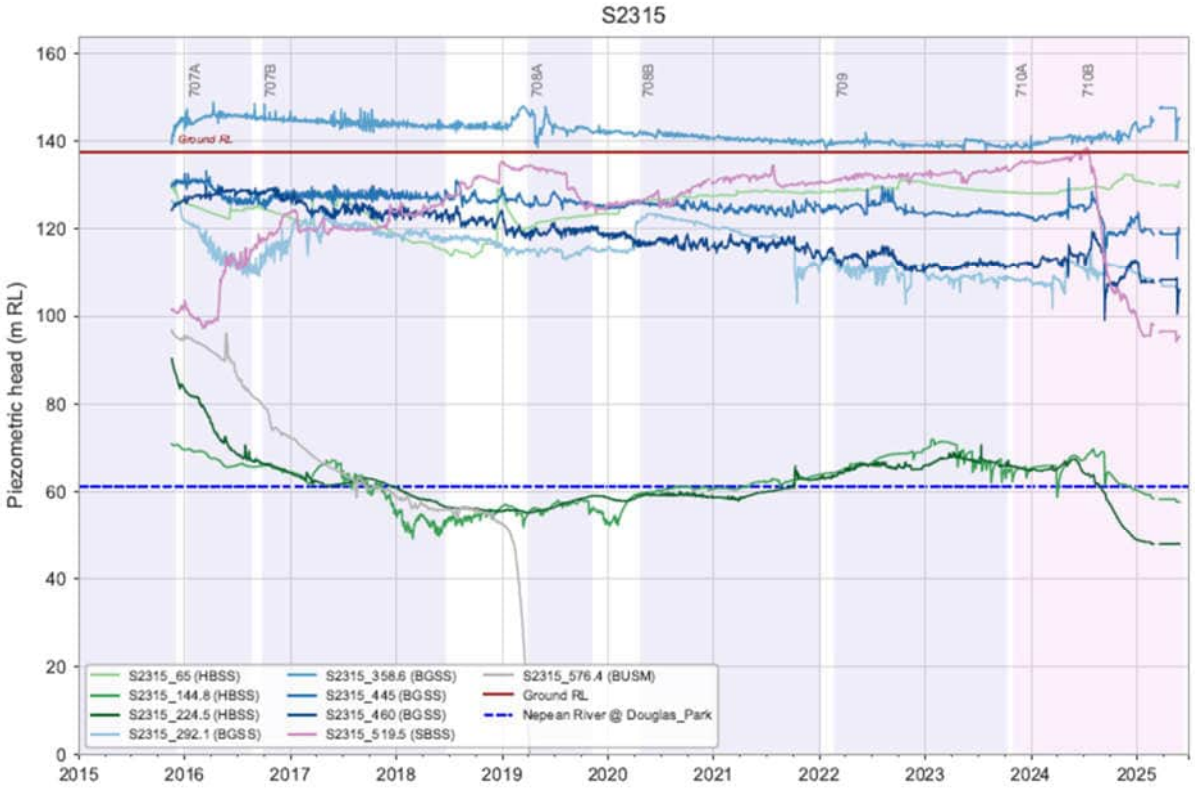

Figure 23 Hydrograph – S2315

Figure 24 shows piezometric head data for S2537 at 129 m (mid HBSS). This VWP is located above LW904 and was installed to replace the mid HBSS sensor at S1941 which was damaged during mining in 2021. Piezometer S2537_129 in the mid HBSS showed a steady decline of greater than 10 m since mining commenced at LW709 in 2022. The piezometric level in the upper HBSS at S1941_65 m (Appendix B) declined by approximately 5 m by the end of Longwall 710 compared with the pre-longwall median. HGEO (2025d) report that the observed changes at S2315 and S2537 are in the order of the SLR (2022) modelled predictions for drawdown in the HBSS within several hundred metres of the extracted longwalls.

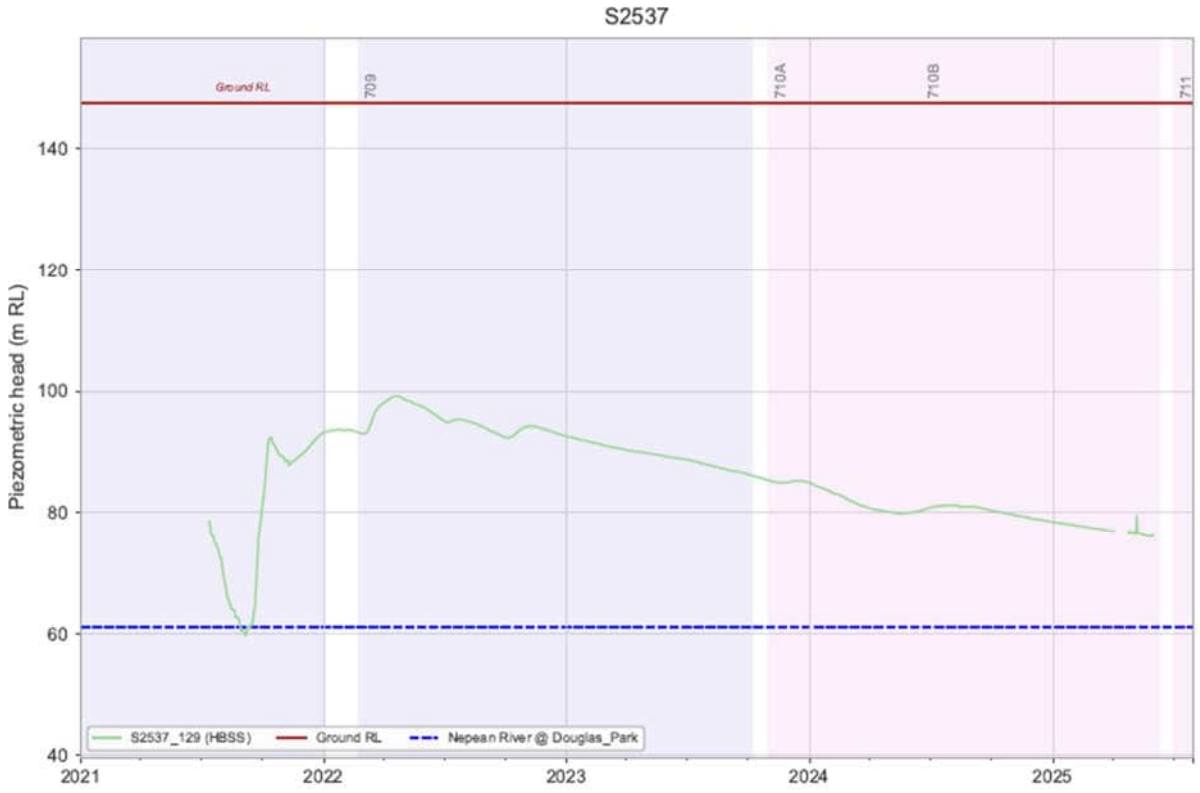

Figure 24 Hydrograph – S2537

Interpreted groundwater elevation contours for the Lower HBSS are shown in Figure 25 based on data collected in June 2025 (or where data were not available, as close to this time as possible during 2024 and 2025). Groundwater in the Lower HBSS at Appin generally flows towards the active mine dewatering area and north towards the centre of the Basin. Localised depressurisation occurs in the north (S2173) and southwest (S2160) and is likely related to pumping from private water supply bores in these areas.

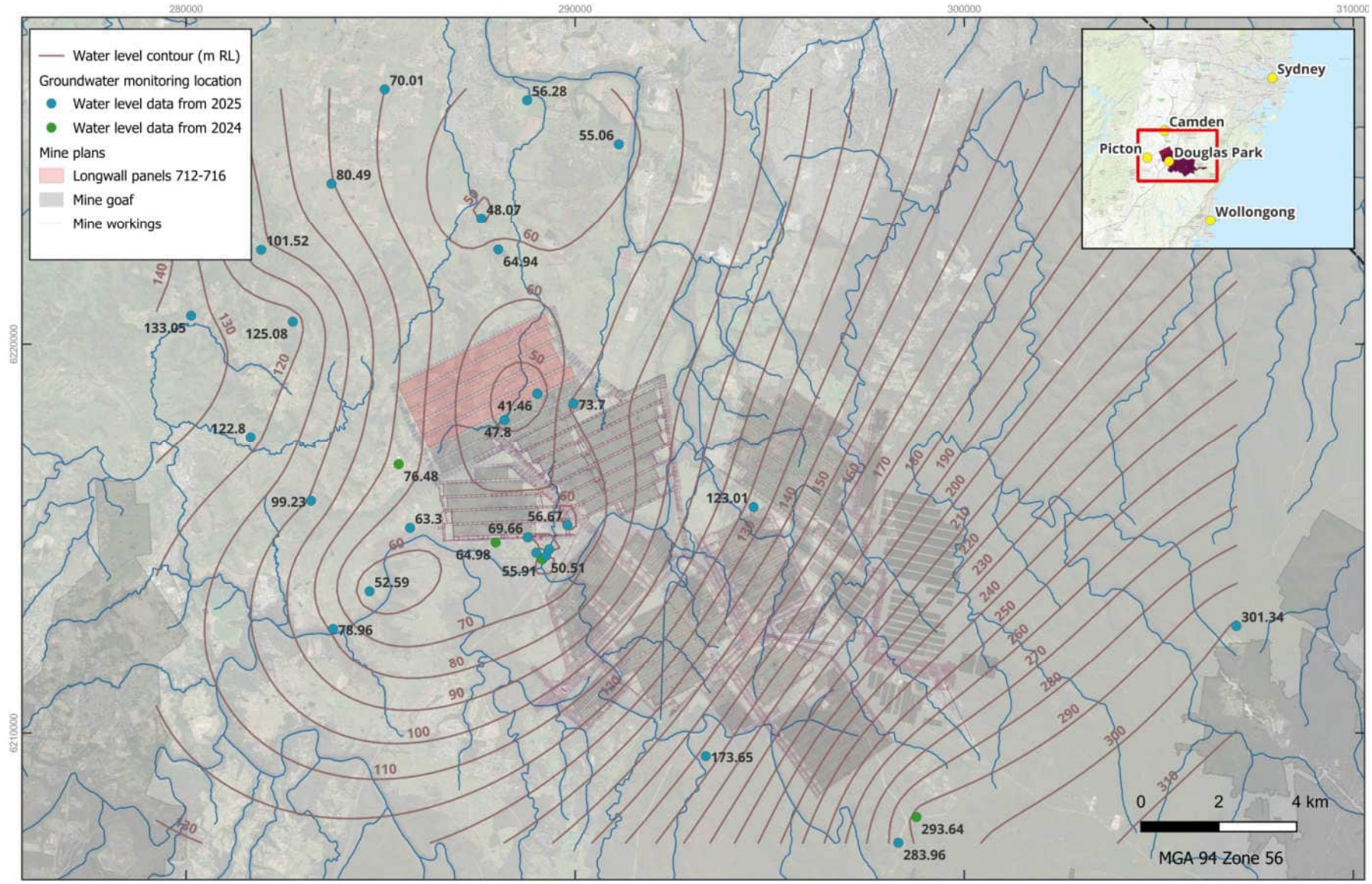

Figure 25: Inferred groundwater elevations in the Lower HBSS

4.4.4 Narrabeen Group

The Narrabeen Group is a sequence of interbedded sandstone, claystone, and siltstone. The main water bearing units are the Bulgo Sandstone and Scarborough Sandstone. These units are interbedded with formations of very low permeability (aquitards) including the Bald Hill Claystone which overlies the Bulgo Sandstone, the Stanwell Park Claystone between the Bulgo Sandstone and the Scarborough Sandstone, and the Wombarra Claystone at the base of the Narrabeen Group.

S1913 overlies LW712 and is a multi-level VWP with sensors at three different depths in the HBSS, as well as sensors in the underlying Bulgo Sandstone, Scarborough Sandstone, and Bulli Coal Seam. Piezometric head data for the upper, middle, and lower Bulgo Sandstone and upper, middle, and lower Scarborough Sandstone at VWP S1913 (which overlies LW712) is presented in Figure 22. Over the period of monitoring, piezometric heads ranged from 74 m to 115 m RL in the upper Bulgo Sandstone, from 108 m to 135 m RL in the lower Bulgo Sandstone, from 112 m to 139 m RL in the upper Scarborough Sandstone, and from 121 m to 151 m RL in the lower Scarborough Sandstone. The data indicate artesian groundwater pressures within the Project area. Piezometric heads within the Narrabeen Group are higher than within the HBSS indicating an upward head gradient.

Piezometric head data for the Bulgo Sandstone and Scarborough Sandstone are also included in Figure 19 (VWP S2500) and Figure 23 (VWP S2315). The data show long term declining trends in piezometric heads for the Bulgo Sandstone which are interpreted to be related to gradual depressurisation associated with the progression of longwall mining in Areas 7 and 9 and groundwater abstraction for the Camden Gas Project which occurs within and to the north of the Project area (Figure 10).

Figure 26 shows piezometric heads at S1941 which overlies LW709. S1941 is a multi-level VWP with sensors at three different depths in the Bulgo Sandstone and three different depths in the Scarborough Sandstone, as well as sensors in the overlying HBSS and underlying Bulli and Wongawilli coal seams. The hydrograph indicates gradual depressurisation of the Bulgo Sandstone and Scarborough Sandstone with the progression of mining of the Bulli Seam.

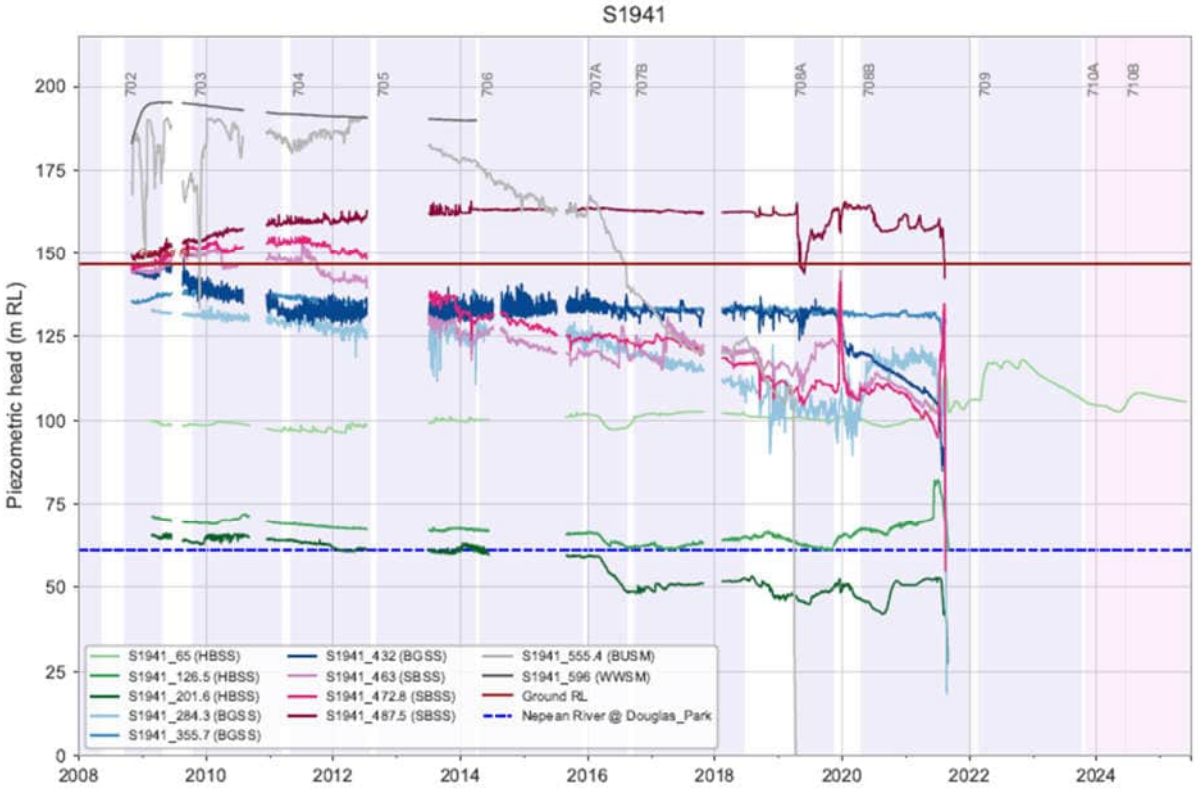

Figure 26 Hydrograph - S1941

Interpreted groundwater level elevation contours for the Upper Bulgo Sandstone are shown on Figure 27 based on data collected in June 2025 (or where data were not available, as close to this time as possible during 2024 and 2025). Groundwater in the Upper Bulgo Sandstone at Appin generally flows towards the active mine dewatering area and to the north towards the centre of the Basin and where production wells for the Camden Gas Project are located (Figure 10).

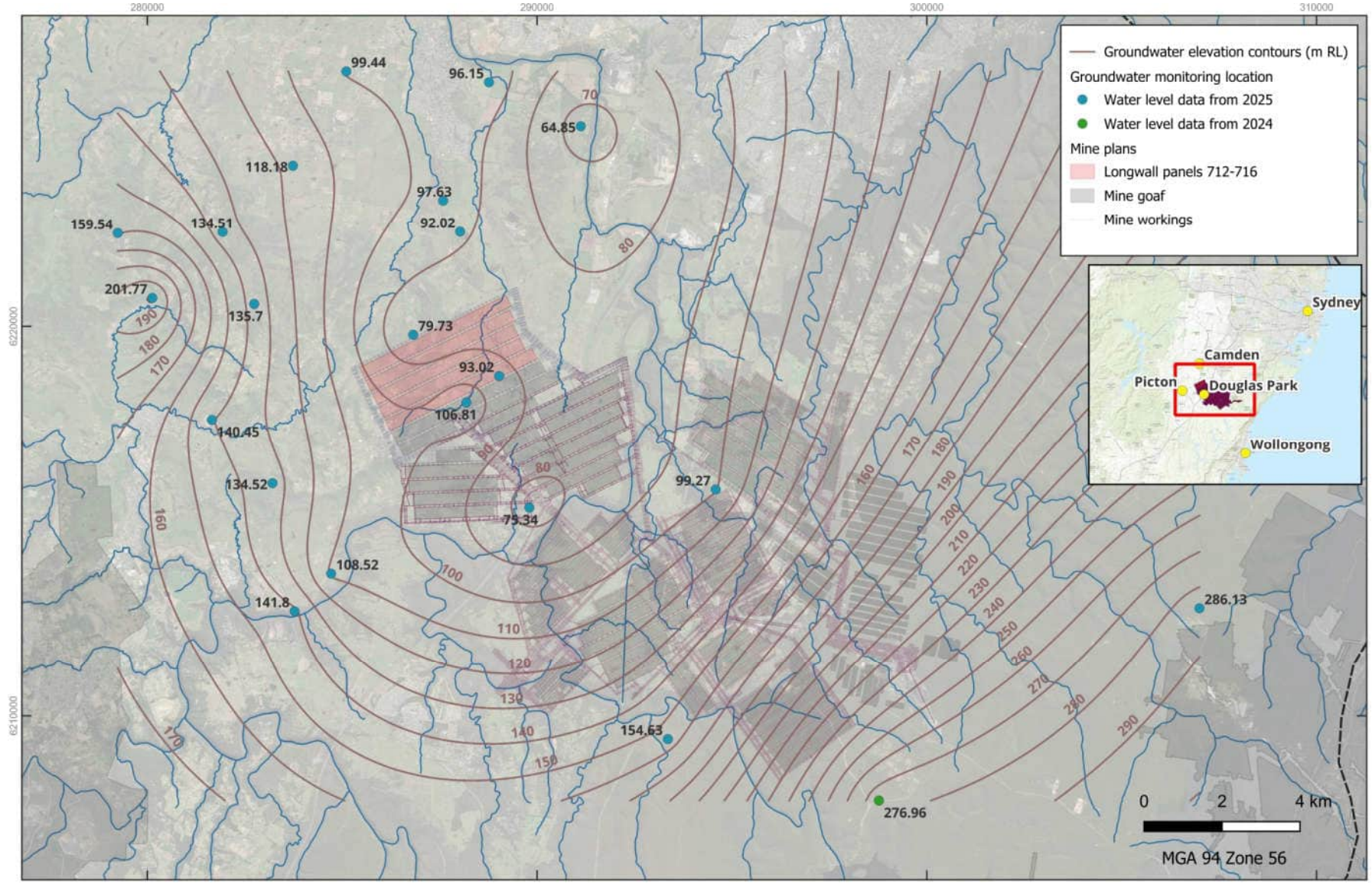

Figure 27: Inferred groundwater elevations in the Upper Bulgo Sandstone

4.4.5 Illawarra Coal Measures

The Illawarra Coal Measures comprise interbedded sandstones, shale and coal seams. The two main coal seams mined in the Southern Coalfield are the uppermost Bulli Seam and the Wongawilli Seam. The target formation at Appin Mine is the Bulli Seam.

Figure 28 shows piezometric heads at S2027 constructed in the Bulli Seam and overlying LW714. Piezometric levels during the period of monitoring ranged between 155 m and -168 m RL. The hydrograph shows a significant decline in heads of more than 320 m in response to coal seam gas extraction activities in the area (Figure 10) and longwall mining at Appin.

Multi-level VWPs within and close to the Project area with sensors in the Bulli Seam (as well as overlying formations) include S1913 (Figure 22) which overlies LW712, S2315 (Figure 23) which overlies LW711, and S1941 (Figure 26) which overlies LW709. S1941 (Figure 26) also has a sensor in the Wongawilli Seam (although data are missing after March 2014). The data indicate artesian groundwater pressures in Bulli Seam. Piezometric heads within the Illawarra Coal Measures (pre-mining) are higher than within the Narrabeen Group and HBSS indicating an upward head gradient.

The hydrographs show a significant decline in piezometric levels in the Bulli Coal Seam in response to coal seam gas extraction activities in the area (Figure 10) and longwall mining at Appin. Piezometric head data indicates depressurisation of 550 m at S1913, 510 m at S2315, and 506 m at S1941.

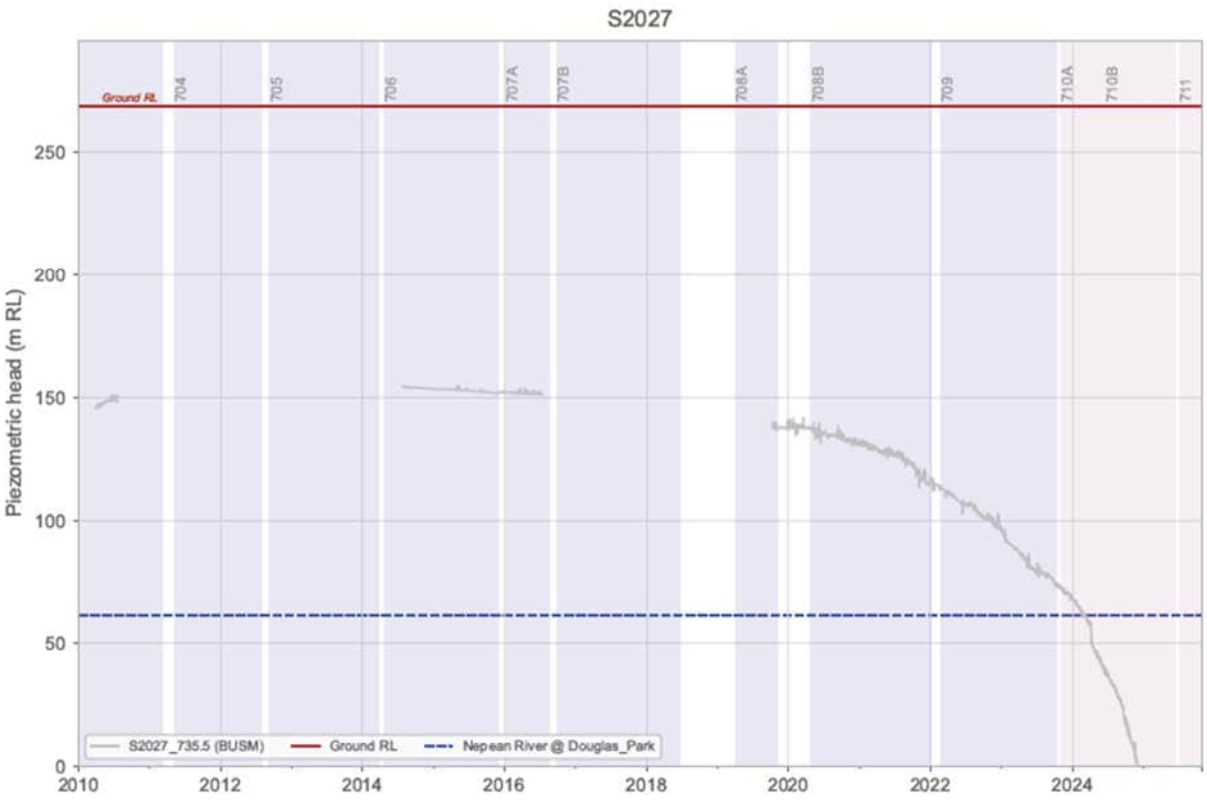

Figure 28 Hydrograph - S2027

Figure 29 shows the inferred potentiometric levels in the Bulli Seam based on data collected in June 2025 (or where data were not available, as close to this time as possible during 2024 and 2025). Historical mining activities at Appin have resulted in significant depressurisation of the Bulli Seam and groundwater flow is towards the mine workings. Significant depressurisation of the Bulli Seam is also observed to the north of the Appin Mine related to coal seam gas extraction activities.

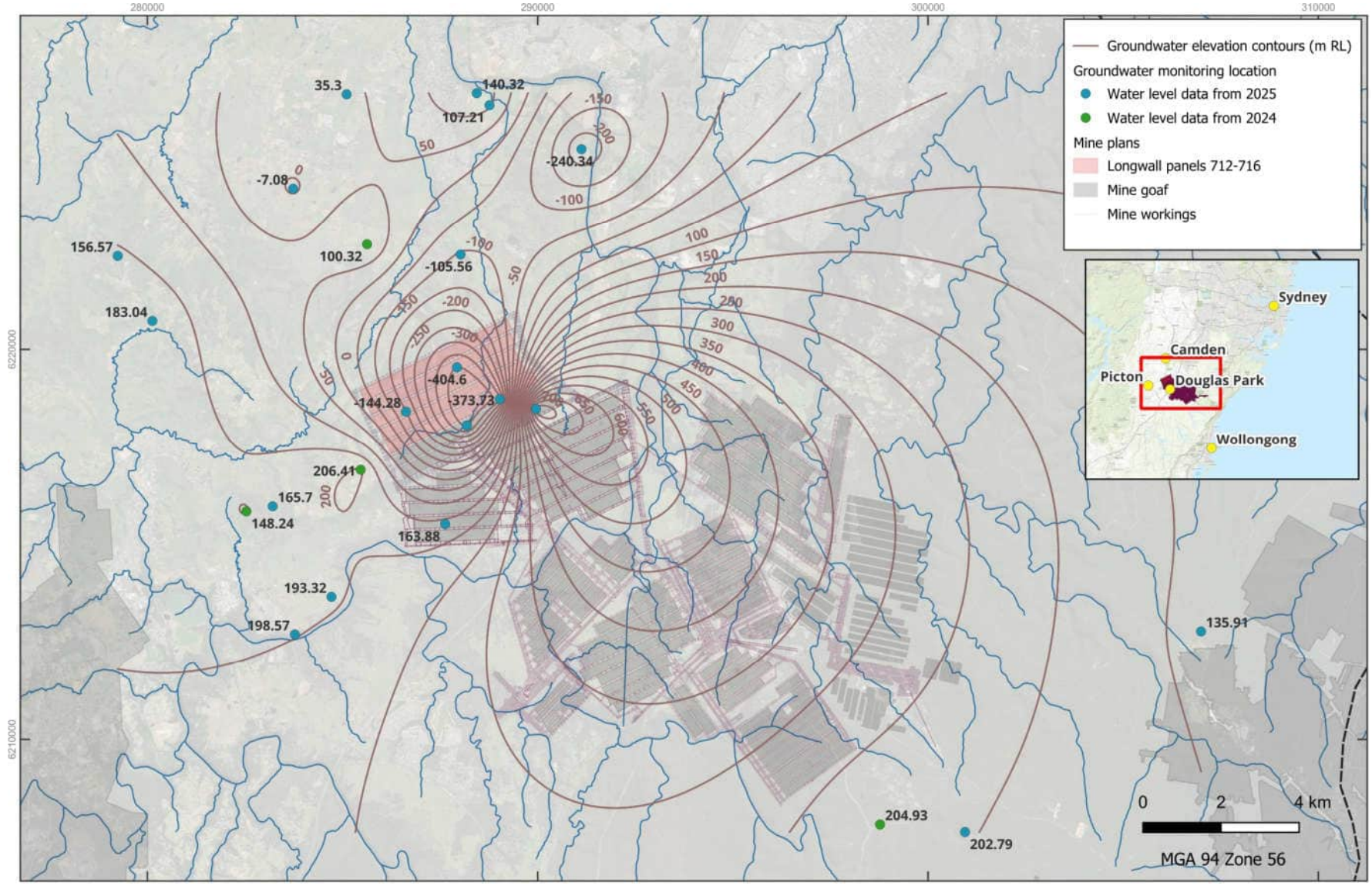

Figure 29 Inferred groundwater elevations in the Bulli Seam

4.5 Hydraulic properties

Hydraulic properties that influence regional groundwater flow and responses to mining include permeability—expressed as horizontal (Kh) and vertical (Kv) hydraulic conductivity—porosity (η), and aquifer storage, namely specific storage (Ss) and specific yield (Sy). These properties are quantified in this section based on field investigations and laboratory-derived measurements.

Longwall mining subsidence can result in significant changes in the hydraulic properties of water bearing formations. These changes are discussed in Section 4.10.2.

The statistics presented in this section are for pre-mining strata properties. These form the basis for parameterisation of the numerical groundwater model and constrain the range of hydraulic properties during the history matching process.

4.5.1 Hydraulic conductivity (K)

In this section we review available measurements of hydraulic conductivity (K) for the key hydrostratigraphic units in the model domain and explain how they inform initial model parameters for a regional simulator that assumes isotropy in the horizontal plane (single K_h) with a distinct vertical conductivity (K_z). In layered systems, effective K parallel to bedding is well represented by the thickness-weighted arithmetic mean, while vertical flow across beds is governed by the thickness-weighted harmonic mean; in laterally heterogeneous units where K is approximately log-normal, the geometric mean provides a realistic central estimate, and in all cases the effective K is bounded by the harmonic and arithmetic limits (Renard & De Marsily, 1997). A recent peer-reviewed synthesis confirms the continued relevance of these averaging schemes for both porous and fractured media and summarises modern upscaling approaches suitable for regional models (Cetre-Orejuela et al., 2024). Accordingly, for each layer we report thickness-weighted arithmetic, geometric and harmonic means of packer-test K, along with log-space percentiles (e.g., P10–P90) to define plausible prior bounds; these provide defensible starting values—arithmetic or geometric means for K_h as guided by geology, and the harmonic mean for K_z—that are then refined through history-matching against the groundwater-level dataset to ensure consistency with observed system behaviour.

Hydraulic conductivity (K) is the ability of a rock mass to transmit water under a specified hydraulic gradient. In situ assessment of K within rock strata is commonly conducted using packer tests (also referred to as Lugeon tests), which isolate discrete intervals of a borehole using a pair of inflatable rubber packers that seal against the borehole wall. Controlled pressure is then applied to each isolated section to evaluate the hydraulic conductivity of the adjacent formation and to characterise the transmissivity of any intersecting fractures (Houlsby, 1976). For coal seams, hydraulic properties are more reliably characterised using injection fall-off tests (IFOTs). These tests operate on similar principles to packer tests but are specifically adapted to the low-permeability and anisotropic nature of coal, providing more representative estimates of seam-scale conductivity.

The hydraulic conductivities of the hydrostratigraphic units at Appin are well characterised with data available for 3,728 packer or IFOT tests conducted at Appin Mine, neighbouring mines, and other projects across the Sydney Basin. Table 8 presents the K statistics for the major hydrostratigraphic units that have been used to define the initial K values in the numerical model and plausible ranges for history-matching.

Hydraulic conductivity vs depth

Scatter plots of pre-mining hydraulic conductivity versus depth for each major stratigraphic unit are presented in Figure 30, Figure 31, and Figure 32. Most of the upper stratigraphic units display a trend of decreasing hydraulic conductivity with depth. Linear regression of the log-transformed packer test data indicates that the trend is significant (at the 95% confidence level) for the Hawkesbury Sandstone, Narrabeen Group, and the coal and interburden units (except for the Loddon and Lawrence sandstones).

The regression intercepts and slopes are broadly similar for the Hawkesbury Sandstone and Narrabeen Group. The implication is that the depth dependence of hydraulic conductivity is somewhat independent of lithology and stratigraphic unit. A decrease in hydraulic conductivity with depth is well recognised in the Hawkesbury Sandstone (Tammetta & Hewitt, 2004) and is related to a decrease in weathering, fracture frequency and aperture width with increasing depth.

The packer test results have been used to assign initial values for hydraulic conductivity in the numerical model in dipping strata according to their depth of burial and to layer subdivisions within stratigraphic units. For stratigraphic units where linear regression indicated the trend with depth was not significant, the arithmetic mean was adopted in the model for Kh.

Hydraulic conductivity vertical anisotropy

In layered sedimentary rocks, the horizontal hydraulic conductivity (Kh) is typically higher than the vertical hydraulic conductivity (Kv) by one or more orders of magnitude (where “horizontal” and “vertical” are relative to the orientation of the bedding). This anisotropy arises because groundwater tends to migrate more readily along laterally continuous, high-permeability layers such as coarse sandstones, while vertical movement is restricted by interbedded low-permeability units like claystones or siltstones.

The degree of anisotropy can vary at scales from centimetres to hundreds of metres (the scale of the formation). Where the rock mass is fractured, groundwater flow is predominantly governed by the geometry, connectivity, and hydraulic properties of the fracture network. Such fracture-dominated flow regimes are especially pronounced in zones impacted by mine subsidence, faulting, or jointing—particularly above the goaf, where deformation enhances secondary permeability.

Aquifer anisotropy can be important in controlling the propagation of groundwater drawdown impacts from mining and is therefore an important parameter in a numerical model. Packer testing does not measure Kv directly; however, Kv can be estimated using the data on the assumption that Kv = Kh at the scale of the measurement. Packer testing results are at the scale of tens of metres and the measurements include permeability due to fracture flow, where fractures are present. According to Domenico and Swartz (1998), for a sedimentary sequence comprising multiple layers, the equivalent Kh and Kv of the sequence is given by the arithmetic mean and harmonic mean of the layer Kh values, respectively. Estimates of vertical anisotropy for the hydrostratigraphic units as expressed by the ratio of Kv/Kh are shown in Table 8 and have informed the values adopted for numerical modelling.

Table 8 Hydraulic conductivity data summary

Formation	Number of tests	Arithmetic mean K (m/day)	Geometric mean K (m/day)	Harmonic mean K (m/day)	P10 K (m/day)	P90 K (m/day)	Harmonic mean/ Arithmetic mean	Significant trend with depth
WMGR	42	**4.0E-02**	4.29E-04	2.28E-05	8.64E-06	1.30E-01	**5.63E-04**	Yes; p = 1.3E-02
HBSS	1124	**1.6E-02**	1.22E-03	3.08E-05	1.04E-04	1.47E-02	**1.97E-03**	Yes; p = 8.0E-39
BACS	265	**2.6E-03**	1.14E-04	6.26E-06	8.64E-07	2.49E-03	**2.41E-03**	Yes; p = 2.0E-05
BGSS	1083	**1.1E-03**	8.28E-05	5.74E-06	8.64E-07	1.33E-03	**5.18E-03**	Yes; p = 9.2E-31
SPCS	70	**7.8E-03**	5.21E-05	5.79E-06	8.64E-07	1.92E-03	**7.39E-04**	Yes; p = 5.9E-06
SBSS	190	**6.3E-03**	4.65E-05	3.71E-06	8.64E-07	1.30E-03	**5.91E-04**	Yes; p = 8.6E-08
WBCS	137	**2.4E-03**	6.68E-05	5.80E-06	8.64E-07	8.99E-04	**2.41E-03**	Yes; p = 1.5E-05
CCSS	94	**2.6E-03**	5.38E-05	5.21E-06	8.64E-07	8.03E-04	**2.02E-03**	Yes; p = 7.5E-05
BUSM	298	**6.4E-03**	1.30E-03	5.81E-05	7.93E-05	1.70E-02	**9.03E-03**	Yes; p = 4.4E-20
LDSS	11	**5.6E-04**	1.93E-05	2.27E-06	8.64E-07	1.07E-03	**4.04E-03**	Not significant (p > 0.05)
LRSS	14	**4.1E-04**	1.17E-05	1.91E-06	8.64E-07	1.42E-03	**4.64E-03**	Not significant (p > 0.05)
Coal Interburden	81	**5.4E-04**	1.06E-04	1.25E-05	8.64E-06	1.36E-03	**2.29E-02**	Yes; p = 2.2E-02
WWSM	211	**6.6E-03**	5.54E-04	3.73E-05	1.76E-05	1.09E-02	**5.69E-03**	Yes; p = 5.3E-08
KBSS	19	**6.4E-05**	8.14E-06	2.15E-06	8.64E-07	1.16E-04	**3.35E-02**	Yes; p = 1.2E-02
Below WWSM	89	**5.6E-04**	1.16E-04	2.69E-05	1.16E-05	2.12E-03	**4.84E-02**	Not significant (p > 0.05)

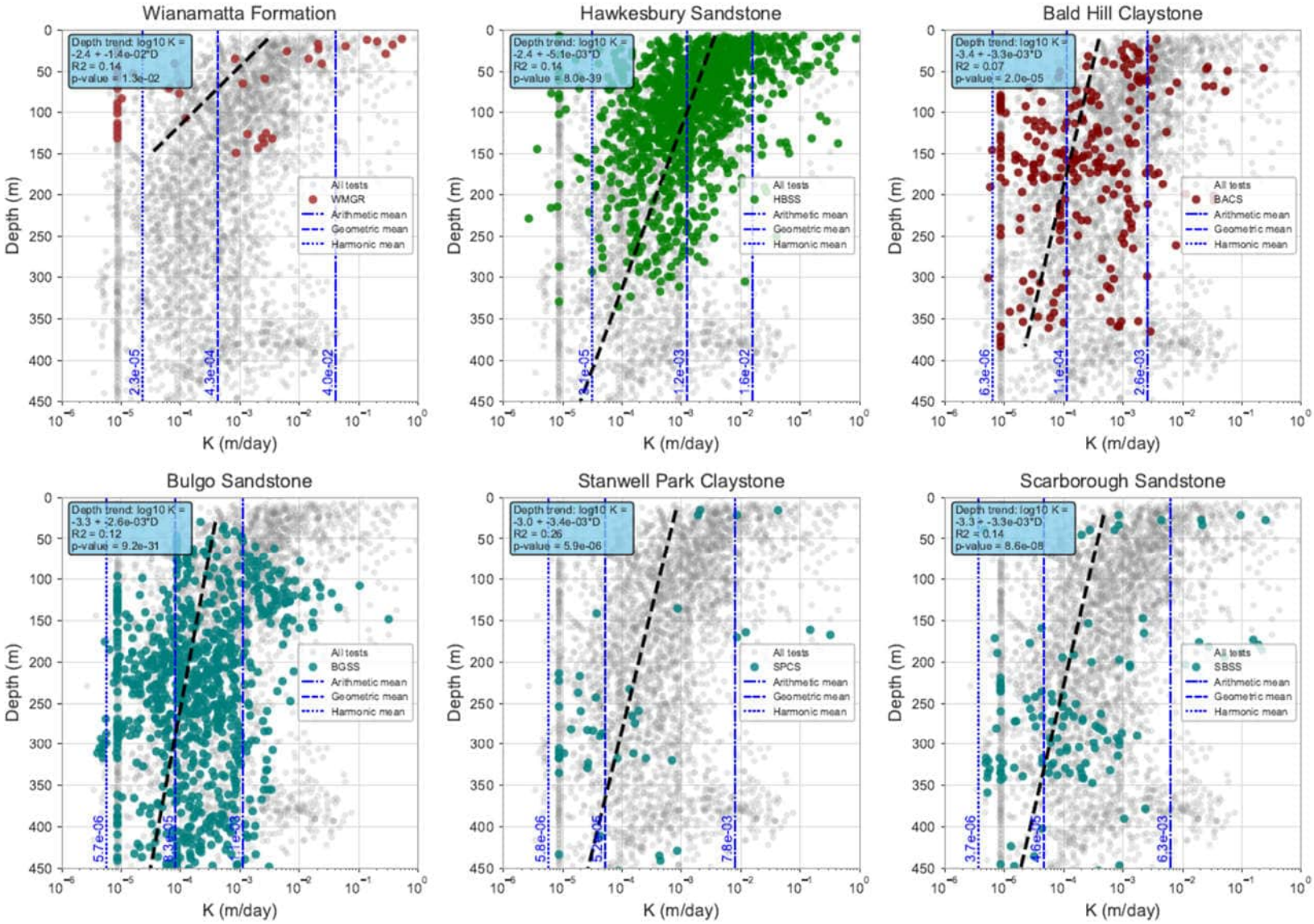

Figure 30: Hydraulic conductivity vs depth (packer test data)

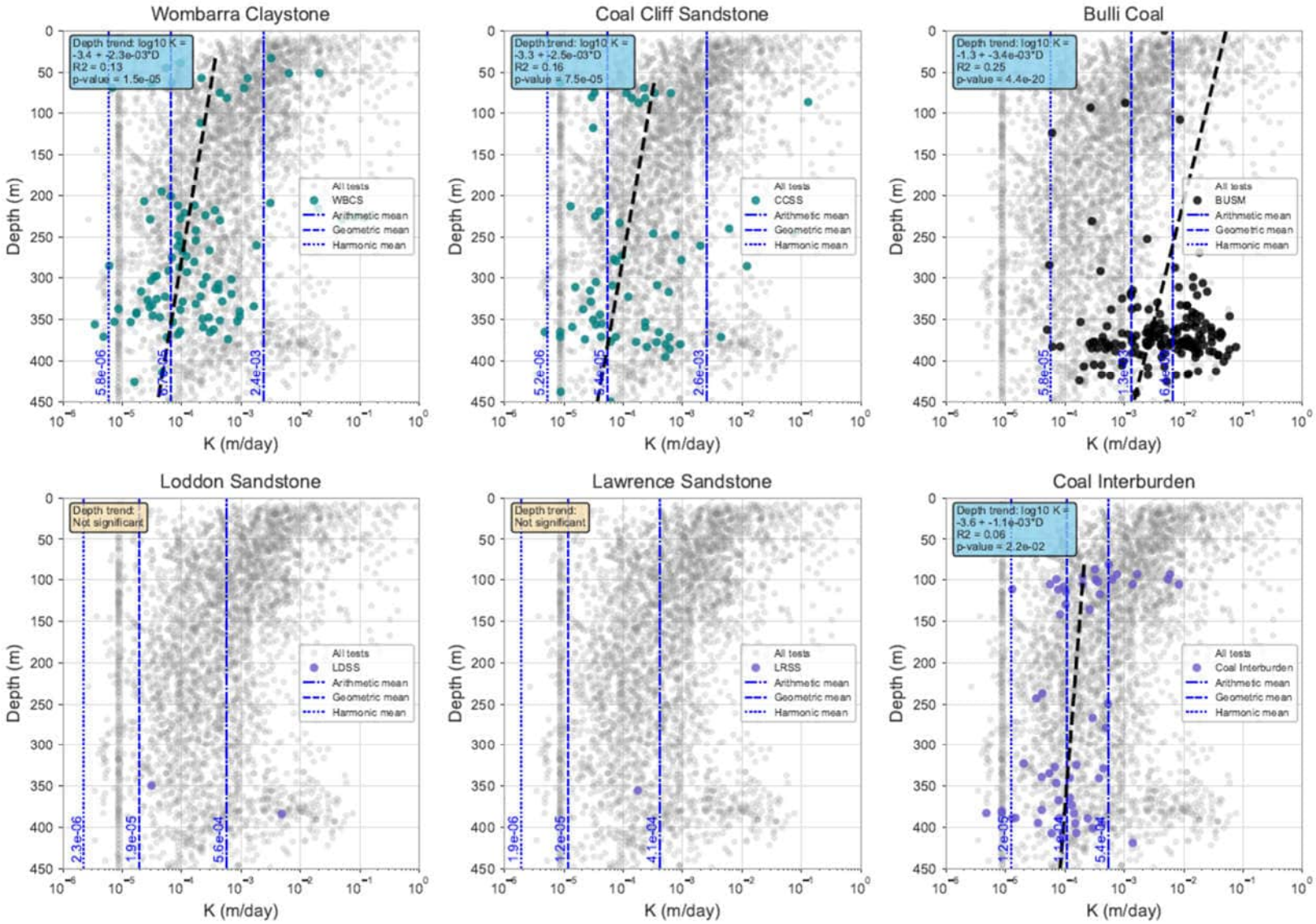

Figure 31: Hydraulic conductivity vs depth (packer test data)

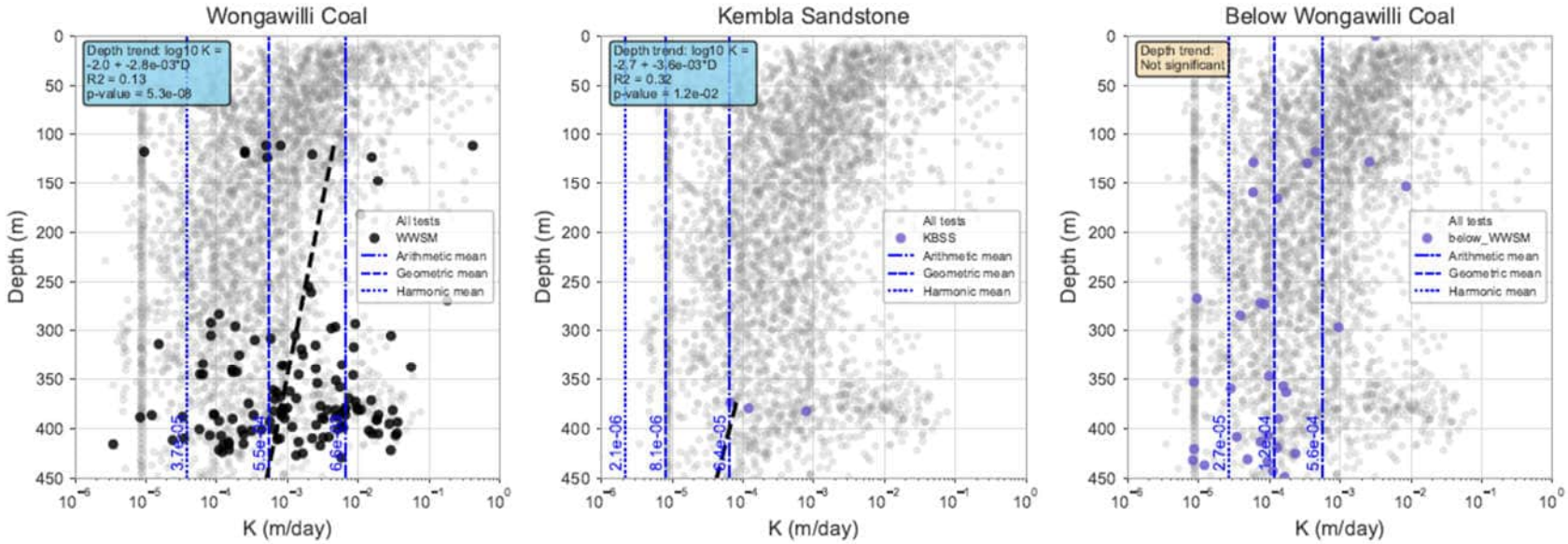

Figure 32 Hydraulic conductivity vs depth (packer test data)

4.5.2 Aquifer Storage Properties (Sy and Ss)

There are no field data for Appin Mine that can be used to estimate specific yield (Sy) or specific storage (Ss).

Specific yield (Sy)

Watershed Hydrogeo (2025) report total and effective porosity based on laboratory testing of core samples collected from the upper stratigraphic units, including the Hawkesbury Sandstone, Newport Formation, Bald Hill Claystone and Colo Vale Sandstone (the equivalent of the Bulgo Sandstone) at Appin and Dendrobium mines. Effective porosity is considered an approximation of Sy, although it is recognised that laboratory-determined effective porosity may be an overestimate of the porosity that is 'drainable' in the field.

The available porosity data show a decline with depth, similar to hydraulic conductivity. Storage properties are expected to decrease with depth due to a reduction in porosity from overburden pressure. Studies conducted in the Sydney metropolitan area and elsewhere indicate a specific yield of between 1 and 2% is reasonable for typical HBSS (Tammetta & Hewitt, 2004). The data for samples collected at Appin Mine indicate substantially higher values with effective porosity measured at 11% (n = 2) and a total porosity of 15% (n = 4) for the HBSS. Specific yields for Sydney Basin sedimentary strata in the context of drainage due to longwall subsidence generally vary between 0.005 and 0.015 (Watershed HydroGeo, 2025).

Watershed Hydrogeo (2025) also report the results of Borehole Magnetic Resonance (BMR) imaging conducted at selected drillholes at Dendrobium Mine to provide continuous logging of density, gamma count, porosity and hydraulic conductivity. BMR porosity estimates were made on a 0.1 m interval, with estimates of total porosity and three constituents: clay-bound water, capillary water, and 'free water'. Of these constituents, free water + capillary water = effective porosity, and it was considered that 'free water' is equivalent to drainable porosity or Sy. The BMR 'free water' results indicated that Sy is in the range 1% to 6.3%. For the HBSS, the BMR free water volume (approx. 6%) and estimated effective porosity from BMR (6 + 4 = 10%) compare well against the effective porosity from the laboratory (11%).

The data from the core tests and BMR (Watershed HydroGeo, 2025) and from previous modelling will be used as the basis for the initial parameterisation of the groundwater model.

Specific storage (Ss)

Field data or direct measurements of specific storage (Ss) are generally not available. The specific storage of HBSS has been estimated to be approximately 1.0 x 10^{-6} m^{-1} in the shallower zones where fracture flow is the dominant flow process (Kelly et al., 2005). Results of long duration pump testing in the HBSS in western Sydney (Tammetta & Hawkes, 2009) provide a similar estimate of 1.5 x 10^{-6} m^{-1} for depths between ground surface and 300m.

Estimates of Ss can also be derived from mechanical properties such as Young's Modulus and porosity, using calculations in Mackie (2009) and porosity values obtained from core testing (Evans et al., 2015). Calculations for Appin suggest that Ss lies in the range 5 x10^{-6} m^{-1} to 5x10^{-5} m^{-1} for coal, and from 1.7x10^{-6} m^{-1} (unfractured, fresh rock) to 8x10^{-6} m^{-1} (fractured rock) for interburden (SLR, 2021).

These estimates are similar to model parameters for other mines in the Southern Coalfield which suggest that Ss is in the order of 1 x 10^{-7} to 3 x 10^{-5} m^{-1} for the coal seams, and about 1 x 10^{-6} m^{-1} for

overburden or interburden (Watershed HydroGeo, 2025). As in previous modelling, a broad trend of generally decreasing Ss with depth is represented in modelling, based on overburden pressure at depth steadily decreasing the 'elastic storage' of the rock formation.

4.6 Structure and groundwater flow

Geological faults are displacements within otherwise intact rock material. The potential influence of faults on surface and groundwater systems is variable. In some cases, faults can have little to no influence on groundwater flow, and in other situations faults can provide a barrier, a flow pathway or a combination of a barrier (to horizontal flow) and a conduit (upward or downward flow via the damage zone) that results in significant changes to water assets and GDEs (IESC, 2021). A fault may exhibit more than one of these characteristics along its length and these may alter over time.

The IESC (2021) Explanatory Note *Characterisation and modelling of geological fault zones* provides guidance on methods to assess whether faults are a barrier or flow pathway, or both, and approaches to represent and parameterise faults in groundwater flow models to enable risks to groundwater assets to be assessed. The document notes that predicting the range of possible groundwater behaviours during and after a coal development requires the identification and characterisation of faults in the area of study or, alternatively, consideration of evidence that faults are absent or cannot have a significant influence on groundwater systems.

The Southern Coalfield mapping (Moffitt, 1999) indicates there are no major regional-scale geological structures intersecting the proposed mine workings (Figure 12). Local-scale structures identified at the coal seam level by ICHPL geologists, including possible structures interpreted from aeromagnetic data, are shown in Figure 13. There are two NNW-SSE orientated zones of geological structure within the Project area that cross the western ends of LW712 to LW716 and the eastern end of LW712 and possibly extend through the eastern ends of the other proposed longwalls. These zones comprise a series of dykes with thicknesses up to approximately 3.5 m and minor faults with displacements up to approximately 3 m (MSEC, 2025). Elsewhere, minor faults with displacements up to approximately 1 m cross the proposed LW712 to LW716.

The two NNW-SSE oriented zones of geological structure extend through longwalls that have previously been mined, including LW903, LW904, LW709, LW710A, and LW710B (Figure 13). Observations made during mining of these longwalls indicate there was no increase in inflows during mining through these structures. This suggests that these fault and dyke zones are not strongly influencing groundwater flow. This is further supported by mine water balance data which show no correlation between structures and mine inflow rates.

Figure 33 shows daily mine water balance data for Areas 7 and 9. The daily mine water balance is monitored by ICHPL and tracks daily volumes of water pumped into the mine (supply), within the mine, and from the mine into storage and/or discharge. The rate of groundwater inflow is determined by subtracting the estimated water supply volume from the total volume of water pumped to storage.

The mine water balance data shown in Figure 33 was collected by two separate operators (one shown in green and the other shown in purple on the graph). The two datasets show differences in the estimated mine inflows and indicate there is uncertainty in the water balance estimates. The management of water in a longwall mining operation is a complex and dynamic process with pumps, sumps, and pipes needing to be continuously moved and modified to supply water for essential activities such as dust suppression, equipment cooling, and drilling operations while simultaneously removing water ingress to maintain safe working conditions and prevent inundation. The increase in the net water balance in Area 7 since the commencement of Longwall 710A has been attributed to increased water use by new underground mining equipment, and no increase in inflow from the workings, including intersected structures, has been observed by underground personnel. As such, the apparent increase in net inflow is likely to be an artifact of changed water use and underground storage.

The vertical lines on Figure 33 show the dates when mining intersected zones of geological structure (mapped at the seam level) with the locations where structure were intersected shown on the inset maps below. The data do not show higher inflows associated with mining through zones of geological structure, with only one intersection out of six intersections corresponding in time with an increase of inflow. As outlined in the previous paragraph, that increase is believed to be associated with a change in underground mining equipment, rather than in increase in groundwater ingress. This supports the observations and conceptual understanding that these fault and dyke zones are not transmissive and do not produce significant groundwater inflow when intersected.

The interpretation that the fault and dyke zones at Appin are not influencing groundwater flow is consistent with other studies of fault behaviour in the Southern Coalfield. SRK (2020) conducted an independent review of the Dendrobium Coal Mine surface lineament interpretation and found that the conditions at Dendrobium (Southern Coalfield) are different to those in the Western Coalfield (e.g. at Springvale Mine) where lineaments around mining areas enhanced subsidence effects to significant distances, leading the transmission of effects out to hundreds of metres or a kilometre or so from Springvale workings. SRK's conclusions, based on review of structural and historical subsidence data, were that the potential for lineaments to be real geological features that re-activate and enhance subsidence or drawdown effects is minimal at Dendrobium. Other studies at Dendrobium have similarly found no correlation between anomalous groundwater depressurisation or the chemistry of mine inflows and proximity to mapped lineaments (HGEO, 2020b, 2020a).

The above evidence is consistent with faults and dykes having low transmissivity, and therefore limited influence on mine water make and groundwater drawdown, particularly in the shallower geological strata (HBSS and BGSS). Nevertheless, during model calibration, several regional and in-seam faults were included in the model to assess their potential role through the automated calibration process.

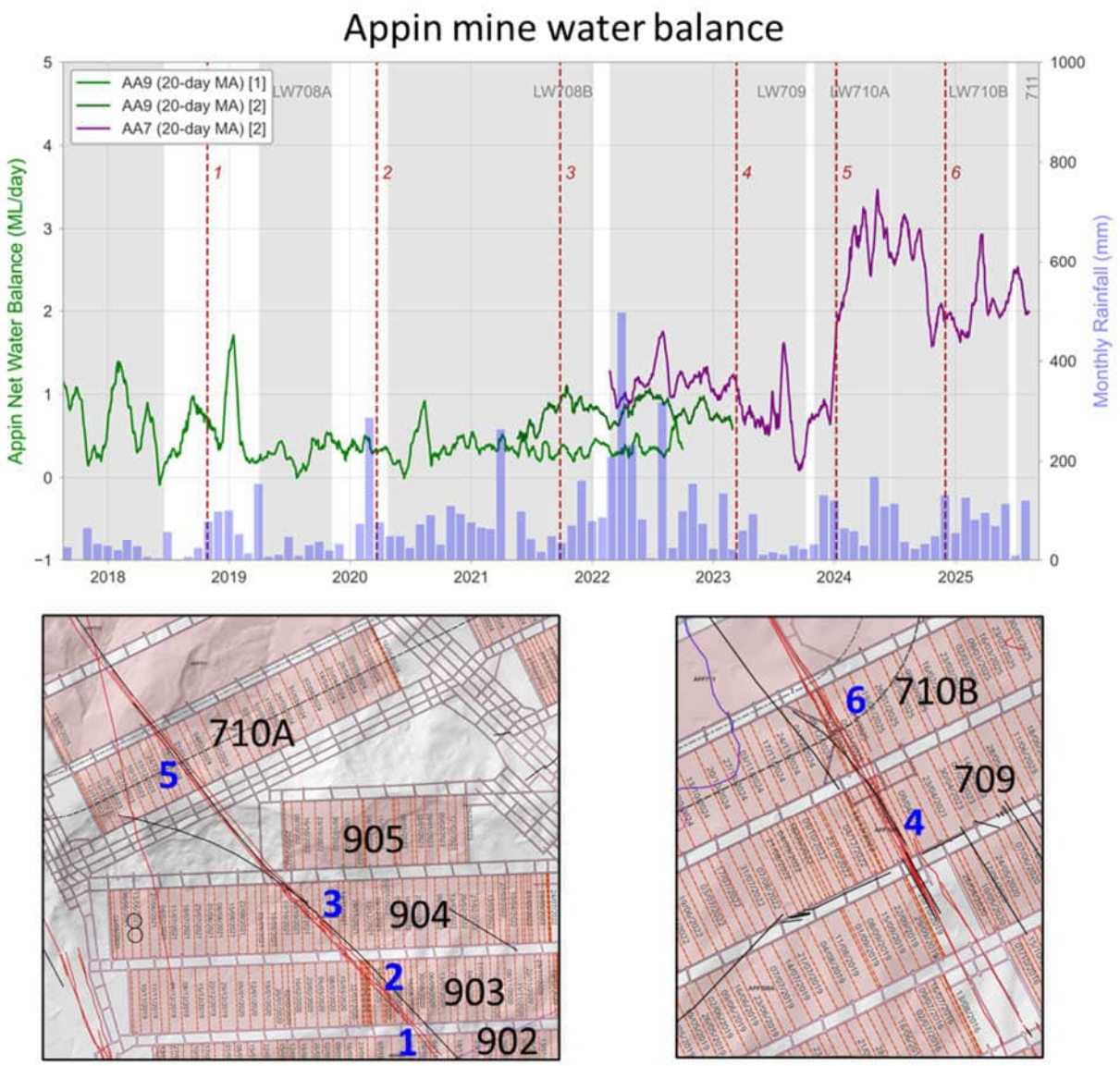

Figure 33 Mine water balance for Areas 7 and 9

4.7 Recharge

Groundwater is recharged from rainfall infiltration and surface water bodies, as well as potential downward leakage from overlying strata.

Rainfall recharge primarily occurs to the Triassic Hawkesbury Sandstone or to the outcropping Narrabeen Group in the south of the model domain (Figure 12).

Estimates of rainfall recharge to surficial strata have been collated from a review of literature (Table 9). The estimates are expressed as percentage of long-term annual rainfall and mm per year. The method of analysis has been included where noted in the reference. Estimates of rainfall recharge range from 3 to 12% of long-term annual rainfall, with most estimates around 6 to 7%. Advisian (2016) report that the weight of evidence from multiple studies is that recharge to the HBSS is within a range of 0 to 8.5% of long-term annual rainfall.

Table 9 Summary of recharge estimates (adapted from Watershed HydroGeo, 2025)

Reference	Analysis method	Recharge		Geology
		%long-term annual rainfall	mm/year	
Watershed HydroGeo, 2025	Soil moisture balance model (2005 to Jul 2024) for Triassic rock outcrop	7.1%	93	HBSS
BoM, 2018	AWRA-L(v6) model (2005 to Jul-2022)	7.1%	93	HBSS
	AWRA-L(v7) model (2005 to Jun-2024)	11.8	155	HBSS
HydroSimulations, 2016a	Chloride mass balance, baseflow separation, water table fluctuation	6.5%	65	HBSS
Crosbie, 2015	Chloride mass balance in shallow groundwater	3 – 8.5%	40-100	HBSS
EMM, 2015	Sydney basin-wide estimate, based on review of Crosbie modelling assessments	5%	n/a	HBSS
		1%	n/a	Permian
Pells & Pells, 2013	Not stated	5%	50	HBSS
Coffey, 2012	Baseflow separation, water table fluctuation	2.7 or 6%	n/a	HBSS
Office of Water, 2011 and NRC, 2021	Not stated, estimate for the whole of the *Nepean Sandstone Groundwater Source*	6%	58	Whole groundwater source
		5%	48	
URS, 2007	Water table fluctuation	3-10%	n/a	HBSS

4.8 Groundwater quality

Average concentrations of key parameters in groundwater near the Project are summarised in Table 10 Average concentrations in groundwater. The data are for groundwater samples collected from ICHPL monitoring bores with sampling pumps in the Ashfield Shale, Hawkesbury Sandstone, Newport Formation, and Bulgo Sandstone during the period 2011 to 2023.

In summary, water within:

- Wianamatta Group is moderately saline (median electrical conductivity 4,750 µS/cm). The data indicates the water is not suitable as drinking water and is suitable for short term irrigation and water for some stock (i.e. sheep and dairy cattle). Due to low yields the Wianamatta Group is not considered a productive groundwater source.
- HBSS has variable salinity but in general is brackish (median electrical conductivity 2,060 µS/cm) with a neutral pH (median pH of 7.5). Groundwater in the HBSS is typically sodium-calcium type water and is generally suitable for stock water and short term irrigation (as the iron concentrations are generally above the trigger for long term irrigation water use).
- Bulgo Sandstone within the Narrabeen Group is moderately saline (median electrical conductivity 4,950 µS/cm) with a neutral pH (median pH 7.2). Groundwater in the Bulgo Sandstone is typically sodium- bicarbonate type water and suitable for some stock (i.e. sheep and dairy cattle) and short term irrigation (as the iron concentrations are generally above the trigger for long term irrigation water use).

Groundwater quality data are not available for the Permian coal measures in the Project area. Water within the coal measures is expected to be moderately saline to saline.

Table 10 Average concentrations in groundwater

Parameter	Units	Ashfield Shale	Hawkesbury Sandstone	Bulgo Sandstone
Number of samples		16	42	18
Physiochemical parameters				
Field EC	µS/cm	5009	3015	5300
Lab. EC	µS/cm	5019	3310	5255
Field pH	pH units	8.2	7.1	7.6
Lab. pH	pH units	8.4	7.6	8.1
Major ions				
Total Alkalinity as $CaCO_3$	mg/L	1260	447	3081
Sulfate as SO_4^{2-}	mg/L	4	31	3
Chloride	mg/L	948	843	139
Calcium	mg/L	45	97	43
Magnesium	mg/L	18	119	16
Sodium	mg/L	1085	395	1342
Potassium	mg/L	22	23	28
Silicon	mg/L	10.24	9.37	6.59
Dissolved metals				

Parameter	Units	Ashfield Shale	Hawkesbury Sandstone	Bulgo Sandstone
Aluminium	mg/L	0.04	0.09	<0.01
Arsenic	mg/L	0.004	0.006	0.003
Barium	mg/L	6.97	1.55	15.00
Copper	mg/L	0.002	<0.001	<0.001
Lead	mg/L	0.044	0.003	0.138
Lithium	mg/L	0.327	0.122	1.002
Manganese	mg/L	0.069	0.108	0.018
Nickel	mg/L	< 0.001	0.005	0.002
Selenium	mg/L	<0.01	<0.01	<0.01
Strontium	mg/L	2.532	1.489	2.311
Zinc	mg/L	0.171	0.015	0.146
Iron	mg/L	0.80	1.61	2.38
Total metals				
Aluminium (total)	mg/L	0.36	0.83	0.04
Manganese (total)	mg/L	0.27	0.14	0.03
Iron (total)	mg/L	1.77	1.92	1.58
Nutrients				
Ammonia	mg/L	3.06	2.07	3.34
Nitrite + Nitrate as N	mg/L	0.11	0.13	0.15
Total phosphorous	mg/L	0.08	0.04	0.04

4.9 Receptors

4.9.1 Connected streams

Nepean River is a ‘gaining river’ in terms of surface water - groundwater interaction, being situated in a well incised gorge (Figure 9) that defines a regional low point in the piezometric surface. The river is conceptualised as receiving baseflow from perched aquifers as well as the regional Hawkesbury Sandstone groundwater system. Other sources of water in Nepean River include unregulated flows from upstream, rainfall-runoff from natural, agricultural, and urban catchment areas, inflows from ephemeral tributaries, and licensed discharges including from Appin and Tahmoor Collieries.

In its upper reaches near Appin Mine, Georges River may exhibit losing stream behaviour. Further downstream, Georges River is conceptualised as receiving baseflow from perched aquifers and the HBSS in addition to unregulated flows from upstream, rainfall-runoff, and tributaries. Cataract River to the south of the Project is incised and conceptualised as potentially gaining.

Tributaries in the Project area, including Navigation Creek, Foot Onslow Creek, Apps Gully, and Matahil Creek are underlain by Wianamatta Shale and are disconnected from the regional HBSS groundwater system. Stream gauge data for Navigation Creek and Foot Onslow Creek indicate these streams behave ephemerally and do not receive baseflow.

4.9.2 Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) are ecosystems where the species composition or natural functions depend on the availability of groundwater (Department of Land and Water Conservation, 2002). GDEs may depend completely or partially on groundwater, for example they may rely on groundwater during drought when surface water is not available. The degree and nature of their dependency influences how much these ecosystems are affected by changes to groundwater quality or quantity (Hatton, T., & Evans, R., 1998).

GDEs are found in a wide range of environments. The BoM Groundwater Dependent Ecosystems Atlas categorises GDEs into three types:

1. Aquifer and subsurface ecosystems - Includes stygofauna, microbial communities, and ecosystems within karst systems or fractured rock.
2. Surface water ecosystems - Streams, rivers, and wetlands that receive groundwater discharge (e.g., baseflow).
3. Terrestrial vegetation ecosystems - Phreatophytic vegetation that accesses groundwater via deep roots.

BoM GDE Atlas

The BoM GDE Atlas is a national inventory of potential GDEs based on data from both national-scale desktop and remote sensing analysis and more detailed analysis undertaken by various State and regional agencies using a range of different approaches including field work, analysis of satellite imagery and application of rules/conceptual models. The BoM GDE Atlas maps features that are potentially reliant on the surface expression of groundwater (including streams, wetlands, and springs) and features that are potentially reliant on subsurface groundwater (including terrestrial ecosystems). GDEs are classified based on their likely interaction with groundwater (low, moderate, high).

The GDEs with a high potential for groundwater interaction that occur within 5 km of the Project include aquatic and terrestrial GDEs and are listed in Table 11. The GDEs with a high conservation significance are identified in the Greater Metropolitan Region Groundwater Sources 2023 water sharing plan and are discussed below.

Table 11 Groundwater dependent ecosystems within 5 km of the Project based on BoM GDE Atlas data

GDE type	Ecosystem type	
Aquatic	Nepean River - Watercourse	Nepean River – Floodplain wetland
Terrestrial	Cumberland Moist Shale Woodland	Grey Myrtle Dry Rainforest
	Cumberland River Flat Forest	Hinterland Sandstone Gully Forest
	Cumberland Shale Hills Woodland	Sandstone Riparian Scrub
	Cumberland Shale Plains Woodland	Sydney Hinterland Transition Woodland
	Cumberland Shale Sandstone Transition Forest	

High priority GDEs in the water sharing plan

The Greater Metropolitan Region Groundwater Sources 2023 Water Sharing Plan lists two high priority GDEs near Appin Mine:

- O'Hares Creek (which includes the catchment of O'Hares, Stokes and Four Mile Creeks, downstream to the junction of O'Hares and Stokes Creeks) located approximately 10.5 km east of the Project; and
- Thirlmere Lakes located approximately 13.5 km west of the Project and just west of Tahmoor Mine. Further information on Thirlmere Lakes is provided below.

The location of O'Hare's Creek and Thirlmere Lakes is shown on Figure 34.

Changes in the NSW government method of assessing whether a GDE is a 'High Priority' GDE has led to a substantial increase in the number of features now included in WSPs. In NSW, GDEs are now assessed for ecological value using the High Ecological Value Aquatic Ecosystems (HEVAE) framework (Dabovic et al., 2019). The framework is used to rank GDEs in terms of their conservation significance, with categories ranging from low value to very high value. This enables management and protection efforts to be prioritised based on biodiversity significance, degree of groundwater reliance, threat status or vulnerability, and cultural or recreational value (Dabovic et al., 2019). High priority GDEs in the model domain based on the HEVAE method are listed in Table 12 and shown on Figure 34.

Table 12 High priority GDEs within 5 km of the Project

Ecosystem type	Location relative to the Project	ID
Cumberland Red Gum Riverflat Forest	4.0 km to the south	4025_1
	4.1 km to the east	4025_2
	4.8 km to the east	4025_3
	5.0 km to the east	4025_4
	5.0 km to the east	4025_5
Cumberland Bangalay x Blue Gum Riverflat Forest	4.6 km to the southeast	3145_1
	3.9 km to the southeast	3145_2
Sydney Hinterland Red Gum Riverflat Forest	4.1 km to the south	6552_1

Thirlmere Lakes

Thirlmere Lakes is a system of five freshwater lakes (Lake Gandangarra, Lake Werri Berri, Lake Couridjah, Lake Baraba and Lake Nerrigorang) situated in a small Hawkesbury Sandstone valley to the west of Appin Mine (Figure 34). The lakes support diverse native habitats, and the area is protected under national park status (Figure 1) and forms part of the Greater Blue Mountains World Heritage Area.

Water levels in Thirlmere Lakes have fluctuated over time, but in 2010 there was a notable decline that was of significant concern to the local community, and this led to the Thirlmere Lakes Research Program (Department of Planning and Environment, 2022). The Research Program found that water levels in the lakes are primarily driven by rainfall and evapotranspiration, with a component of losses from each lake to groundwater. In the longer-term, the lakes will likely continue to oscillate between

being dry (or nearly so) and maintaining higher water levels, largely dependent on the occurrence of droughts and the frequency, intensity and duration of major rainfall events. Mining impacts on regional groundwater may affect lake water levels by reducing inflows to the lakes and by increasing the hydraulic gradients away from the lakes. However, such impacts may take decades to express themselves in a measurable way (Department of Planning and Environment, 2022).

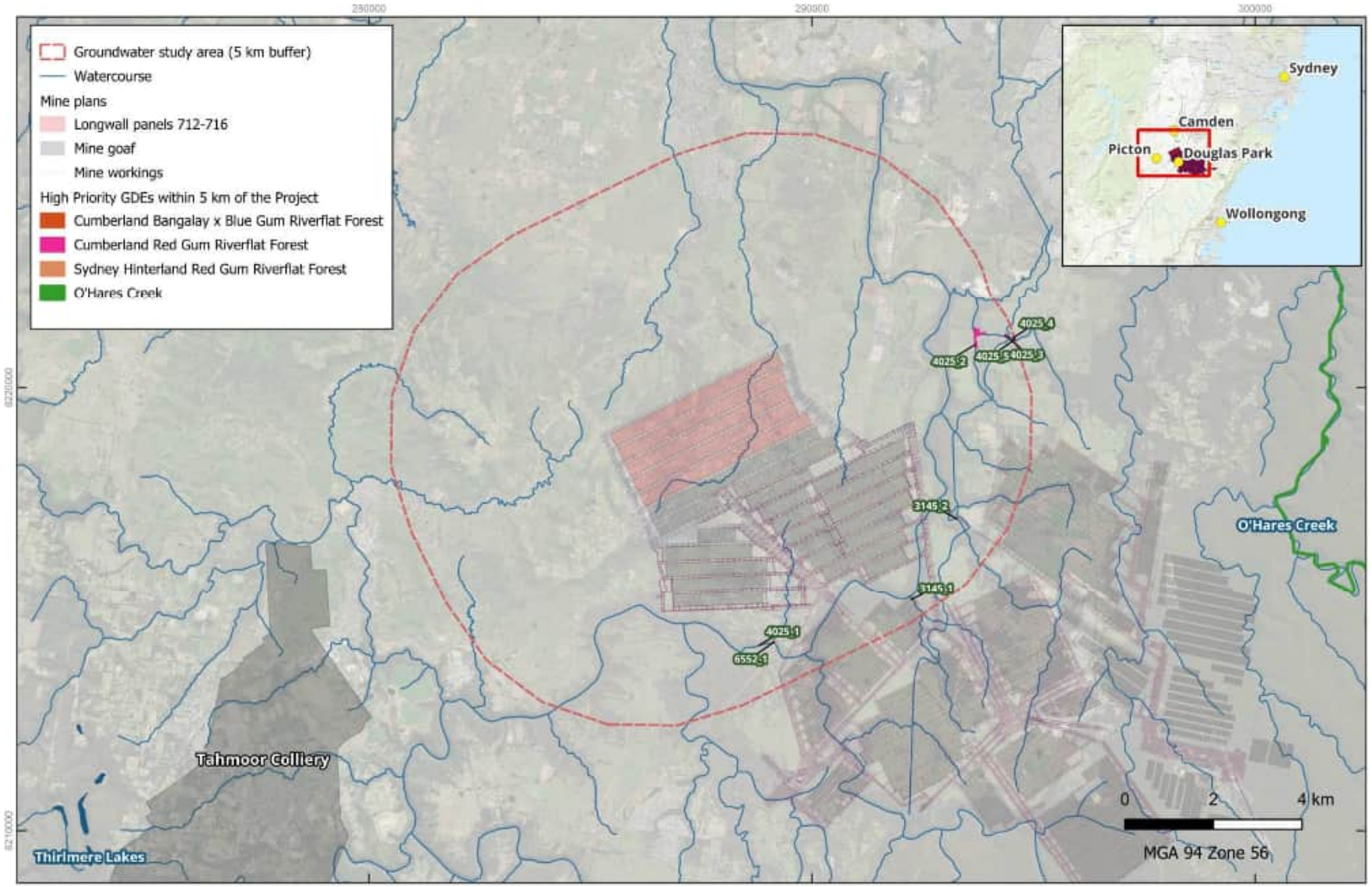

Figure 34 High Priority GDEs based on the HEVAE method

4.9.3 Private water supply bores

A search of the BoM's National Groundwater Information System (NGIS) for registered bores within the model domain indicated there are 940 registered bores excluding bores used for monitoring, dewatering, coal seam gas abstraction, or exploration, and bores with a status of abandoned, removed, or not operational. A summary of registered bores by location relative to the Project is provided in Table 13.

Table 13 Location of registered bores relative to the Project and other mining operations

Location		Number	Bore purpose
Bores in the Appin Mine area	Bores overlying LW712-716	5	Water supply (5)
	Other bores within the 600 m study area	8	Water supply (6), irrigation (2)
	Bores overlying Appin Mine goaf	15	Water supply (10), irrigation (1), stock and domestic (1), commercial and industrial (1), unknown (2)
Bores within other mining areas	Bores overlying Tahmoor Mine	38	Water supply (19), irrigation (12), stock and domestic (1), other (2), unknown (4)
	Bores overlying Metropolitan Colliery	1	Unknown
	Bores overlying Coalcliff Colliery	2	Water supply (1), unknown (1)
Bores not within mining areas		871	Water supply, irrigation, stock and domestic, commercial and industrial, unknown
TOTAL		**940**	

There are 221 registered bores within 10 km of the longwall panels. Construction details are not available for most bores in the area and therefore to assess the target formation, bore depths or screened intervals (where available) were intersected with the geology model used to develop the numerical groundwater model layers. The results indicate that most landholder bores within 10 km of the Project are taking groundwater from the HBSS (195 out of 221 bores). To the North of Appin Mine, 64 registered bores with depths of less than 30 m occur within the extent of the mapped alluvium along the Nepean River and the Mount Hunter Rivulet and may be accessing groundwater in the alluvium (SLR, 2022). The maximum yield of private water supply bores near Appin Mine does not exceed 1.5 L/s (SLR, 2022).

Registered bores near the Project are show on Figure 35. Details of the 13 registered bores within the 600 m study area are provided in Table 14.

Table 14 Private water supply bores near the Project

State bore ID	Purpose	Status	Aquifer^	Bore depth (m)	SWL (m)	EC (mg/L)
Bores overlying LW712-716						
GW072196	Water supply	Unknown	Mid HBSS	-	-	5360#
GW100289	Water supply	Active	Wianamatta Group or alluvium	30	10^	1540#
GW106675	Water supply	Active	Mid HBSS	183	20^	5290#
GW108907*	Water supply	Unknown	Lower HBSS	210	83.7 (12/12/2024)	1200^
GW105531	Water supply	Unknown	Lower HBSS	210	79	2070^
Other bores within the 600 m study area						
GW112381	Water supply	Active	Mid HBSS	152	70^	Fresh^
GW105574#	Water supply	Unknown	Lower HBSS	210	25.2 (190 m sensor)	3630^
GW105376*	Water supply	Unknown	Lower HBSS	218.5	63.9 (28/5/2025)	Fresh^
GW072874*	Water supply	Active	Lower HBSS	189	73.3 (16/6/2023)	4730#
GW107791	Water supply	Active	Lower HBSS	231	37^	Fresh^
GW102619*	Irrigation	Active	Lower HBSS	224	66.9 (18/4/2025)	-
GW026516	Irrigation	Proposed	Wianamatta Group or alluvium	10	-	-
GW108990	Water supply	Unknown	Mid HBSS	150	-	-

*Monitored by ICHPL

HGEO (2025d)

^SLR (2022)

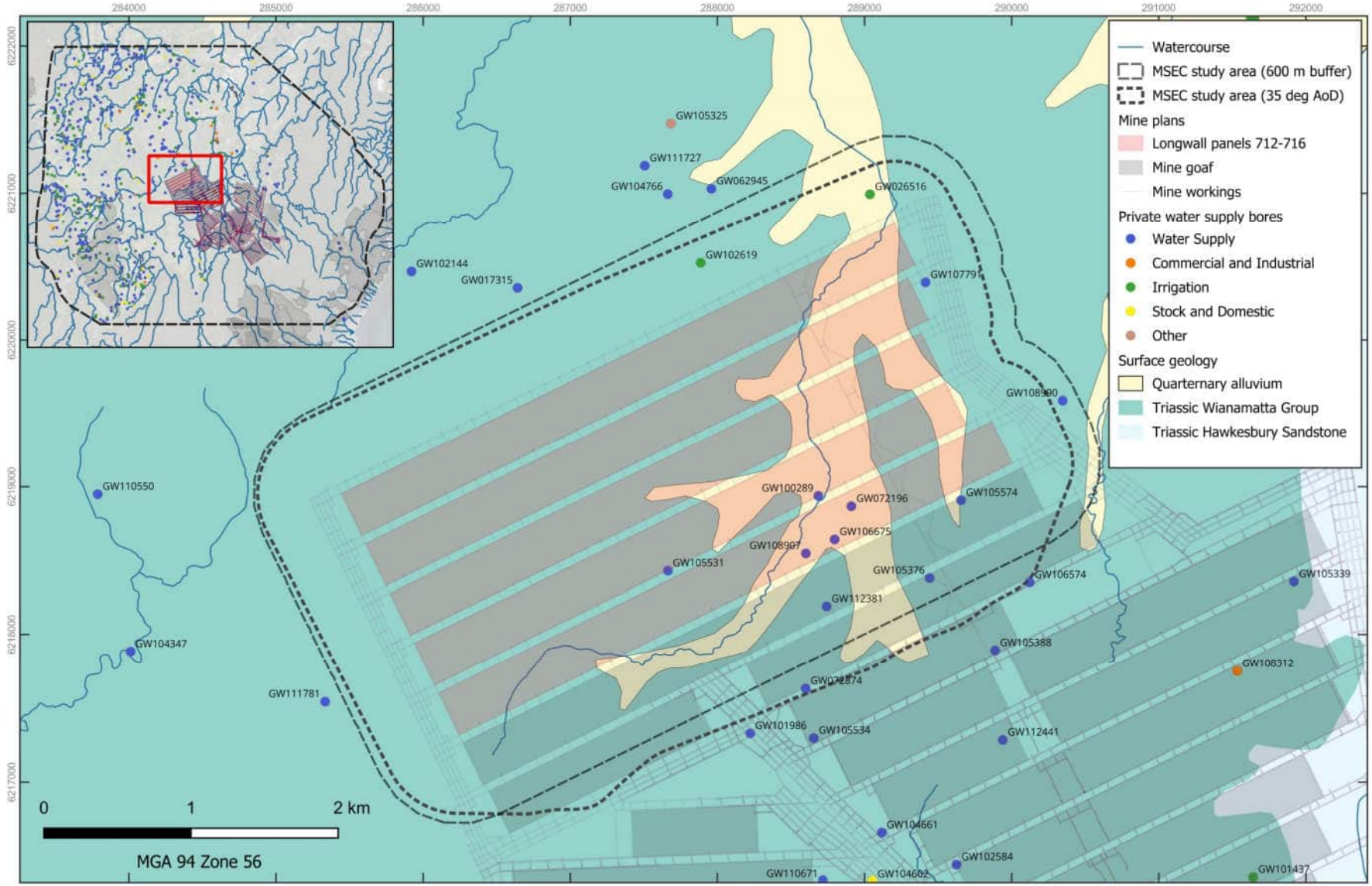

Figure 35: Registered bores near the Project

4.10 Groundwater impact pathways

As longwall mining progresses, the removal of coal results in the overburden caving into the void and stresses propagating upward and outward through the overlying strata. The resulting fracturing and deformation of the overburden can cause significant changes in aquifer properties and provide pathways for vertical groundwater movement between shallow groundwater and surface water systems and the underground mine. Groundwater level decline may occur either due to drainage of groundwater into the goaf or due to an increase in storage associated with an increase in porosity. Several authors have developed empirical approaches to estimating the height of connective fracturing or complete groundwater drainage above the longwall panels which are discussed in Section 4.10.2.

Longwall mining involves dewatering which also has the potential to cause the depressurisation of groundwater systems which can impact on connected surface water systems and related assets. To predict depressurisation associated with the extraction of LW712 to LW716, HGEO developed a numerical groundwater flow model, calibrated to data collected for previously extracted longwalls at Appin Mine. The model simulates the changes in aquifer properties due to subsidence as well as dewatering. The modelling results are presented in Section **6**.

4.10.1 Impact pathway diagram

An impact pathway diagram (IPD) (IESC, 2024) has been developed to show how the Project is predicted to adversely affect surface water and groundwater resources (Figure 36). The diagram shows the potential pathways from the sources of impact to the receptors, and how these pathways interact. Further detail on the impact pathways and how they have been represented in the numerical groundwater flow model are provided in the sections below.

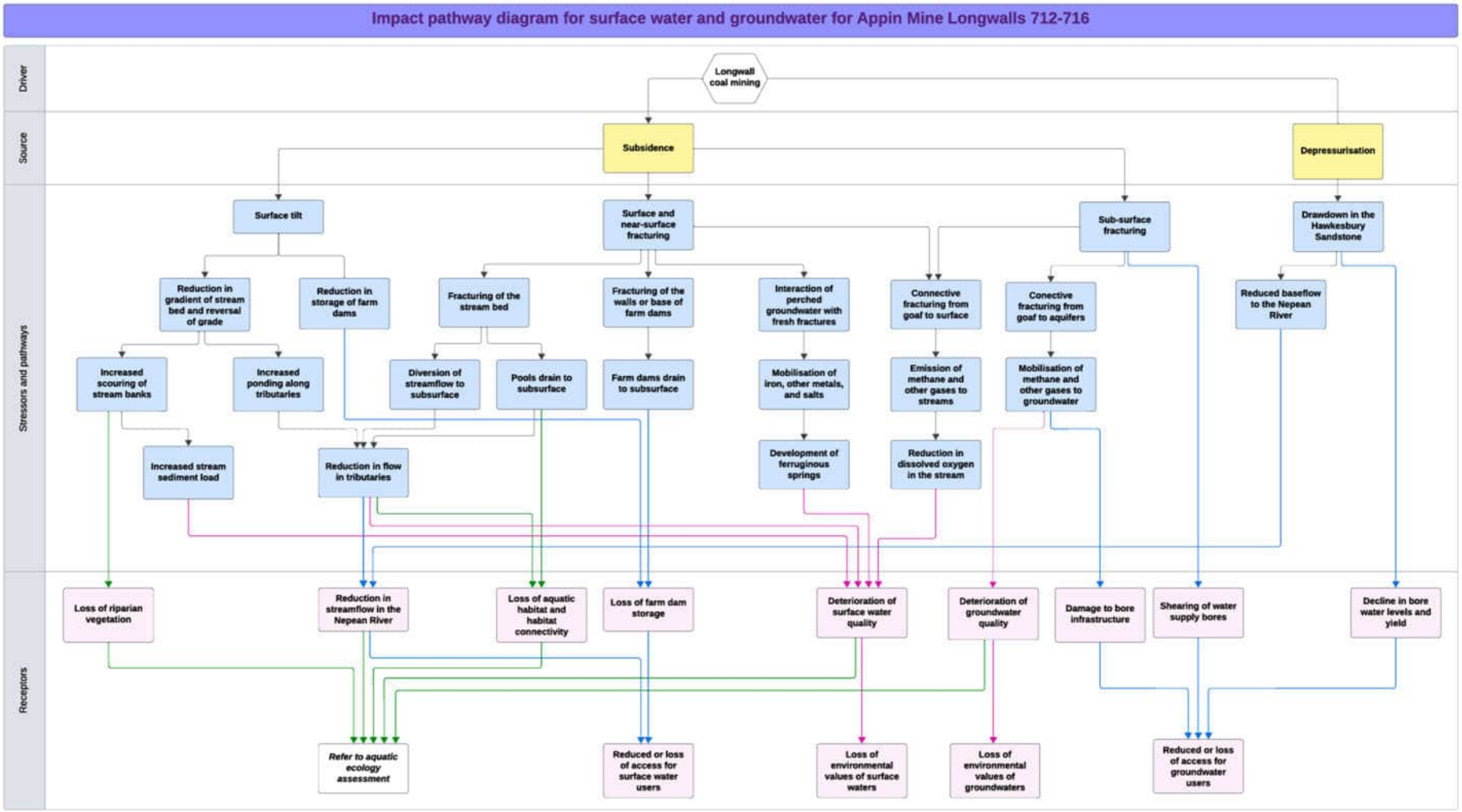

Figure 36 Impact pathway diagram

4.10.2 Longwall subsidence effects

4.10.2.1 Literature review

Longwall coal mining results in ground subsidence and associated deformation and fracturing of overlying and adjacent strata (Peng & Chiang, 1984; Whittaker & Reddish, 1989). While authors differ in their terminology, there is general agreement on the overall patterns of deformation. Forster and Enever (1992) carried out studies at pillar and longwall mines in NSW and developed a conceptual model to describe a sequence of deformational zones above longwall and pillar extraction areas. A similar conceptual model was provided by the Department of Planning (2008) (Figure 37) and other authors have developed similar conceptual schemes.

In these conceptual models, fracturing is most intense and vertically connected immediately above the collapsed longwall (goaf) (the 'caved zone'), and within the 'fracture zone' the intensity of fracturing grades upwards through to less fractured strata (Booth, 2002). Near the ground surface, subsidence and tension across the subsidence trough combine to cause 'surface cracking'. Surface fracturing associated with conventional movement is estimated to extend up to 20 to 30 m below the surface (Guo et al., 2007b), while fracturing beneath streambeds associated with valley closure is estimated to extent up to 20 m below the surface (Mills, 2007). Depending on the height of the fractured zone above the goaf, the surface fracture zone may be separated from the deeper fracture zone by a "constrained zone" in which strata fracturing is minimal and permeability remains relatively low (Booth, 2002).

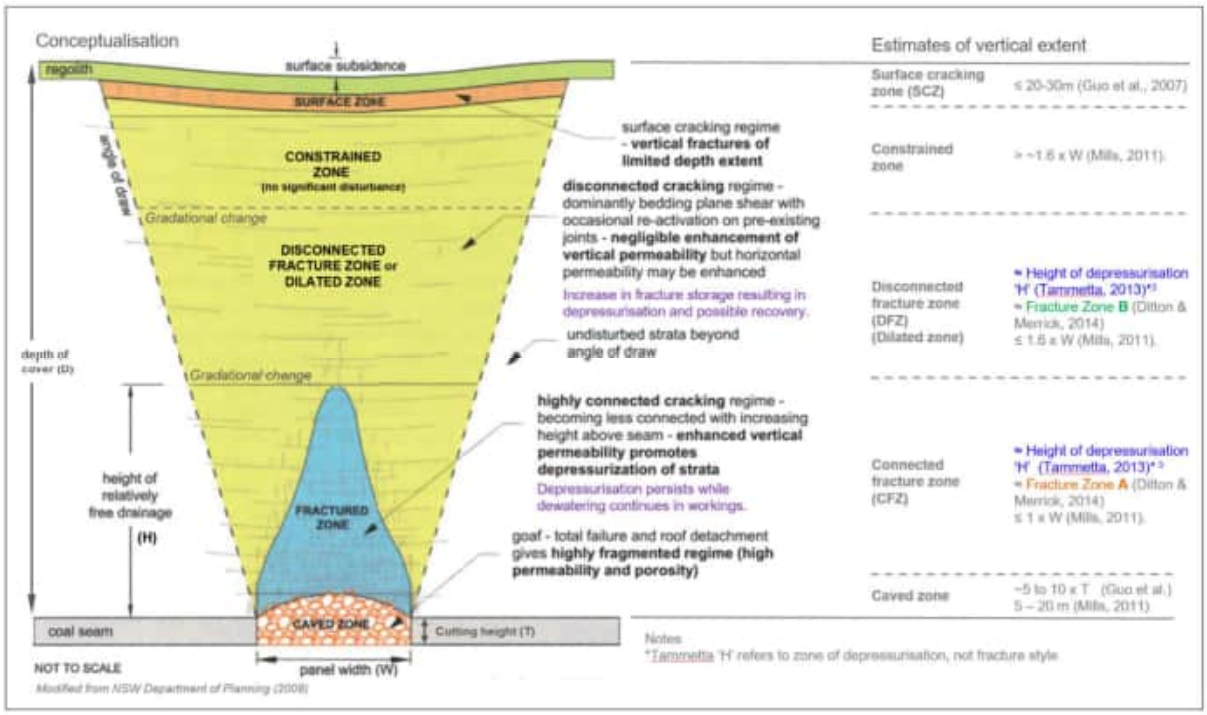

Figure 37 Conceptual models for subsidence deformation above extracted longwalls

In addition to fracturing of strata extending upward from extracted longwall panels, deformation and fracturing is also observed:

- Beyond the longwall footprint. Deformation and fracturing of geological strata may also occur outside the footprint of longwalls via mechanisms such as valley closure and formation of basal

shears (SCT, 2016; Walsh et al., 2014), and reactivation of existing geological structures or lineaments, as observed at Springvale Mine (Galvin et al., 2016).

- Beneath the mined panel. Deformation due to unloading and heaving can occur in the floor strata (Meaney, 1997; Karacan et al., 2011).

Fracturing of the overlying and adjacent strata can cause significant changes in aquifer characteristics such as hydraulic conductivity and secondary porosity (storage), and potentially can provide pathways for vertical groundwater movement between shallow groundwater and surface water systems and underground mines (Advisian, 2016; McNally & Evans, 2007). Therefore, the height to which vertically connected, and potentially free-draining fracture networks extend above the mined seam is important in assessing potential impact of longwall mining on groundwater and surface water systems.

4.10.2.2 Empirical approaches to estimating the height of connective fracturing

Several authors developed empirical approaches to estimating the height of connected fracturing or complete groundwater drainage above longwalls; for example, Forster (1995); Guo et al., (2007); Mills, (2011); Tammetta (2013); Ditton and Merrick (2014) and Adhikary et al. (2020). These methods have been used at numerous coal mines in NSW to provide guidance on the height of fracturing (or depressurisation) for the development of numerical groundwater models. It is important to note that the terms used by authors may not be equivalent; Tammetta refers to the "height of desaturation" (more precisely, complete depressurisation); Ditton and Merrick refer to a "zone of continuous cracking" (A-Zone), and Mills refers to a zone of large downward movement (Zone #2). The Tammetta, (2013) and Ditton and Merrick, (2014) are the most commonly applied methods for estimating the height of connective fracturing in the Southern Coalfield and are outlined below.

Tammetta (2013)

Tammetta (2013) developed an empirical model to estimate what he describes as "the height of complete groundwater drainage (***H***) above extracted longwall panels". More precisely H, as used in the model, refers to the height of complete *depressurisation,* where vibrating wire piezometers record zero or near-zero pressure head, rather than complete drainage of pore water. The model is based on multiple hydraulic head profiles from 18 mine sites and above longwalls ranging between 110 m and 260 m in width. Tammetta found that H is primarily influenced by the geometry of the mined void (mining width, and mining height) and the thickness of the overburden, with minimal dependence on other factors, according to the following equation:

$$H = 1438 \times \ln(4.315 \times 10^{-5} \times (WT^{1.4} D^{0.2}) + 0.9818) + 26$$

Where ***H*** is the height of the zone of depressurisation above the seam top, ***W*** is the width of the longwall void, **T** is the mined height or cutting height, and ***D*** is the depth of cover (overburden thickness). All units are in metres (m).

Ditton and Merrick (2014)

Ditton and Merrick (2014) developed analytical models for estimating the height of the zone of connected fracturing (A-zone) above longwall coal mine workings by integrating a range of international and Australian research findings, physical modelling studies, and field monitoring results.

Their model combined geotechnical principles with empirical observations to estimate the height of connected fracturing above the mined seam as a function of parameters related to mining geometry

and geological factors as follows (parameter notation changed to be more consistent with Tammetta's):

$$A_{geol} = 1.52\,W'^{0.4}\,d^{0.535}\,T^{0.464}\,g'^{-0.4} \quad (\pm 0.15W' to\ 0.1W', depending\ on \frac{W}{d} ratio)$$

Where $\mathbf{A_{geol}}$ refers to the A-zone height estimate based on the 'geology' model which is more conservative and accounts for geological conditions; ***W*** is the longwall width, ***W'*** is the effective longwall width (minimum(W, 1.4d)), ***d*** is the depth of cover, ***T*** is the mined height or cutting height, and ***g'*** is the effective thickness of a geological strata unit or spanning beam located above the longwall that influences subsidence behaviour and fracture propagation (ranges between 15 and 30 depending on depth of cover and assumed to be ~20 at Appin). All units are in metres (m). The estimated 95% confidence interval is given in parentheses.

4.10.2.3 Studies of connective fracturing in the Southern Coalfield

The Independent Expert Panel for Mining in the Catchment (IEPMC) provides expert advice to the Department of Planning on the impact of mining activities in the Greater Sydney Water Catchment Special Areas. In relation to hydrogeological impacts and height of fracturing, the IEPMC considered that: *"Rather than carrying out a full analysis of the Tammetta and Ditton databases to validate those empirical models], it would be quicker and more productive for Dendrobium Mine and Metropolitan Mine to develop their own site-specific databases"* (IEPMC, 2019).

There are no site measurements of the fractured height at Appin. Studies conducted at nearby mines Dendrobium and Tahmoor are summarised below.

Dendrobium

ICHPL has carried out extensive investigations above eleven extracted longwalls at Dendrobium allowing detailed characterisation of sub-surface fracturing and depressurisation (HGEO, 2020b, 2025b; Parsons Brinckerhoff, 2015), and development of a site-specific conceptual model for fracturing and depressurisation above longwalls. The studies concluded that mining-induced fracturing is highly variable but appears to extend to the surface above longwalls of width 249 m in Area 3A and 305 m in Area 3B. The density of fracturing and the proportion of high-angle fractures, decreases with height above the goaf, with anomalous fracturing within the Bald Hill Claystone and within 120 m of the goaf.

Piezometers installed after longwall extraction indicate significant depressurisation throughout all strata, with near-zero pressure heads recorded in most piezometers in the months following mining. Over the longer-term, most monitoring sites show evidence for groundwater recovery and development of perched water tables over several years following mining. The perched horizons are most extensive in strata above the uppermost Colo Vale Sandstone and implies that the degree vertical connectivity decreases markedly above a height of approximately 160 to 200 m above the goaf. Estimates of the height of depressurisation (H) above extracted longwalls at Dendrobium range between that approximated by Ditton's A-zone (where recovery occurs) to that of Tammetta (HGEO, 2025c). Therefore, the empirical formula of Tammetta provides a conservative upper estimate for the height of depressurisation. The wide range reflects the heterogeneous nature of fracturing and vertical connectivity above extracted longwalls.

At Appin, due to the greater depth of cover above the Bulli Coal Seam, there is less depressurisation in the HBSS directly over longwalls and the strata remain saturated throughout the HBSS and BGSS. In some monitoring bores at Appin there is evidence for rapid but transient drawdown in the order of 5 m to 10 m in the HBSS, followed by recovery over a period of months. As at Dendrobium this initial

drawdown is attributed to an increase in fracture storage (bedding plane separation), after which the new fracture storage fills and groundwater pressures recover.

Tahmoor

SCT conducted drilling above Longwall 10A (TBF040) at Tahmoor Mine in 2014. Core logging showed a general trend of increasing defect frequency with depth from about 70 m to the base of the hole at 243.9 m depth, as well as occurrences of 'borehole breakout' from 75-80 m depth. Borehole breakout is a sign of stress and SCT interpreted this location as the height to which mining-induced fractures occur above the mined seam (SCT, 2014, referenced in SLR, 2022). SLR (2022) report that the observed fractured zone height is consistent with the estimation from the Ditton (2014) method.

4.10.2.4 Estimated height of connective fracturing at Appin

The height of connected fracturing (or depressurisation) above existing and proposed longwalls at Appin Mine was calculated using empirical models of Ditton and Merrick (2014) and Tammetta (2013). The estimated heights are shown for Area 7 longwalls including proposed Longwalls 712 to 716 on the hydrogeological cross section in Figure 13. The cross section shows that, based on those empirical models, there is potential for connective fracturing and depressurisation to extend into the Bulgo Sandstone (Ditton A-geol zone) and potentially into the overlying Bald Hill Claystone (Tammetta).

Figure 38 shows the average heights of fracturing and the range (minimum to maximum) over each longwall in Areas 7 and 9. Also shown is the average depth of cover (d) and the range in depth of cover for each longwall. This comparative plot shows that the height of connected fracturing (or depressurisation) is broadly similar for Longwalls 712-716 as for previous longwalls 710 and 905. The depth of cover (red symbols) increases from Longwall 712 to 716 and is generally greater than previous longwalls in Area 7 and 9.

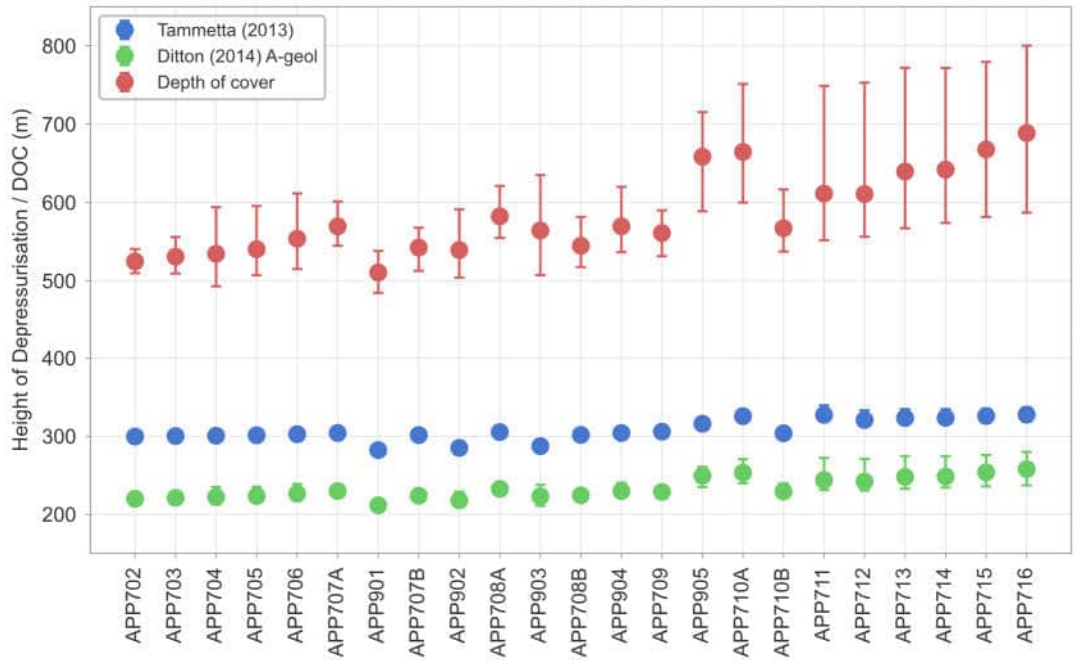

Figure 38 Height of depressurisation and depth of cover (mean, max-min)

Figure 39 shows the same estimates expressed in terms of the average (and range) in the separation distance between the ground surface and the top of the height of fracturing based on the Tammetta model. The data illustrate the depth of the zone below the surface where subsidence fracturing will be dominated by bedding plane fracturing or minimal disturbance. The estimated separation distance is greater than 200 m for all longwalls in Areas 7 and 9, with the separation above Longwall 710 approaching 350 m. This is consistent with the generally minor groundwater drawdown observed in groundwater bores located over previously mined longwalls at Appin. The estimated average separation zone above Longwalls 712 to 716 is equal to greater than the depth of previously extracted longwalls at Appin Mine, increasing to more than 350 m above Longwall 716. The groundwater impacts associated with the Project are therefore expected to be similar to or less than the impacts that have been observed during the mining of previous longwalls at Appin Mine.

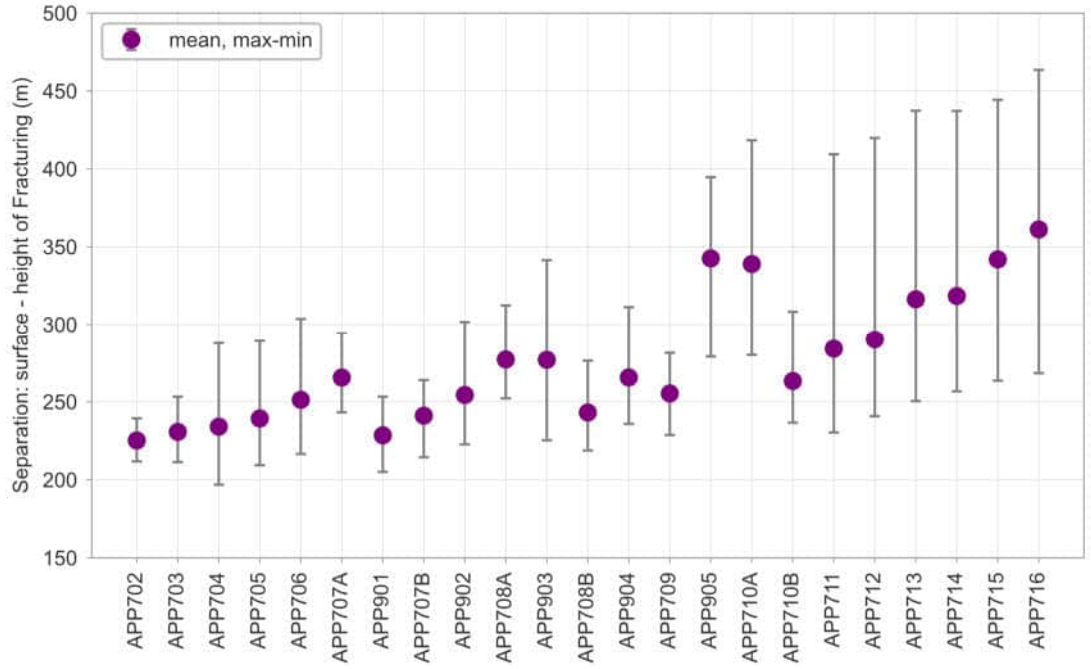

Figure 39 Depth of fracturing below the surface

4.11 Conceptual hydrogeological model

The primary hydrostratigraphic units within the Appin Mine area are:

- Quaternary alluvium – Localised along rivers and creeks, likely unconfined and recharged from rainfall and surface water flow. Groundwater resources in the alluvium are limited, and flow likely follows topography and streamflow in a general northerly direction.
- Hawkesbury Sandstone – Main groundwater source in the area and widely accessed for groundwater supply due to the shallow depths and good groundwater quality, despite generally low groundwater yields (~0.2 to 1 L/s). Groundwater flow is generally in a northerly direction, with some influence from mining observed in the lower part of the sequence, and local influences where the formation is intersected by rivers and private abstraction bores.
- Narrabeen Group – A sequence of interbedded sandstones and low permeability claystones that act as aquitards and limit vertical conductivity between the Bulli Seam and HBSS. The main water bearing unit is the confined Bulgo Sandstone. This unit can be used for groundwater supply but

typically produces lower bore yields and poorer water quality than the HBSS. Groundwater flow is to the north towards the active mining area, centre of the Basin, and Camden Gas Project.

- Illawarra Coal Measures – Comprises interbedded sandstones, shale and coal seams with groundwater occurrence associated with the more permeable coal seams. Groundwater is confined and flow is towards the active mining area. There has been significant depressurisation of the Bulli Coal Seam in response to coal seam gas extraction in the area and longwall mining at Appin.

Recharge to the groundwater system is primarily from rainfall infiltration where the Hawkesbury Sandstone outcrops to the south, east, and west of the Project or where the Narrabeen Group outcrops in the south of the model domain. Recharge also occurs via lateral groundwater flow from outside the study area. Discharge from the groundwater system occurs via abstraction from private water supply bores and coal seam gas wells, dewatering for mine operations at Appin, and where Nepean River, Cataract River, and Georges River are incised and the HBSS provides baseflow. There are no major geological structures (faults) intersecting the proposed longwalls and no indication of higher inflows during mining through in-seam zones of geological structure based on mine water balance data and observations from previous longwalls.

Potential receptors include: 223 registered bores within 10 km of the Project, 195 of which access the HBSS; Nepean River, Cataract River, and Georges River which are gaining streams and receive baseflow from the HBSS where they are incised; and high priority groundwater dependent ecosystems (GDEs) in the Water Sharing Plan including Cumberland Red Gum Riverflat Forest, Cumberland Bangalay x Blue Gum Riverflat Forest, and Sydney Hinterland Red Gum Riverflat Forest.

Longwall mining at Appin Mine has been ongoing for more than 40 years and the impacts are well understood. Longwall mining results in fracturing and deformation of the overburden, providing pathways for the vertical movement of water in the subsurface. Extensive monitoring of surface water and groundwater systems at Appin has shown limited depressurisation of the HBSS and Bulgo Sandstone, and no impacts to surface water systems in Areas 7 and 9. As the depths of cover above LW712 to LW716 are greater than or equal to the depths of cover for previous longwalls, the subsidence impacts and associated impacts on groundwater are expected to be less than or equal to the impacts that have been observed during the mining of previous longwalls at Appin.

Groundwater monitoring data for previous longwalls at Appin Mine show depressurisation within the Scarborough Sandstone, Bulgo Sandstone, and HBSS, consistent with previously assessed impacts for the BSO (Heritage Computing, 2009). There is potential for drawdown in private water supply bores near the Project Area that access groundwater from the Lower or Mid HBSS. Impacts to streams and GDEs are unlikely due to their distance from the Project and likely connection to the Upper HBSS.

5. Groundwater modelling

The effects of mining on groundwater levels and on connected surface water systems are assessed using a numerical groundwater model. Groundwater models are numerical representations of the regional groundwater system. Models provide better support for environmental decisions when they are designed to address specific management or impact-assessment questions, rather than attempting to replicate all (or many) elements of the hydrological system (Doherty & Moore, 2019). Importantly, groundwater predictions should include estimates of uncertainty which requires that the model can be run many hundreds (or thousands) of times during model calibration and uncertainty analysis. In practice, this requires that the model be constructed with sufficient complexity to represent the governing processes yet streamlined so that it can be run repeatedly within a feasible timeframe. This assessment aims to balance those requirements, in line with key principles outlined in the Australian Groundwater Modelling Guidelines (AGMG; Barnett et al., 2012) and the IESC guidelines for uncertainty analysis (Middlemis & Peeters, 2018).

Based on the description of the project and environmental factors in the preceding sections, the key groundwater predictions (or quantities) of interest are:

- Change in groundwater level or pressure and registered landholder water supply bores which may affect their yield and or water quality.
- Change in groundwater level or pressure at High Priority terrestrial GDEs.
- Change in baseflow to major watercourses which may affect aquatic GDEs and which may need to be accounted for in water licencing.
- The rate of groundwater inflow to the underground mine workings.

Those predictions require that the model is primarily able to simulate the change in piezometric head within the Hawkesbury Sandstone which is the main aquifer used for water supply in the area, and which supports baseflow to major watercourse and supports identified High Priority GDEs. Several water supply bores access groundwater within the underlying Bulgo Sandstone. Assessing mining effects on those shallow aquifer systems requires that the model is able to simulate the strong vertical hydraulic gradients that develop above and near the mine workings, and the mechanisms by which mining and mine subsidence affects aquifer properties immediately above the workings. In addition, the model needs to include the cumulative effects of previous mine and coal seam gas developments and Appin and neighbouring operational mines. Those objectives informed the model design and updates, as outlined in the following sub-sections.

The analysis of predictive uncertainty was integrated into the calibration workflow using the iterative ensemble smoother methodology implemented in PEST++IES. Therefore, all model outputs are presented in terms of a median or base prediction, with percentile ranges (e.g. P10, P90) derived from multiple calibrated models runs. The IES methodology is described below.

5.1 Model structure

5.1.1 Previous groundwater models

The numerical model used in this GIA was based broadly on the structure and extent of numerical models developed for previous groundwater assessments at Appin Mine, with some significant enhancements. The first numerical model for Appin mine was developed by Noel Merrick of Heritage

Computing (2009) using MODFLOW-Surfact. That model formed the basis for subsequent numerical models by HydroSimulations (2018), and SLR (2022, 2023) which used the MODFLOW-USG numerical code. The more recent models by SLR used an unstructured model mesh to allow better refinement around key mining and surface water features.

The numerical model used in this study retained the same broad layering structure and initial parameterisation of previous models to retain consistency and build on previous knowledge. However, the following key changes were made:

- A new 3D Voronoi mesh was constructed with appropriate refinements around the past and proposed future mine workings.
- The upper-most model layers (HBSS, WMGR and superficial layer) were re-evaluated based recent exploration geology data and Lidar surface elevation data.
- Water extraction from Coal Seam Gas (CSG) wells is based on actual water make reported by AGL (2010-2024), which is an order of magnitude less than was assumed in the previous model.
- Additional groundwater observation data were included to assist in model history matching (calibration), including timeseries head data up to August 2025 and observations from regional bores from the BOM groundwater database.
- The same temporal discretisation was applied as for previous models, that is, quarterly stress periods which were extended beyond the proposed mine plan.

5.1.2 Model code and software

Groundwater modelling was conducted using MODFLOW 6, the latest version of the U.S. Geological Survey's modular hydrologic simulation program. MODFLOW 6 adopts a flexible framework that supports unstructured grids, allowing for complex model geometries and enhanced representation of hydrological features. It uses a control-volume finite-difference (CVFD) approach to solve groundwater flow equations and includes advanced features such as time-varying aquifer properties, surface-water-groundwater interaction, adaptive time-stepping, and integrated solvers for efficient computation. The model uses the Newton–Raphson (NR) formulation in MODFLOW 6, recommended for complex water-table problems, which improves model convergence and avoids drying/rewetting instabilities under steep hydraulic gradients or frequent wetting and drying typical of mining applications.

The model setup and some data processing were performed using Groundwater Vistas Version 9 (GV9), a graphical user interface designed to streamline MODFLOW model development through the use of digital elevation models, shapefiles, and other GIS input data. In order to apply some of the parameter estimation and uncertainty tools of the PEST suite (Doherty, 2015), it was necessary to add several model pre-processing and post-processing steps within a batch-scripted framework, summarised in Figure 40.

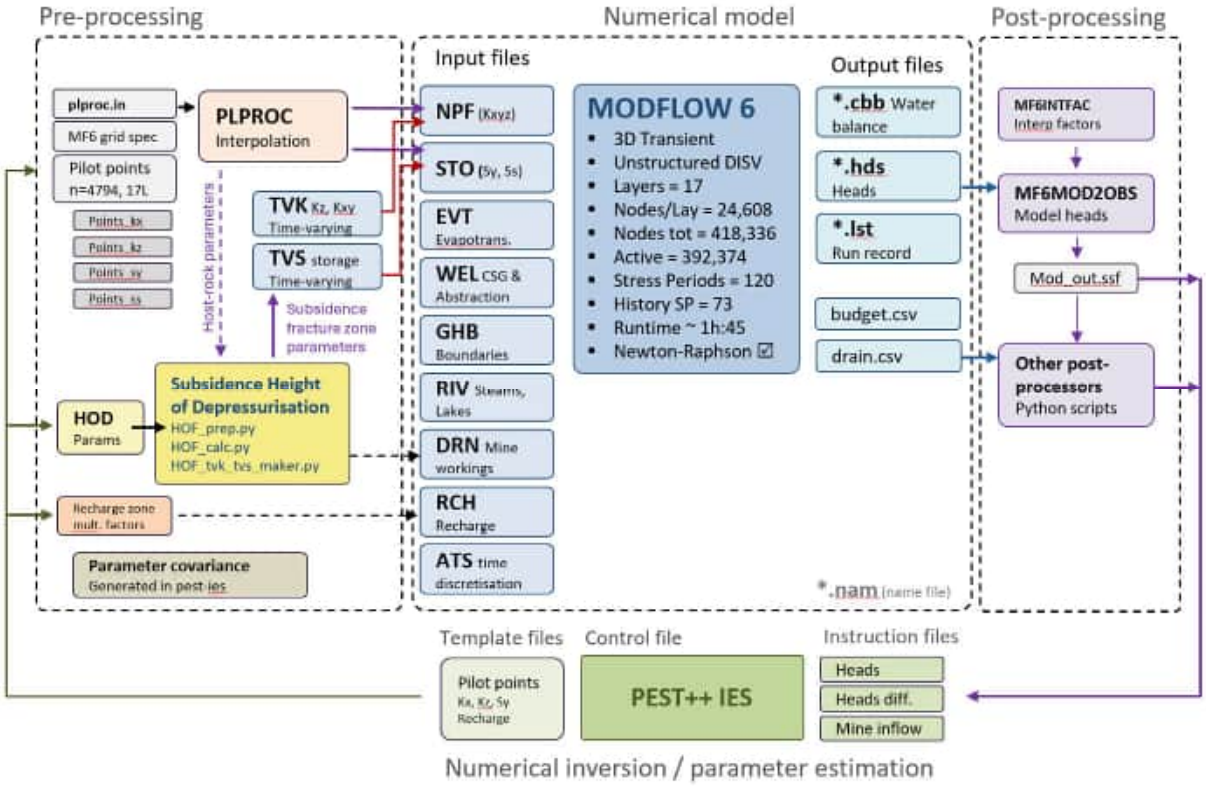

Figure 40 Overview diagram of the script-based model structure

5.1.3 Model domain and mesh design

The groundwater model was discretised into a three-dimensional mesh using the DISV (Discretization by Vertices) package in MODFLOW 6. This method combines structured vertical layering with flexible, unstructured polygonal cells in the horizontal plane. A voronoi mesh was generated using AlgoMesh Version 2, which was refined around key features such as watercourses, groundwater bores, and longwall geometry to improve resolution and accuracy. The Voronoi geometry produces near-perpendicular bisecting flow paths between adjacent cells, aligning with MODFLOW 6 assumptions and minimizing computational errors (Figure 41).

The model domain extends approximately 42 km from west to east and approximately 35 km from north to south, covering an area of approximately 1,316 km^2. The overall model extent was designed to accommodate future mining at Appin Mine and neighbouring mines, and simulate the regional groundwater flow patterns in the southern Sydney Basin. The western and eastern boundaries were set to broadly coincide with major watershed boundaries and assigned as no-flow, while the southern and northern boundaries are set far enough from the proposed mining (>15 km) to avoid boundary interference. This is supported by previous modelling and monitoring data which indicates that incremental (project related) depressurisation effects are unlikely to extend further than 5 km within the BGSS, and 1 to 2 km in the lower HBSS. The large spatial area of the model extent resulted in the need for an unstructured grid with varying cell sizes, and refinement in the areas of interest. Refinement was carried out as follows:

- Mining areas were discretised with a regular hexagonal mesh of various cell sizes: Approximately 100 m wide in the Project area (Longwalls 712 – 716), which allows for each proposed longwall to be represented by approximately three cells wide. Previous Appin mine areas have slightly larger

cells (175m, 220m), with 250 m cells at Tahmoor mine, and 300 m cells covering more distant neighbouring mines.

- Polylines along mapped rivers and creeks were used to ensure the mesh conformed to mapped drainage network, and to enforce variable details along streams (e.g. greater detail along streams closest to Appin Mine). Voronoi cell sizes along rivers and creeks varies from 100 m to 200 m.
- Slight refinement was applied to areas mapped as alluvium, and the area enclosing CSG wells active between 2012 and 2024 (~280 m cell size).
- Outside those areas of interest, the cell side was allowed to vary up to a maximum of ~700 m.

The total number of cells per layer is 24,608, with a total of 418,336 cells in the 17 layers. Some layers are allowed to 'pinch-out' where they are not present due to erosion, in which case they become inactive or direct through-flow cells in MODFLOW6. Excluding those unactive cells, there are 392,374 active cells.

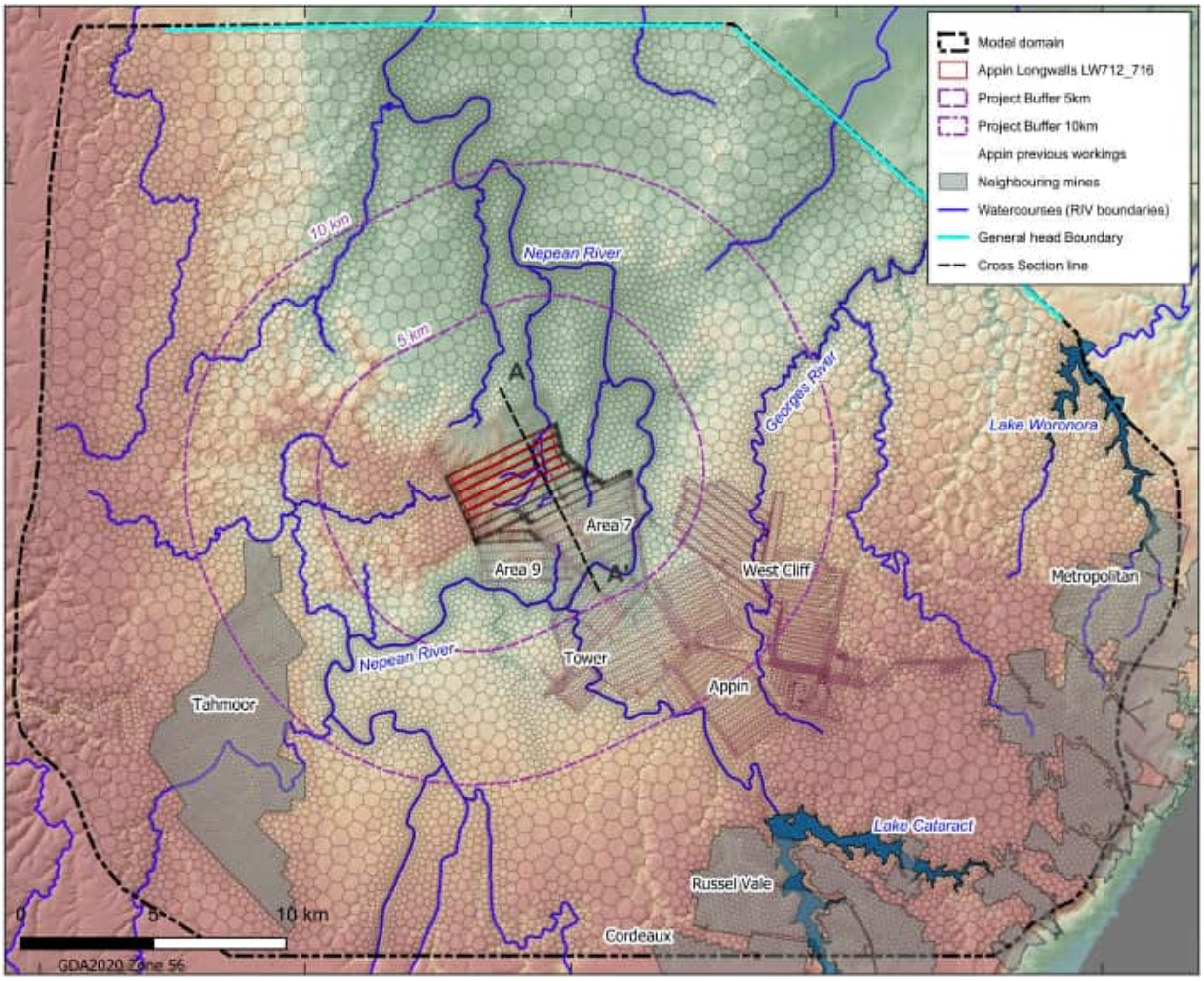

Figure 41 Model domain, mesh and Boundary Conditions

5.1.4 Model Layers

The groundwater model consists of 17 layers as listed in Table 15. Model layer 1 is present across the whole model extent, and includes the Quaternary Alluvium, regolith and weathered Wianamatta Group and HBSS. The Wianamatta Group is assigned to Layer 2 where present and allowed to "pinch-out"

elsewhere. The HBSS has been divided into 3 layers, and the Bulgo Sandstone has been divided into 3 layers to allow vertical gradients through the stratigraphic column to be represented. Some layers "pinch out" in locations where that geological layer has been eroded at outcrop. Where layers are pinched out, MODFLOW6 ignores the layer and allows groundwater to pass through those cells to the underlying layer. The Bulli Seam is represented in layer 14 for the purpose of modelling longwall mining at Appin, Metropolitan, Tahmoor and other historical mines. The Wongawilli Seam is represented in layer 16 to represent neighbouring mines where extraction is within that seam (e.g. Russell Vale). The model layer boundary surfaces were largely based on the previous model iterations which themselves used mining company 3D geology models and regional data. However, the upper model layers were revised to reflect more recent datasets: The model surface was based on accurate Lidar data and the Wianamatta Group shale and Hawkesbury Sandstone boundaries were updated based on the most recent ICHPL geological model.

Table 15 Numerical model layers and hydrostratigraphy

Layer	Hydrostratigraphic unit	Lithology	Average thickness (m)
1	Regolith/Alluvium	Unconsolidated, variable and minor unconfined aquifers	5 – 15
2	Wianamatta Shale	Shale and bedded sandstone	0 - 313
3	Hawkesbury Sandstone - upper	Coarse fluvial sandstone, porous aquifer	31
4	Hawkesbury Sandstone - mid	Coarse fluvial sandstone	58
5	Hawkesbury Sandstone - lower	Coarse fluvial sandstone	69
6	Bald Hill Claystone	Brown claystone; regional aquitard	30
7	Bulgo Sandstone - upper	Coarse qz-lithic sandstone	59
8	Bulgo Sandstone – mid	Coarse qz-lithic sandstone	59
9	Bulgo Sandstone - lower	Coarse qz-lithic sandstone	60
10	Stanwell Park Claystone	Interbedded shale and qz-lith sandstone	17
11	Scarborough SSt	Coarse qz-lithic sandstone	30
12	Wombara Claystone	Greenish-grey claystone	25
13	Coal Cliff Sandstone	Med-Coarse qz-lithic sandstone	20
14	Bulli Coal Seam	Coal and shale beds	2.7
15	Loddon Sandstone	Interbedded claystone / sandstone	24
16	Wongawilli Coal Seam	Coal and shale beds	2.4
17	Lower Coal Measures	Bedded sandstone, coal, claystone	200

5.1.5 Model Timing and numerical solver

Numerical models are discretised with respect to time by dividing the period of interest into a number of discrete Stress Periods. Model conditions such as mining extent and natural boundary conditions such as recharge are varied from one Stress Period to the next. Each Stress Period is further subdivided into time steps to facilitate convergence of the numerical solution.

Time was discretised in a similar manner to previous numerical models, with quarterly Stress Periods used during recent mining history and the main predictive period and with longer Stress Periods for previous mining periods and long-term post-mining periods, as listed in Table 16. A total of 120 Stress Periods was used to simulate the previous and proposed mining periods.

Table 16 Temporal discretisation

Stress Period	Time period	SP Length (number)	Type	Model stage
1	1959 Q3	N/A (1)	Steady State	Initial conditions
2 - 11	1960 - 2009	5-yearly (10)	Transient	Previous mining ("spin-up")
12 – 73	2010 – 2025 Q2	Quarterly (62)	Transient	Recent mining history matching
74 – 115	2025 Q3 - 2035	Quarterly (42)	Transient	Proposed mining LW712-716
116 - 120	2035 - 2040	1 year (5)	Transient	Post-mining period

The MODFLOW6 Adaptive Time-Stepping (ATS) option was used to assist model convergence during computationally difficult stress periods – the most difficult being periods 2 to 11 when numerous historical mining areas become active. ATS automatically decreases time-step size when the simulation becomes numerically difficult (sometimes to small fractions of one day) and increases it when the difficulty passes.

Numerical solver settings were specified in MODFLOW6 Iterative Model Solution (IMS) package. Solver parameters were initially set with the predefined COMPLEX setting which is optimised for non-linear models such as in complex mining scenarios. Parameters such as the maximum head change between outer iterations (HCLOSE) were relaxed to 0.05 in some Stress Periods to facilitate convergence. The entire model typically takes between 1.5 and 2 hours to run but can be longer depending on the parameter ensemble (up to 3 hours). This is near the practical limit of runtime for rigorous uncertainty analysis, with each calibration run taking several days to a week to complete.

5.1.6 Faults

As discussed in Section 4.6, data from Appin and Dendrobium are consistent with faults and dykes having low transmissivity, and therefore limited influence on mine water make and groundwater drawdown, particularly in the shallower geological strata (HBSS and BGSS).

However, during model calibration, several regional and in-seam faults were included in the model to assess their potential effects and impacts. For example, depending on its hydraulic characteristics, a fault may act as a barrier, or a zone enhanced permeability along which drawdown may propagate. Each fault or fault segment is assigned hydraulic properties (Kv and Kh) that are allowed to vary along the length of each fault segment using pilot points located at each end. This parametrisation was achieved using the *calc_linear_gauss_interp_factors* in the parameter pre-processor PLPROC (Doherty, 2020). The parameter values are then interpolated to the model mesh by PLPROC using a distance-weighted function, as shown in Figure 42. The fault parameters are assigned to model cells (nodes) whose centroids are located within a perpendicular distance (w) of 50 m from the fault (where w is user-specified). Beyond a distance of 50 + a (where a is user-specified and assigned 6 m in this study), the fault has no influence on the pre-existing model aquifer properties. Nodes located

The values of Kv and Kh at each pilot point has allowed to vary within reasonable bounds during calibration.

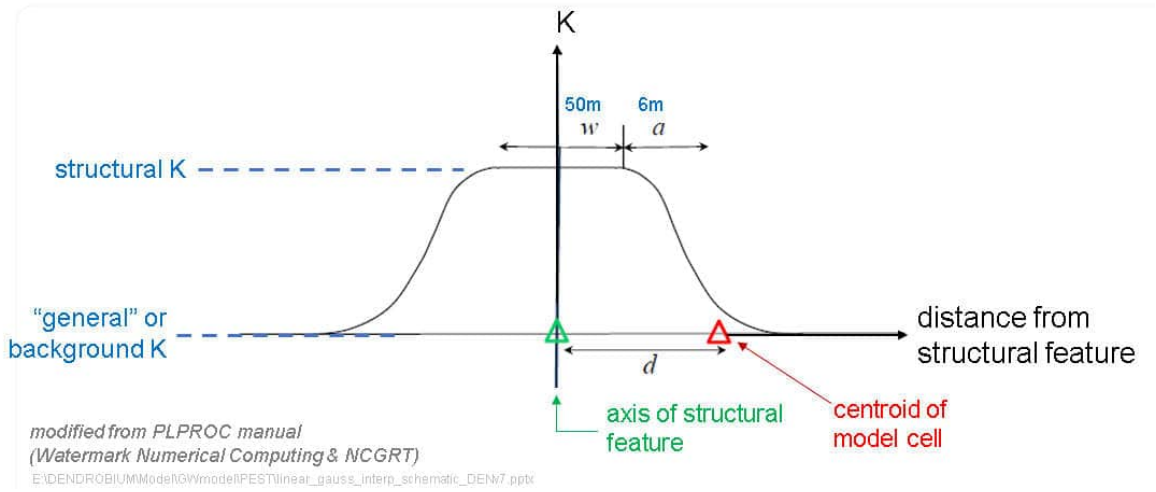

Figure 42. Spatial interpolation of fault parameters

5.2 Model boundary conditions

This section presents a summary of the numerical boundary conditions and assumptions used to simulate important regional hydraulic controls (groundwater recharge, rivers and lakes) and system stresses such as mining and CSG extraction.

5.2.1 Recharge and Evapotranspiration

Diffuse rainfall recharge is simulated using the recharge package (RCH). Recharge was distributed in five regionally distinct zones within the model domain based on location and lithology as shown in Figure 43. Rainfall generally decreases from the Illawarra escarpment towards the west. Three regional rainfall zones were defined based on the average distribution of deep drainage as shown in the BOM Australian Water Outlook water balance model (zones 1 to 3). Additional zones were designated for areas of shale outcrop (zone 4) and alluvium (zone 5) to allow for variation of recharge to those areas during calibration. For each of the three rainfall zones, representative SILO rainfall and evapotranspiration timeseries were obtained. The shale and alluvium zones were initially assigned the same timeseries as the Central Sandstone zone (2). Nominal initial recharge rates were calculated on the basis of 1% of average rainfall during each stress period, and the long-term average rainfall for each zone for future prediction stress periods. The value of 1% was used so that, during calibration, a recharge multiplier would represent a meaningful value (i.e. % rainfall). The initial 1% rainfall recharge value, while low in comparison to some estimates discussed previously, approximately matches the calibrated recharge rate for the previous (SLR, 2022) model. During calibration, the initial recharge rates for all five zones was allowed to vary independently using a recharge multiplier on the entire timeseries.

Evapotranspiration (EVT) from shallow water tables was simulated using the MODFLOW6 EVT package and was calculated for the same regional zones as the rainfall zones (1 to 3). In the case of EVT, the maximum EVT rate was applied as the reference evapotranspiration (FAO56) from SILO

data in each rainfall zone, based on the average for each stress period. The overall average maximum EVT rate applied is approximately 3 mm/day. EVT was applied to cells in the topmost layer of the model with a uniform extinction depth of 3 m, which was fixed during calibration.

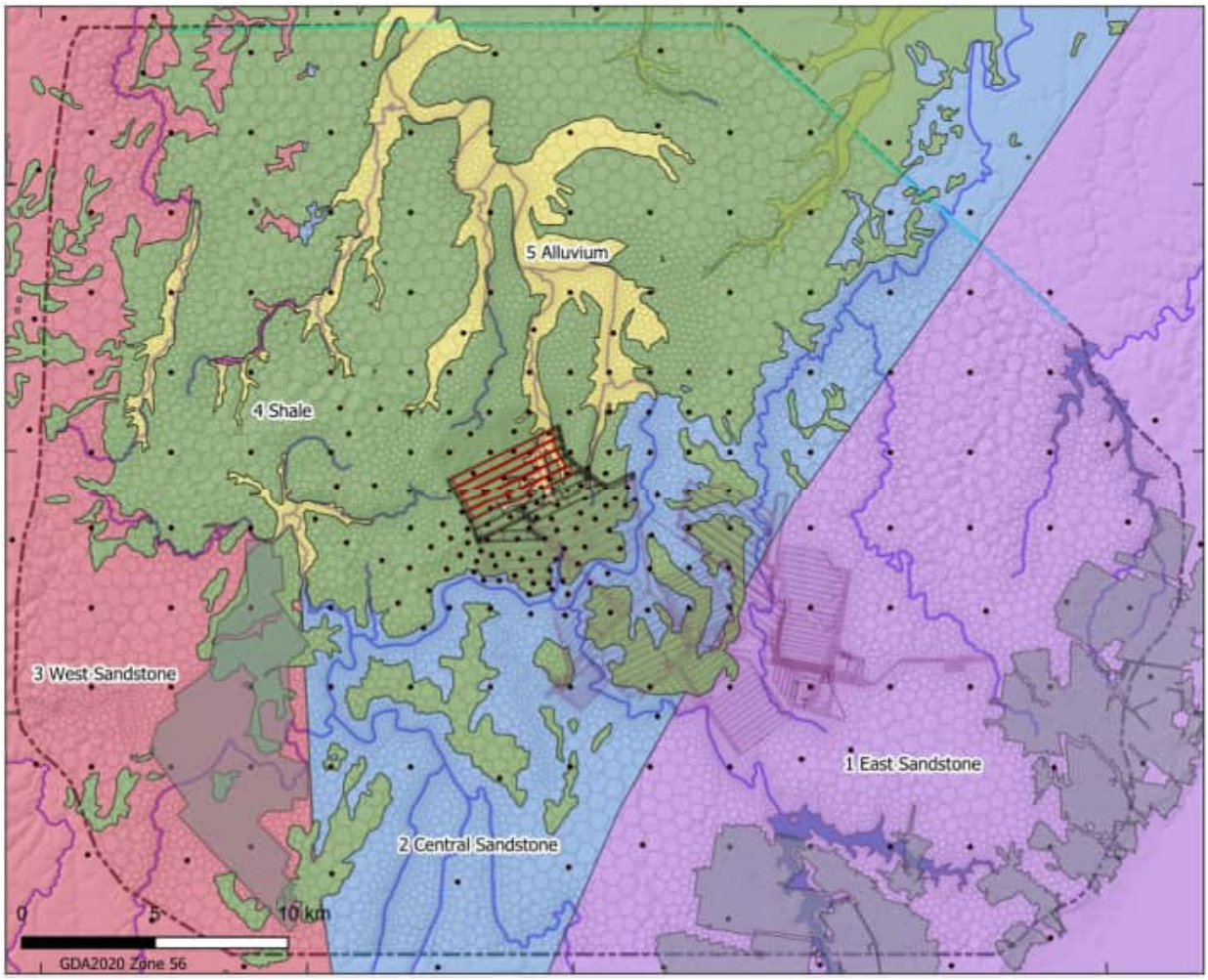

Figure 43 Model groundwater recharge zones and pilot point locations

5.2.2 Watercourses and lakes

All major watercourses are represented using the MODFLOW River (RIV) package. Major rivers which are assumed to flow most of the time (Nepean River, Cataract River, Avon, Bargo, Cordeaux, Georges, Mount Hunter, O'Hares Creek, Stonequarry Creek, Waratah, Werriberri and Woronora) were represented as RIV boundaries with a stage equal to the mean river level and with the riverbed elevation (RBOT) set at a nominal offset depth of 1 m. This allows for the river boundary to act as a water sink or a water source depending on the piezometric head in adjacent cells. That is, they are assumed to be perennial. Time-varying stages were not applied because the objective of the model is to assess potential loss from watercourses on a regional scale, rather to simulate groundwater-surface water interactions in detail. The river conductance was set at a value above that of typical HBSS, so that flow into and out of the streams is limited by the hydraulic conductivity of the host aquifer (which was allowed to vary during calibration). Other minor watercourses and drainage lines, including Navigation and Matahil Creeks were similarly represented as RIV boundary cells, but with the riverbed RBOT equal to the RIV stage, representing a gaining only (or ephemeral) stream and analogous to a MODFLOW6 Drain boundary.

Water storage reservoirs within the model domain (Lake Cataract and Lake Woronora) were represented as RIV boundaries with a time-constant stage set equal to the long term (20-year) average lake level. The reservoirs were given a nominal depth so that parts of each lake may gain or lose water depending on the piezometric head in the adjacent cells, although it is assumed that the reservoirs are predominantly gaining features. All watercourse and lake RIV boundaries were assigned boundary names in MODFLOW6 input files so that the baseflows could be reported for each using the Observation package.

5.2.3 Coal Seam Gas Wells

The MODFLOW 6 Well (WEL) package was used to simulate groundwater extraction and Bulli Coal Seam depressurisation associated with Camden Gas Project production wells operated by AGL between 2001 and 2024. Review of AGL annual reports indicates that a total of 31.1 ML of water was produced from the wellfield (average of 6.08 kL/day), with production peaking early, between 2012 and 2014, then declining through to 2024. A total of 85 wells yielded more than negligible volumes of water and were represented in the model with variable extraction rates over the life of the wellfield, as reported by AGL. The reported water production is an order of magnitude lower than the water licence allocation, which had been assumed as the basis for extraction in the previous numerical model. The well boundary condition was assigned to the Bulli Coal Seam only (Layer 14), since the casings and annuli of CSG wells are sealed to the surface and perforated only within the seams.

There is a high degree of uncertainty in relation to drawdown from CSG extraction as represented in a groundwater model. GSG extraction and depressurisation result in complex changes to coal seam hydraulic properties due to a number of counteracting factors, including an increase in effective stress which may reduce coal cleat aperture (and permeability), and, as CSG production is established, desorption and exsolution of methane gas which results in of two-phase (gas, water) flow (Marinas et al., 2013; Morad et al., 2008). Such processes are approximated in a groundwater flow model in which only single-phase groundwater flow is simulated, resulting in difficulty in closely matching transient groundwater head responses near CSG wells. For this reason, observations piezometric head in the Bulli Coal seam in piezometers located close to CSG wells is de-weighted for purpose of history matching.

Groundwater extraction at registered water supply bores was not included in the mine impact model. Most registered bores within 5 km of the Project are screened within the HBSS with a small number screen within the Wianamatta Shale and Bulgo Sandstone. It is assumed that actual abstraction will be significantly less on average than the allocation, and drawdown of the HBSS due to stock and domestic bores is assumed to be minor over the long term. In addition, extraction rates are not metered and are therefore highly uncertain. However, all registered bores are included in the model as observations points with which to assess mine-related drawdown on yield.

5.2.4 Mining

Coal mining has been carried out within the southern Sydney Basin and model domain for more than 130 years. Early mining was carried out using manual methods such as “bord and pillar”. Over the last 50 years mining has become highly mechanised with most mining now carried out using longwall extraction. Methods of mining are described elsewhere in the application and will not be repeated here. The subsidence effects of longwall mining and prevailing conceptual models are described in Section 4 of this report. The following subsections describe how underground mining and subsidence effects are implemented in the groundwater model.

Details of the geometry and timing of past mining are known reasonably well for recent mines, including at Appin, Tahmoor and Metropolitan. However, for older mines those details are often known only approximately. Such uncertainties can result in difficulties in matching observed mining effects in terms of precise timing, however the aim of modelling is to match the magnitude and rate of mining impacts.

5.2.4.1 Mine workings and development headings

Mine workings such as development roadways, mains developments and board and pillar extraction are generally confined to the working seam and do not result in significant subsidence or pervasive fracturing of adjacent geological strata. Such workings are represented using the MODFLOW6 Drain boundary package (DRN). The Drain boundary removes water from model cell at a rate dependent on the difference in piezometric head between the mine drain and adjacent model cells. The rate of flow is further limited by a conductance term. For mining applications, the conductance term was set to an arbitrarily high value (e.g. 100 m^2/day) so that simulated mine inflow is limited by the host rock permeability (primarily within the coal seam). This is conceptually consistent with groundwater inflow into mine workings during active mining when water is pumped from the mine workings. When mining is complete and a mine is no longer being dewatered, the drain boundary can be deactivated, allowing the mine cells and surrounding depressurised cells to re-pressurise.

In addition to using the Drain package, the hydraulic conductivity and storage parameters are increased at the time of mining to reflect the creation of void space. This was achieved using the TVK and TVS packages in MODFLOW6.

5.2.4.2 Longwall mining and subsidence effects

The implementation of longwall mining in groundwater models requires simulation of both groundwater and coal extraction at the working seam, as well as the effects of subsidence fracturing and associated depressurisation in the overlying strata and near-surface zones. Groundwater models are typically regional in scale; consequently, mining effects must be represented at a relatively coarse resolution—on the order of tens to hundreds of metres. This contrasts with some geotechnical models that resolve strata deformation and fracturing at much finer scales (for example, around one metre) or that explicitly represent individual fractures. Representing longwall mining effects in numerical groundwater models at this regional scale is therefore challenging in terms of representing the effects in conceptually consistent way while preserving a realistic water balance. In previous Southern Coalfield models, mining-induced effects have been incorporated in several ways, including:

- Transient material properties (TVK/TVS): In this approach, hydraulic properties within the fracture zone are varied through time, and drain boundaries are activated only within the coal seam to simulate progressive dewatering of the mined horizon.
- Stacked drains: Drain boundaries are applied to each model layer within the connected fracture zone to represent the free-draining behaviour of the fractured strata, thereby simulating depressurisation above the goaf.
- Connected linear networks (CLN): The goaf fracture network is represented as conduits rather than as porous media. Fractures within each vertical column of cells are aggregated into a single conduit element.

Each of these approaches have their strengths and limitations both in terms of achieving a reasonable water balance and matching observational data. In addition, CLNs have been found to be computationally unstable when applied in large numbers in the mine setting. A review by Turnage et

al. (2018) outlines some of the strengths and limitations of the TVM and CLN methods, mainly in the context of simulating coal seam gas and fault representation.

In this assessment, the effects of longwall mining was simulated using a combination of MODFLOW6 Drain boundaries and temporal variation in the properties of overlying strata using the TVK and TVS packages, as follows:

- First-workings, roadways and mains were represented using the MODFLOW6 Drains, as described in the previous section. The drains were activated at the time of mining and remain active for the duration of the mine.
- Longwall panels were represented by MODFLOW6 Drains boundaries at seam level, as described above. The Hydraulic conductivity and storage characteristics of the collapsed zone within the seam were informed by those calculated by Tammetta (2016), and implemented using the TVK and TVS packages.
- Subsidence fracturing above the goaf was represented using the TVK and TVS package to increase hydraulic conductivity and storage (Specific Yield) in overlying strata from the time of longwall extraction. The use of quarterly stress periods means that each longwall is extracted progressively over three or more stress periods. The vertical variation of the hydraulic conductivity and specific yield were defined using a logistic function as described below.
- Surface fracturing was similarly represented using the TVK and TVS package to increase hydraulic conductivity and storage (Specific Yield) to a defined depth in the area above each longwall.

Note that the use of the TVK and TVS packages assumes an equivalent porous media approach to simulating fracturing and deformation. This approach is considered appropriate at the regional model scale and where the model is not being used to explicitly simulate solute transport. An important implication of the use of the equivalent porous media assumption, is that impacts to surface water features such as diversion of flow from an individual fracture within a stream bed (for instance) cannot be predicted. Instead, such losses would be distributed over one or more model cells where surface fracturing is represented as an increase fracture permeability and storage.

5.2.4.3 Representation of the height of depressurisation

The vertical variation in hydraulic properties due to subsidence fracturing above the goaf was defined using a generalised logistic function (or Richards curve), as illustrated in Figure 44.

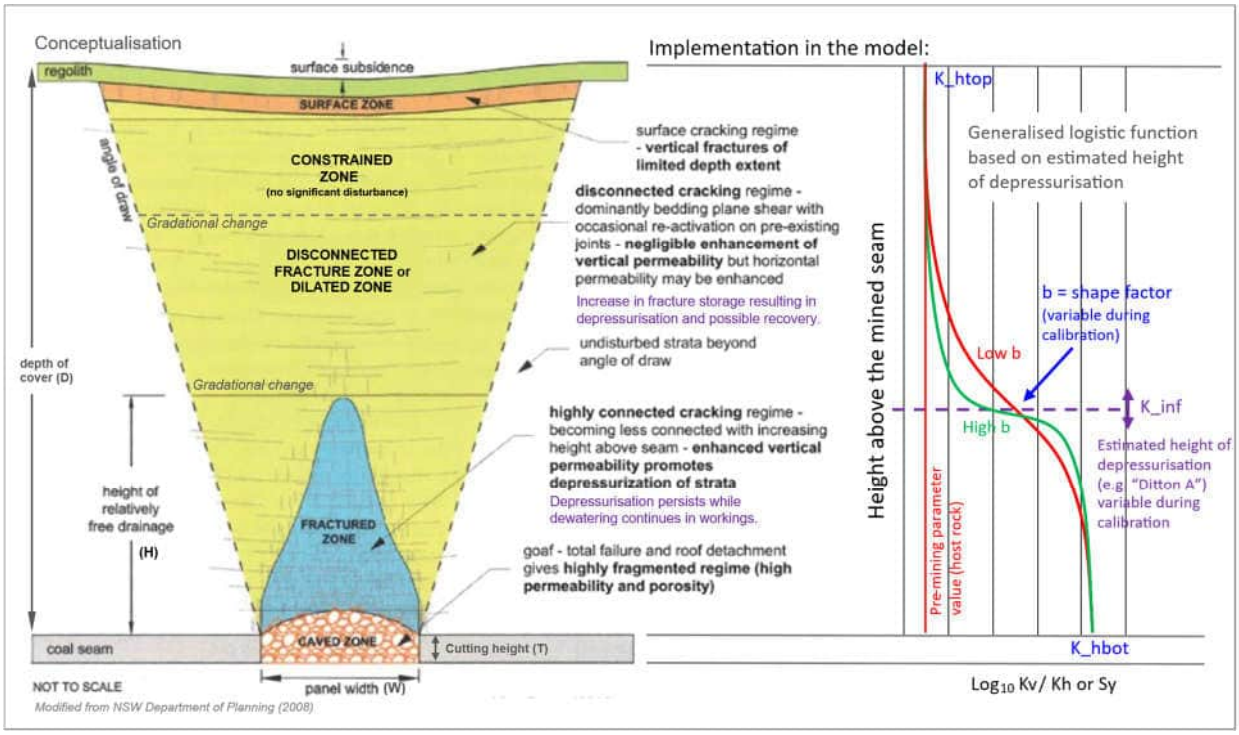

Figure 44 Definition of hydraulic parameters for fracturing above extracted longwalls

The generalised logistic function is defined for Kh, Kv had Sy, by a maximum value (at the seam) and minimum value (at the surface). The height of the inflection point of the curve is defined as the estimated height of depressurisation (e.g. by Ditton A), and the shape or steepness of the inflection can be varied with a shape factor (b). This results in 4 parameters for each property.

The approach was developed based on extensive drilling investigations above extracted longwalls at Dendrobium Mine by ICHPL and has been implemented successfully in recent numerical models for the Dendrobium Mine. It allows for the independent assignment of a height of vertically connected fracturing (Kv > Kh) while the height to which fracturing is dominated by bedding plane dilation (Kh > Kv) may persist to a greater height (e.g. Ditton Zone B). Similarly, a vertical change in specific yield due to the increase in fracture storage can be varied independently. An increase in fracture storage within shallower strata (without a significant increase in Kv) is an important mechanism to explain observed transition declines and recovery in head in some monitoring mores above or near longwalls (e.g.S2281_61 and S2281_99). The starting values for maximum permeability and storage just above the goaf were based on the studies at Dendrobium and the work of Tammetta (2016).

Evidence from boreholes in the area suggests that surface cracking generally does not occur at distances beyond the longwall panel footprint (SCT, 2020). Therefore, in the numerical model, surface cracking parameters were only adopted in model cells overlying the longwall panel.

During calibration, each parameter is allowed to vary, in addition to pre-mining host-rock parameter values, in order to match observed mining effects in groundwater monitoring data. Parameters were defined for groups of longwalls with similar mining geometries, resulting in eight groups in Appin Areas 7 and 9. Longwalls 706 to 710 were parameterised individually to take advantage of the large amount of monitoring data in that area. In total 31 longwall parameter groups were defined for Appin Mine and surrounding longwall mines. During calibration it was found that the initial heights of depressurisation based on Ditton A-zone and maximum fracture permeability values from observations at Dendrobium resulted in depressurisation that was much greater than that observed in site specific monitoring data,

implying that those initial estimates were too high for Appin Mine. It was therefore necessary to set wide uncertainty bounds on parameters during subsequent calibration runs to allow PEST++ optimise the model. An example of Height of Depressurisation parameters applied by PESTpp-ies above a longwall panel during model history matching is shown in Figure 45.

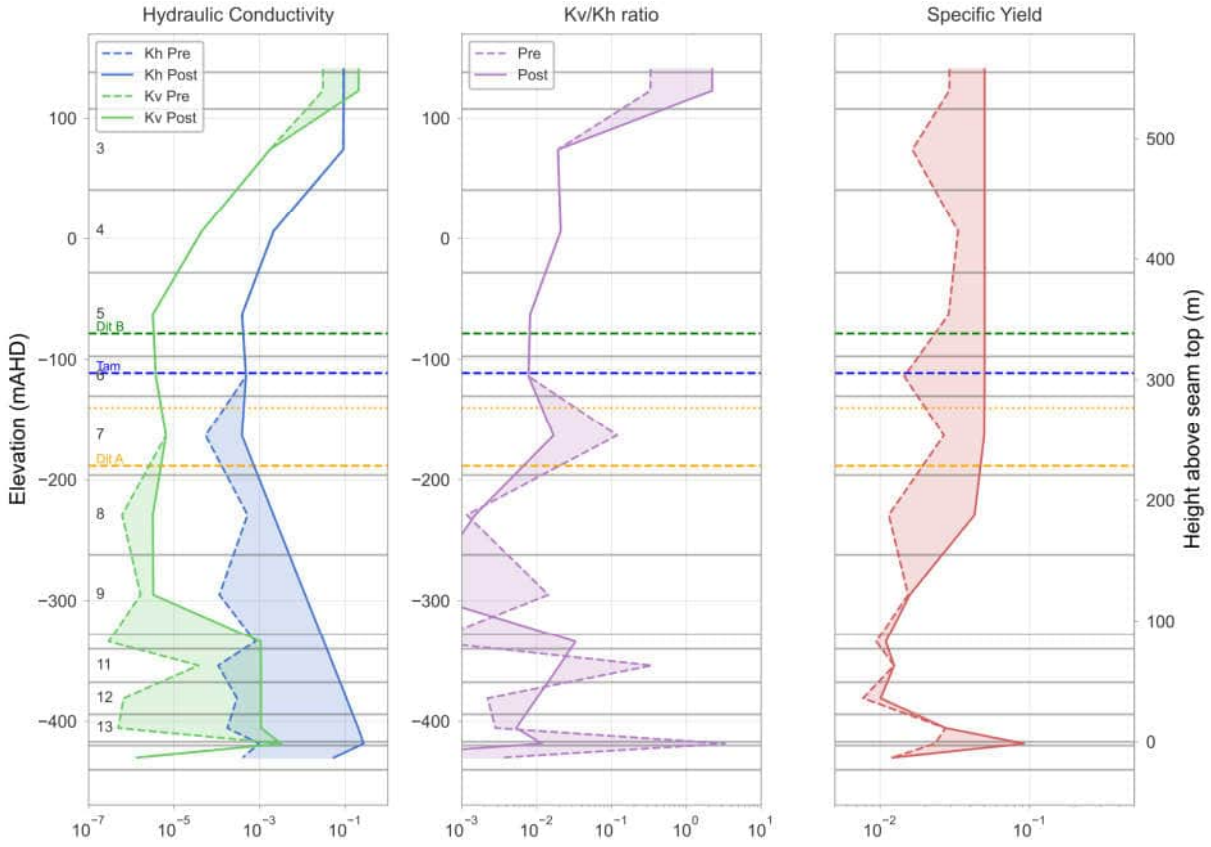

Figure 45 Example of model Height of Depressurisation parameters applied by PESTpp

5.3 Model performance and history matching

5.3.1 Model stability

The numerical model typically required about two hours to complete a full simulation, with some scenarios and parameter sets taking up to three hours. These run times reflect the relatively large number of active model cells and layers, and slower solver convergence in several stress periods when multiple mining areas were active. Despite this, the model achieved good numerical stability, with water balance discrepancies at the end of each stress period remaining below 0.01%. Long individual model run times meant that parameter-estimation sequences required several days to complete. A small number of runs failed to converge and were therefore excluded from parameter ensembles.

5.3.2 Water Balance

A representative transient model water balance is shown in Table 17, for Stress Period 75, the start of the predictive period (31/12/2025). The water balances show the computed volume of water that moves into and out of the model domain (aquifer) for the period. For the purposes of model water accounting, water that is released from aquifer storage is represented as “inflow” whereas water that is

taken up by the aquifer is “outflow”. The overall model water budget is approximately 195 ML/day. Major components of the water budget are shaded darker blue and minor components light blue.

The transient water budget shows the following:

- Water balance inflows are dominated by diffuse rainfall recharge (92%), with minor inputs from stream / river recharge and inflow through elevated parts of the northern aquifer boundary (GBH).
- Water balance outflow is dominated by Evapotranspiration (~70%) and baseflow to streams and rivers (~23%).
- Inflow into all mines in the model domain during SP75 is in the order of 5 ML/day, about to 2.6% of the regional water budget.
- The average CSG water production rate when the wellfield was operational averaged ~6 kL/day, which is insignificant in terms of the regional water budget.

All water balance components vary to a small degree Stress Periods due to time-varying recharge, EVT and mining; however the overall magnitude of the water balance remains relatively constant.

Table 17. Model transient water balance for Stress Period 75 end (31 December 2025)

Model element	Representing	Into model (m3/day)	In%	Out of model (m3/day)	Out%
Recharge	Rain recharge	179,627	92.0	0	0.0
EVT	Evapotranspiration	0	0.0	136,991	70.1
General Head	Northern boundary	1,848	0.9	1,939	1.0
River	Stream, Lakes	2,432	1.2	44,558	22.8
Wells	CSG extraction	0	0.0	0	0.0
Drains	Mine voids	0	0.0	4,997	2.6
Storage (Sy)	Aquifer storage	6,995	3.6	6,490	3.3
Storage (Ss)	Aquifer storage	4,399	2.3	326	0.2
Totals		**195,302**	**100.0**	**195,302**	**100.0**

5.4 Parameter estimation

Model history-matching (or calibration) was carried out using the parameter-estimation software PESTpp-IES (White, 2018; White et al., 2020). PESTpp-IES applies an iterative ensemble smoother, in which an ensemble of model realisations—each representing a different plausible set of parameter values—is updated over successive iterations. After each iteration, the simulated heads and flows for all realisations are compared with observations. Statistical updating then adjusts parameters across the ensemble in a way that improves the match to observations while also reducing the uncertainty of those parameters. This produces a posterior ensemble that reflects updated, observation-consistent uncertainty. An estimate of predictive uncertainty is then obtained by running predictive scenarios using the posterior parameter ensemble. In this sense, “uncertainty analysis” is an integral part of the history matching process.

The size of the ensemble – and the number if model runs per iteration – is typically in the range of 100 to 300 for models with runtimes less than 15 minutes. With runtimes in the order of two to three hours, such large ensembles become impractical, and for this assessment an initial ensemble size of 60 realisations was used. Following calibration, the ensemble was filtered to remove unrealistic or high-phi realisations resulting in a predictive ensemble of 48.

Subspace regularisation is inherent in the numerical formulation of the IES algorithm. It limits the magnitude of parameter adjustments away from their prior distribution and helps prevent over-fitting by restricting updates to the most informed directions in parameter space.

The objective function (phi) for the history matching process was the weighted sum of the squared residuals, where a residual is the observed value minus the modelled equivalent for each observation. As outlined previously in this report observations included measurements of piezometric head at minoring bores (n = 32,207 observations) and approximate measurements of mine inflow (n = 51 quarterly mean values). Piezometric head measurement observations were supplemented by the change in head between stress periods ("gwdiff"; n = 31,811) and vertical head differences in monitoring bores with multiple VWP arrays ("hdif"; n = 68,008), making a total of 132,077 observations used in history matching.

Observations were given an initial equal weighting of 1.0, but lower weightings were applied to data that were judged to be of poor quality or implausible based on other observations. Monitoring sites for which weights were reduced due to data quality concerns are listed with comments in Appendix D. During the history matching process, the relative weightings of those observation groups could be further specified using the *ies_phi_factor_file* function. This allowed the groundwater inflow observations to have a greater visibility to PESTpp-IES that would have otherwise been the case due to the smaller number of observations. Uncertainty in observations was specified using the *standard_deviation* variable for each observation, nominally 0.5 m for manual observations and up to 2.2 m for grouted VWPs based on estimates reported by HGEO (2024).

Model hydraulic parameters are summarised in Table 18. Aquifer parameters for all hydro stratigraphic units were applied using 282 pilot points per model layer and for each property (Kh, Kv, Ss and Sy), resulting in 19,176 parameters. Pilot point locations are shown as black markers in Figure 43. Zonation was applied to the Layer 1 to reflect the major outcrop lithologies (Sandstone, Shale, Alluvium). Several faults were included in the model parametrisation as described previously with individual parameters applied to the ends of each fault segment. Rainfall recharge was allowed to vary through use of a recharge multiplier which was applied to the base time-series in each recharge zone. Mining height of depressurisation parameters were applied above previous and planned longwalls as described in Section 5.1.6.

Table 18. Parameter groups estimated through history-matching process

Parameter	Layer	Method	Transform
Hydraulic conductivity (horizontal) (Kh)	17	Pilot points (n=282 per layer)	Log
Hydraulic conductivity (vertical) (Kv)	17	Pilot points (n=282 per layer)	Log
Specific Yield (Sy)	17	Pilot points (n=282 per layer)	Log
Specific Storage (Ss)	17	Pilot points (n=282 per layer)	Log
Fault properties	All	Pilot points (2 per fault segment)	Log
Recharge multiplier	1	Pilot points (n=282 per layer)	Log

Parameter	Layer	Method	Transform
Mining Height of Depressurisation	Varies	Height shape function; See Section 5.1.6	Log or none (height)

Prior uncertainty pounds for each parameter group were applied on the basis of observed or estimated variability in available measurements. Parameters for hydraulic conductivity were nominally allowed to vary by an order of magnitude for log-transformed hydraulic parameters, broadly in line with variability seen in packer testing data. Non-transformed parameters for the height of the inflection point for Height of Depressurisation was given a broad range and *standard_deviation* parameter of 50 m.

History matching was carried out in several phases. Initially manual coarse adjustments were made to parameters to align with overall elements of the water budget, after which parameter values were refined in several PESTpp-IES history matching runs. Between each run, further changes were made to the model, including structural changes such as the addition of faults or refining the mine sequence, and addition of derived observations such as temporal and vertical head difference. The next run would incorporate the optimised parameter ensemble from the previous run and any other changes applied. During the final PESTpp-IES run the objective function was reduced by approximately an order of magnitude (7.6×10^{-9} to 1.9×10^{-9}) and it was determined that further iterations and modifications would result in little improvement.

5.4.1 Optimised parameters

The mean values for optimised model hydraulic parameters are listed in Table 19. Those values represent the mean values of all pilot points in each layer for the base realisation (with the lowest objective function). The values remain consistent with estimates from packer testing and are broadly within the range of parameter values applied in previous numerical models for Appin, noting there is a wide range in optimised hydraulic parameters in previous models (Figure 46). Optimised recharge multiplier parameters ranged between 0.15% an 10% of total rainfall, being highest in the eastern sandstone zone.

The average recharge rate implied by the model water balance is 6.4% of rainfall which is consistent with previous regional numerical models and with estimates of regional recharge based on a range of methods as presented in Section 4.7.

Table 19. Calibrated aquifer properties (arithmetic mean of all pilot points)

Layer	Hydrostratigraphic unit	Kh (mean)	Kv (mean)	Kv/Kh (mean)	Sy (mean)	Ss (mean)
1	ALLUV	3.83E-01	6.58E-02	4.90E-01	6.73E-02	2.06E-03
2	WMGR	6.64E-02	1.62E-02	5.30E-01	3.06E-02	8.03E-04
3	HBSS upr	1.09E-01	2.87E-02	3.87E-01	6.19E-02	6.32E-04
4	HBSS - mid	4.37E-02	7.91E-03	1.25E-01	3.82E-02	2.08E-04
5	HBSS - lwr	1.48E-02	1.20E-03	8.94E-02	2.59E-02	4.26E-05
6	BHCS	3.32E-03	2.71E-04	3.28E-02	1.52E-02	1.59E-05
7	BGSS - upr	2.15E-03	1.36E-04	7.48E-02	2.32E-02	9.28E-06
8	BGSS - mid	6.83E-04	1.66E-05	5.04E-02	2.02E-02	3.67E-06

Layer	Hydrostratigraphic unit	Kh (mean)	Kv (mean)	Kv/Kh (mean)	Sy (mean)	Ss (mean)
9	BGSS - lwr	2.72E-04	6.72E-06	7.12E-02	1.74E-02	2.86E-06
10	SPCS	2.42E-04	3.31E-06	4.33E-02	1.12E-02	2.80E-06
11	SBSS	1.53E-04	1.24E-05	4.44E-01	1.53E-02	2.73E-06
12	WBSS	1.66E-04	3.34E-06	5.30E-02	1.24E-02	3.04E-06
13	CCSS	1.97E-04	2.51E-06	4.65E-02	1.54E-02	4.09E-06
14	Bulli Seam	1.82E-02	4.09E-04	1.67E-01	1.78E-02	2.95E-06
15	LDSS	1.93E-04	3.27E-06	5.22E-02	1.50E-02	1.92E-06
16	WW Seam	2.10E-02	2.29E-04	6.47E-02	1.73E-02	2.13E-06
17	Lower CM	3.03E-04	4.54E-06	4.89E-02	9.54E-03	1.74E-06

Note: Where E denotes scientific notation exponent of 10

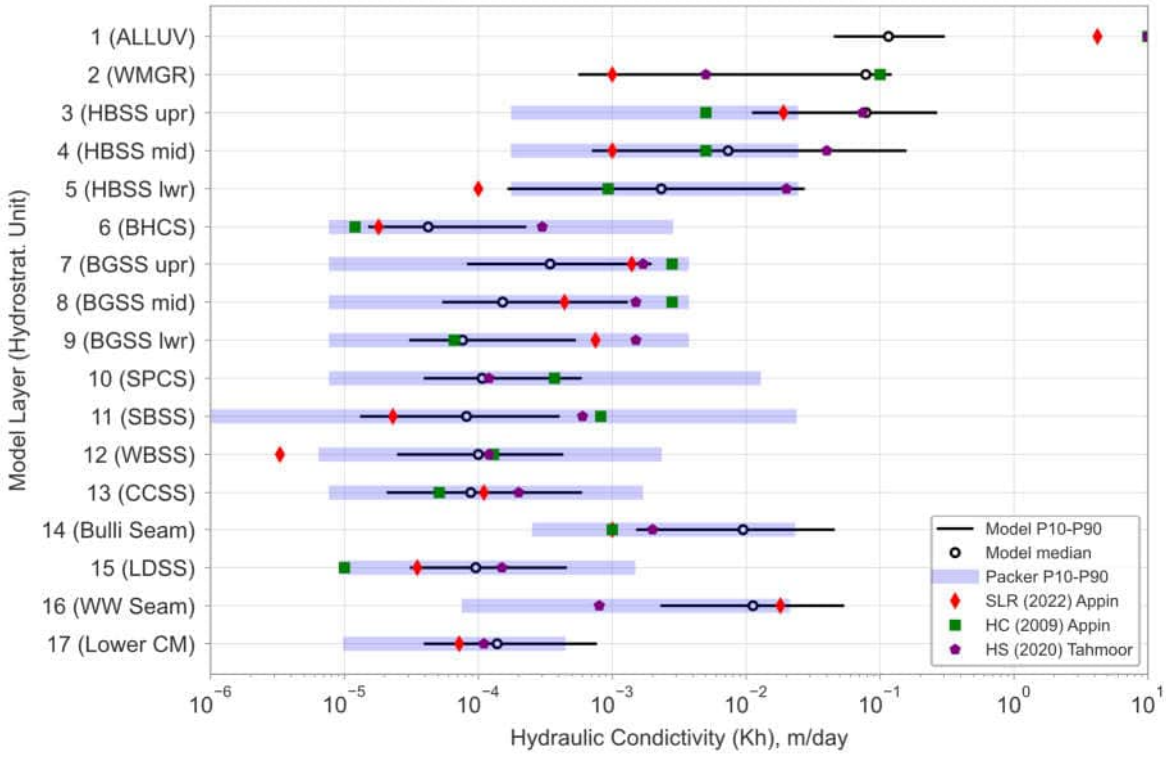

Figure 46. Summary of optimised model Kh ranges comparted with previous models

5.4.2 Model performance

Numerical groundwater model performance is assessed by comparing simulated system behaviour with field observations, using both quantitative statistics and qualitative pattern-matching. Current guidelines (Barnett et al., 2012b) emphasise that the purpose of calibration is not to reproduce every observed value exactly, but to ensure that the model captures the dominant processes that control

predicted drawdown and inflows, while reducing parameter uncertainty through history matching. Formal measures of fit—such as mean error (ME), mean absolute error (MAE) and scaled RMSE—are used to evaluate the agreement between simulated and observed piezometric heads, recognising that some discrepancies are expected due to data limitations and structural simplifications. For transient responses, a model's ability to reproduce temporal trends, timing and relative changes is generally more important than matching absolute head levels, particularly where predictions focus on drawdown or head differences. Similarly, mine inflow evaluation focuses on the models ability to reproduces the magnitude of inflow and main trends in system responses. The following sections present these performance assessments for heads, transient head behaviour and mine inflows.

5.4.2.1 Piezometric heads

A bivariate plot of modelled versus observed piezometric heads is shown in Figure 47, providing an overview of model performance in terms of piezometric head across all hydrostratigraphic units. The plot includes all transient observations and modelled values for the base optimised parameter realisation that have high weightings in terms of data reliability. Key history matching statistics are shown on the plot and presented in Table 20 compared with previous models for Appin.

Ideally observation data should plot close to the 1:1 line indicating a close match between observed and simulated results. Results for the optimised model are generally distributed along the 1:1 line. with are some deviations as discussed further below. Most of the larger deviations relate to the timing of drawdown, rather than the magnitude of drawdown, as can be seen in the following section. Notably, there are a number of observations from VWPs located within the SBSS that plot below the line indicating that the model tended to *over*-estimate drawdown impacts in that unit.

The Mean Error (ME) is 9.3 and the mean Absolute Error (MAE) is 32.4. The RMSE is 49.4 m producing a scaled RMSE of 3.9% of the total range in heads. These results are comparable to previous Appin models and improves on the first models for the region for which observation data were limited at the time.

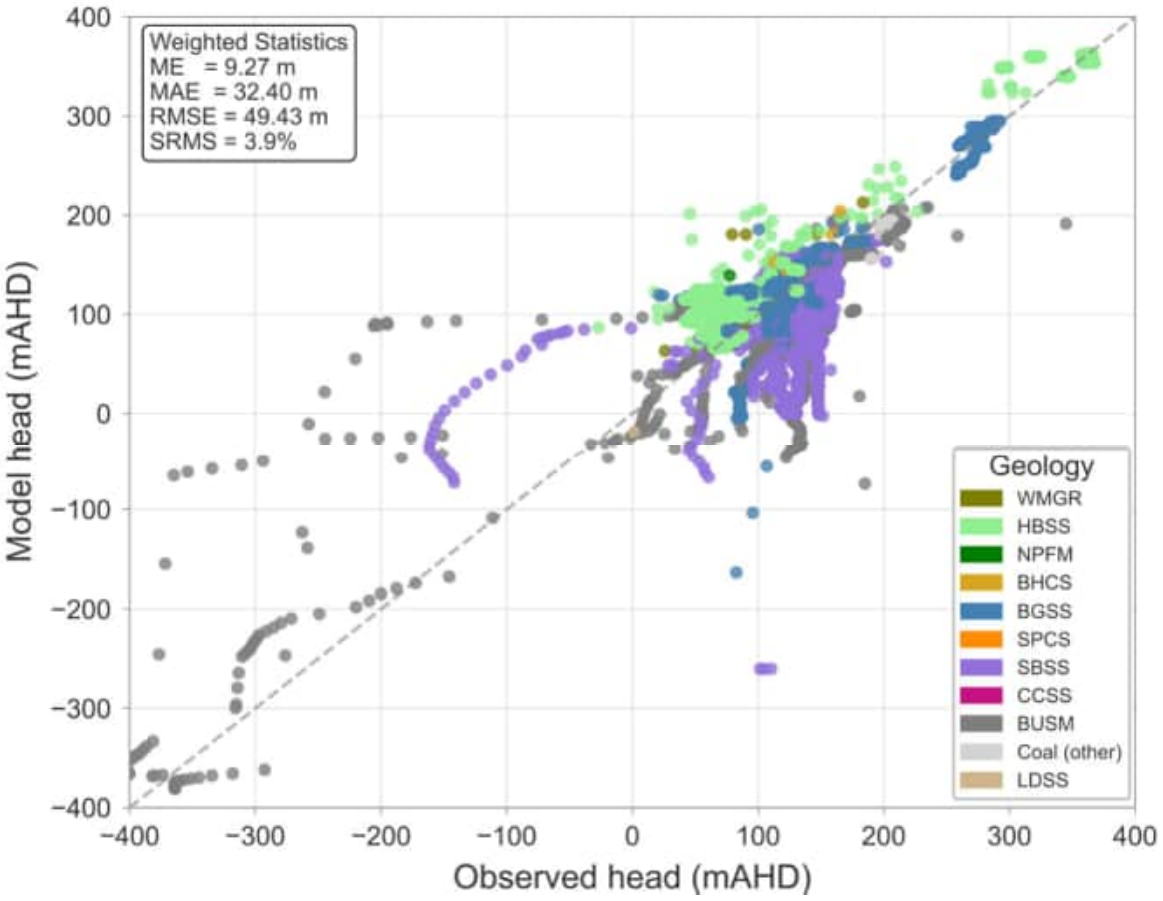

Figure 47. Bivariate plot of modelled versus observed heads for all transient data

Table 20. History matching statistics

Statistic	Heritage Computing (2009)	Hydro-Simulations (2018)	SLR (2022)	This assessment
Number of obs (n)	220	4275	12,580	132,077
Root Mean Square Error (**RMSE**, m)	98.3	95	44.4	49.4
Scaled Root Mean Square (**SRMS**, %)	9.6	33	4.7	3.9
Mean Error (**ME**, m)	39.5	36.1	-1.0	9.3
Mean Absolute Error (**MAE**, m)	117.9	56.1	25.5	32.4

5.4.2.2 Temporal trends in hydrographs

A full set of simulated–observed groundwater-level hydrographs is provided in Appendix C. These illustrate the range of calibration performance achieved across the monitoring network, with some locations exhibiting close agreement in both magnitude and temporal behaviour and others showing larger discrepancies. A representative subset is reproduced in Figure 48 to demonstrate cases where the model captures the drawdown response and trend particularly well at sites proximal to the Project Area. Common patterns in the simulated–observed comparison include the following:

- Bulli Coal Seam: Depressurisation within the working seam is generally well simulated, with the model capturing large declines in head near mine workings (Figure 48 A, B). At other locations the magnitude of decline may be relatively well-matched, but the timing is not. This may reflect uncertainty in respect of the timing of roadway development.

- The SBSS is a deep sandstone unit between the Bulgo Sandstone and the Bulli Seam. The model tends to over-predict drawdown in this unit in terms of magnitude. Head change in this unit is sensitive to parameters relating to subsidence fracturing and height of depressurisation and this suggests that fracturing may not be as extensive as Appin as assumed from the prevailing empirical models (e.g. Tammetta). Of particular interest are the hydrographs for S2080_440, S2080_447 and S2080_454, all located within the SBSS and within 600 m of LW703 and 900 m of LW901. They show very little depressurisation, despite there being 30+ m of depressurisation in the overlying BGSS (S2080_417, S2080_241) which is more accurately simulated.

- Drawdown in the BGSS is relatively well simulated in terms of magnitude and overall trends near the Project Area, although matches are variable. Relatively good matches in trend are seen at S1996 (located between Appin Colliery and neighbouring mines to the south), S2080 (as mentioned above), S1913 (460 m from LW710B), S1936 (above LW706), S1941 (above LW904), and S2173 (5 km north of existing Longwalls).

- Simulated drawdown in the HBSS is minor, and this matches observations in bores that are located above or close to extracted Longwalls which show relatively little (and spatially variable) drawdown or transient drawdown followed by recovery. Drawdown is stimulated in the HBSS at S1936 (above LW706) and S2080_170; whereas at VWPs such as S1941_65, S1941_126.5, S2025_10 and others, no drawdown is predicted, consistent with no clear trend in observed data. Close matching of trends in the HBSS may be complicated by local pumping effects (which is not simulated and would be difficult to quantify) and possible local variations in recharge.

It is apparent from previous regional modelling studies that achieving a close match to all absolute heads and temporal trends in a regional scale impact model has been consistently challenging. This is reflected in the similarity and spread of calibration statistics presented in Table 20. Experience gained during development of the current Appin model suggests that remaining discrepancies likely arise from a combination of factors, including unreliable or inconsistent monitoring datasets, uncertainty in historical mining schedules, and regional or site-specific influences that are either unknown or cannot be reliably represented at the spatial and temporal resolution of the model. Nevertheless, the current model reproduces the key temporal trends and drawdown responses that are known to be related to mining, and, as shown in the following section, provides plausible forecasts that are consistent with previous assessments and with the magnitude of observed effects at key monitoring sites

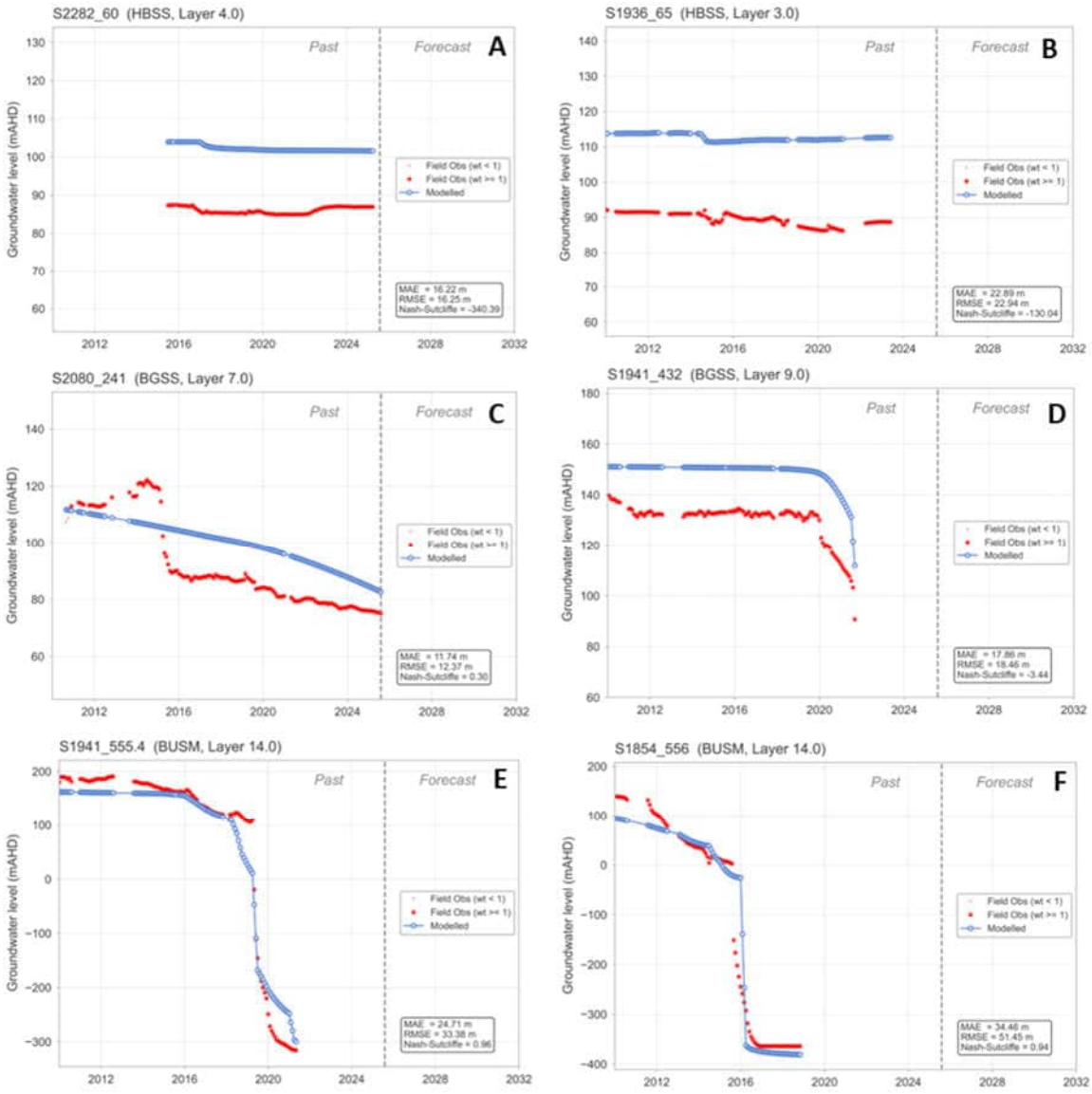

Figure 48. Selected calibration hydrographs for sites near the Project Area

5.4.2.3 Mine inflows

A timeseries plot of simulated groundwater inflow to the underground mine workings in Appin Areas 7 and 9 is shown in Figure 57 (Results Section 6.2). The figure shows that model estimates of past mine inflow match the net mine water balance data relatively well. The mine water budget indicates that groundwater inflow between 2016 and 2022 varied between ~0.5 and 1.0 ML/day, increasing to ~2.0 ML/day in 2024. The simulated mine inflows match observations in terms of the magnitude of inflow, and also capture an increase in inflow, although more gradual than observed. The relatively good match in terms of groundwater inflow to the mine is important in terms of overall water budget and simulating the total drainage of groundwater from the connected fracture network that forms above the goaf.

5.4.3 Sensitivity analysis

Model sensitivity analysis is a key component of groundwater modelling practice, aimed at identifying how variations in model parameters influence simulation outputs. It provides a structured means of understanding which parameters exert the greatest control on model behaviour and, conversely, which

have negligible influence. As outlined in the *Australian Groundwater Modelling Guidelines* (Barnett et al., 2012), sensitivity analysis complements calibration by testing the robustness of a model and by revealing dependencies between parameters and predictions.

In this assessment, sensitivity analysis was carried out using PESTPP-SEN, which implements global sensitivity analysis (GSA) (White et al., 2020). Specifically, we applied the Morris method of GSA, a computationally efficient one-at-a-time screening method well suited to models with long run times (Campolongo et al., 2007; Morris, 1991).

5.4.3.1 Method

The Morris method is a GSA screening technique that efficiently identifies which model parameters most influence simulation outputs. It explores the multidimensional parameter space (the "hypercube") using *r* random paths, each consisting of *m + 1* model runs where *m* is the number of adjustable parameters. Within each path, parameters are perturbed one at a time by a fixed increment (Δ) in a single model run to calculate elementary effects (EE) - finite-difference estimates of how changes in each parameter affect the model response (in this case, the objective function, phi). From those estimates, three statistics are derived: **μ** (the mean of the effects, indicating the overall direction of influence), **μ*** (the mean of their absolute values, showing the overall strength of influence regardless of sign), and **σ** (their standard deviation, reflecting nonlinearity or interactions among parameters). Together, μ*, μ, and σ summarise which parameters matter most, and whether their effects are consistent, nonlinear, or interdependent.

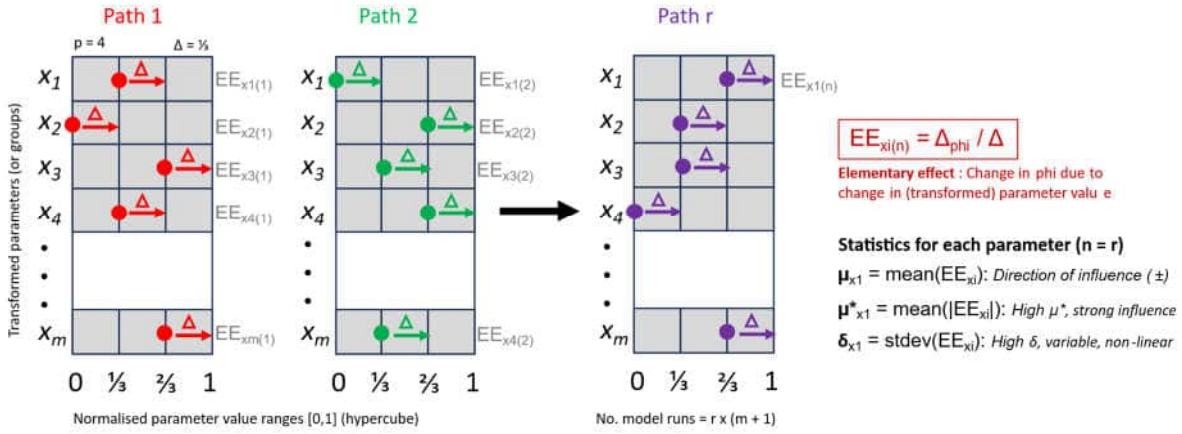

Figure 49. Illustration of the Morris method for global sensitivity analysis (GSA)

Although the Morris algorithm is efficient, it requires a large number of model runs to complete, and it is impractical to assess individual parameters in a highly parameterised model with long run times. Therefore, the analysis was carried out using parameter groups defined according to their type and stratigraphic position. In total, 34 parameter groups were defined including subsidence fracturing parameter groups and pilot point Kv, Kh, Sy and Ss parameters in four stratigraphic groups, fault properties and rainfall recharge. The grouped analysis resulted in a total run time of around 2 days.

5.4.3.2 Sensitivity analysis results

The results of the global sensitivity analysis are summarised as a bar chart in Figure 50. The Mean absolute sensitivity of each parameter group (μ*) is shown for each parameter group in terms of its influence on observations of piezometric head and mine inflow.

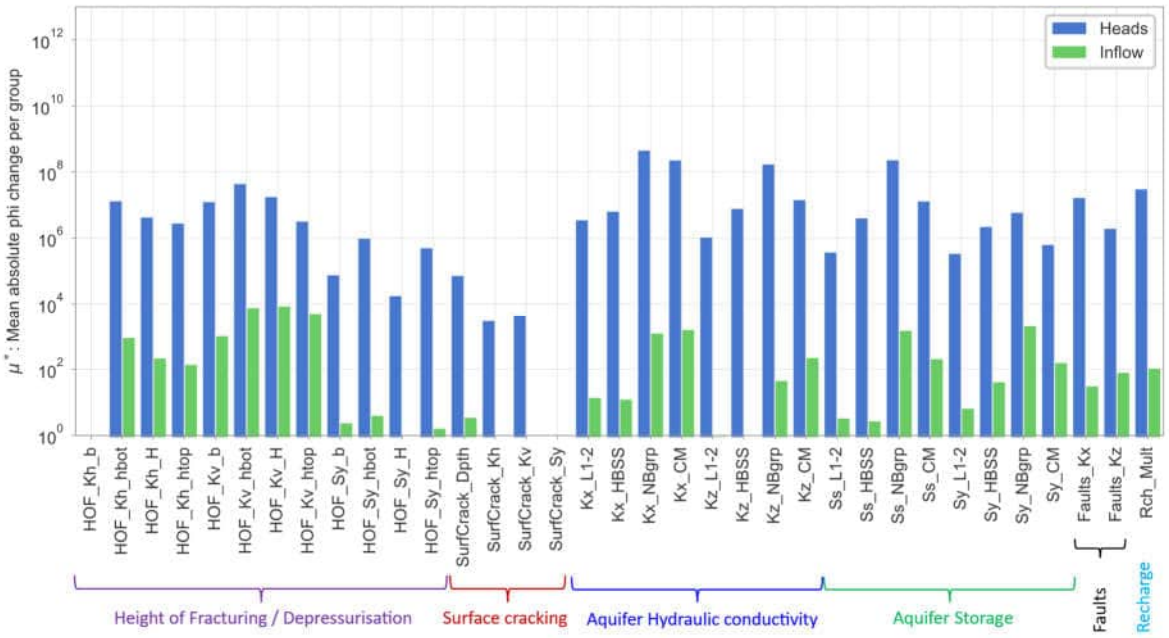

Figure 50. Mean absolute sensitivity of grouped parameters (μ*)

Most parameter groups are relatively sensitive with respect to changes in piezometric head, but particularly parameters related to hydraulic conductivity (horizontal and vertical) in the Narrabeen Group (NBgrp) and coal measures (CM), the height of fracturing (HOF, particularly Kv). Surface cracking parameters, the HOF shape parameter for Kh and storage parameters in the shallower stratigraphic units were less sensitive relative to other parameter groups.

With respect to mine inflow, parameter group sensitivities were more variable, with the most sensitive being hydraulic conductivity (but not storage) within the subsidence fractured zones, and the hydraulic conductivity and storage parameters in the Narrabeen Group and Coal measures. Surface cracking parameters have negligible influence on inflow as expected.

Fault parameters are moderately sensitive with respect to changes on heads and inflow, with horizontal being more sensitive than vertical hydraulic conductivity (Kx), for heads. This result is consistent with experience during calibration, with very minor and spatially variable improvements in calibration after faults were introduced to the model. The rainfall recharge multiplier is moderately sensitive with respect to heads and inflow.

The variability in the influence of parameter groups (sigma) is broadly correlated with μ*, with large variability in the most sensitive parameters. This is expected in a large complex model and indicates significant non-linearity in parameter response

5.4.4 Model Limitations

The numerical model developed in this assessment is able to capture important groundwater trends and is considered fit for the purpose of estimating impacts from the proposed mining extension. As with all numerical models, not all aspects of the monitoring data can be matched closely. This can be due to a number of factors including uncertainty or errors in the monitoring data itself, or uncertainty related to model structure whereby some aspects of historical mining, groundwater abstraction or natural drivers are not well known and are assumed. In addition, there may be local scale processes that cannot be captured at the regional scale of the model (e.g. recharge). The calibration process provided some insights into refinements that could be explored in future assessments, specifically:

- Recharge: application of a more temporally variable recharge sequence based on daily soil-moisture accounting, may improve simulation of rainfall responses in shallow piezometers.
- Consideration of the depth of weathering, particularly beneath major watercourses. Including a deeper weathering profile may improve simulation of heads in the lower HBSS.
- Height of Depressurisation. Further assessment of subsidence effects on aquifer properties above the goaf as more monitoring data and drilling data become available.
- Water supply abstraction: Inclusion of private water supply pumping if reliable abstraction rates are available, and/or inclusion of pumping as a variable parameter during calibration.
- Geological faults: further assessment of the potential role of geological structure in groundwater flow and drawdown. Future monitoring could target areas near mapped faults to improve that knowledge.

6. Predicted impacts on groundwater

Potential impacts to groundwater due to drawdown from the project and cumulative drawdown from previous and neighbouring mines was assessed using the numerical model as described in the previous section. In order to isolate impacts from the project and to determine total cumulative drawdown impacts, the model was run under three scenarios, as follows:

- A – Null scenario: No mining
- C – All mining, but without project (LW712-716)
- D – All mining: Neighbouring mines + Appin including Project (LW712-716)

Assessment of impacts was undertaken as follows:

- D-A = Full cumulative impact
- D-C = Incremental impact of the project.

For each scenario, the model was run multiple times using the calibrated parameter ensemble, allowing calculation of impacts for the base realisation and percentile estimates (P10, P90) for all model runs. In terms of drawdown, only the base (or expected) and the P90 predictions (pessimistic) are of interest. Model predictions include groundwater depressurisation, change in river baseflow, drawdown at private water supply bores and GDEs, and estimated of groundwater inflow to the mine. The results are presented in the following sections.

6.1 Depressurisation

Fracturing of the overburden and mine dewatering have the potential to cause depressurisation of overlying formations. The magnitude and extent of depressurisation will depend on a number of different factors including the hydrostratigraphy, hydraulic properties of aquifers and aquitards, and height of connective fracturing. Depressurisation is greatest at the working coal seam and decreases with distance, and stratigraphic height above the mine.

In the following subsections, contour maps of depressurisation are presented for the incremental effects of the project (Scenario D-C) and full cumulative effects for all mining (Scenario D-A) for the Lower HBSS and the upper BGSS stratigraphic units (model layers 5 and 7). The maps represent the maximum drawdown predicted to occur between 2026 and 2035. Results for those two hydro stratigraphic units best represent the maximum potential impacts to major watercourses, GDEs and private water supply bores which intersect and are mainly influenced by groundwater within the HBSS. Uncertainty in the estimates of drawdown is illustrated in contour maps showing the extent of the 2 m drawdown contour at the P50 (expected) and P90 (pessimistic), based on numerous model runs using the calibrated parameter ensemble.

6.1.1 Incremental depressurisation

Contour maps of maximum incremental depressurisation of the project within the lower HBSS and upper BGSS are shown in Figure 51 and Figure 52. Within the lower HBSS depressurisation of between 0 and 17 m is expected (up to 20 m P90), with the highest drawdown expected above the proposed longwalls. The 2 m drawdown contour extends to a maximum of 430 m from the western edge of the proposed longwall (up to 480 m at P90). Model results indicate most drawdown effects will occur near the western end of the longwalls. Given the uncertainty and potential variability in

geological conditions across the area, it is reasonable to draw a broader conclusion that drawdown in the lower HBSS may vary between 0 and 17 m in areas directly above the proposed longwalls with 2 m or more drawdown extending up to 430 m from the longwall footprint.

Within the upper BGSS depressurisation of between 0 and 36 m is expected (up to 40 m P90), with the highest drawdown expected above the western end of the proposed longwalls. The 2 m drawdown contour extends to a maximum of approximately 800 m form the western and northern edges of the proposed longwalls (up to 900 – 1000 m at P90). There are no registered private water supply bores, nor major watercourses that intersect the upper BGSS in the area of groundwater drawdown influence.

6.1.2 Cumulative depressurisation

Contours of maximum cumulative depressurisation between 2026 and 2035 related to all mining including the Project are shown in Figure 53 and Figure 54 for the lower HBSS and upper BGSS.

In the lower HBSS depressurisation of between 0 and 20 m is expected (up to 23 m P90), within the Project area. Cumulative drawdown extends south of the Project area, covering previous mining areas at Appin, Tower and West Cliff. The highest cumulative drawdown in the lower HBSS is predicted to occur above recently extracted Longwalls 902-905 where it ranges between ~3 m and ~40 m. The cumulative 2 m drawdown contour encompasses most of the extracted longwalls across Appin, Tower and West Cliff, but does not extend to or merge with that of neighbouring mines to the west (Tahmoor), south (Cordeaux) and east (Metropolitan).

Within the upper BGSS cumulative depressurisation up to 76 m is expected (up to 100 m P90), within the project area. Cumulative drawdown in the upper BGSS extends south, such that the 2 m drawdown contour encompasses previous mine areas at Appin, Tower and West Cliff and extends 2 to 4 km from the mine areas. The 2 m drawdown contour partly overlaps and merges with the broad cones of drawdown predicted for neighbouring mines to the west (Tahmoor), south (Cordeaux) and east (Metropolitan). Note that neighbouring mines are not included in this model with the same detail as for Appin and the reader is referred to separate assessments for more accurate assessments or drawdown associated with those mines.

In general, the extents and distributions of cumulative drawdown are consistent with those predicted in the previous groundwater assessment for Appin Longwalls 709-711 and 905 (SLR, 2022).

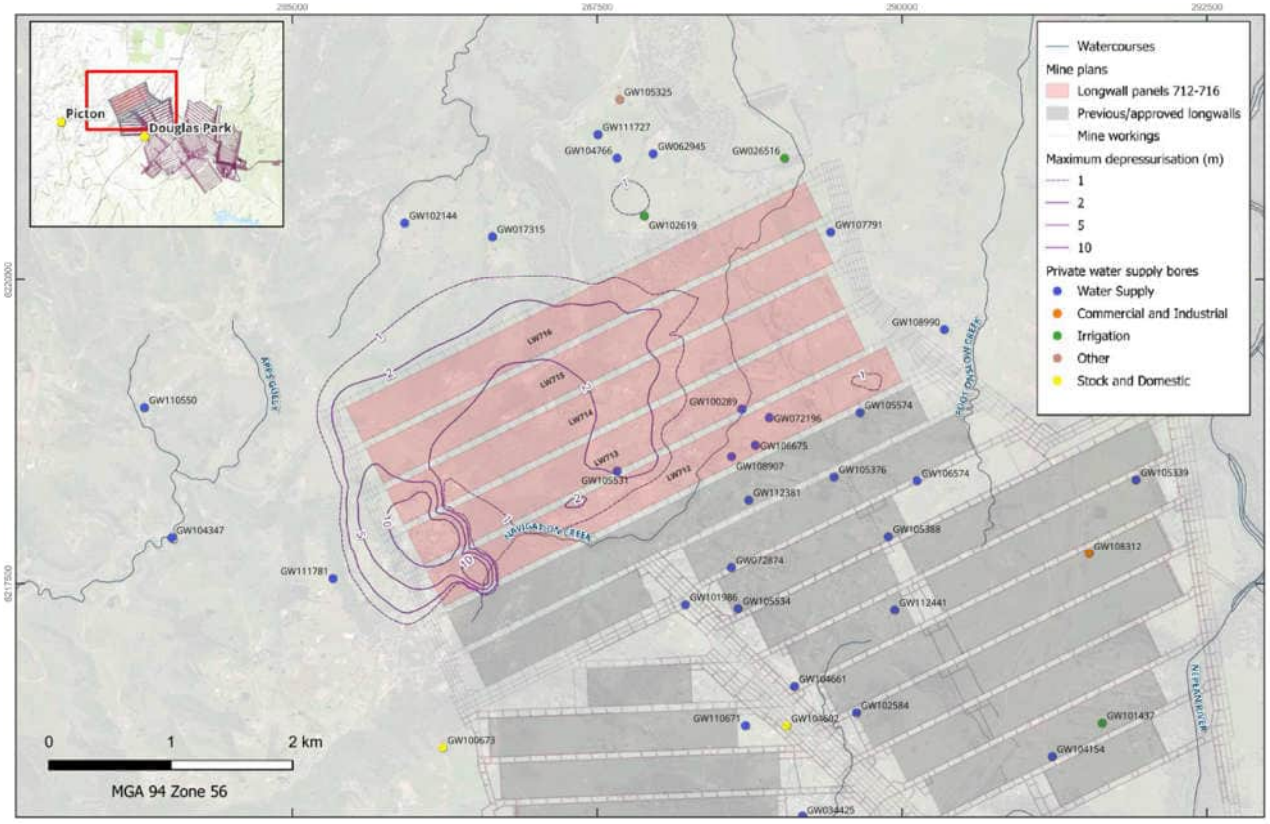

Figure 51 Incremental maximum depressurisation in the Lower HBSS

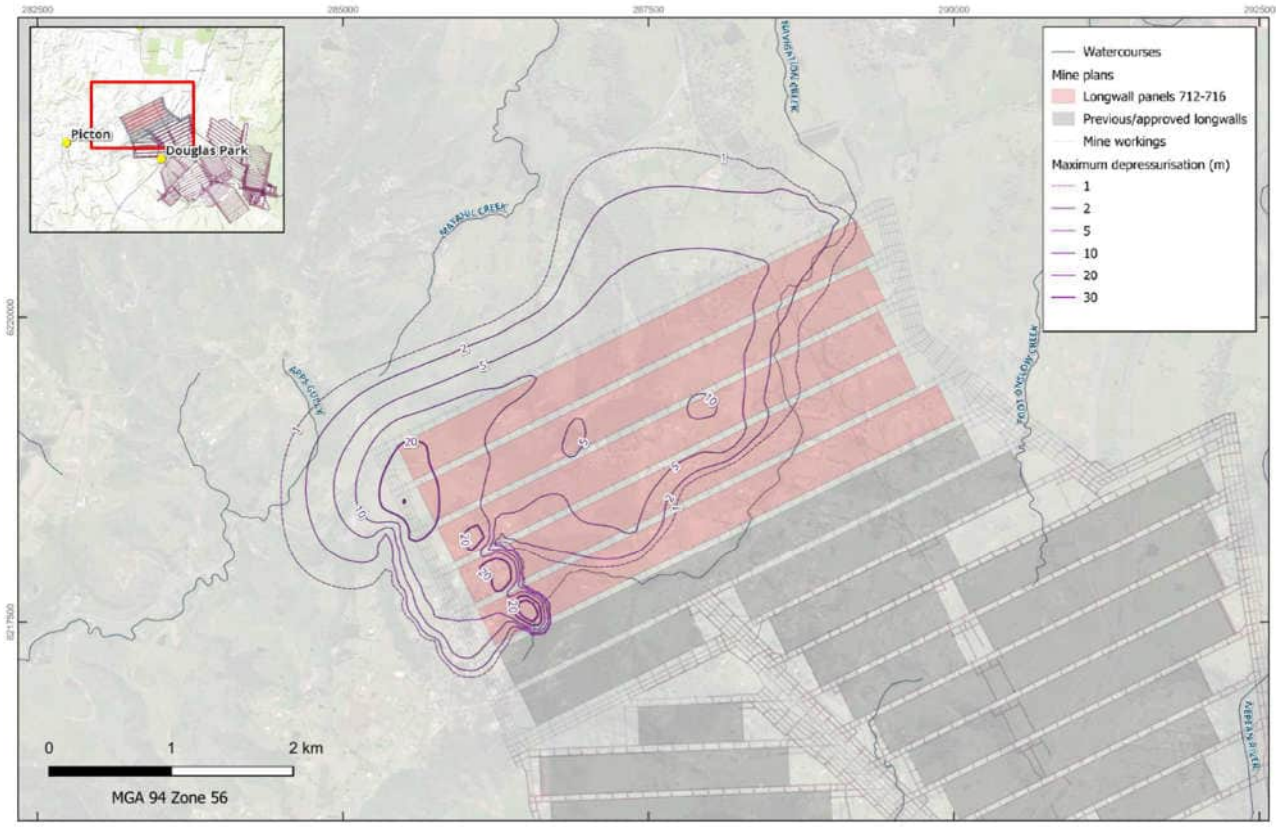

Figure 52 Incremental maximum depressurisation in the Upper Bulgo Sandstone

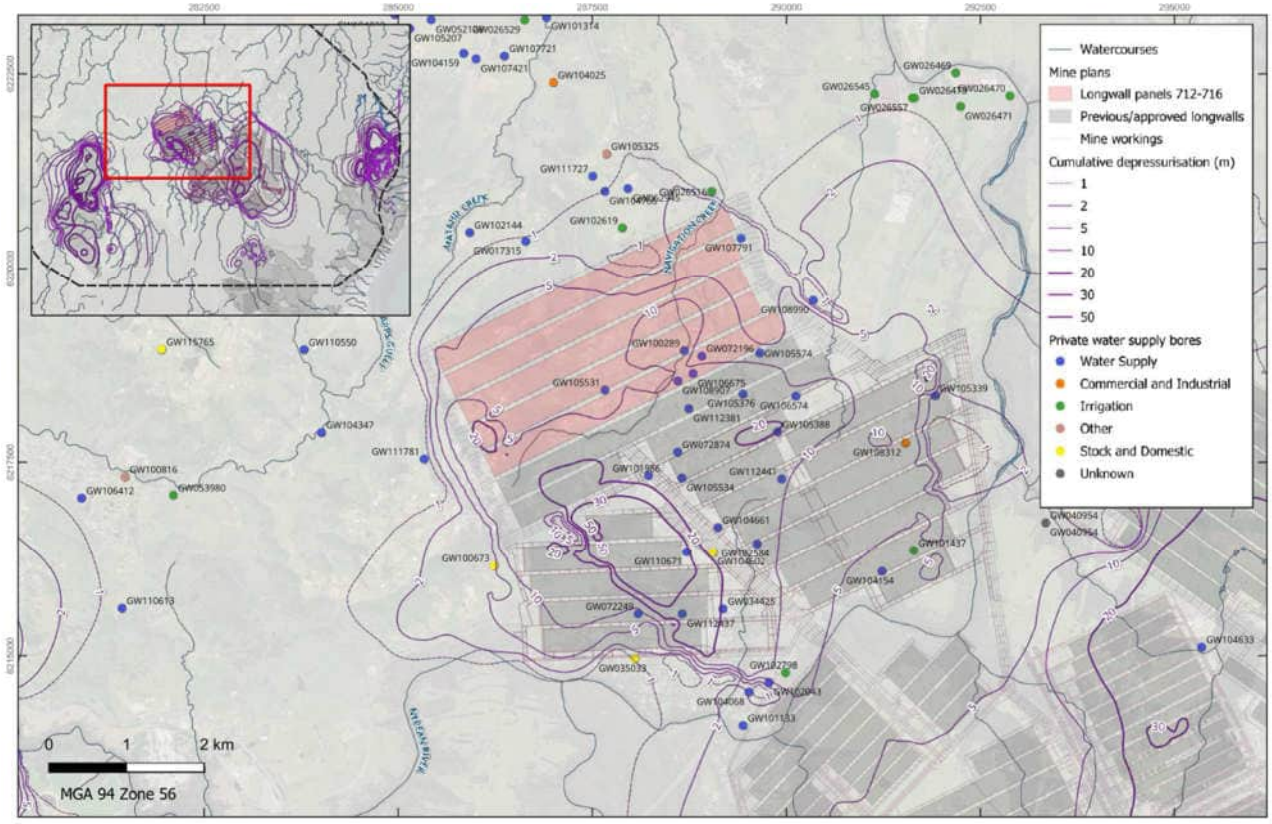

Figure 53 Cumulative maximum depressurisation in the Lower HBSS

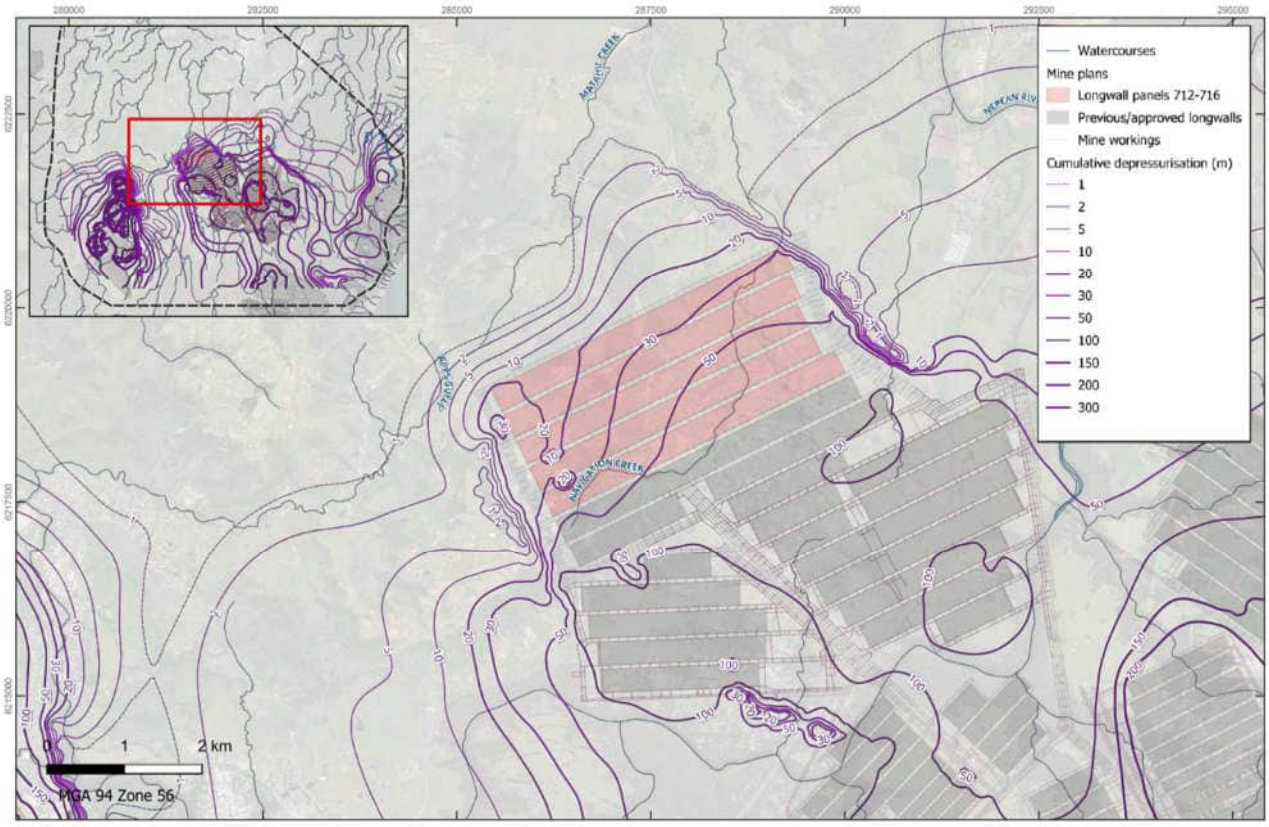

Figure 54 Cumulative maximum depressurisation in the Upper Bulgo Sandstone

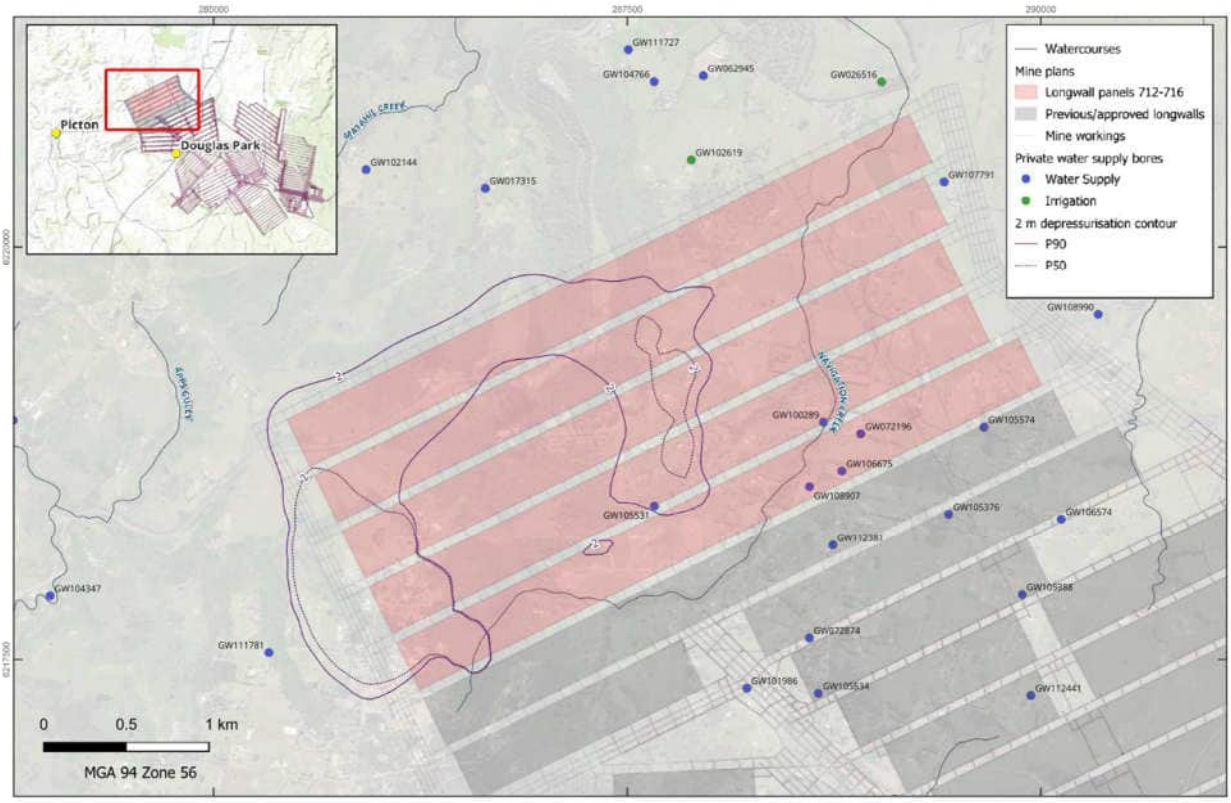

Figure 55 Predictive uncertainty – 2 m drawdown contours in the lower HBSS (P50 and P90)

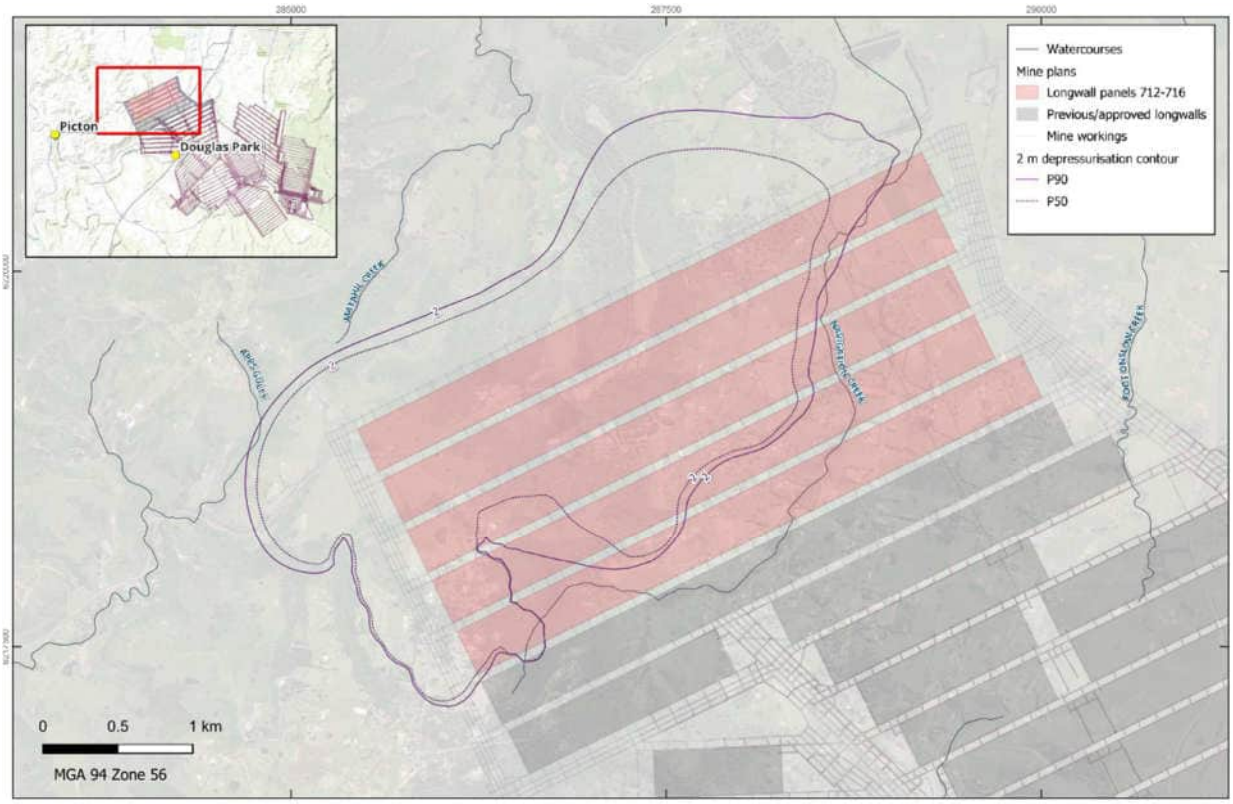

Figure 56 Predictive uncertainty – 2 m drawdown contours in the upper BGSS (P50 and P90)

6.1.3 Depressurisation at private water supply bores

Predicted drawdown at private water supply bores within the MSEC defined Project Area is shown in Table 21. The table includes three bores beyond the immediate Project Area for which greater than negligible incremental drawdown is predicted due to the project. The drawdown values represent the maximum drawdown predicted at the bore between 2026 and 2035. For each bore, the median (expected) and 90th percentile drawdown is presented for the incremental (Project) effect and the cumulative (all mines) effect based on multiple model runs using the calibrated parameter ensemble. The drawdown values are obtained from the deepest model layer that the bore intersects, based on its published depth. If the depth is unknow it is assigned to the mid-HBSS (Layer 4). This is a conservative approach, since many bores will be screened (or open) over a large depth interval and would experience less drawdown in standing water level than the theoretical maximum at the base of the bore.

All 13 registered water supply bores within the Project Area access groundwater from the HBSS or the Alluvium. Numerical model predictions indicate incremental drawdown related to the project of up to approximately 0.5 m with no bores expected to exceed 2 m incremental drawdown. The NSW Aquifer Interference Policy minimum impact threshold for water supply works in a highly productive porous aquifer is >2 m of cumulative drawdown. Cumulative drawdown greater than 2 m may occur at 6 bores as shown in Table 21 in bold font. Of those bores, three (#) were identified in the previous groundwater assessment in relation to drawdown exceeding 2 m due to Longwalls 709-711 and 905.

Note that the above predicted impacts relate to regional drawdown or depressurisation from mining activities. For bores located directly above mined longwalls, there is a risk of physical damage to bore casing from subsidence related movement. Bores that are reported to experience drawdown impacts such as a decline in standing water level or a decline in yield due to the Project will be subject to make good provisions as outlined in the EP Water Management Plan.

Table 21 Private water supply bores within the Project Areas, or >0.1 m predicted drawdown

Bore ID	Dist. From LW (m)	Bore depth (model layer)	Aquifer	Incremental (LW712-716)		Cumulative (All Mines)	
				Median*	P90*	Median	P90
GW072196	0	? (L4)	mid HBSS	-0.05	-0.07	-0.64	-0.78
GW106675	0	183 m (L4)	mid HBSS	-0.04	-0.06	-0.65	-0.84
GW100289	0	30 m (L2)	upr HBSS	<0.01	-0.03	-0.02	-0.06
GW108907	0	210 m (L5)	lwr HBSS	<0.01	<0.01	**-3.42**	**-5.13**
GW105531	4	210 m (L5)	lwr HBSS	-0.48	-0.81	**-3.52**	**-4.22**
GW105574#	76	210 m (L5)	lwr HBSS	<0.01	<0.01	-1.97	**-3.69**
GW107791	94	231 m (L5)	lwr HBSS	<0.01	-0.01	-0.45	-0.73
GW026516	251	10 m (L2)	Alluvium	-0.01	-0.01	-0.01	-0.01
GW112381	318	152 m (L4)	mid HBSS	<0.01	-0.01	**-2.00**	**-2.57**
GW102619	336	224 m (L5)	lwr HBSS	-0.02	-0.04	-0.12	-0.16
GW105376#	457	218.5 m (L5)	lwr HBSS	<0.01	<0.01	**-4.02**	**-7.09**
GW108990	495	150 m (L4)	mid HBSS	<0.01	<0.01	-0.15	-0.24

Bore ID	Dist. From LW (m)	Bore depth (model layer)	Aquifer	Incremental (LW712-716)		Cumulative (All Mines)	
				Median*	P90*	Median	P90
GW072874#	759	189 (L5)	lwr HBSS	<0.01	<0.01	**-6.74**	**-9.19**
GW062945	759	150 m (L4)	mid HBSS	-0.15	-0.19	-0.17	-0.22
GW104766	857	192 m (L4)	mid HBSS	-0.13	-0.16	-0.15	-0.18
GW105325	1277	159 m (L4)	mid HBSS	-0.07	-0.09	-0.08	-0.11

Note*: Median (expected) and P90 (conservative) of the maximum drawdown at each site between 2026 and 2035 based on numerous models runs. Bores with '#' are those at which >2 m drawdown was predicted in the previous assessment (LW709-711 & 905).

Note that Table 21 excludes two deep bores registered in the BOM bore database as commercial/industrial use: GW112481 (within the project area) and GW115070 (1.5 km north of the project). Those bores likely relate to former AGL CSG wells designated RB12 and LB05, respectively, which have been decommissioned.

6.1.4 Impacts on streams

Predicted changes in baseflow in watercourses within the Project Study Area, and in the Nepean River are shown in Table 22. The change in baseflow values represents mean change in groundwater discharge to model River boundaries, grouped by watercourse, between 2026 and 2035. For each watercourse, the median (expected) and 90th percentile change is presented for the incremental (Project) effect and the cumulative (all mines) effect.

The predicted incremental change in baseflow due to the Project is negligible (<0.1 ML/year) for all watercourses in the Project Study Area, except for Navigation Creek where there may be a very minor loss of baseflow (0.55 ML/year) from the lower reaches of the creek which may be currently gaining. However, that potential loss is only in the P90 estimate and therefore not expected under median conditions. The cumulative change due to all mining is also negligible for the period 2026-2035, except for Navigation Creek, as described above. There is negligible predicted incremental or cumulative loss from the Nepean River, with previous minor cumulative effects having fully recovered before the project period. Note that minor watercourses crossing the Project Study Area are largely ephemeral in nature and therefore do not receive significant baseflow. The model prediction of negligible or minor baseflow loss is therefore consistent with that conceptual framework.

As with previous numerical models, minor watercourses are represented as ephemeral drain features. Surface flow losses due to subsidence fracturing and diversion of rainfall-runoff have not been explicitly modelled; however, such losses are expected to be negligible. End of Panel assessments for Longwalls 708–710, which passed directly beneath Foot Onslow Creek and Navigation Creek, reported no surface fracturing or diversion of flows attributable to mining.

Previous mining at Appin, Tower and West Cliff may have resulted in a change in baseflow in the Nepean River in the order of -9.1 ML/year, peaking between 1992 and 2002. Those cumulative effects recovered fully by 2020 as mining moved northward and away from the river. The mean flow in the Nepean River at Maldon Weir is 377 ML/day (138 GL/year) and therefore the estimated peak loss of baseflow is unlikely to have been measurable. End of Panel assessments for Appin Areas 7 and 9 found no evidence for a decline in flow in the Nepean River between the Maldon and Menangle Weirs.

Table 22 Predicted change in baseflow in local watercourses to 2035

Watercourse	Type	Incremental change (ML/year, LW712-716)		Cumulative change (ML/year, All Mines)	
		Median*	P90*	Median	P90
Foot Onslow Ck	Ephemeral	<0.1	<0.1	<0.1	<0.1
Matahil Ck	Ephemeral	<0.1	<0.1	<0.1	<0.1
Navigation Ck	Ephemeral	<0.1	-0.55	<0.1	-0.55
Nepean River	Perennial	<0.1	<0.1	<0.1	<0.1
Racecourse Ck	Ephemeral	<0.1	<0.1	<0.1	<0.1

Note*: Median (expected) and P90 (conservative) of the mean change in baseflow between 2026 and 2035 based on numerous models runs.

6.1.5 Depressurisation at GDEs

Predicted drawdown at high priority Groundwater Dependent Ecosystems within 5km m of the project is shown in Table 23. The drawdown values represent the maximum drawdown predicted at the GDE location 2026 and 2035. For each location, the median (expected) and 90th percentile drawdown is presented for the incremental (Project) effect and the cumulative (all mines) effect based on multiple model runs using the calibrated parameter ensemble. The drawdown values are obtained from the upper-most saturated model layer that underlies the GDE location. For the specified locations those layers equate to either the mid- or upper HBSS which outcrops in the major river and stream gorges near the Project.

Table 23 shows that the predicted incremental drawdown due to the Project is negligible at all high priority GDE locations (in the sub-mm range). The cumulative drawdown due to all mines ranges up to 0.17 m, with P90 estimates up to 0.42 m. Based on the locations of the GDEs those cumulative effects likely relate to previous mining at West Cliff and Tower Collieries.

The NSW Aquifer Interference Policy minimum impact threshold for GDEs in a highly productive porous aquifer is >10% cumulative variation in the water table 40m from any high priority GDE, allowing for typical climatic “post-water sharing plan” variations.

The annual range in groundwater level at the GDE sites is unknown but can be estimated approximately from nearby groundwater monitoring sites. The two closest sites with a sufficient monitoring period and which are apparently unaffected by pumping and/or mining related drawdown are S1993 and S2280. The annual range in piezometric head at S1993 (at 86.5 m depth; mid-HBSS) over the 12-year period 2014 to 2025 is between 0.4 m and 3.2 m (average annual range 1.6 m). The annual range in piezometric head at S2280 (at 60 m depth; mid-HBSS) over the 11-year period 2015 to 2025 is between 1.9 m and 5.3 m (average annual range 3.2 m). Limited data from AGL’s CSG monitoring bores (MPMB-series) located north of the project show annual groundwater level variations within the HBSS and Alluvium of between 1.1 m and 2.2 m. The annual groundwater level range is therefore highly variable both spatially and from year to year. Based on the above it would be reasonable to assume an annual range in groundwater level could be in the order of ~2 m, with larger variations possible over the longer term due to variations in rainfall. Given that most of the identified

sites are associated with riparian vegetation corridors, the groundwater levels at those sites are likely to be influenced by surface water-groundwater interactions.

In summary, based on numerical model predictions it is possible that cumulative groundwater drawdown exceeding 10% of the average annual variation is possible at three high priority GDE sites (shown in bold font in Table 23). That potential drawdown is related to previous mining activities, with negligible additional drawdown expected as a result of Longwalls 712-716.

Table 23 Predicted maximum change in groundwater level at GDE locations to 2035

GDE location	Dist. From Project (km)	Natural range (m)	Model layer	Incremental Change (metres, LW712-716)		Cumulative Change (metres, All Mines)	
				Median*	P90*	Median	P90
GDE3145_1A	4.5	~2.0	4	<0.01	<0.01	<0.01	-0.06
GDE3145_2A	3.9	~2.0	3	<0.01	<0.01	-0.14	**-0.42**
GDE4025_1A	4.0	~2.0	4	<0.01	<0.01	<0.01	<0.01
GDE4025_2A	4.1	~2.0	3	<0.01	<0.01	-0.02	-0.14
GDE4025_3A	4.9	~2.0	3	<0.01	<0.01	-0.16	**-0.21**
GDE4025_4A	4.8	~2.0	3	<0.01	<0.01	-0.13	-0.18
GDE4025_5A	5.0	~2.0	3	<0.01	<0.01	-0.17	**-0.22**
GDE6552_1A	4.0	~2.0	4	<0.01	<0.01	-0.02	-0.02

Note*: Median (expected) and P90 (worst case) of the maximum drawdown at each site between 2026 and 2035 based on numerous models runs.

6.2 Groundwater interception (mine inflows)

The predicted rate of groundwater inflow to the underground mine workings in Appin Areas 7 and 9 is plotted Figure 57. Also plotted is the quarterly average net mine water balance for the areas, which is an approximate estimate of the actual groundwater inflow. The predicted mine inflow rates are the sum all mine drain boundaries assigned to Areas 7 and 9. A time-weighted mean is calculated for each stress period, and the predictive uncertainty is represented by the shaded P5-P95 range.

The model estimates of past mine inflow match the net mine water balance data relatively well given the uncertainties in the pumping data. It is predicted that groundwater inflow rates will remain relatively stable during extraction the extraction of Longwalls 712-716 and within the range 1.4 to 2.8 ML/day (510 to 1020 ML/yr).

The Project study area as defined by the 600 m buffer is entirely within the Sydney Basin Nepean Groundwater Source; however, there is potential for a small proportion of induced flow or storage loss from the adjacent Sydney Basin Central Groundwater Source to the southwest of the Nepean River and ~2.5 km from Longwall 712. The proportion of groundwater take attributable to each groundwater source, including induced groundwater flow between sources, was estimated using Zone Budget (a program within the Modflow6 suite). The analysis indicates that practically all of the groundwater take due to the project (510 to 1020 ML/yr) will be from the Sydney Basin Nepean Groundwater Source, of which 0.4 to 0.8 ML/yr (~0.1%) is induced flow from the Sydney Basin Central Groundwater Source.

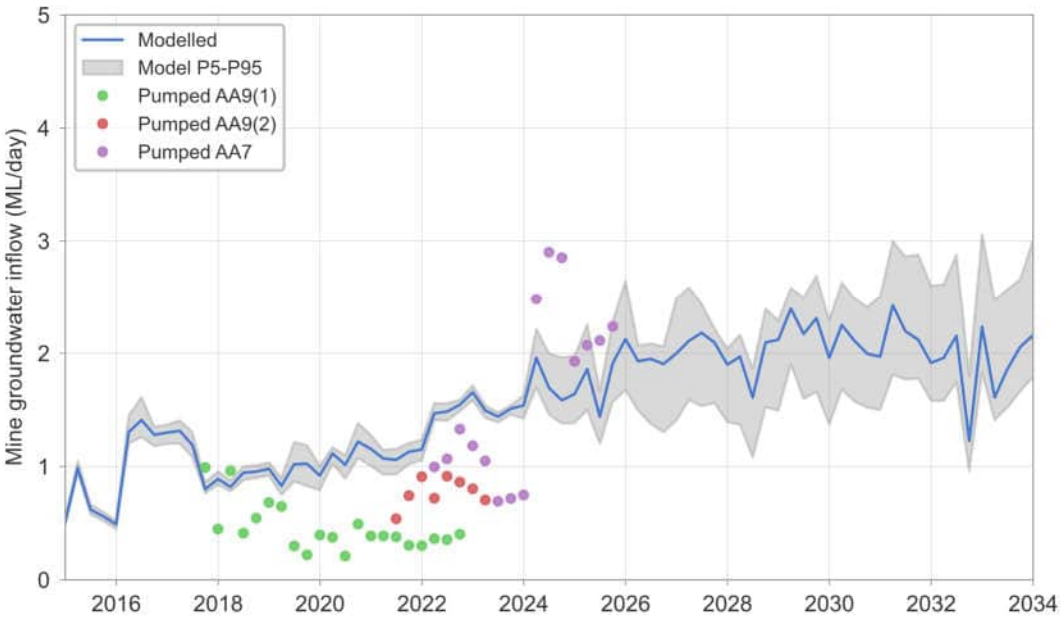

Figure 57 Predicted inflow of groundwater to underground mine workings in Appin Areas 7 and 9

The predicted groundwater inflow to active mining areas is closely comparable to previous predictions by Heritage Computing (2009) for Billi Seam Operations at Appin (Table 1). Slight discrepancies are expected since the current mine plan differs from that originally proposed in terms of longwall orientations.

Table 24 Predicted mine inflow compared with previous model predictions (ML/day)

Model year	AA7&AA9 (HC, 2009)	Total Inflow (HC, 2009)	This Report (Predicted and P5-P95 range)
2015	0.48	0.78	0.7 (0.6 - 0.7)
2016	0.72	1.03	1.3 (1.2 - 1.4)
2017	0.74	1.05	1.0 (1.0 - 1.1)
2018	0.96	1.27	0.9 (0.9 - 1.0)
2019	0.96	1.27	0.8 (0.8 - 1.1)
2020	1.17	1.46	1.0 (1.0 - 1.2)
2021	1.15	1.47	1.0 (1.0 - 1.2)
2022	1.32	1.70	1.5 (1.5 - 1.6)
2023	1.29	1.71	1.5 (1.4 - 1.5)
2024	1.48	2.08	2.1 (1.5 - 2.0)
2025	1.47	2.09	2.0 (1.5 - 2.2)
2026	1.45	2.34	1.9 (1.4 - 2.2)
2027	1.44	2.34	2.1 (1.5 - 2.3)

Model year	AA7&AA9 (HC, 2009)	Total Inflow (HC, 2009)	This Report (Predicted and P5-P95 range)
2028	1.43	2.62	2.0 (1.4 - 2.2)
2029	1.43	2.61	2.2 (1.6 - 2.5)
2030	1.41	2.89	2.2 (1.6 - 2.5)
2031	1.41	2.90	2.4 (1.7 - 2.8)
2032	1.40	3.20	2.1 (1.5 - 2.6)
2033	1.40	3.21	2.1 (1.6 - 2.7)
2034	1.40	3.50	2.1 (1.6 - 2.7)

Notes: HC (2009) is Heritage Computing (2009)

6.3 Impacts on groundwater quality

Fracturing of the overburden due to longwall mining has the potential to mobilise methane and other formation gases which may accumulate within groundwater bores. A recent End of Panel assessment showed that dissolved methane is naturally present in groundwater within all geological formations, including the Hawkesbury Sandstone which is used for water supply (HGEO, 2025a). Accumulation of methane in bores and the appearance of methane bubble streams in dams and water courses is therefore likely derived from the local host-rock (HBSS) rather than deeper sources.

Increased iron staining can occur if iron is dissolved and mobilised in new fractures or shears, or if groundwater drawdown results in oxidation of previous saturated rocks or sediments. This may result in a reduction in water quality, including aesthetic characteristics such as colour and odour.

Where impacts to water quality or damage to bore infrastructure are reported, steps should be taken to ensure its safe operation, as outlined in the Water Management Plan. This may include stopping the operation of the bore until gas emissions cease, providing an exclusion zone around the bore head, or grouting the bore. If the bore becomes unserviceable, then a new bore may be required.

The Bulgo Sandstone is low yielding and moderately saline. Its use as a water supply in the region is limited (only 2 out of 223 registered bores within 10 km of the Project access groundwater from this formation) with preferential use of the shallower HBSS. Risks to the beneficial use of groundwater in the region are therefore considered low.

7. Groundwater monitoring and management program

Groundwater monitoring for the Project will be conducted in accordance with a Water Management Plan (WMP) that will be prepared in consultation with the regulator. The WMP details the groundwater monitoring program, including the groundwater monitoring locations, frequency of water level/pressure monitoring, and frequency and parameters for groundwater quality monitoring.

7.1 Groundwater monitoring network

The groundwater monitoring network recommended for the Project is shown in Figure 58. The network includes single and multi-level VWPs, groundwater monitoring bores, and sampling pump installations in the area overlying and surrounding the Project.

Seven exploration boreholes (S1913, S2500, S2315, S1954, S1936, S1941, and S2157) have been fitted with multi-level VWPs. Each installation has between 9 and 13 sensors installed at different depths through the profile. Groundwater pressures are also monitored at five other monitoring locations: one targeting the Wianamatta Group (S2632) and four targeting the Hawkesbury Sandstone (S2536, S2536A, S2537, S2538). Each piezometer monitors water pressure on a 6 to 12 hourly interval and transmits data automatically via File Transfer Protocol (FTP).

The monitoring network includes sampling pumps at five locations (S2632, S2536, S2536A, S2537, and S2538) that can be used to collect groundwater samples for water quality analysis.

The groundwater monitoring network also includes private water supply bores (as detailed in Section 7.4).

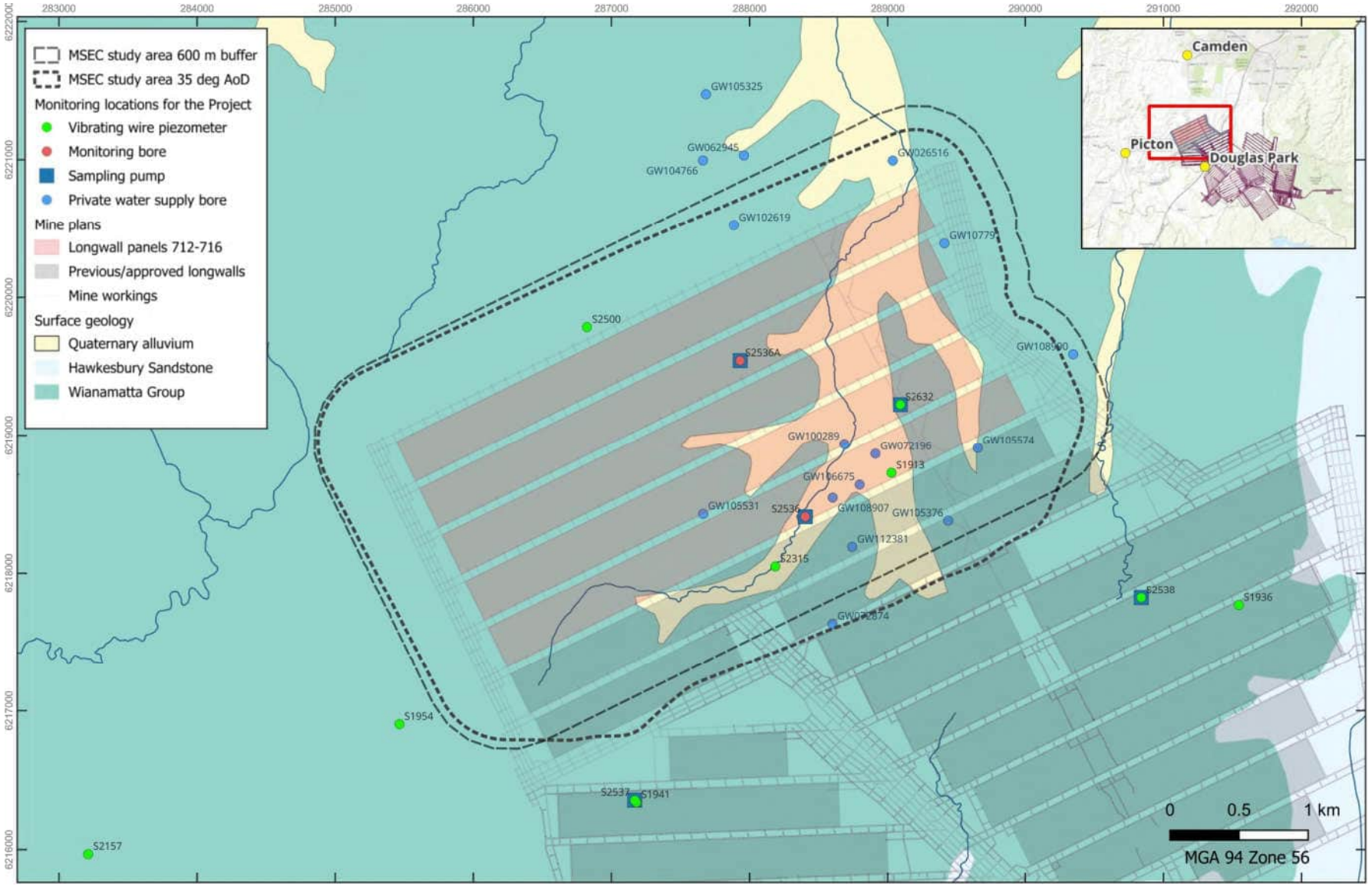

Figure 58 Groundwater monitoring network for the Project

7.2 Groundwater monitoring program

The groundwater monitoring program recommended for the Project is summarised in Table 25. The purpose of the groundwater monitoring program is to establish baseline conditions prior to mining, verify predicted impacts, and provide for early identification of adverse impacts not previously predicted. The groundwater monitoring program should be detailed in a Water Management Plan (WMP) prepared in consultation with the regulator.

The groundwater monitoring program recommended for the Project includes:

- Monitoring of groundwater levels/pressures at multi-level VWPs and groundwater monitoring bores in the Project area and surrounds. Monitoring of water pressure is conducted on a 6 to 12 hourly interval at 13 locations and data are transmitted automatically via FTP.
- Collection of groundwater samples from groundwater monitoring bores and sampling pumps in the Project area and surrounds for analysis for water quality on a quarterly basis.
- Monitoring of groundwater levels/pressures at private water supply bores (as detailed in Section 7.4).
- Monitoring of mine inflow volumes and water quality within the underground mine.

Following post-processing (including converting pressure readings from VWPs to groundwater elevations) and quality review, the data collected should be stored in a central groundwater monitoring database.

Water quality monitoring should include field analysis of pH and EC, as well as annual sampling for laboratory analysis of a full suite of analytes, including:

- physicochemical indicators – pH, electrical conductivity, total dissolved solids;
- major ions – calcium, fluoride, magnesium, potassium, sodium, chloride, sulphate;
- total alkalinity as $CaCO_3$, HCO_3^-, CO_3^{2-}; and
- dissolved metals – aluminium, arsenic, barium, boron, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, strontium, silver, vanadium and zinc.

The groundwater monitoring data should be reviewed and compared to the assessment criteria on an annual basis and/or at the end of each longwall panel to assess whether the impacts observed are consistent with the predicted impacts. The groundwater monitoring program should additionally be reviewed every five years to confirm the program is meeting the intended objectives.

Table 25 Groundwater monitoring program for the Project

ID	Easting	Northing	Ground level (m AHD)	Number of sensors	Geology	Ground water level/ pressure	Ground water quality
S1913	289028	6218729	117.0	10	HBSS (3), BGSS (3), SBSS (3), BUCO (1)	Y	N
S2632	289092.4	6219225.7	113.0	1	WMGR	Y	Y
S2536	288404.1	6218410.7	128.3	1	Qa	Y	Y
S2536A	287932.4	6219544.1	134.3	1	HBSS	Y	Y
S2500	286823.3	6219786.7	237.5	10	WMGR (2), HBSS (2), NPFM (1), BGSS (4), SBSS (1)	Y	N
S2315	288186.5	6218050.8	137.6	9	HBSS (3), BGSS (4), SBSS (1), BUSM (1)	Y	N
S1954	285466.0	6216903.7	310.0	13	WMGR (7), HBSS (5), BUSM (1)	Y	N
S1936	291547.3	6217767.8	148.1	10	HBSS (3), BGSS (3), SBSS (3), BUSM (1)	Y	N
S1941	287180.7	6216341.0	146.8	10	HBSS (3), BGSS (3), SBSS (3), BUSM (1)	Y	N
S2157	283212.0	6215968.8	224.4	10	WMGR (1), HBSS (3), BGSS (3), SPCS (1), SBSS (1), BUSM (1)	Y	N
S2537	287168.9	6216357.0	147.5	1	HBSS	Y	Y
S2538	290840.8	6217822.0	122.4	1	HBSS	Y	Y

7.3 Assessment criteria

Proposed groundwater assessment criteria for the Project are presented in Table 26. The assessment criteria for groundwater levels are based on comparison to trigger levels calculated as the change in groundwater levels predicted by the numerical model. Investigation into groundwater level trends should be undertaken if readings from three consecutive months are outside of the proposed trigger level. Investigation should include review of climate trends, condition of the monitoring point, data quality, as well as water level and quality trends at other relevant monitoring bores and VWPs to identify the cause for the change in levels beyond those predicted.

Collection of groundwater samples for water quality analysis from S2632, S2536, S2536A, S2537, and S2538 is recommended. Field measurement of pH and electrical conductivity (EC) should be undertaken to provide early detection of potential adverse changes in water quality. The triggers will be established once two years of groundwater quality data are available.

Comparison of the groundwater monitoring data to the assessment criteria should be conducted on an annual basis and documented in an annual report. The report should compare predicted and observed levels to identify any potential adverse changes beyond those predicted with consideration given to climate trends, data quality, and water level and quality trends at control sites.

Table 26 Recommended assessment criteria for the Project

Type	Recommended assessment criteria
Groundwater levels	Readings from three consecutive months are outside of the trigger levels for the individual bore/sensor.
Groundwater quality – Quaternary alluvium	Three consecutive readings for pH outside of the 5th and 95th percentile and EC outside of the 95th percentile of baseline data for Quaternary alluvium at bore S2536, to be determined from baseline data (two years of data with a minimum of 18 samples).
Groundwater quality – Hawkesbury Sandstone	Three consecutive readings for pH outside of the 5th and 95th percentile and EC outside of the 95th percentile of baseline data for HBSS at bores S2536A and S1959, to be determined from baseline data (two years of data with a minimum of 18 samples).

7.4 Private water supply bores to be monitored for the Project

If accessible, and landholder access is granted, it is recommended that private water supply bores within the immediate vicinity of the Appin Mine are monitored for groundwater levels, water quality and any gas emissions. Registered bores near the Project that are recommended for monitoring are listed in Table 27. The location of these bores is shown on Figure 35.

A landholder bore survey should initially be conducted in the Project area to assess the current groundwater usage, bore construction, and pump infrastructure details including depth of installation for each bore.

Data loggers that record daily water level data are currently installed in GW108907, GW105376, GW072874, and GW102619. Where bore infrastructure and landholder permission allows, data loggers should be installed in the other 10 bores in Table 27 to monitor time series groundwater levels. Water levels in bores used for water supply will be affected by pumping and the data loggers should be installed at an appropriate depth to account for this. Data loggers should be downloaded

periodically and water levels measured manually using an electronic dip meter (where possible) to verify the data collected and minimise data loss (e.g., due to logger failure).

Where gas emissions are detected, the bore must be managed in a manner to ensure user safety. This may include monitoring for gas in and around the bore, temporary ceasing the operation of the bore, sealing of the bore and re-establishment of the bore once subsidence effects are reduced.

Collection of groundwater samples for water quality analysis on an annual basis is recommended. Water quality analysis should include field parameters pH and EC as well as laboratory analysis for the parameters outlined in Section 7.2.

Review of the groundwater monitoring data collected for private water supply bores should be conducted following each panel and summarised in the End of Panel Report. The report should assess the serviceability of each bore taking into consideration potential subsidence and depressurisation impacts.

Table 27 Private water supply bores to be monitored for the Project

State bore ID	Easting	Northing	Bore depth(m)	Purpose	Aquifer
GW072196	288911	6218867	Not specified	Water supply	Mid HBSS
GW100289	288686	6218937	30	Water supply	Wianamatta Group or alluvium
GW106675	288797	6218642	183	Water supply	Mid HBSS
GW108907*	288602	6218547	210	Water supply	Lower HBSS
GW112381	288743	6218191	152	Water supply	Mid HBSS
GW105574	289656	6218908	210	Water supply	Lower HBSS
GW105376*	289443	6218380	218.5	Water supply	Lower HBSS
GW072874*	288601	6217630	189	Water supply	Lower HBSS
GW107791	289415	6220392	231	Water supply	Lower HBSS
GW105531	287664	6218430	210	Water supply	Lower HBSS
GW102619*	287887	6220525	224	Irrigation	Lower HBSS
GW026516	289037	6220994	10	Irrigation	Wianamatta Group or alluvium
GW108990	290347	6219588	150	Water supply	Mid HBSS
GW062945	287960	6221031	150	Water supply	Mid HBSS
GW104766	287663	6220995	192	Water supply	Mid HBSS
GW105325	287685	6221474	159	Other	Mid HBSS

Note: Bores marked with * are those with dataloggers currently installed

7.5 Recommended groundwater level drawdown thresholds

Groundwater level monitoring thresholds are recommended in Table 28 (see also Appendix E), based on the 90th, 95th and 99th percentile estimates of cumulative drawdown at each monitoring bore. The TARP threshold triggers are defined as follows:

- Level 1: 30-day rolling median is greater than P90 drawdown predictions or greater than 1.0 m of mining induced drawdown where predicted drawdown is less than 1 m.
- Level 2: 30-day rolling median is greater than P95 predictions and 0.5m greater than level 1 values (to prevent trigger escalation due to natural water table variations where probabilities are closely distributed).
- Level 3: 30-day rolling median is greater than P99 predictions and 0.5m greater than level 2 values. The default Level 3 minimum (2.0 m) is based on the minimal impact consideration in the NSW Aquifer Interference Policy.

Table 28 Recommended groundwater drawdown TARP triggers (metres)

Bore ID	Type	Level 1 (P90)	Level 2 (P95)	Level 3 (P99)
GW108907	private	5.1	5.6	7.2
GW105376	private	7.1	7.6	10.8
GW072874	private	9.2	9.7	12.8
GW102619	private	1.0	1.5	2.0
GW072196	private	1.0	1.5	2.0
GW100289	private	1.0	1.5	2.0
GW106675	private	1.0	1.5	2.0
GW112381	private	2.6	3.1	3.6
GW105574	private	3.7	4.2	4.7
GW107791	private	1.0	1.5	2.0
GW105531	private	4.2	4.7	5.2
GW026516	private	1.0	1.5	2.0
GW108990	private	1.0	1.5	2.0
GW062945	private	1.0	1.5	2.0
GW104766	private	1.0	1.5	2.0
GW105325	private	1.0	1.5	2.0
S2536	ICHPL (Alluv)	1.0	1.5	2.0
S2536A	ICHPL (HBSS)	9.8	10.3	12.3
S1913	ICHPL (HBSS)	10.3	10.8	12.3
S2500	ICHPL (HBSS)	4.7	5.2	5.7
S2315	ICHPL (HBSS)	13.8	14.3	15.9
S1954	ICHPL (HBSS)	1.0	1.5	2.0
S1936	ICHPL (HBSS)	7.9	8.4	10.8
S1941	ICHPL (HBSS)	19.6	20.1	21.2
S2157	ICHPL (HBSS)	1.0	1.5	2.0
S2632	ICHPL (WMGR)	8.3	8.9	10.4
S2537	ICHPL (HBSS)	19.6	20.1	21.2
S2538	ICHPL (HBSS)	8.1	9.0	11.2

8. Conclusions

ICHPL is proposing to extract coal from LW712 to LW716. Groundwater modelling has been undertaken to forecast potential impacts to the local hydrogeological system to support the EP approval process.

A groundwater model was developed based on previous models with some structural changes. The model extends approximately 42 km from west to east and 35 km from north to south, covering an area of 1,316 km^2. The model consists of 17 layers, simulating extraction from the Bulli Seam and potential impacts in the overlying hydrostratigraphy. Fracturing above the longwalls was simulated by varying hydraulic parameters over the longwall panels with initial heights of fracturing informed by the empirical models of Ditton and Merrick (2014) and Tammetta (2013). Surface fracturing was simulated in the model by adopting enhanced horizontal and vertical conductivity in the model. History matching was carried out using PEST++ to match observed groundwater levels at Appin Mine.

Three model scenarios were used to simulate the mining of LW712 to LW716 and assess impacts to groundwater, including cumulative impacts. The model predictions were generally consistent with the predictions from the BSO EIS report (Heritage Computing, 2009). The key conclusions from the groundwater assessment are as follows:

- Groundwater drawdown in the lower HBSS of between 0 and 17 m is expected in areas directly above the proposed longwalls with 2 m or more drawdown extending up to 430 m from the longwall footprint. The forecast drawdown is in line with the range of drawdown observed in areas previously mined.
- Within the upper BGSS, depressurisation of between 0 and 36 m is forecast, with the highest drawdown expected above the western end of the proposed longwalls. Drawdown of up to 2 m may extend to a distance of approximately 800 m form the western and northern edges of the proposed longwalls.
- More than 2 m of cumulative depressurisation (Aquifer Interference Policy threshold for highly productive aquifers) is predicted for six private water supply bores, with a maximum of 0.48 m of incremental depressurisation due to the Project.
- Model forecasts indicate negligible or very minor incremental change in baseflow to watercourses due to the Project. The forecast cumulative change due to all mining is also negligible for the period 2026-2035, including for the Nepean River which is located more than 2.5 km from the Project.
- Cumulative groundwater drawdown exceeding 10% of the average annual variation is possible at three high priority GDE sites that are listed in the Water Sharing Plan. That potential drawdown is related to previous mining activities, with negligible additional drawdown expected as a result of Longwalls 712-716.
- The rate of groundwater flow into the mine workings is predicted to remain relatively stable during extraction of Longwalls 712–716, within the range 1.4 to 2.8 ML/day (510 to 1,020 ML/year). Practically all of this inflow (99.9%) will be derived from the Sydney Basin Nepean Groundwater Source, with less than 1 ML/year representing induced flow from the adjacent Sydney Basin Central Groundwater Source.
- Fracturing of the overburden due to longwall subsidence has the potential to result in damage to bore casings or mobilise methane and other formation gases which may accumulate within groundwater bores. Increased iron staining can occur if iron is dissolved and mobilised in new

fractures or shears, or if groundwater drawdown results in oxidation of previous saturated rocks or sediments. This may result in a reduction in water quality, including aesthetic characteristics such as colour and odour.

Monitoring of groundwater pressures and quality will be undertaken to verify predicted impacts in accordance with a Water Management Plan (WMP) prepared in consultation with the regulator. Monitoring results will be compared to assessment criteria developed based on model predictions and baseline conditions. The recommended groundwater monitoring network for the Project comprises 12 locations with 77 pressure sensors and 5 sampling pumps. The network includes seven multi-level VWPs that monitor water pressure on a 6 to 12 hourly interval and automatically transmit data, providing for early identification of adverse impacts not predicted.

A landholder bore survey is recommended to assess current groundwater usage, bore construction, and pump infrastructure details including depth of installation. Following that, periodic monitoring of private water supply bores should be conducted.

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APPENDIX A – Groundwater monitoring locations

Monitoring bore ID	Easting	Northing	Ground level (mAHD)	Number of VWP sensors	Number of sampling pumps	Target formation(s)	Mine area	Installation date
GW072874	288601	6217630	140.9	1	0	HBSS	Appin 9	9/03/2021
GW1	298008	6217965	242.0	1	0	HBSS	Westcliff	4/03/2020
GW100673	285895	6215584		1	0	HBSS	Appin 9	10/12/2019
GW101986	288223	6217328	174.7	1	0	HBSS	Appin 9	20/01/202
GW102619	287887	6220525		1	0	HBSS	Appin 9	19/11/2019
GW103095	279684	6220398		1	0	HBSS	Appin 9	22/02/2021
GW104602	289054	6216338		1	0	HBSS	Appin 9	28/08/2020
GW105376	289443	6218380	159.0	1	0	HBSS	Appin 9	6/05/2021
GW106574	290123	6218350	136.0	3	0	WGSH	Appin 9	21/04/2020
GW108907	288602	6218547	125.8	1	0	HBSS	Appin 7	16/09/2021
GW110671	288709	6216337		1	0	HBSS	Appin 9	10/12/2019
GW-30Quirks	288459	6218322		1	0	HBSS	Appin 9	21/06/2021
GW-Dowel	287823	6215406	132.0	1	0	HBSS	Appin 7	21/07/2020
S0890	285890	6208709	232.8	0	0		BUSM Other	
S1077	292095	6211880	172.8	1	0	BUCO	Appin	
S1089	293084	6210351	209.4	1	0	BUCO	Appin 3	
S1101	291476	6213128	156.2	1	0	BUCO	Appin Undif	
S1126	293696	6218369	148.0	1	0	BUCO	Appin Undif	
S1137	291603	6217058	112.3	1	0	WWCO	Appin 7	
S1153	291090	6201906	337.3	1	0	BUCO	Dendrobium 6	17/11/1991
S1157	284508	6218533	245.5	0	0		Appin 9	

Monitoring bore ID	Easting	Northing	Ground level (mAHD)	Number of VWP sensors	Number of sampling pumps	Target formation(s)	Mine area	Installation date
S1162	293574	6201089	353.7	1	0	BUCO	Dendrobium 4	10/05/1992
S1163	290217	6201398	327.8	1	0	BUCO	Dendrobium 6	8/08/1992
S1175	289947	6219322	133.0	1	0	BUCO	Appin 7	
S1176	291451	6220532	102.3	1	0	BUCO	Appin 7	18/09/1992
S1177	293104	6220728	104.0	1	0	BUCO	Westcliff	6/12/1992
S1179	286264	6221014	126.9	1	0	BUCO	Appin 10	
S1181	291611	6223608	71.9	1	0	BUCO	Appin 10	31/05/1993
S1182	283842	6222663	120.4	1	0	BUCO	Appin 10	
S1183	284603	6224088	96.0	1	0	BUCO	Appin 10	30/08/1993
S1184	284200	6226052	88.1	1	0	BUCO	Appin 10	29/11/1993
S1185	285630	6222694	115.4	1	0	BUCO	Appin 10	26/05/1994
S1187	290206	6221263	84.7	1	0	BUCO	Appin 7	8/11/1994
S1188	289503	6224101	91.3	1	0	BUCO	Appin 10	16/01/1995
S1189	288526	6225112	70.0	1	0	BUCO	Appin 10	2/05/1995
S1193	293080	6200893	361.8	1	0	BUCO	Dendrobium 6	2/05/1993
S1267	288440	6226577	64.7	1	0	BUCO	Appin 10	10/11/1995
S1268	286409	6220275	151.8	1	0	BUCO	Appin 7	1/02/1996
S1269	291228	6221836	72.4	1	0	BUCO	Appin 9	22/03/1996
S1270	290069	6220222	111.5	1	0	BUCO	Appin 9	16/05/1996
S1271	285556	6221695	136.1	1	0	BUCO	Appin 10	10/07/1996
S1272	287030	6222734	111.2	1	0	BUCO	Appin 10	15/08/1996
S1273	288696	6223196	94.2	1	0	BUCO	Appin 10	

Monitoring bore ID	Easting	Northing	Ground level (mAHD)	Number of VWP sensors	Number of sampling pumps	Target formation(s)	Mine area	Installation date
S1274	289902	6226042	67.3	1	0	BUCO	Appin 10	4/02/1997
S1275	285902	6218572	295.5	1	0	BUCO	Appin 9	5/05/1997
S1304	291281	6214968	122.1	1	0	BUCO	Appin 7	24/03/1997
S1305	292040	6214907	121.3	1	0	BUCO	Appin 1	2/06/1997
S1306	290544	6212815	143.3	1	0	HBSS	Appin 1	4/02/1997
S1307	292133	6210782	184.2	1	0	HBSS	Appin 1	6/07/1997
S1308	292181	6211542	177.4	0	0		Appin Undif	
S1309	292223	6212253	158.6	1	0	HBSS	Appin 1	4/03/1997
S1313	291062	6224464	75.1	1	0	BUCO	Appin 10	25/06/1997
S1318	290274	6213917	132.7	1	0	HBSS	Appin 7	4/03/1997
S1320	296760	6213931	228.7	1	0	BGSS	Westcliff	
S1323	295896	6215126	208.2	1	0	BUCO	Westcliff	
S1331	292543	6215403	112.1	1	0	BUCO	Appin 7	12/11/2003
S1401	292556	6216466	120.6	1	0	BUCO	Appin 7	21/03/2002
S1453	297624	6212731	234.4	0	0		Westcliff	
S1499	287668	6210479	192.3	1	0	BUCO	Appin 8	21/06/2004
S1519	300638	6213148	313.8	1	0	BUCO	BUSM Other	
S1520	302355	6214581	345.0	1	0	BUCO	BUSM Other	
S1521	307162	6213347	364.6	1	0	BUCO	BUSM Other	
S1522	301789	6211528	342.3	1	0	BUCO	BUSM Other	
S1524	303188	6212642	355.3	1	0	BUCO	BUSM Other	
S1525	304340	6212766	368.1	1	0	BUCO	BUSM Other	

Monitoring bore ID	Easting	Northing	Ground level (mAHD)	Number of VWP sensors	Number of sampling pumps	Target formation(s)	Mine area	Installation date
S1538	304976	6214465	346.4	1	0	BUCO	BUSM Other	
S1539	305904	6214554	341.4	1	0	BUCO	BUSM Other	
S1540	305193	6215412	351.9	1	0	BUCO	BUSM Other	
S1541	304462	6215283	335.2	1	0	BUCO	BUSM Other	
S1542	306425	6213508	358.9	1	0	BUCO	BUSM Other	
S1727	287987	6212345	153.6	1	0	BUCO	Appin 8	25/05/2005
S1728	287859	6213835	134.6	1	0	BUCO	Appin 7	13/07/2005
S1729	291144	6218598	131.7	1	0	BUCO	Appin 7	20/07/2005
S1732	293829	6207399	289.2	1	0	BUCO	Appin 3	2/08/2005
S1733	293865	6208136	279.0	1	0	BUCO	Appin 3	4/08/2005
S1740	294825	6206963	302.6	1	0	BUCO	Appin 3	28/09/2005
S1741	293641	6209527	236.1	1	0	BUCO	Appin 3	31/08/2005
S1746	295216	6207858	299.7	1	0	BUCO	Appin 3	7/11/2005
S1747	294025	6209069	256.4	1	0	BUCO	Appin 3	7/11/2005
S1751	294401	6208424	271.8	1	0	BUCO	Appin 3	14/12/2005
S1752	292649	6209302	232.1	1	0	BUCO	Appin 3	9/01/2006
S1756	290325	6217981	137.1	1	0	BUCO	Appin 7	
S1757	289019	6218024	128.1	1	0	BUCO	Appin 7	
S1763	288307	6217527	147.6	1	0	BUCO	Appin 7	
S1794	294481	6209684	240.9	1	0	BUCO	Appin 3	13/04/2006
S1840	294052	6218810	161.2	1	0	BUCO	Westcliff	11/07/2006
S1842	290739	6218167	108.9	1	0	BUCO	Appin 7	23/08/2006

Monitoring bore ID	Easting	Northing	Ground level (mAHD)	Number of VWP sensors	Number of sampling pumps	Target formation(s)	Mine area	Installation date
S1843	291265	6219574	112.2	1	0	BUCO	Appin 7	23/11/2006
S1854	291622	6218969	142.2	1	0	BUCO	Appin 7	20/10/2006
S1857	294674	6218972	164.9	1	0	BUCO	Westcliff	9/11/2006
S1901	289500	6218463	155.5	1	0	BUCO	Appin 9	27/07/2007
S1905	288394	6216859	194.9	1	0	BUCO	Appin 9	30/11/2007
S1913	289028	6218729	117.0	10	0	HBSS (3), BGSS (3), SBSS (3), BUCO (1)	Appin 9	21/04/2008
S1923	282953	6221534	131.2	0	0		Tahmoor	
S1933	288438	6218395	128.4	1	0	BUCO	Appin 9	3/07/2008
S1936	291547	6217768	148.1	10	0	HBSS (3), BGSS (3), SBSS (3), BUCO (1)	Appin 9	1/09/2008
S1937	285785	6215645	129.2	1	0	BUCO	Appin 9	26/07/2008
S1941	287181	6216341	146.8	11	0	HBSS (3), BGSS (3), SBSS (3), BUCO (1), WWCO (1)	Appin 9	1/08/2008
S1942	288537	6219619	108.6	1	0	BUCO	Appin 9	3/09/2008
S1946	287933	6214710	119.0	1	0	BUCO	Appin 9	7/10/2008
S1949	288160	6216333	161.3	1	0	BUCO	Appin 9	30/10/2008
S1950	287356	6215956	133.1	1	0	BUCO	Appin 9	5/11/2008
S1954	285466	6216904	310.0	12	4	WGSH (6), HBSS (5), BUCO (1)	Appin 9	1/12/2008
S1955	289942	6219875	115.1	1	0	BUCO	Appin 9	28/11/2008
S1959	285463	6216881	310.3	0	3	WGSH (2), HBSS (1)	Appin 9	
S1960	287596	6218390	151.6	1	0	BUCO	Appin 9	24/12/2008
S1961	287176	6217906	159.9	1	0	BUCO	Appin 9	24/12/2008

Monitoring bore ID	Easting	Northing	Ground level (mAHD)	Number of VWP sensors	Number of sampling pumps	Target formation(s)	Mine area	Installation date
S1962	285364	6218275	285.7	1	0	BUCO	Appin 9	13/01/2009
S1967	284812	6215000	124.9	1	0	BUCO	Appin 7	27/01/2009
S1968	285345	6219132	318.0	1	0	BUCO	Appin 9	2/03/2009
S1971	287494	6218981	137.4	1	0	BUCO	Appin 9	20/02/2009
S1973	283205	6218537	310.8	1	0	BUCO	Appin 9	23/03/2009
S1974	283615	6217258	200.2	1	0	BUCO	Appin 9	27/03/2009
S1993	294585	6215806	164.4	10	0	HBSS (3), BGSS (3), SBSS (3), BUCO (1)	Westcliff	1/04/2008
S1996	298772	6207843	381.6	10	0	HBSS (2), BGSS (3), SPCL (3), BUCO (1), WWCO (1)	Appin 3	13/04/2009
S1997	306997	6212765	370.2	11	0	HBSS (3), BGSS (3), SBSS (3), CCSS (1), BUCO (1)	BUSM Other	27/04/2009
S2022	284621	6215991	294.4	1	0	BUCO	Appin 9	26/08/2009
S2024	288519	6216417	146.8	1	0	BUCO	Appin 9	11/09/2009
S2025	300949	6207652	371.2	2	0	HBSS, BUCO	Appin 3	17/09/2009
S2027	286626	6218407	268.6	1	0	BUCO	Appin 9	28/09/2009
S2028	282712	6217053	187.1	1	0	BUCO	Appin 9	12/10/2009
S2030	297650	6217828	228.3	1	0	BUCO	Westcliff	
S2031	284354	6219199	311.7	1	0	BUCO	Appin 9	23/11/2009
S2032	300022	6206732	358.8	2	0	BUCO, WWCO	Appin 3	19/10/2009
S2035	286389	6219243	281.8	1	0	LOSS	Appin 9	30/10/2009
S2036	300017	6206725	358.6	2	0	BUCO, WWCO	Appin 3	
S2037	286735	6216059	136.6	1	0	BUCO	Appin 9	26/02/2010

Monitoring bore ID	Easting	Northing	Ground level (mAHD)	Number of VWP sensors	Number of sampling pumps	Target formation(s)	Mine area	Installation date
S2038	286229	6217296	307.7	1	0	BUCO	Appin 9	14/12/2009
S2039	284009	6221863	118.5	1	0	BUCO	Appin 9	26/11/2009
S2040	284790	6218183	251.4	1	0	BUCO	Appin 9	23/12/2009
S2042	287921	6219546	134.6	1	0	BUCO	Appin 9	14/12/2009
S2055	288727	6219102	117.6	1	0	BUCO	Appin 9	30/03/2010
S2056	286730	6216261	149.7	1	0	BUCO	Appin 9	15/05/2010
S2057	284047	6221150	137.4	1	0	LOSS	Appin 9	22/01/2010
S2062	286275	6216632	294.7	1	0	BUCO	Appin 9	3/03/2010
S2067	287863	6217298	185.3	1	0	BUCO	Appin 9	19/04/2010
S2080	289803	6215342	125.9	10	0	HBSS (3), BGSS (3), SBSS (3), CCSS (1)	Appin 9	6/08/2010
S2081	289813	6215300	126.9	0	2	HBSS (1), BGSS (1)	Appin 9	
S2083	284419	6218444	232.2	1	0	BUCO	Appin 9	21/07/2010
S2085	286203	6215440	116.3	1	0	BUCO	Appin 9	16/08/2010
S2090	284976	6216642	285.2	1	0	BUCO	Appin 9	7/09/2010
S2104	283806	6218446	284.1	1	0	BUCO	Appin 9	18/10/2010
S2105	285556	6216319	320.5	1	0	CCSS	Appin 9	1/11/2010
S2106	285056	6218762	306.8	1	0	CCSS	Appin 9	1/11/2010
S2107	282275	6214313	138.0	1	0	BUCO	Appin 8	2/11/2010
S2109	284686	6219090	306.9	1	0	BUCO	Appin 9	
S2110	282537	6215837	182.2	1	0	BUCO	Appin 9	
S2111	284825	6219828	307.3	1	0	BGSS	Appin 9	
S2113	285263	6217844	287.6	0	0		Appin 9	

Monitoring bore ID	Easting	Northing	Ground level (mAHD)	Number of VWP sensors	Number of sampling pumps	Target formation(s)	Mine area	Installation date
S2116	292054	6200890	358.6	2	0	BUCO, WWCO	Dendrobium 6	18/07/2011
S2119	282934	6212729	148.1	1	0	BUCO	Appin 8	21/02/2011
S2121	282636	6210535	189.1	1	0	BUCO	Appin 8	21/04/2011
S2122	292125	6208565	254.1	2	0	BUCO, WWCO	Appin 3	20/04/2011
S2123	283155	6216724	203.3	1	0	LOSS	Appin 8	24/03/2011
S2127	284080	6217923	202.1	1	0	BUCO	Appin 9	27/04/2011
S2129	283453	6217968	245.0	1	0	BUCO	Appin 9	2/06/2011
S2131	291195	6207967	258.1	2	0	BUCO, WWCO	Appin 3	23/05/2011
S2132	283609	6214020	145.9	1	0	BUCO	Appin 8	19/05/2011
S2133	284168	6218810	295.2	1	0	BUCO	Appin 9	22/06/2011
S2140	285663	6219435	300.3	1	0	BUCO	Appin 9	
S2149	282415	6215044	153.5	10	0	HBSS (3), BGSS (3), SBSS (1), BUCO (1), BACO (1), CHCO (1)	Appin 8	
S2149A	282391	6214988	152.7	0	5	HBSS (4), BGSS (1)	Appin 8	
S2149B	282387	6214988	152.6	0	0		Appin 8	
S2150	282971	6214153	151.3	1	0	BUCO	Appin 8	
S2151	283019	6215017	184.8	7	0	BUCO, BACO, CHCO, WWCO, ACCO, TGCO	Appin 8	10/11/2011
S2155	285116	6215354	149.1	1	0	BUCO	Appin 8	14/11/2011
S2157	283212	6215969	224.5	10	0	WGSH (1), HBSS (3), BGSS (3), SPCL (1), SBSS (1), BUCO (1)	Appin 8	16/01/2012
S2158	283779	6212690	138.9	13	0	HBSS (3), BGSS (3), SPCL (1), SBSS (1), BUCO (1), WWCO (2), ACCO (1), TGCO (1)	Appin 8	23/02/2012

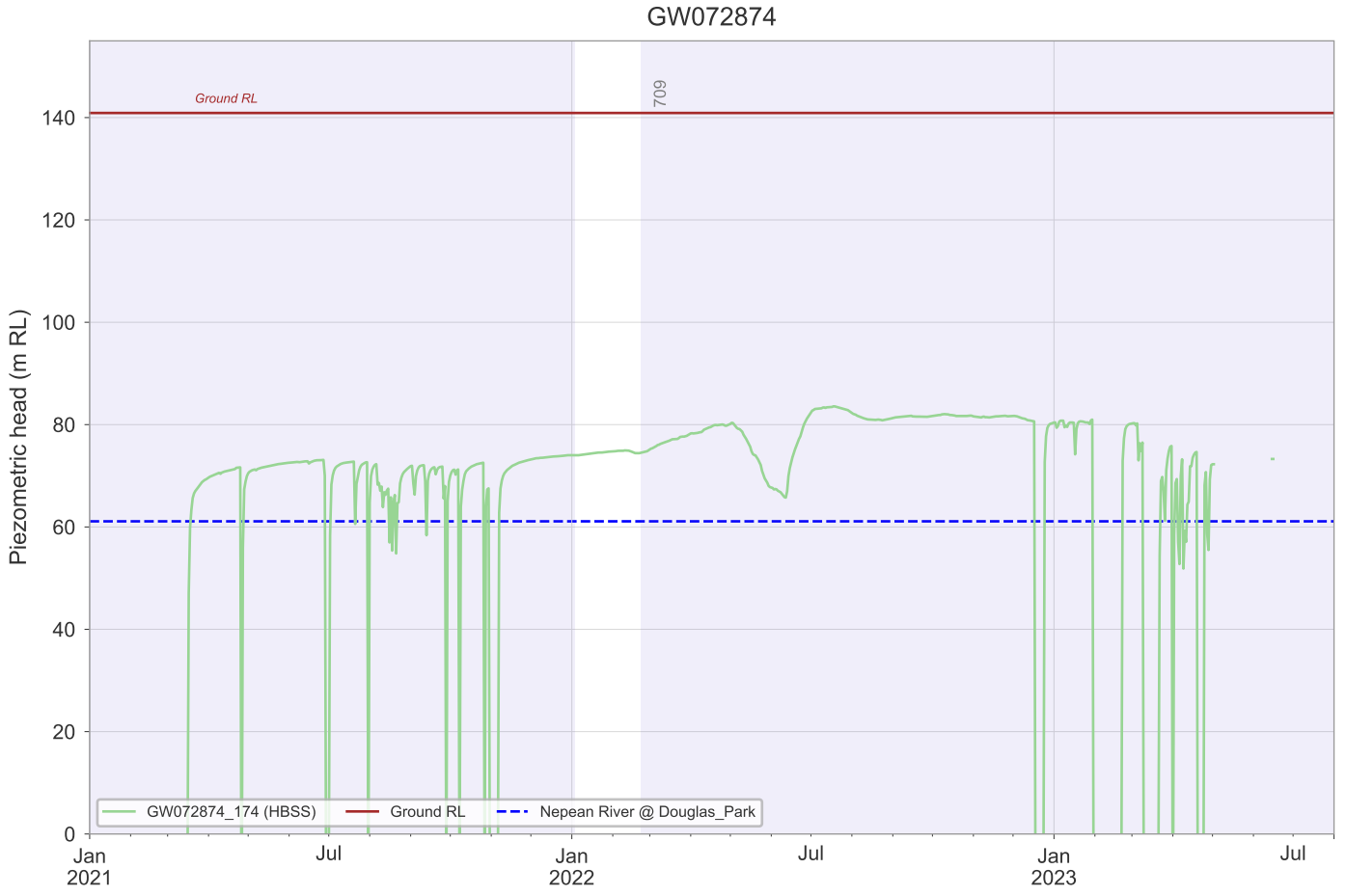
Monitoring bore ID	Easting	Northing	Ground level (mAHD)	Number of VWP sensors	Number of sampling pumps	Target formation(s)	Mine area	Installation date
S2158A	283774	6212690	139.1	0	2	HBSS (1), BGSS (1)	Appin 8	
S2158B	283785	6212693	139.1	0	3	HBSS (3)	Appin 8	
S2159	283040	6214663	197.9	1	0	BUCO	Appin 8	14/11/2011
S2160	284717	6213651	133.4	9	5	HBSS (2), BGSS (3), SPCL (1), SBSS (1), BUCO (1), BACO (1)	Appin 8	12/04/2012
S2164	283894	6214831	171.2	1	0	BUCO	Appin 8	2/12/2011
S2165	288767	6226270	66.9	13	5	WGSH (1), HBSS (4), BGSS (3), SPCL (1), SBSS (1), BUCO (1), BACO (1), WWCO (1)	Appin 10	
S2165A	288767	6226274	67.0	0	0		Appin 10	
S2173	287590	6223237	110.2	10	5	WGSH (2), HBSS (3), BGSS (3), SPCL (1), SBSS (1)	Appin 10	2/08/2012
S2177	291123	6225144	70.0	9	0	HBSS (3), BGSS (3), SPCL (1), SBSS (1), BUCO (1)	Appin 10	
S2177A	291122	6225143	69.9	1	5	WGSH, BGSS (pumps)	Appin 10	
S2200	290145	6215544	136.3	1	0	CCSS	Appin 9	7/04/2014
S2217	297658	6217833	228.7	1	0	HBSS	Westcliff	1/12/2013
S2218	296778	6217610	186.5	1	0	HBSS	Westcliff	1/12/2013
S2219	296738	6217720	206.5	1	0	HBSS	Westcliff	1/12/2013
S2280	285758	6215275	122.3	2	1	HBSS	Appin 9	
S2281	287958	6214897	125.1	2	1	HBSS	Appin 9	
S2282	288786	6215032	133.0	2	0	HBSS	Appin 9	
S2283	289000	6214636	127.1	2	0	HBSS	Appin 9	

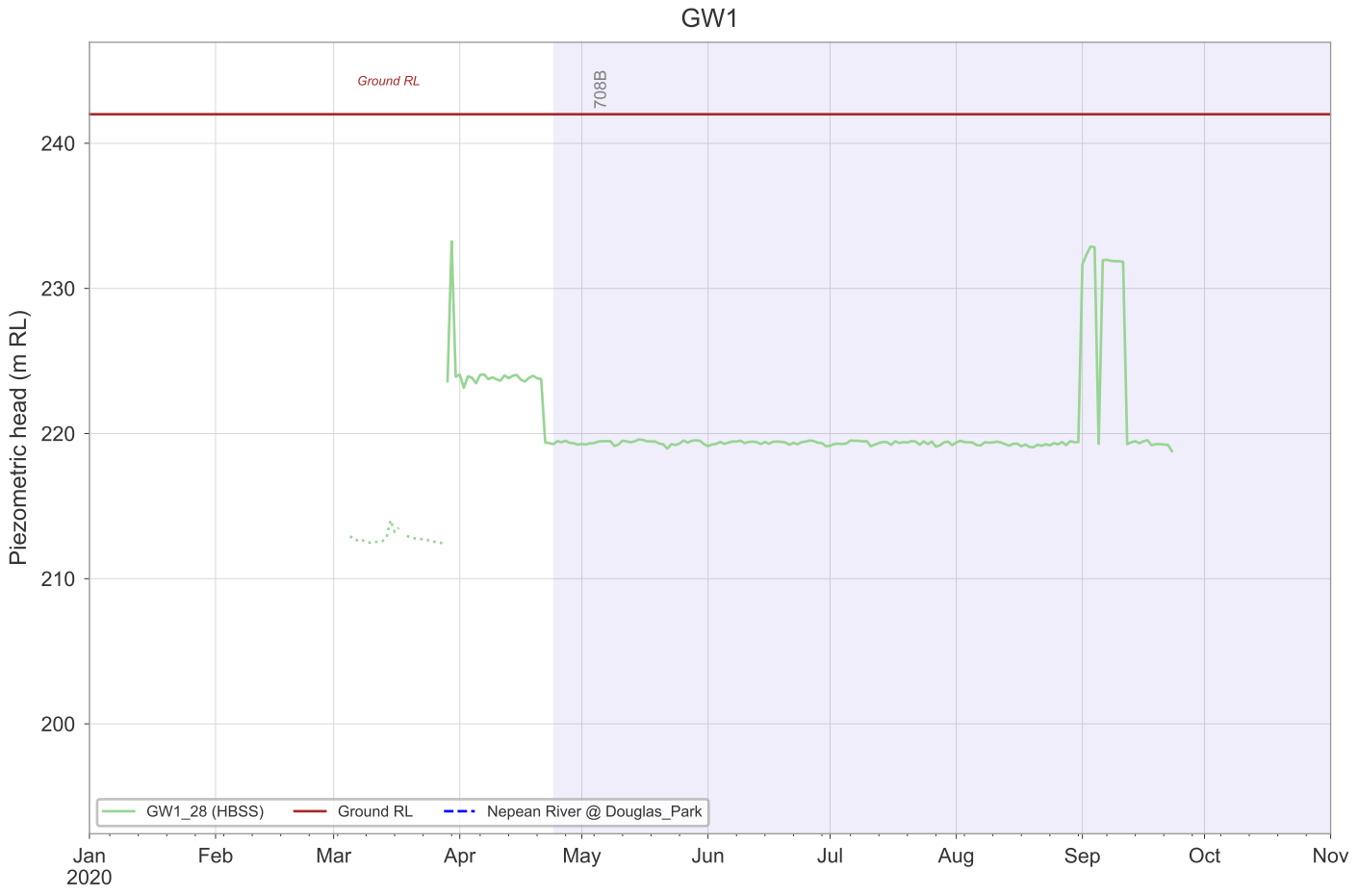
Monitoring bore ID	Easting	Northing	Ground level (mAHD)	Number of VWP sensors	Number of sampling pumps	Target formation(s)	Mine area	Installation date
S2285	289248	6214559	113.3	2	0	HBSS	Appin 9	
S2286	289330	6214721	114.6	2	0	HBSS	Appin 9	
S2308	289958	6218476	144.7	8	0	HBSS (3), BGSS (2), SBSS (3), BUCO (1)	Appin 7	
S2315	288187	6218051	137.6	9	0	HBSS (3), BGSS (3), SBSS (2), BUCO (1)	Appin 7	
S2373	292043	6200899	359.0	4	0	HBSS	Dendrobium 6	11/09/2017
S2374	291115	6201461	324.4	4	0	HBSS	Dendrobium 6	13/08/2017
S2488A	285106	6226549	75.9	11	0	HBSS (3), BHCL (1), BGSS (3), SPCL (1), SBSS (1), BUCO (1), BACO (1)	Appin 10	
S2492	288027	6222432	91.3	10	0	HBSS (3), BHCL (1), BGSS (3), SPCL (1), SBSS (1), BUCO (1)	Appin 10	17/03/2020
S2499	283736	6224133	107.6	12	0	HBSS (3), BHCL (1), BGSS (3), SPCL (1), SBSS (1), BUCO (1), BACO (1), WWCO (1)	Appin 10	25/06/2020
S2500	286823	6219787	237.5	11	0	WGSH (2), HBSS (3), BGSS (4), SBSS (1)	Appin 7	3/07/2020
S2501	287074	6219329	252.6	1	0	BUCO	Appin 7	
S2533	286301	6216638	293.9	4	0	WGSH	Appin 9	26/05/2021
S2536	288404	6218411	128.3	1	0	WGSH	Appin 9	27/08/2021
S2536A	287932	6219544	134.3	1	0	HBSS	Appin 9	27/07/2021
S2537	287169	6216357	147.5	1	0	HBSS	Appin 9	5/07/2021
S2538	290841	6217822	122.4	1	0	HBSS	Appin 9	12/07/2021

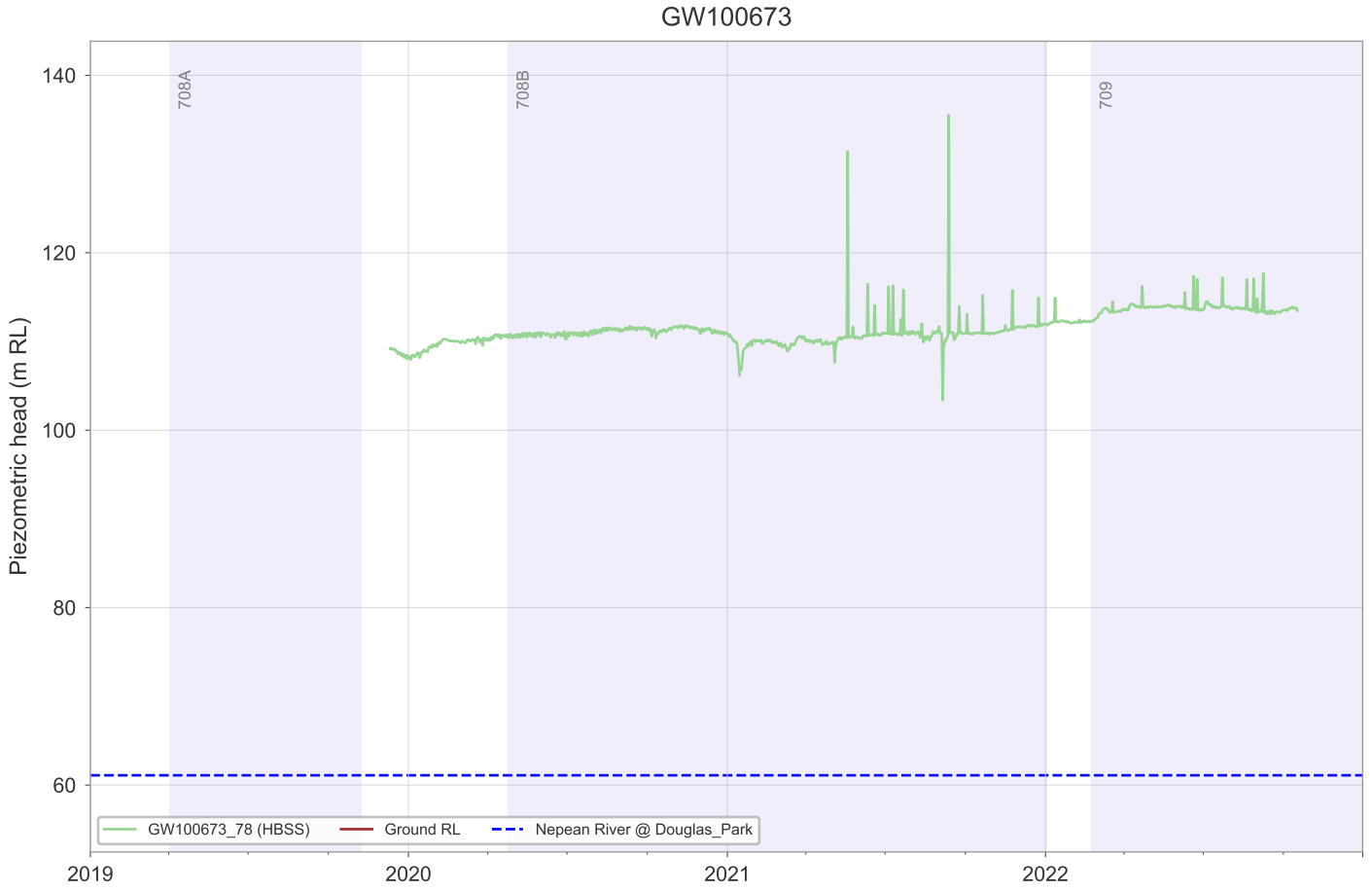
Monitoring bore ID	Easting	Northing	Ground level (mAHD)	Number of VWP sensors	Number of sampling pumps	Target formation(s)	Mine area	Installation date
S2540	280130	6220729	212.8	9	0	HBSS (3), BHCL (1), BGSS (3), SBSS (1), BUCO (1)	Appin Undif	
S2543	279243	6222396	261.3	10	0	HBSS (3), BHCL (1), BGSS (3), SBSS (2), BUCO (1)	Appin Undif	29/09/2021
S2561	281931	6222425	154.8	9	0	HBSS (3), BHCL (1), BGSS (3), SBSS (2)	Appin Undif	30/09/2021
S2624	293357	6209408	236.0	9	0	HBSS (3), BHCL (1), BGSS (3), SBSS (1), LOSS (1)	Appin 3	8/03/2023
S2631	281658	6217606	192.4	9	0	HBSS (3), BHCL (1), BGSS (3), SBSS (1), LOSS (1)	Appin 10	10/11/2022
S2632	289092	6219226	113.0	1	1	WGSH	Appin Undif	
S2633	290603	6219515	91.8	1	1	HBSS	Appin Undif	7/08/2022
S2639	282744	6220576	194.5	8	0	HBSS (3), BHCL (1), BGSS (3), SBSS (1)	Appin Undif	16/03/2023
S2661	286742	6220881	132.5	9	0	HBSS (3), BHCL (1), BGSS (4), BUCO (1)	Appin 10	9/04/2024
S2677	289223	6221098	94.9	9	0	HBSS (3), BHCL (1), BGSS (3), SBSS (1), BUCO (1)	Appin 10	

WGSH – Wianamatta Group shales, HBSS – Hawkesbury Sandstone, BHCL – Bald Hill Claystone, BGSS – Bulgo Sandstone – SPCL – Stanwell Park Claystone, SBSS – Scarborough Sandstone, CCSS – Coalcliff Sandstone, BUCO – Bulli Coal Seam, LOSS – Loddon Sandstone, BACO – Balgownie Coal Seam, CHCO – Cape Horn Coal Seam, WWCO – Wongawilli Coal Seam, ACCO – America Creek Coal Seam, TGCO – Tongarra Coal Seam

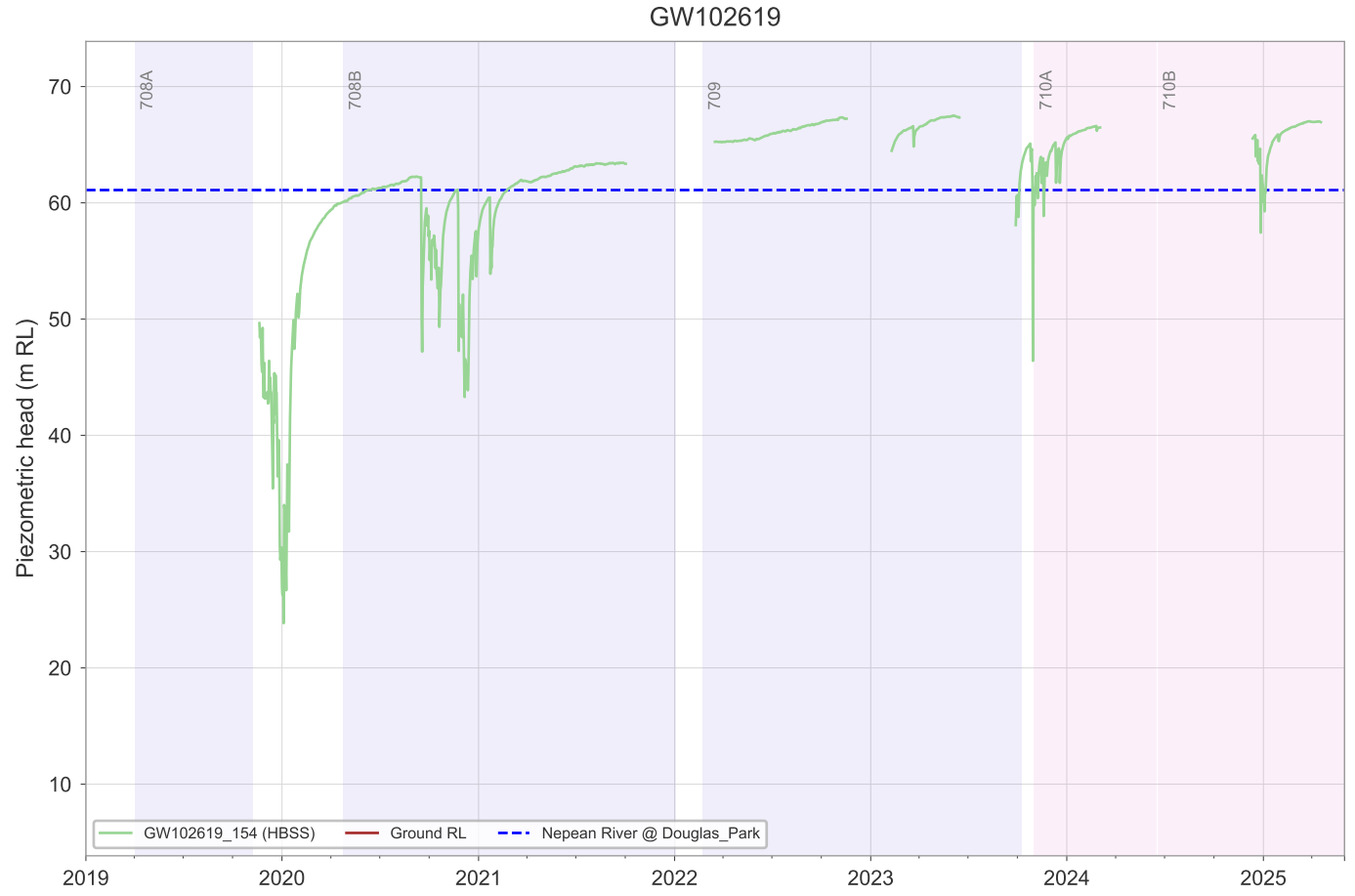
APPENDIX B – Hydrographs


GW072874
Ground RL
709
Piezometric head (m RL)
140
120
100
80
60
40
20
0
GW072874_174 (HBSS)
Ground RL
Nepean River @ Douglas_Park
Jan
2021
Jul
Jan
2022
Jul
Jan
2023
Jul

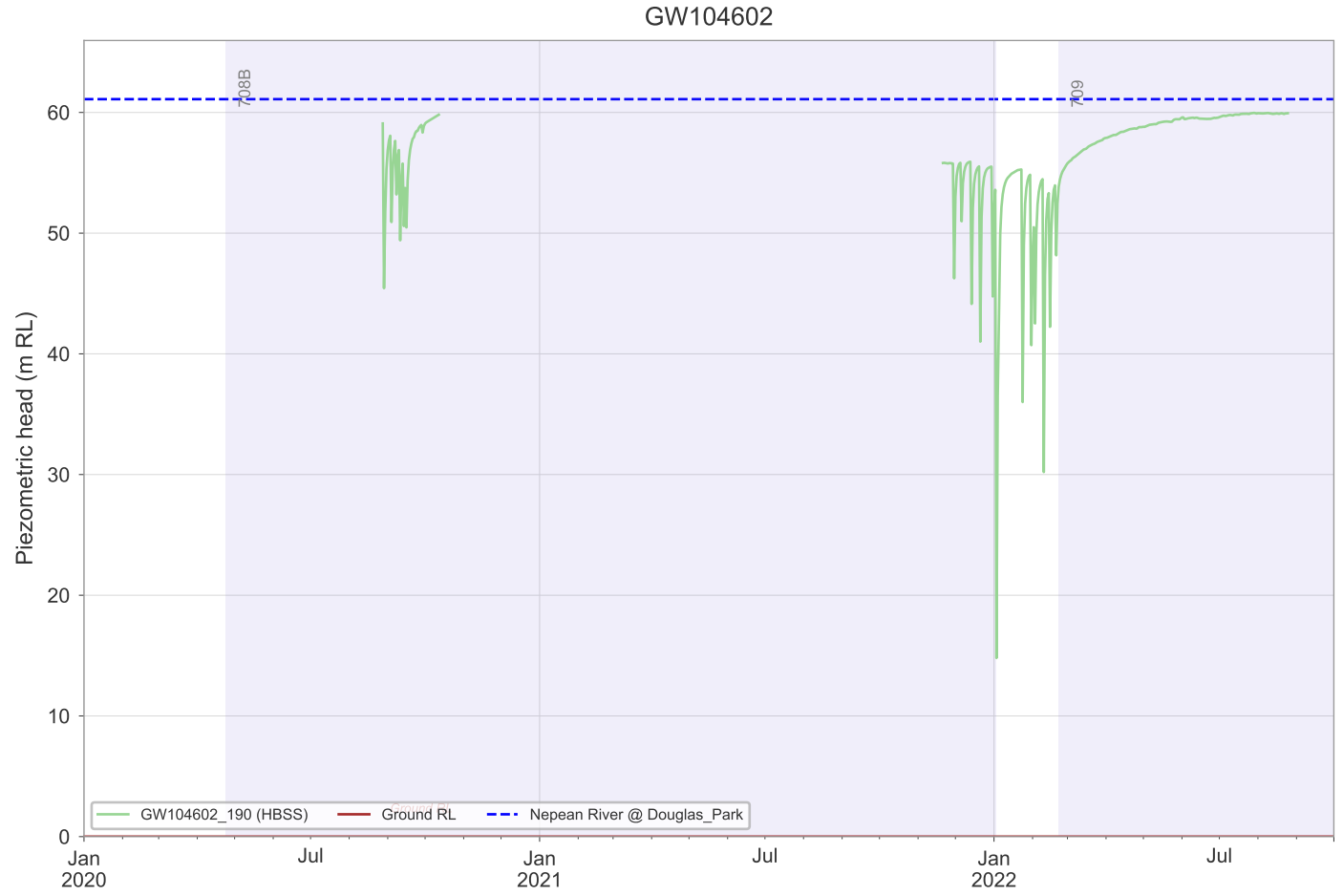

GW1
Ground RL
708B
Piezometric head (m RL)
240
230
220
210
200
GW1_28 (HBSS)
Ground RL
Nepean River @ Douglas_Park
Jan
2020
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

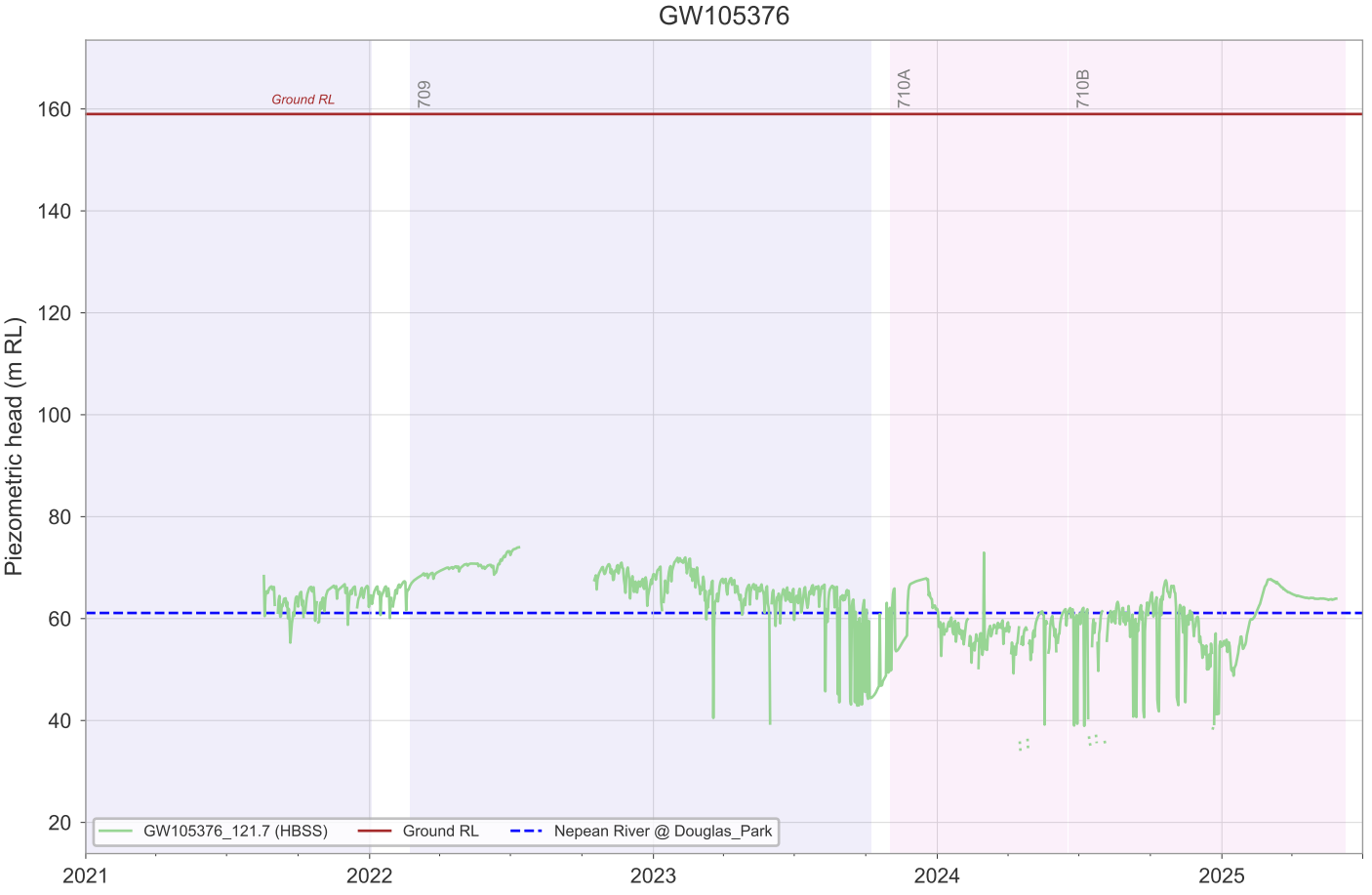

GW100673
Piezometric head (m RL)
140
120
100
80
60
708A
708B
709
GW100673_78 (HBSS)
Ground RL
Nepean River @ Douglas_Park
2019
2020
2021
2022

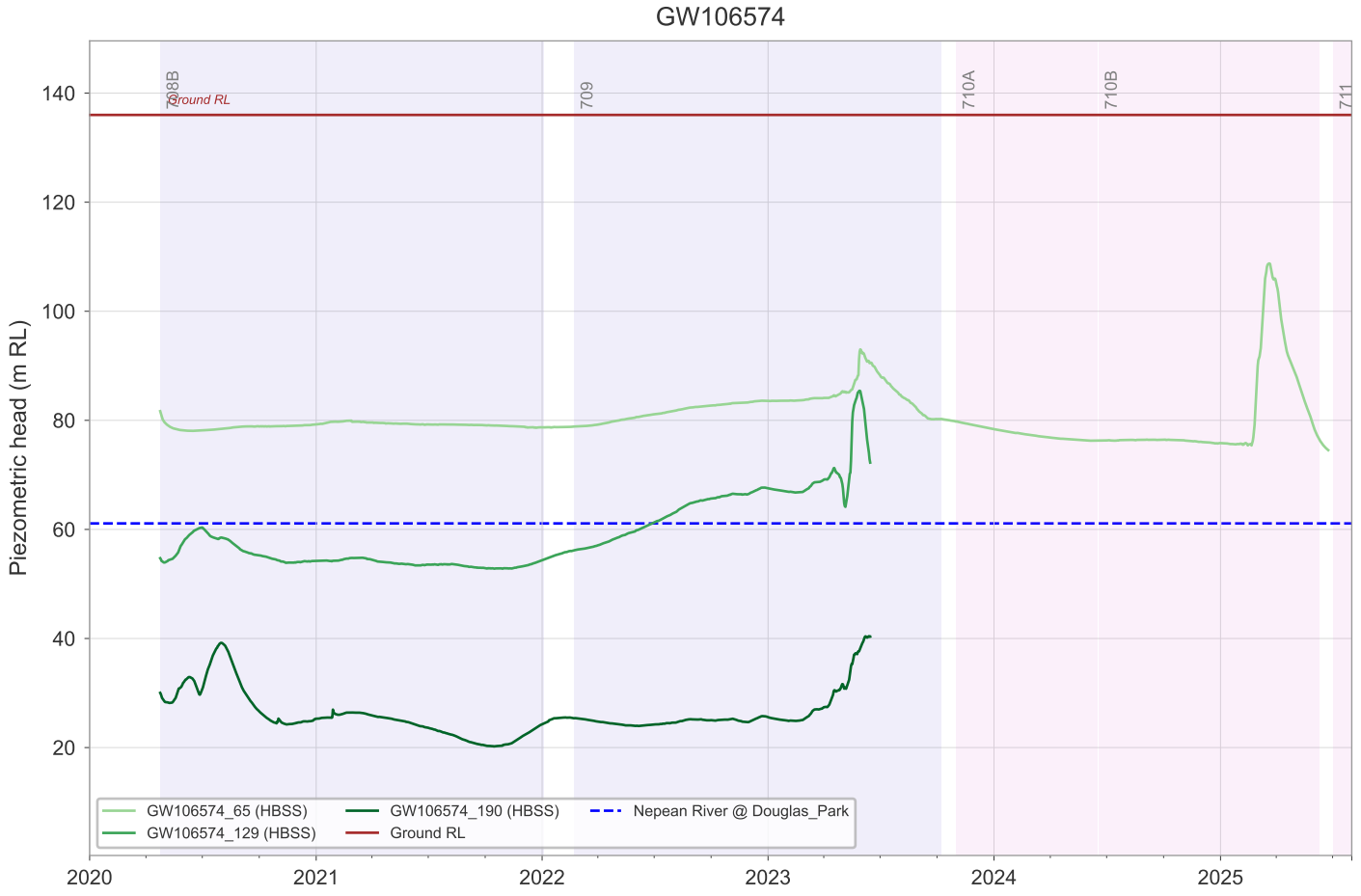

GW101986
Piezometric head (m RL)
180
160
140
120
100
80
60
40
Ground RL
709
710A
710B
711
GW101986_119 (HBSS)
Ground RL
Nepean River @ Douglas_Park
Jan 2022
Jul
Jan 2023
Jul
Jan 2024
Jul
Jan 2025
Jul

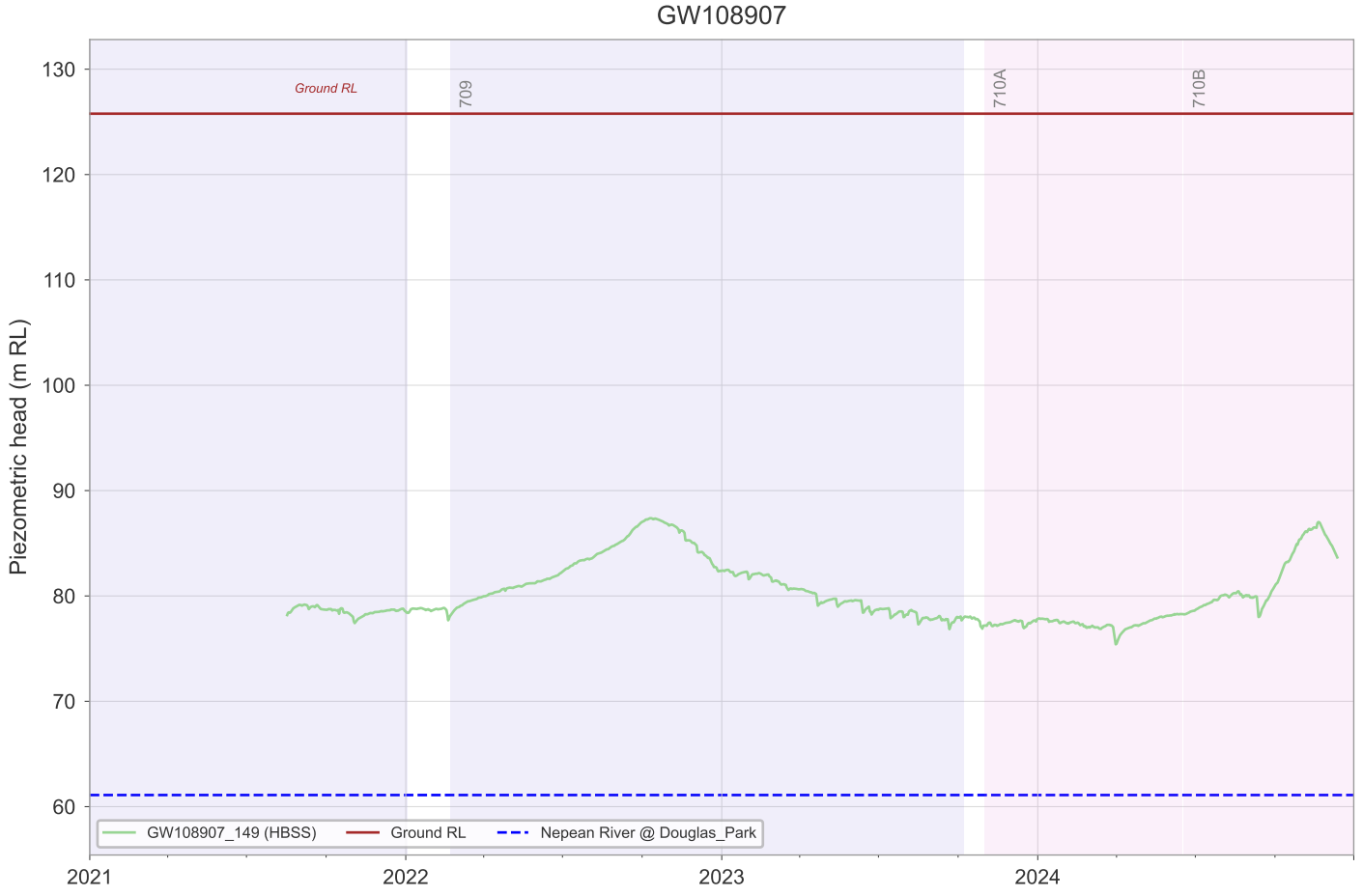

GW102619
708A
708B
709
710A
710B
Piezometric head (m RL)
70
60
50
40
30
20
10
2019
2020
2021
2022
2023
2024
2025
GW102619_154 (HBSS)
Ground RL
Nepean River @ Douglas_Park

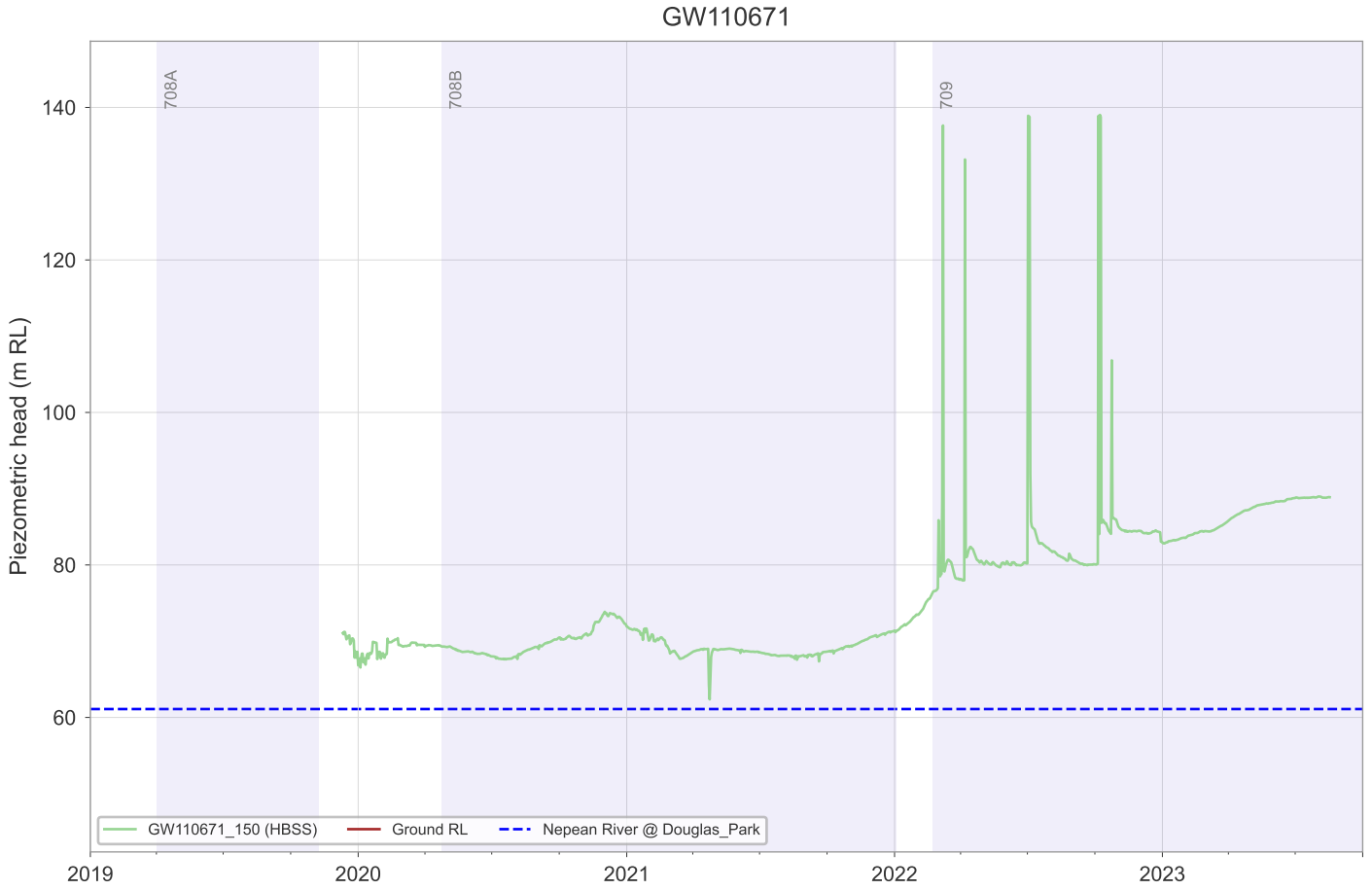

GW103095
Piezometric head (m RL)
100
95
90
85
80
Jan
2021
Feb
Mar
Apr
May
GW103095_100 (HBSS)
Ground RL
Nepean River @ Douglas_Park

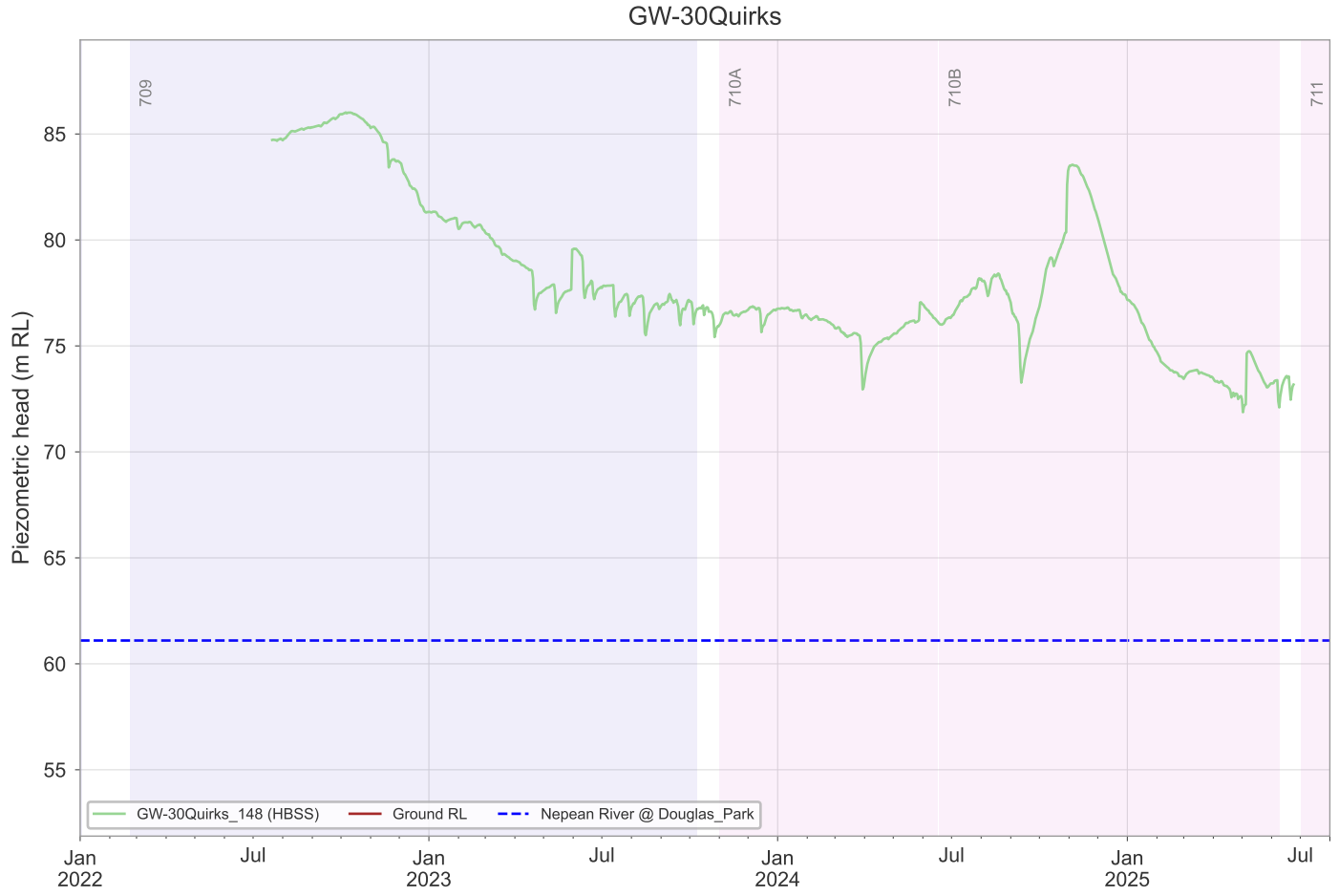

GW104602
708B
709
Piezometric head (m RL)
60
50
40
30
20
10
0
GW104602_190 (HBSS)
Ground RL
Nepean River @ Douglas_Park
Jan
2020
Jul
Jan
2021
Jul
Jan
2022
Jul

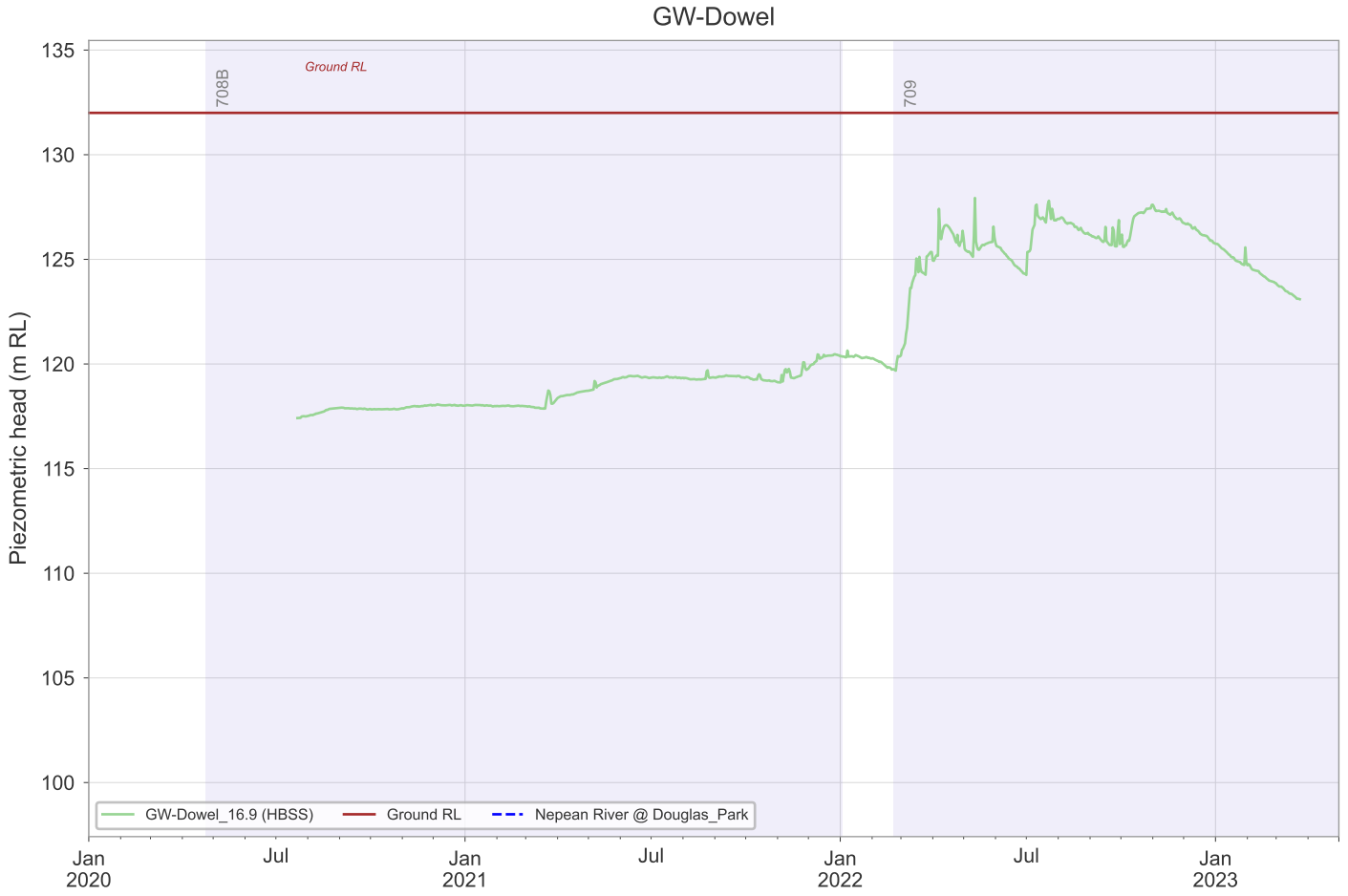

GW105376
Ground RL
709
710A
710B
Piezometric head (m RL)
160
140
120
100
80
60
40
20
GW105376_121.7 (HBSS)
Ground RL
Nepean River @ Douglas_Park
2021
2022
2023
2024
2025

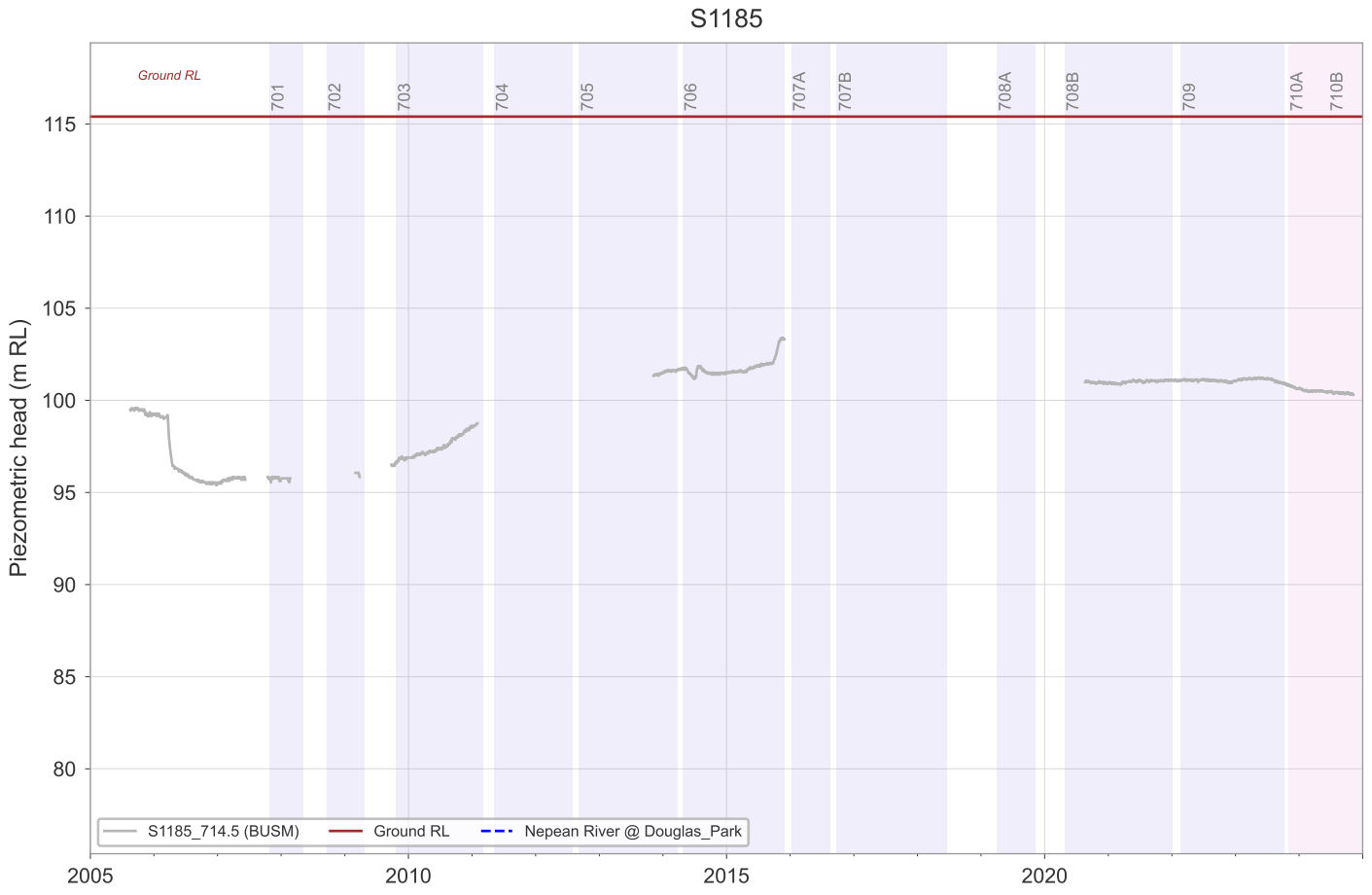

GW106574
Piezometric head (m RL)
140
120
100
80
60
40
20
708B
709
710A
710B
711
Ground RL
2020
2021
2022
2023
2024
2025
GW106574_65 (HBSS)
GW106574_129 (HBSS)
GW106574_190 (HBSS)
Ground RL
Nepean River @ Douglas_Park

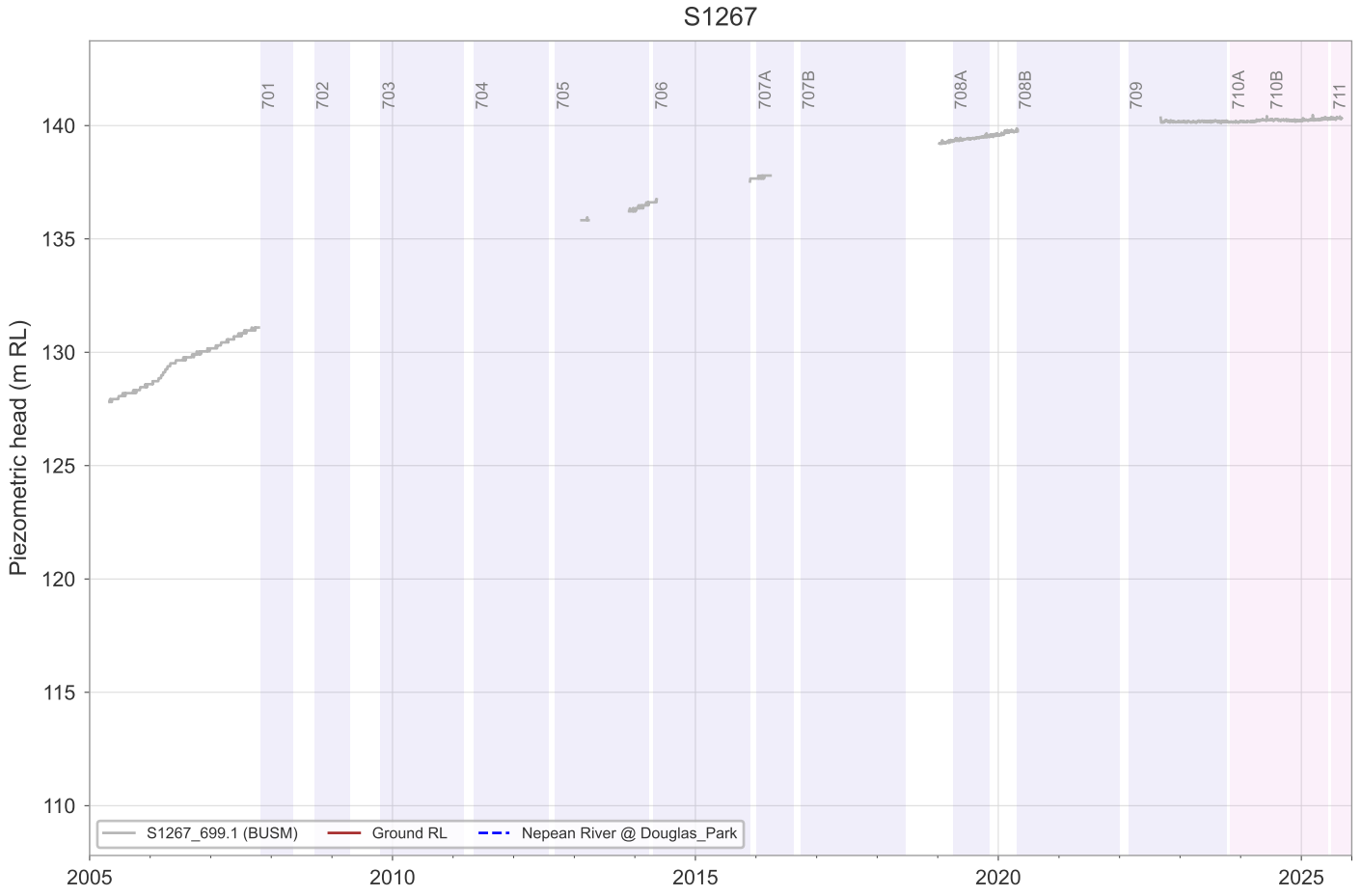

GW108907
Piezometric head (m RL)
130
120
110
100
90
80
70
60
Ground RL
709
710A
710B
2021
2022
2023
2024
GW108907_149 (HBSS)
Ground RL
Nepean River @ Douglas_Park

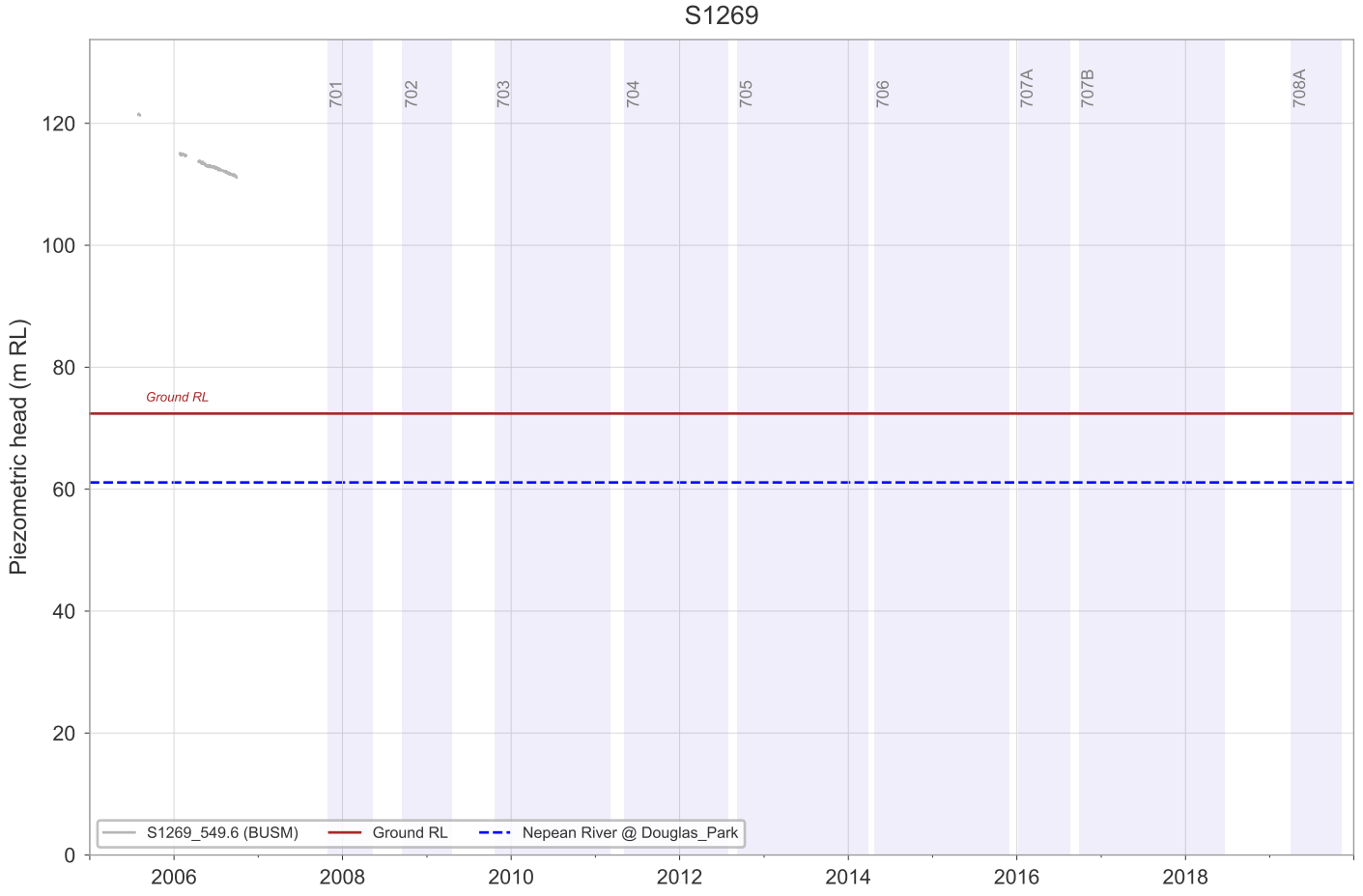

GW110671
708A
708B
709
140
120
100
80
60
Piezometric head (m RL)
GW110671_150 (HBSS)
Ground RL
Nepean River @ Douglas_Park
2019
2020
2021
2022
2023

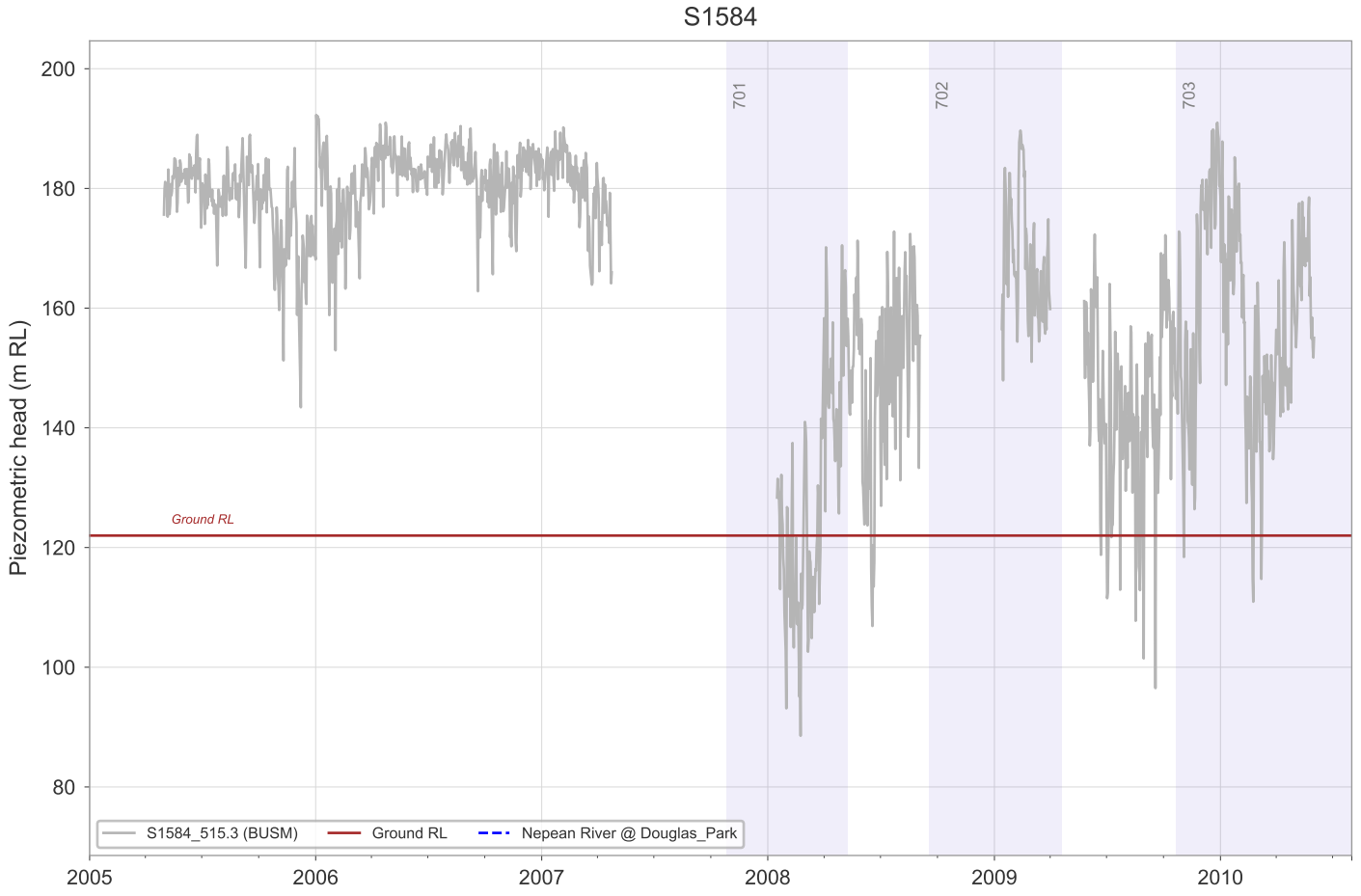

GW-30Quirks
709
710A
710B
711
85
80
75
70
65
60
55
Piezometric head (m RL)
GW-30Quirks_148 (HBSS)
Ground RL
Nepean River @ Douglas_Park
Jan
2022
Jul
Jan
2023
Jul
Jan
2024
Jul
Jan
2025
Jul

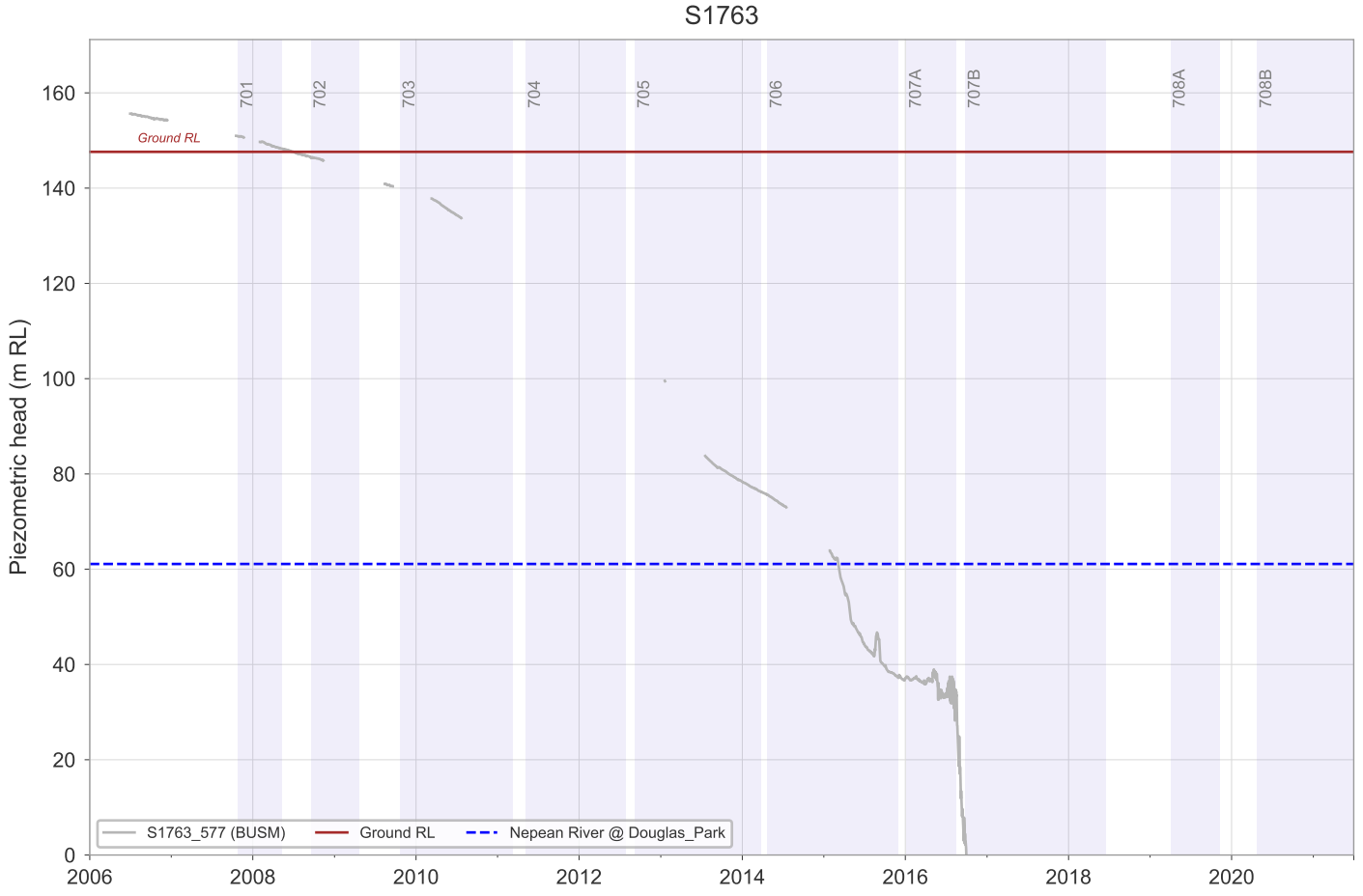

GW-Dowel
Ground RL
708B
709
Piezometric head (m RL)
135
130
125
120
115
110
105
100
GW-Dowel_16.9 (HBSS)
Ground RL
Nepean River @ Douglas_Park
Jan 2020
Jul
Jan 2021
Jul
Jan 2022
Jul
Jan 2023

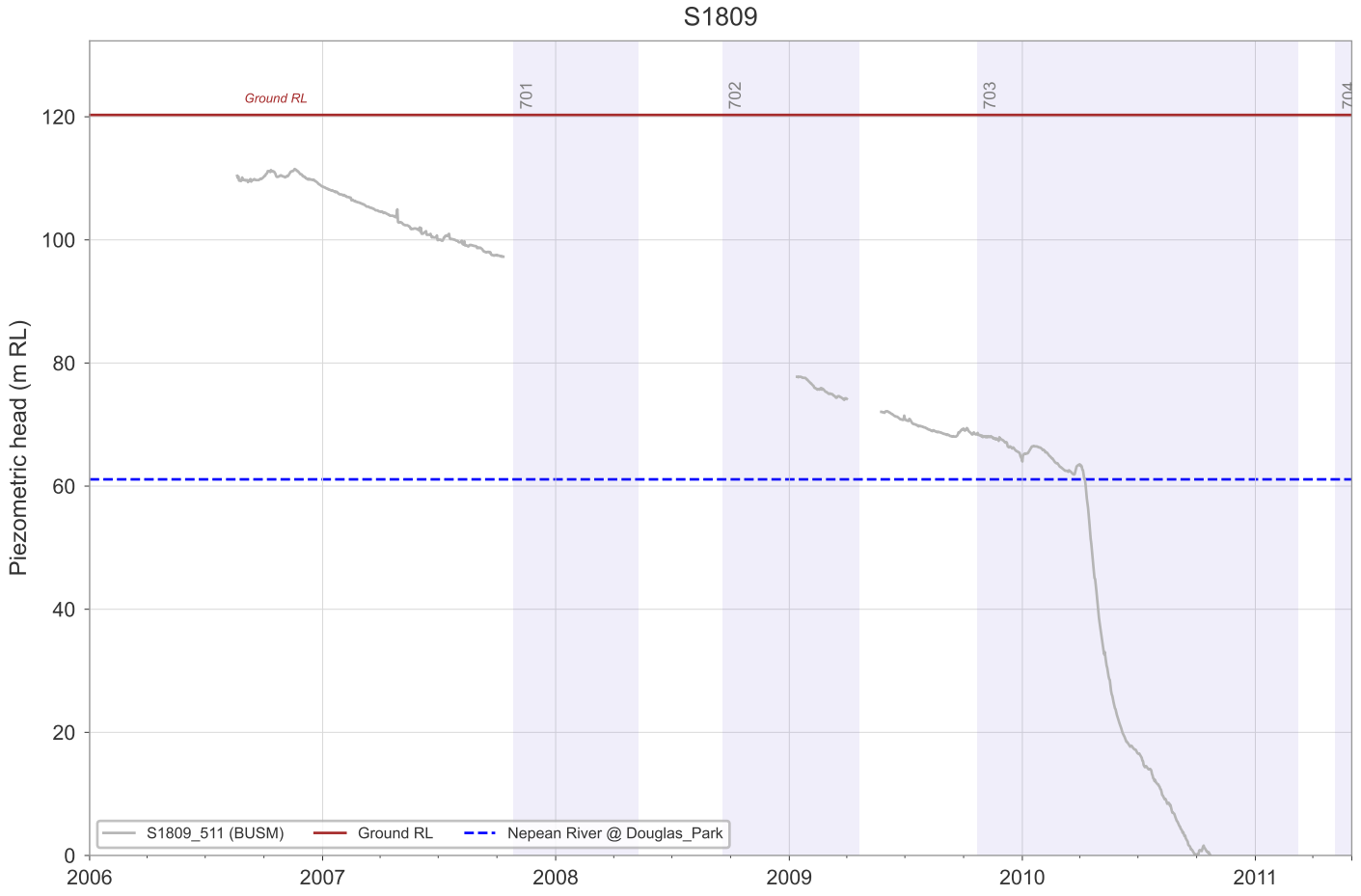

S1185
Ground RL
701
702
703
704
705
706
707A
707B
708A
708B
709
710A
710B
Piezometric head (m RL)
115
110
105
100
95
90
85
80
S1185_714.5 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2005
2010
2015
2020


S1267
Piezometric head (m RL)
701
702
703
704
705
706
707A
707B
708A
708B
709
710A
710B
711
140
135
130
125
120
115
110
S1267_699.1 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2005
2010
2015
2020
2025


S1269
Piezometric head (m RL)
701
702
703
704
705
706
707A
707B
708A
120
100
80
60
40
20
0
Ground RL
S1269_549.6 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2006
2008
2010
2012
2014
2016
2018


S1584
Piezometric head (m RL)
200
180
160
140
120
100
80
701
702
703
Ground RL
S1584_515.3 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2005
2006
2007
2008
2009
2010

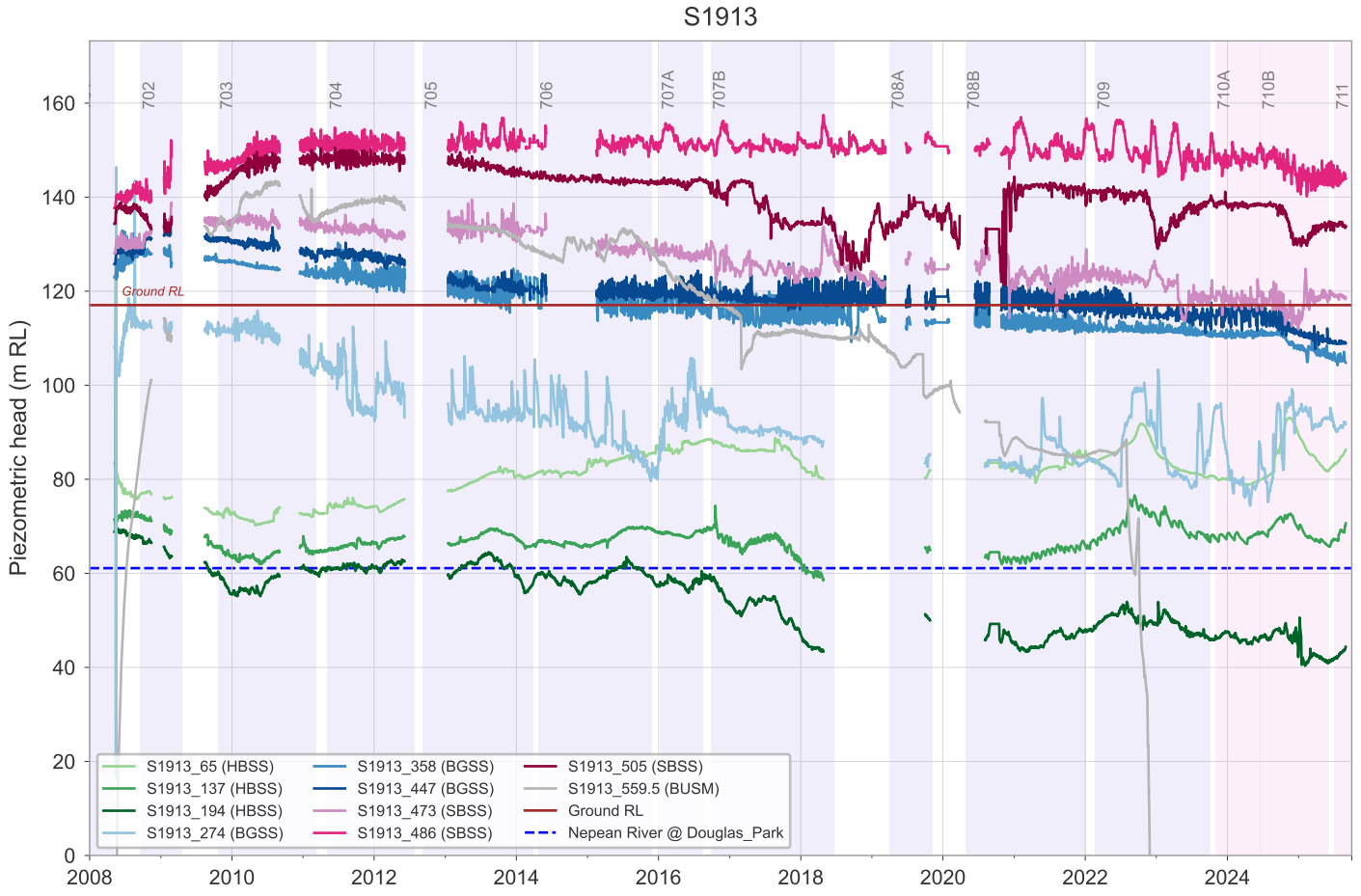

S1763
Piezometric head (m RL)
160
140
120
100
80
60
40
20
0
701
702
703
704
705
706
707A
707B
708A
708B
Ground RL
S1763_577 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2006
2008
2010
2012
2014
2016
2018
2020

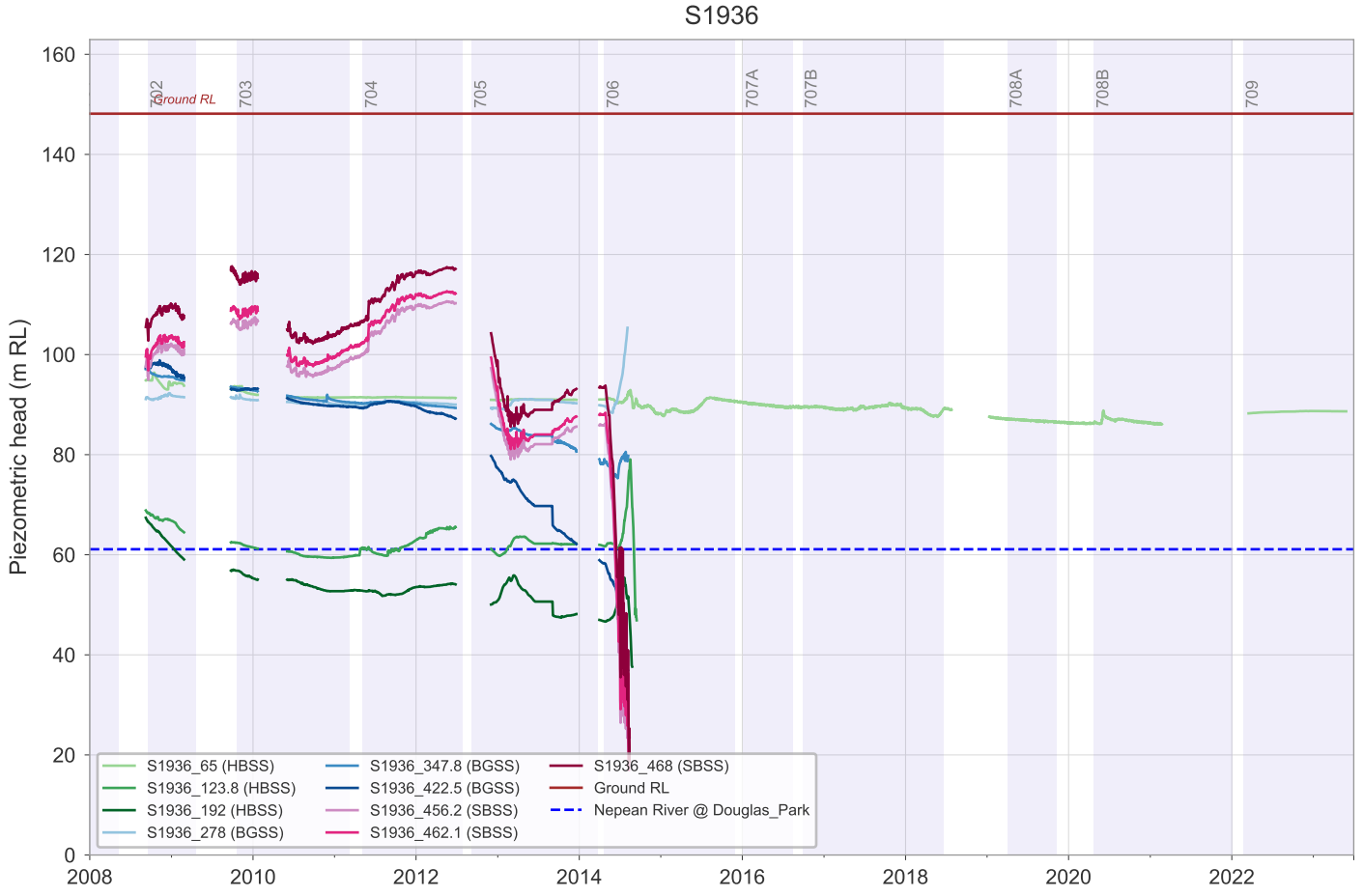

S1809
Ground RL
701
702
703
704
Piezometric head (m RL)
120
100
80
60
40
20
0
2006
2007
2008
2009
2010
2011
S1809_511 (BUSM)
Ground RL
Nepean River @ Douglas_Park

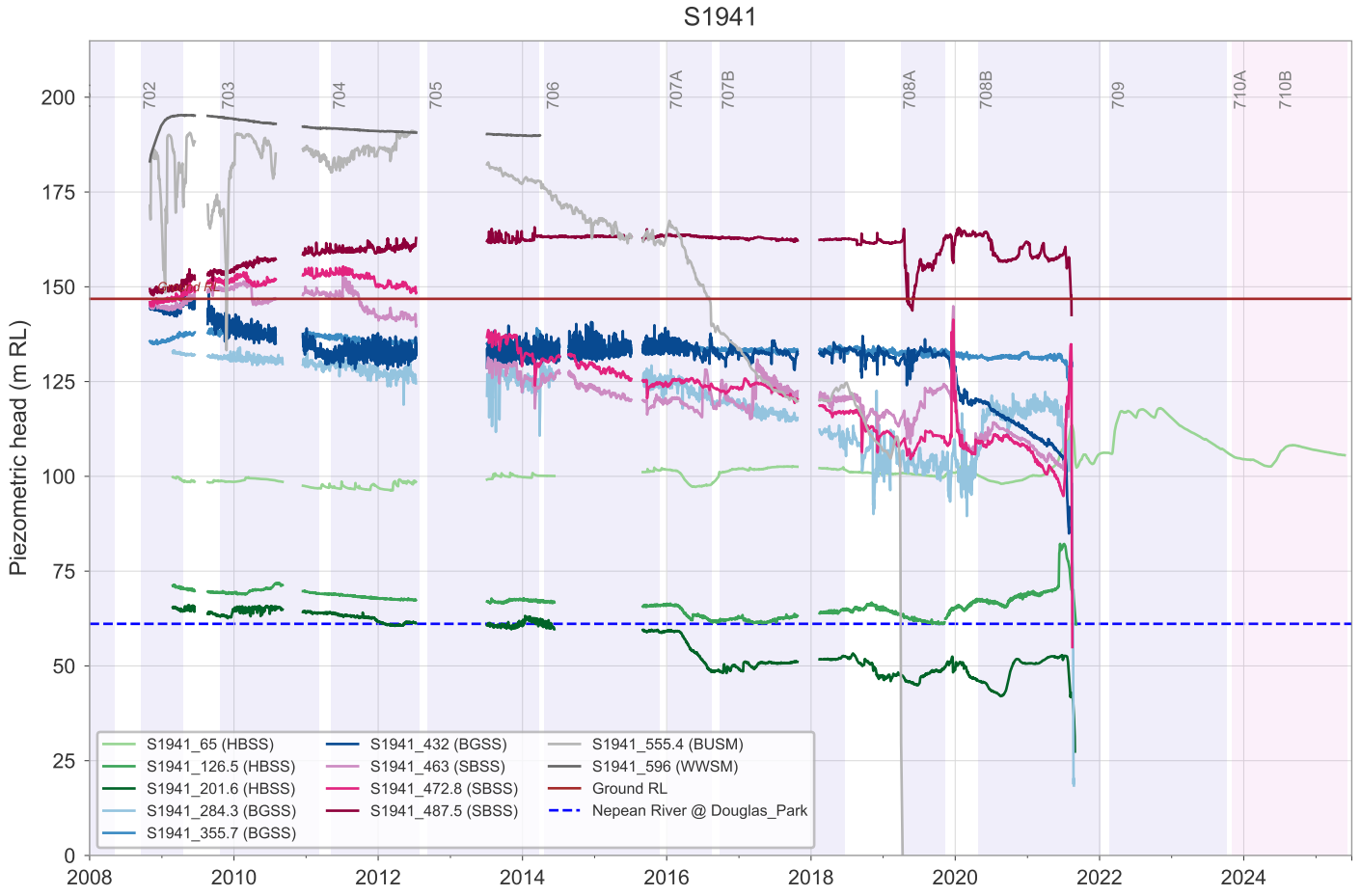

S1853
701
702
703
704
705
Piezometric head (m RL)
500
400
300
200
100
0
2007
2008
2009
2010
2011
2012
2013
2014
Ground RL
S1853_639.3 (BUSM)
Ground RL
Nepean River @ Douglas_Park

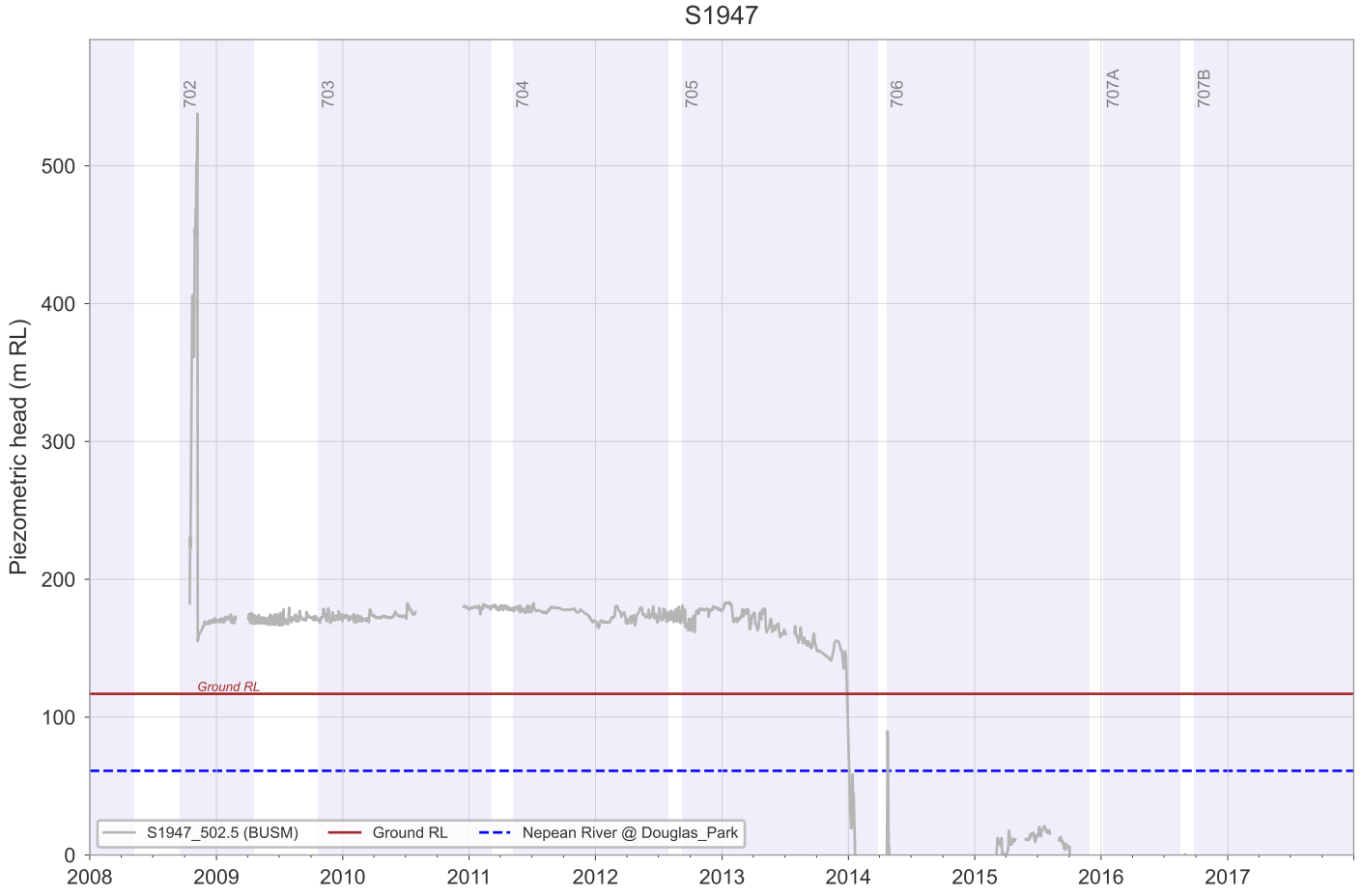

S1854
Piezometric head (m RL)
701
702
703
704
705
706
707A
707B
Ground RL
S1854_556 (BUSM)
Ground RL
Nepean River @ Douglas_Park
0
25
50
75
100
125
150
175
2006
2008
2010
2012
2014
2016
2018

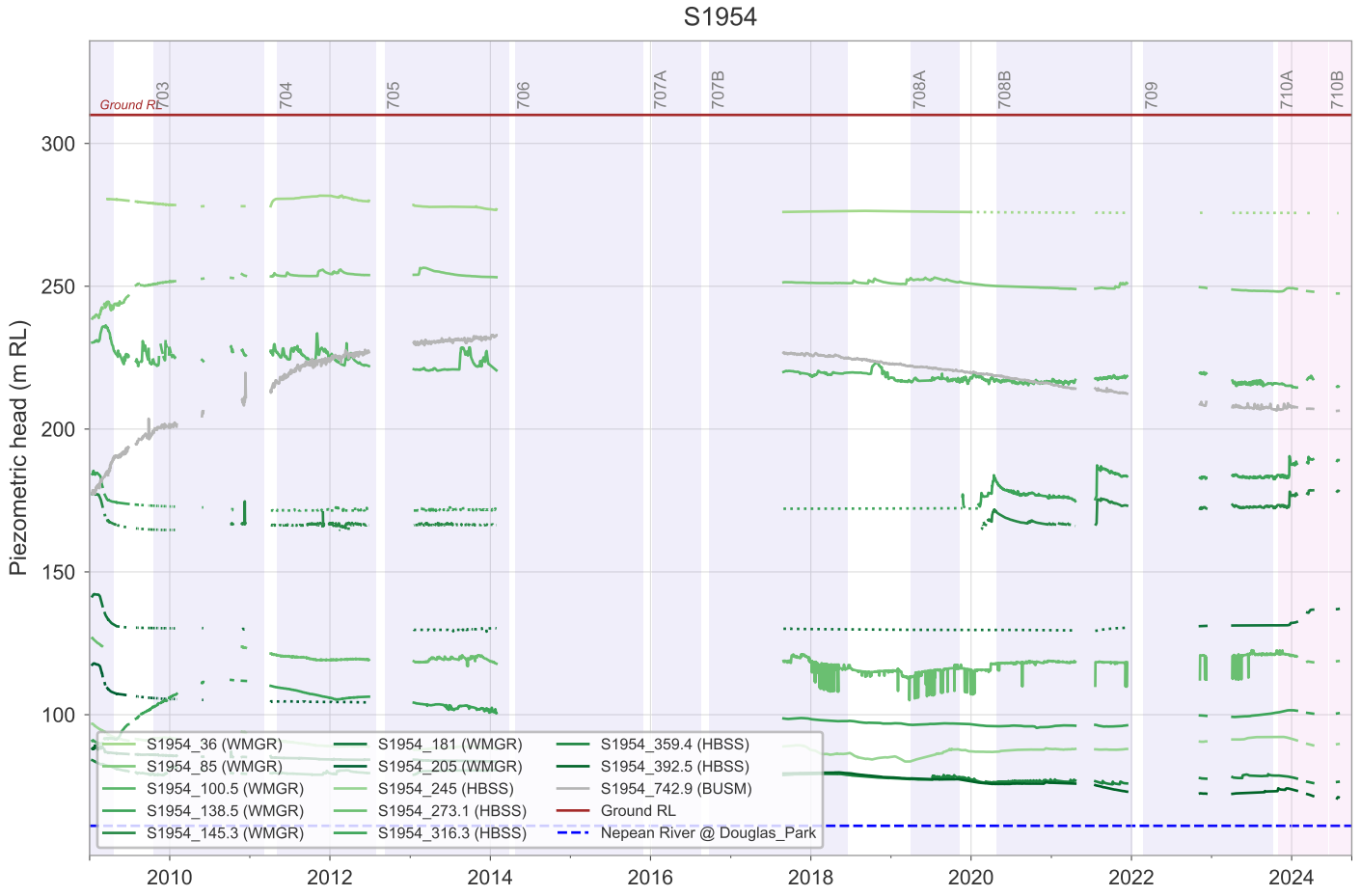

S1905
Piezometric head (m RL)
701
Ground RL
702
703
704
705
706
707A
707B
S1905_616.5 (BUSM)
Ground RL
Nepean River @ Douglas_Park
0
25
50
75
100
125
150
175
200
2008
2010
2012
2014
2016
2018

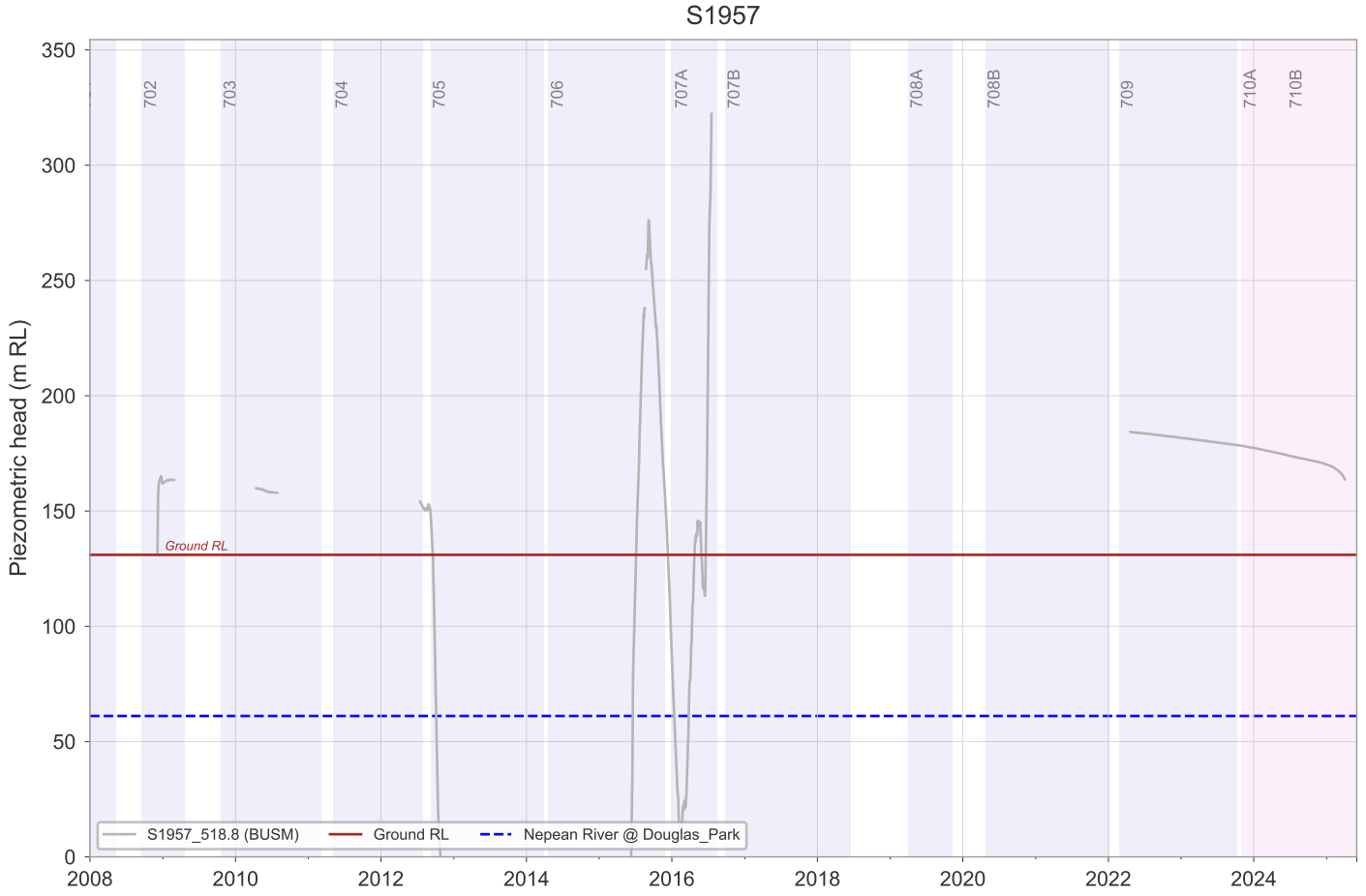

S1913
Piezometric head (m RL)
Ground RL
S1913_65 (HBSS)
S1913_137 (HBSS)
S1913_194 (HBSS)
S1913_274 (BGSS)
S1913_358 (BGSS)
S1913_447 (BGSS)
S1913_473 (SBSS)
S1913_486 (SBSS)
S1913_505 (SBSS)
S1913_559.5 (BUSM)
Ground RL
Nepean River @ Douglas_Park

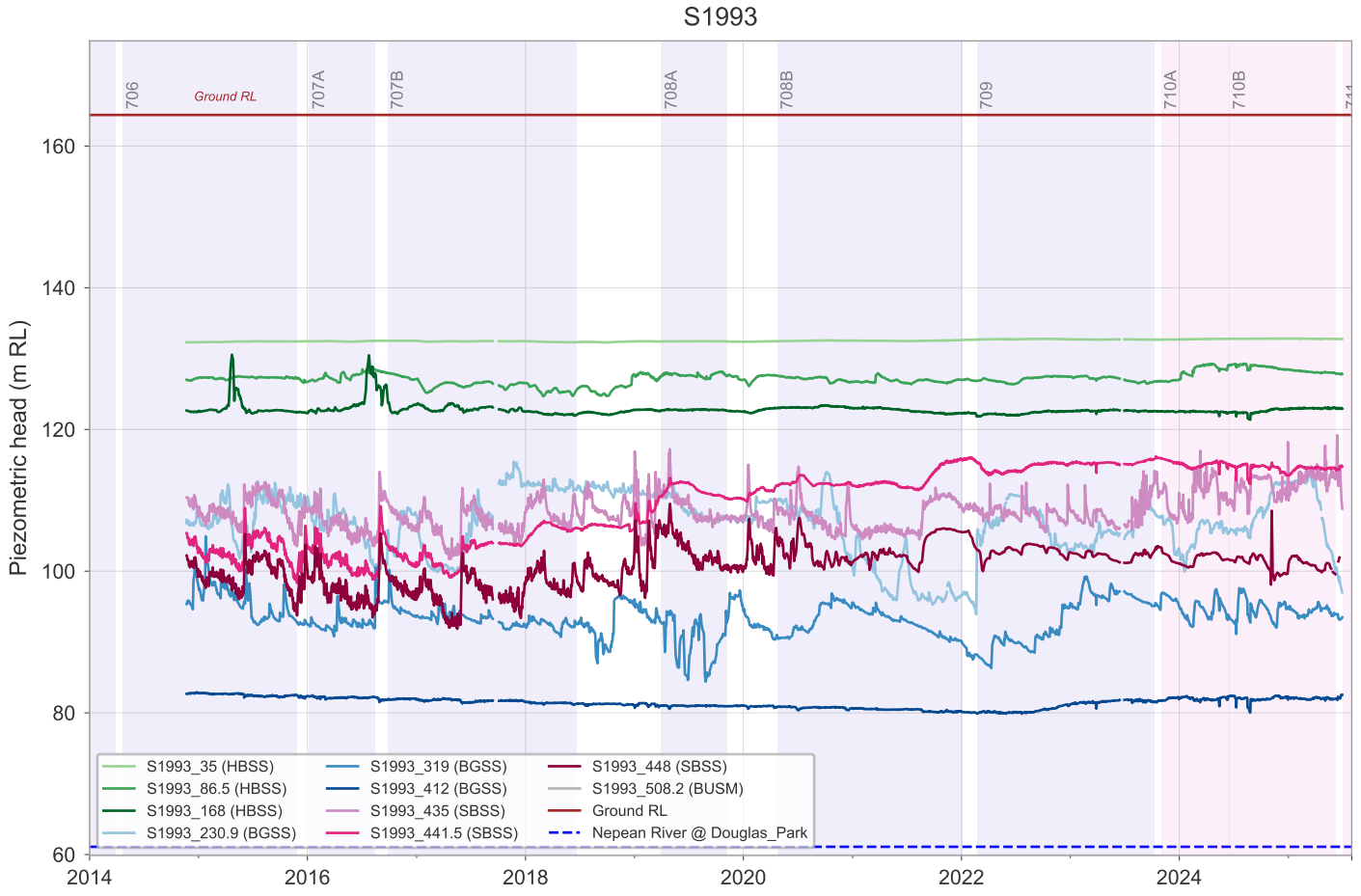

S1936
Piezometric head (m RL)
Ground RL
S1936_65 (HBSS)
S1936_123.8 (HBSS)
S1936_192 (HBSS)
S1936_278 (BGSS)
S1936_347.8 (BGSS)
S1936_422.5 (BGSS)
S1936_456.2 (SBSS)
S1936_462.1 (SBSS)
S1936_468 (SBSS)
Ground RL
Nepean River @ Douglas_Park

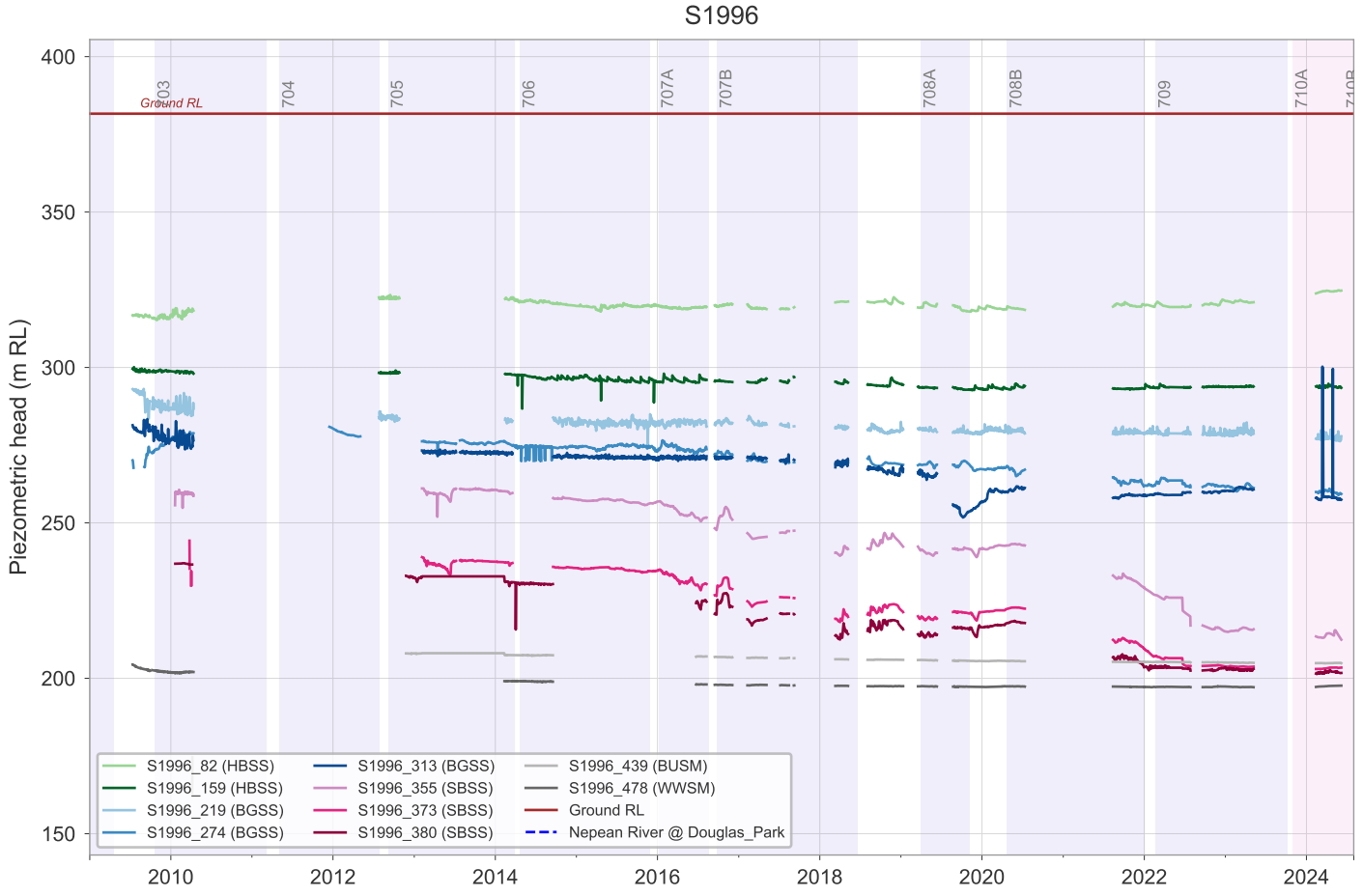

S1941
Piezometric head (m RL)
702
703
704
705
706
707A
707B
708A
708B
709
710A
710B
S1941_65 (HBSS)
S1941_126.5 (HBSS)
S1941_201.6 (HBSS)
S1941_284.3 (BGSS)
S1941_355.7 (BGSS)
S1941_432 (BGSS)
S1941_463 (SBSS)
S1941_472.8 (SBSS)
S1941_487.5 (SBSS)
S1941_555.4 (BUSM)
S1941_596 (WWSM)
Ground RL
Nepean River @ Douglas_Park

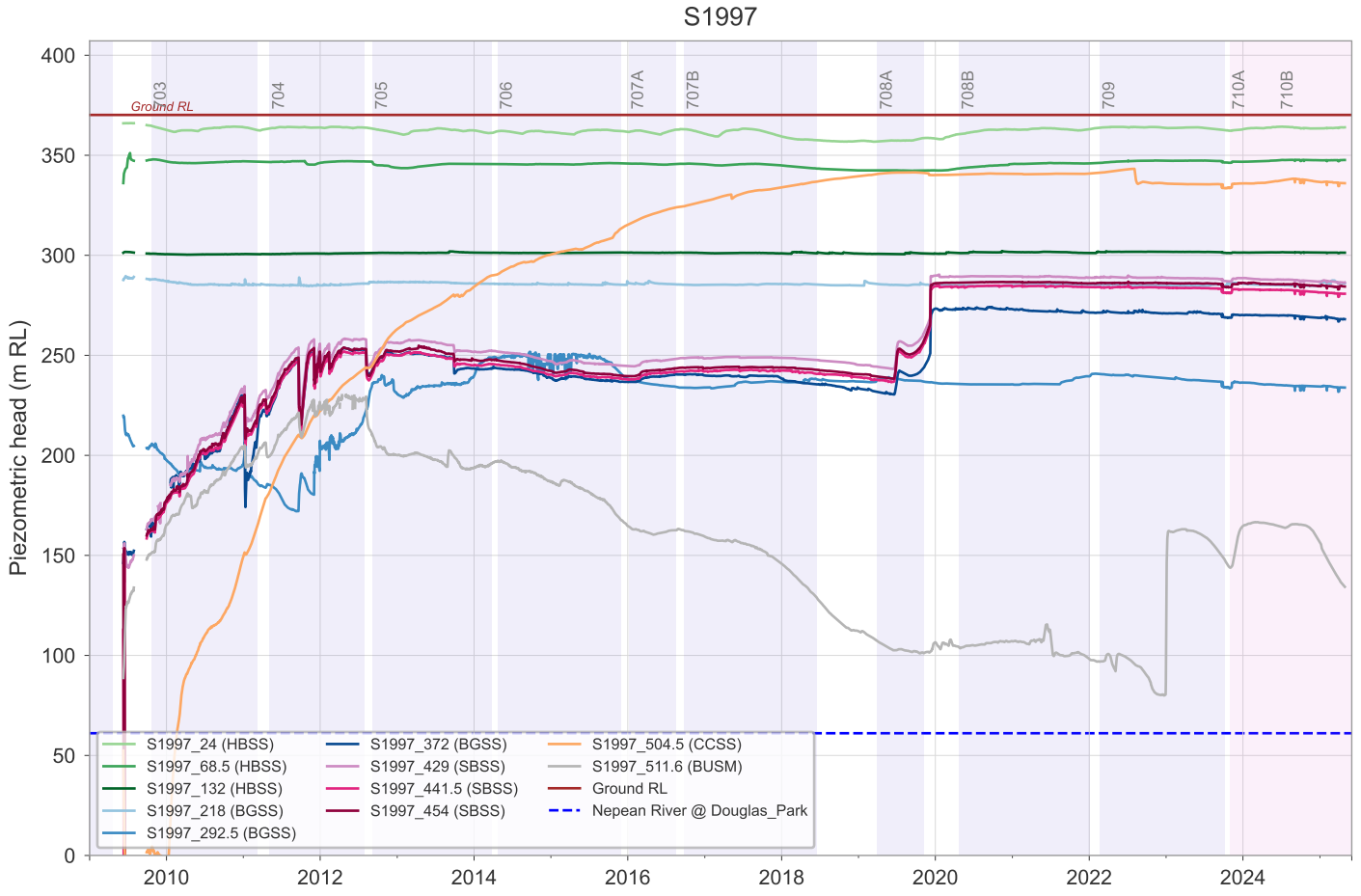

S1947
Piezometric head (m RL)
702
703
704
705
706
707A
707B
Ground RL
S1947_502.5 (BUSM)
Ground RL
Nepean River @ Douglas_Park


S1954
Ground RL
703
704
705
706
707A
707B
708A
708B
709
710A
710B
Piezometric head (m RL)
300
250
200
150
100
2010
2012
2014
2016
2018
2020
2022
2024
S1954_36 (WMGR)
S1954_85 (WMGR)
S1954_100.5 (WMGR)
S1954_138.5 (WMGR)
S1954_145.3 (WMGR)
S1954_181 (WMGR)
S1954_205 (WMGR)
S1954_245 (HBSS)
S1954_273.1 (HBSS)
S1954_316.3 (HBSS)
S1954_359.4 (HBSS)
S1954_392.5 (HBSS)
S1954_742.9 (BUSM)
Ground RL
Nepean River @ Douglas_Park

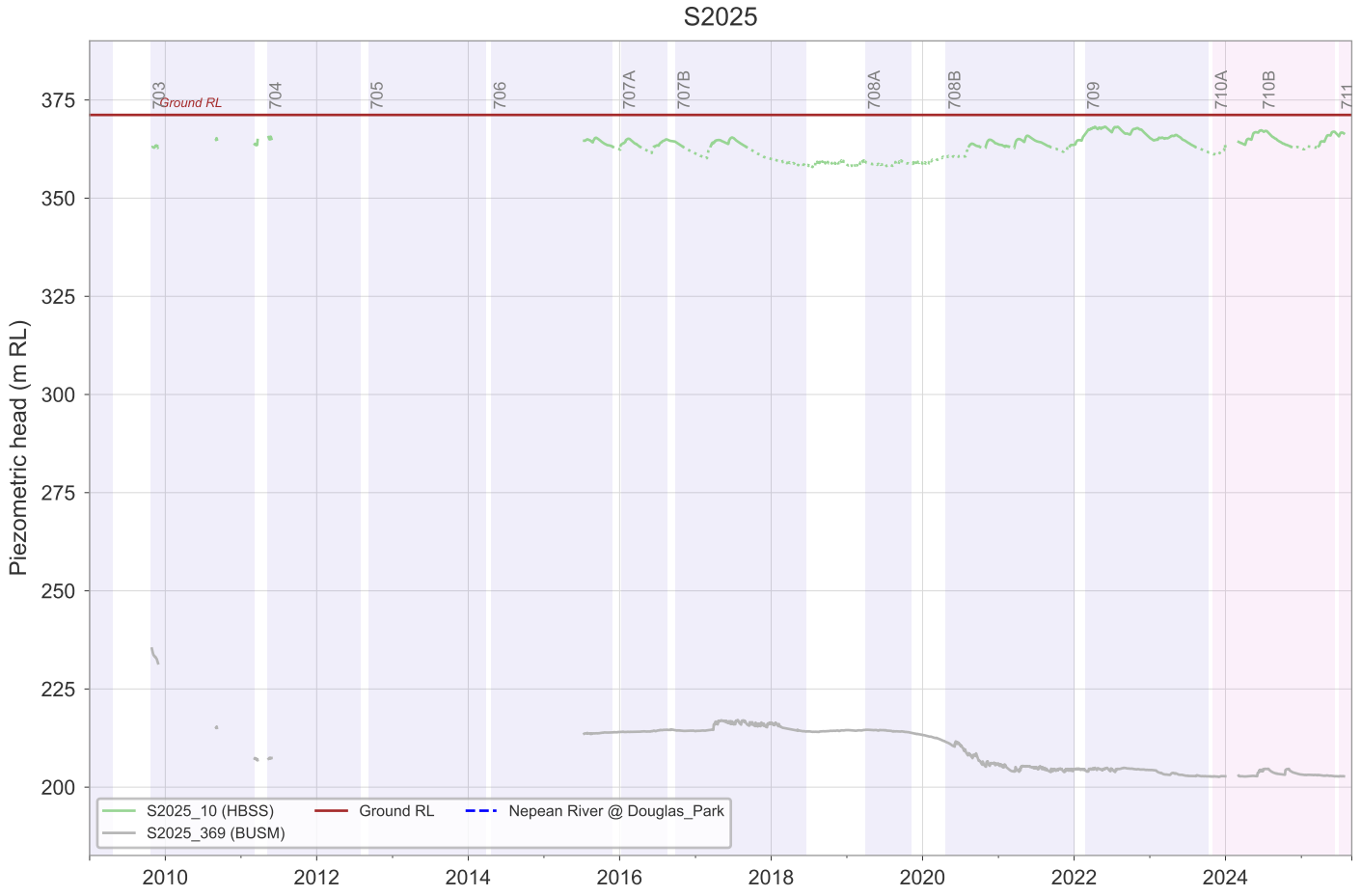

S1957
702
703
704
705
706
707A
707B
708A
708B
709
710A
710B
Piezometric head (m RL)
350
300
250
200
150
100
50
0
Ground RL
2008
2010
2012
2014
2016
2018
2020
2022
2024
S1957_518.8 (BUSM)
Ground RL
Nepean River @ Douglas_Park

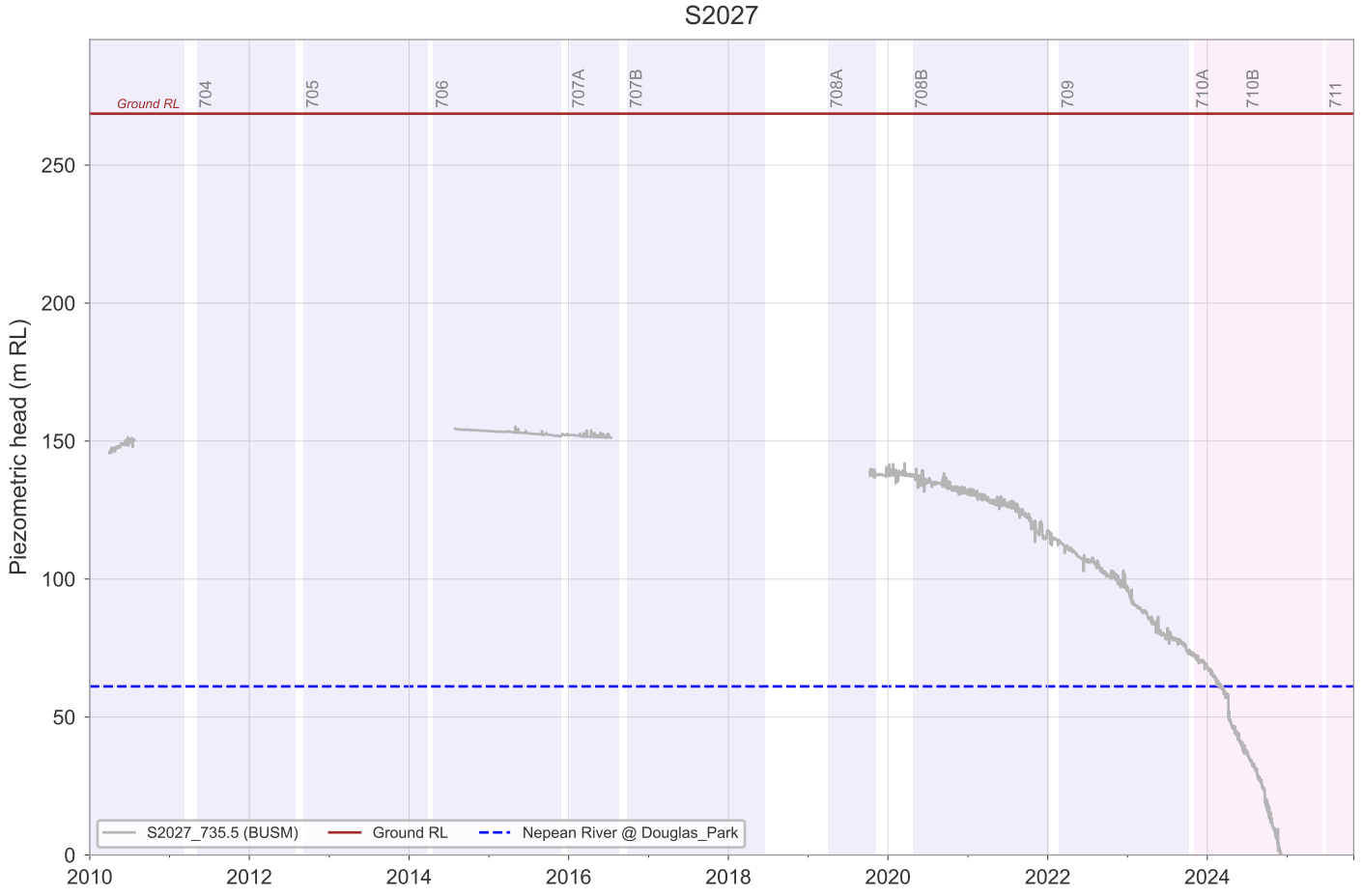

S1993
706
Ground RL
707A
707B
708A
708B
709
710A
710B
Piezometric head (m RL)
160
140
120
100
80
60
2014
2016
2018
2020
2022
2024
S1993_35 (HBSS)
S1993_86.5 (HBSS)
S1993_168 (HBSS)
S1993_230.9 (BGSS)
S1993_319 (BGSS)
S1993_412 (BGSS)
S1993_435 (SBSS)
S1993_441.5 (SBSS)
S1993_448 (SBSS)
S1993_508.2 (BUSM)
Ground RL
Nepean River @ Douglas_Park

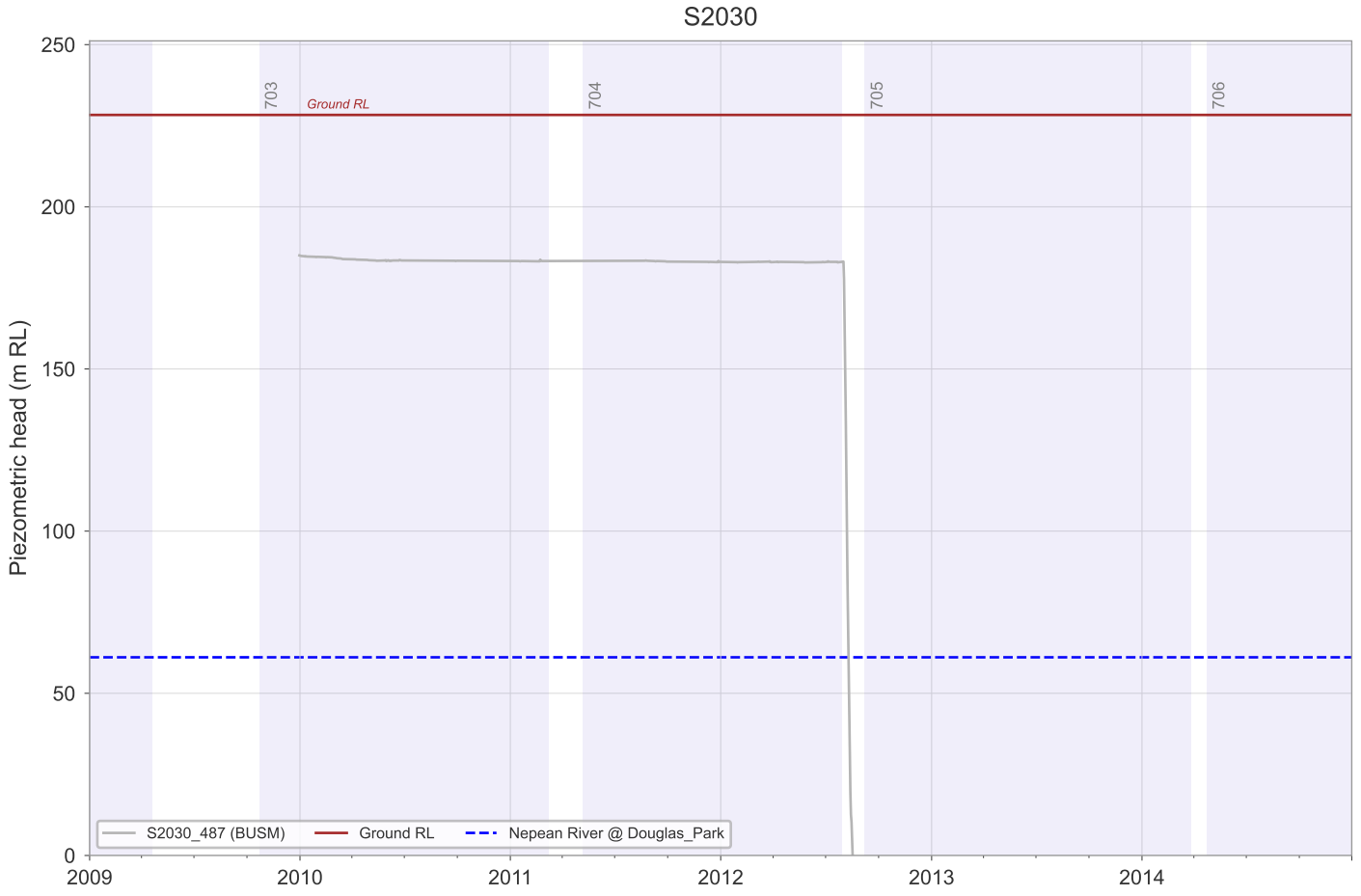

S1996
703
Ground RL
704
705
706
707A
707B
708A
708B
709
710A
Piezometric head (m RL)
400
350
300
250
200
150
2010
2012
2014
2016
2018
2020
2022
2024
S1996_82 (HBSS)
S1996_159 (HBSS)
S1996_219 (BGSS)
S1996_274 (BGSS)
S1996_313 (BGSS)
S1996_355 (SBSS)
S1996_373 (SBSS)
S1996_380 (SBSS)
S1996_439 (BUSM)
S1996_478 (WWSM)
Ground RL
Nepean River @ Douglas_Park

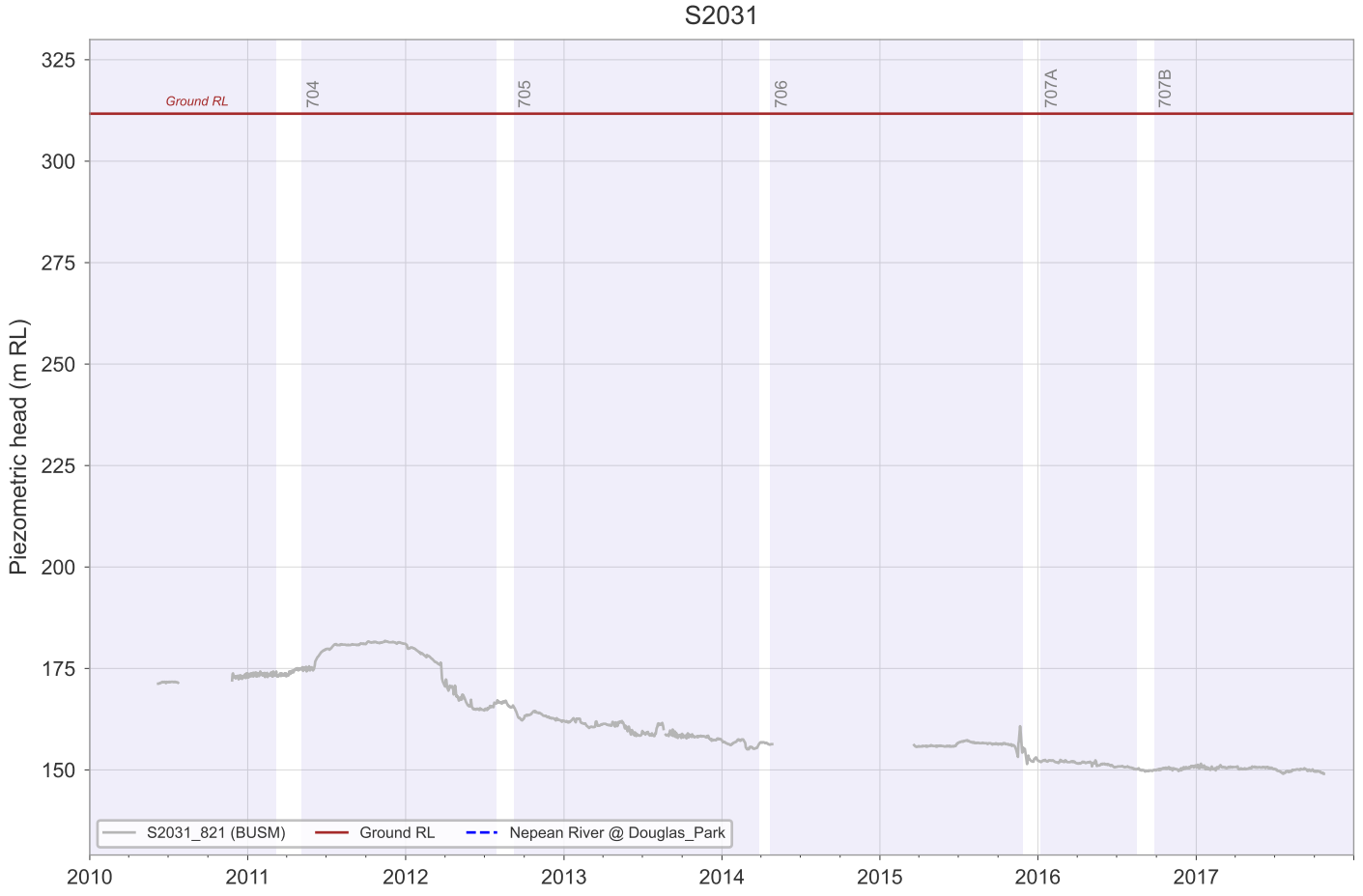

S1997
Piezometric head (m RL)
Ground RL
703
704
705
706
707A
707B
708A
708B
709
710A
710B
S1997_24 (HBSS)
S1997_68.5 (HBSS)
S1997_132 (HBSS)
S1997_218 (BGSS)
S1997_292.5 (BGSS)
S1997_372 (BGSS)
S1997_429 (SBSS)
S1997_441.5 (SBSS)
S1997_454 (SBSS)
S1997_504.5 (CCSS)
S1997_511.6 (BUSM)
Ground RL
Nepean River @ Douglas_Park

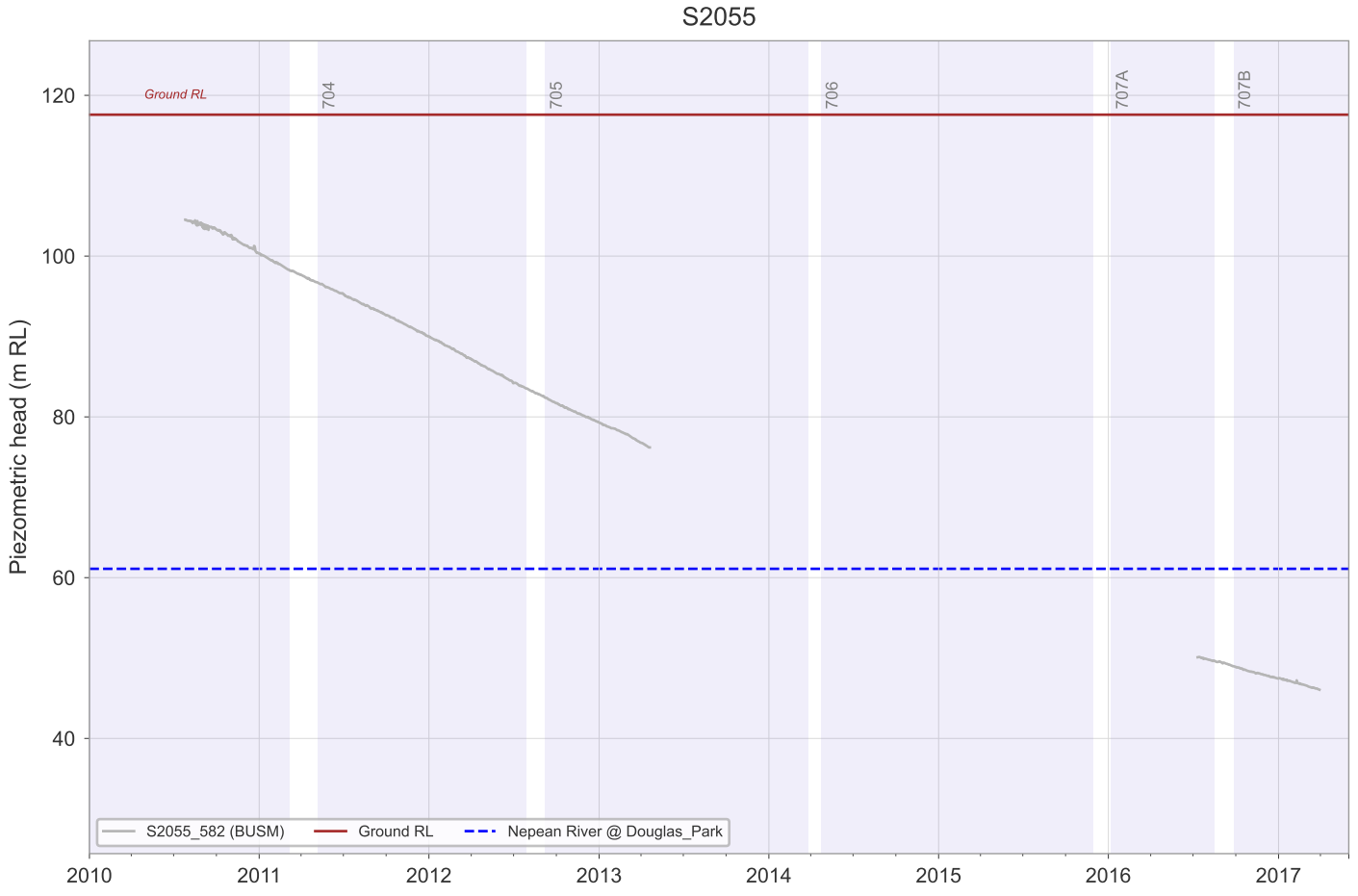

S2022
Piezometric head (m RL)
Ground RL
704
705
706
707A
707B
708A
S2022_703.5 (BUSM)
Ground RL
Nepean River @ Douglas_Park

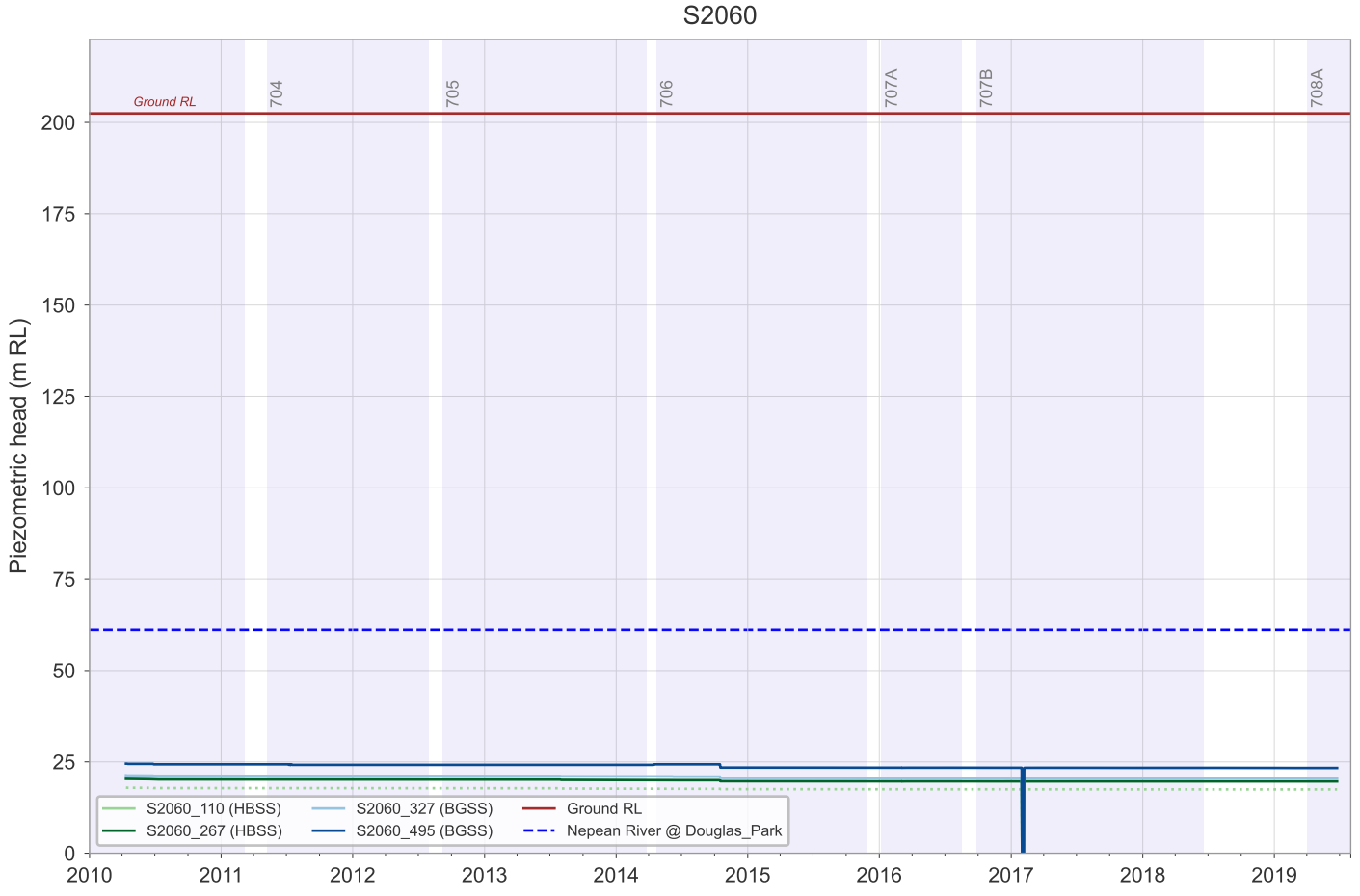

S2025
Piezometric head (m RL)
375
350
325
300
275
250
225
200
703
704
705
706
707A
707B
708A
708B
709
710A
710B
711
Ground RL
S2025_10 (HBSS)
S2025_369 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2010
2012
2014
2016
2018
2020
2022
2024

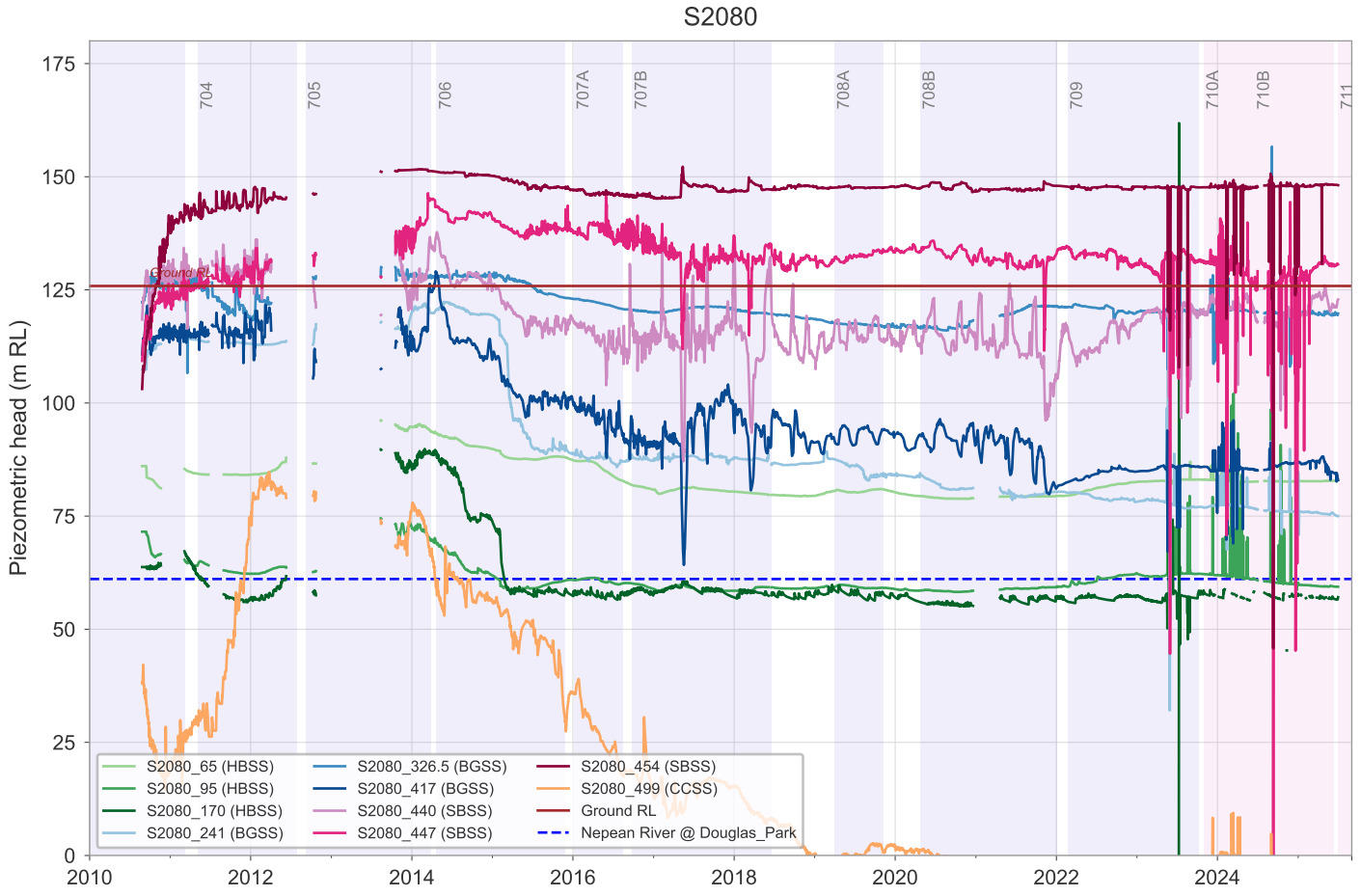

S2027
Piezometric head (m RL)
250
200
150
100
50
0
Ground RL
704
705
706
707A
707B
708A
708B
709
710A
710B
711
S2027_735.5 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2010
2012
2014
2016
2018
2020
2022
2024

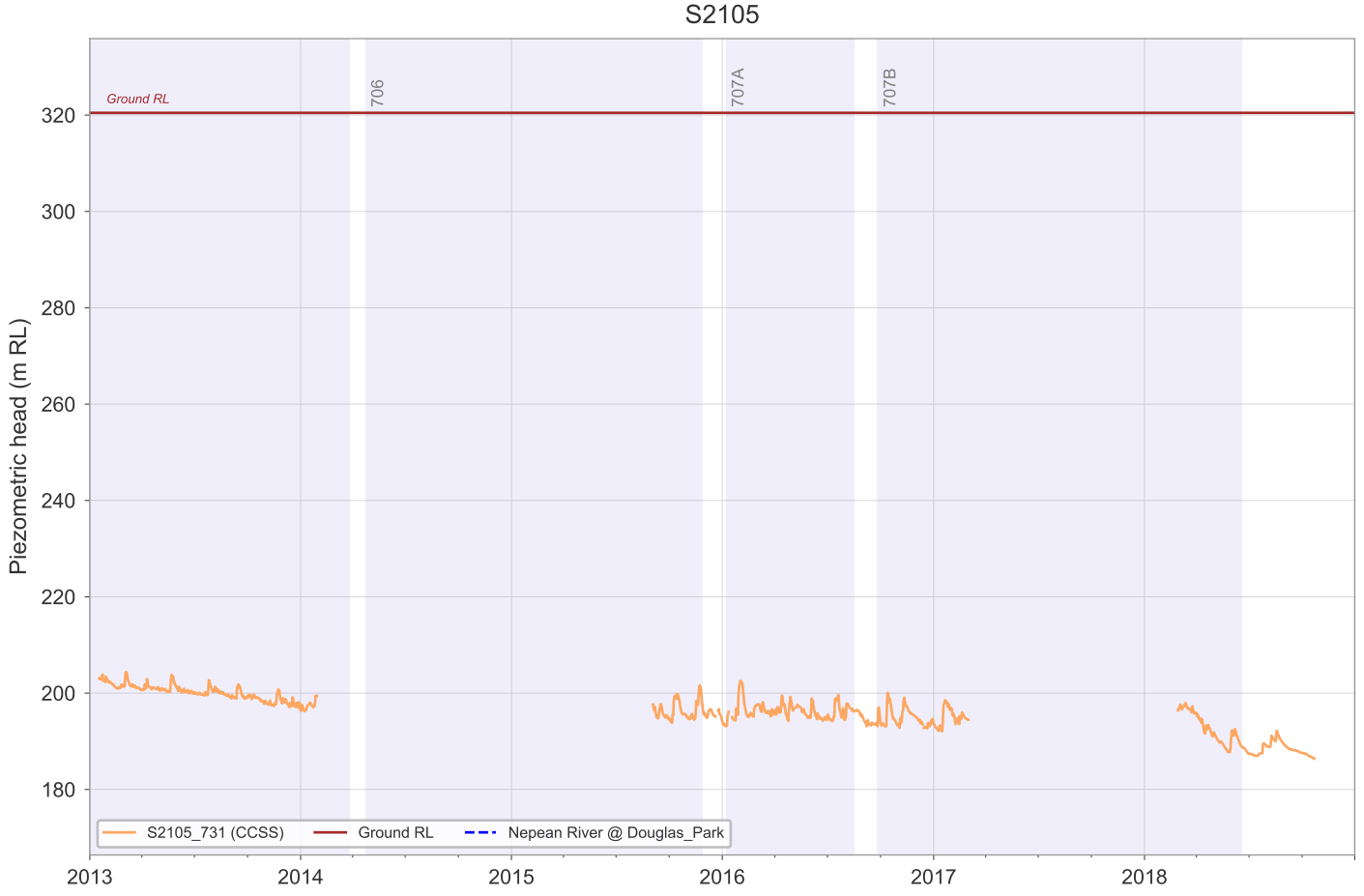

S2030
Piezometric head (m RL)
250
200
150
100
50
0
703
704
705
706
Ground RL
S2030_487 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2009
2010
2011
2012
2013
2014

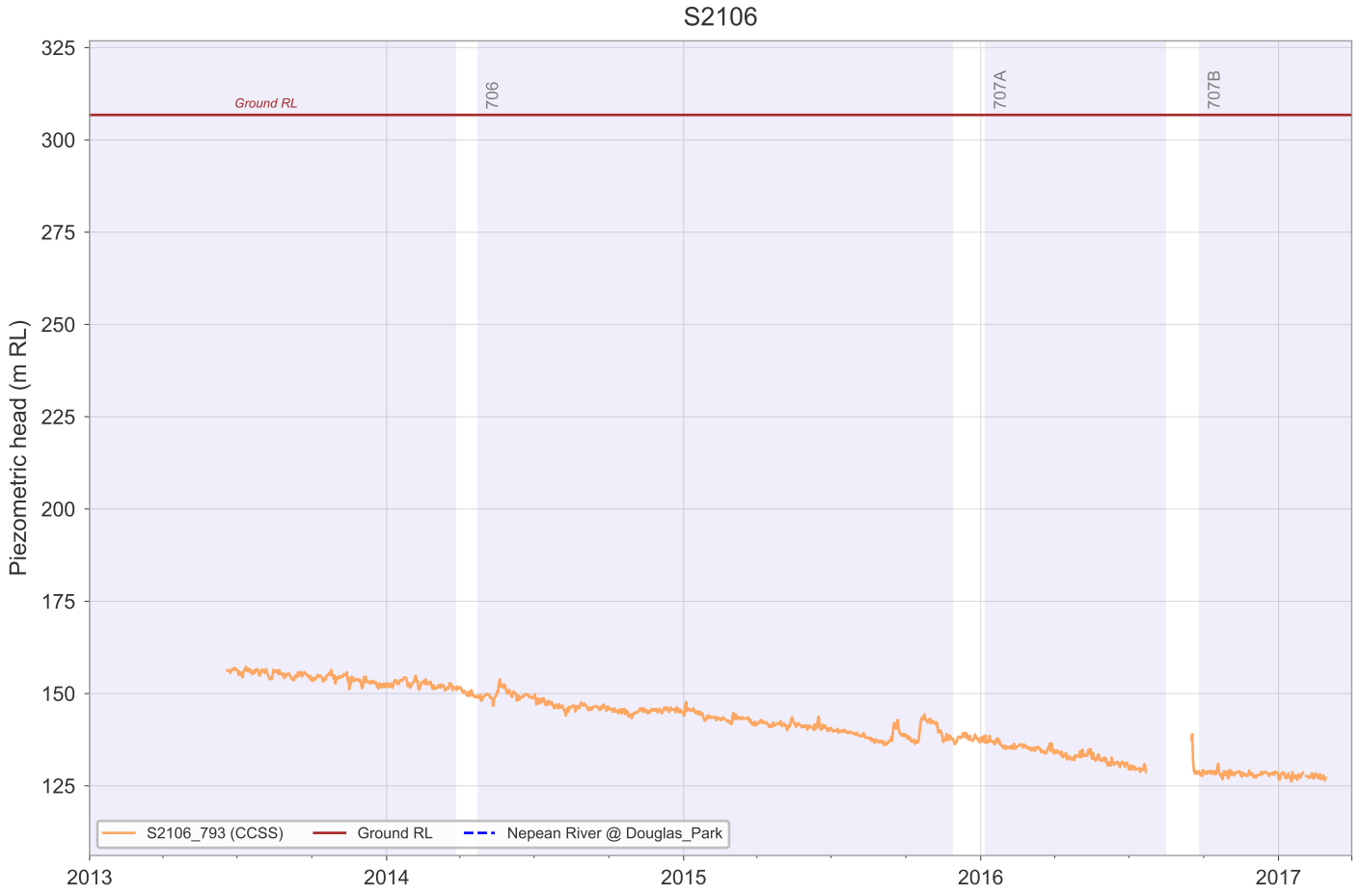

S2031
Piezometric head (m RL)
325
300
275
250
225
200
175
150
Ground RL
704
705
706
707A
707B
S2031_821 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2010
2011
2012
2013
2014
2015
2016
2017

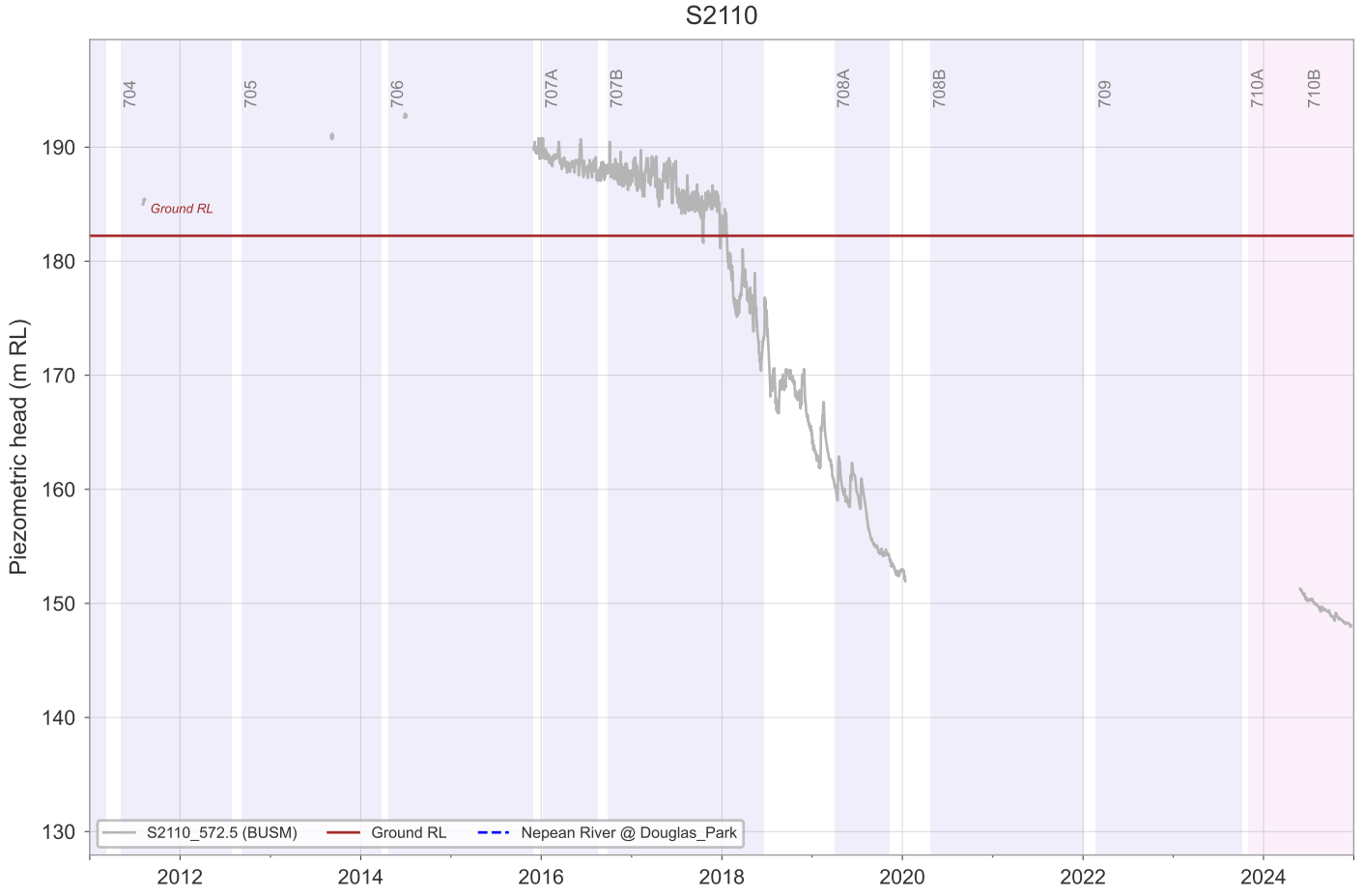

S2055
Ground RL
704
705
706
707A
707B
120
100
80
60
40
Piezometric head (m RL)
S2055_582 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2010
2011
2012
2013
2014
2015
2016
2017

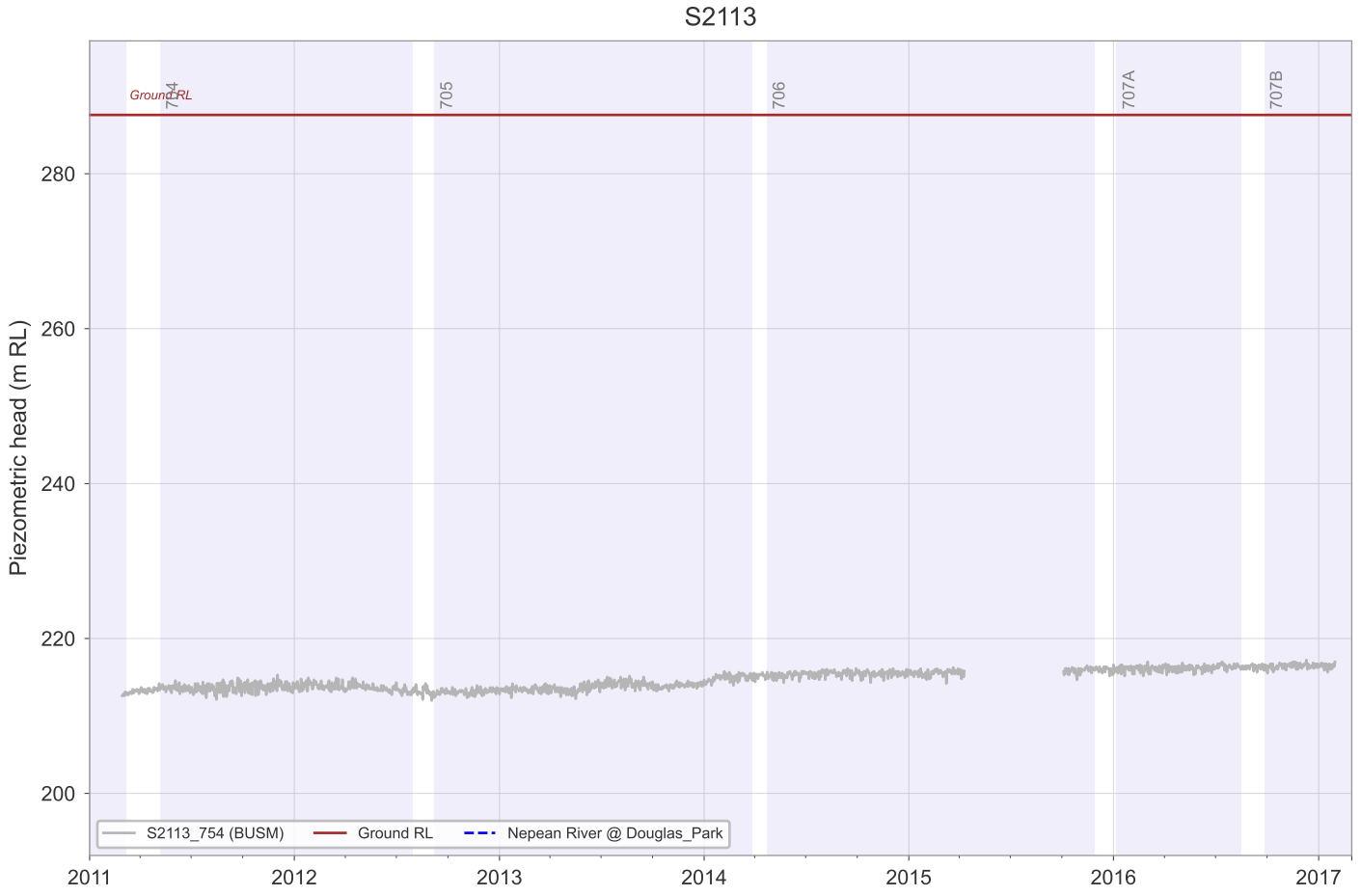

S2060
Ground RL
704
705
706
707A
707B
708A
200
175
150
125
100
75
50
25
0
Piezometric head (m RL)
S2060_110 (HBSS)
S2060_267 (HBSS)
S2060_327 (BGSS)
S2060_495 (BGSS)
Ground RL
Nepean River @ Douglas_Park
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

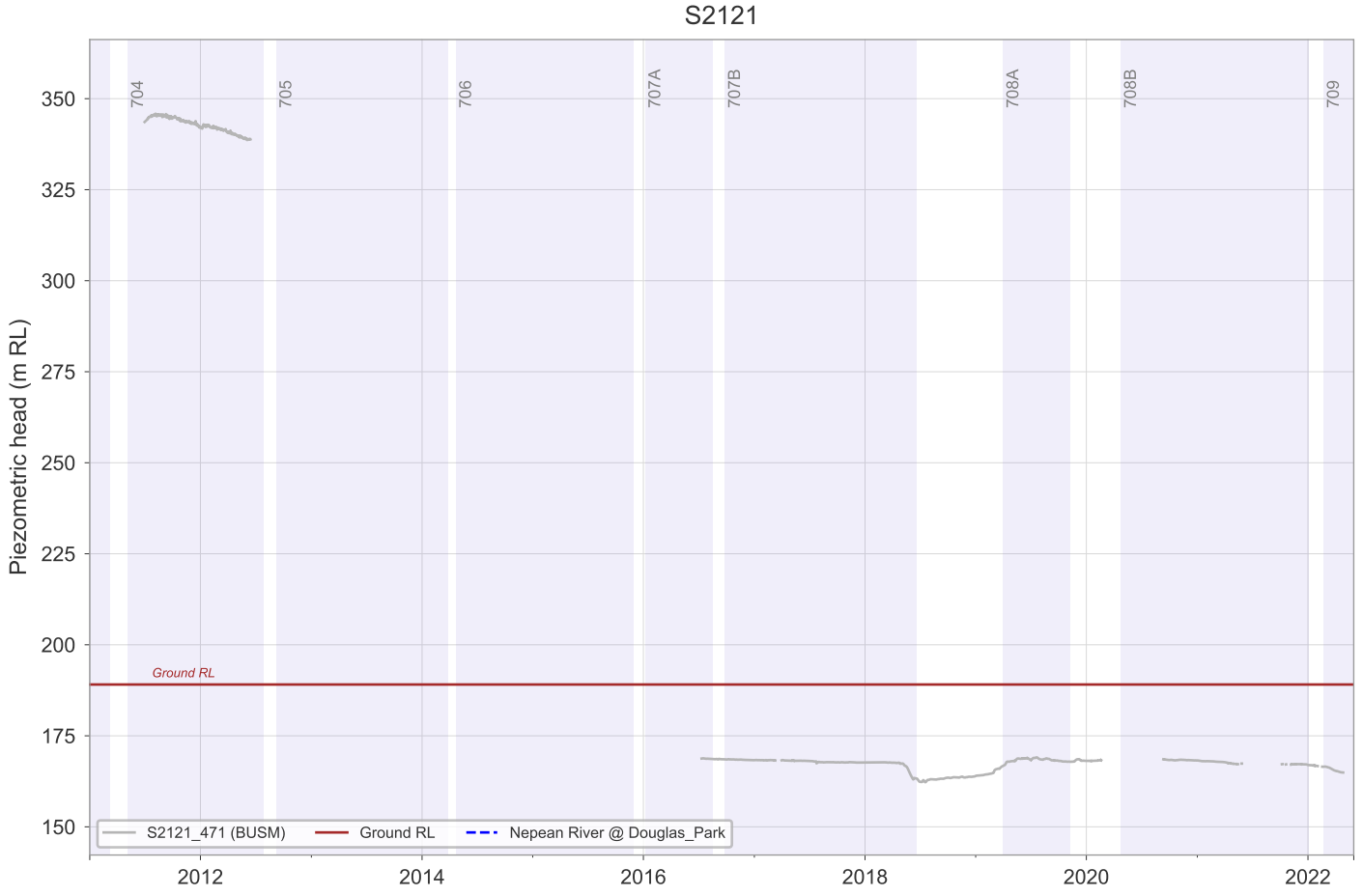

S2080
Piezometric head (m RL)
704
705
706
707A
707B
708A
708B
709
710A
710B
711
Ground RL
S2080_65 (HBSS)
S2080_95 (HBSS)
S2080_170 (HBSS)
S2080_241 (BGSS)
S2080_326.5 (BGSS)
S2080_417 (BGSS)
S2080_440 (SBSS)
S2080_447 (SBSS)
S2080_454 (SBSS)
S2080_499 (CCSS)
Ground RL
Nepean River @ Douglas_Park

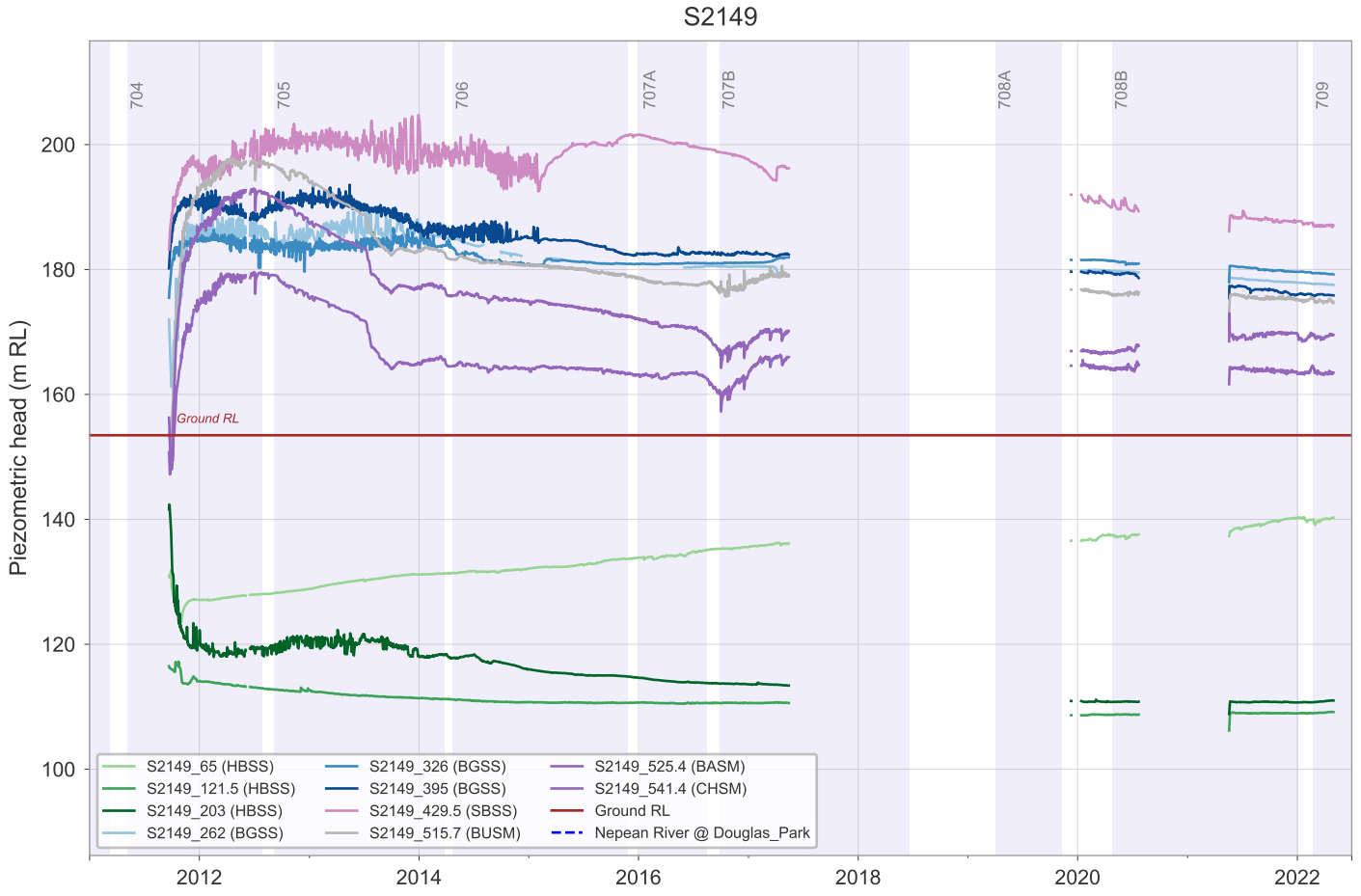

S2105
Piezometric head (m RL)
Ground RL
706
707A
707B
S2105_731 (CCSS)
Ground RL
Nepean River @ Douglas_Park

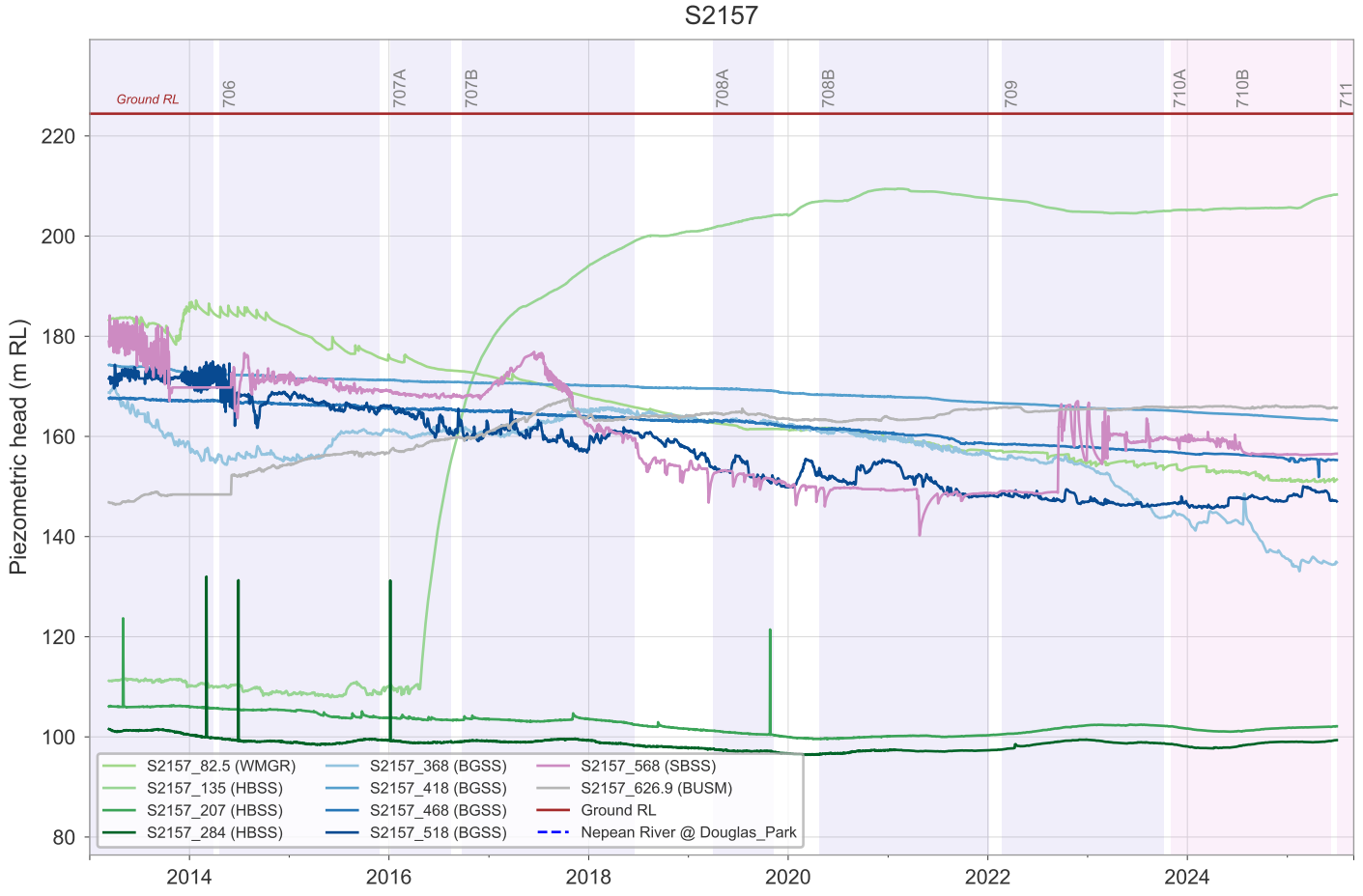

S2106
Piezometric head (m RL)
325
300
275
250
225
200
175
150
125
Ground RL
706
707A
707B
S2106_793 (CCSS)
Ground RL
Nepean River @ Douglas_Park
2013
2014
2015
2016
2017

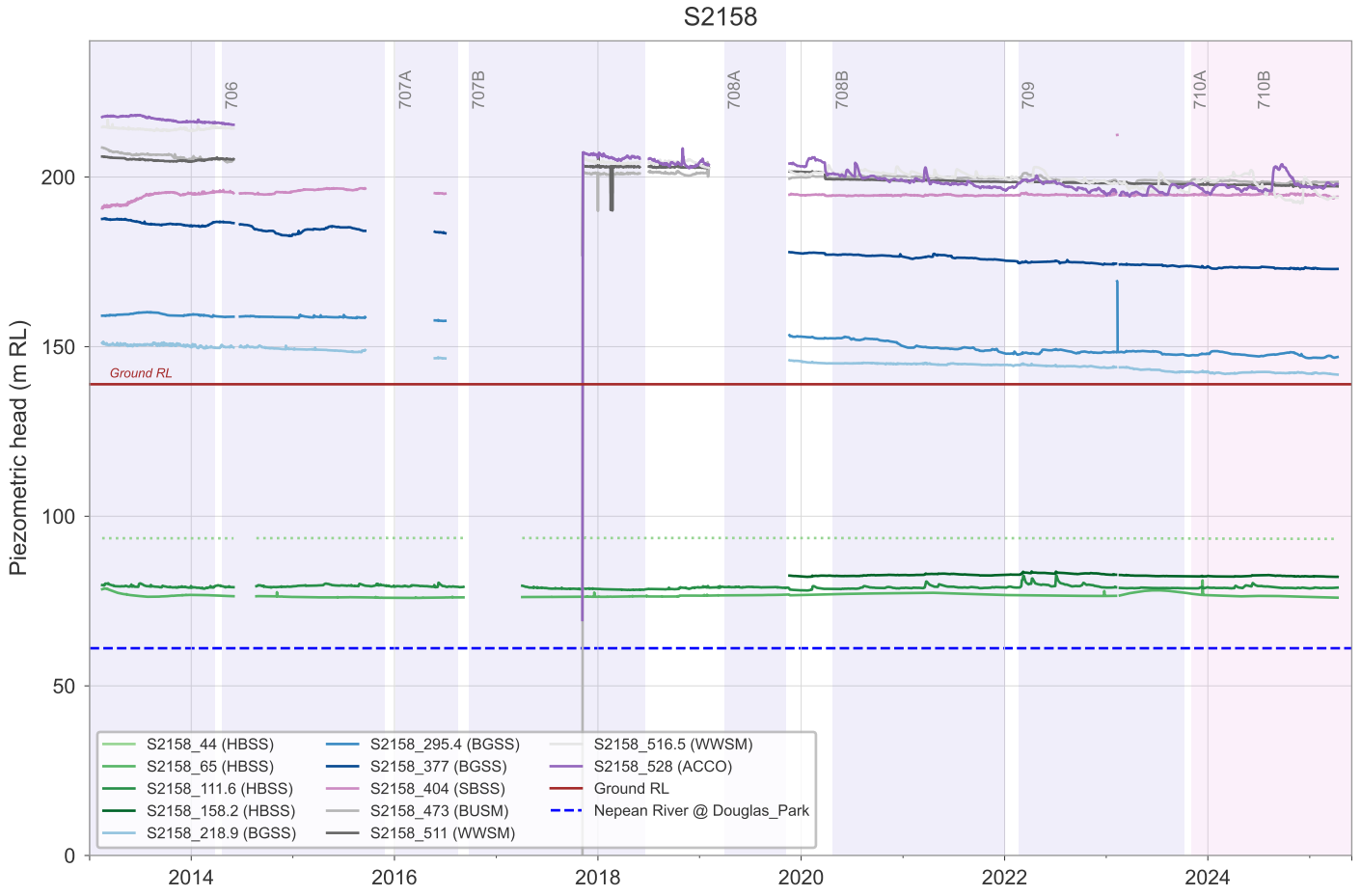

S2110
Piezometric head (m RL)
190
180
170
160
150
140
130
704
705
706
707A
707B
708A
708B
709
710A
710B
Ground RL
S2110_572.5 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2012
2014
2016
2018
2020
2022
2024

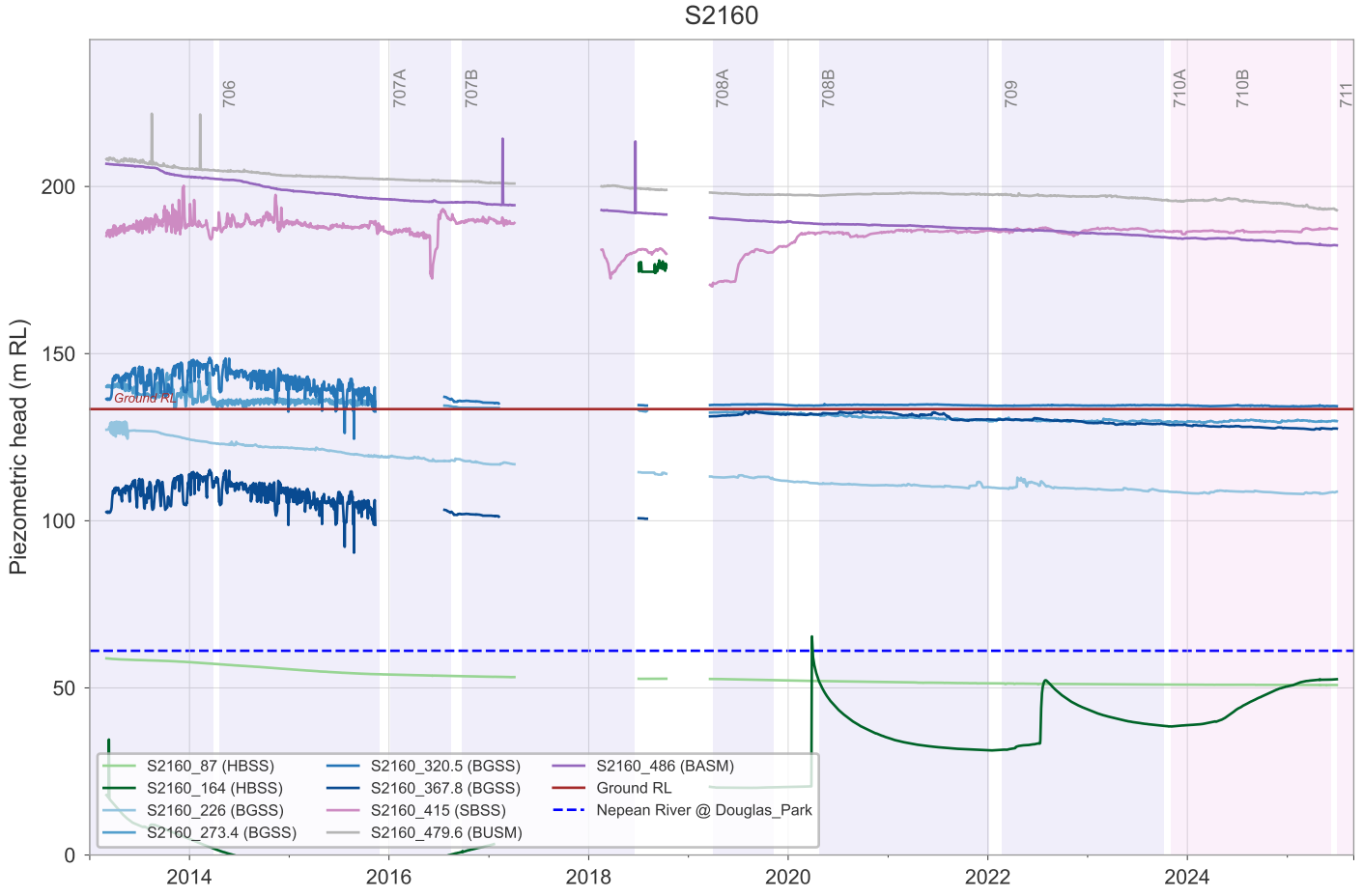

S2113
Ground RL
704
705
706
707A
707B
Piezometric head (m RL)
280
260
240
220
200
2011
2012
2013
2014
2015
2016
2017
S2113_754 (BUSM)
Ground RL
Nepean River @ Douglas_Park

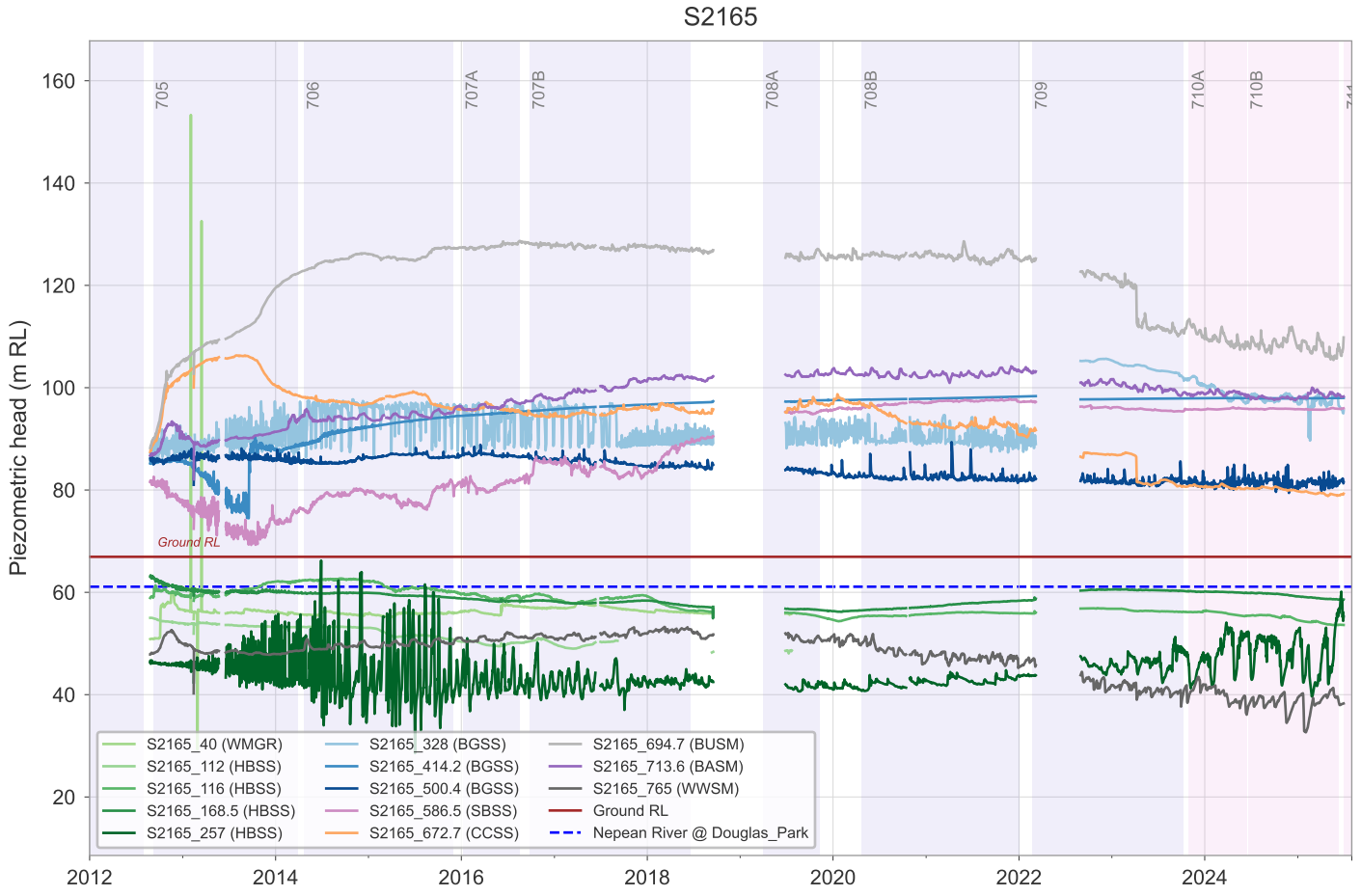

S2121
704
705
706
707A
707B
708A
708B
709
Piezometric head (m RL)
350
325
300
275
250
225
200
175
150
Ground RL
2012
2014
2016
2018
2020
2022
S2121_471 (BUSM)
Ground RL
Nepean River @ Douglas_Park

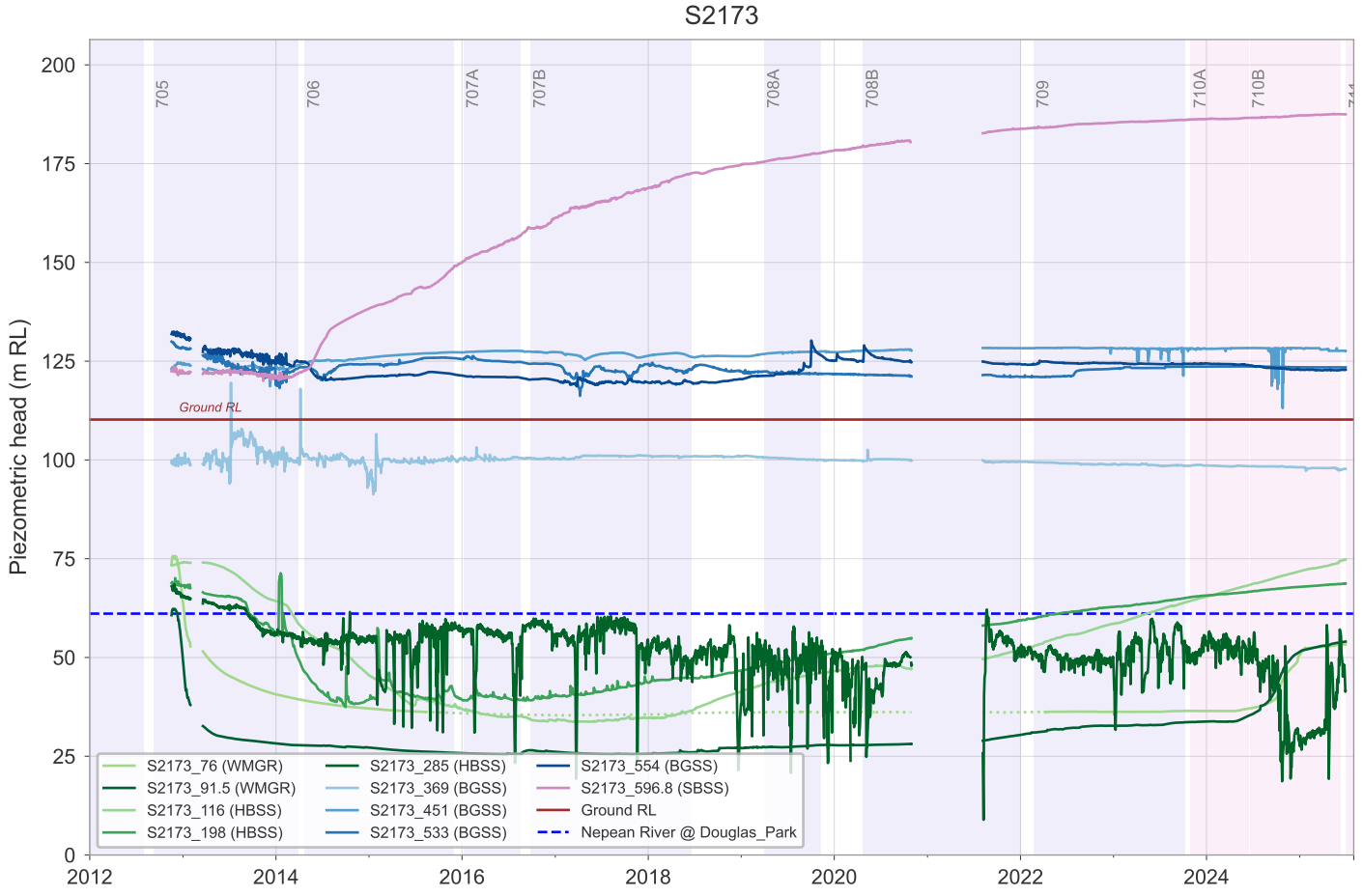

S2149
704
705
706
707A
707B
708A
708B
709
Ground RL
Piezometric head (m RL)
200
180
160
140
120
100
2012
2014
2016
2018
2020
2022
S2149_65 (HBSS)
S2149_121.5 (HBSS)
S2149_203 (HBSS)
S2149_262 (BGSS)
S2149_326 (BGSS)
S2149_395 (BGSS)
S2149_429.5 (SBSS)
S2149_515.7 (BUSM)
S2149_525.4 (BASM)
S2149_541.4 (CHSM)
Ground RL
Nepean River @ Douglas_Park

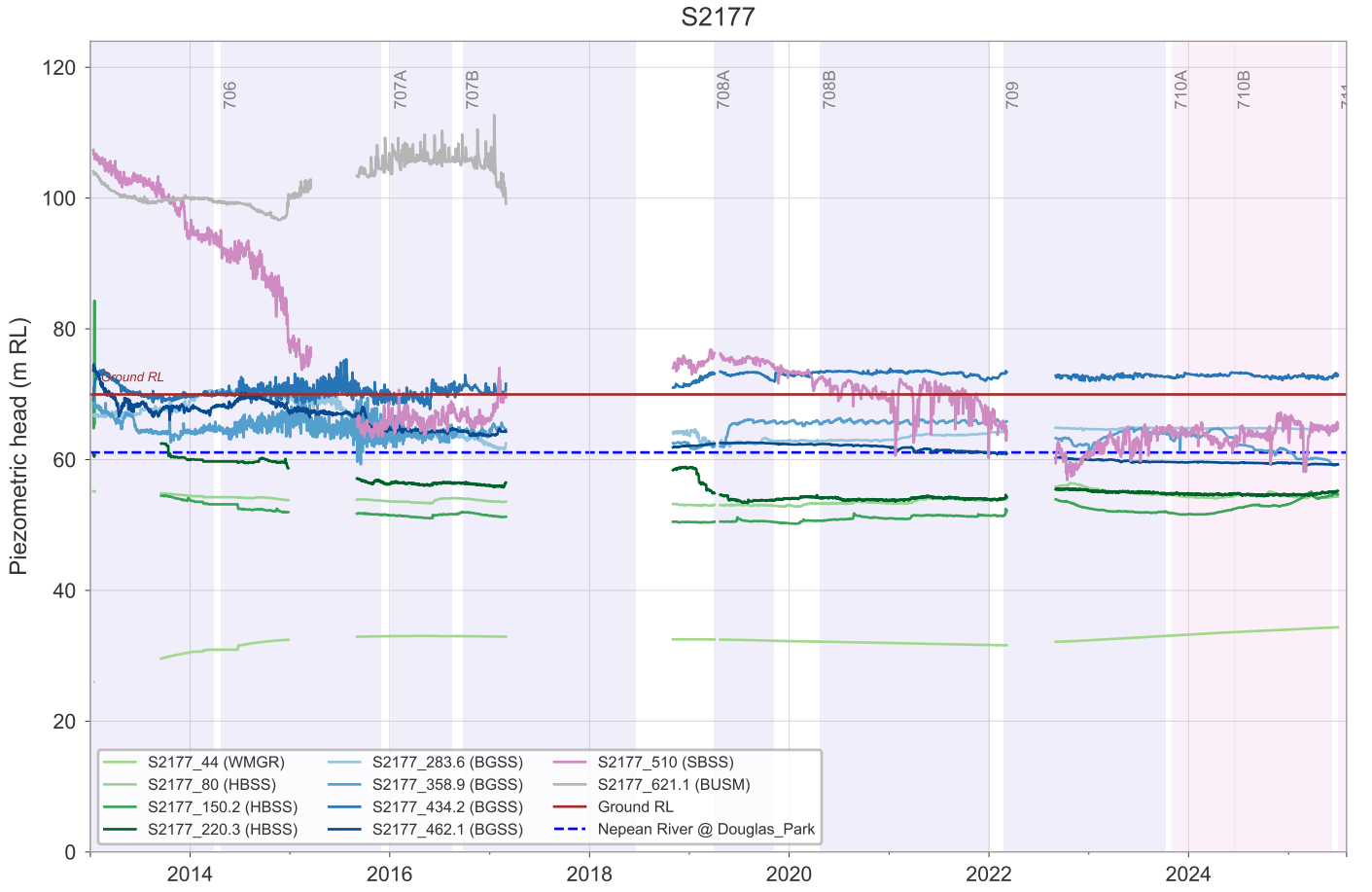

S2157
Ground RL
706
707A
707B
708A
708B
709
710A
710B
711
Piezometric head (m RL)
220
200
180
160
140
120
100
80
2014
2016
2018
2020
2022
2024
S2157_82.5 (WMGR)
S2157_135 (HBSS)
S2157_207 (HBSS)
S2157_284 (HBSS)
S2157_368 (BGSS)
S2157_418 (BGSS)
S2157_468 (BGSS)
S2157_518 (BGSS)
S2157_568 (SBSS)
S2157_626.9 (BUSM)
Ground RL
Nepean River @ Douglas_Park


S2158
706
707A
707B
708A
708B
709
710A
710B
Ground RL
Piezometric head (m RL)
0
50
100
150
200
2014
2016
2018
2020
2022
2024
S2158_44 (HBSS)
S2158_65 (HBSS)
S2158_111.6 (HBSS)
S2158_158.2 (HBSS)
S2158_218.9 (BGSS)
S2158_295.4 (BGSS)
S2158_377 (BGSS)
S2158_404 (SBSS)
S2158_473 (BUSM)
S2158_511 (WWSM)
S2158_516.5 (WWSM)
S2158_528 (ACCO)
Ground RL
Nepean River @ Douglas_Park

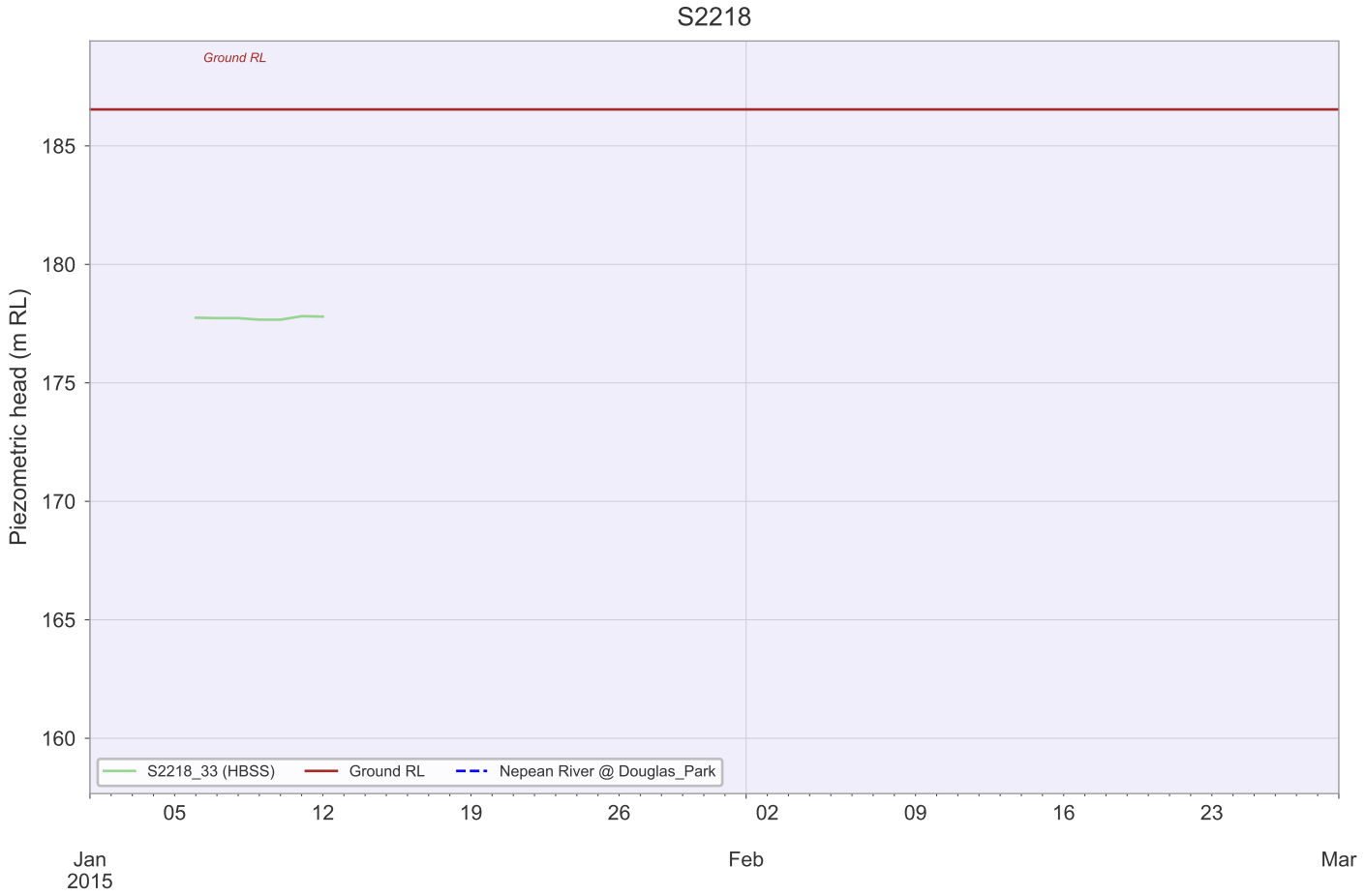

S2160
706
707A
707B
708A
708B
709
710A
710B
711
Ground RL
Piezometric head (m RL)
0
50
100
150
200
2014
2016
2018
2020
2022
2024
S2160_87 (HBSS)
S2160_164 (HBSS)
S2160_226 (BGSS)
S2160_273.4 (BGSS)
S2160_320.5 (BGSS)
S2160_367.8 (BGSS)
S2160_415 (SBSS)
S2160_479.6 (BUSM)
S2160_486 (BASM)
Ground RL
Nepean River @ Douglas_Park


S2165
Piezometric head (m RL)
705
706
707A
707B
708A
708B
709
710A
710B
Ground RL
S2165_40 (WMGR)
S2165_112 (HBSS)
S2165_116 (HBSS)
S2165_168.5 (HBSS)
S2165_257 (HBSS)
S2165_328 (BGSS)
S2165_414.2 (BGSS)
S2165_500.4 (BGSS)
S2165_586.5 (SBSS)
S2165_672.7 (CCSS)
S2165_694.7 (BUSM)
S2165_713.6 (BASM)
S2165_765 (WWSM)
Ground RL
Nepean River @ Douglas_Park

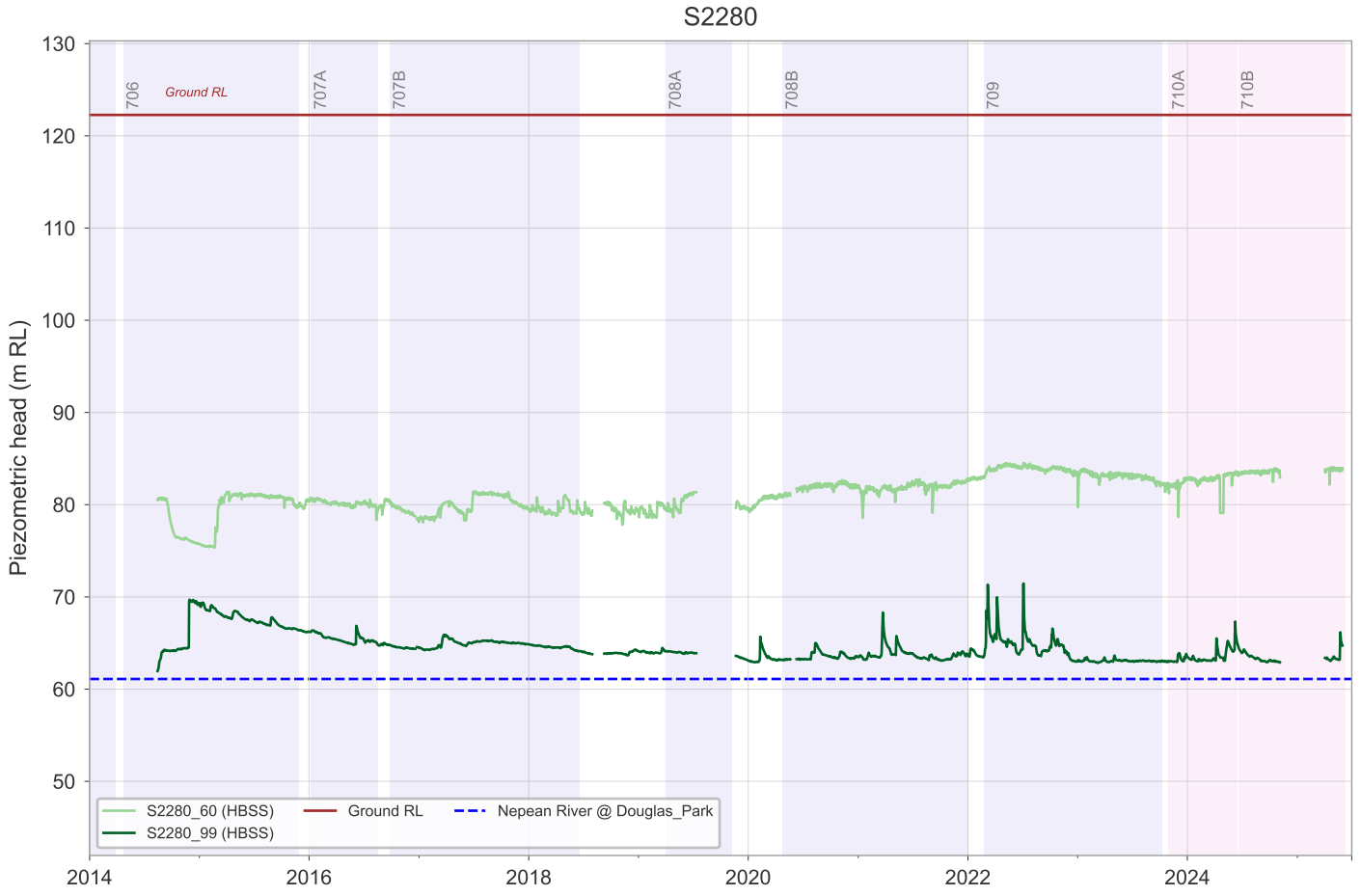

S2173
Piezometric head (m RL)
705
706
707A
707B
708A
708B
709
710A
710B
Ground RL
S2173_76 (WMGR)
S2173_91.5 (WMGR)
S2173_116 (HBSS)
S2173_198 (HBSS)
S2173_285 (HBSS)
S2173_369 (BGSS)
S2173_451 (BGSS)
S2173_533 (BGSS)
S2173_554 (BGSS)
S2173_596.8 (SBSS)
Ground RL
Nepean River @ Douglas_Park

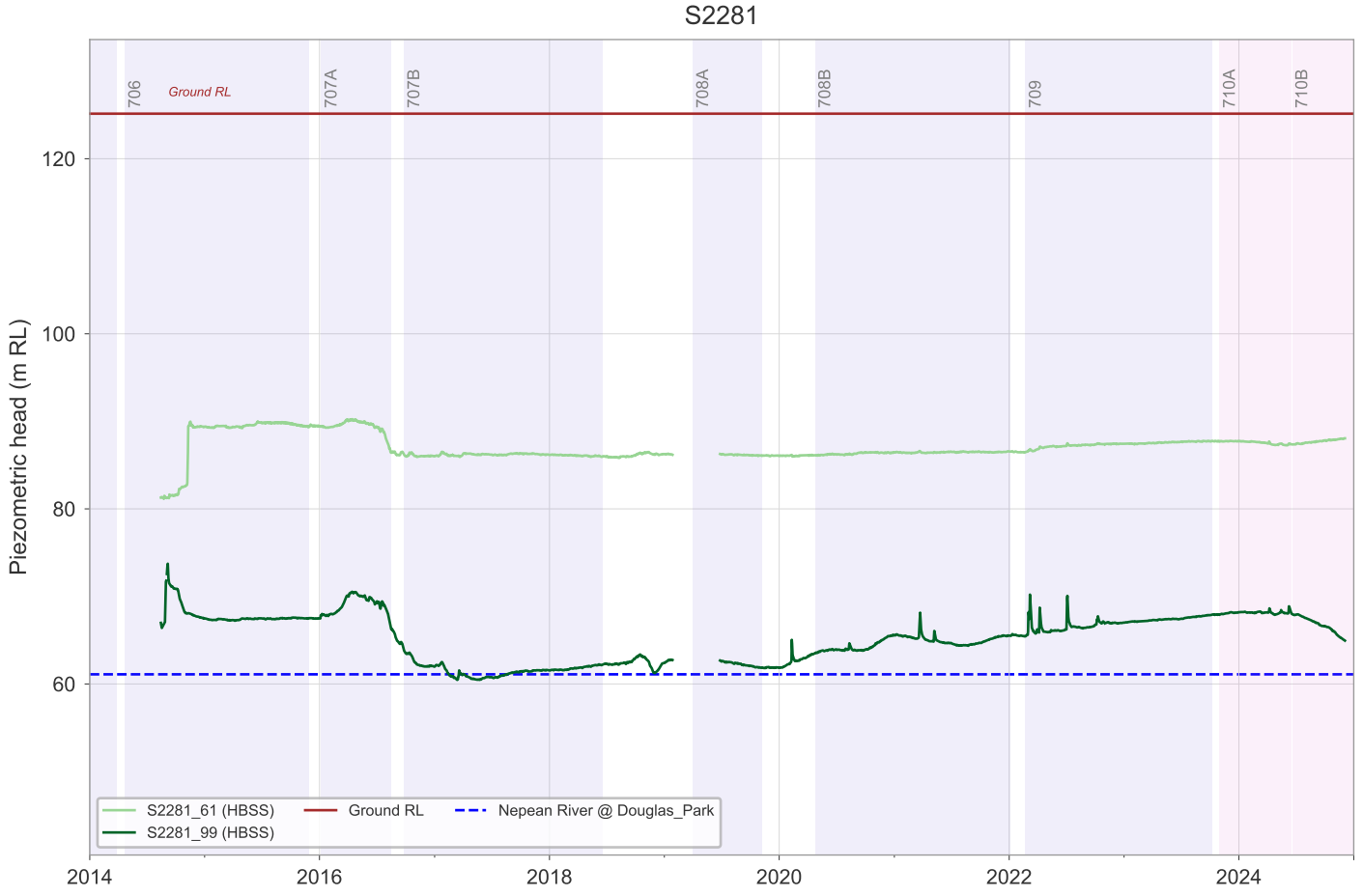

S2177
Piezometric head (m RL)
120
100
80
60
40
20
0
706
707A
707B
708A
708B
709
710A
710B
Ground RL
S2177_44 (WMGR)
S2177_80 (HBSS)
S2177_150.2 (HBSS)
S2177_220.3 (HBSS)
S2177_283.6 (BGSS)
S2177_358.9 (BGSS)
S2177_434.2 (BGSS)
S2177_462.1 (BGSS)
S2177_510 (SBSS)
S2177_621.1 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2014
2016
2018
2020
2022
2024


S2217
Piezometric head (m RL)
230
225
220
215
210
Ground RL
706
S2217_18.8 (HBSS)
Ground RL
Nepean River @ Douglas_Park
Jan
2013
Apr
Jul
Oct
Jan
2014
Apr
Jul
Oct


S2218
Ground RL
185
180
175
170
165
160
Piezometric head (m RL)
S2218_33 (HBSS)
Ground RL
Nepean River @ Douglas_Park
05
12
19
26
02
09
16
23
Jan
2015
Feb
Mar

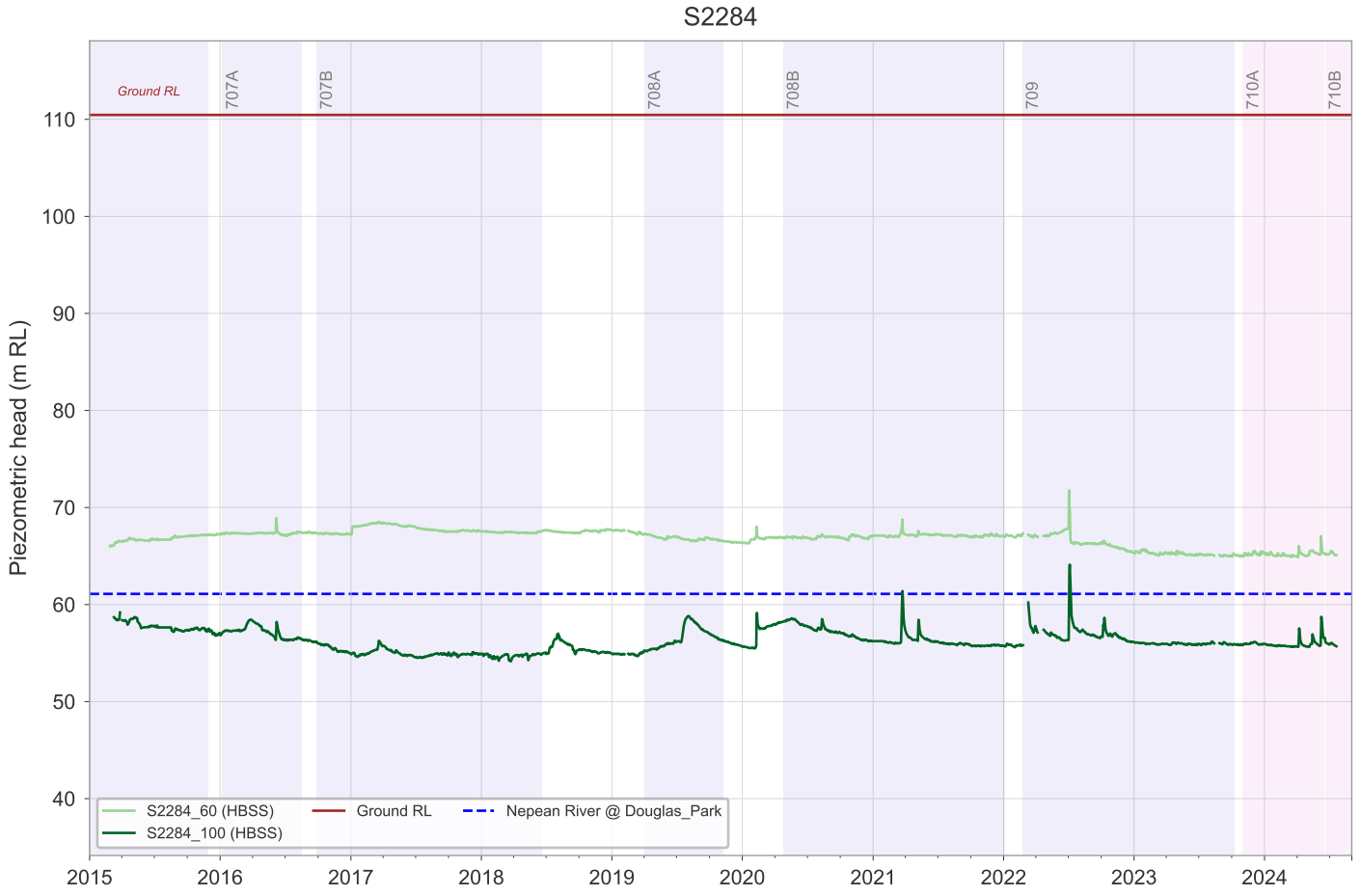

S2219
Ground RL
210
200
190
180
170
160
Piezometric head (m RL)
S2219_51 (HBSS)
Ground RL
Nepean River @ Douglas_Park
05
12
19
26
02
09
16
23
Jan
2015
Feb
Mar

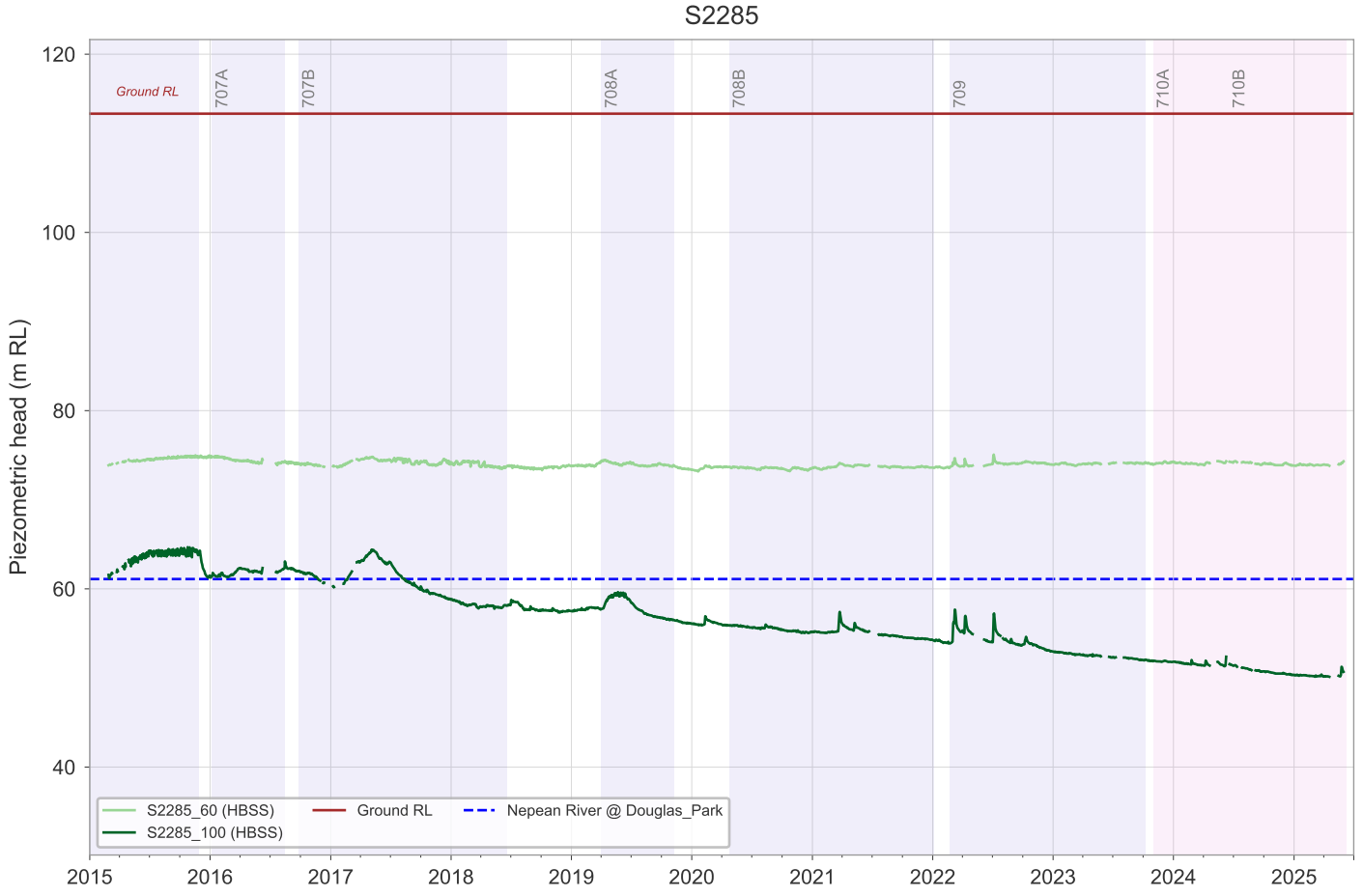

S2280
Piezometric head (m RL)
130
120
110
100
90
80
70
60
50
706
Ground RL
707A
707B
708A
708B
709
710A
710B
S2280_60 (HBSS)
S2280_99 (HBSS)
Ground RL
Nepean River @ Douglas_Park
2014
2016
2018
2020
2022
2024


S2281
Piezometric head (m RL)
120
100
80
60
706
Ground RL
707A
707B
708A
708B
709
710A
710B
S2281_61 (HBSS)
S2281_99 (HBSS)
Ground RL
Nepean River @ Douglas_Park
2014
2016
2018
2020
2022
2024


S2282
Ground RL
707A
707B
708A
708B
709
710A
710B
Piezometric head (m RL)
140
120
100
80
60
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
S2282_60 (HBSS)
S2282_100 (HBSS)
Ground RL
Nepean River @ Douglas_Park

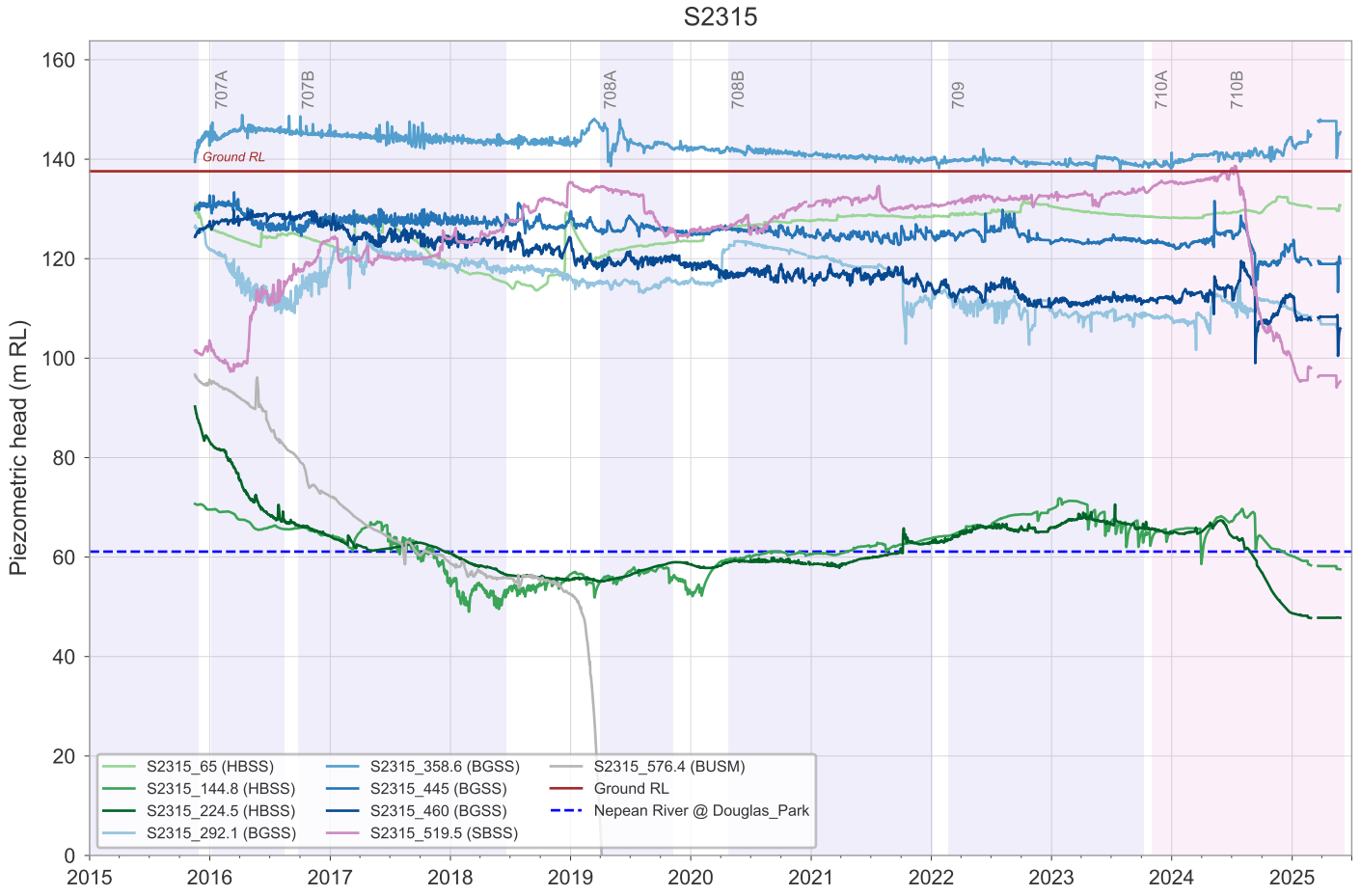

S2283
Ground RL
707A
707B
708A
708B
709
710A
710B
Piezometric head (m RL)
120
100
80
60
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
S2283_60 (HBSS)
S2283_100 (HBSS)
Ground RL
Nepean River @ Douglas_Park

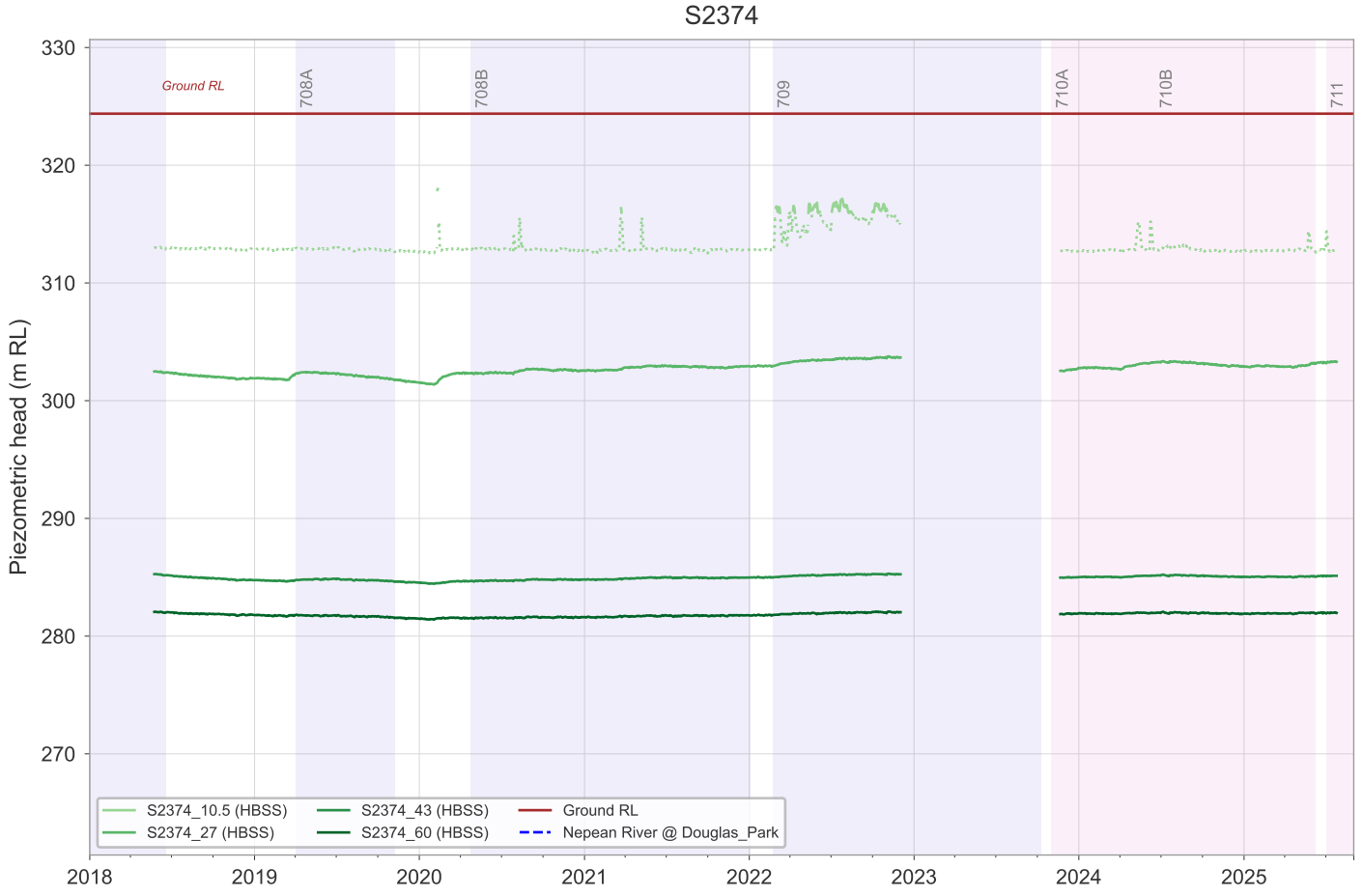

S2284
Ground RL
707A
707B
708A
708B
709
710A
710B
Piezometric head (m RL)
110
100
90
80
70
60
50
40
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
S2284_60 (HBSS)
S2284_100 (HBSS)
Ground RL
Nepean River @ Douglas_Park

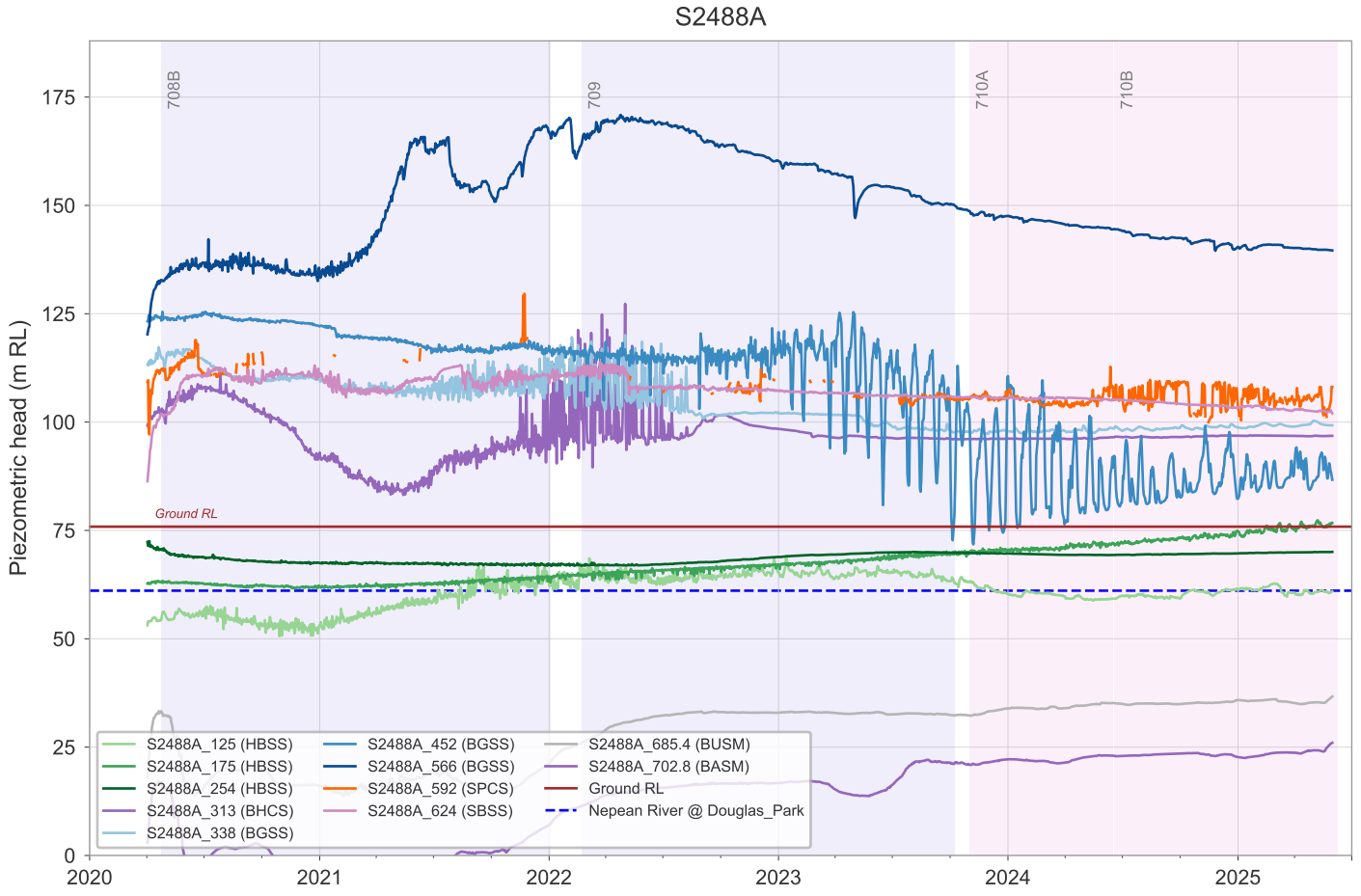

S2285
Ground RL
707A
707B
708A
708B
709
710A
710B
Piezometric head (m RL)
120
100
80
60
40
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
S2285_60 (HBSS)
S2285_100 (HBSS)
Ground RL
Nepean River @ Douglas_Park

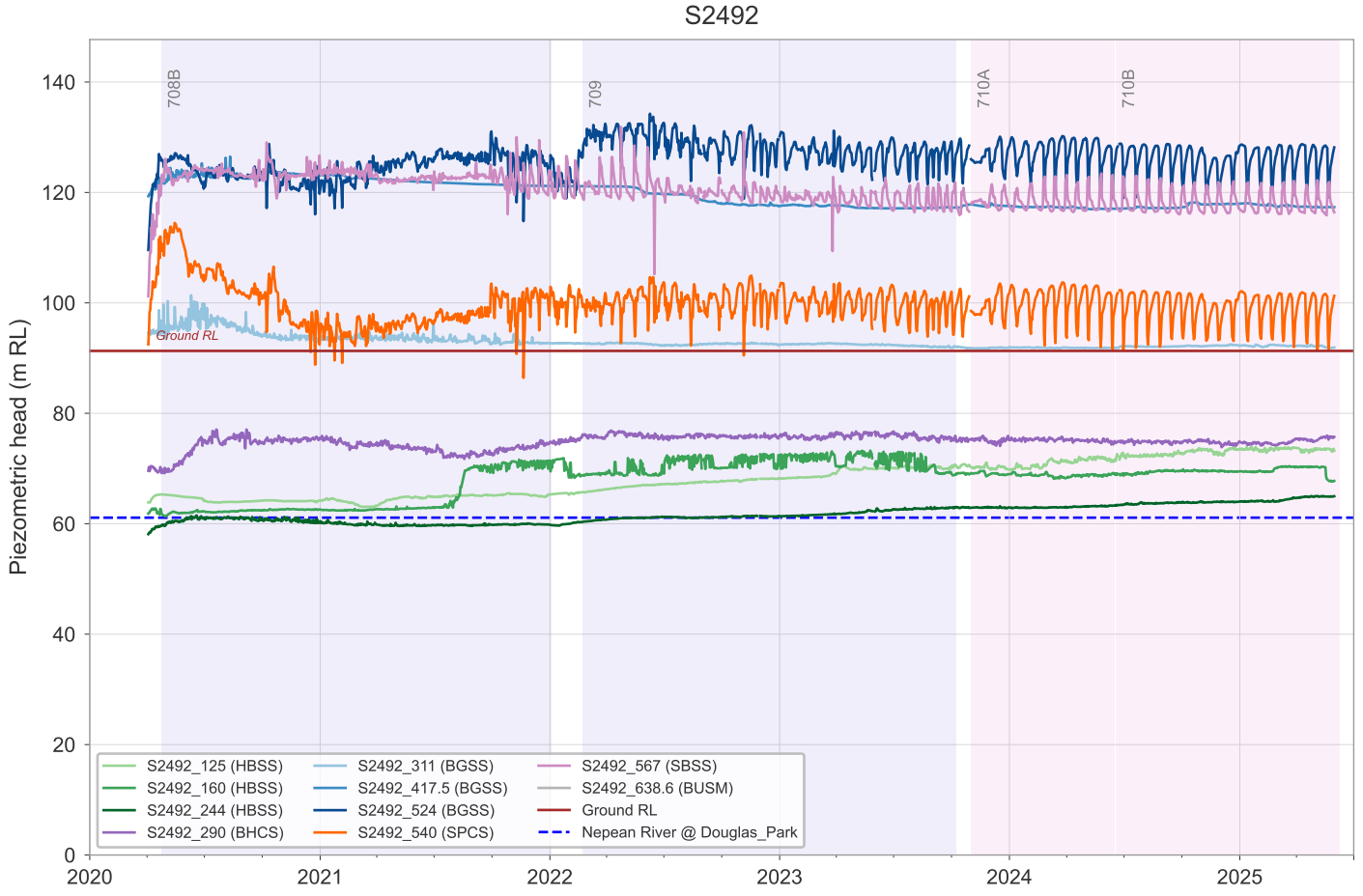

S2286
Ground RL
707A
707B
708A
708B
709
710A
710B
Piezometric head (m RL)
120
100
80
60
40
20
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
S2286_60 (HBSS)
S2286_100 (HBSS)
Ground RL
Nepean River @ Douglas_Park

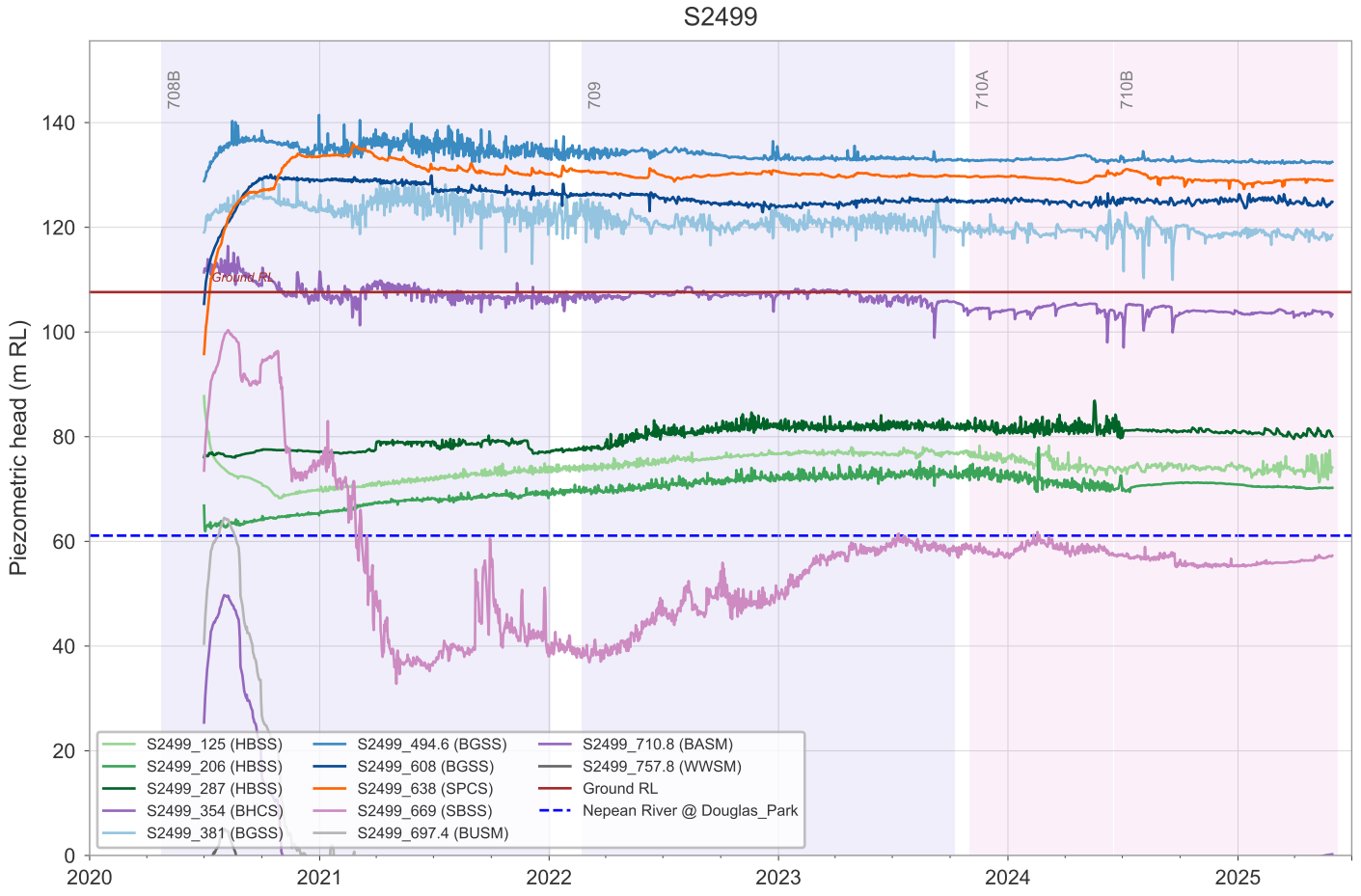

S2308
Ground RL
707A
707B
708A
708B
709
710A
710B
Piezometric head (m RL)
160
140
120
100
80
60
40
20
0
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
S2308_70 (HBSS)
S2308_135.2 (HBSS)
S2308_200.3 (HBSS)
S2308_287.7 (BGSS)
S2308_378.9 (BGSS)
S2308_503 (SBSS)
S2308_514.5 (SBSS)
S2308_574.4 (BUSM)
Ground RL
Nepean River @ Douglas_Park

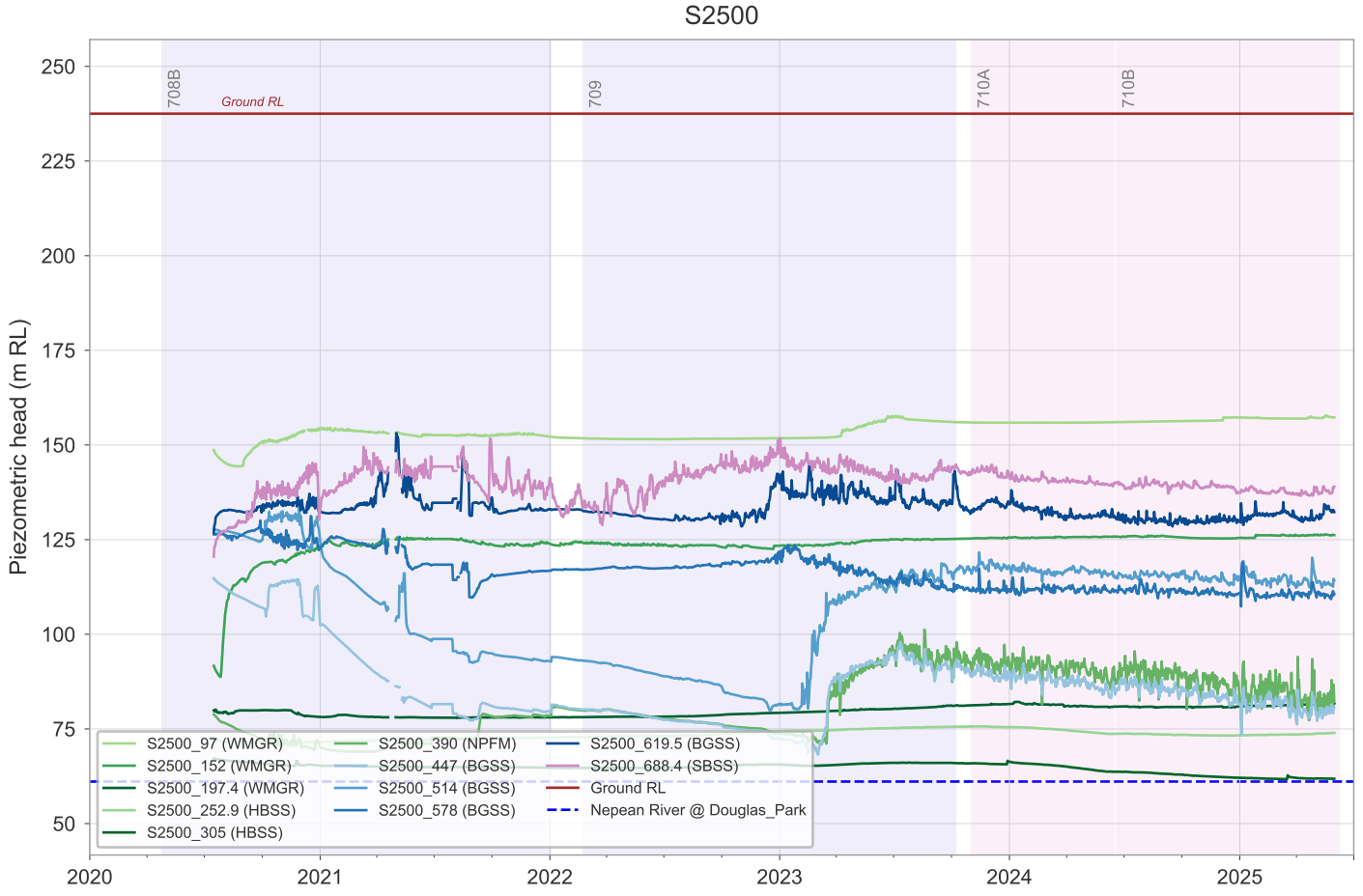

S2315
Piezometric head (m RL)
Ground RL
707A
707B
708A
708B
709
710A
710B
S2315_65 (HBSS)
S2315_144.8 (HBSS)
S2315_224.5 (HBSS)
S2315_292.1 (BGSS)
S2315_358.6 (BGSS)
S2315_445 (BGSS)
S2315_460 (BGSS)
S2315_519.5 (SBSS)
S2315_576.4 (BUSM)
Ground RL
Nepean River @ Douglas_Park

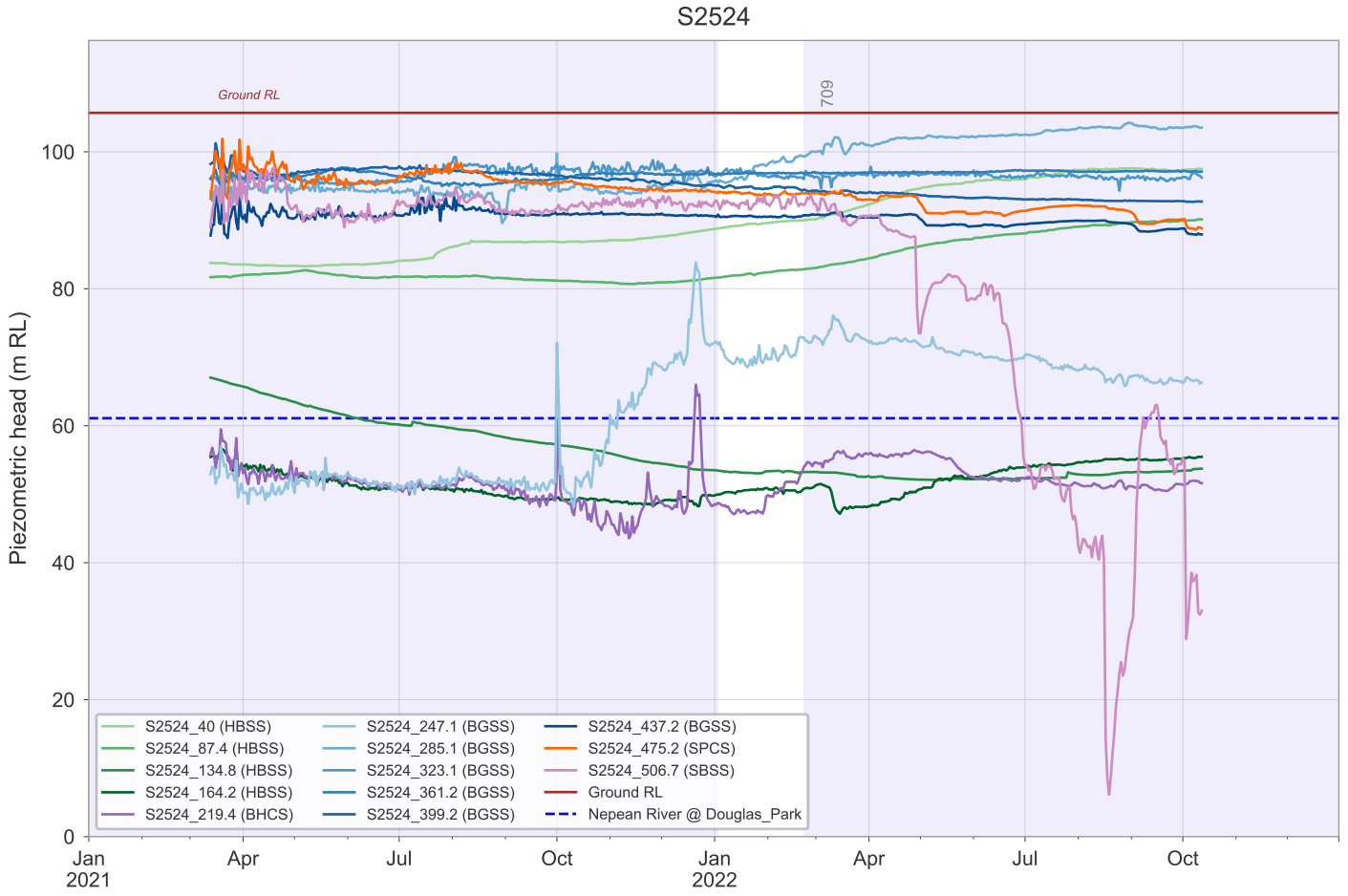

S2374
Piezometric head (m RL)
Ground RL
708A
708B
709
710A
710B
711
S2374_10.5 (HBSS)
S2374_27 (HBSS)
S2374_43 (HBSS)
S2374_60 (HBSS)
Ground RL
Nepean River @ Douglas_Park

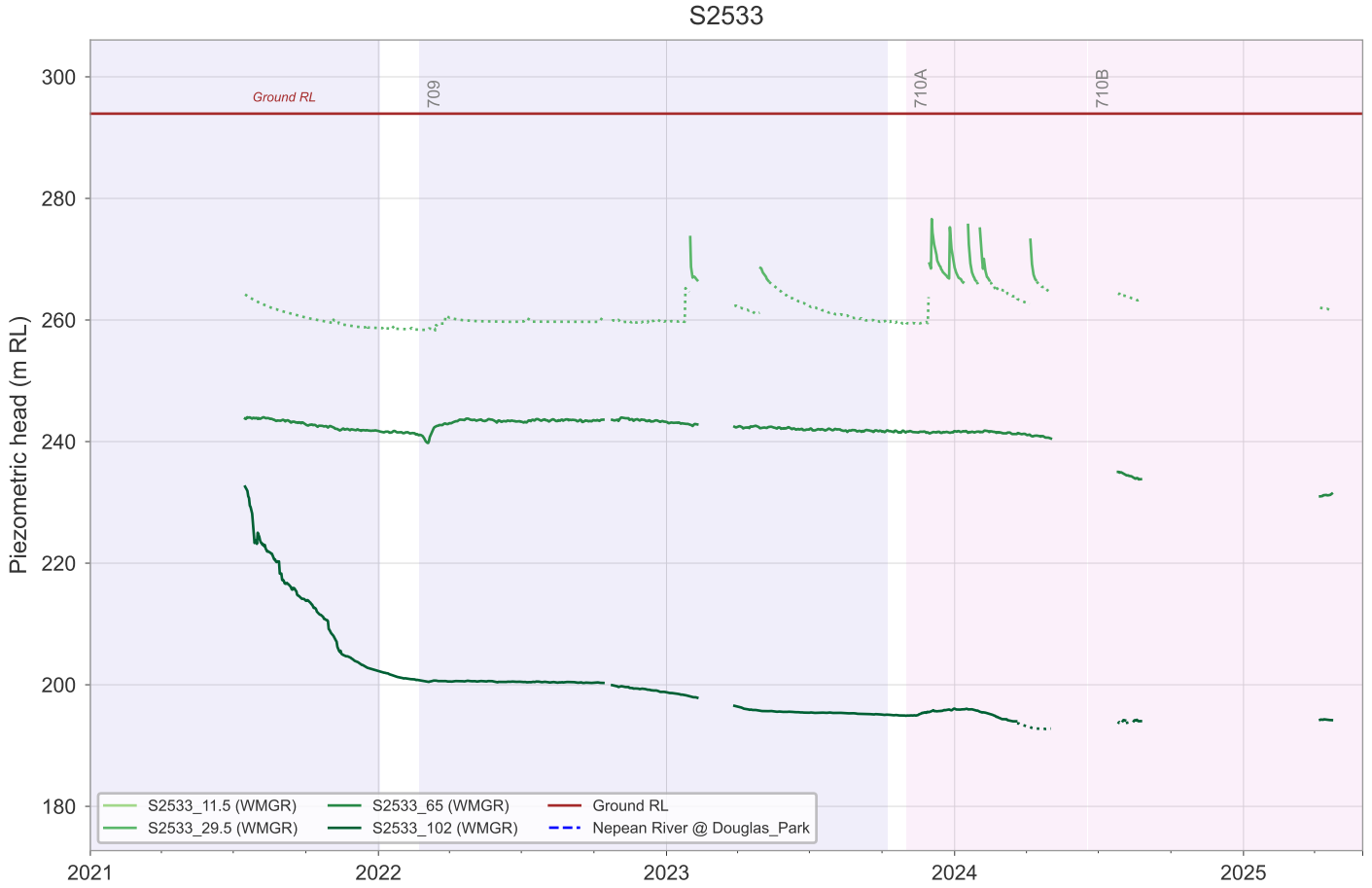

S2488A
Piezometric head (m RL)
708B
709
710A
710B
Ground RL
S2488A_125 (HBSS)
S2488A_175 (HBSS)
S2488A_254 (HBSS)
S2488A_313 (BHCS)
S2488A_338 (BGSS)
S2488A_452 (BGSS)
S2488A_566 (BGSS)
S2488A_592 (SPCS)
S2488A_624 (SBSS)
S2488A_685.4 (BUSM)
S2488A_702.8 (BASM)
Ground RL
Nepean River @ Douglas_Park

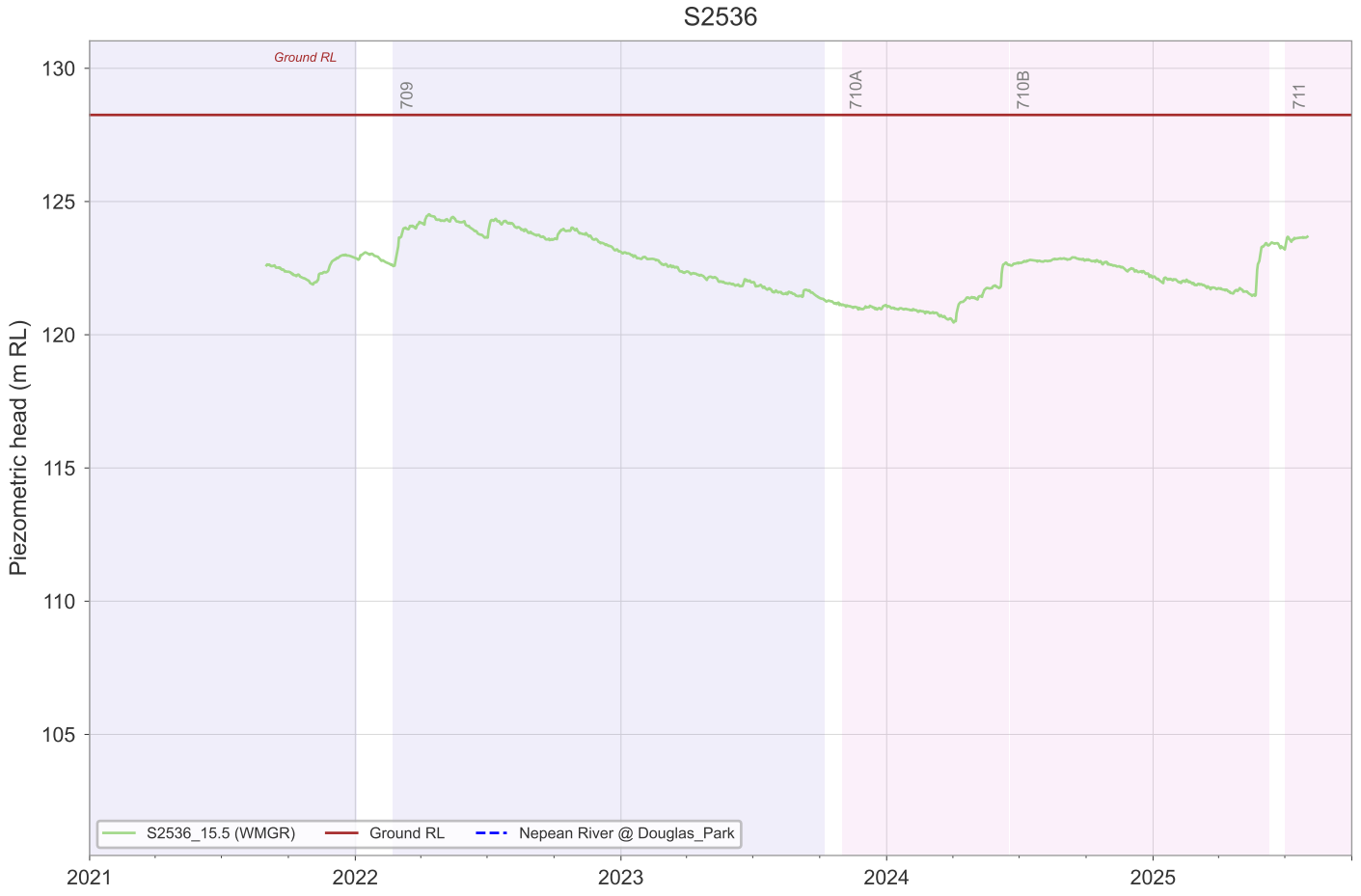

S2492
Piezometric head (m RL)
708B
709
710A
710B
Ground RL
S2492_125 (HBSS)
S2492_160 (HBSS)
S2492_244 (HBSS)
S2492_290 (BHCS)
S2492_311 (BGSS)
S2492_417.5 (BGSS)
S2492_524 (BGSS)
S2492_540 (SPCS)
S2492_567 (SBSS)
S2492_638.6 (BUSM)
Ground RL
Nepean River @ Douglas_Park

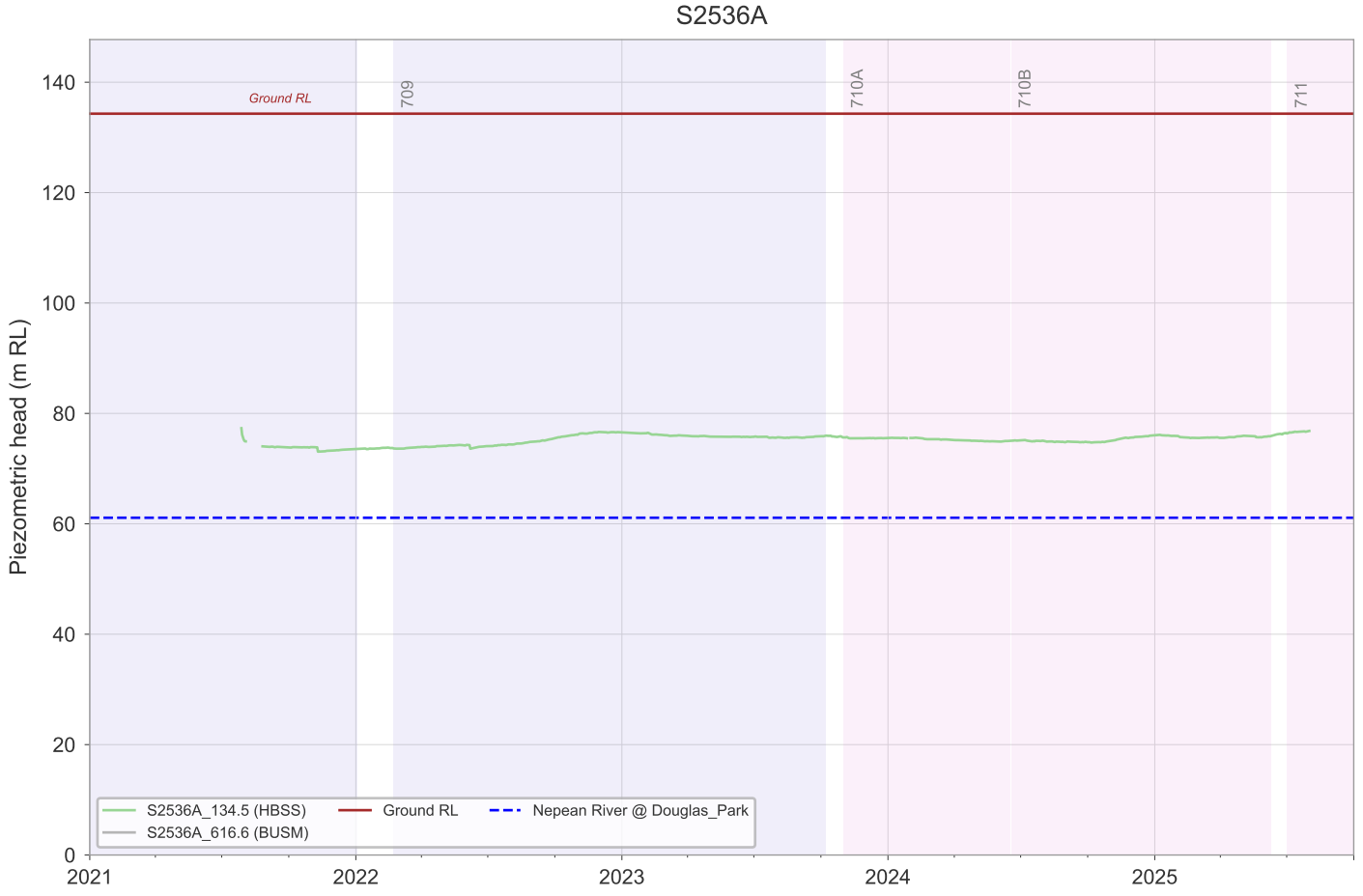

S2499
708B
709
710A
710B
Ground RL
Piezometric head (m RL)
0
20
40
60
80
100
120
140
2020
2021
2022
2023
2024
2025
S2499_125 (HBSS)
S2499_206 (HBSS)
S2499_287 (HBSS)
S2499_354 (BHCS)
S2499_381 (BGSS)
S2499_494.6 (BGSS)
S2499_608 (BGSS)
S2499_638 (SPCS)
S2499_669 (SBSS)
S2499_697.4 (BUSM)
S2499_710.8 (BASM)
S2499_757.8 (WWSM)
Ground RL
Nepean River @ Douglas_Park

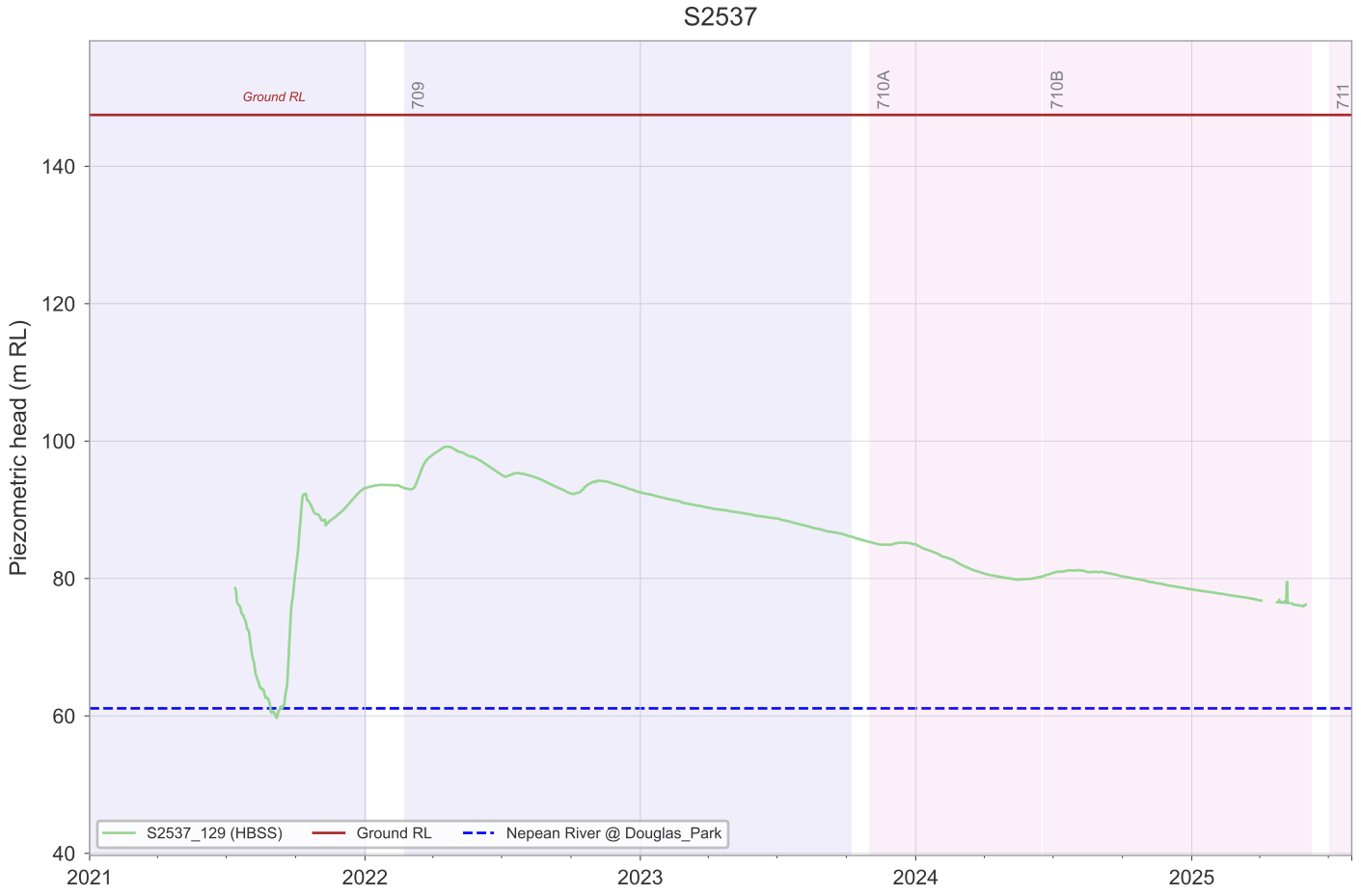

S2500
708B
Ground RL
709
710A
710B
Piezometric head (m RL)
50
75
100
125
150
175
200
225
250
2020
2021
2022
2023
2024
2025
S2500_97 (WMGR)
S2500_152 (WMGR)
S2500_197.4 (WMGR)
S2500_252.9 (HBSS)
S2500_305 (HBSS)
S2500_390 (NPFM)
S2500_447 (BGSS)
S2500_514 (BGSS)
S2500_578 (BGSS)
S2500_619.5 (BGSS)
S2500_688.4 (SBSS)
Ground RL
Nepean River @ Douglas_Park


S2524
Ground RL
709
Piezometric head (m RL)
0
20
40
60
80
100
Jan
2021
Apr
Jul
Oct
Jan
2022
Apr
Jul
Oct
S2524_40 (HBSS)
S2524_87.4 (HBSS)
S2524_134.8 (HBSS)
S2524_164.2 (HBSS)
S2524_219.4 (BHCS)
S2524_247.1 (BGSS)
S2524_285.1 (BGSS)
S2524_323.1 (BGSS)
S2524_361.2 (BGSS)
S2524_399.2 (BGSS)
S2524_437.2 (BGSS)
S2524_475.2 (SPCS)
S2524_506.7 (SBSS)
Ground RL
Nepean River @ Douglas_Park

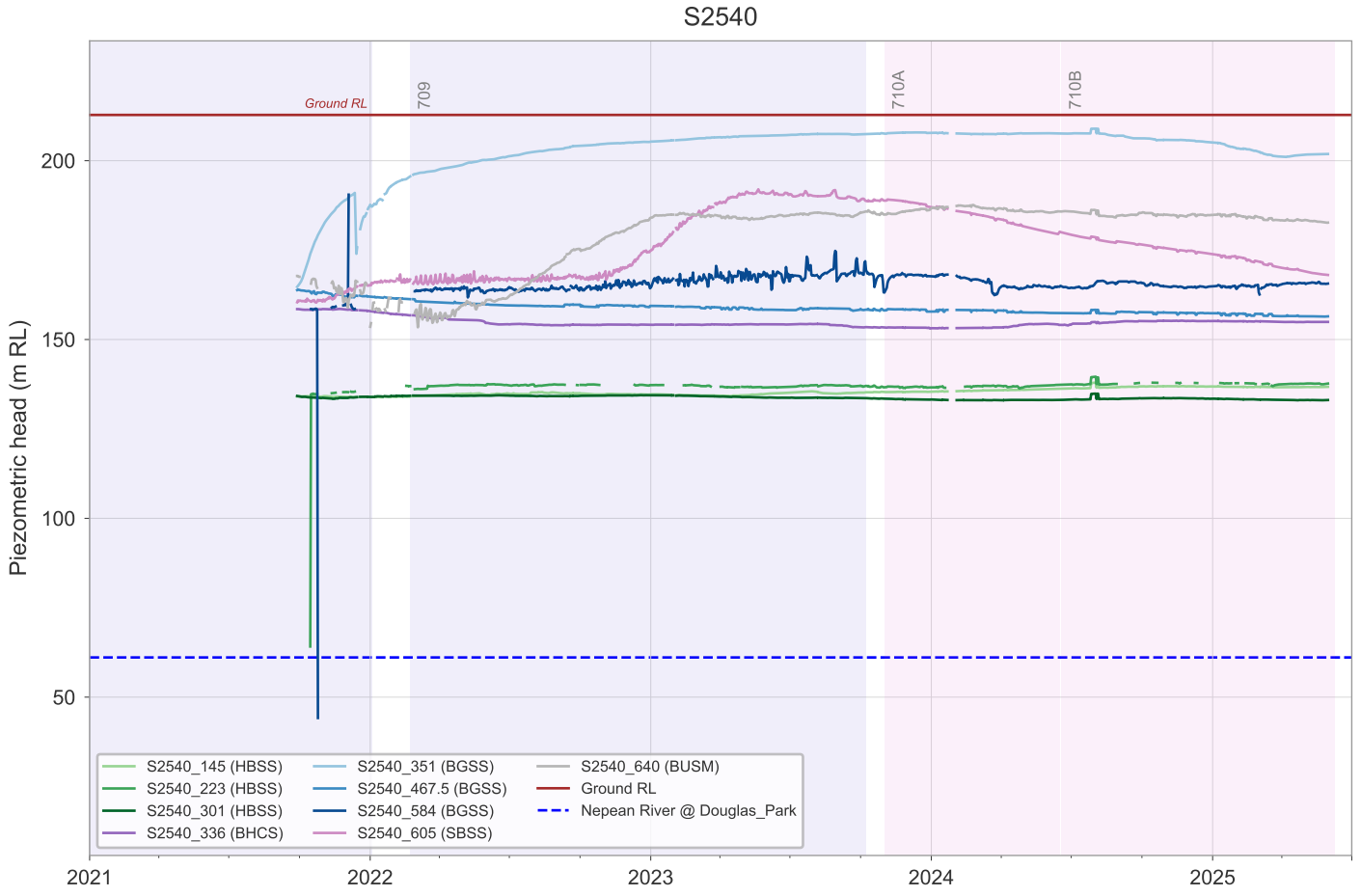

S2533
Ground RL
709
710A
710B
Piezometric head (m RL)
180
200
220
240
260
280
300
2021
2022
2023
2024
2025
S2533_11.5 (WMGR)
S2533_29.5 (WMGR)
S2533_65 (WMGR)
S2533_102 (WMGR)
Ground RL
Nepean River @ Douglas_Park


S2536
Ground RL
709
710A
710B
711
130
125
120
115
110
105
Piezometric head (m RL)
S2536_15.5 (WMGR)
Ground RL
Nepean River @ Douglas_Park
2021
2022
2023
2024
2025

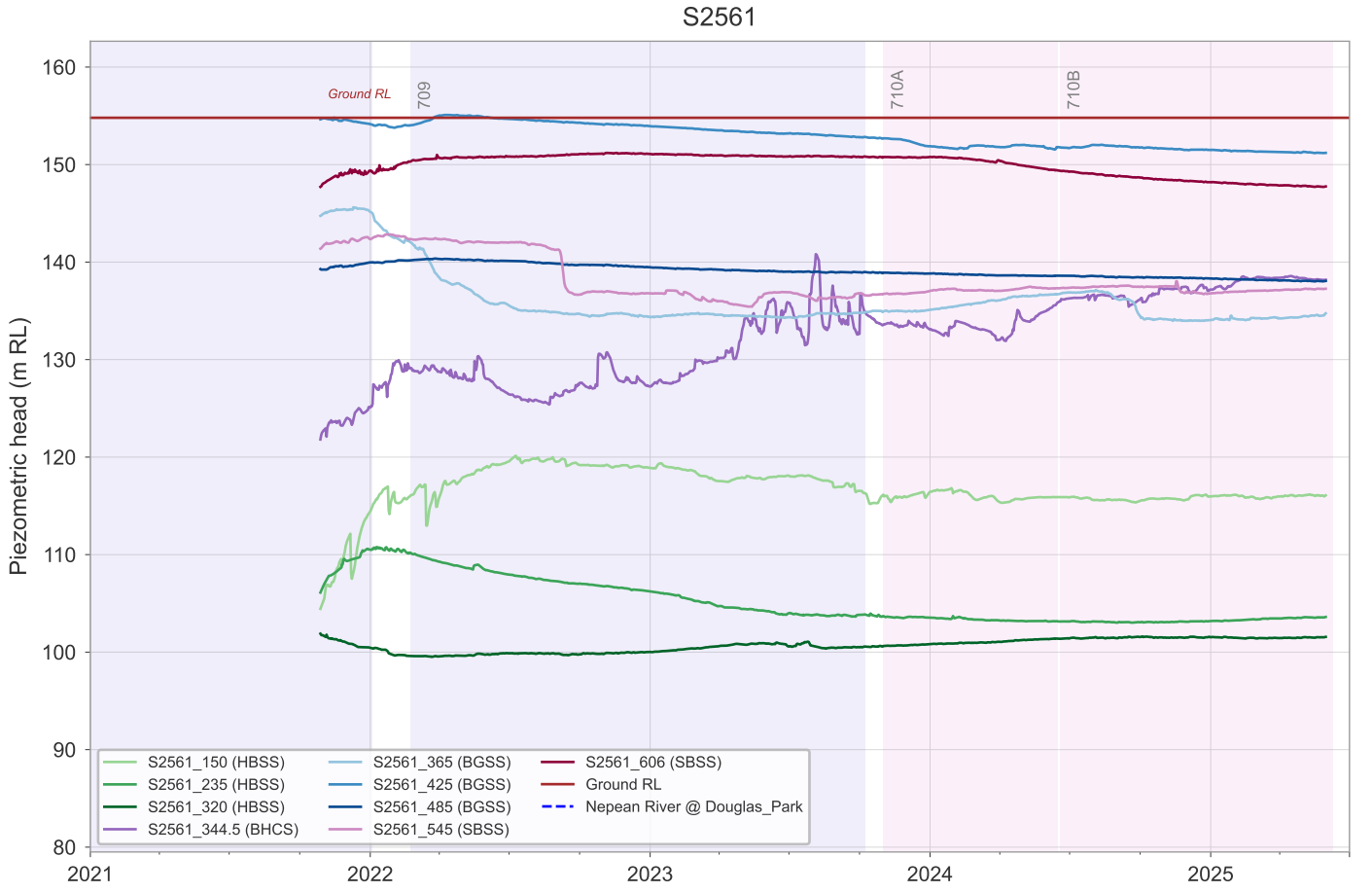

S2536A
Ground RL
709
710A
710B
711
140
120
100
80
60
40
20
0
Piezometric head (m RL)
S2536A_134.5 (HBSS)
S2536A_616.6 (BUSM)
Ground RL
Nepean River @ Douglas_Park
2021
2022
2023
2024
2025

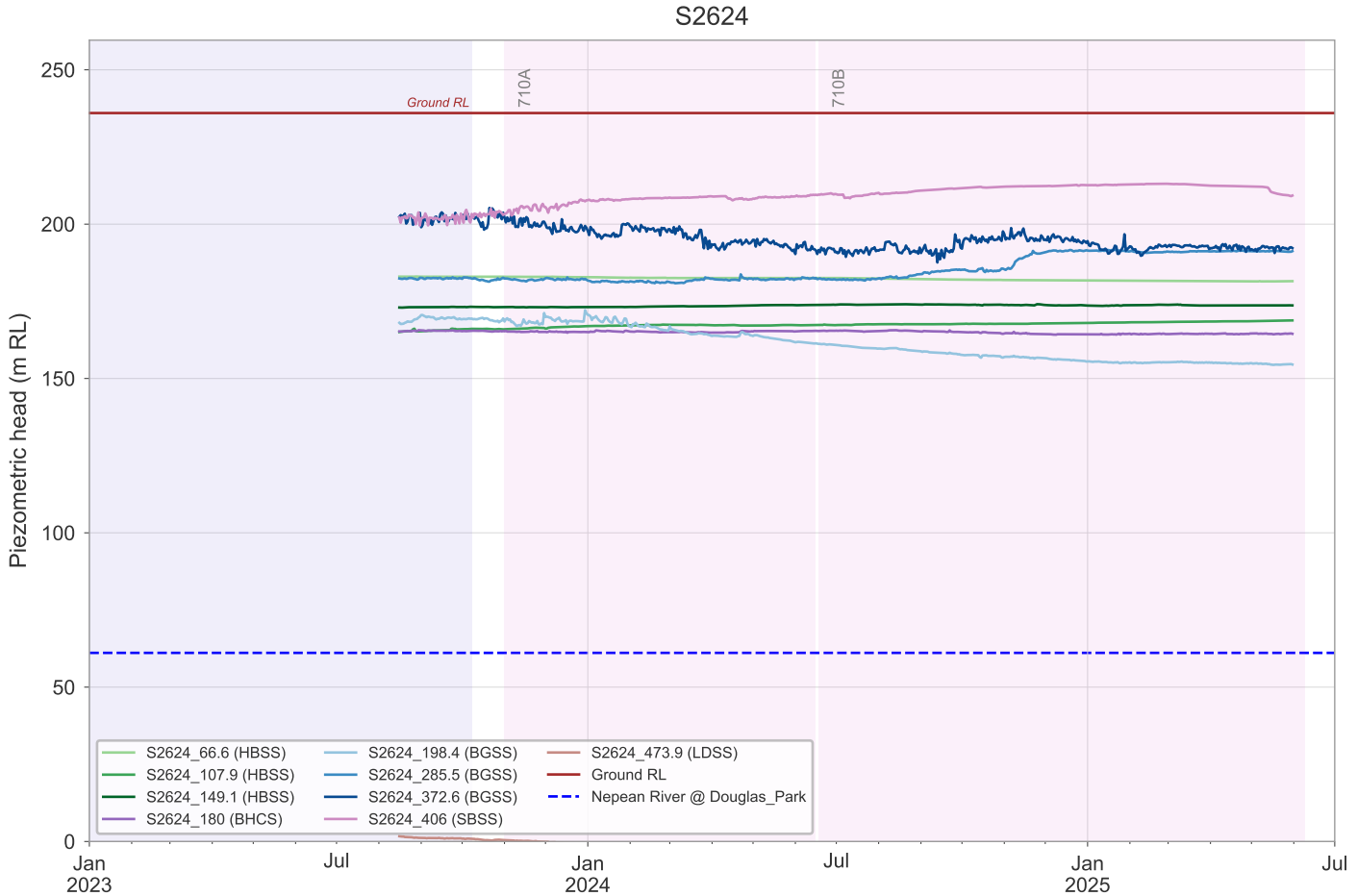

S2537
Ground RL
709
710A
710B
711
Piezometric head (m RL)
140
120
100
80
60
40
2021
2022
2023
2024
2025
S2537_129 (HBSS)
Ground RL
Nepean River @ Douglas_Park

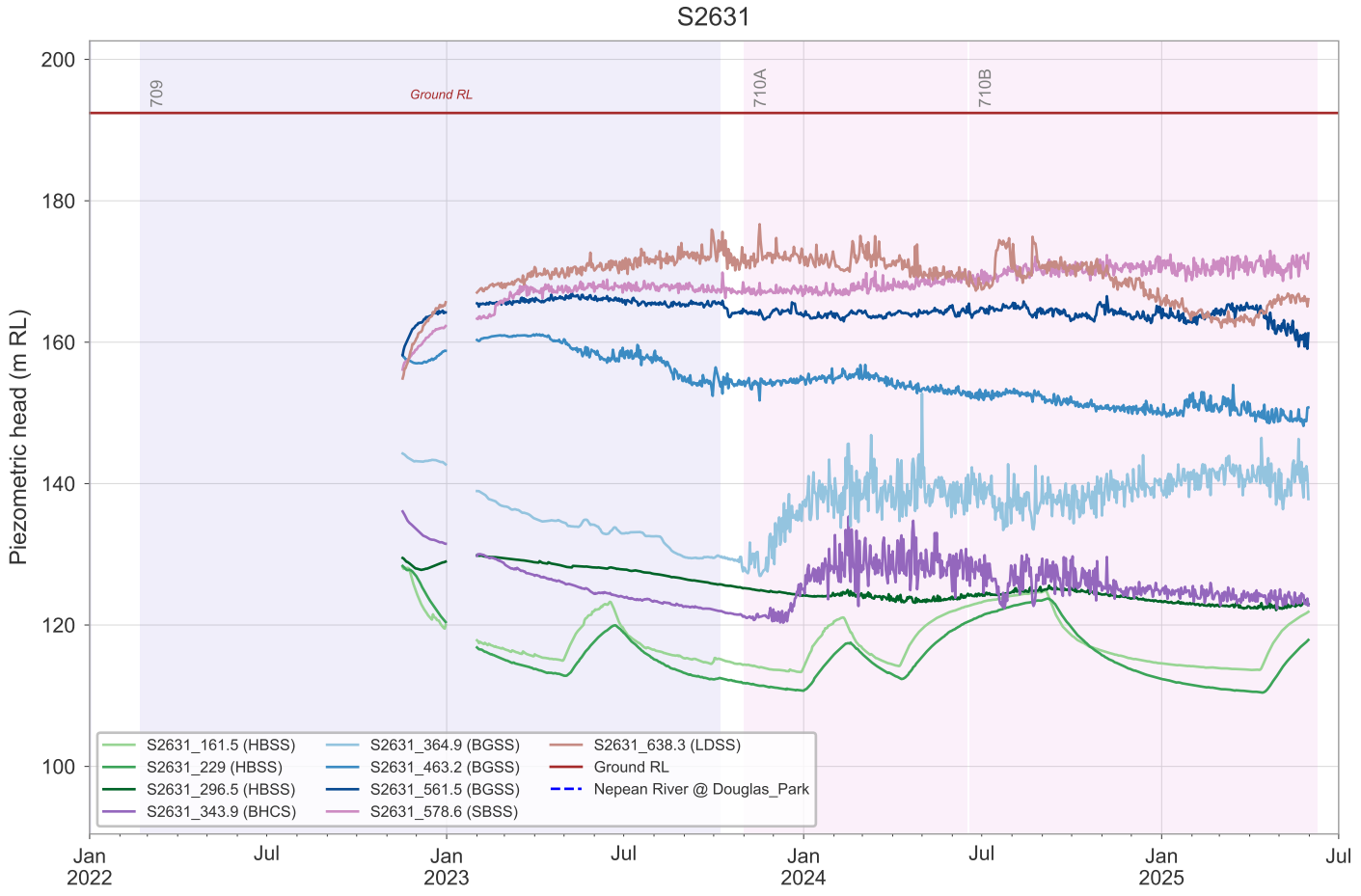

S2538
Ground RL
709
710A
710B
711
Piezometric head (m RL)
120
100
80
60
40
20
2021
2022
2023
2024
2025
S2538_129.5 (HBSS)
Ground RL
Nepean River @ Douglas_Park

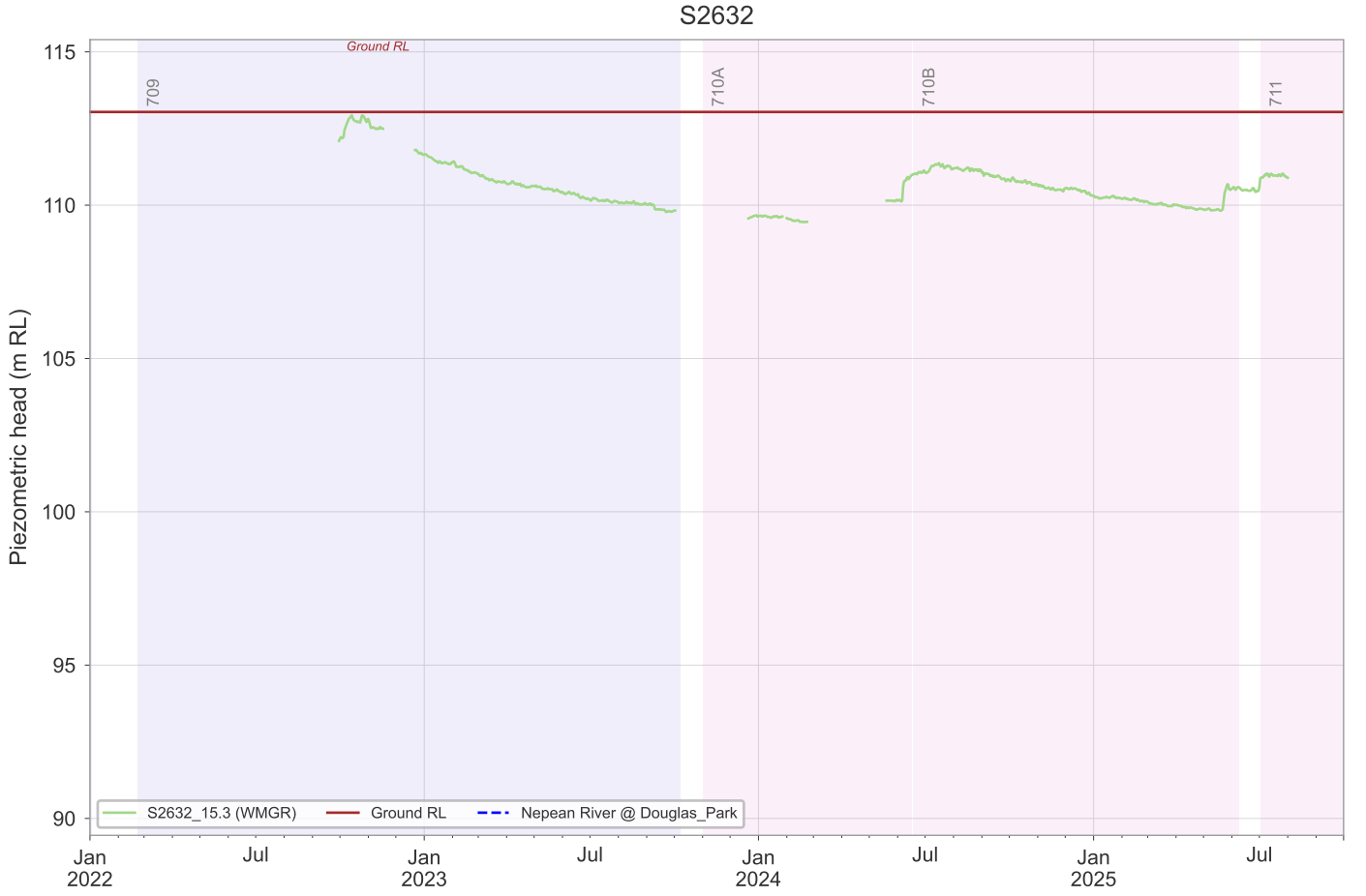

S2540
Ground RL
709
710A
710B
Piezometric head (m RL)
200
150
100
50
2021
2022
2023
2024
2025
S2540_145 (HBSS)
S2540_223 (HBSS)
S2540_301 (HBSS)
S2540_336 (BHCS)
S2540_351 (BGSS)
S2540_467.5 (BGSS)
S2540_584 (BGSS)
S2540_605 (SBSS)
S2540_640 (BUSM)
Ground RL
Nepean River @ Douglas_Park

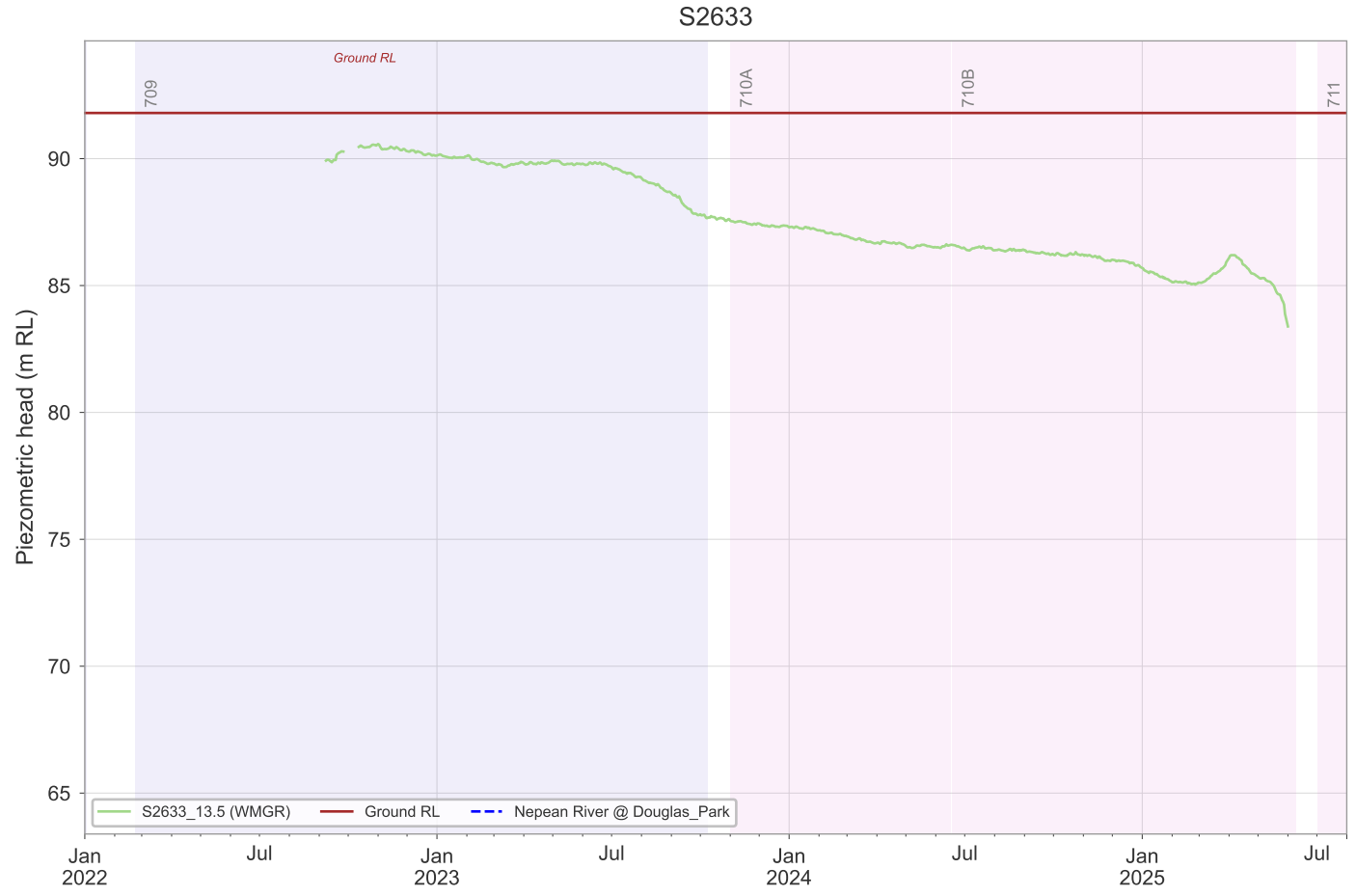

S2543
Ground RL
709
710A
710B
Piezometric head (m RL)
260
240
220
200
180
160
140
120
2021
2022
2023
2024
2025
S2543_165 (HBSS)
S2543_234.5 (HBSS)
S2543_304 (HBSS)
S2543_357.5 (BHCS)
S2543_382 (BGSS)
S2543_446 (BGSS)
S2543_510 (BGSS)
S2543_574 (SPCS)
S2543_639 (SBSS)
S2543_657.4 (BUSM)
Ground RL
Nepean River @ Douglas_Park

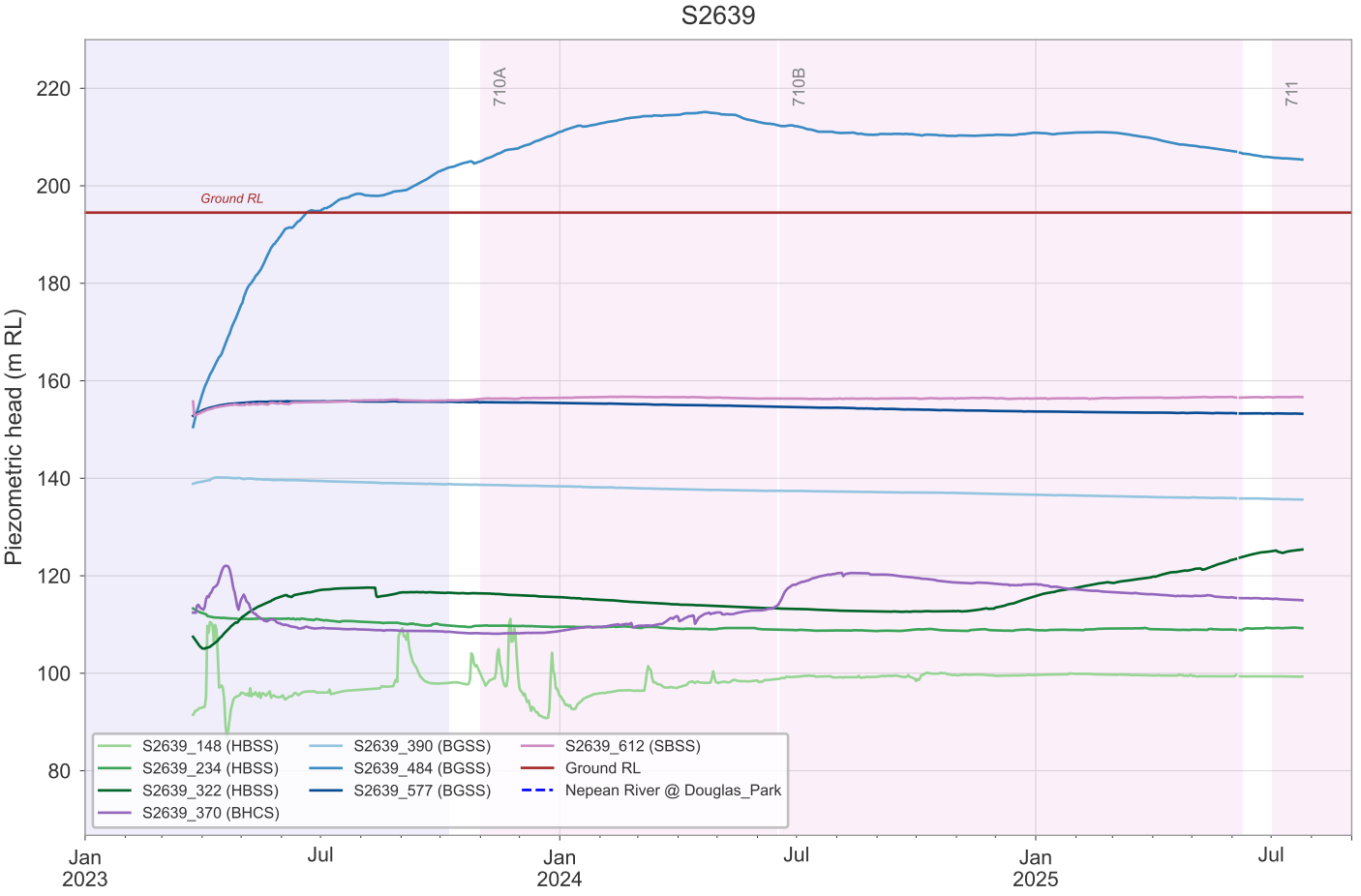

S2561
Ground RL
709
710A
710B
Piezometric head (m RL)
160
150
140
130
120
110
100
90
80
2021
2022
2023
2024
2025
S2561_150 (HBSS)
S2561_235 (HBSS)
S2561_320 (HBSS)
S2561_344.5 (BHCS)
S2561_365 (BGSS)
S2561_425 (BGSS)
S2561_485 (BGSS)
S2561_545 (SBSS)
S2561_606 (SBSS)
Ground RL
Nepean River @ Douglas_Park


S2624
Ground RL
710A
710B
Piezometric head (m RL)
250
200
150
100
50
0
Jan
2023
Jul
Jan
2024
Jul
Jan
2025
Jul
S2624_66.6 (HBSS)
S2624_107.9 (HBSS)
S2624_149.1 (HBSS)
S2624_180 (BHCS)
S2624_198.4 (BGSS)
S2624_285.5 (BGSS)
S2624_372.6 (BGSS)
S2624_406 (SBSS)
S2624_473.9 (LDSS)
Ground RL
Nepean River @ Douglas_Park


S2631
Piezometric head (m RL)
200
180
160
140
120
100
709
Ground RL
710A
710B
S2631_161.5 (HBSS)
S2631_229 (HBSS)
S2631_296.5 (HBSS)
S2631_343.9 (BHCS)
S2631_364.9 (BGSS)
S2631_463.2 (BGSS)
S2631_561.5 (BGSS)
S2631_578.6 (SBSS)
S2631_638.3 (LDSS)
Ground RL
Nepean River @ Douglas_Park
Jan 2022
Jul
Jan 2023
Jul
Jan 2024
Jul
Jan 2025
Jul


S2632
Piezometric head (m RL)
115
110
105
100
95
90
Ground RL
709
710A
710B
711
S2632_15.3 (WMGR)
Ground RL
Nepean River @ Douglas_Park
Jan 2022
Jul
Jan 2023
Jul
Jan 2024
Jul
Jan 2025
Jul

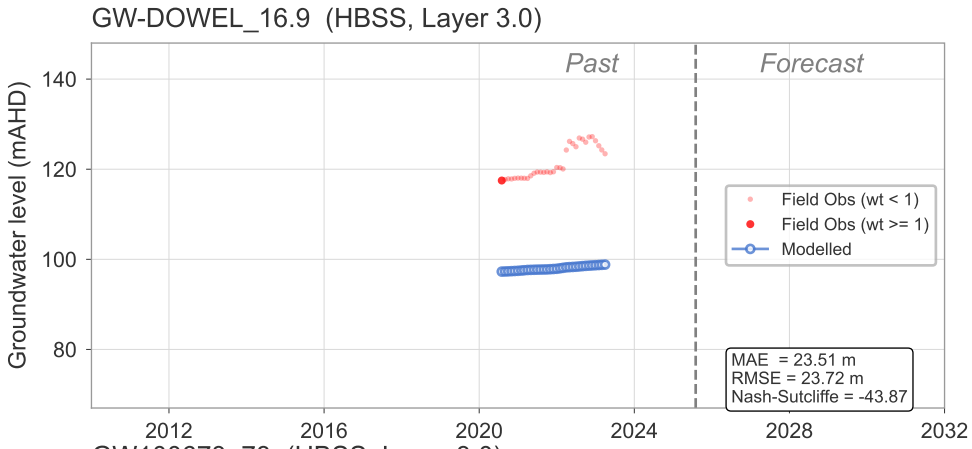

S2633
Ground RL
709
710A
710B
711
Piezometric head (m RL)
90
85
80
75
70
65
S2633_13.5 (WMGR)
Ground RL
Nepean River @ Douglas_Park
Jan 2022
Jul
Jan 2023
Jul
Jan 2024
Jul
Jan 2025
Jul

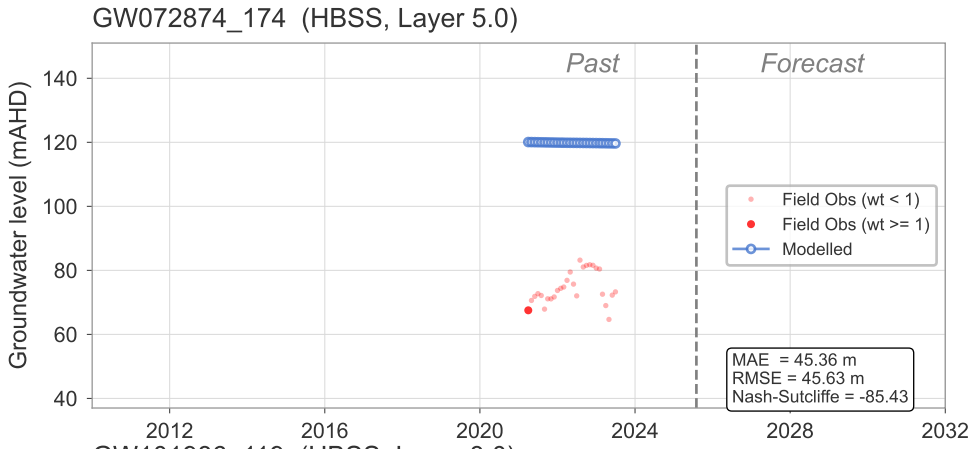

S2639
710A
710B
711
Ground RL
Piezometric head (m RL)
220
200
180
160
140
120
100
80
S2639_148 (HBSS)
S2639_234 (HBSS)
S2639_322 (HBSS)
S2639_370 (BHCS)
S2639_390 (BGSS)
S2639_484 (BGSS)
S2639_577 (BGSS)
S2639_612 (SBSS)
Ground RL
Nepean River @ Douglas_Park
Jan 2023
Jul
Jan 2024
Jul
Jan 2025
Jul

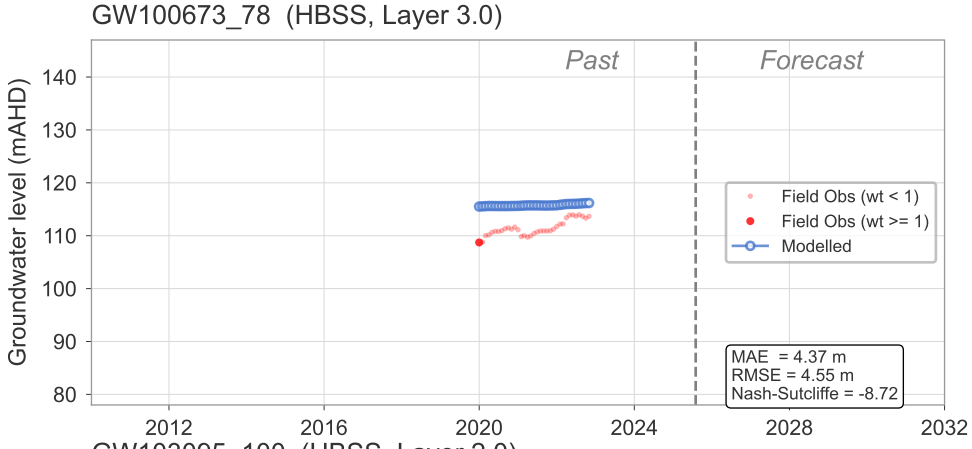
APPENDIX C – Calibration Hydrographs

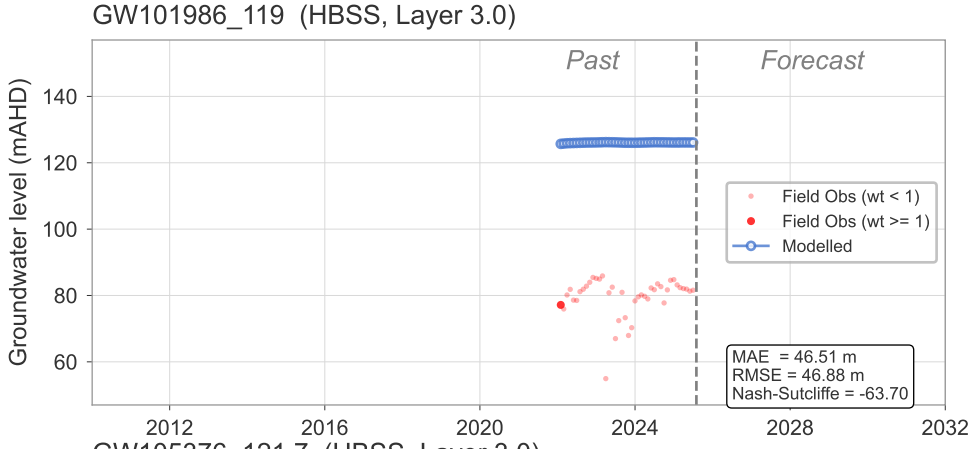
Monitoring data quality assessment					
Bore_ID	**Depth**	**Geol**	**Layer**	**Weight**	**Comment**
gw072874	174	HBSS	5	0	Spurious head measurement (28/02/2023)
gw102619	shallow	HBSS	3	0.1	Pumping-affected period
gw104602	shallow	HBSS	3	0.1	Pumping-affected period
S1185		BUSM	14	0.01	Unrealistic data; inconsistent with nearby bores
S1267	699	BUSM	14	0.01	Unusual recovery trend
S1269	549.6	BUSM	14	0.01	Large head difference; likely erroneous
s1853	639.3	BUSM	14	0	Two anomalously high readings
S1905	616.5	BUSM	14	0.01	Uncertain timing; retain early data only
s1913	All	All		0.5	Pre-2010 equilibration unreliable
s1936	Various	SBSS	11	0.1	Spurious data from mechanical stress before cable shear
s1941	various	SBSS	11	0.1	Spurious data from mechanical stress before cable shear
S1954		BUSM	14	0	Spurious first-SP data
s1954	various	Various		0.1	Early equilibration period deweighted
s1954	Various	WMGR	2	0.1	Multiple VWP depths with large range; possible perched heads
s1954	Various	HBSS		0.1	Several anomalous measurements
S1957	518.8	BUSM	14	0	Erratic June 2015 data; likely malfunction
S1993	various	various		0.01	Unrealistic data; inconsistent with nearby bores
S1997	511.6	BUSM	14	0.1	Sudden 2023 pressure increase; suspect
S1997	various	SBSS	11	0.01	Suspect 2009–2011 and 2020–2025 data
S2030	487	BUSM	14	0.1	Depressurisation timing inconsistent with LW38 sequence
S2080	All	All		0.1	Pre-Nov 2011 equilibration unreliable
s2080	499	CCSS	13	0.1	Spurious pressure increase
s2080	170	HBSS	5	0.1	Spurious pressure increase (2013–2015)
s2080	Various	BGSS		0.5	Spurious BGSS/SBSS increase (Mar–May 2014)
s2149	various	All		0.1	Pre-Jan 2012 equilibration unreliable
s2149	65	HBSS	3	0.5	Shallow HBSS sensor with unrealistic increasing trend
s2157	135	HBSS	3	0	Spurious head increase from Apr 2016
S2157	various	various		0.1	Non-mining trends not reproducible; deweighted
S2160	164	HBSS	5	0.01	Spurious data
S2160	367.8	BGSS	9	0.01	Spurious step change
S2165	various	various		0.1	Non-mining trends; possible CSG influence
S2173	596.8	BUSM	14	0.01	Erroneous data identified by SLR
s2286	100	HBSS	5	0.1	Pumping-affected early data
s2308	70	HBSS	3	0.01	Spurious increase; inconsistent with nearby sensors
S2315	224.5	HBSS	5	0.01	Spurious early data
S2315	519.5	SBSS	11	0.01	Spurious early data
S2488A	various	Various		0.1	Early equilibration; later data spurious per SLR
s2492	various	Various		0.1	Early equilibration period deweighted
S2492	540	SPCS	10	0.01	Spurious early data
S2492	638.6	BUSM	14	0.01	Unrealistic early data
s2499	various	Various		0.1	Early equilibration period deweighted
S2499	various	various		0.01	Early equilibration noted in data
s2533	various	WMGR	2	0.1	Large head range; likely perched conditions
S2536A		BUSM	14	0.01	CSG depressurisation effects
s2537	129	HBSS	4	0.1	Spurious rapid early decline
s2538	129.5	HBSS	4	0.1	Initial offset in late 2021
s2540	351	BGSS	7	0.1	Unusual head increase inconsistent with BGSS sensors
s2540	605	SBSS	11	0.1	Unusual head increase inconsistent with SBSS sensors
s2540	640	BUSM	14	0.1	Unusual head increase inconsistent with BUSM sensors
s2631	various	Various		0.1	Early equilibration period deweighted
s2639	484	BGSS	8	0	Unrealistic increase; inconsistent with nearby sensors

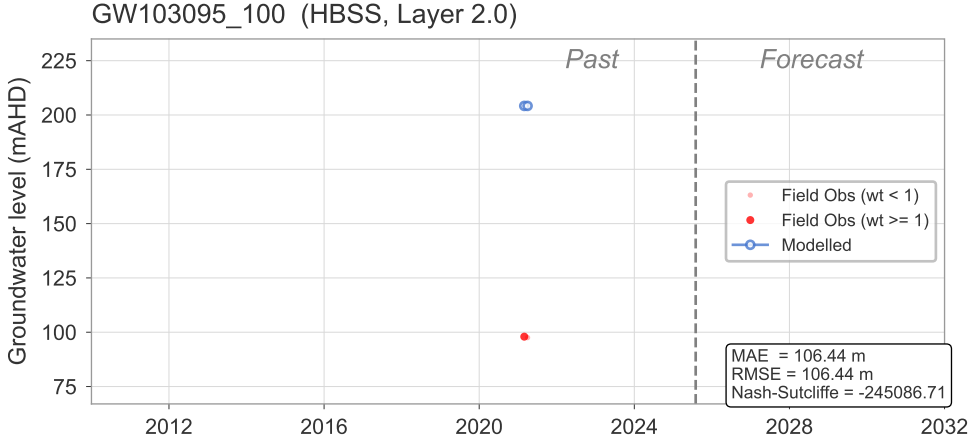
Modelled and observed groundwater hydrographs

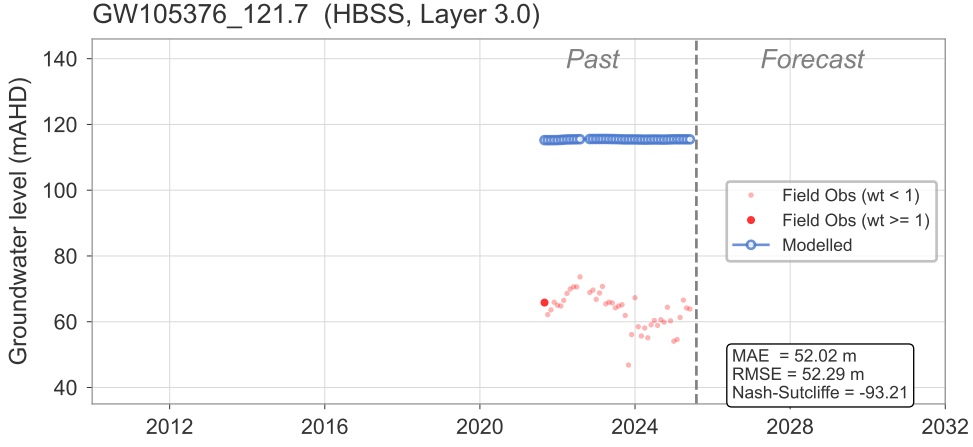












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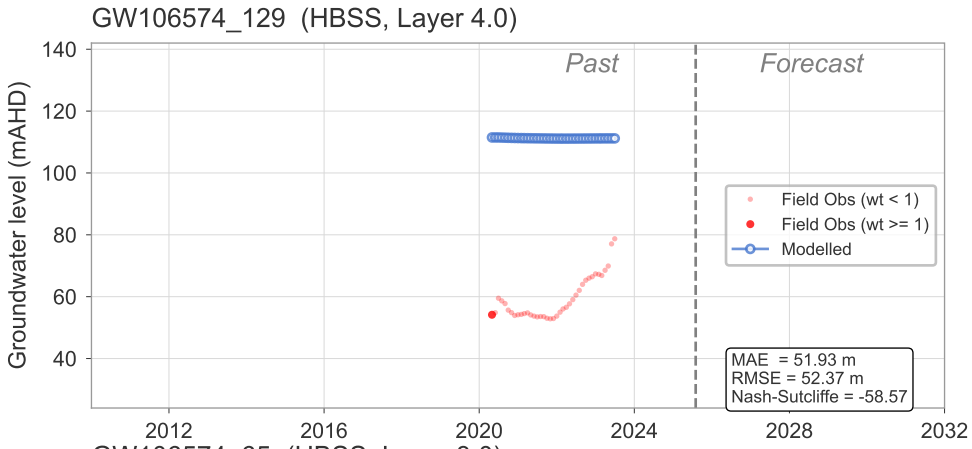

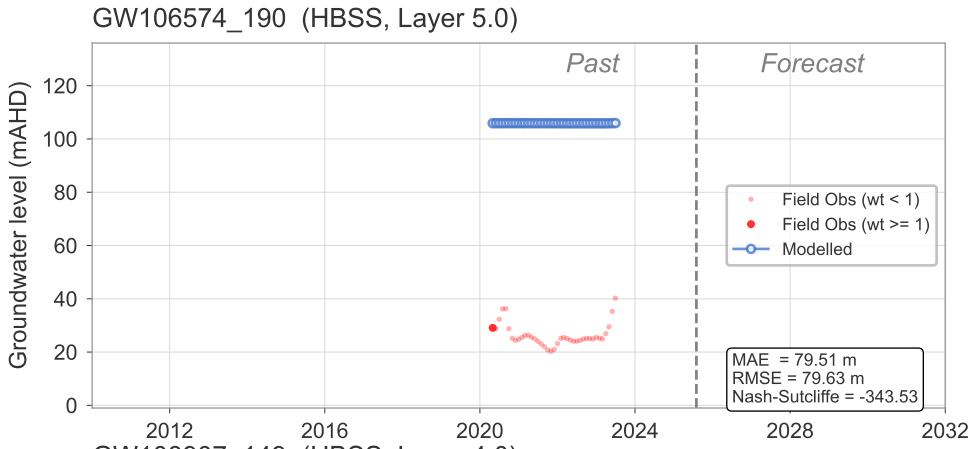

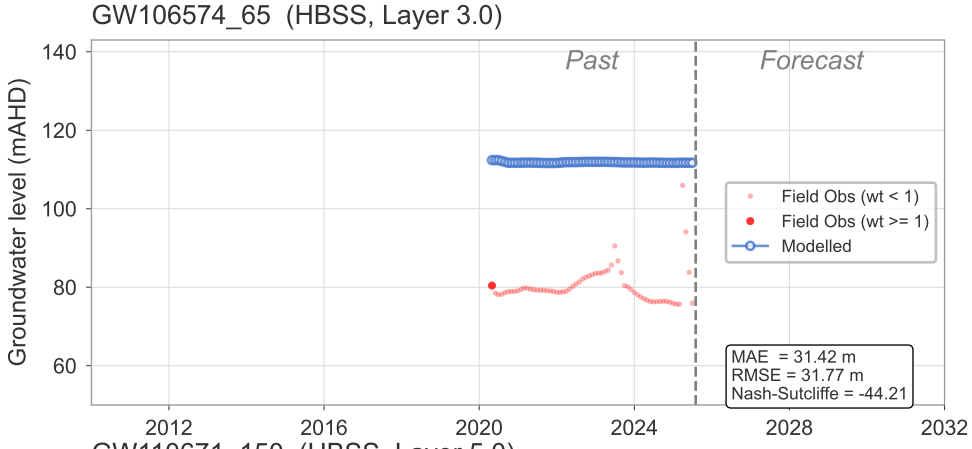

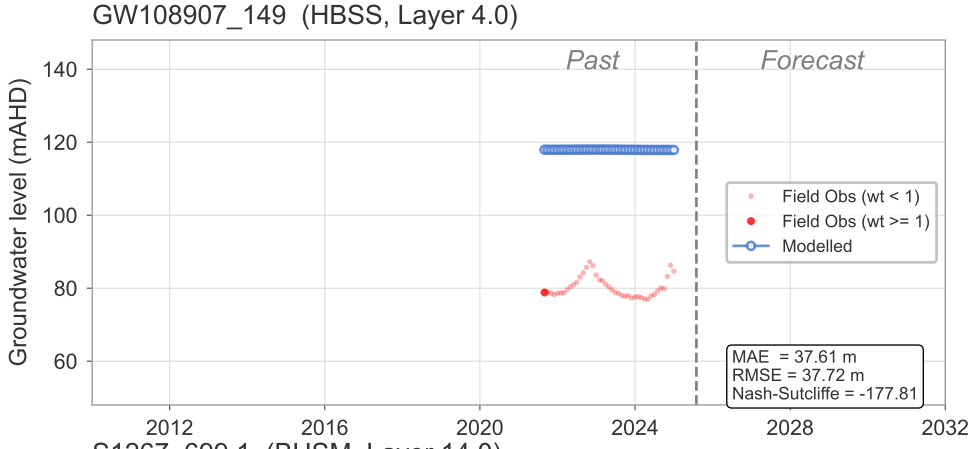

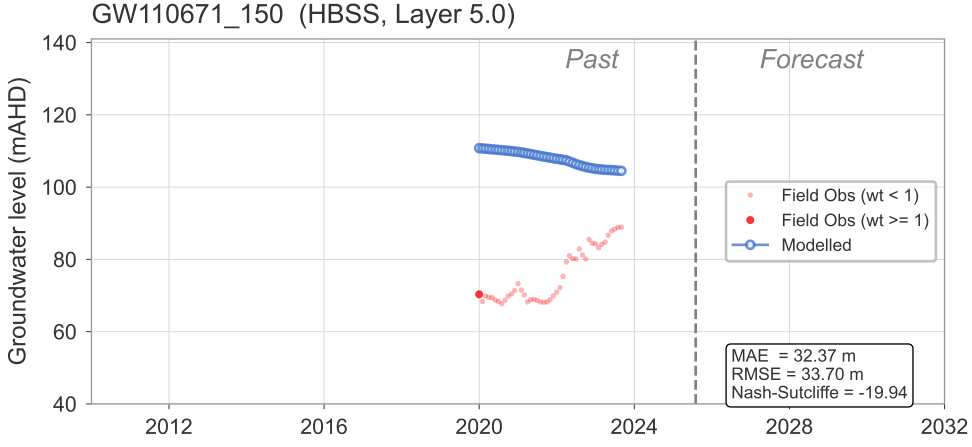

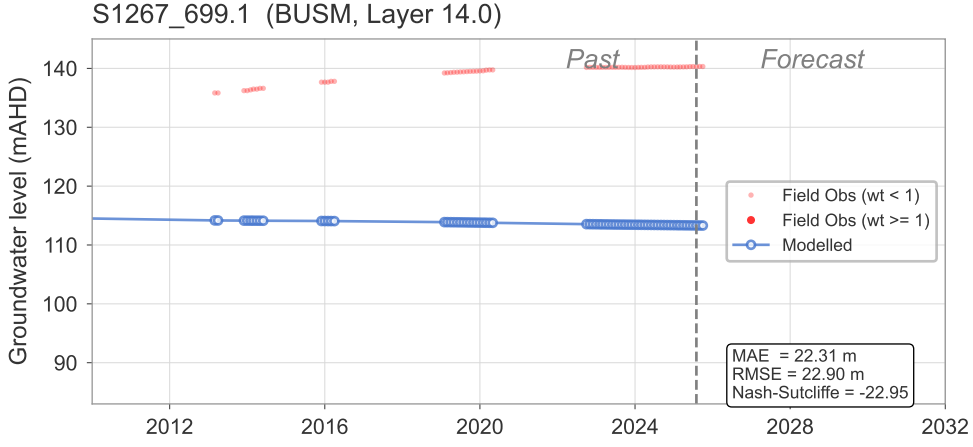

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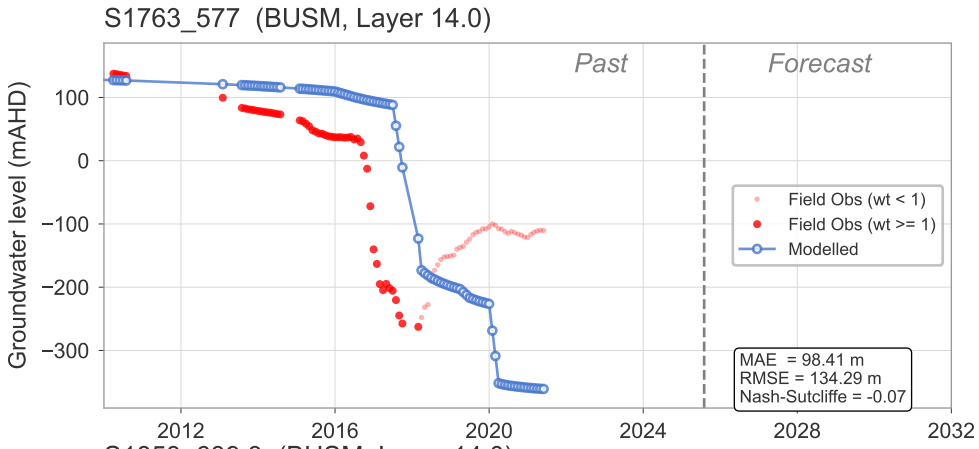

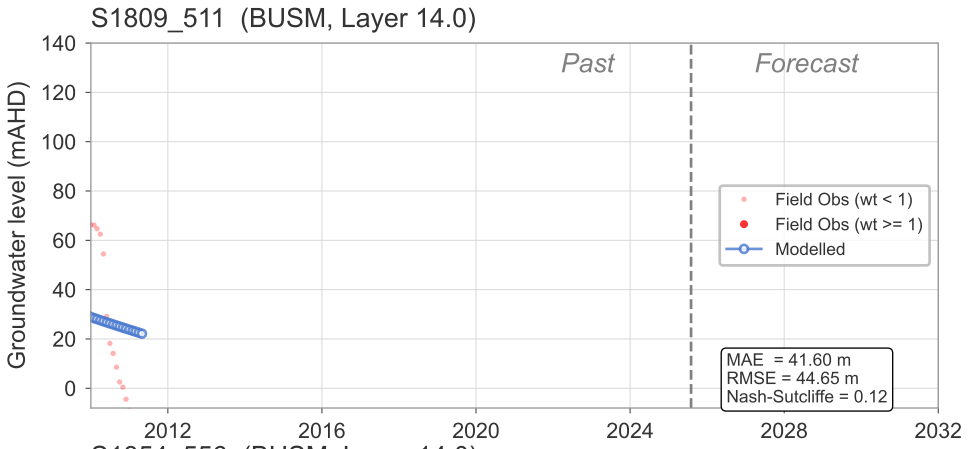

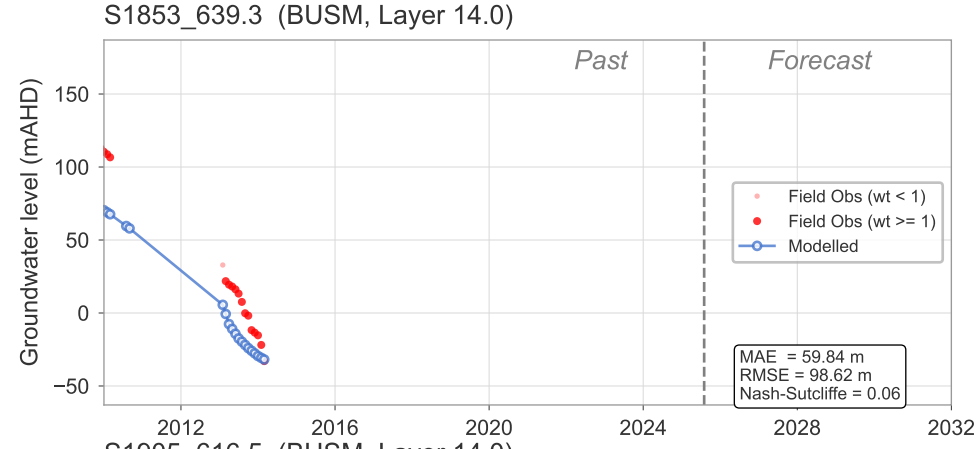

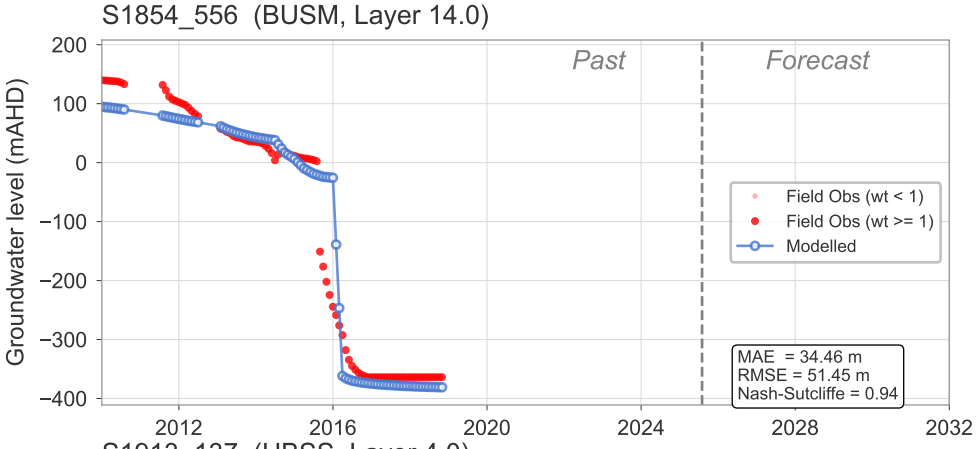

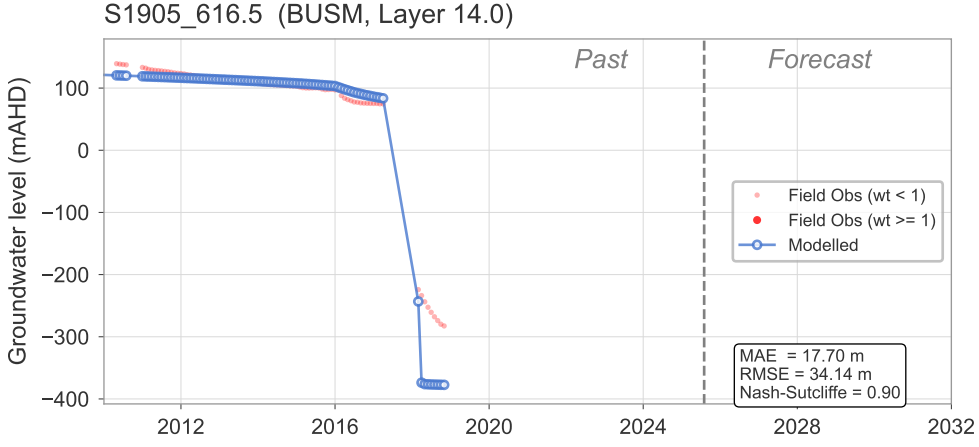

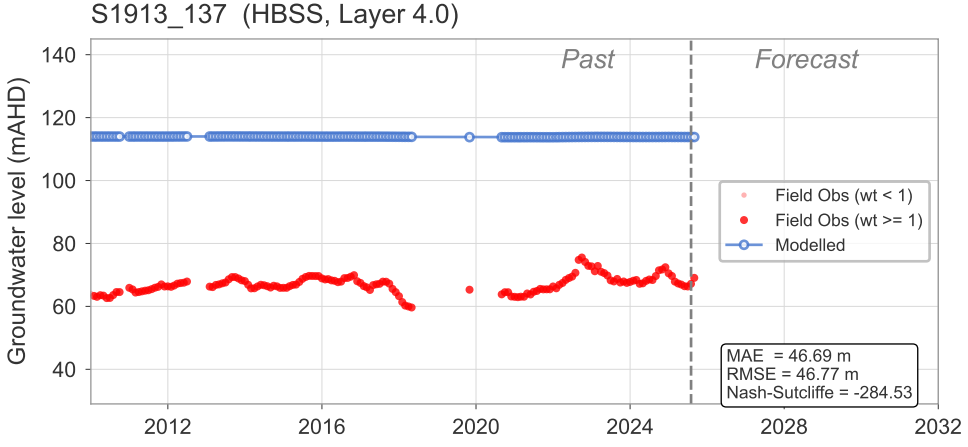

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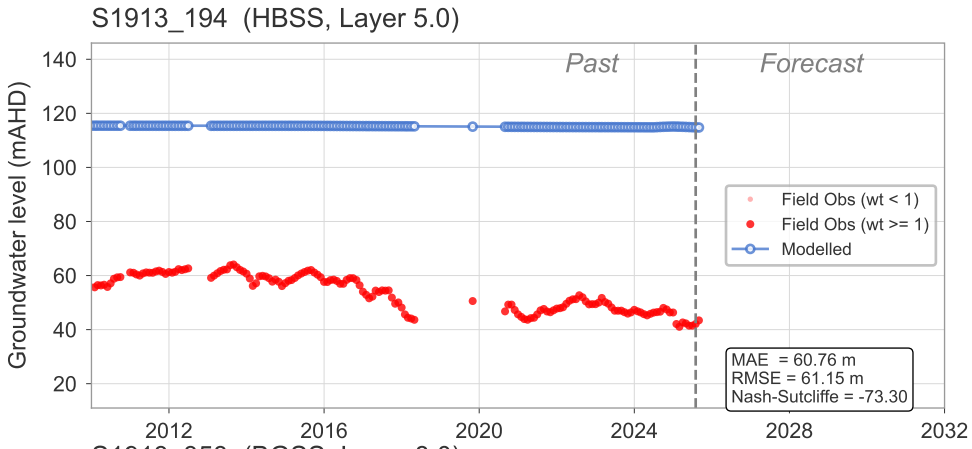

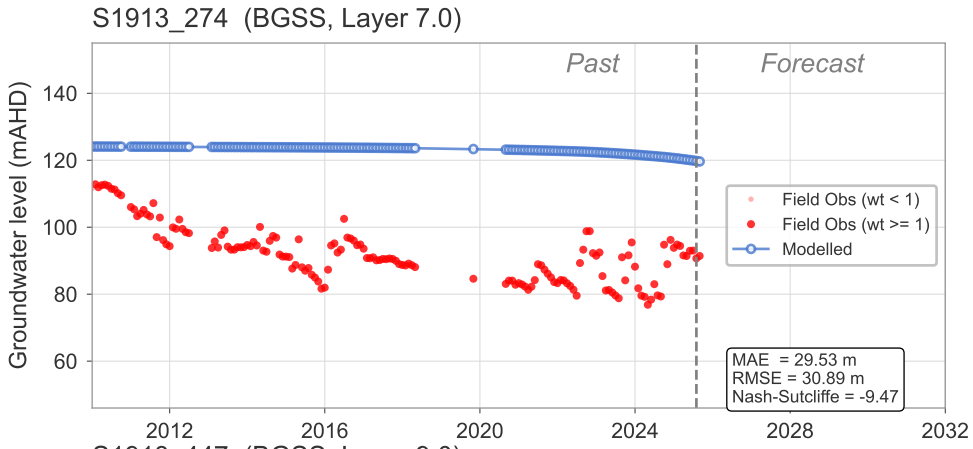

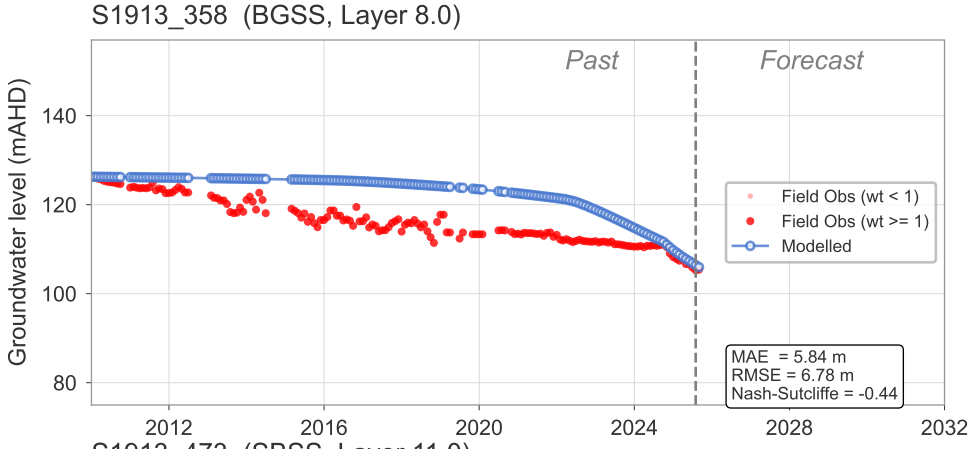

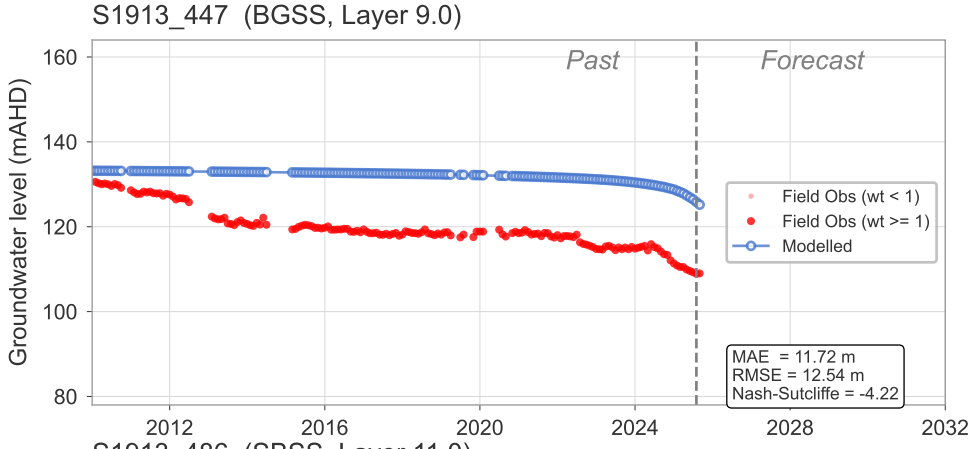

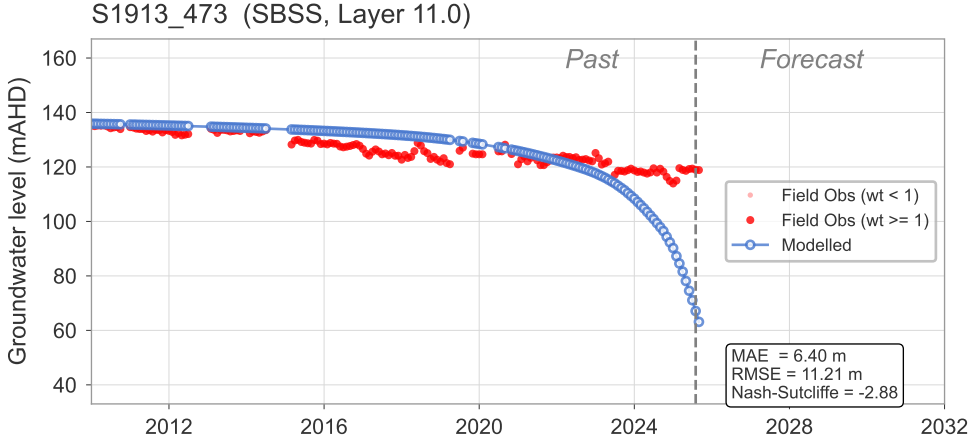

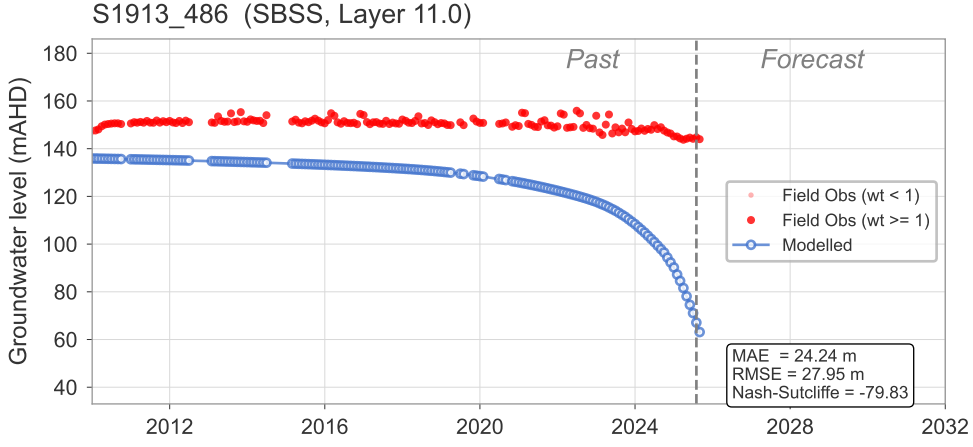

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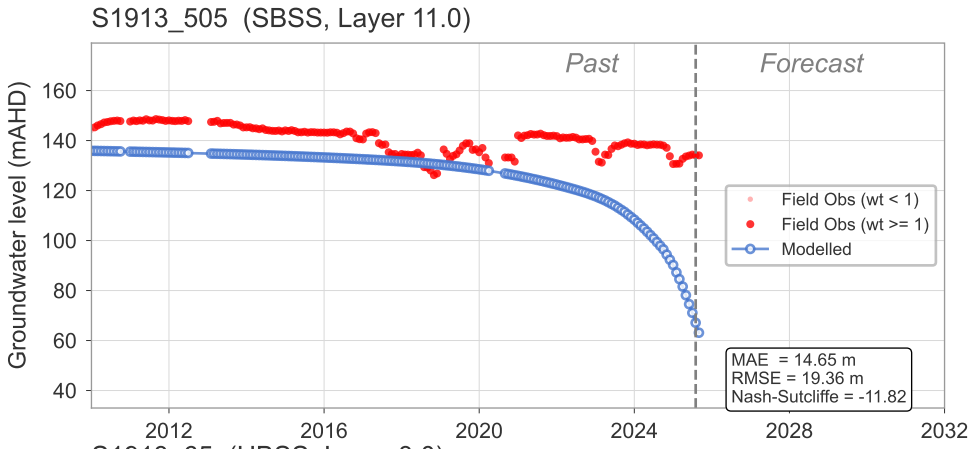
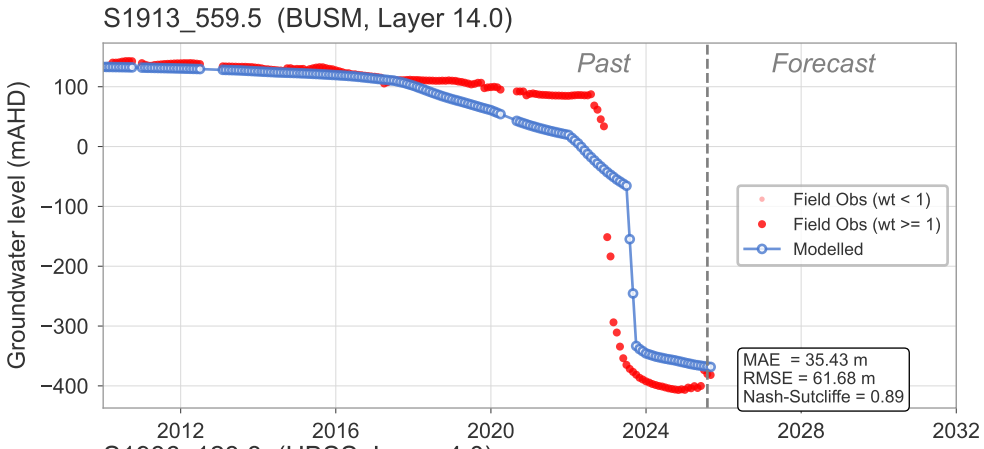
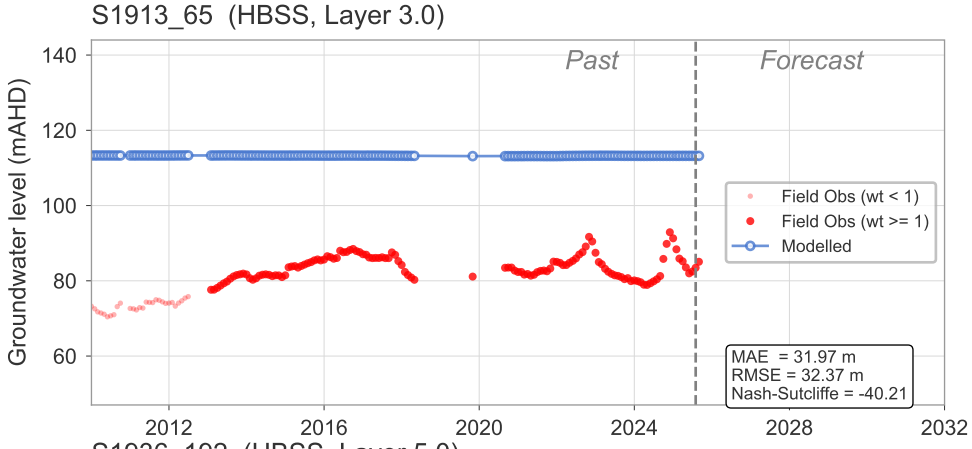
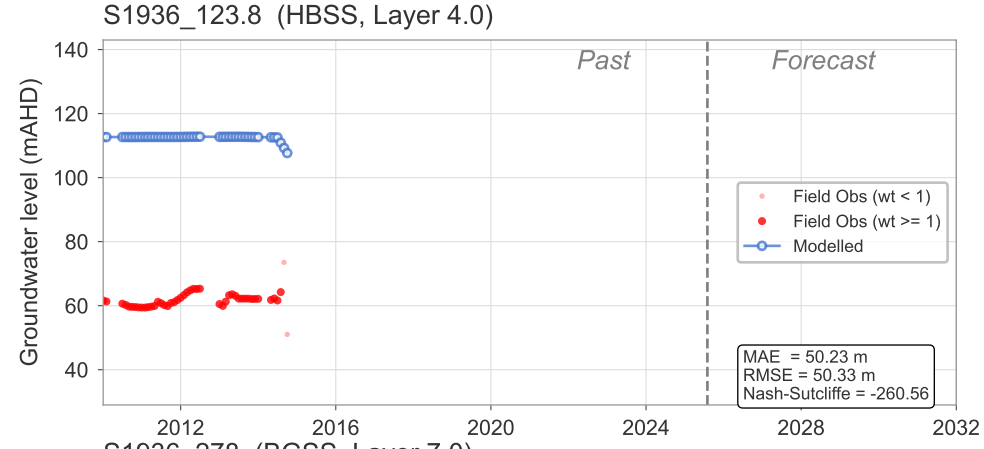
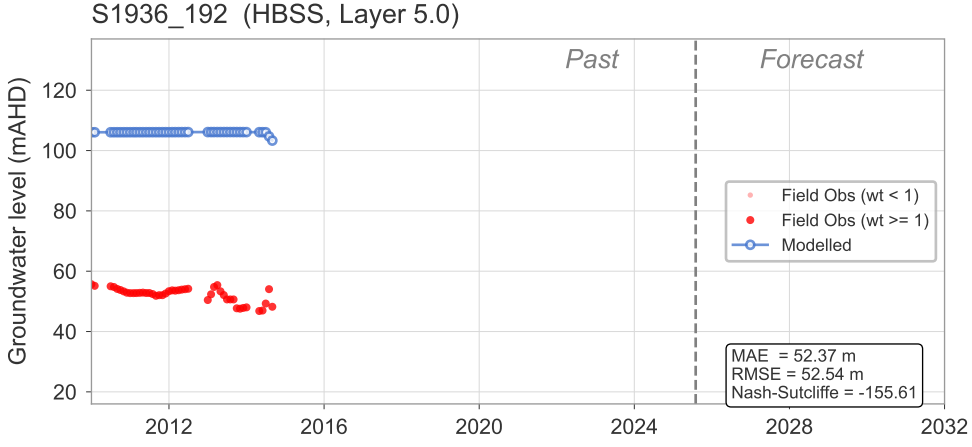
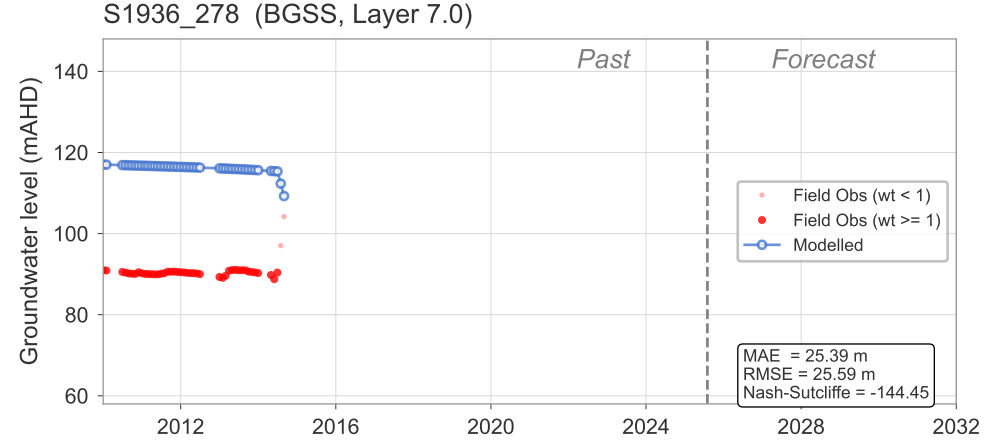




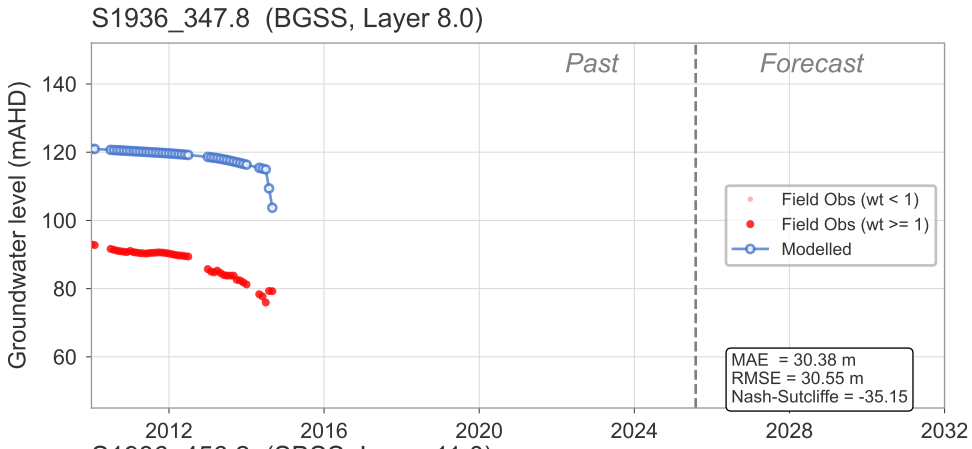


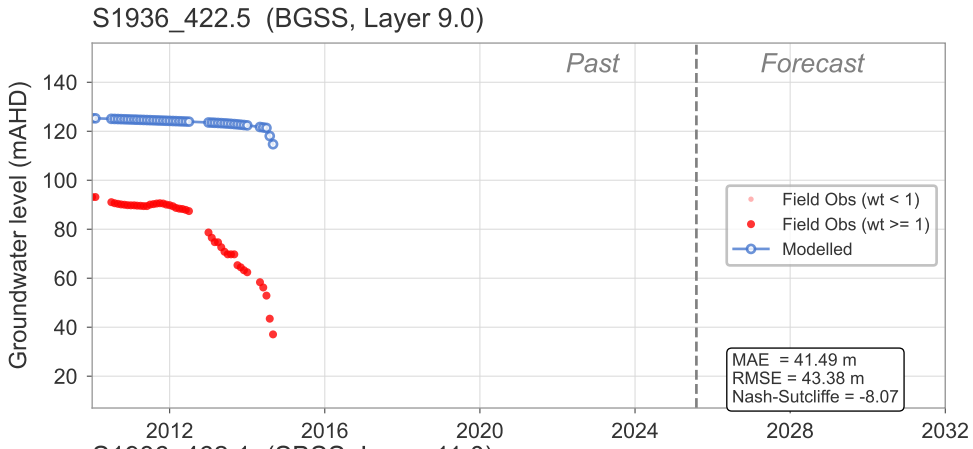


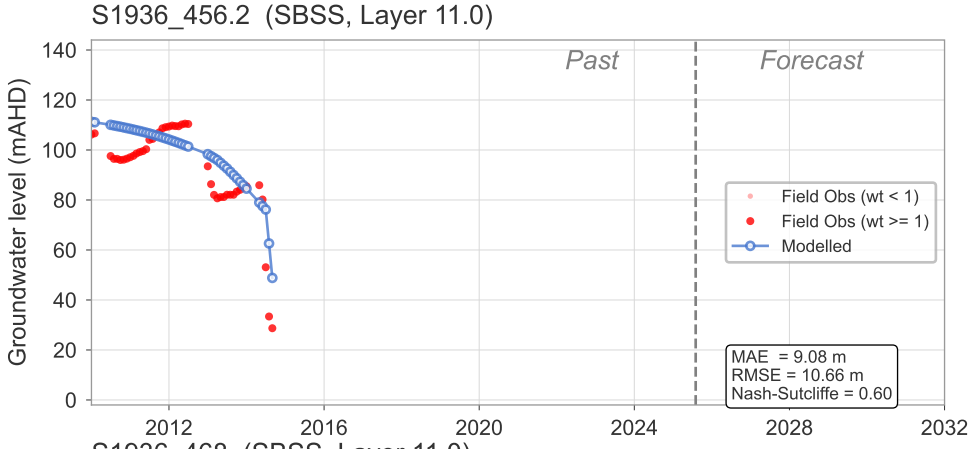


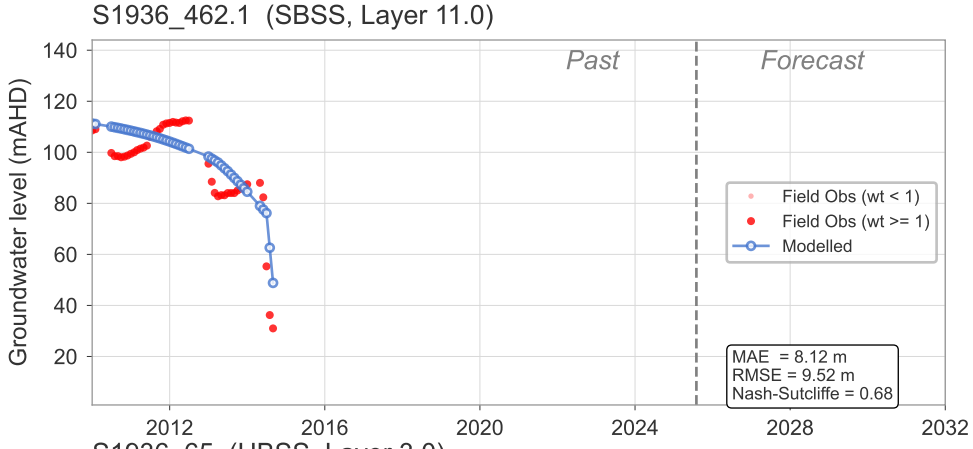


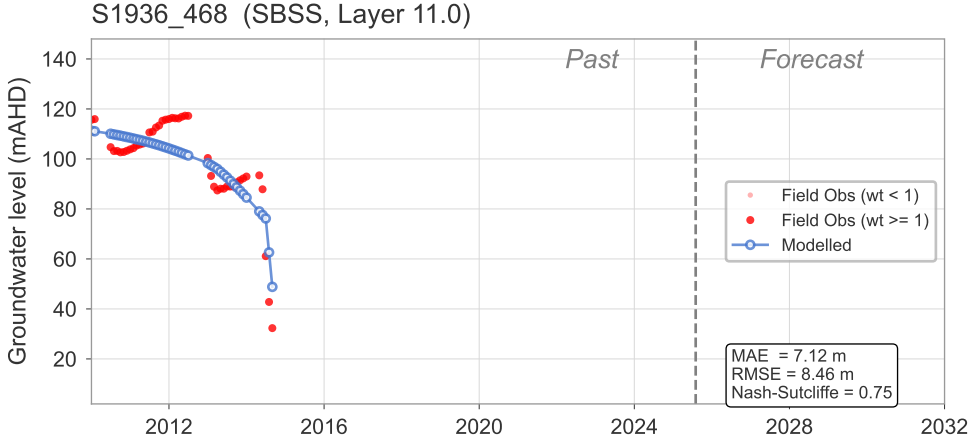
Modelled and observed groundwater hydrographs

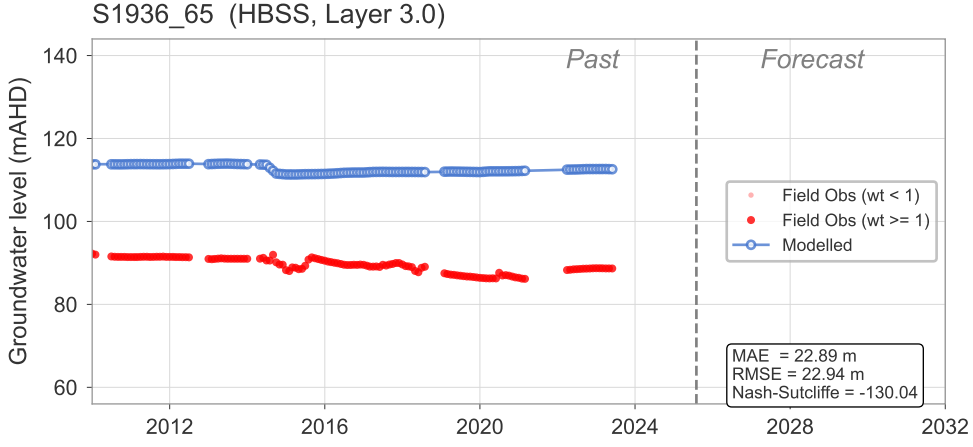












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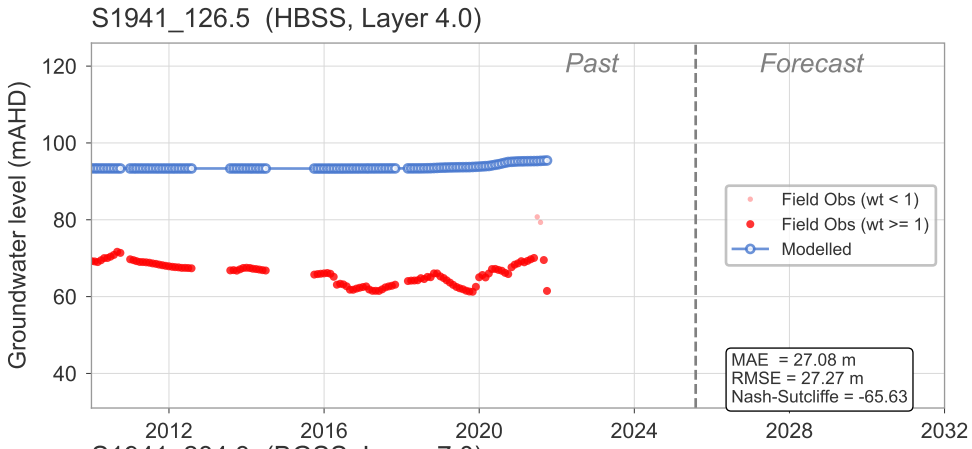

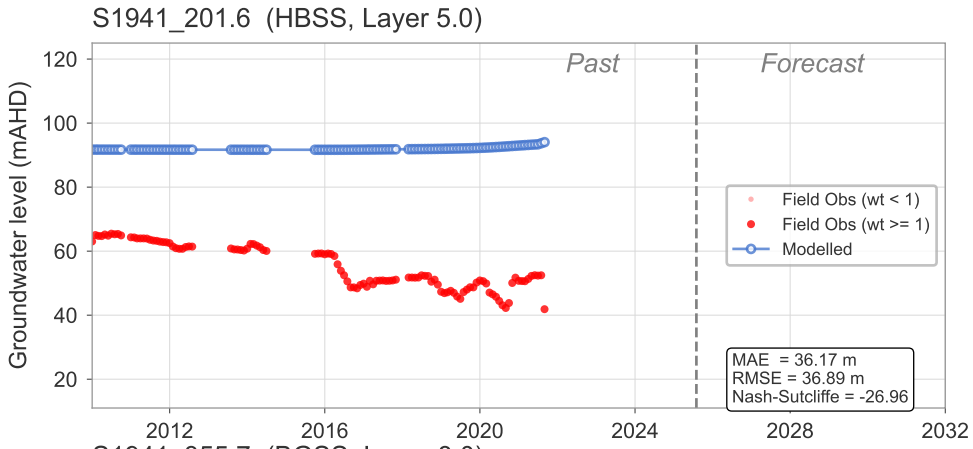

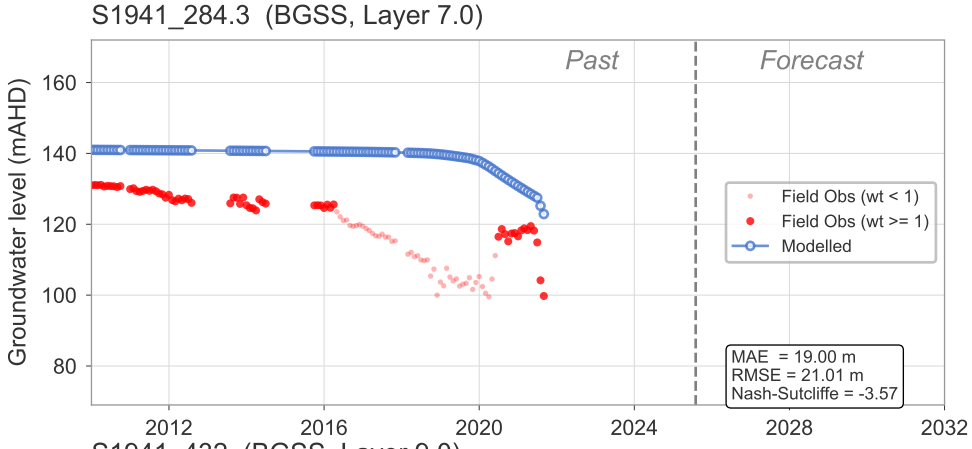

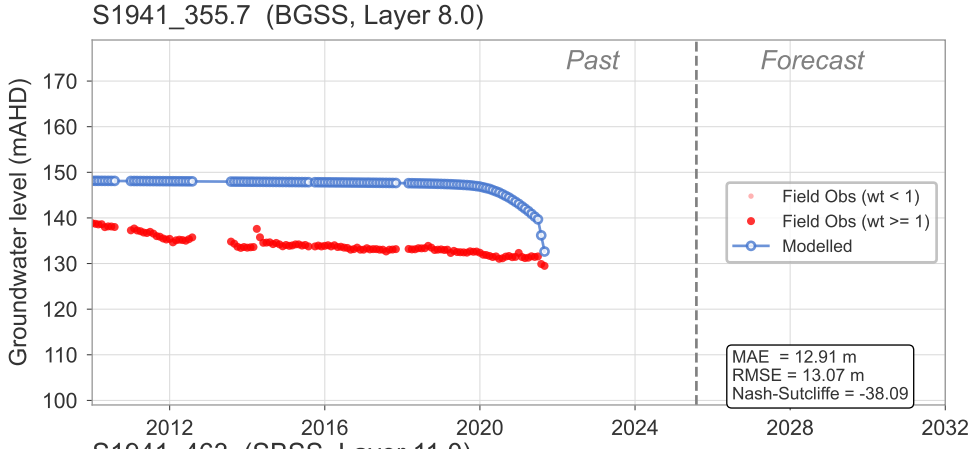

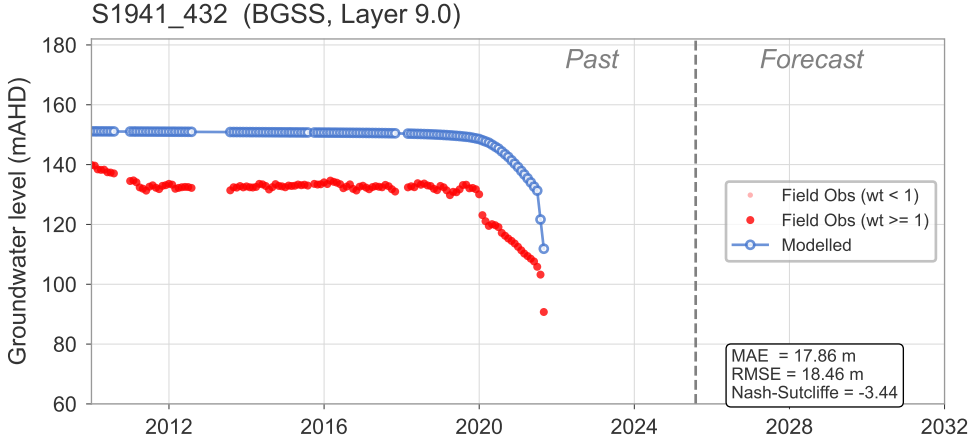

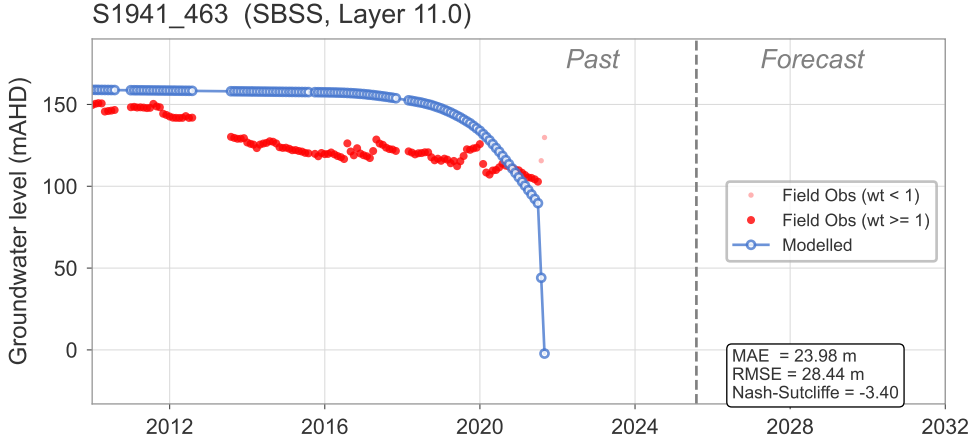

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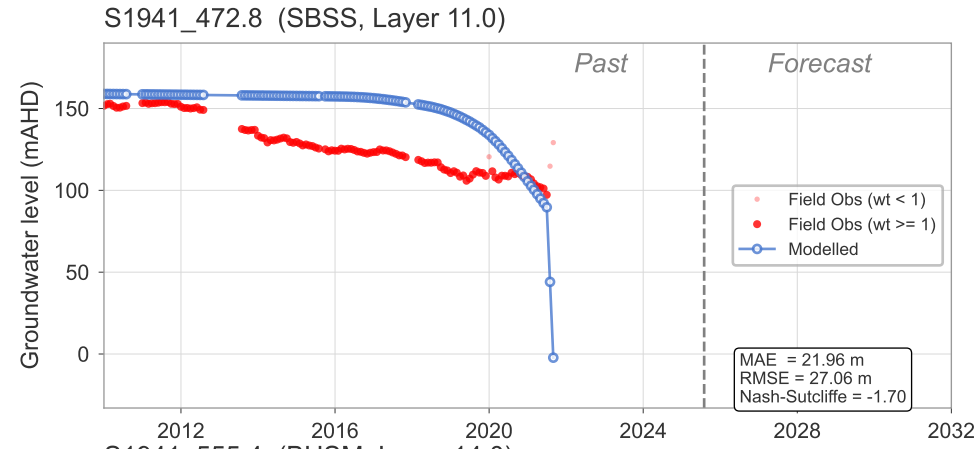

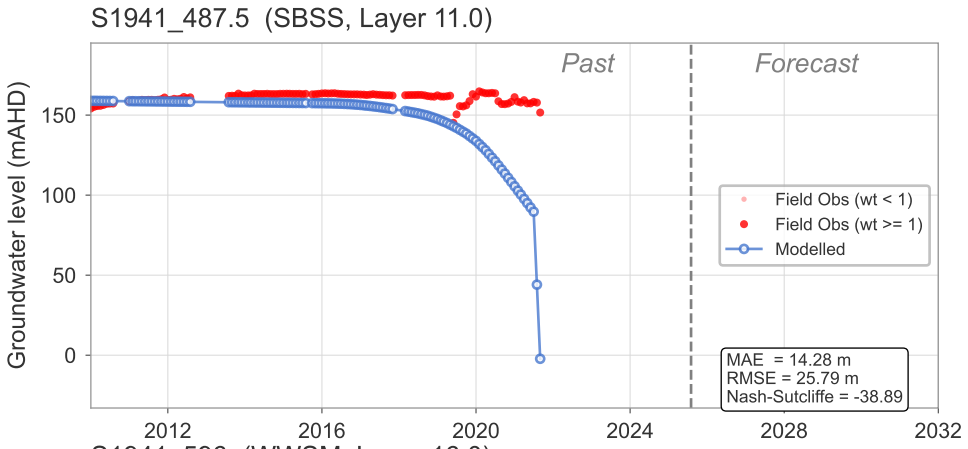

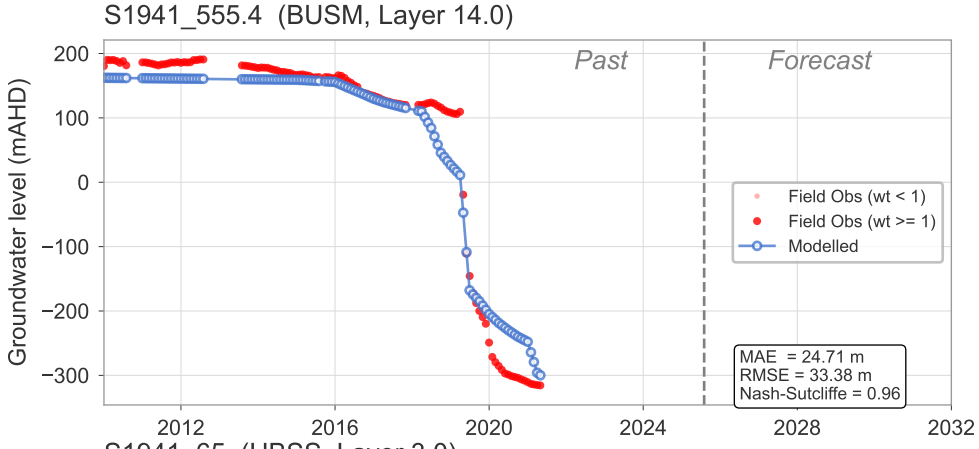

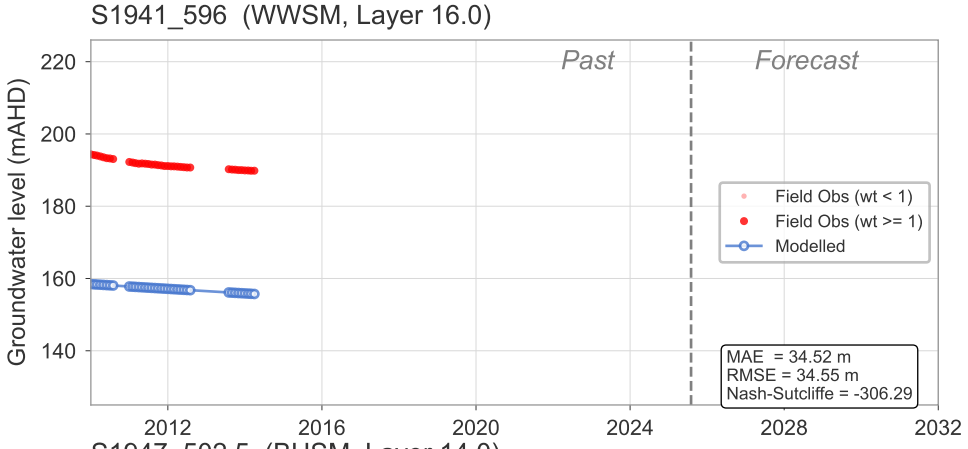

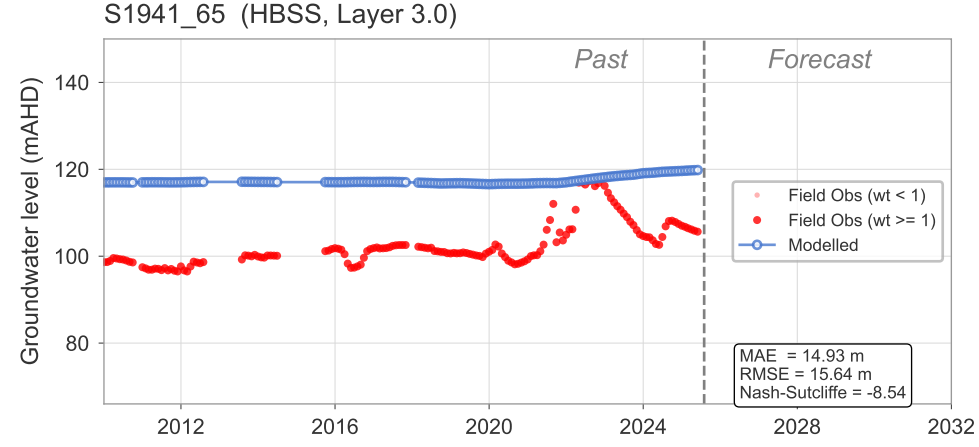

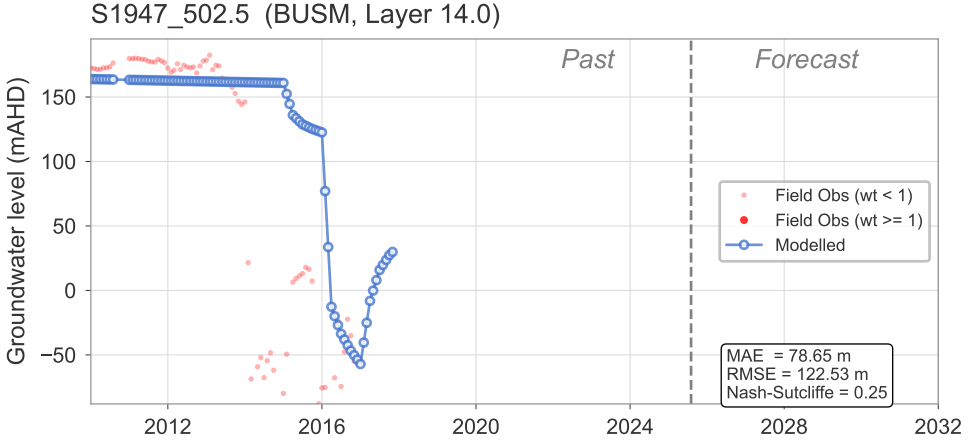

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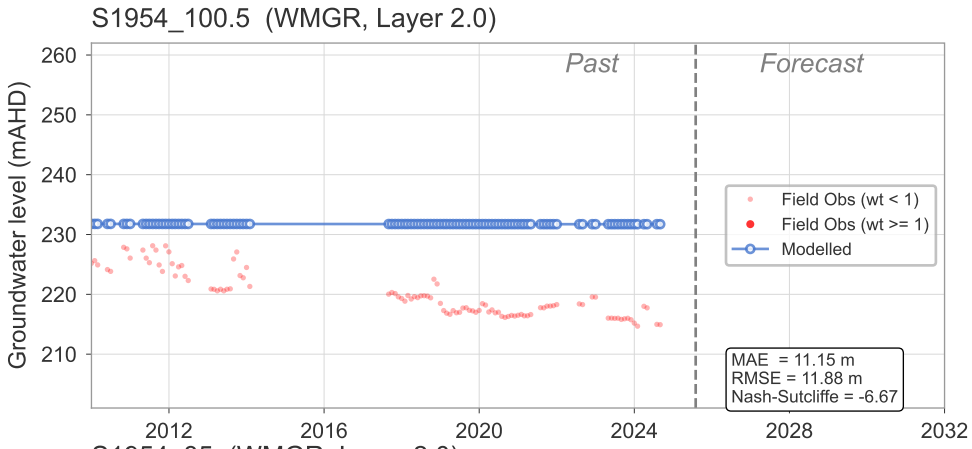

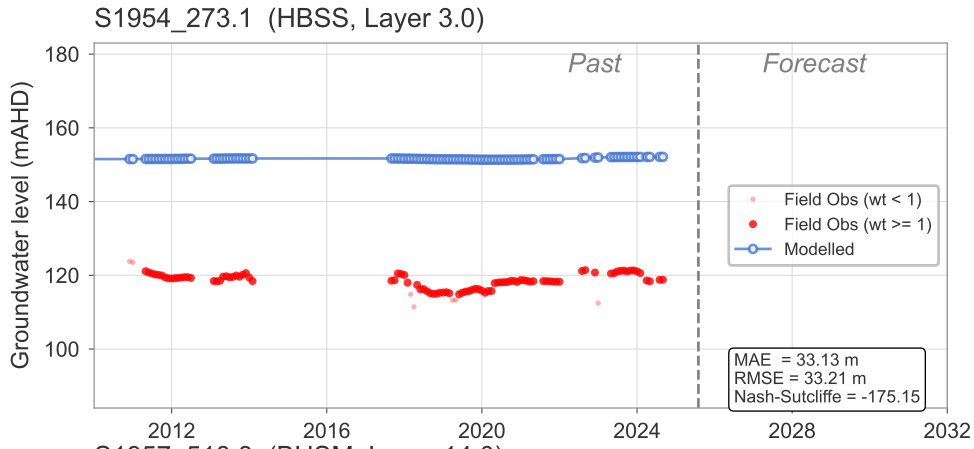

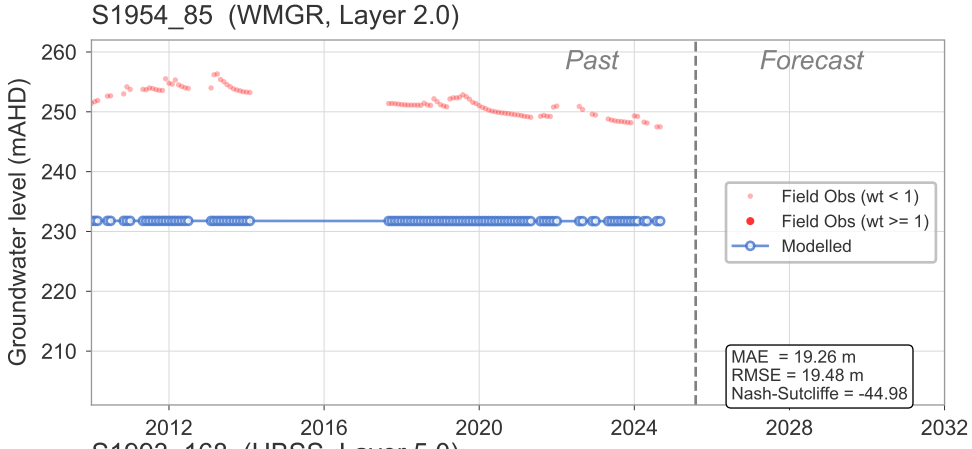

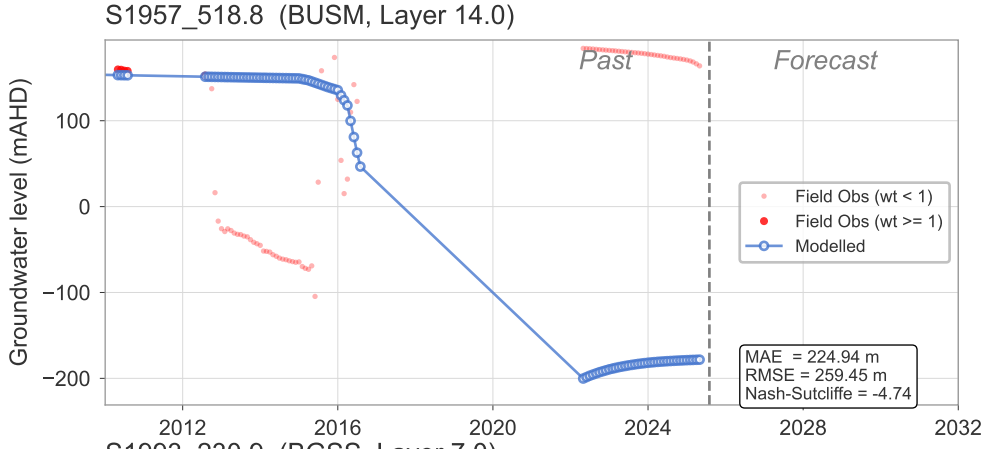

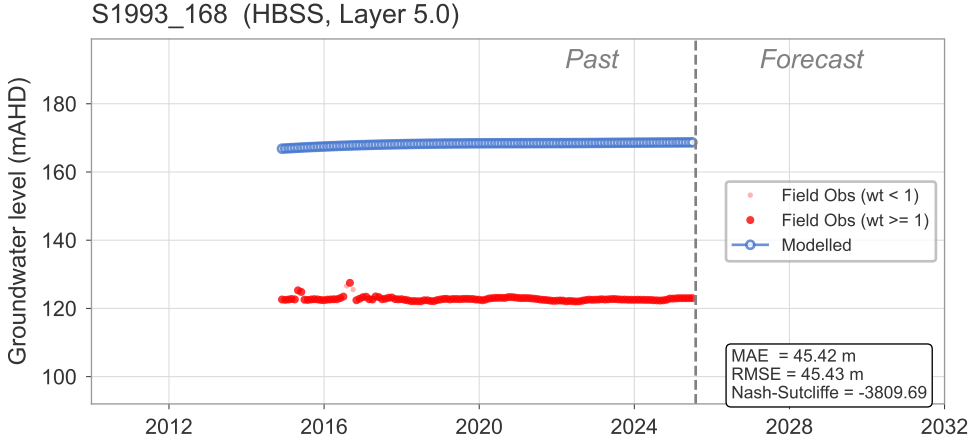

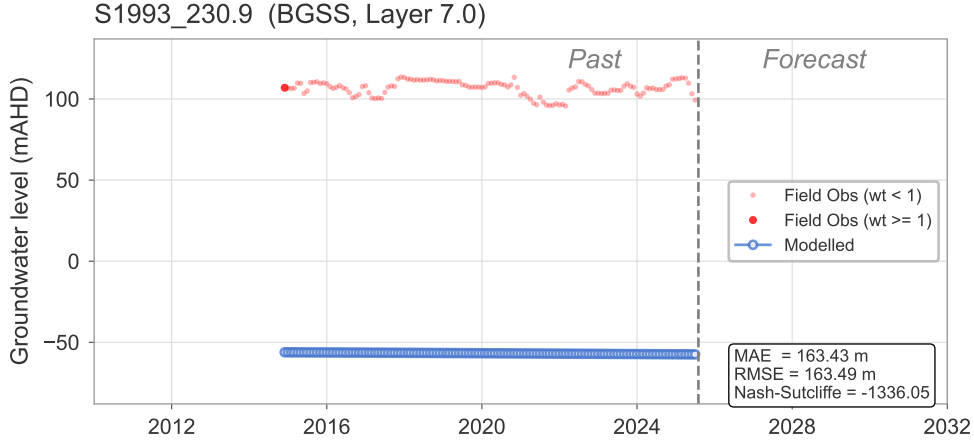

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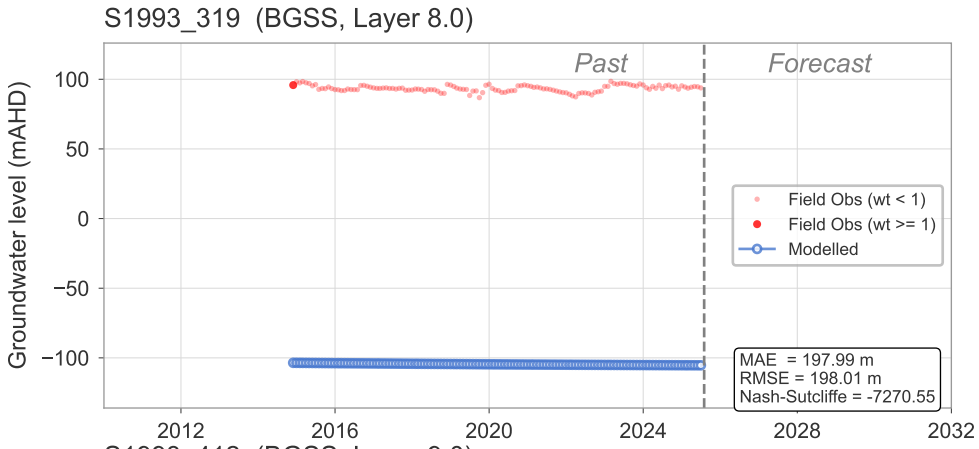

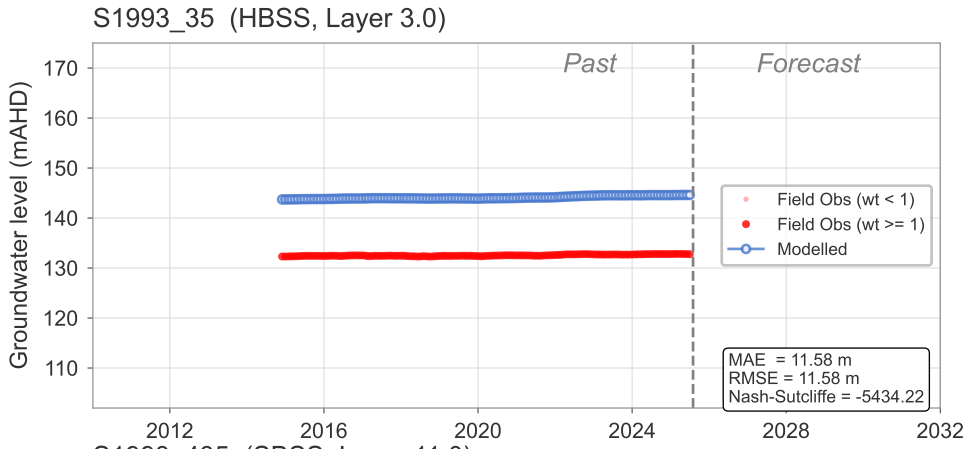

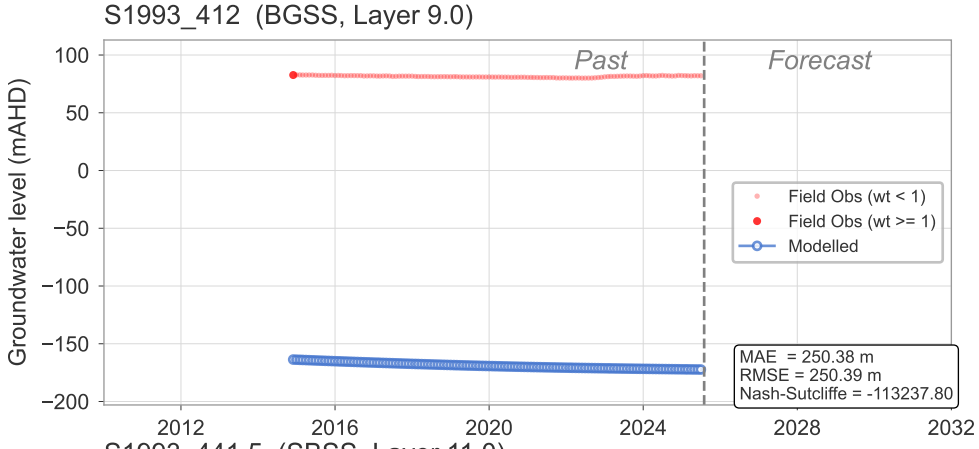

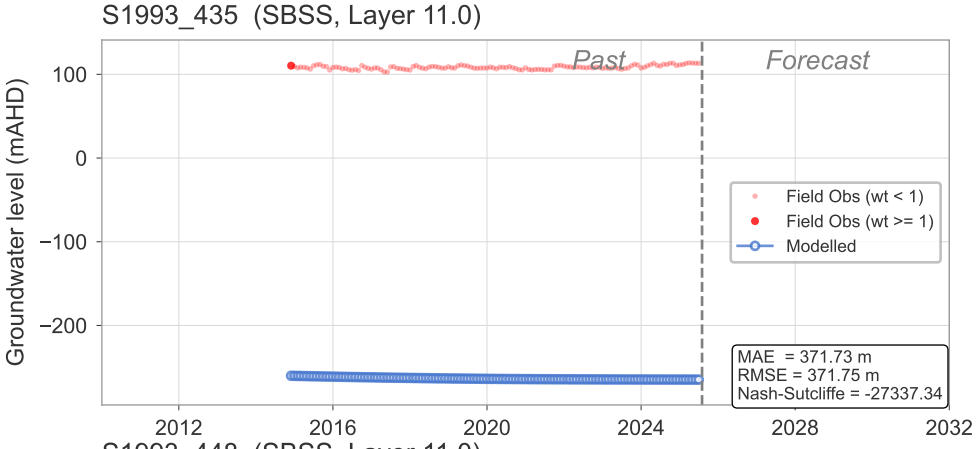

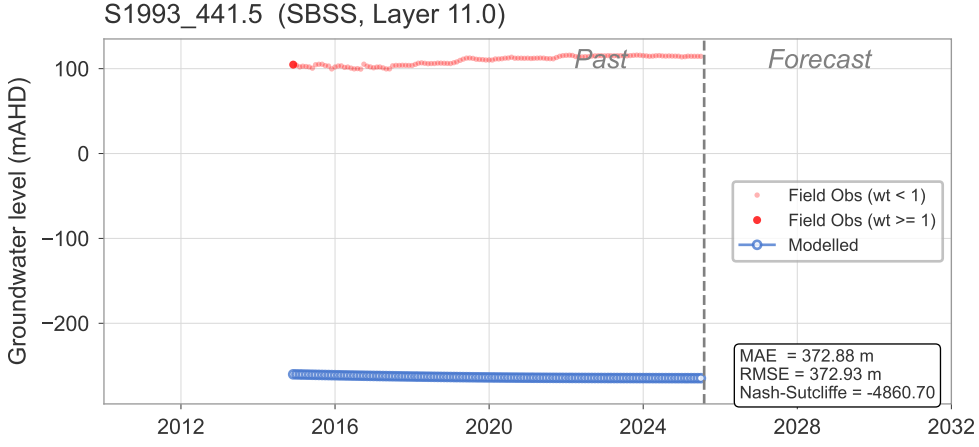

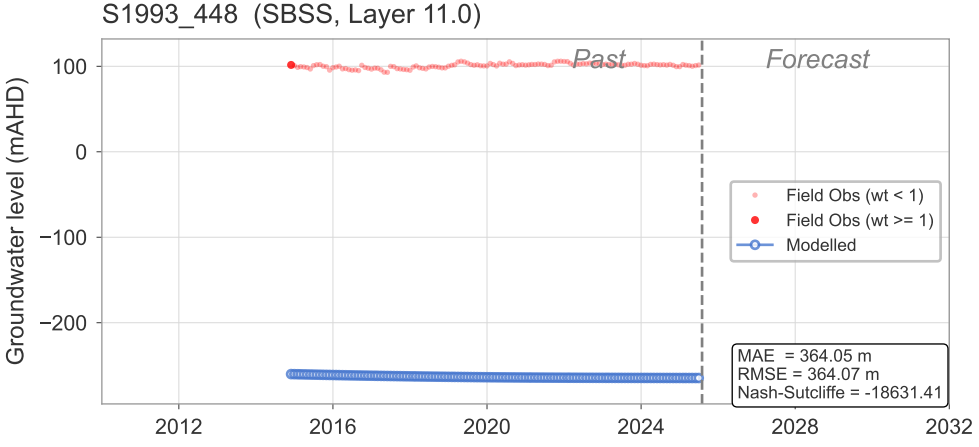

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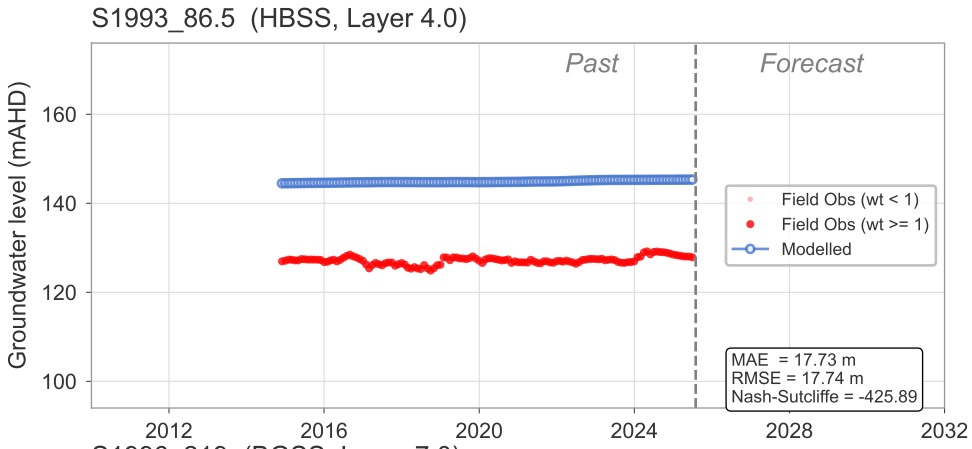

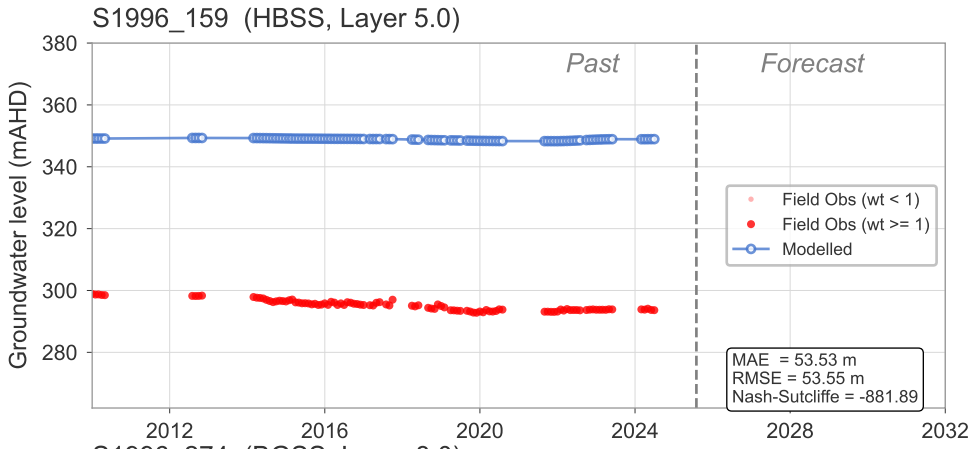

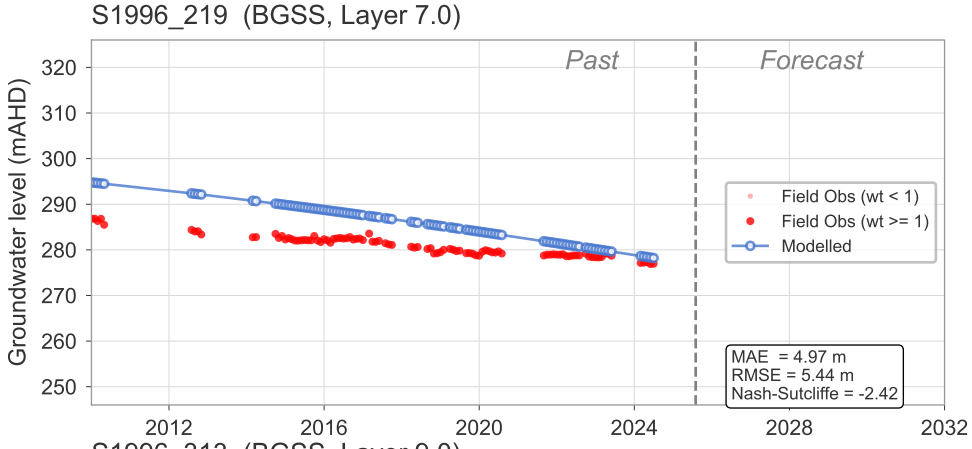

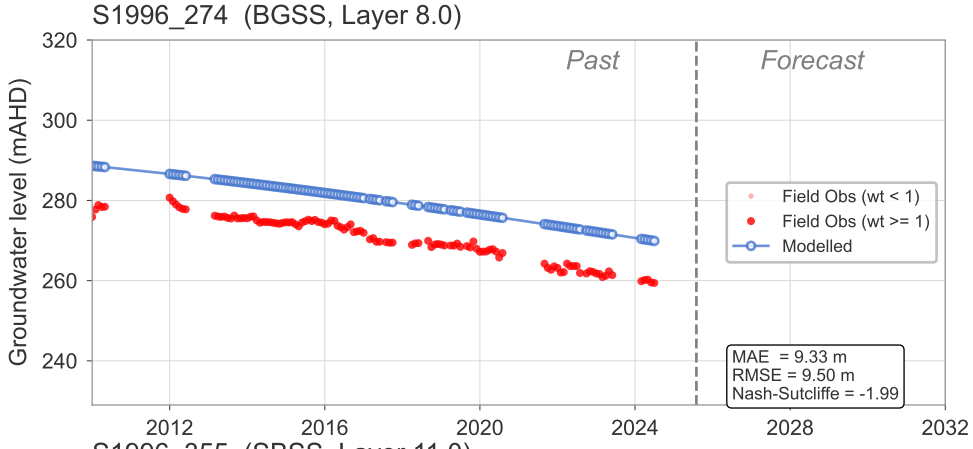

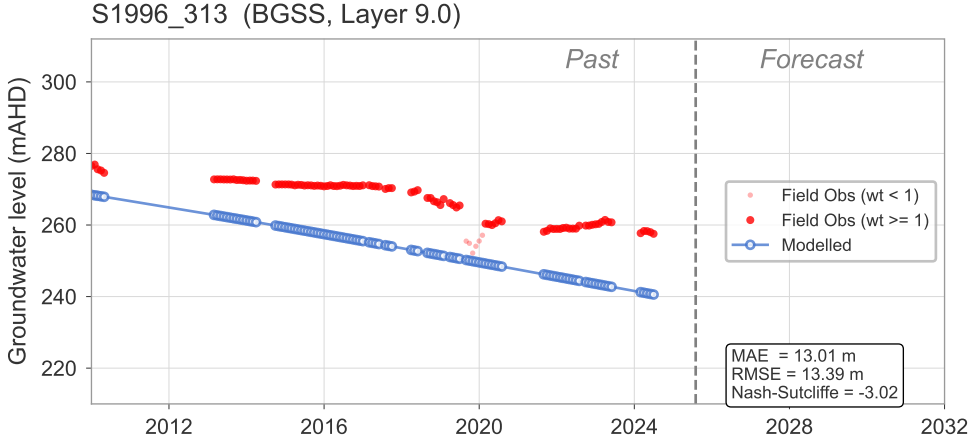

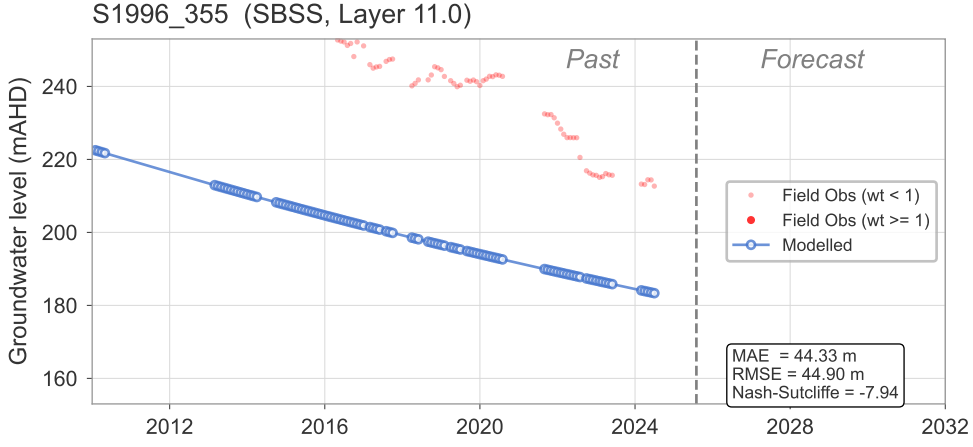

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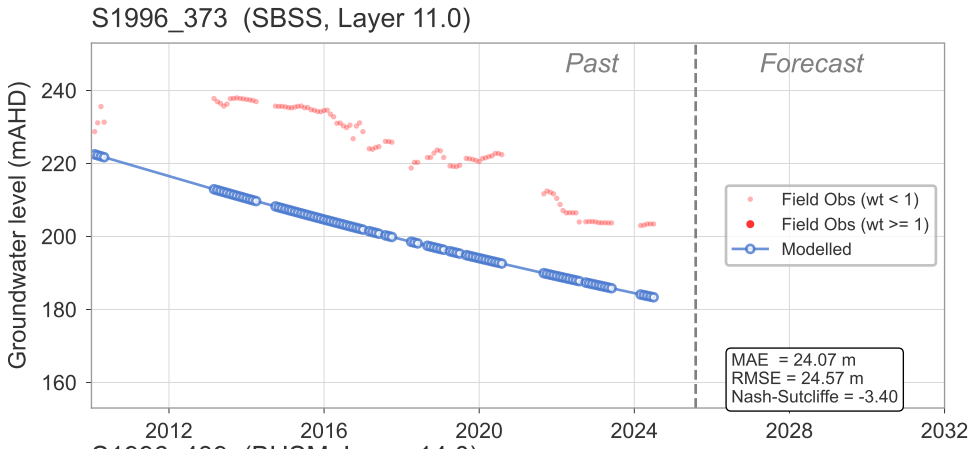
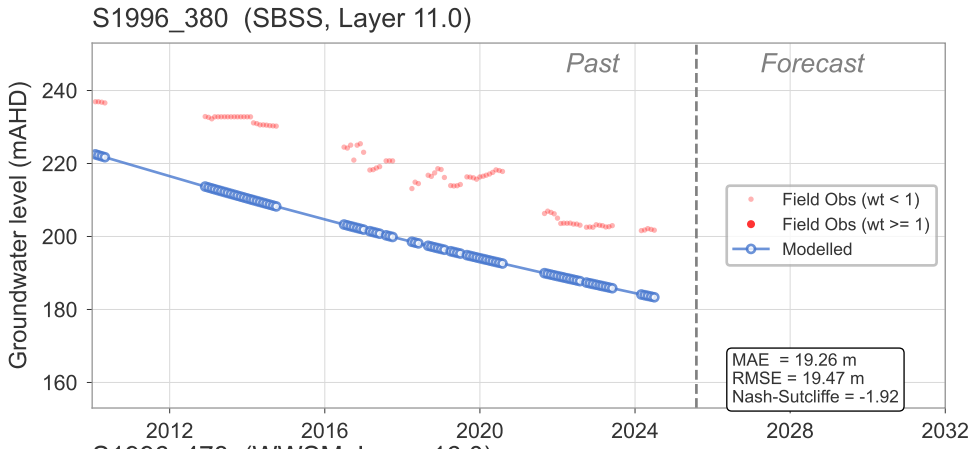
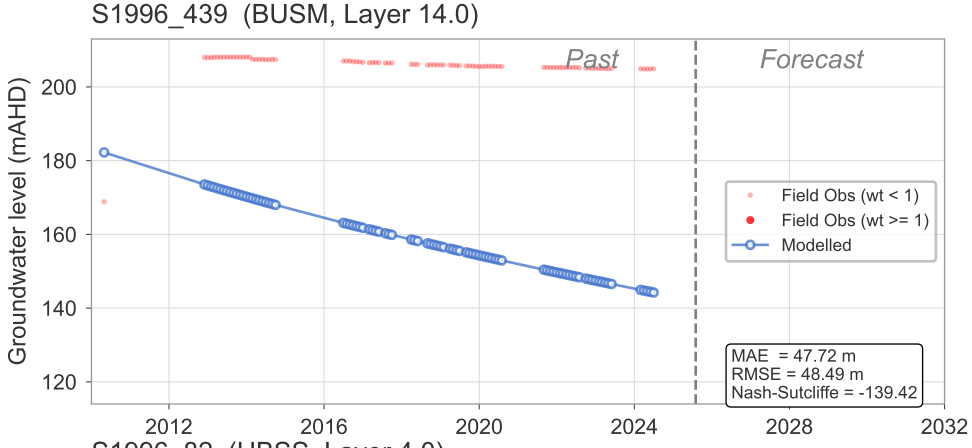
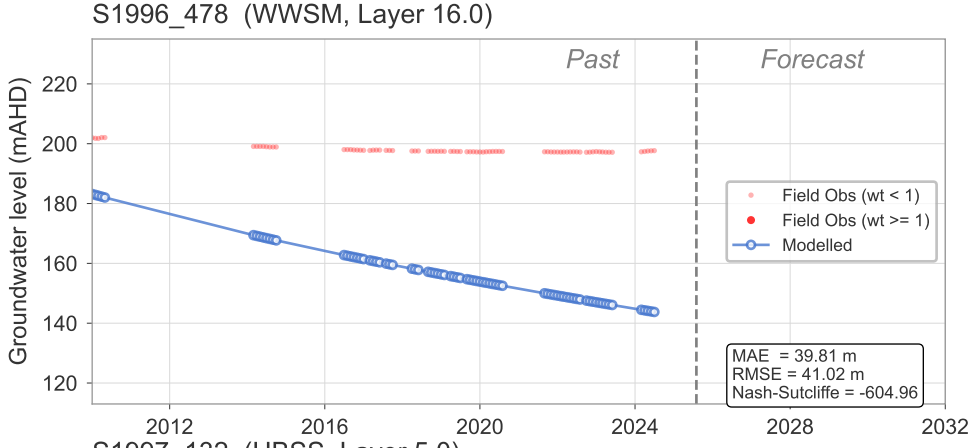
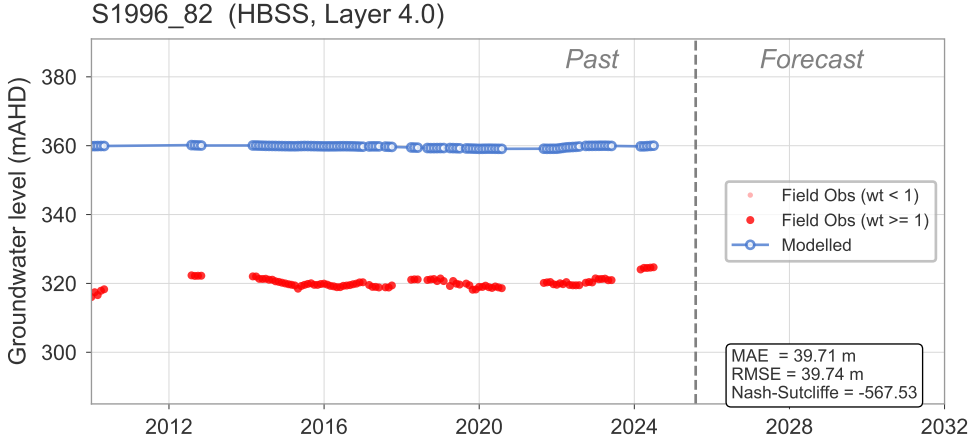
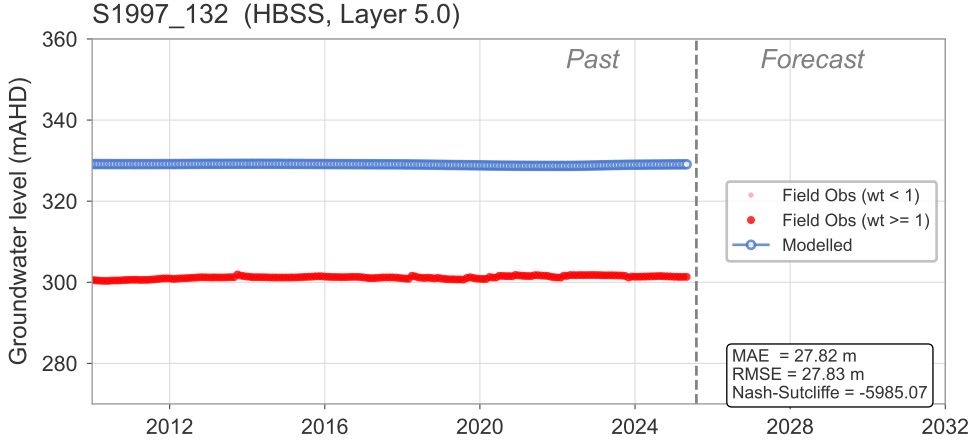




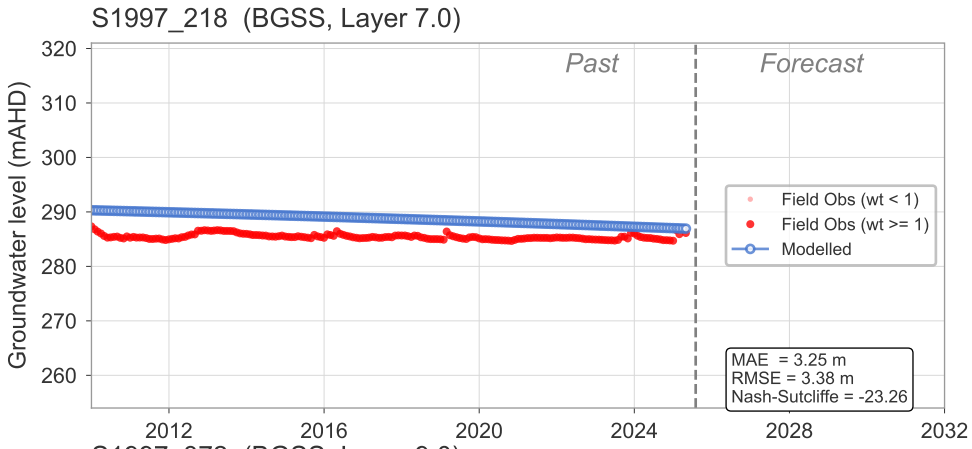


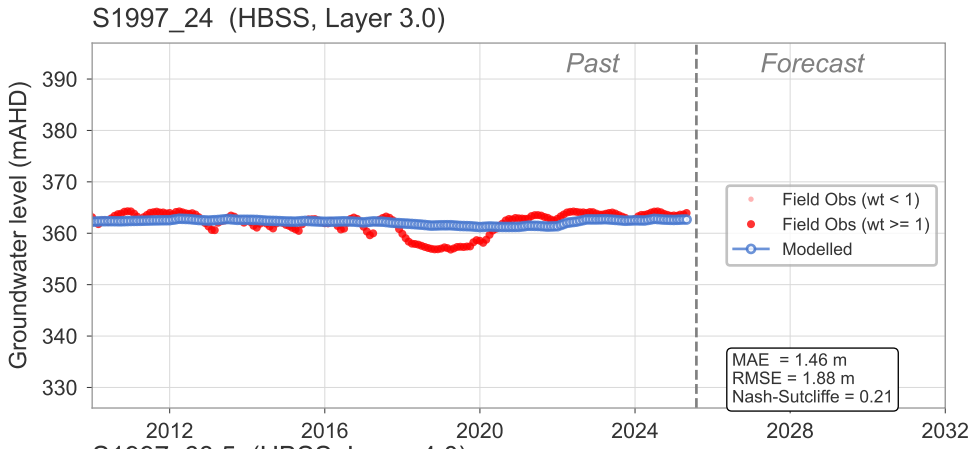


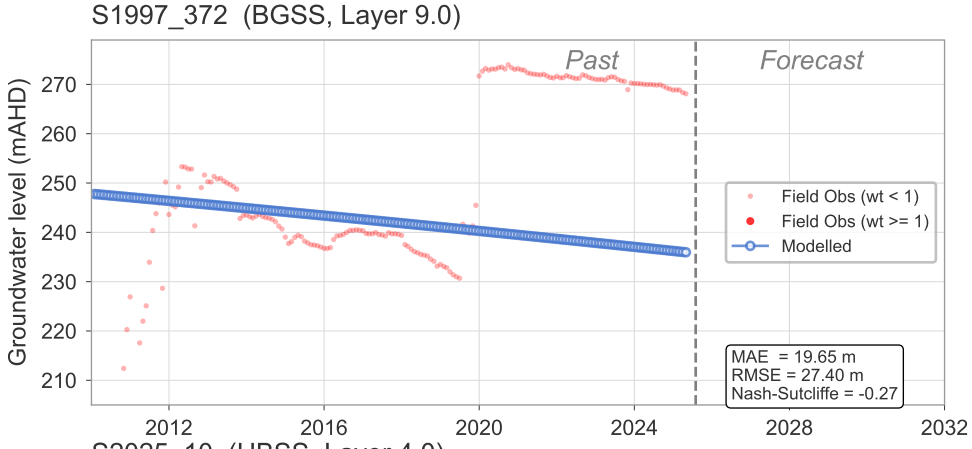


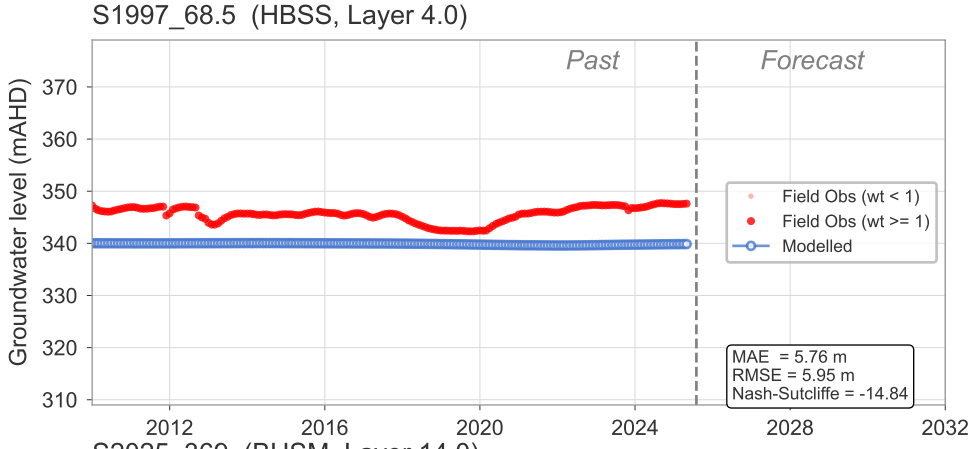


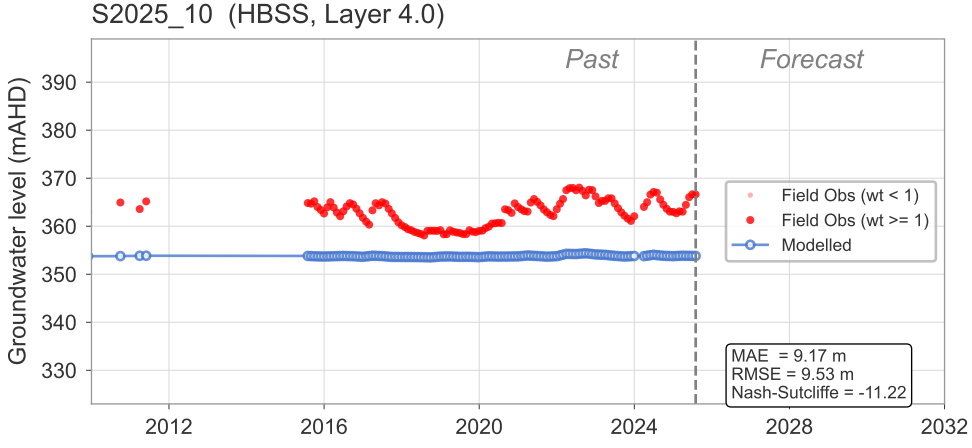
Modelled and observed groundwater hydrographs

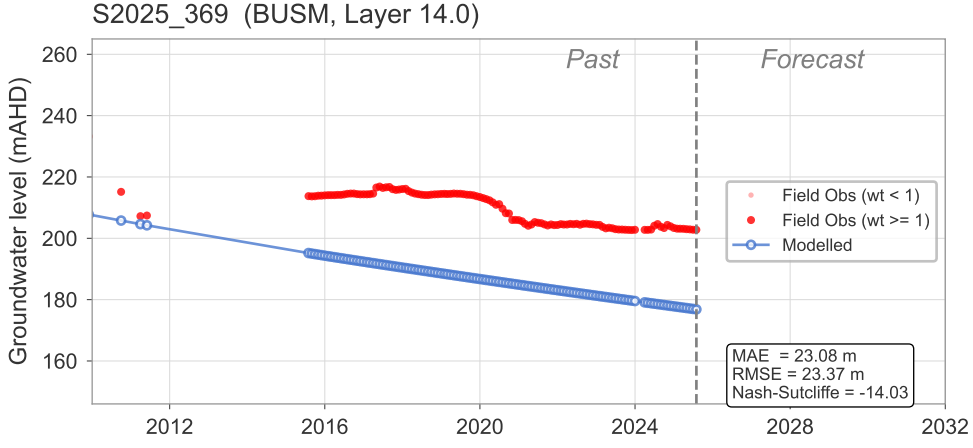






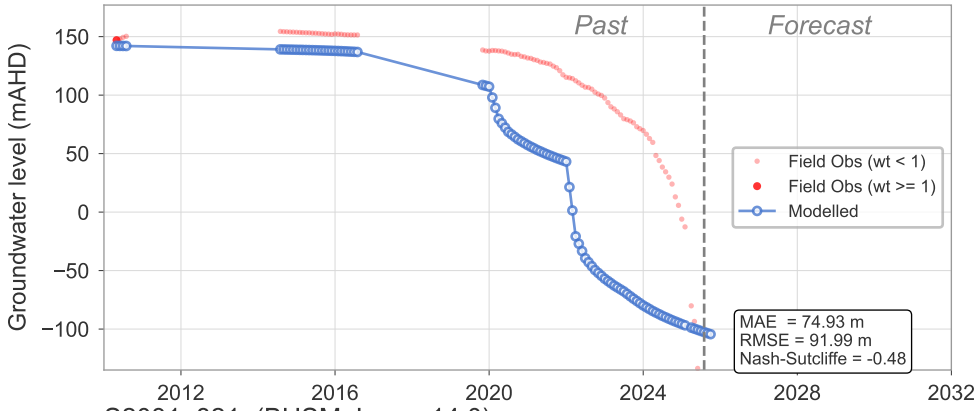






Modelled and observed groundwater hydrographs

S2027_735.5 (BUSM, Layer 14.0)



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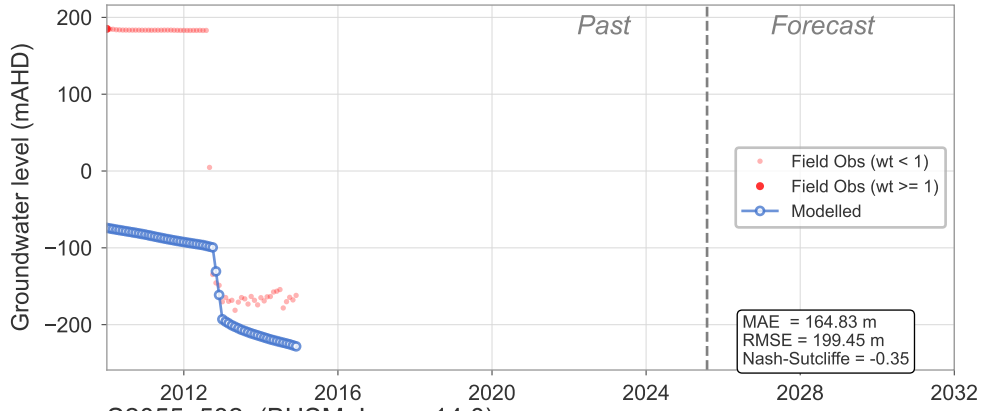

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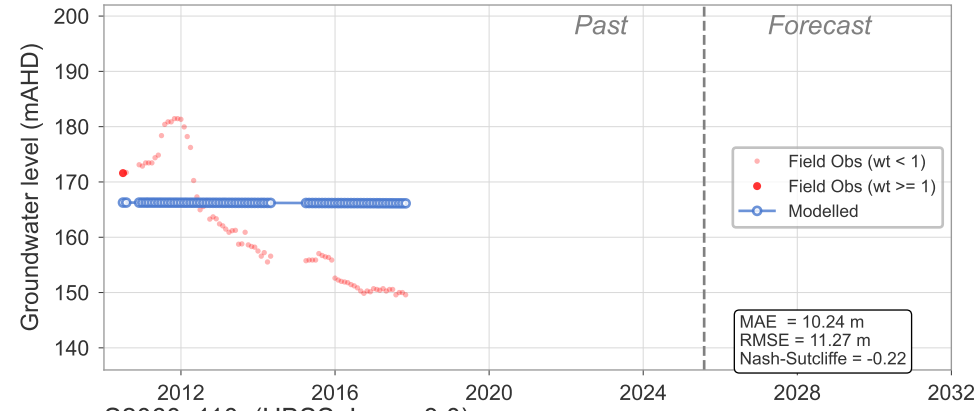

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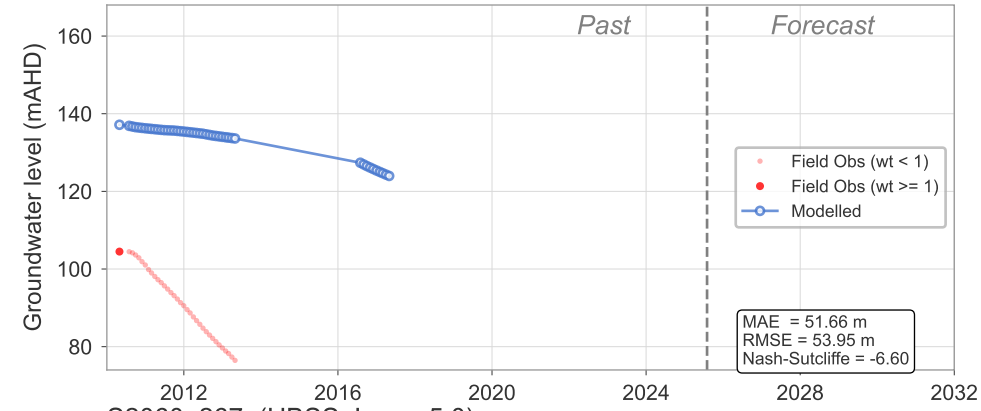
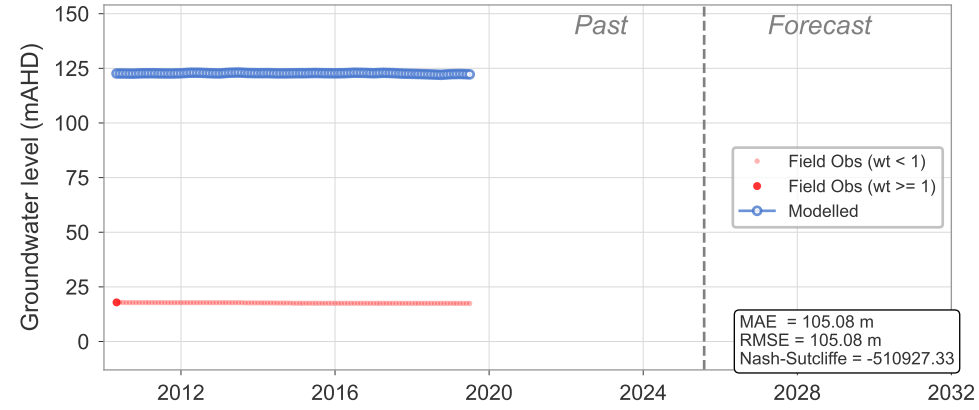
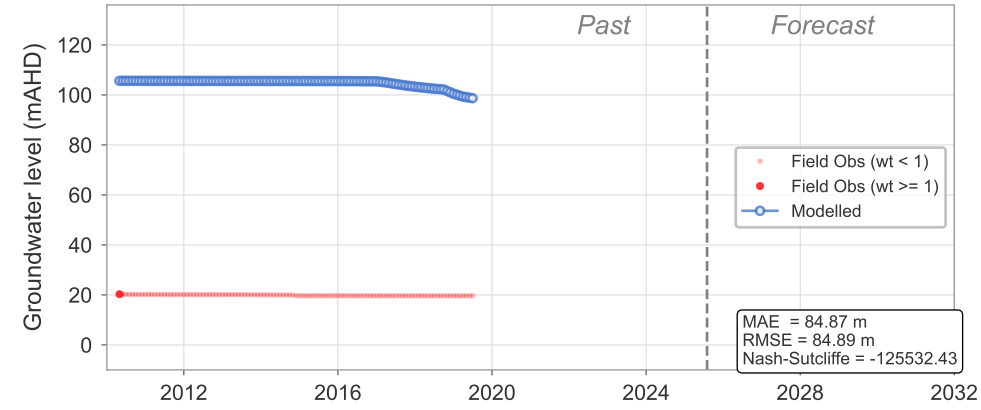


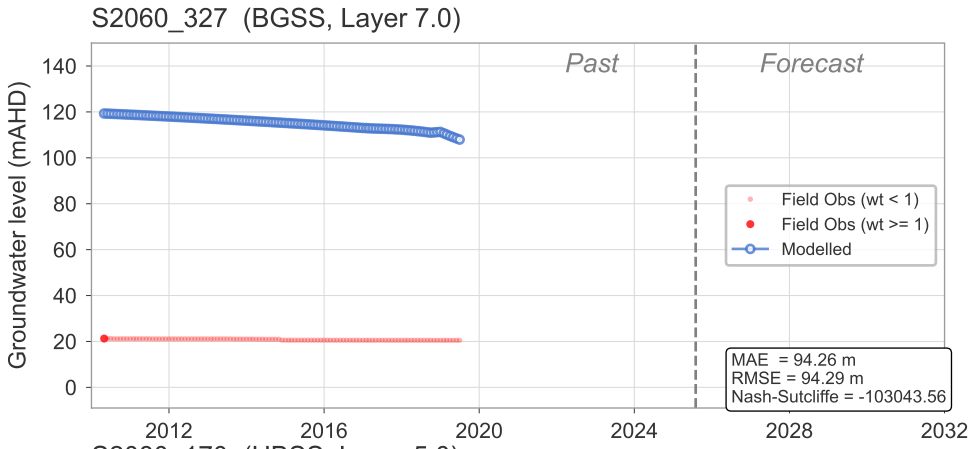
S2060_110 (HBSS, Layer 3.0)

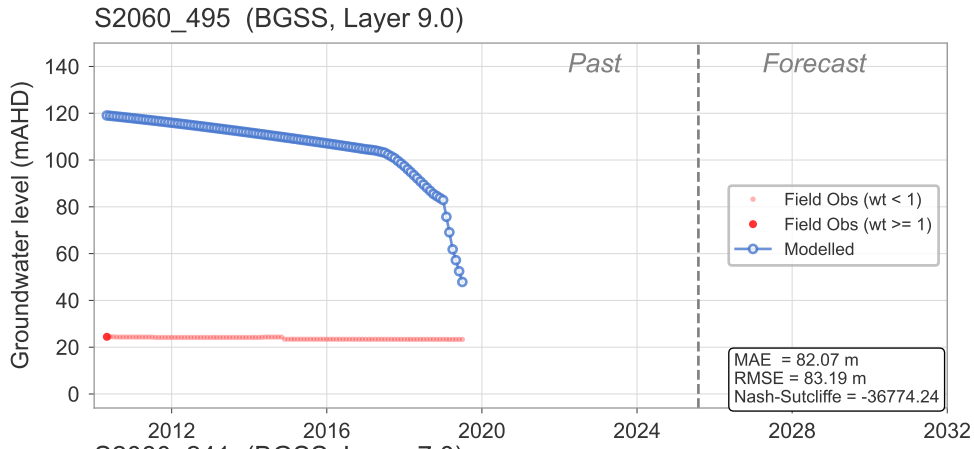


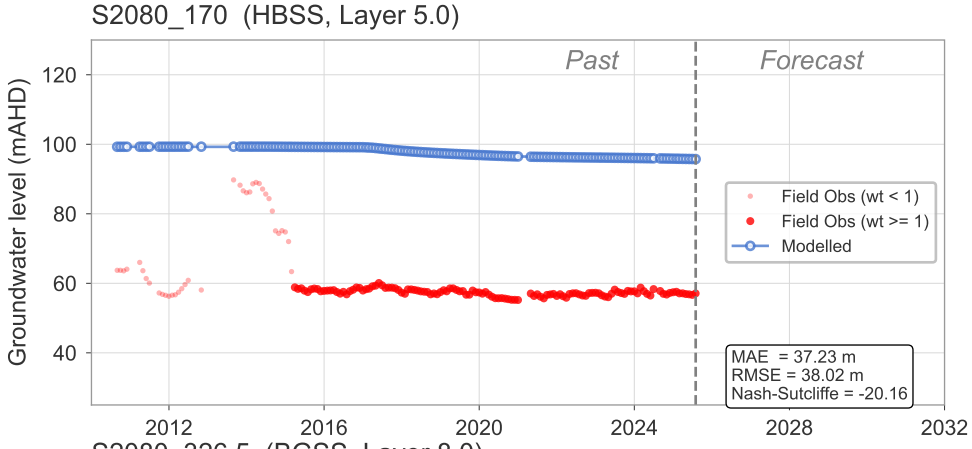
S2060_267 (HBSS, Layer 5.0)

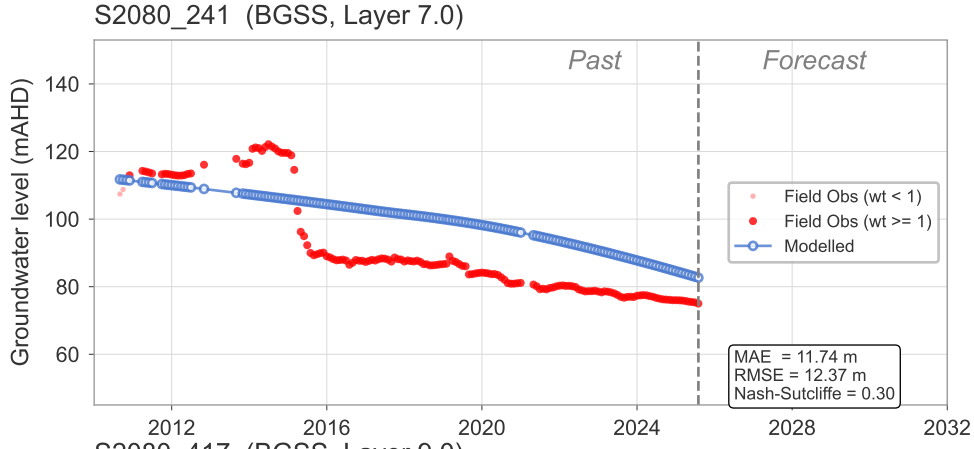


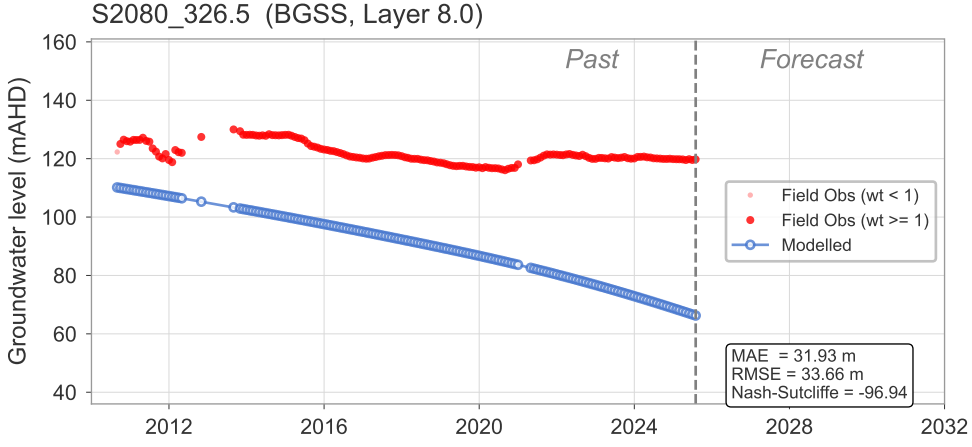
Modelled and observed groundwater hydrographs

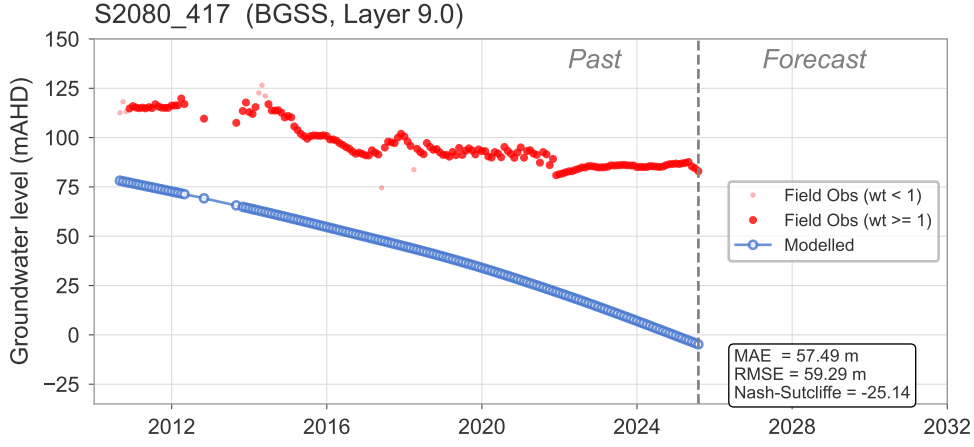




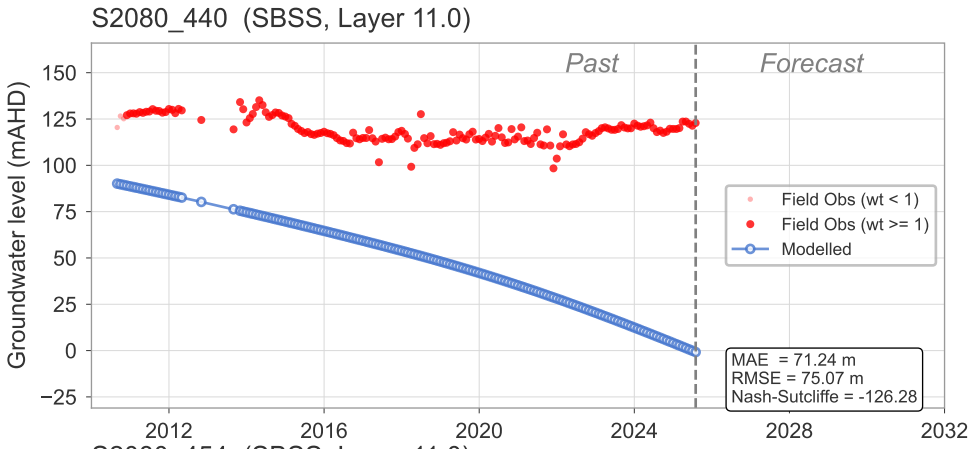


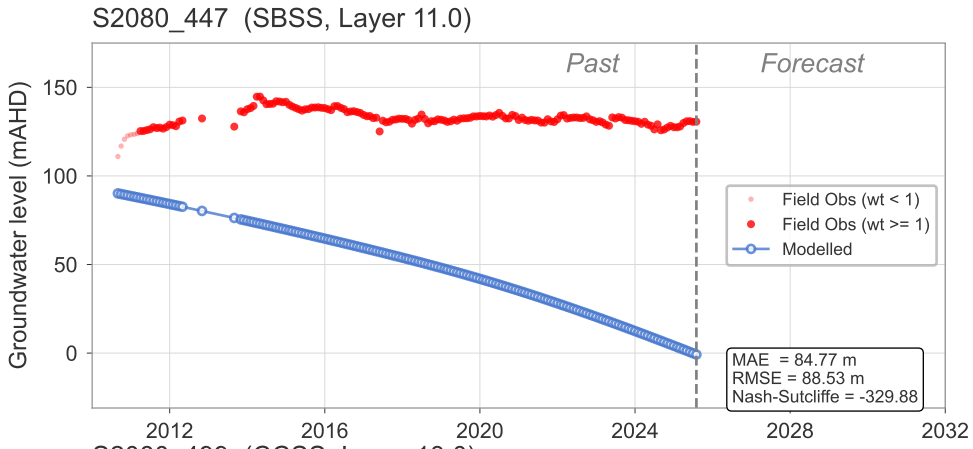


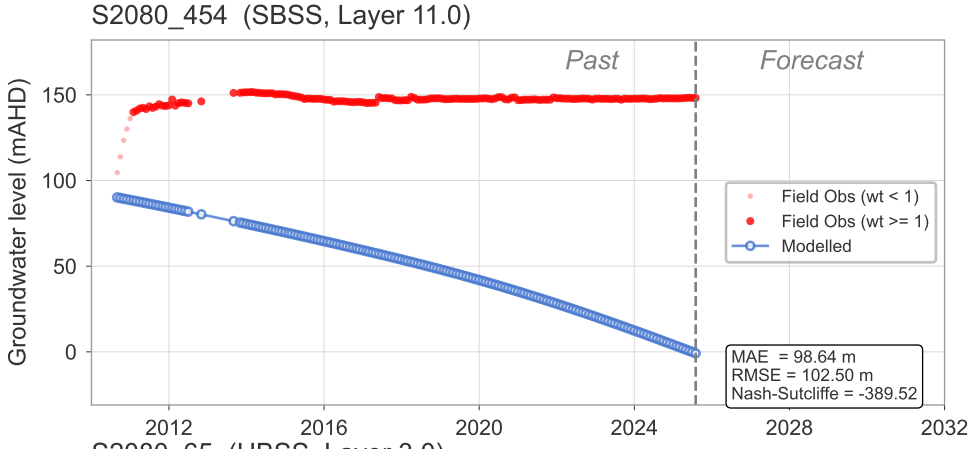


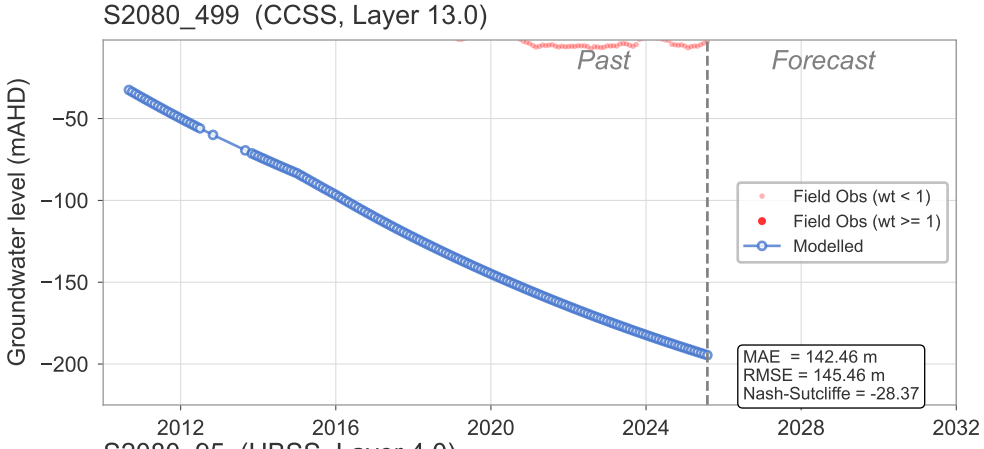


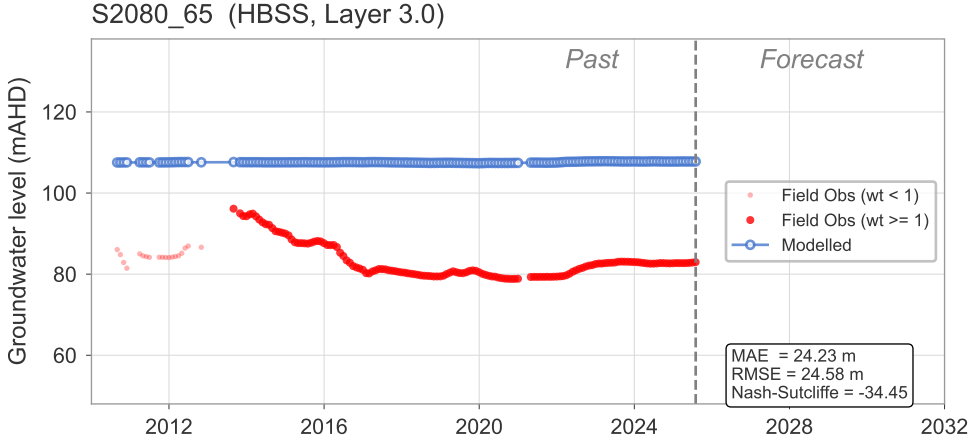
Modelled and observed groundwater hydrographs

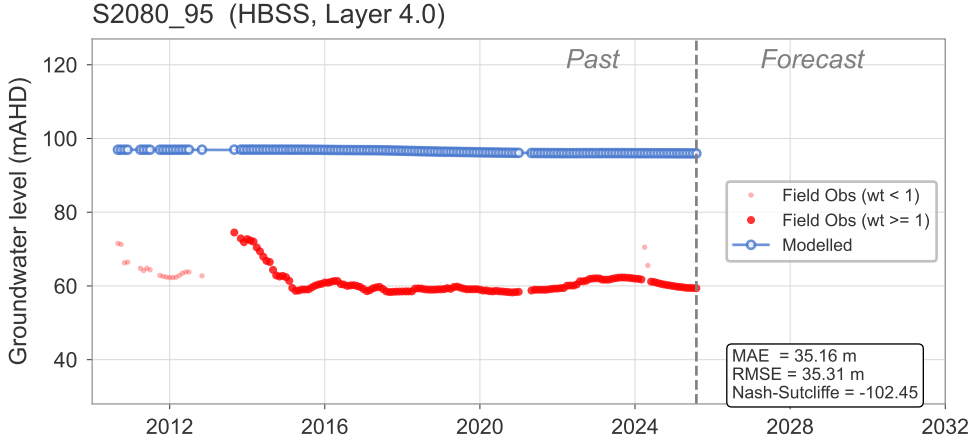




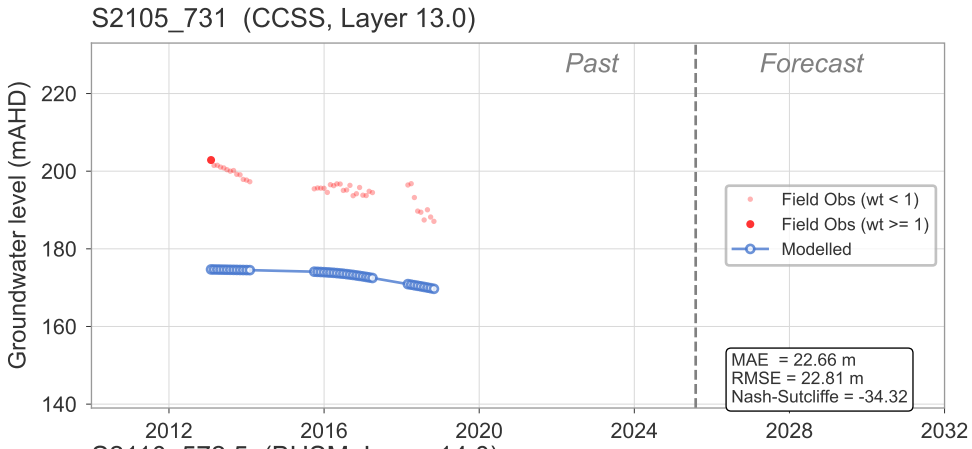


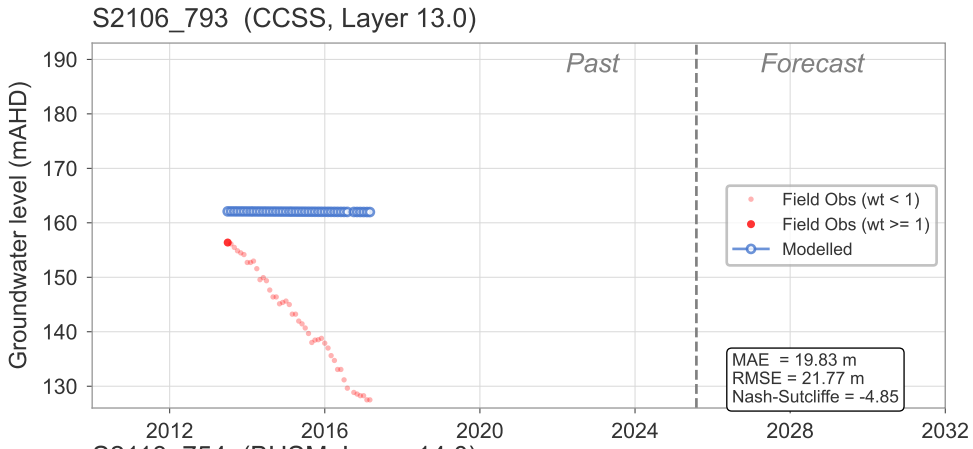


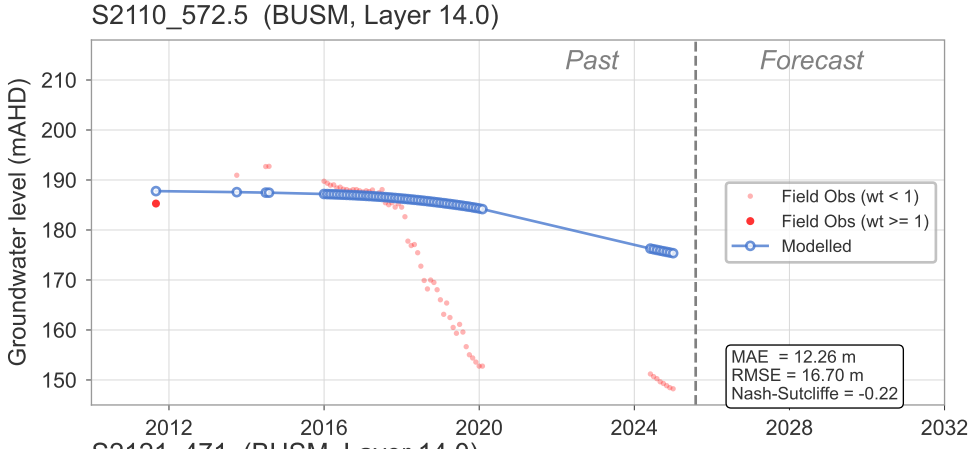


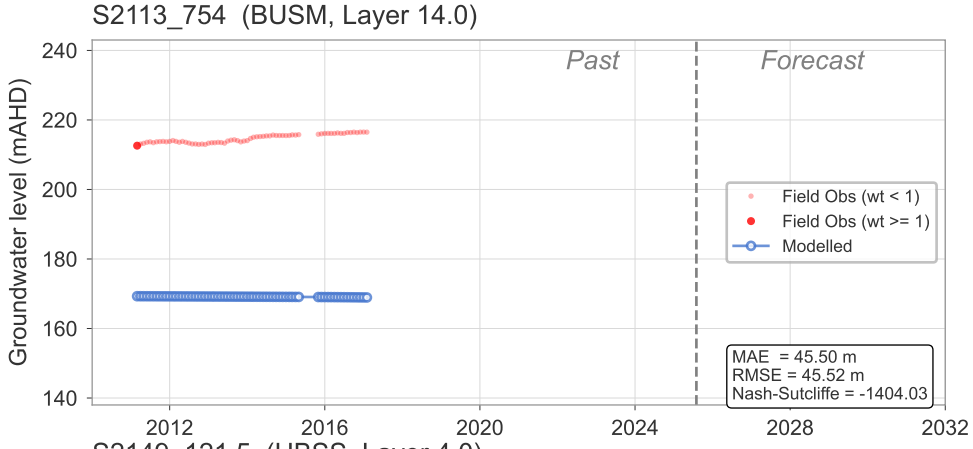


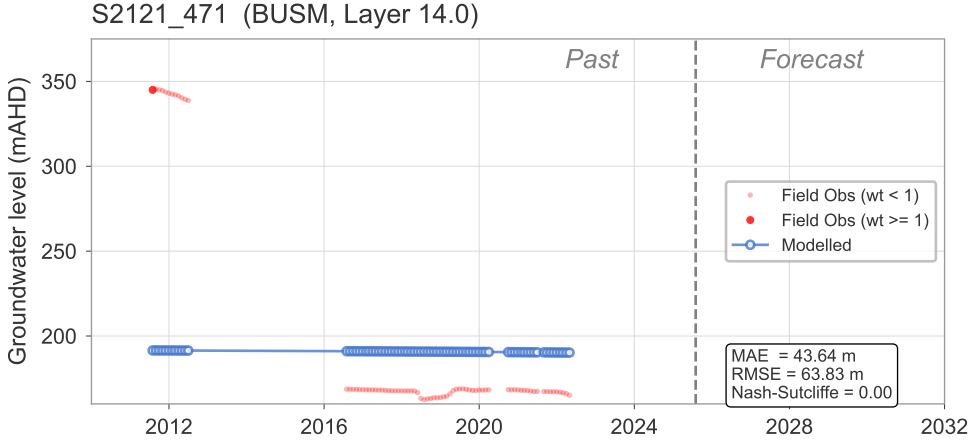
Modelled and observed groundwater hydrographs

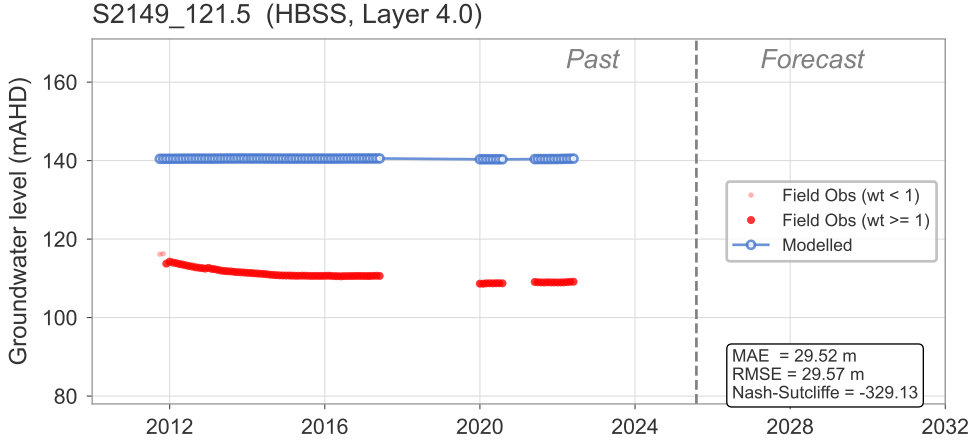




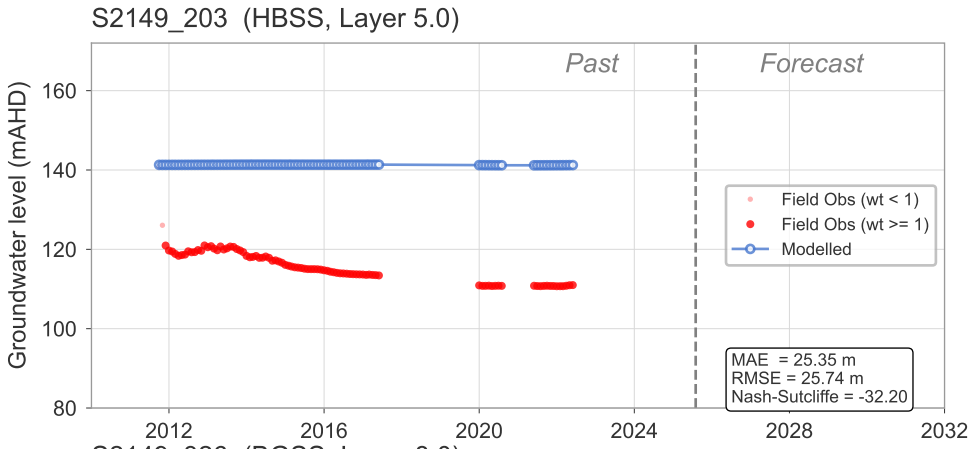


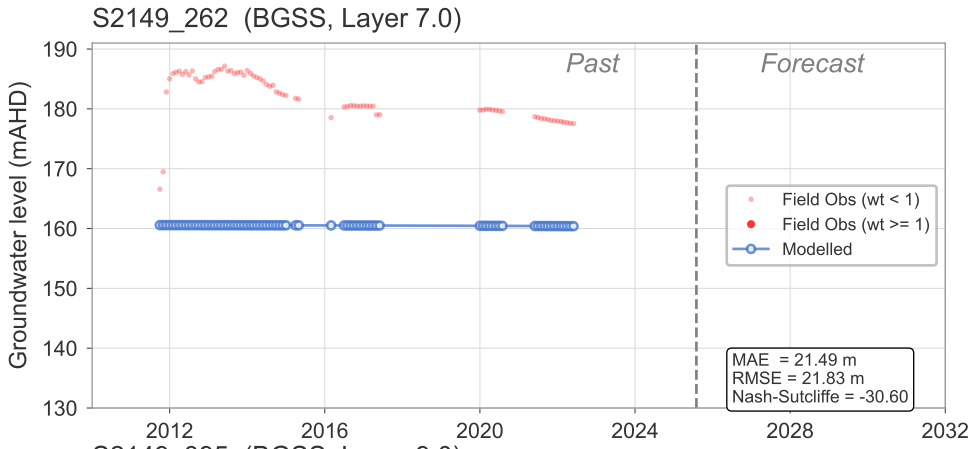


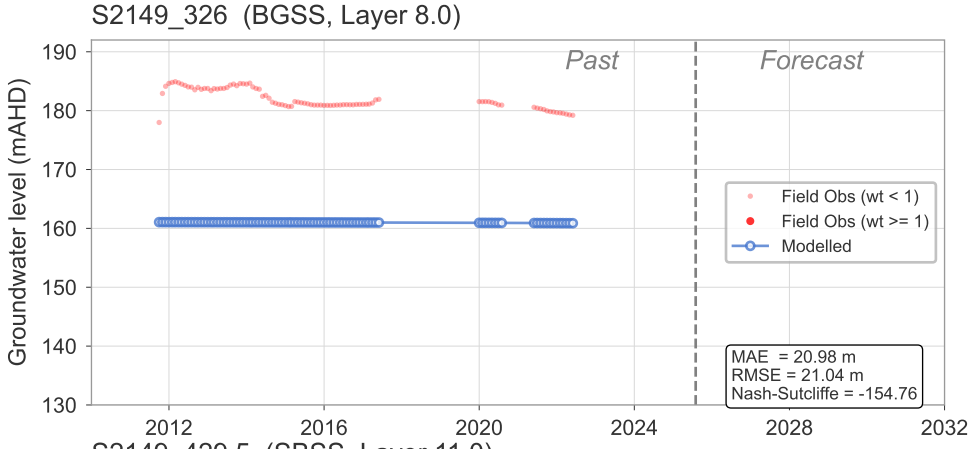


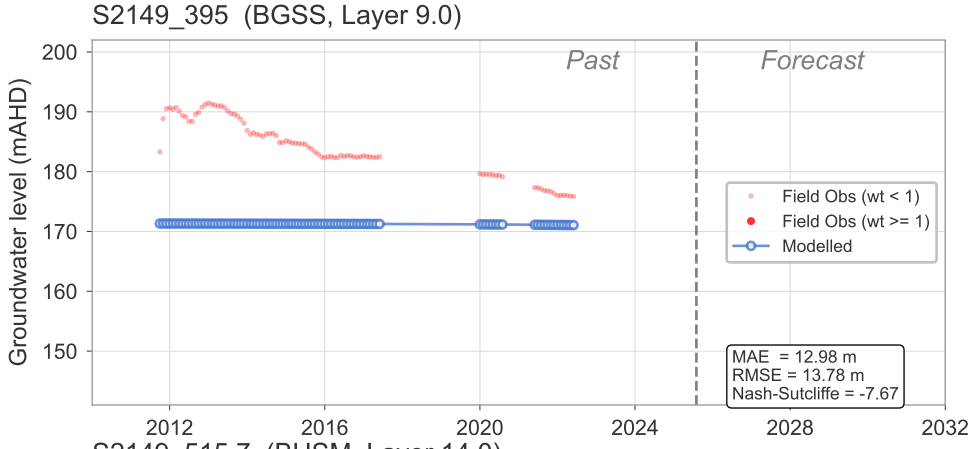


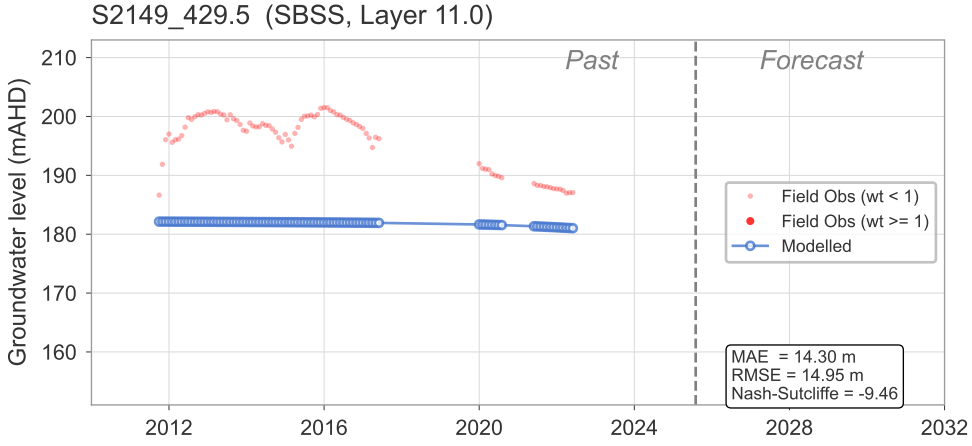
Modelled and observed groundwater hydrographs

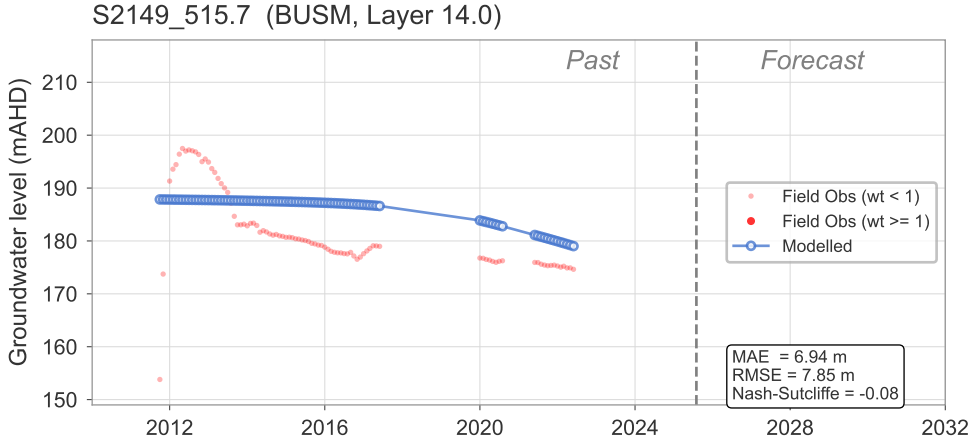




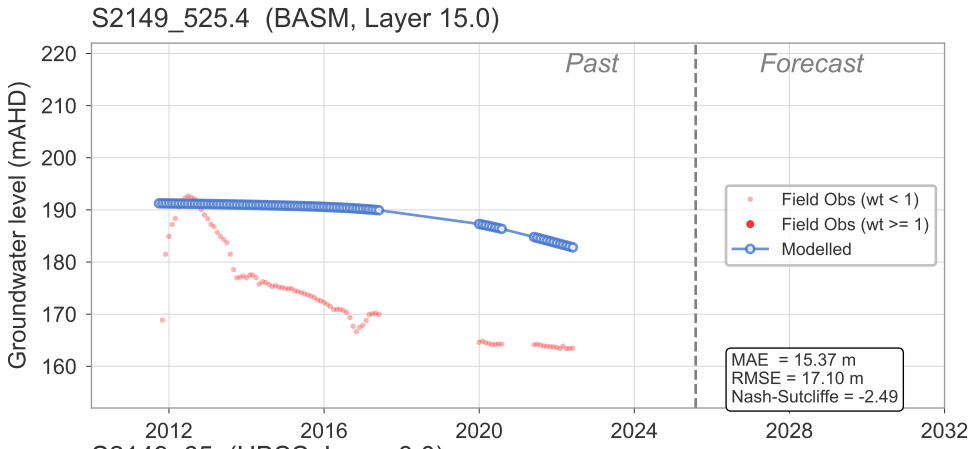


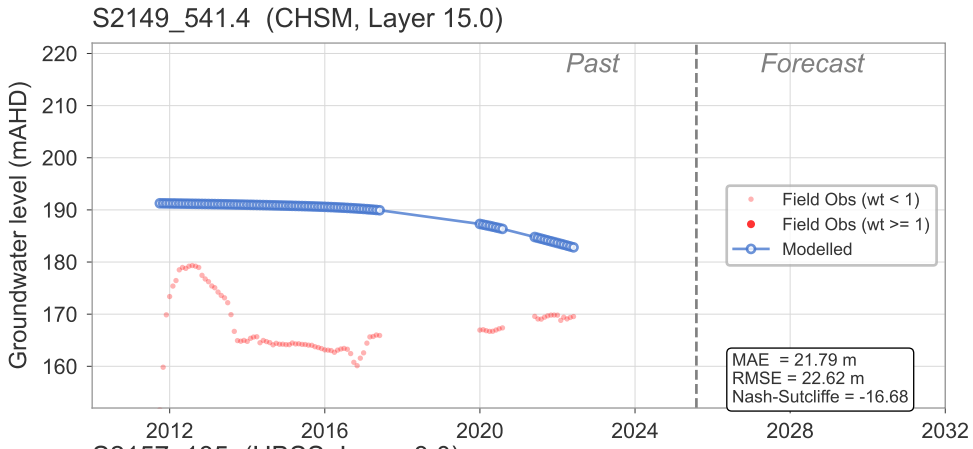


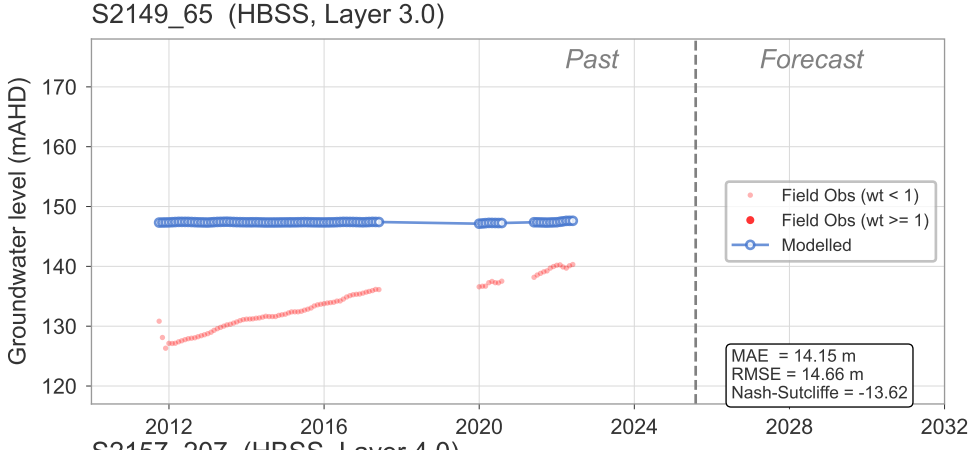


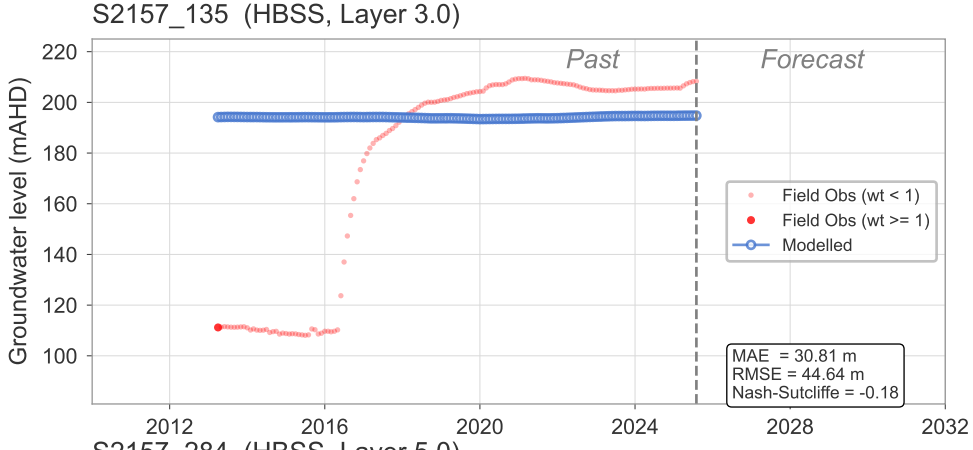


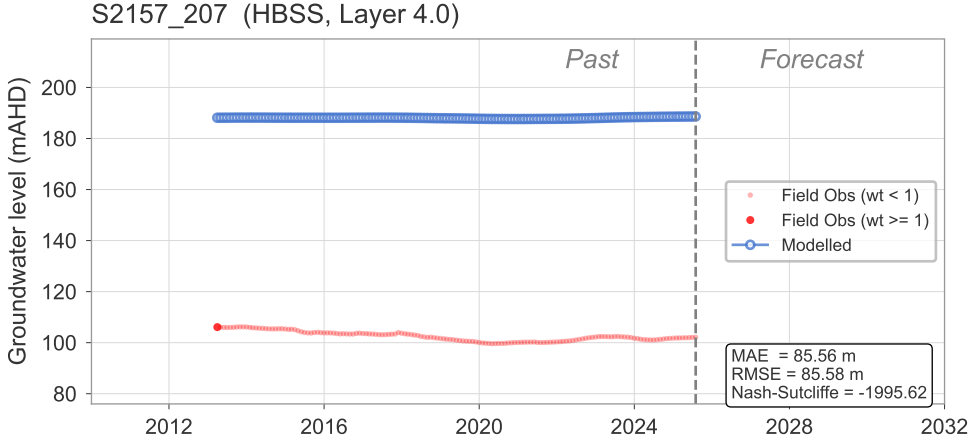
Modelled and observed groundwater hydrographs

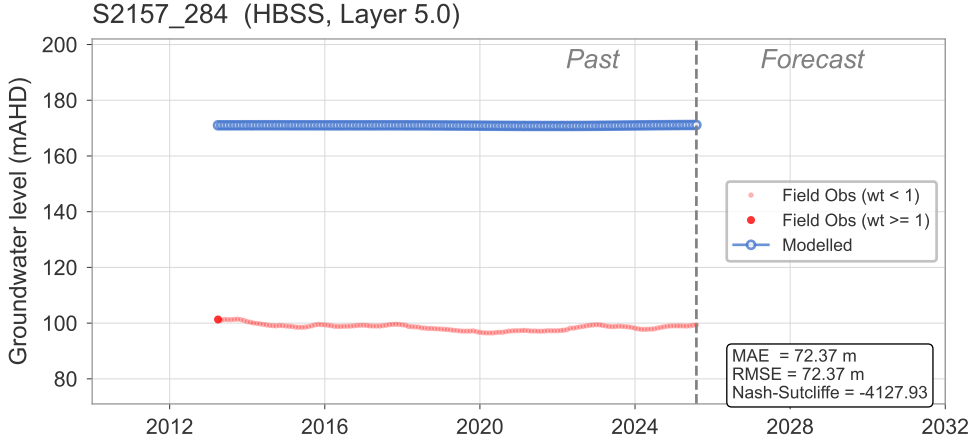




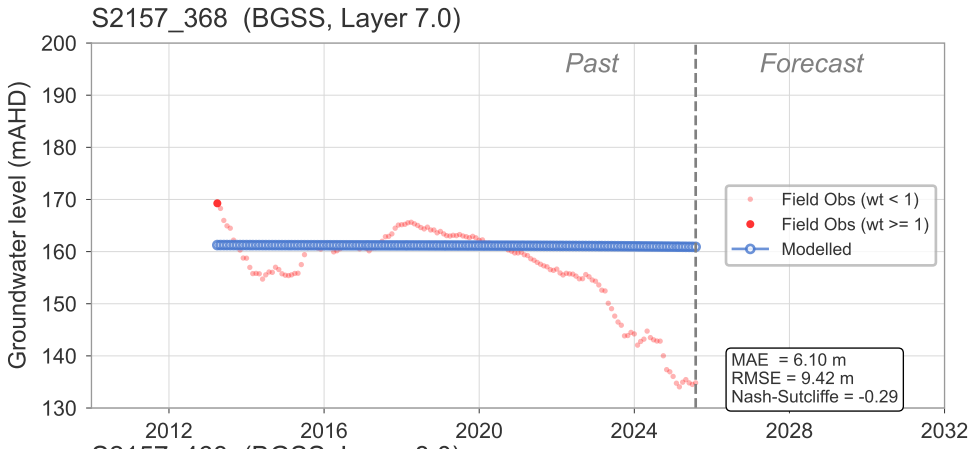


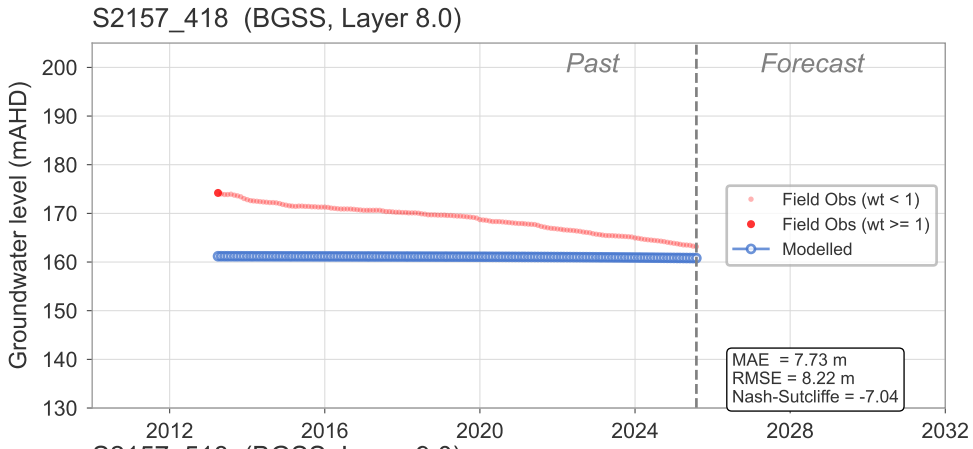


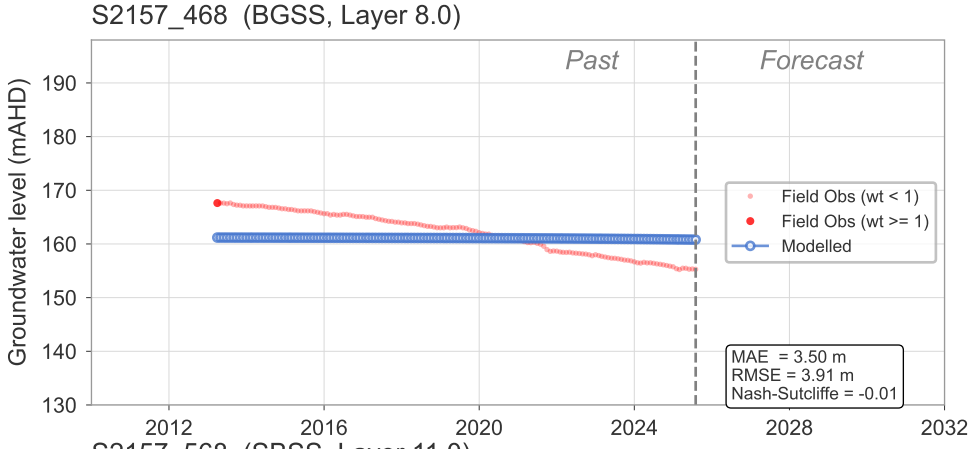


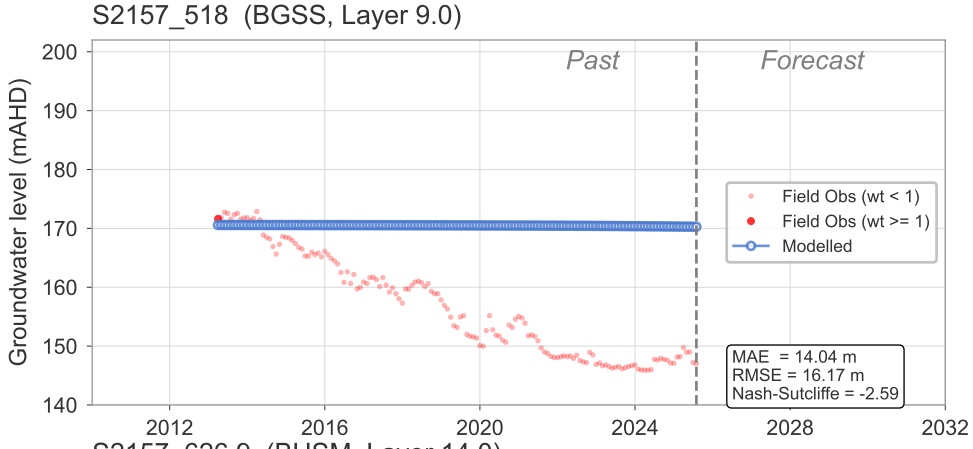


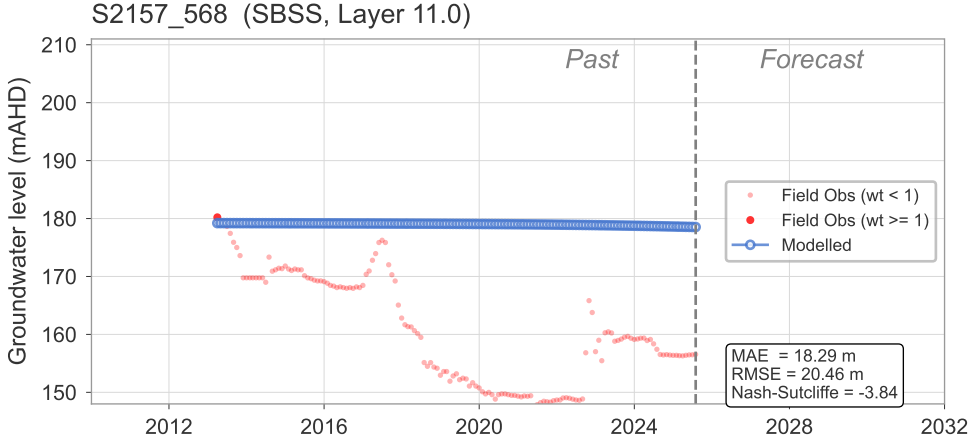
Modelled and observed groundwater hydrographs

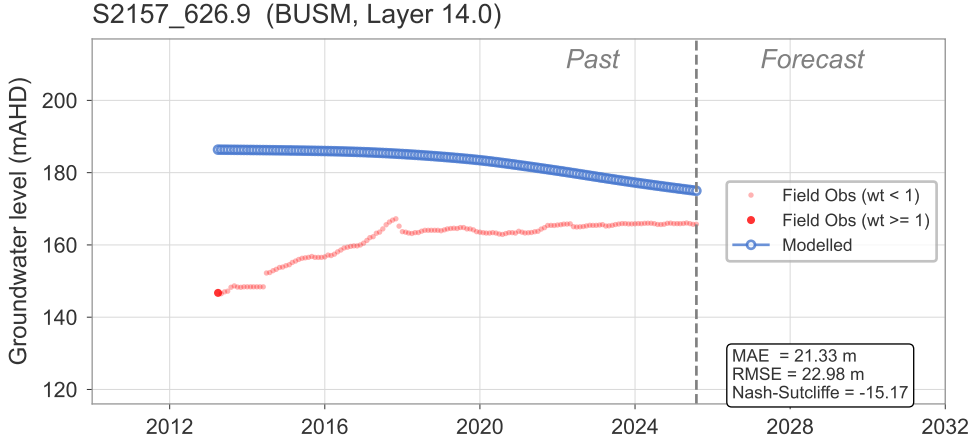




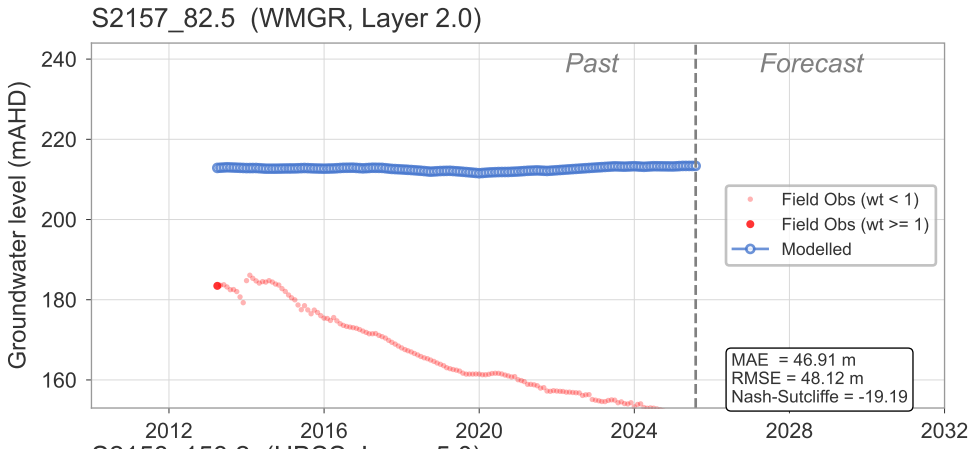


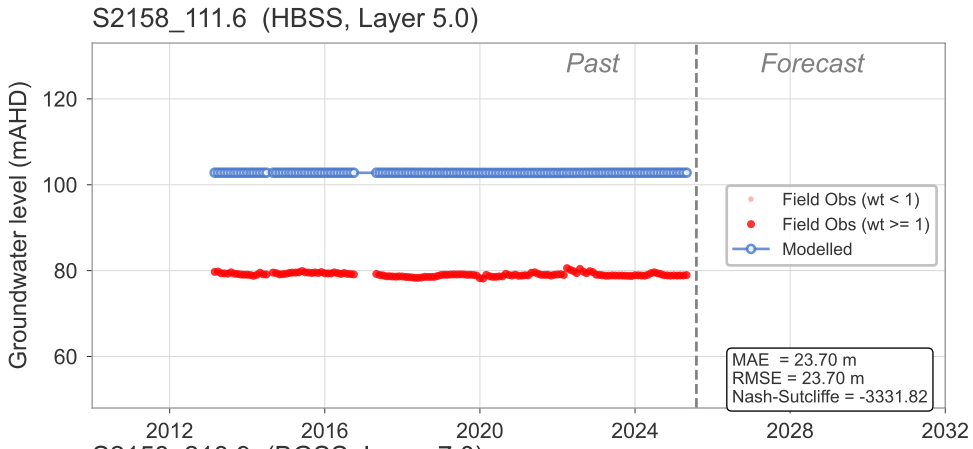


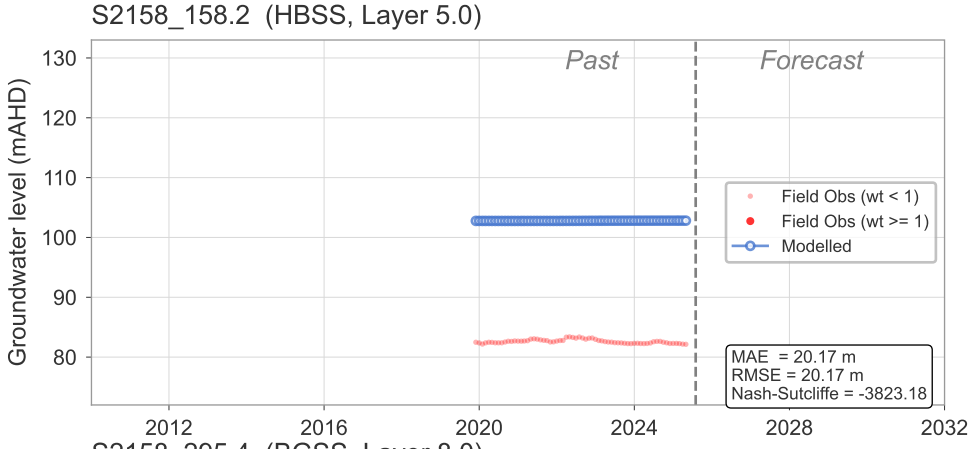


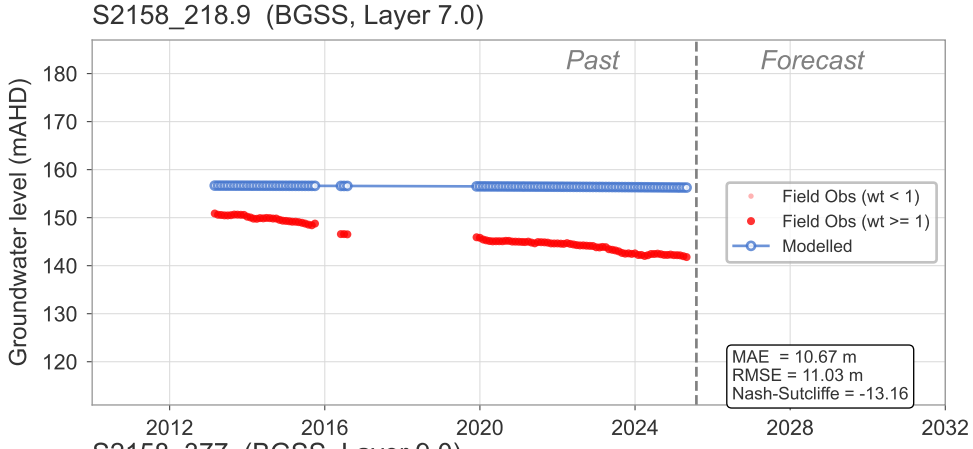


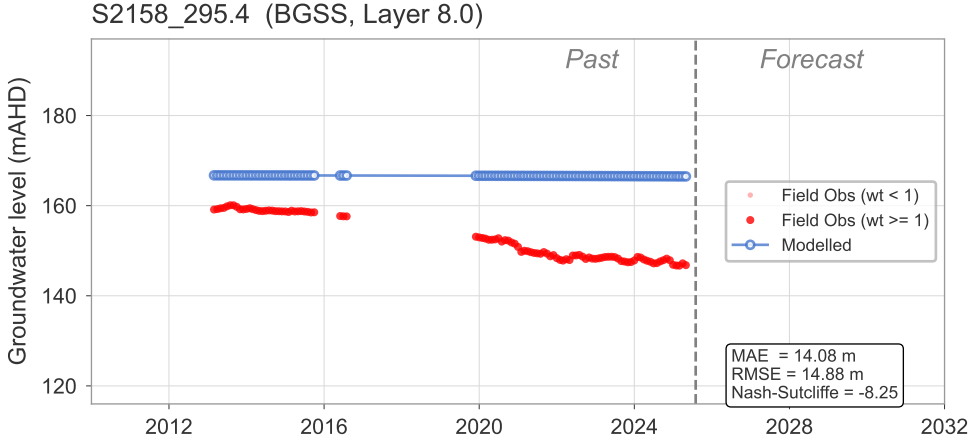
Modelled and observed groundwater hydrographs

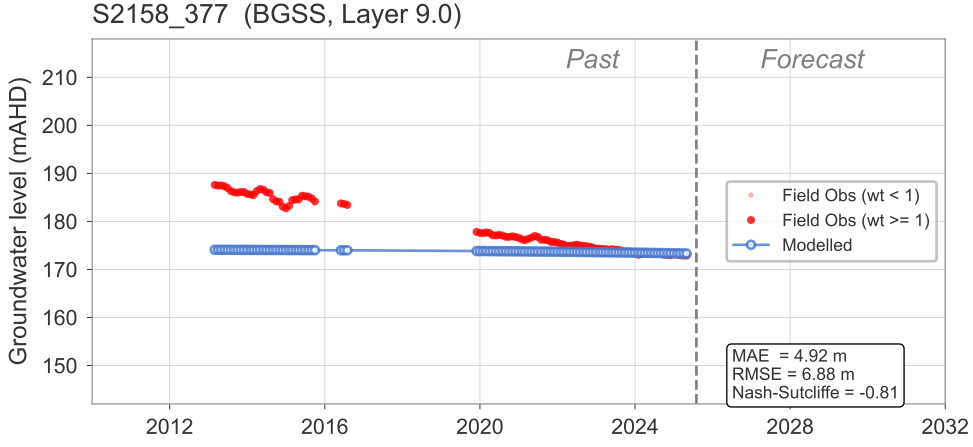












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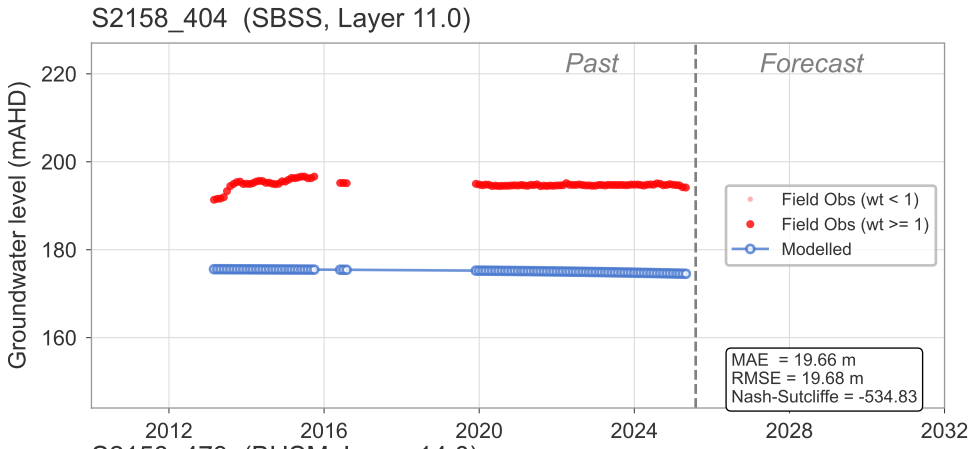

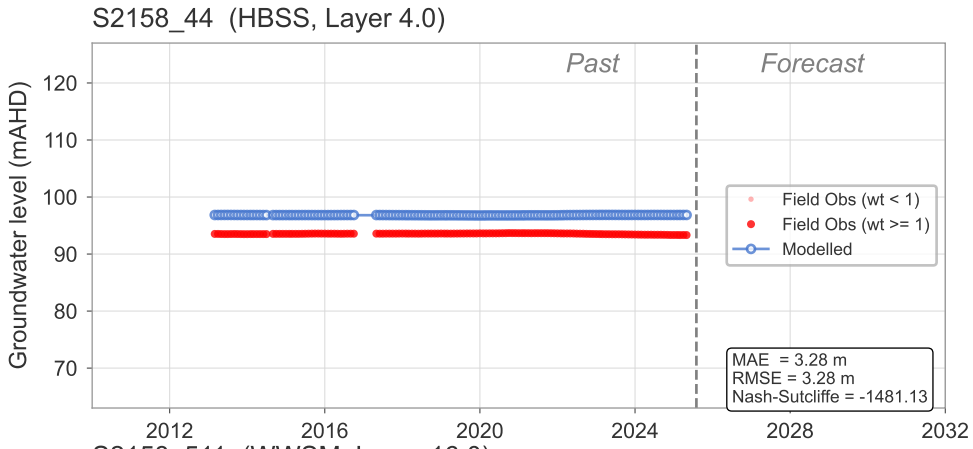

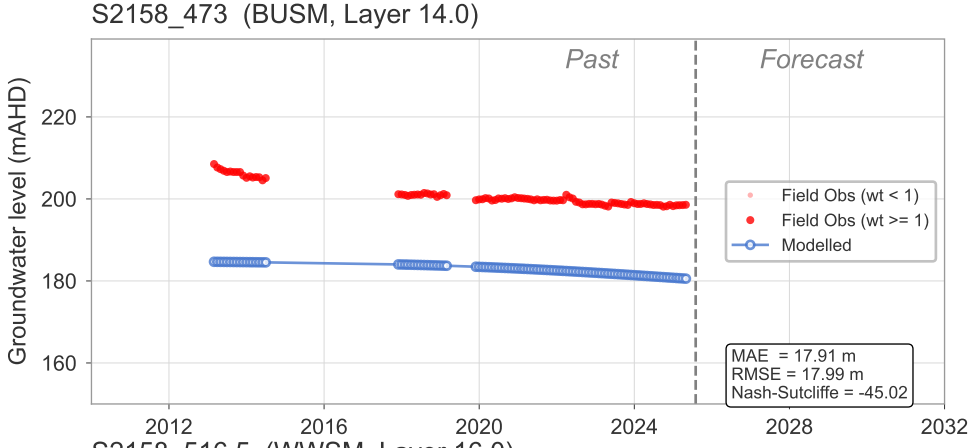

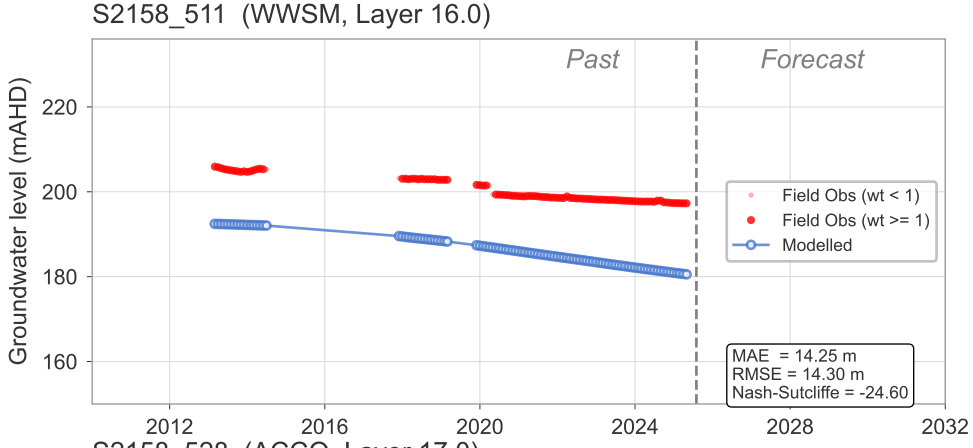

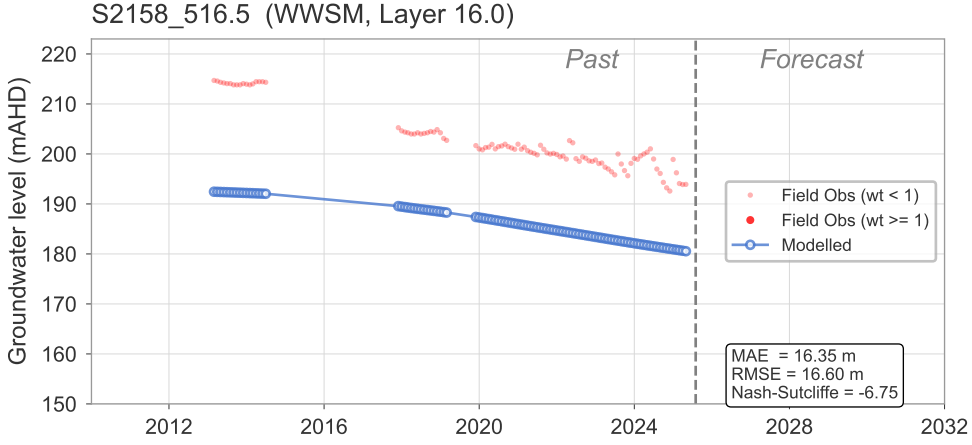

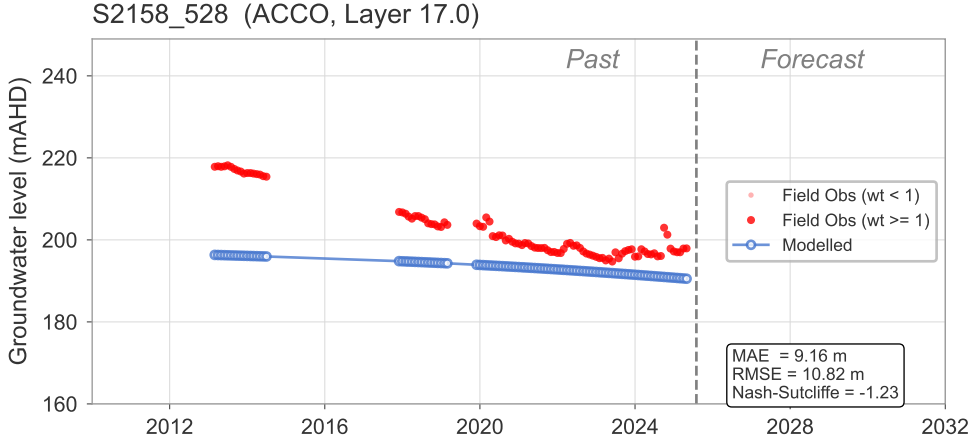

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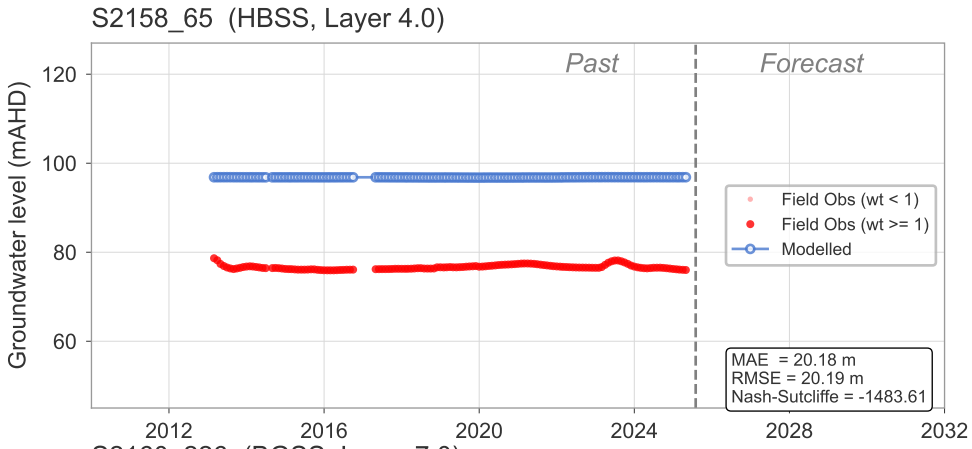
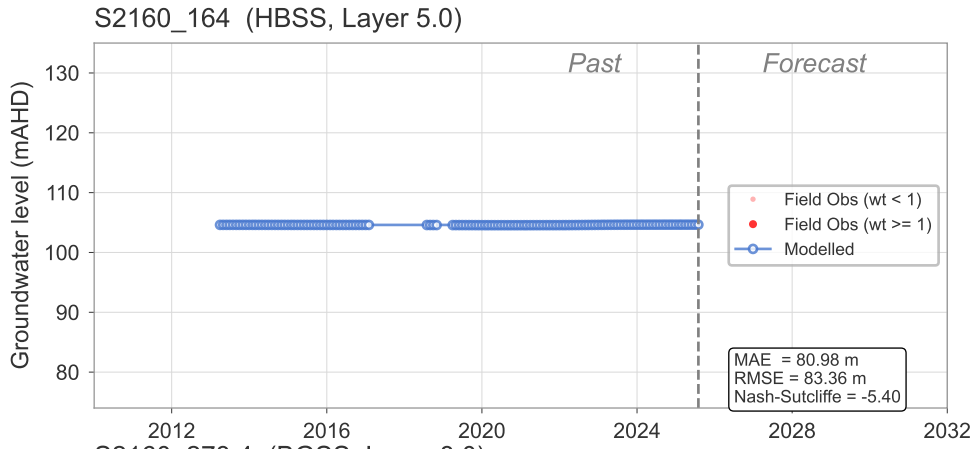
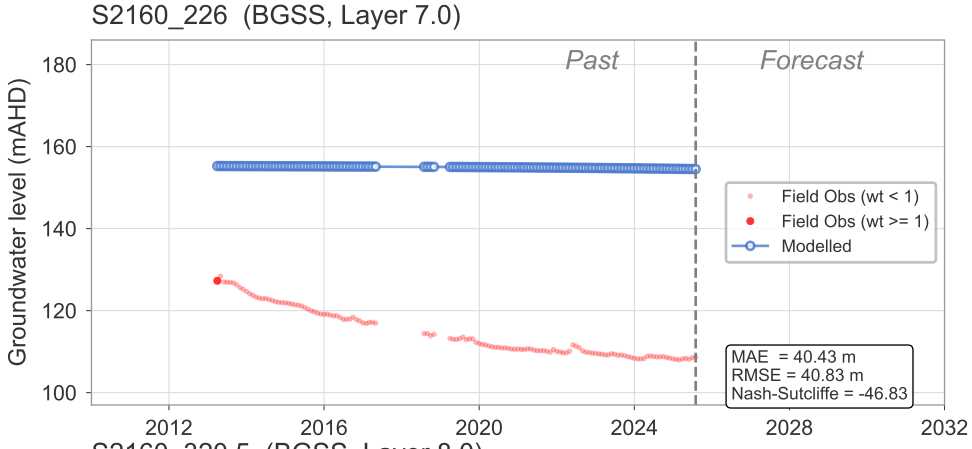
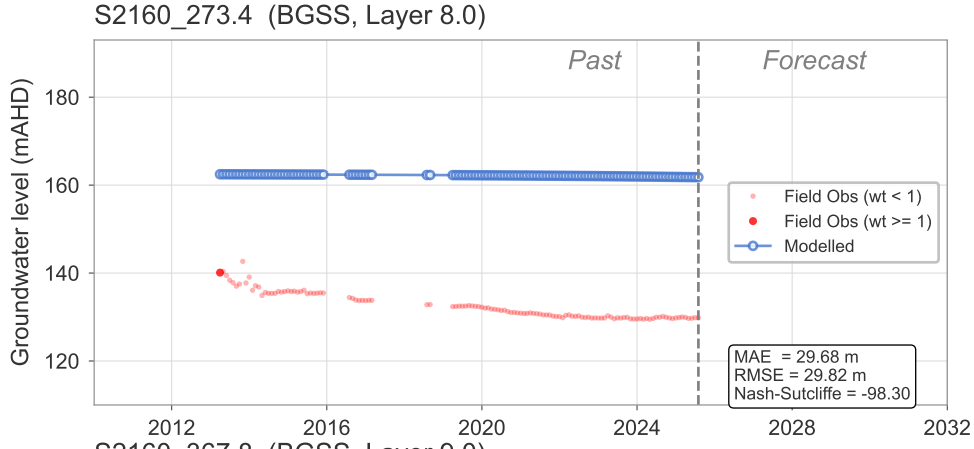
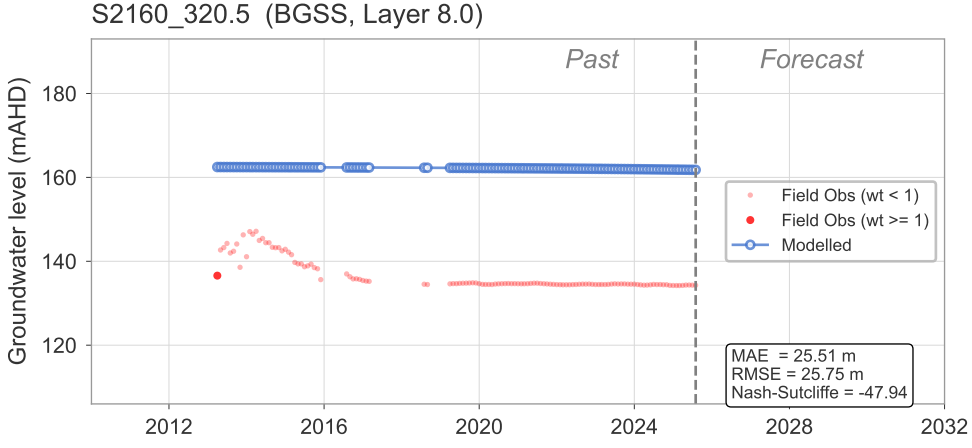
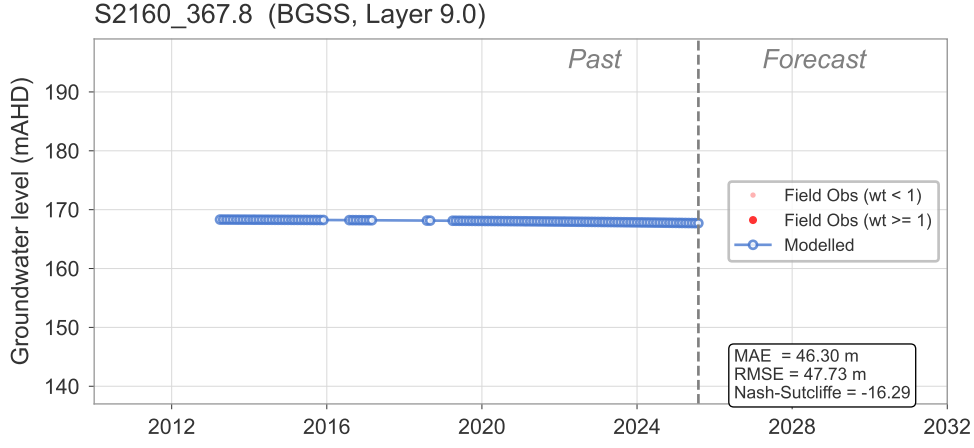




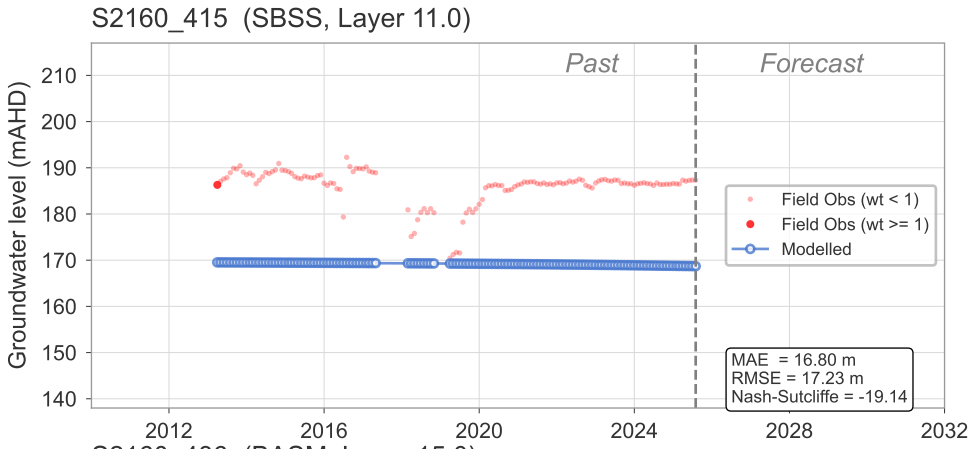


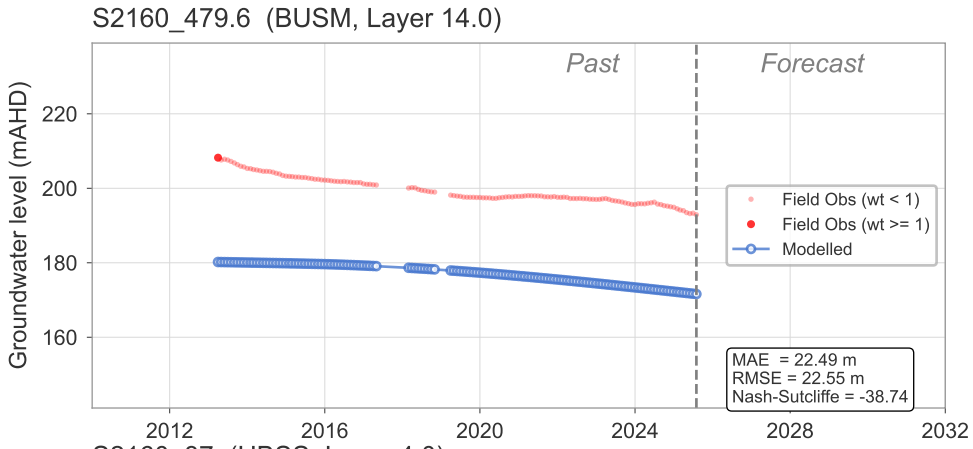


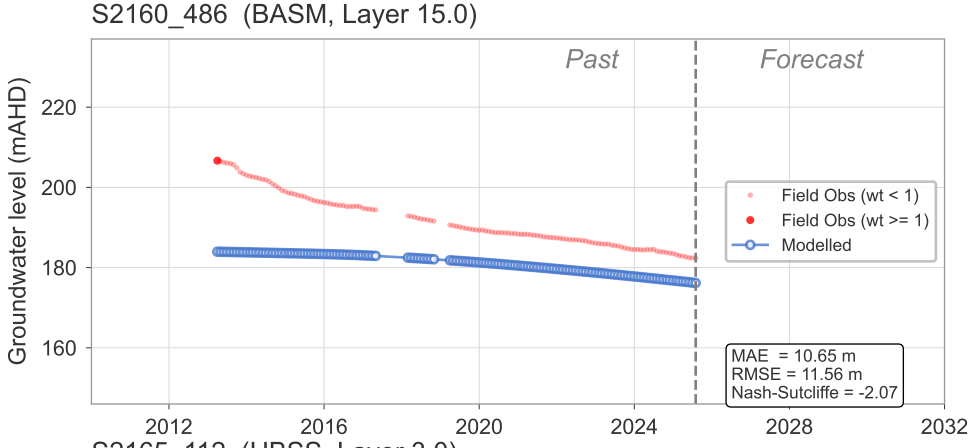


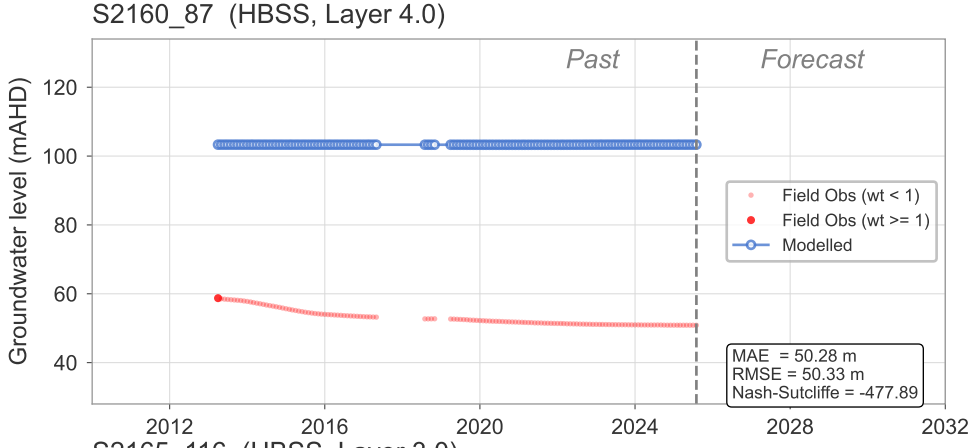


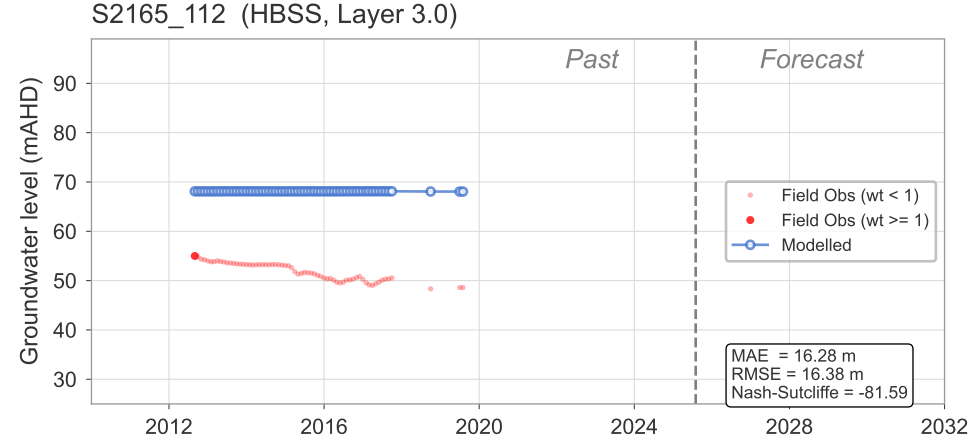
Modelled and observed groundwater hydrographs

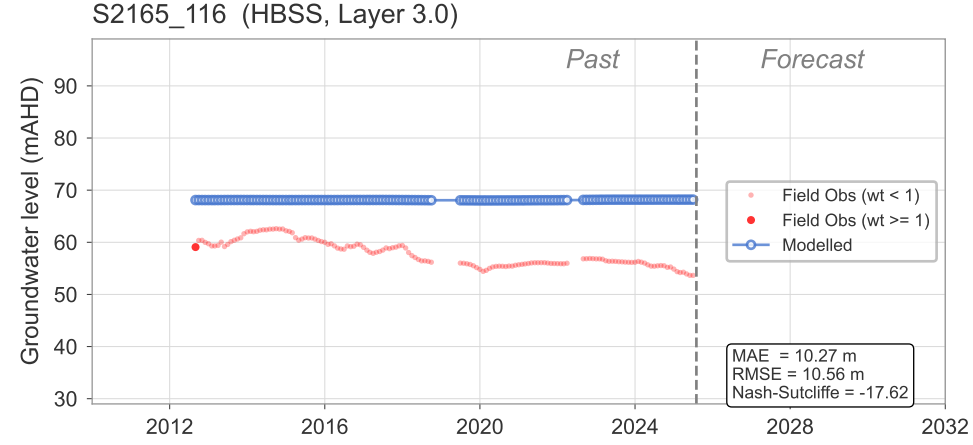












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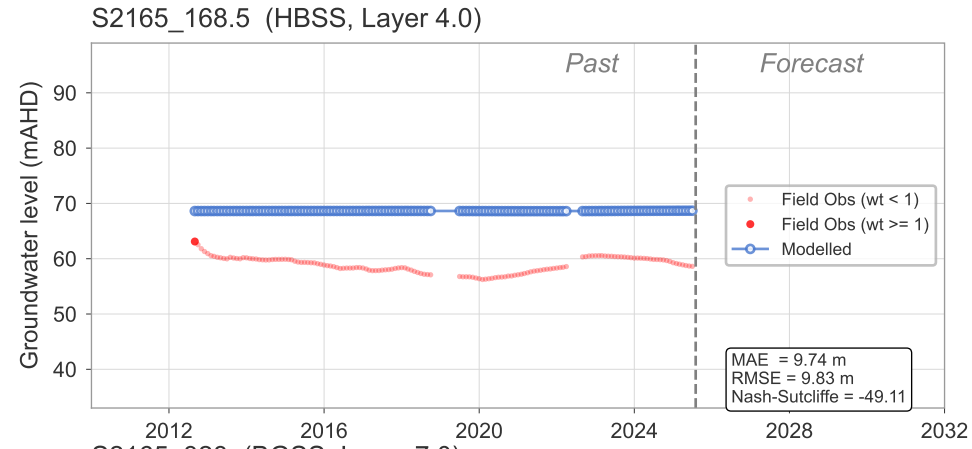

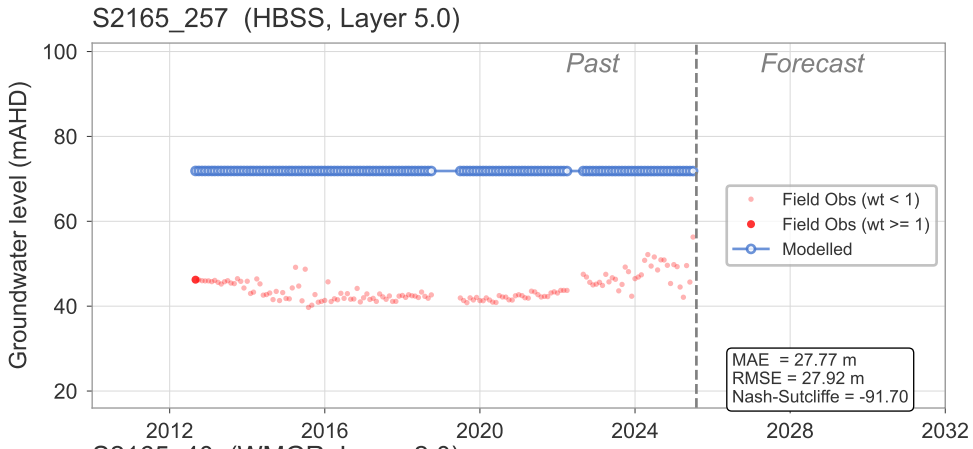

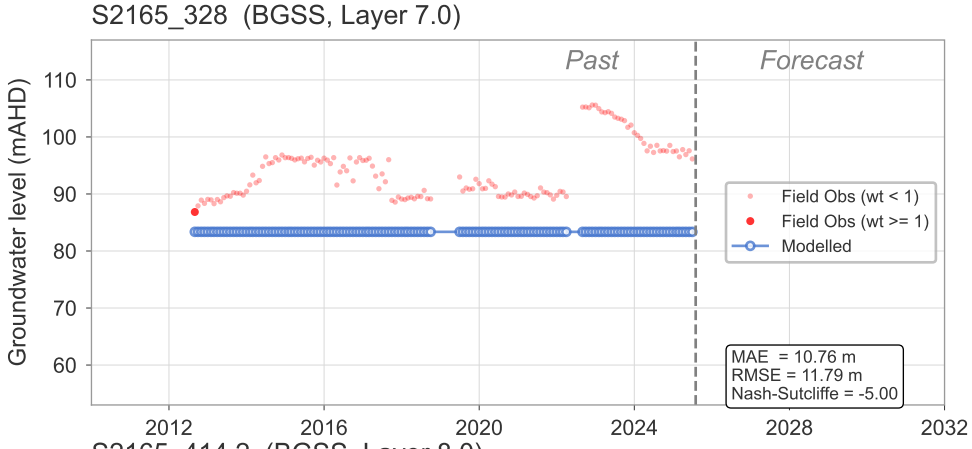

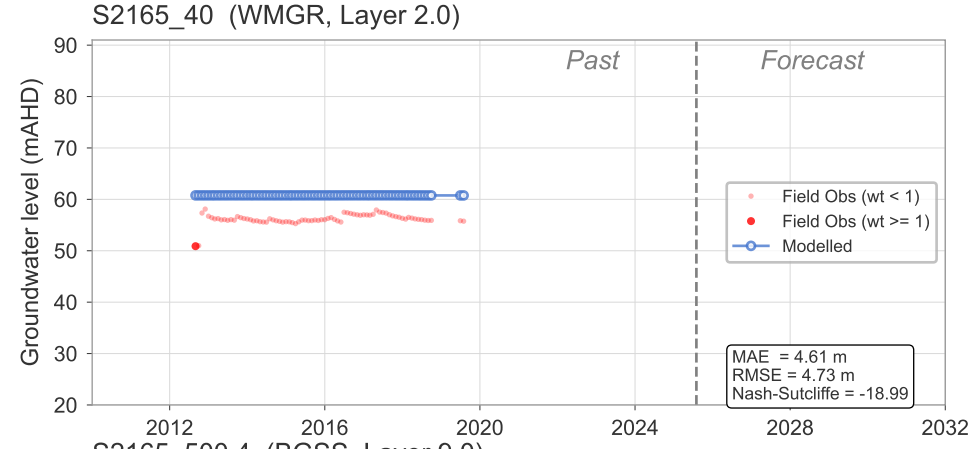

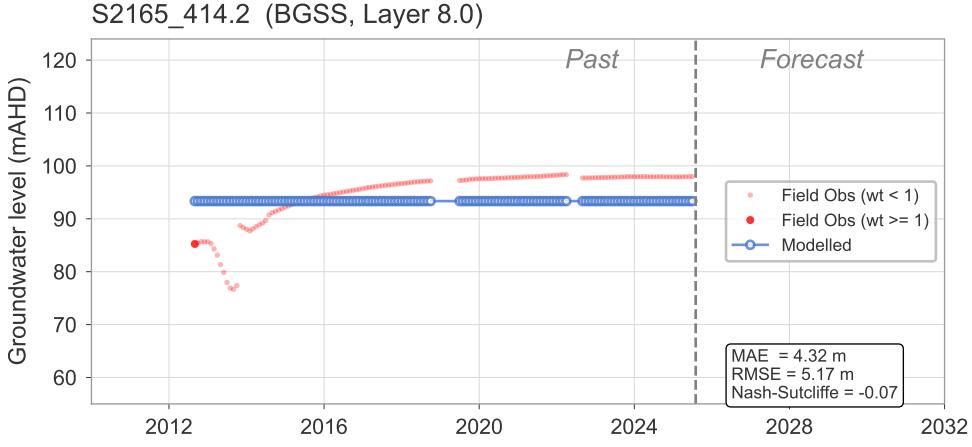

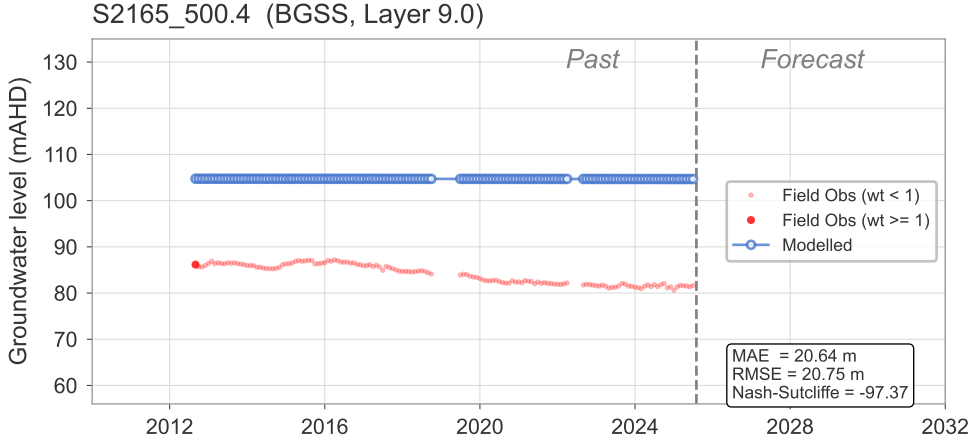

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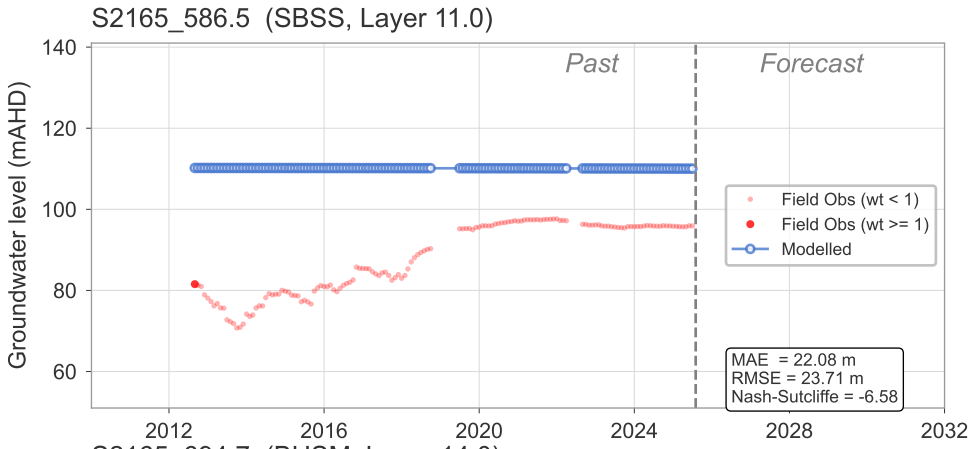

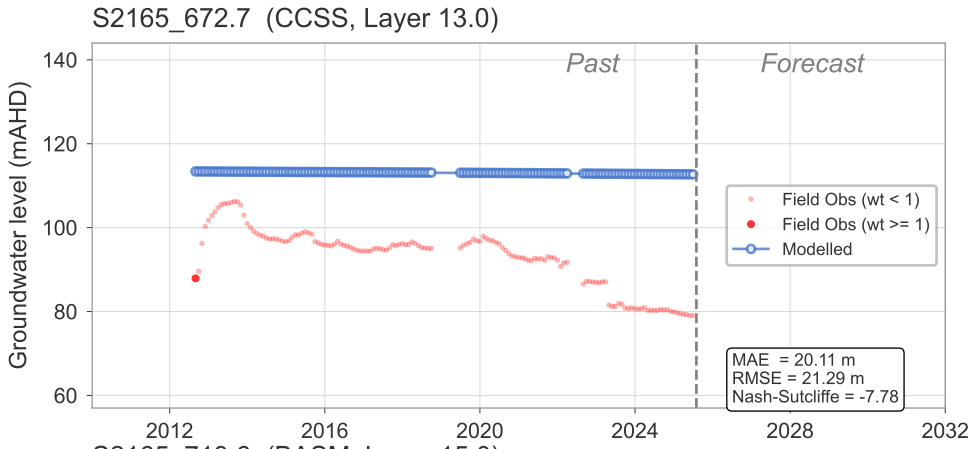

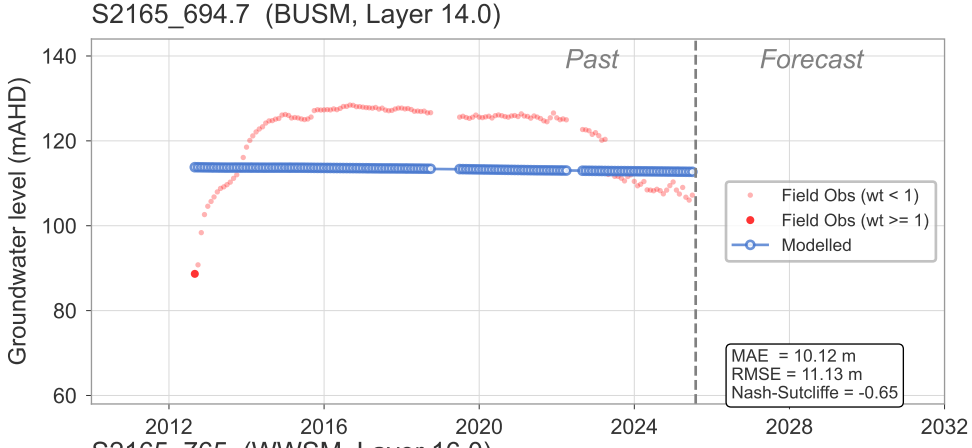

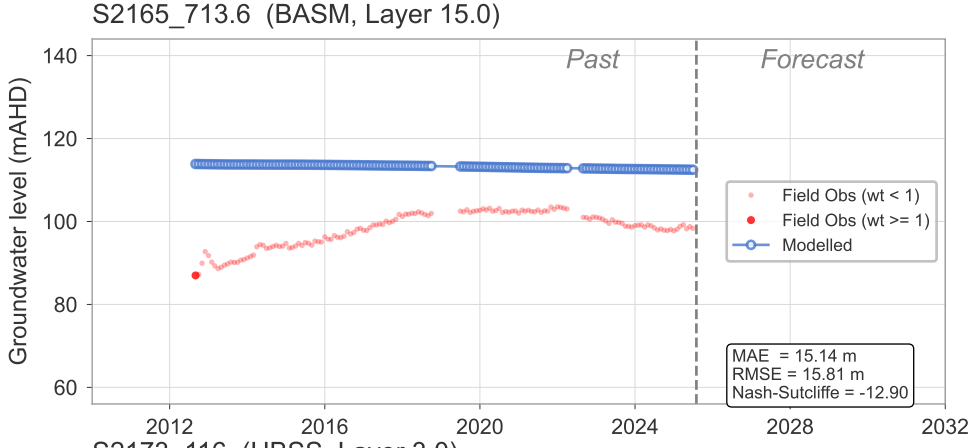

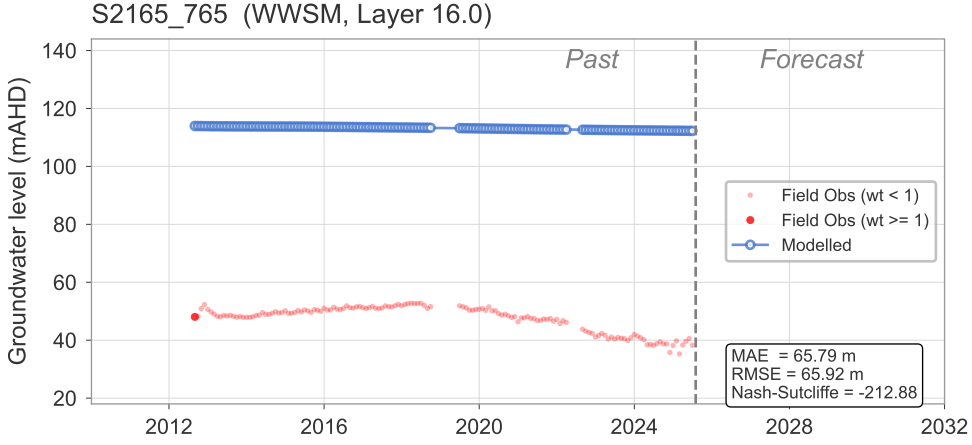

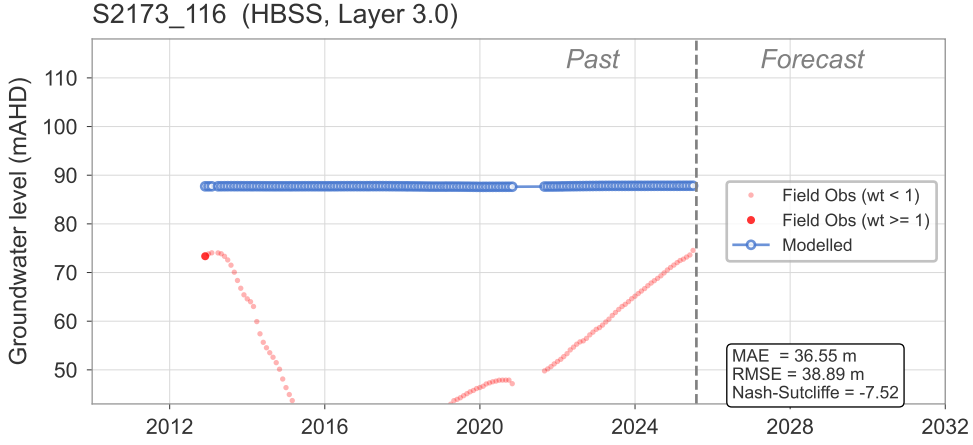

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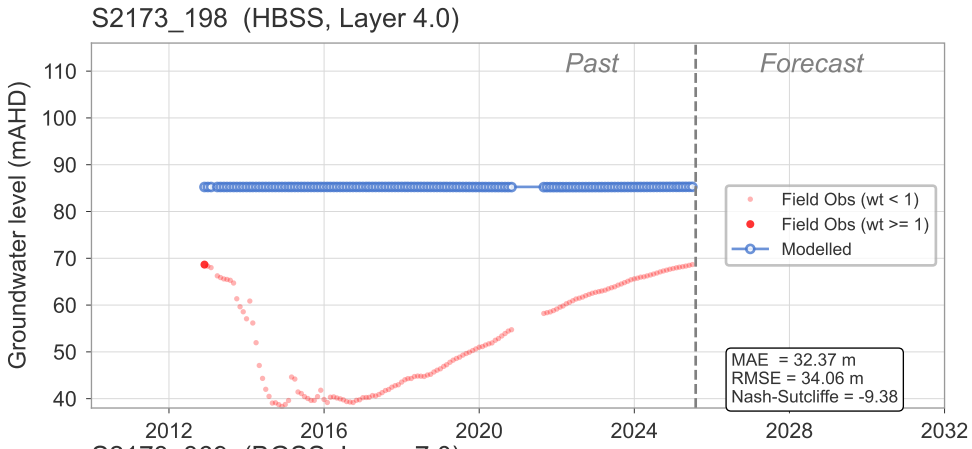

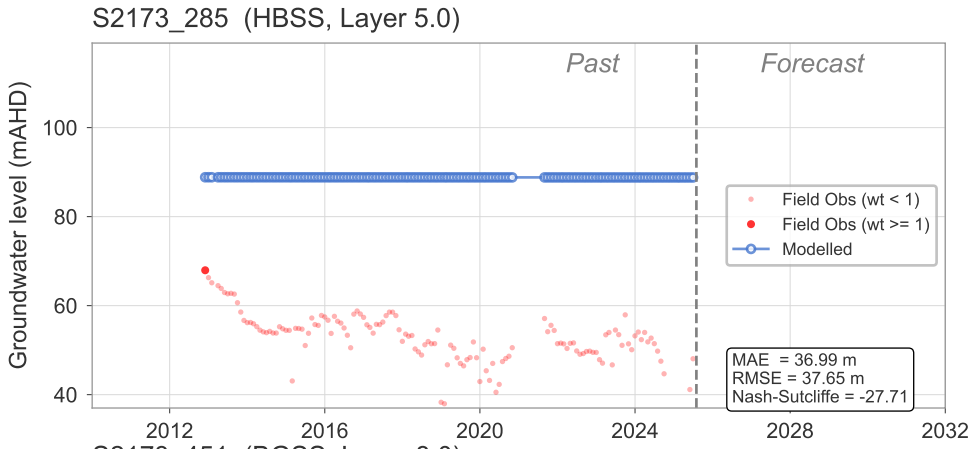

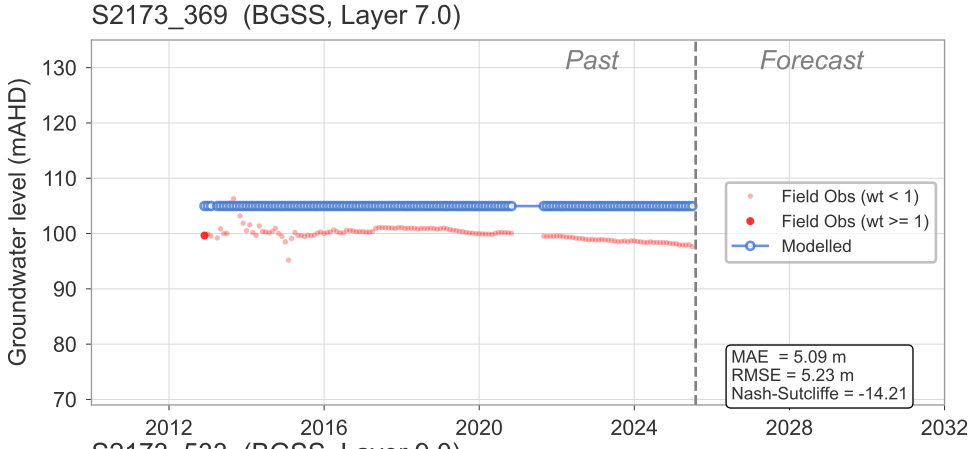

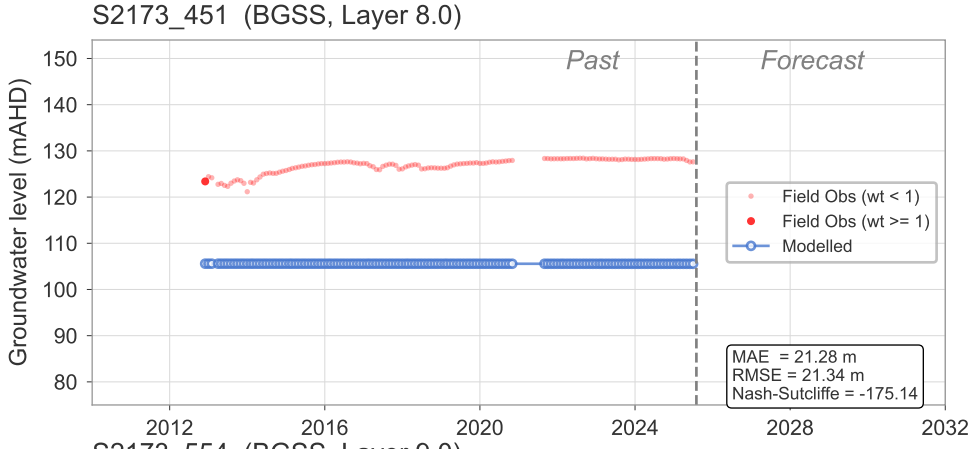

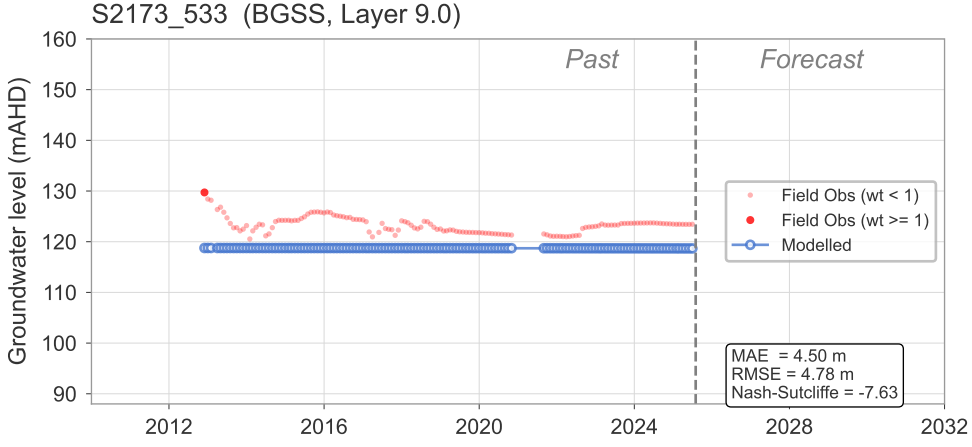

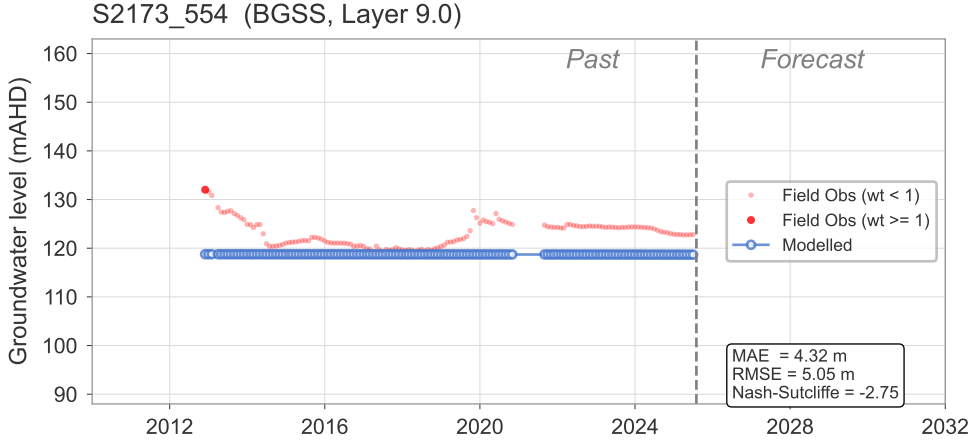

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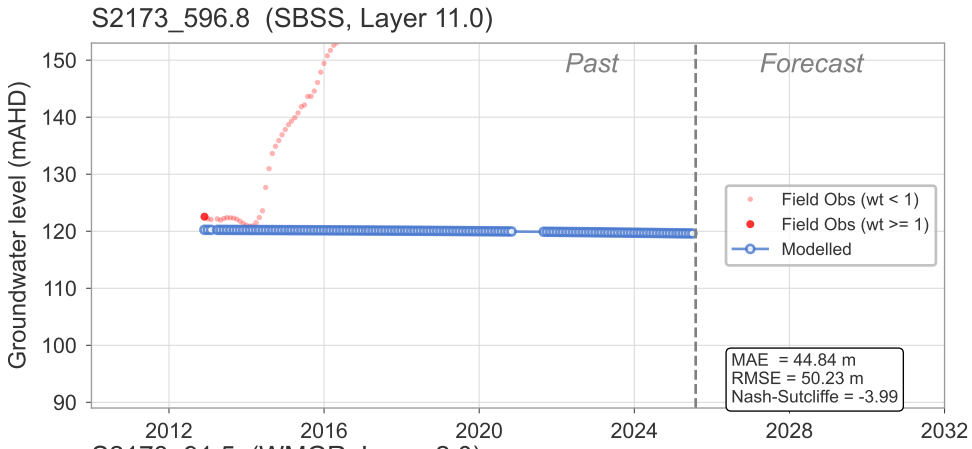

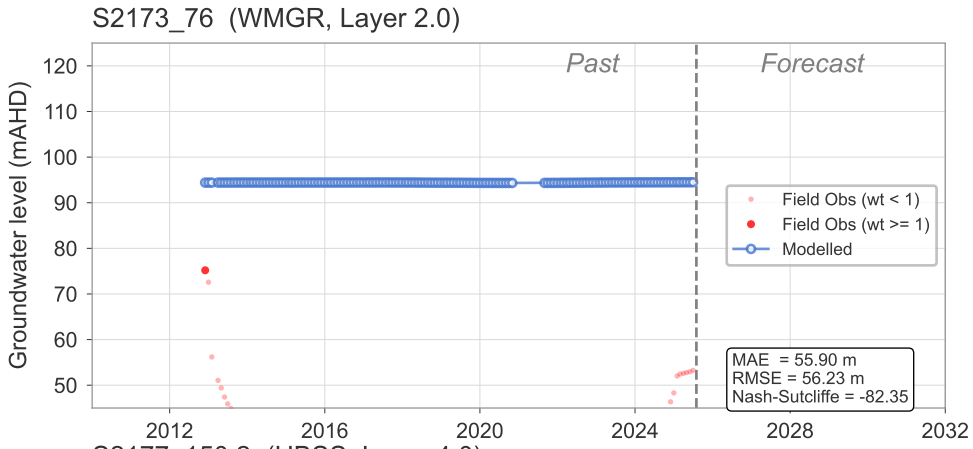

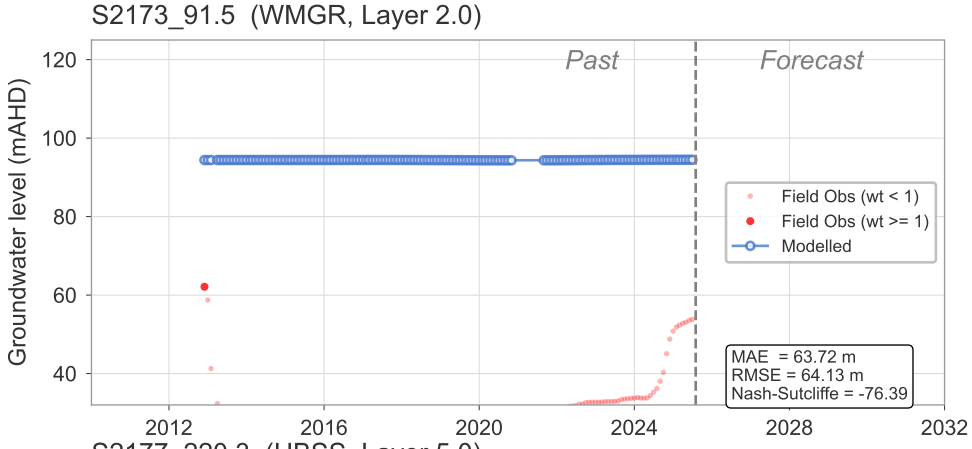

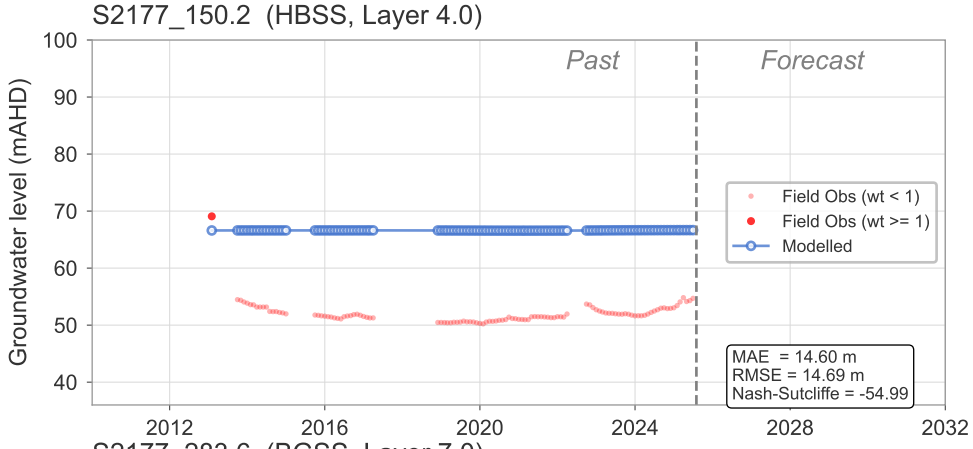

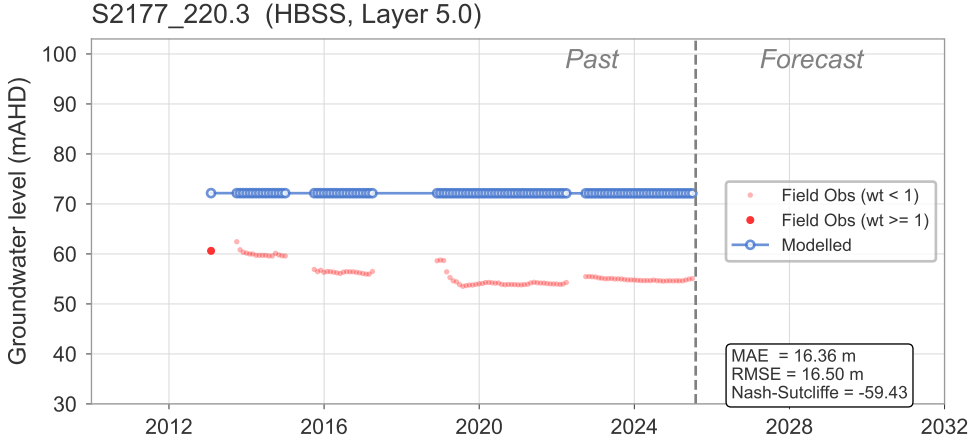

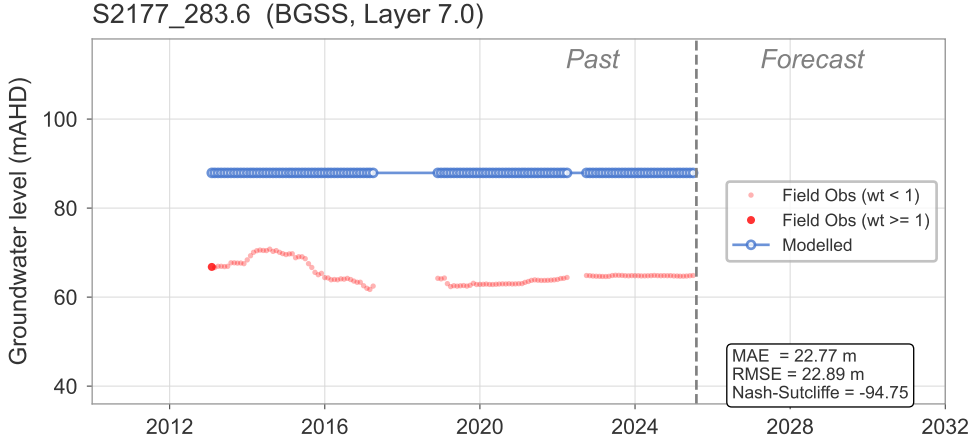

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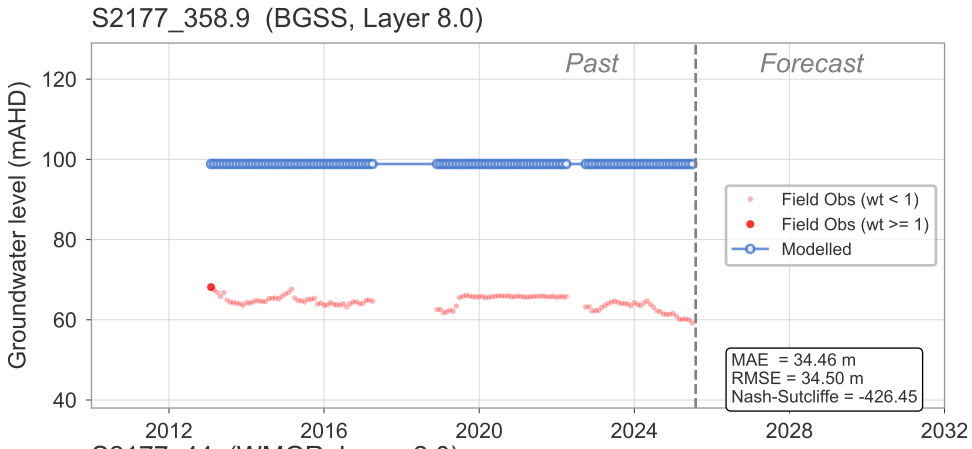

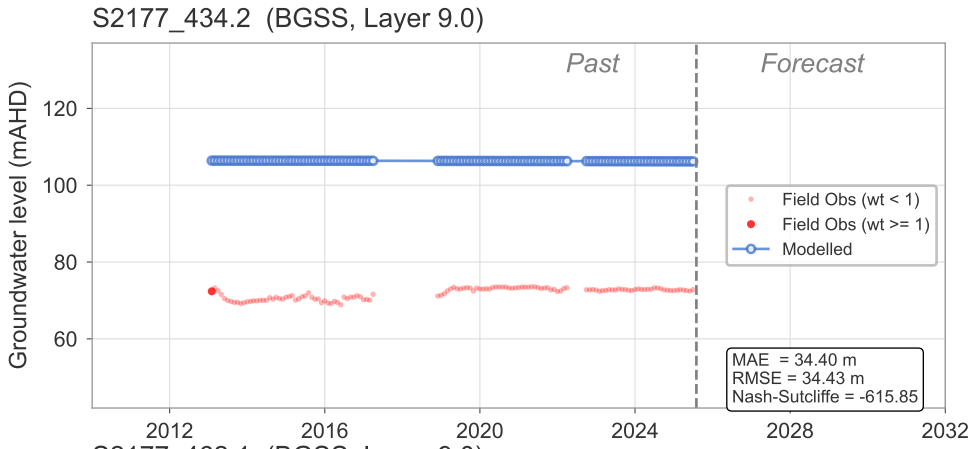

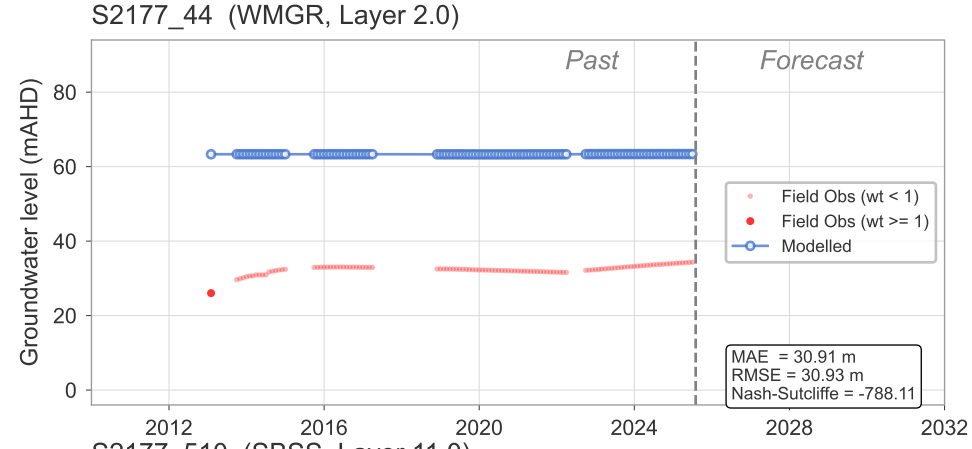

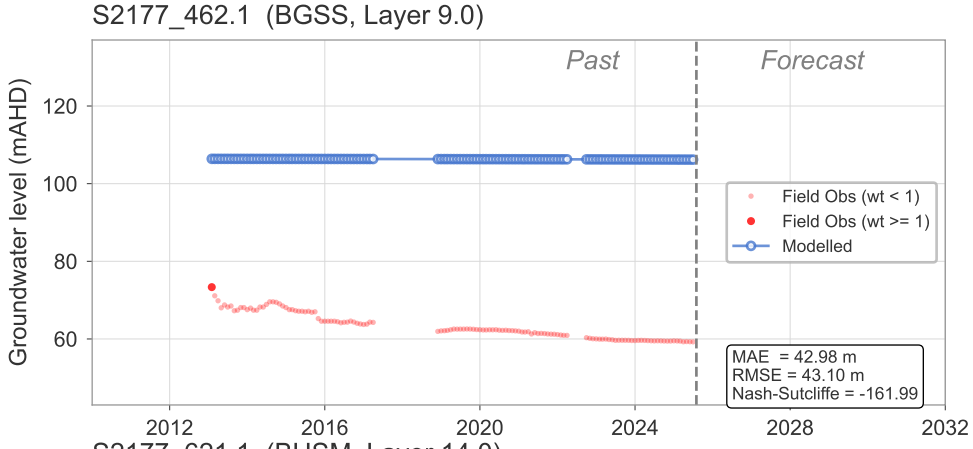

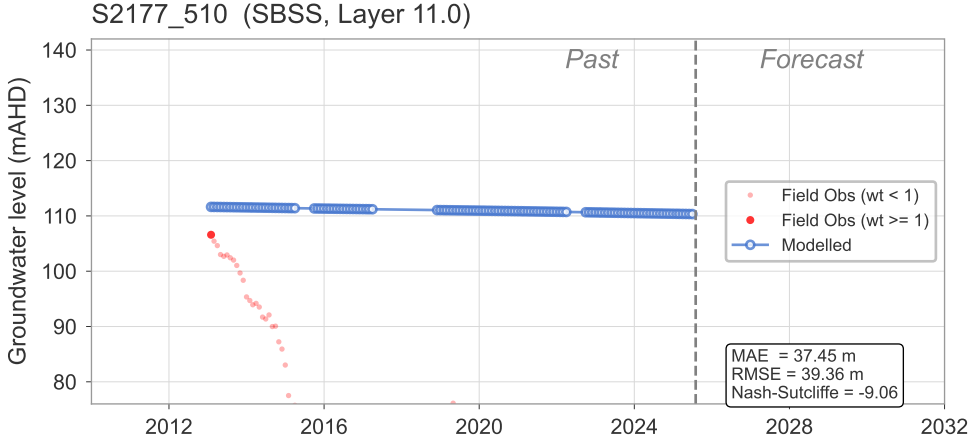

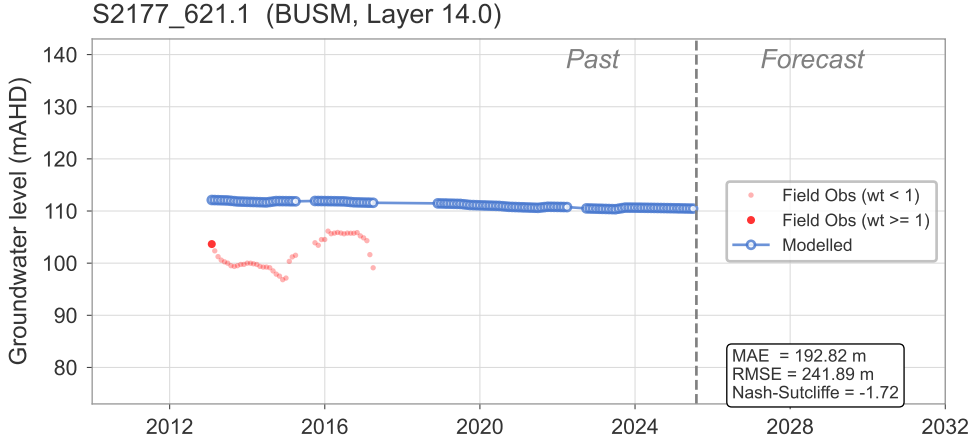

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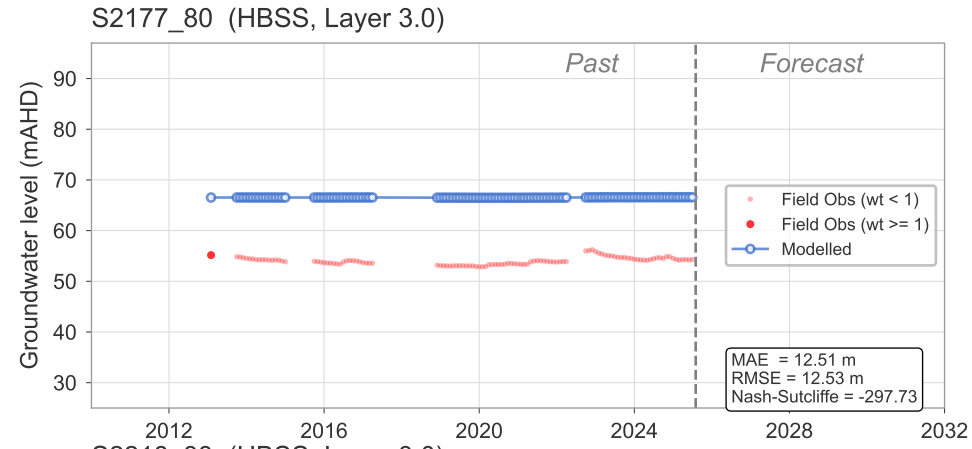

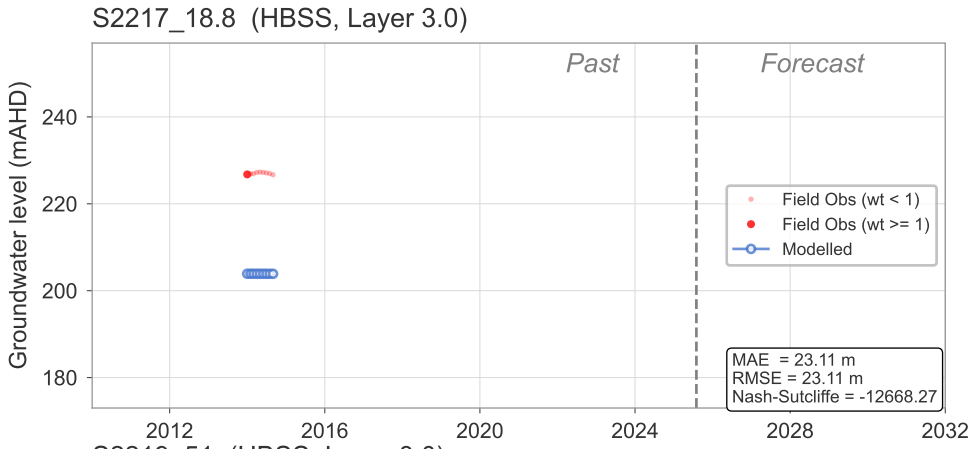

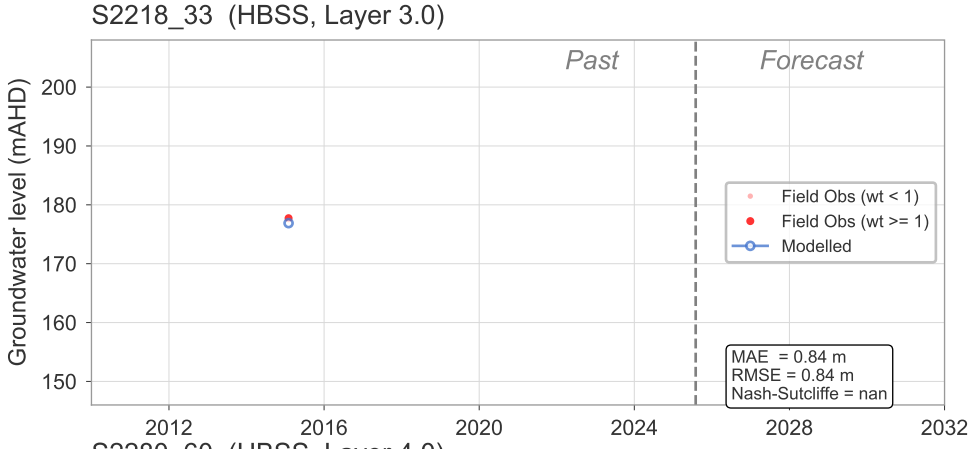

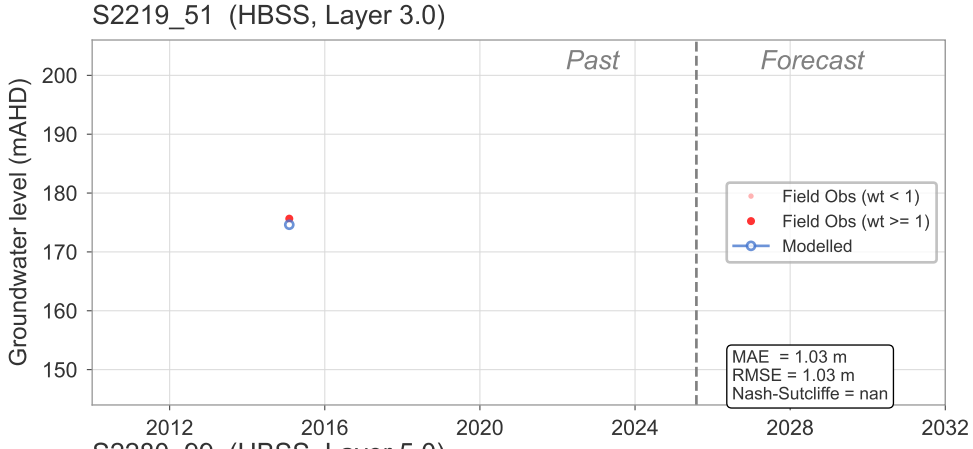

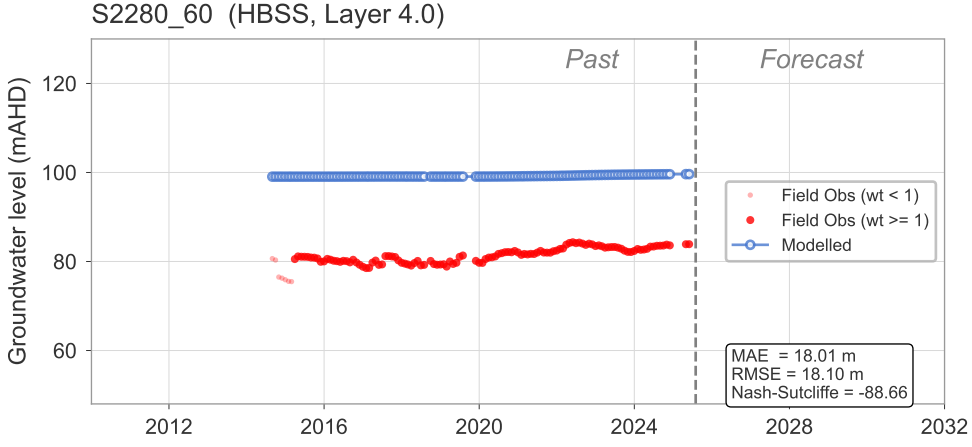

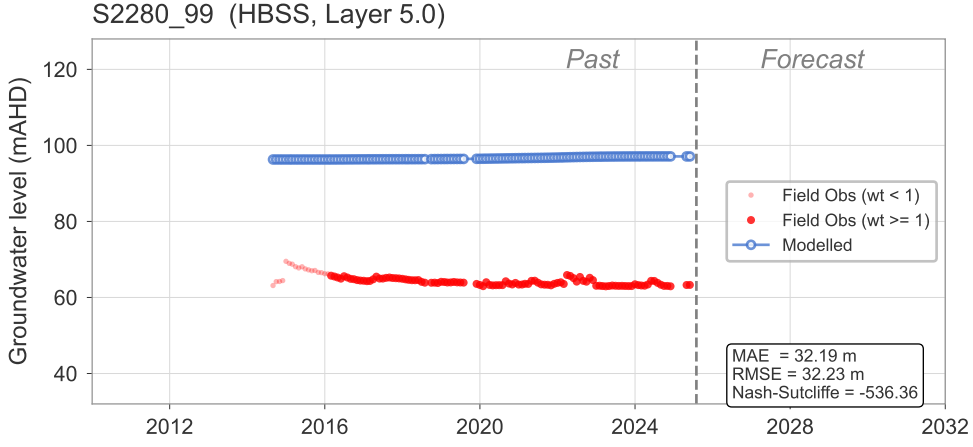

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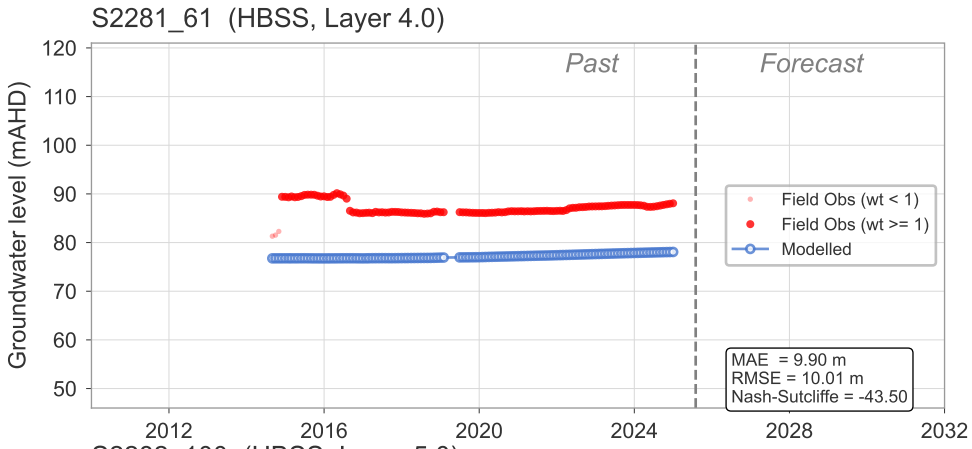
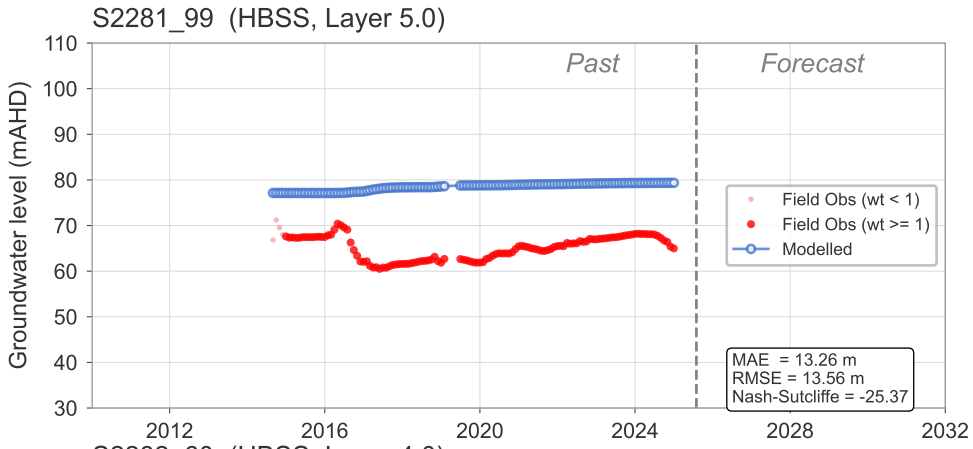
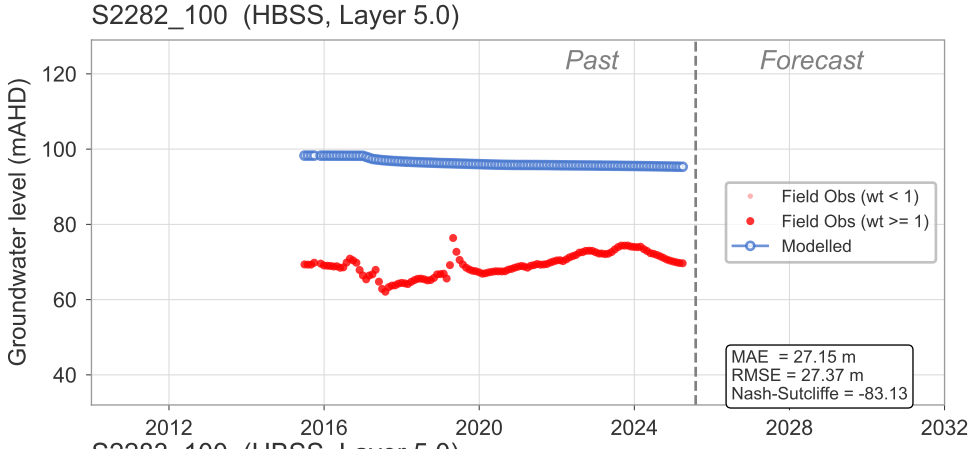
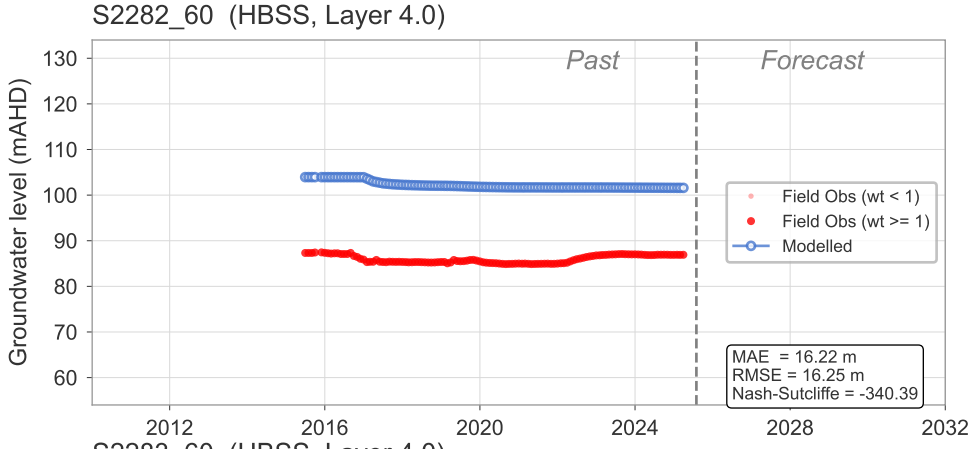
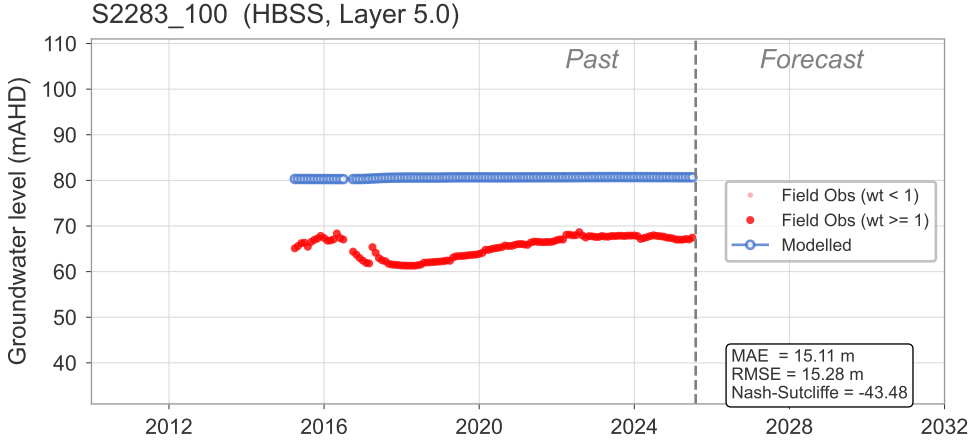
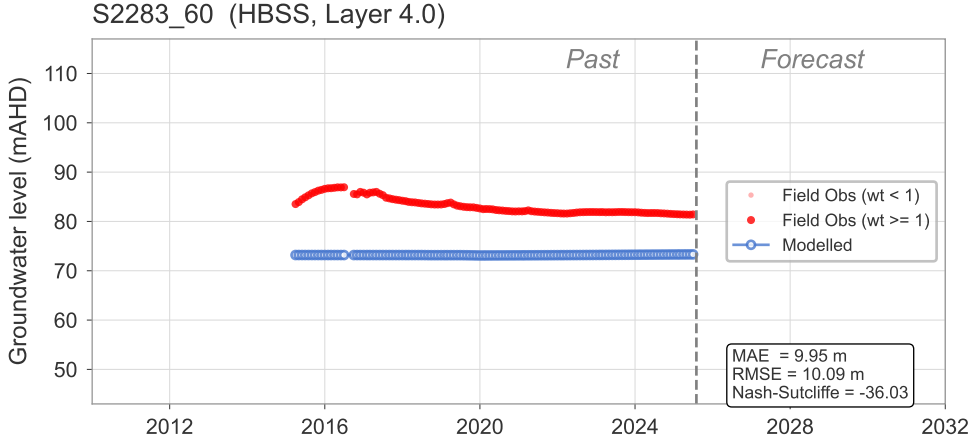




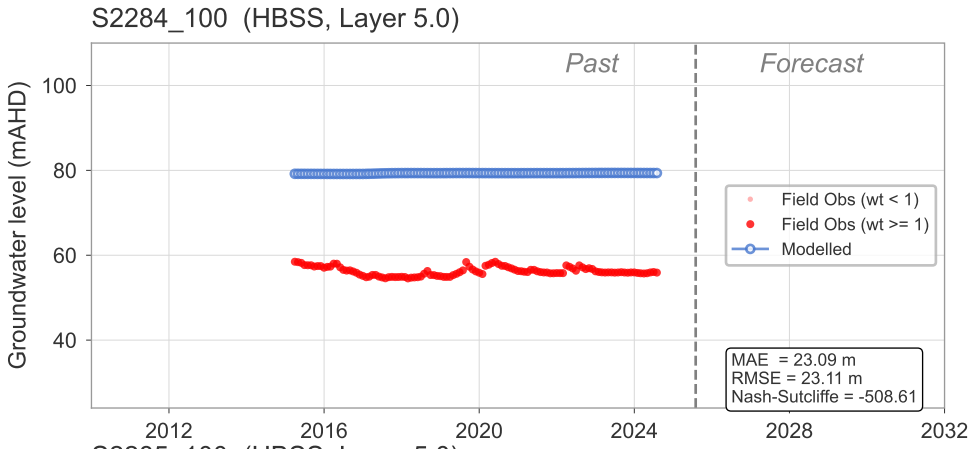


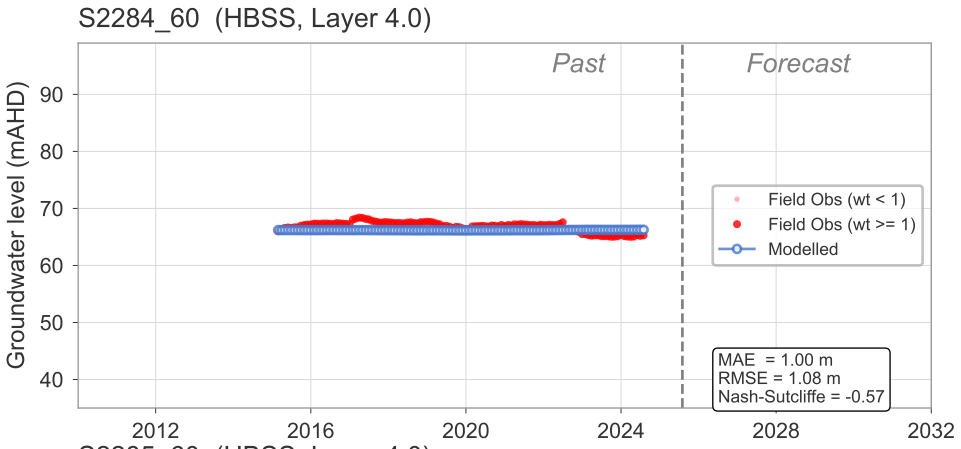


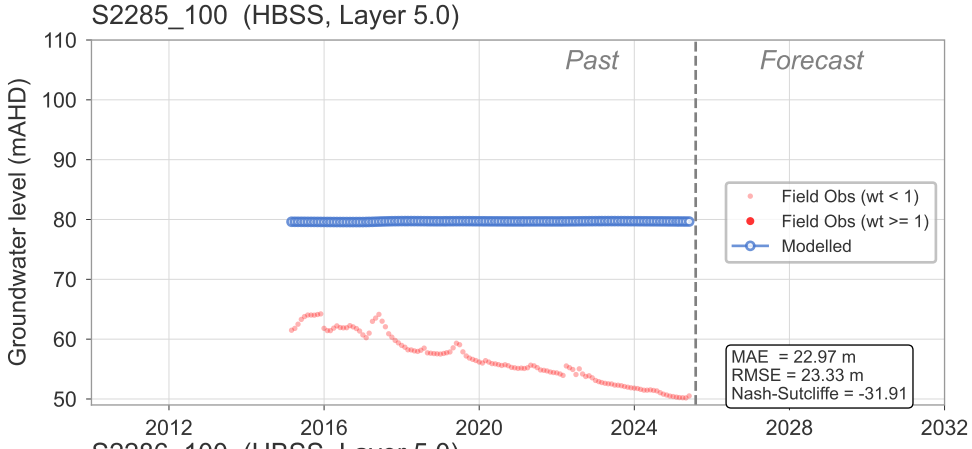


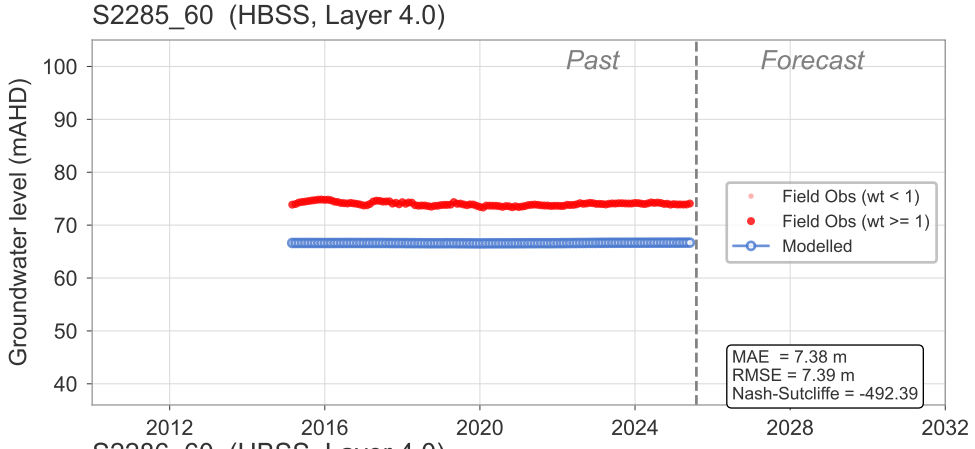


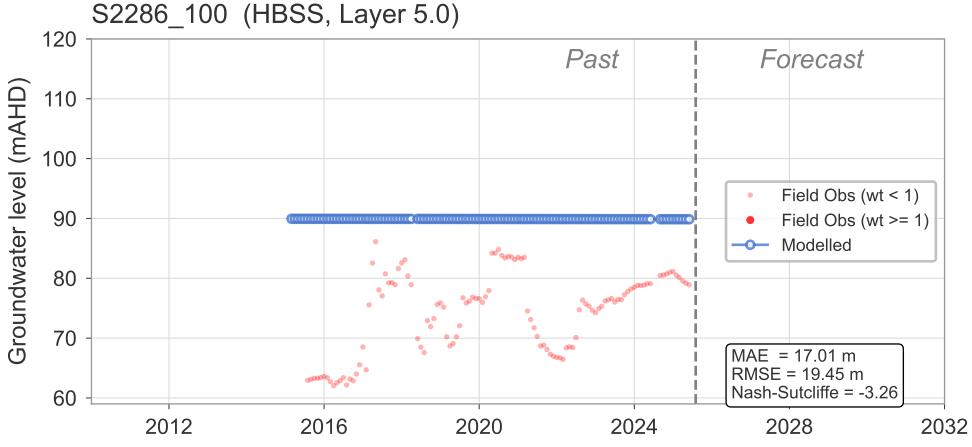
Modelled and observed groundwater hydrographs

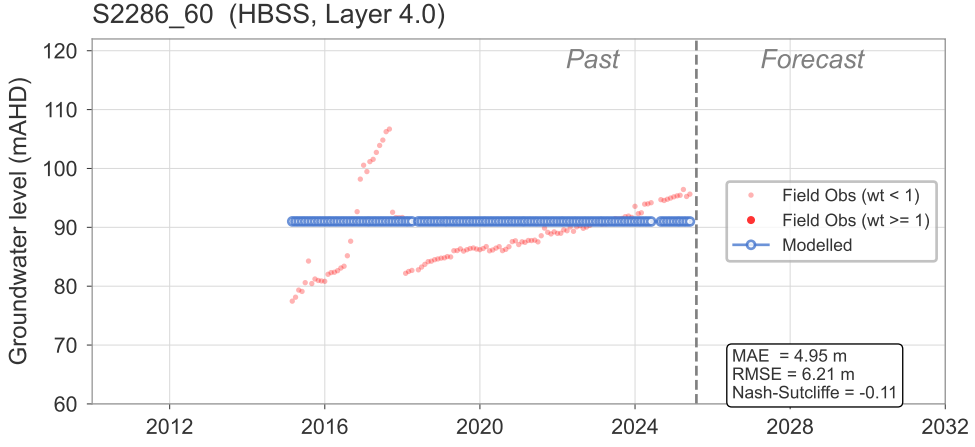












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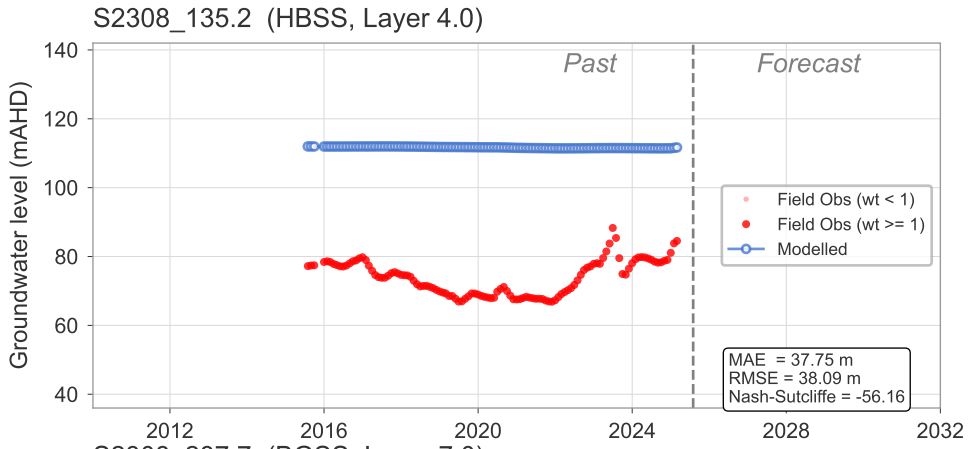

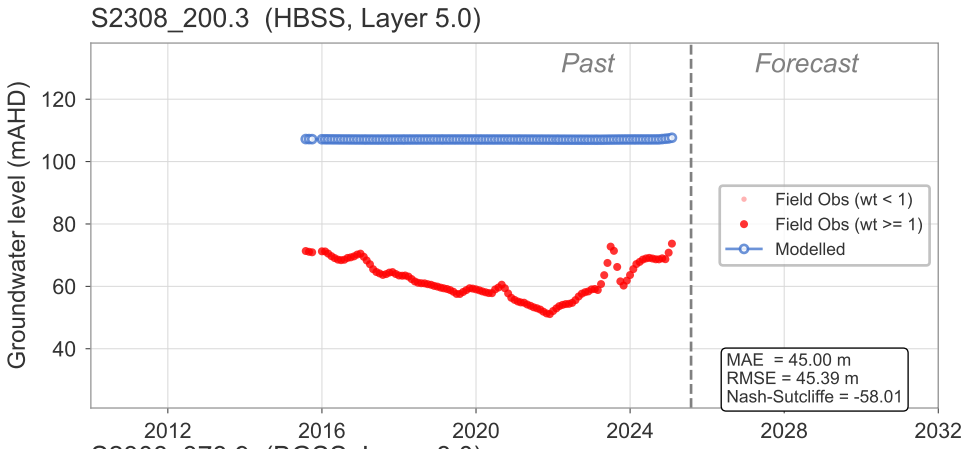

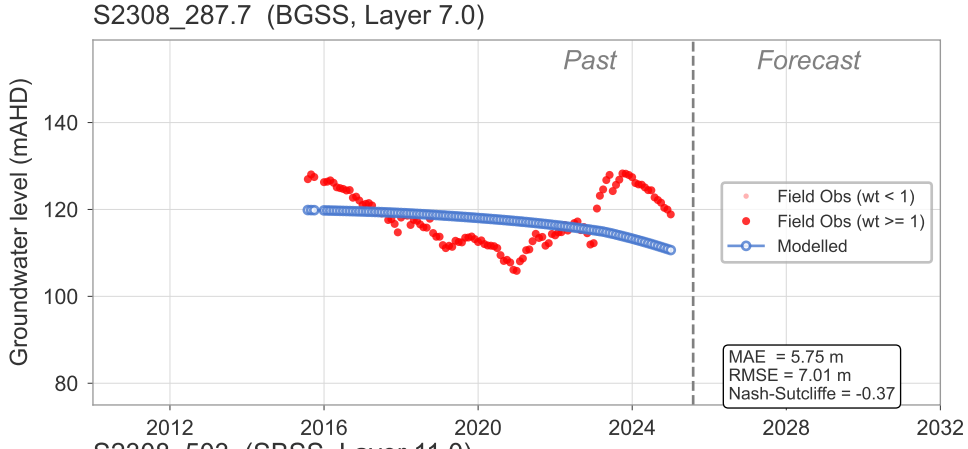

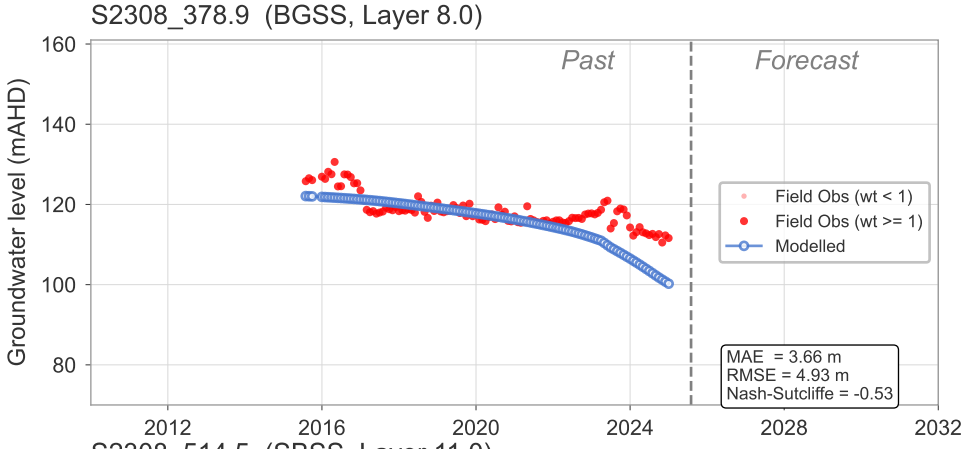

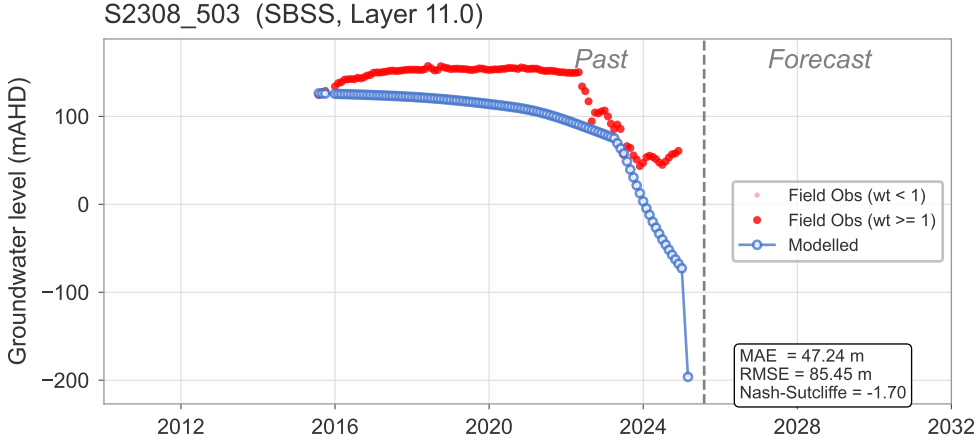

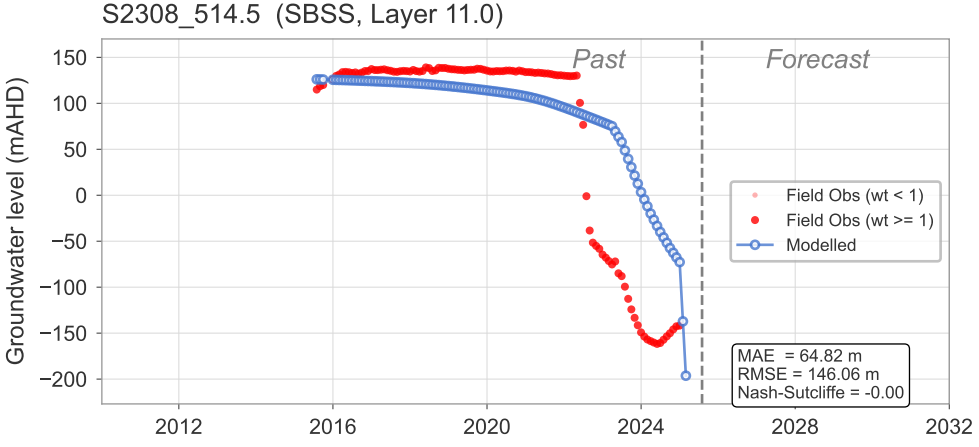

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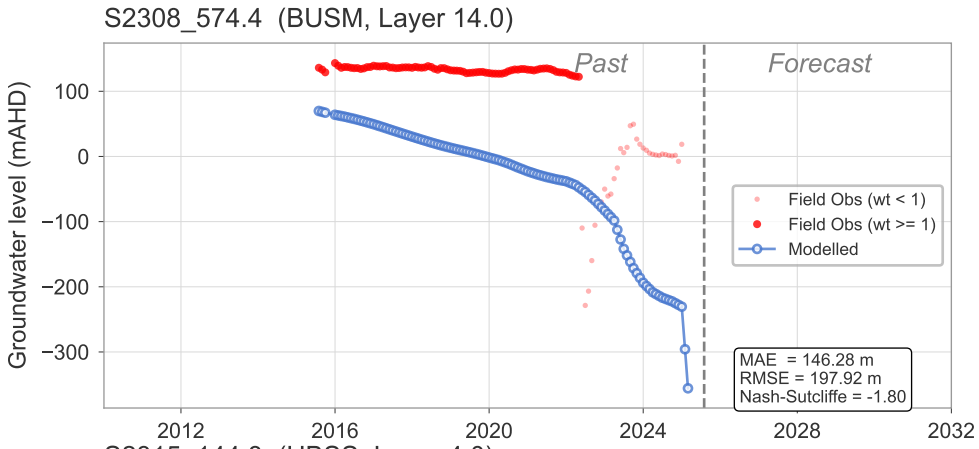
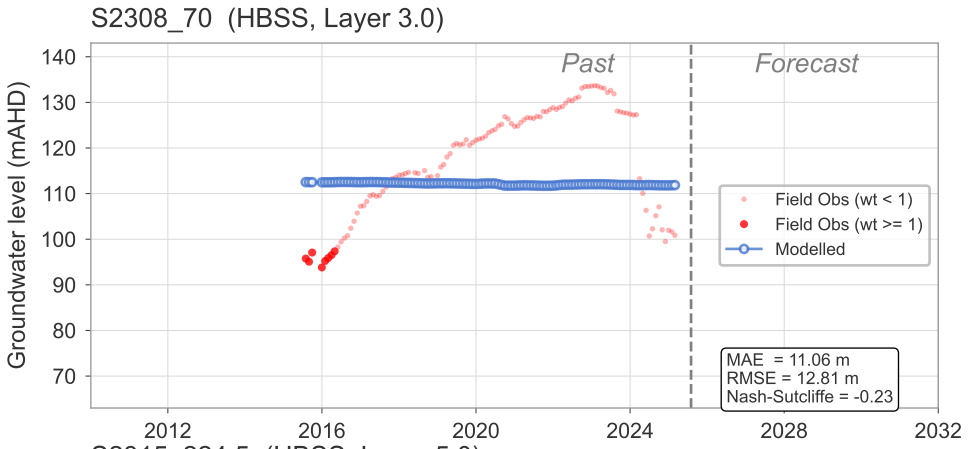
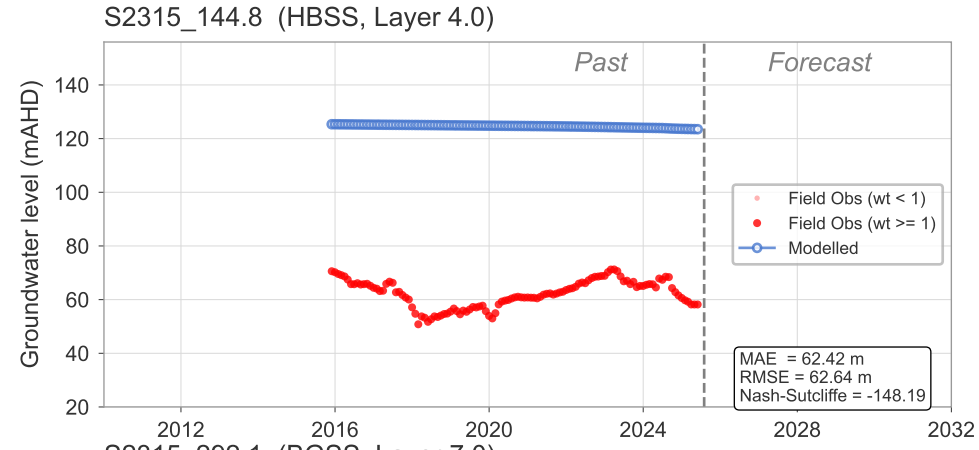
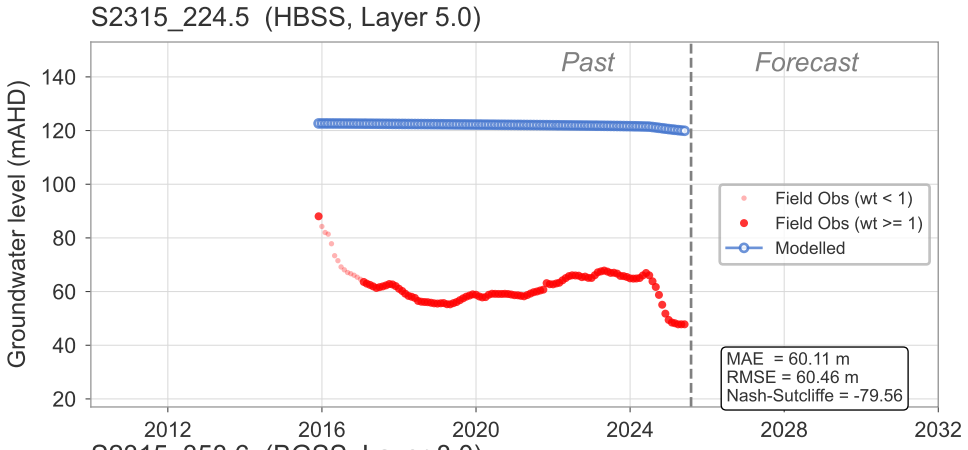
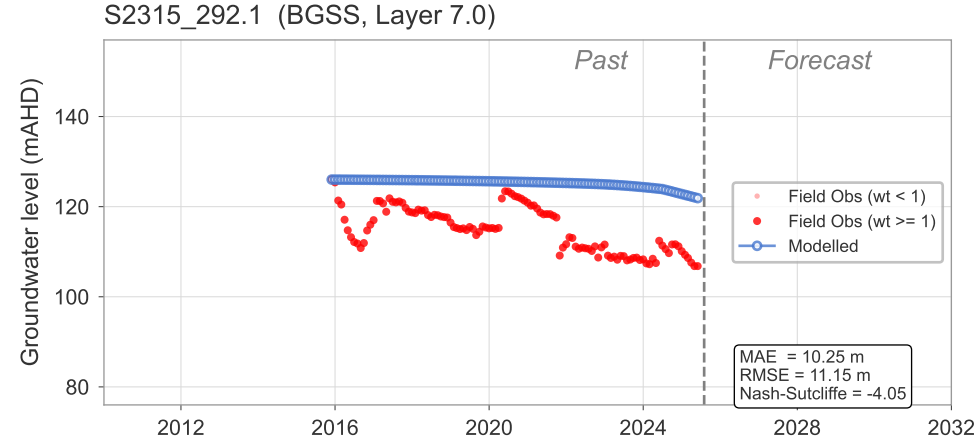
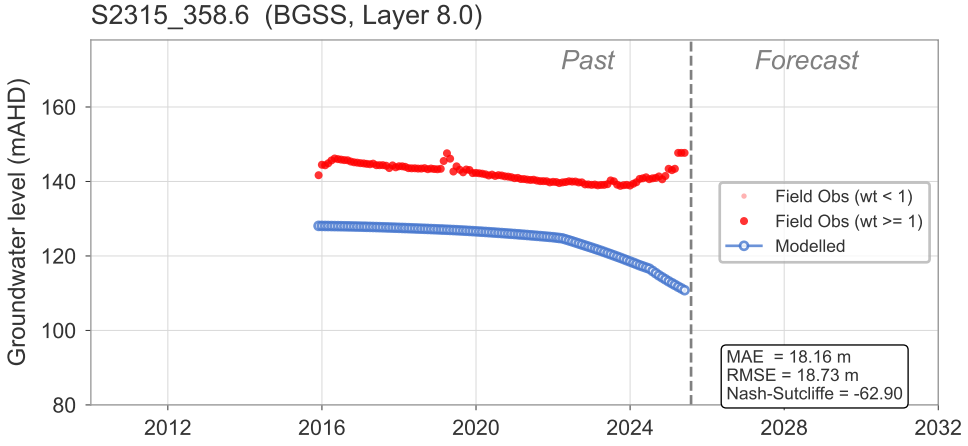




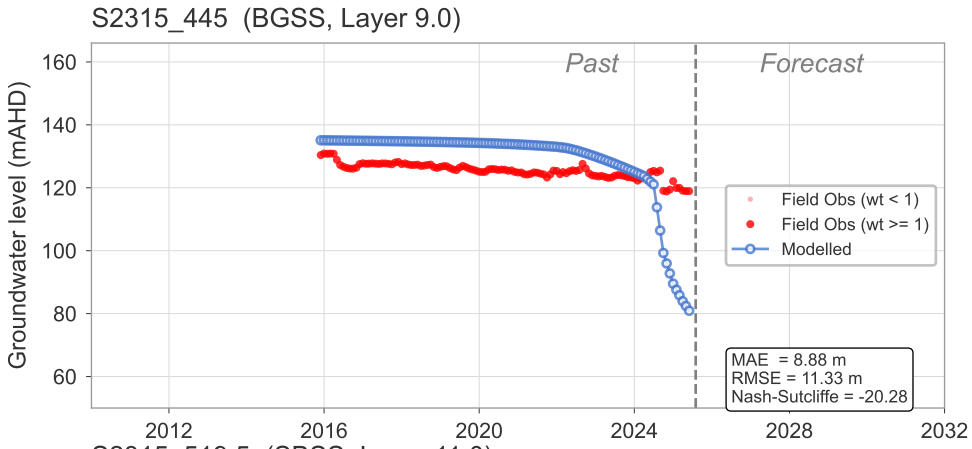


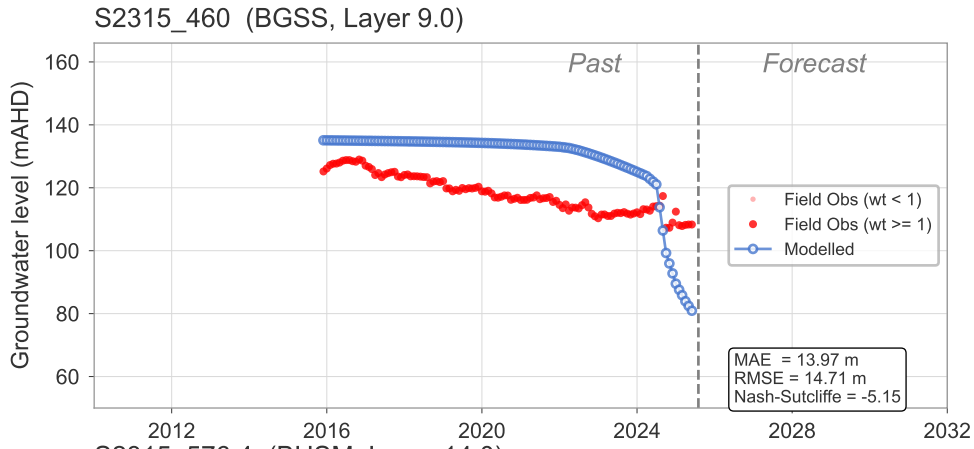


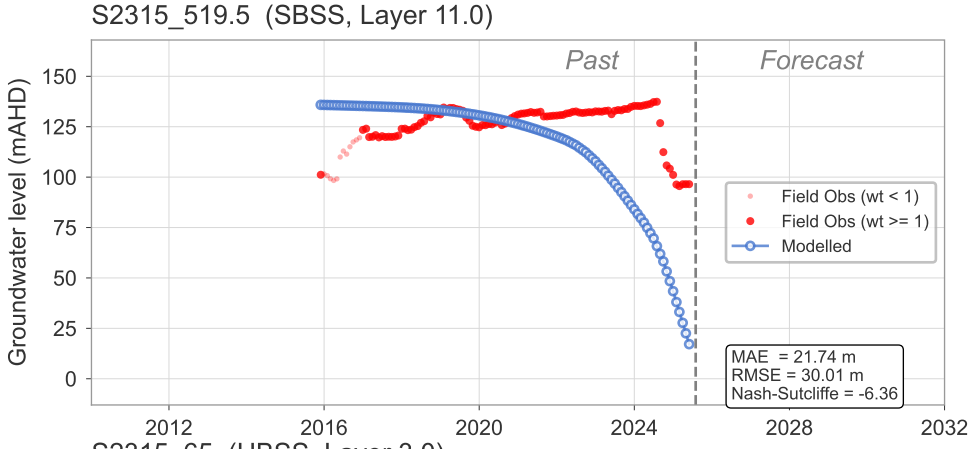


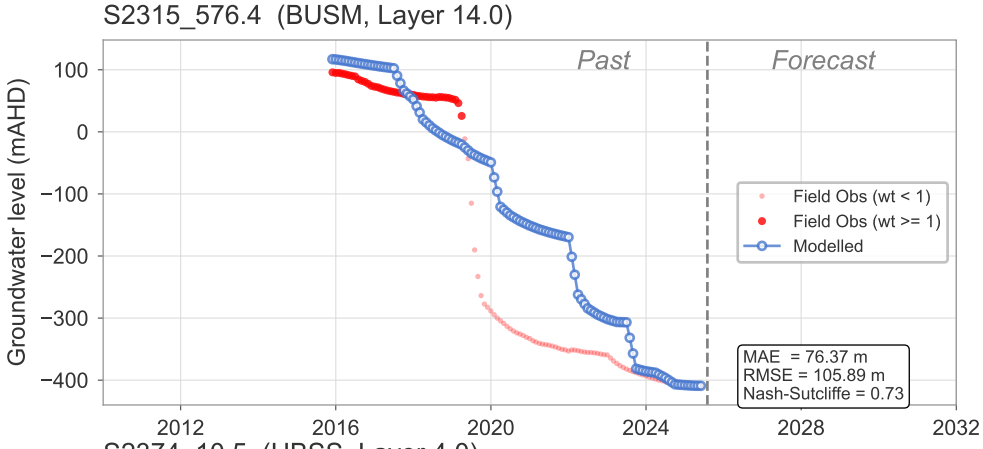


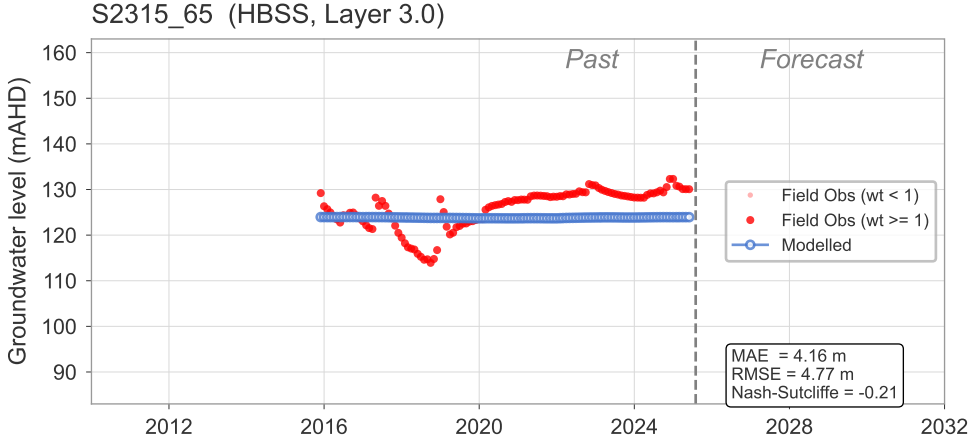
Modelled and observed groundwater hydrographs

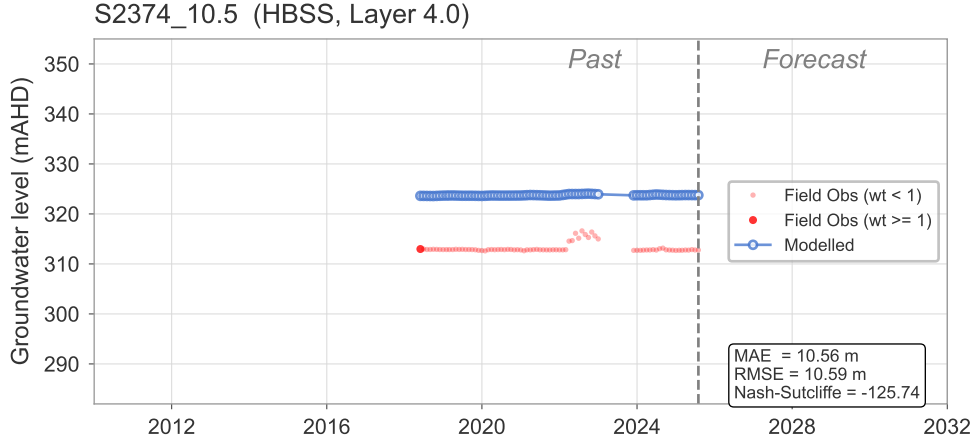












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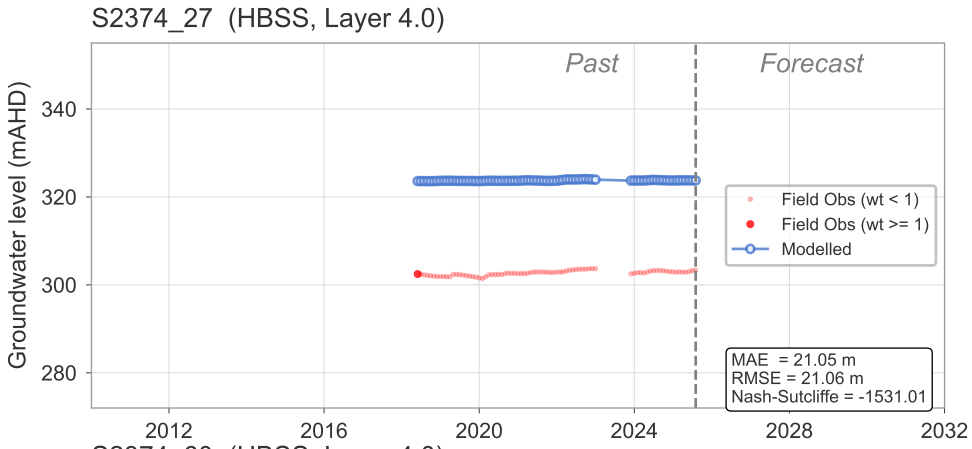

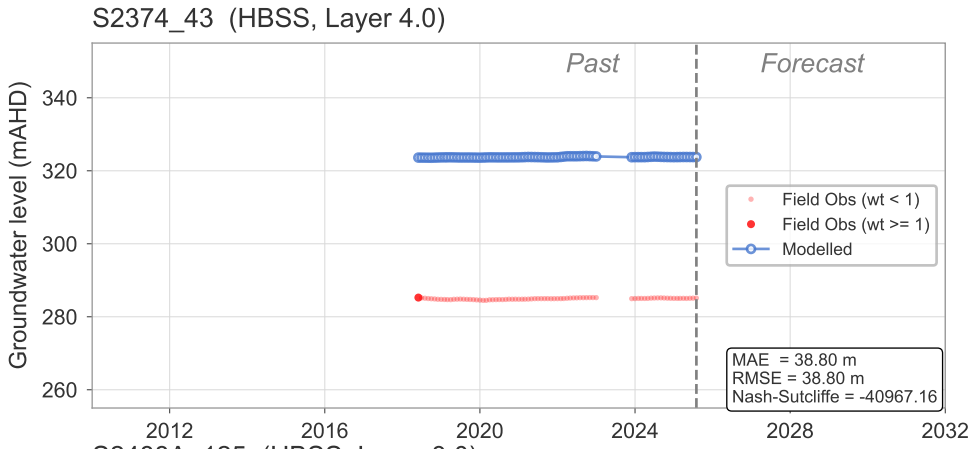

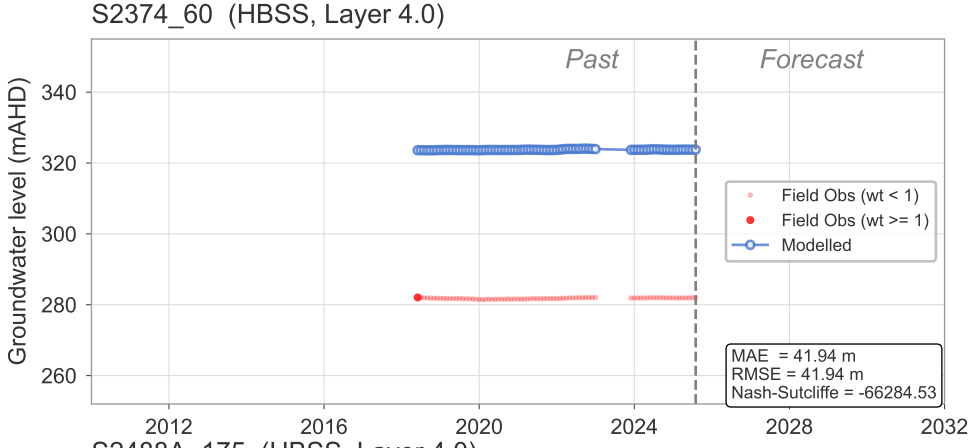

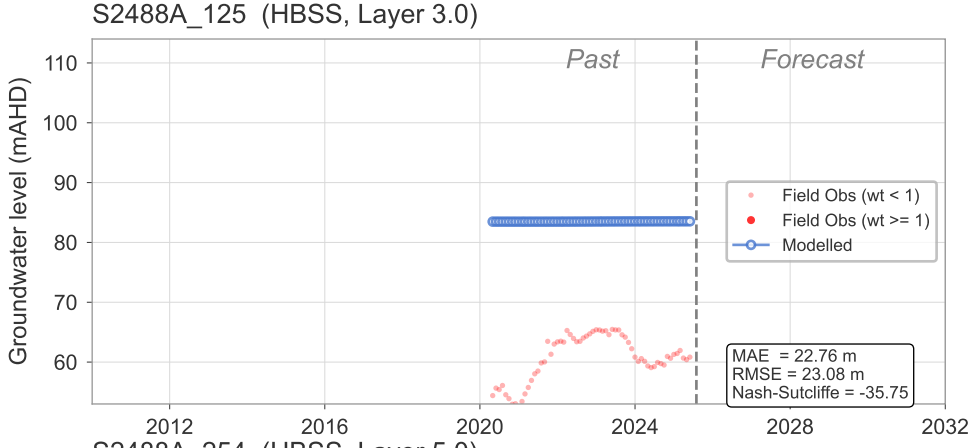

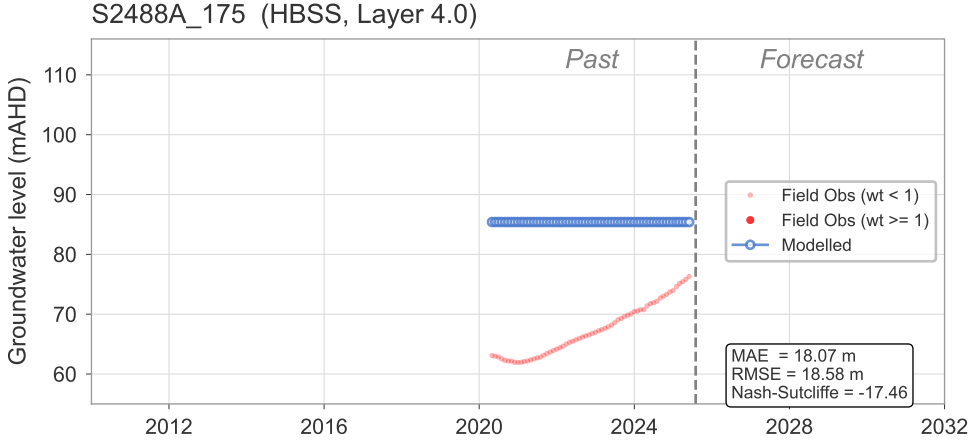

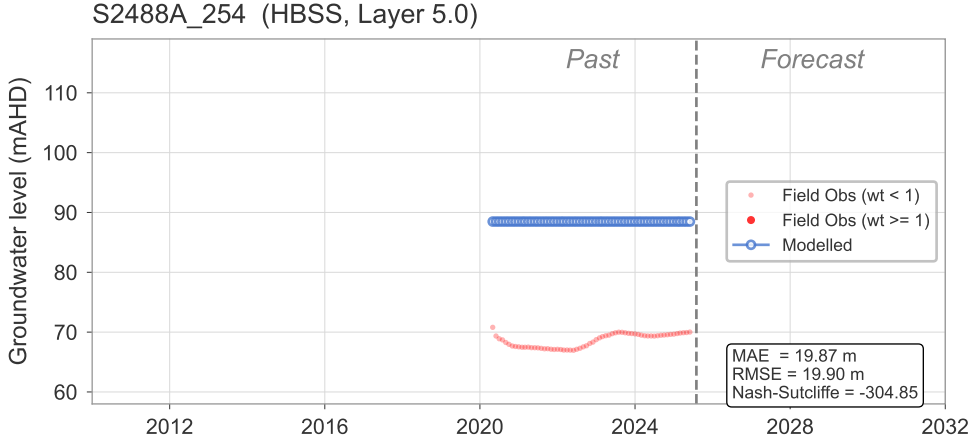

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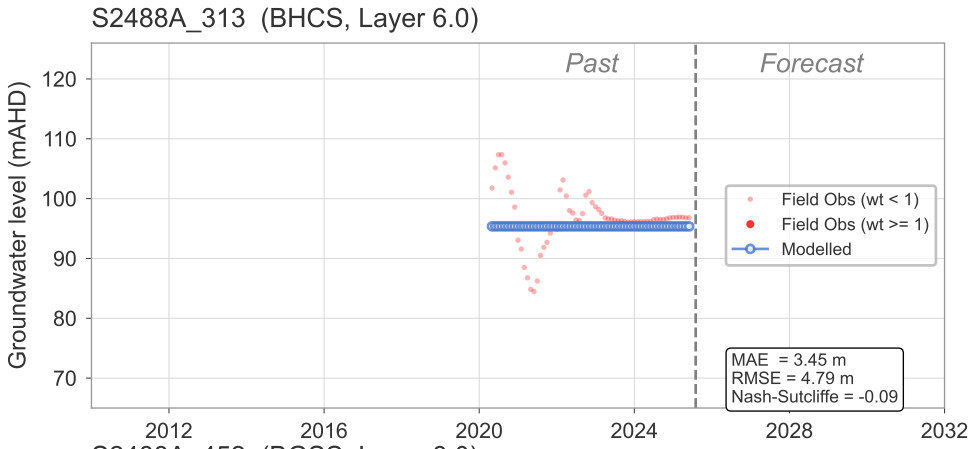

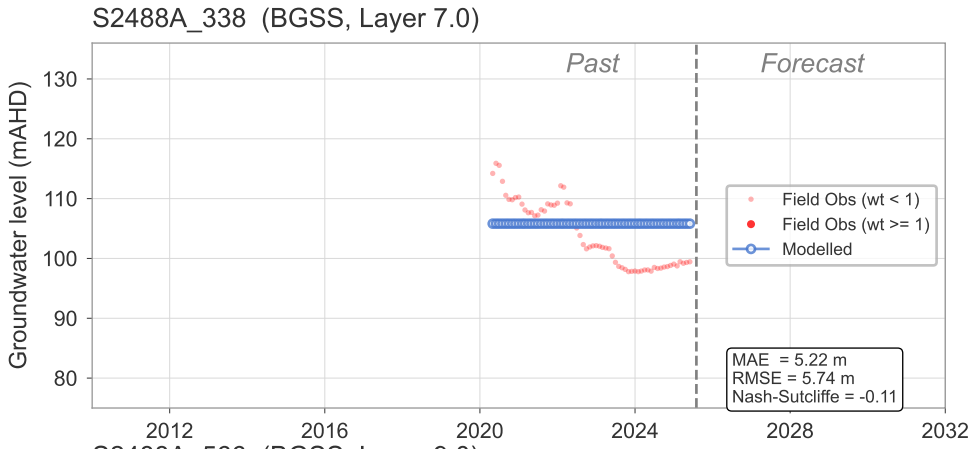

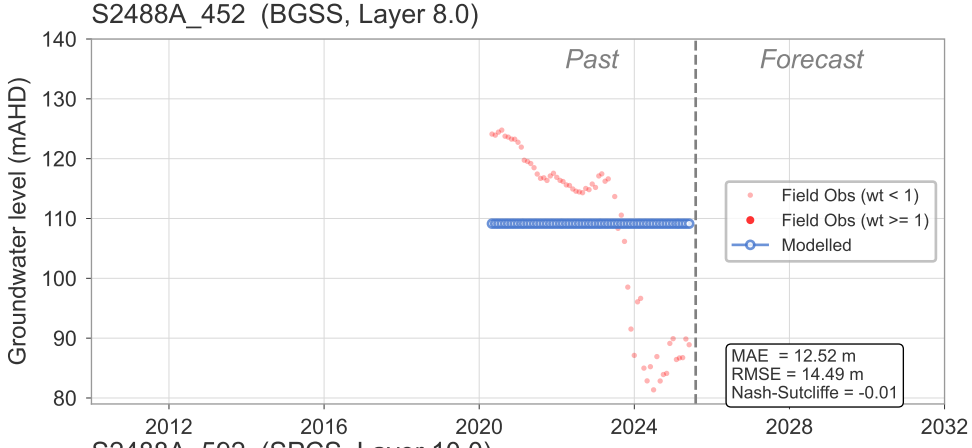

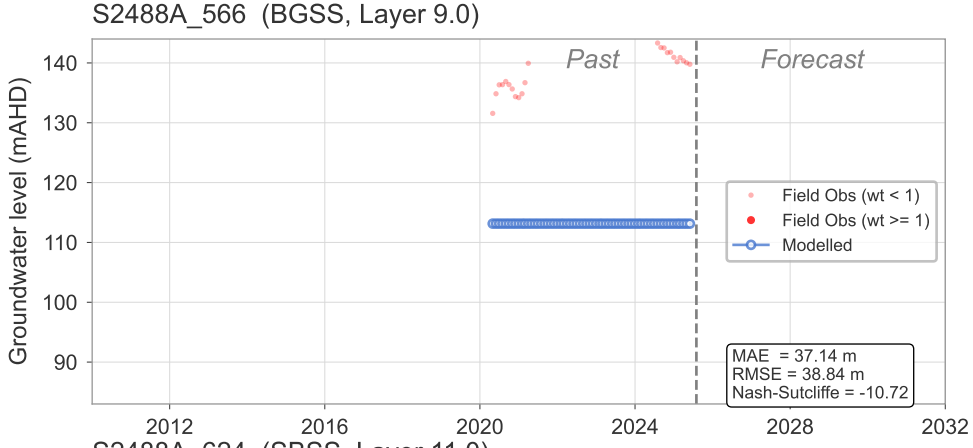

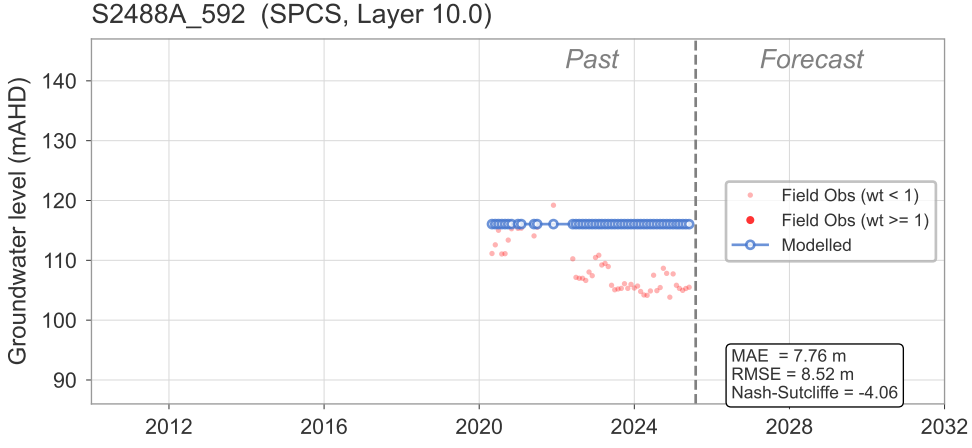

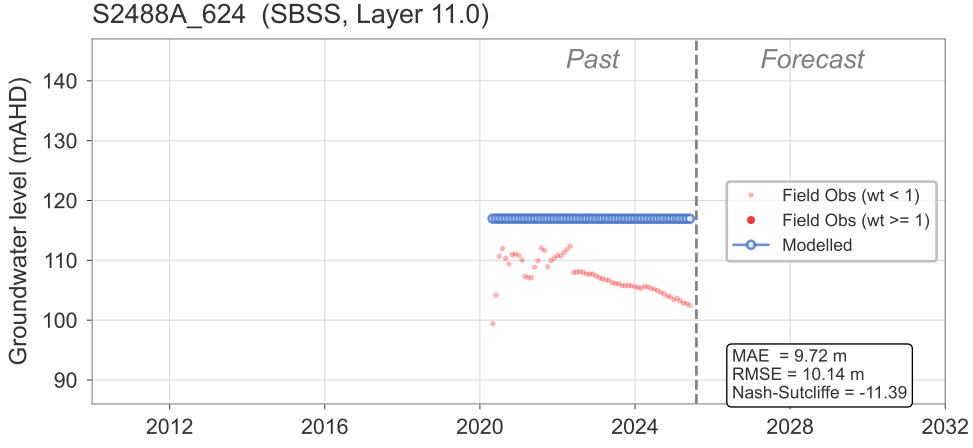

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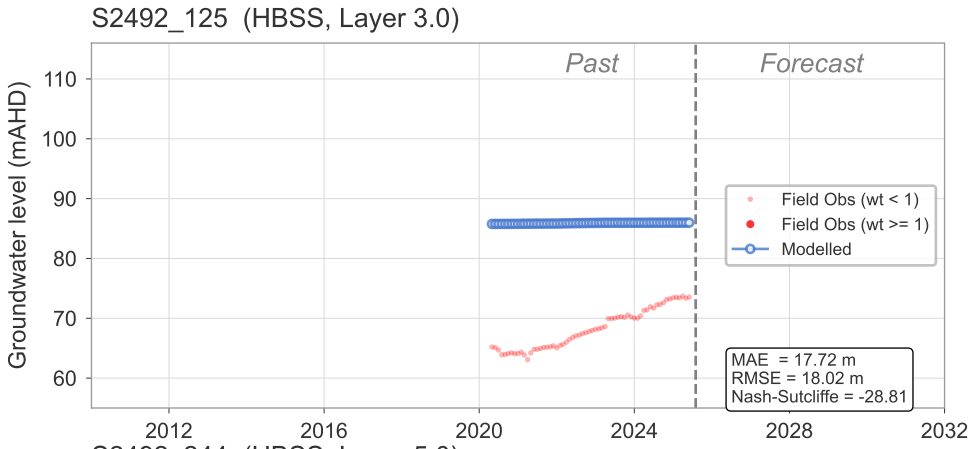

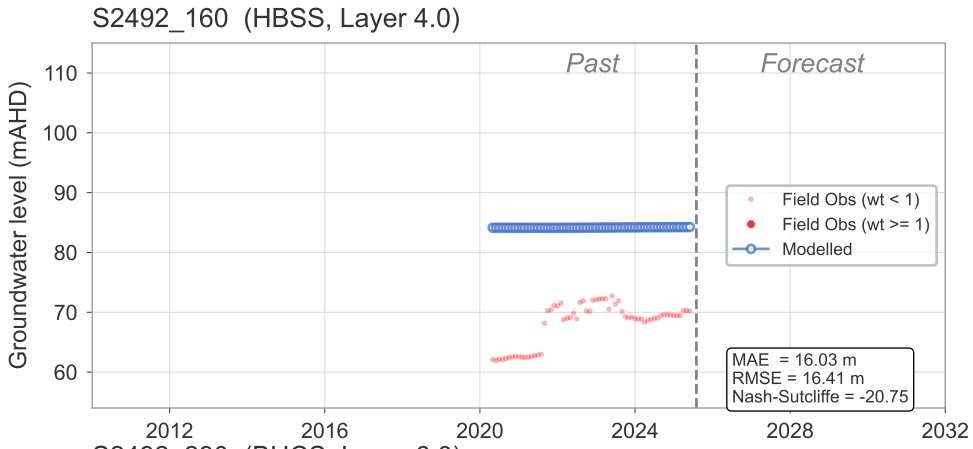

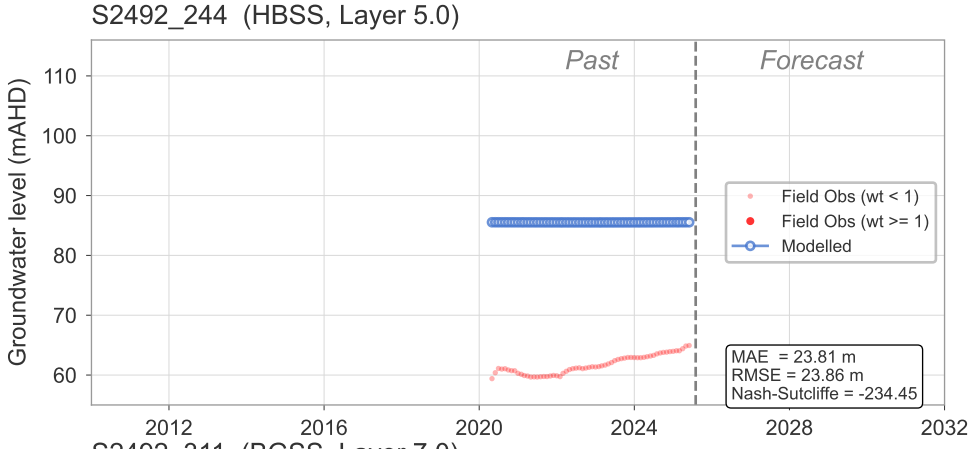

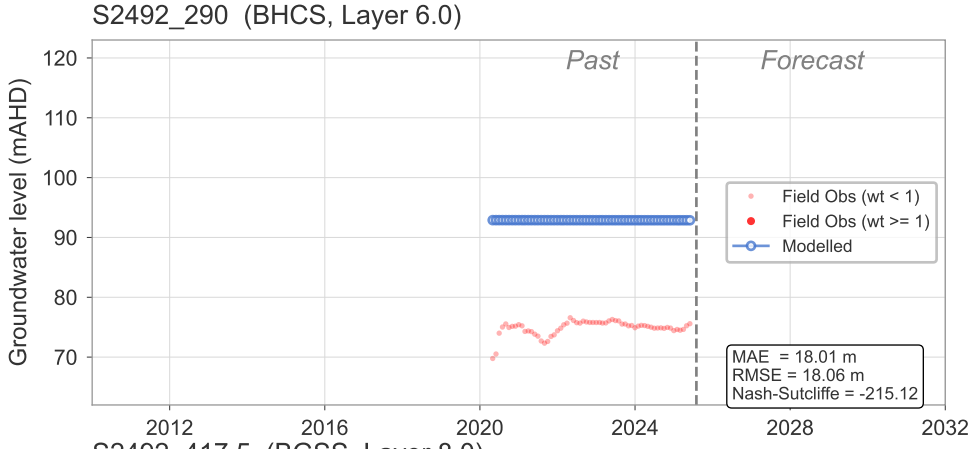

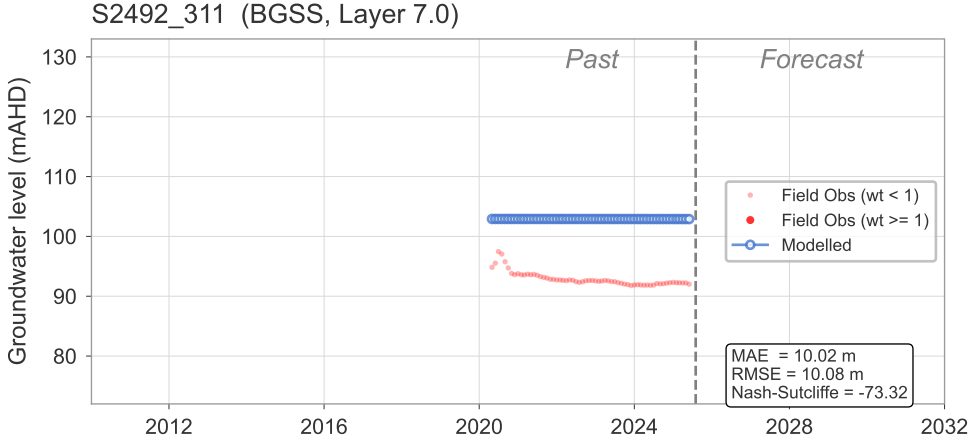

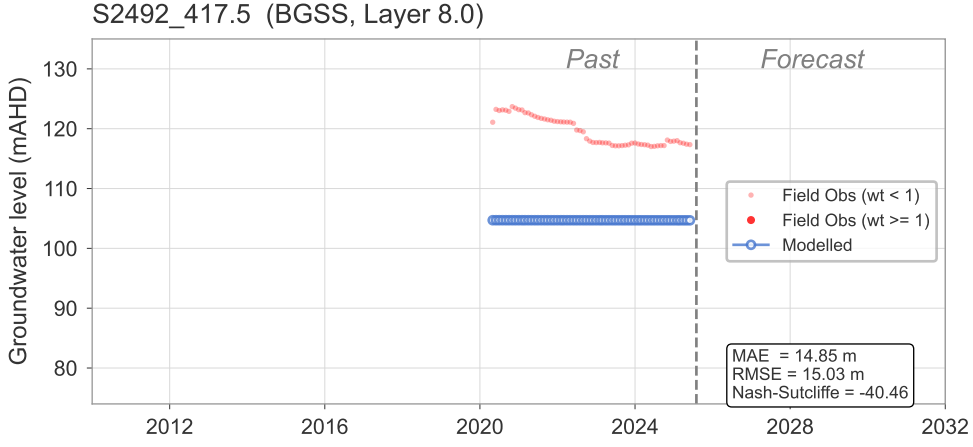

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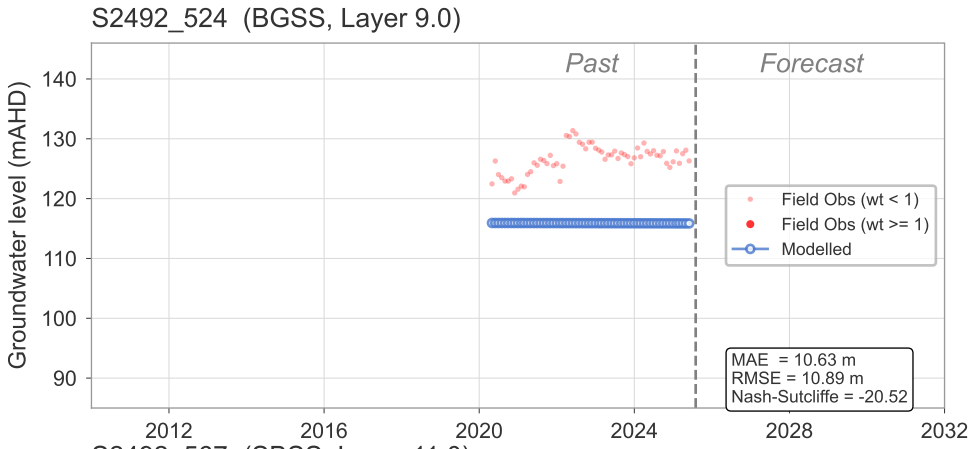

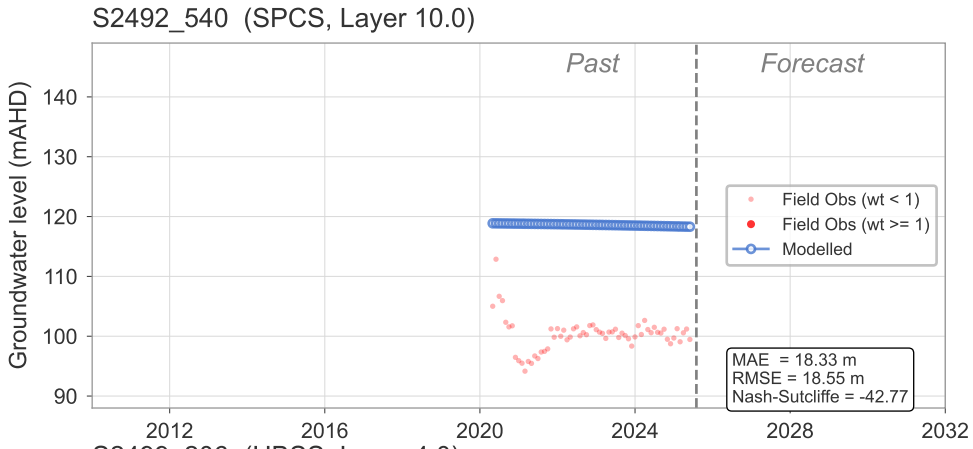

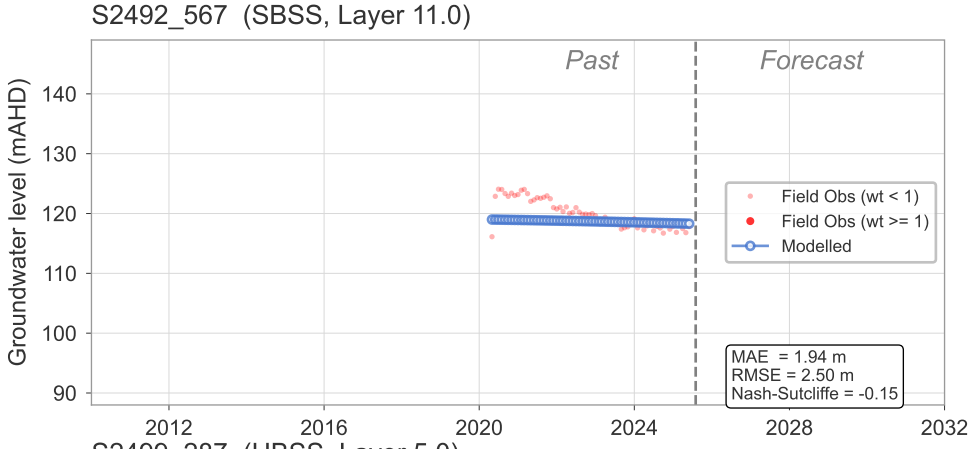

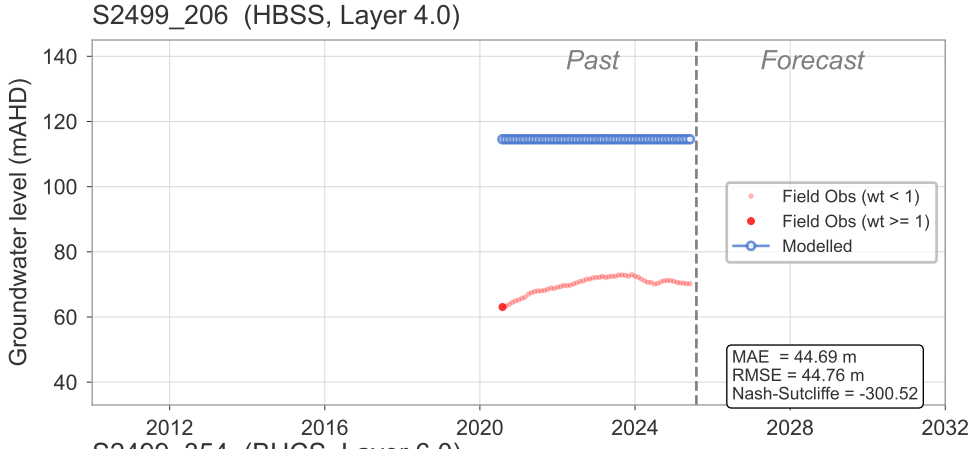

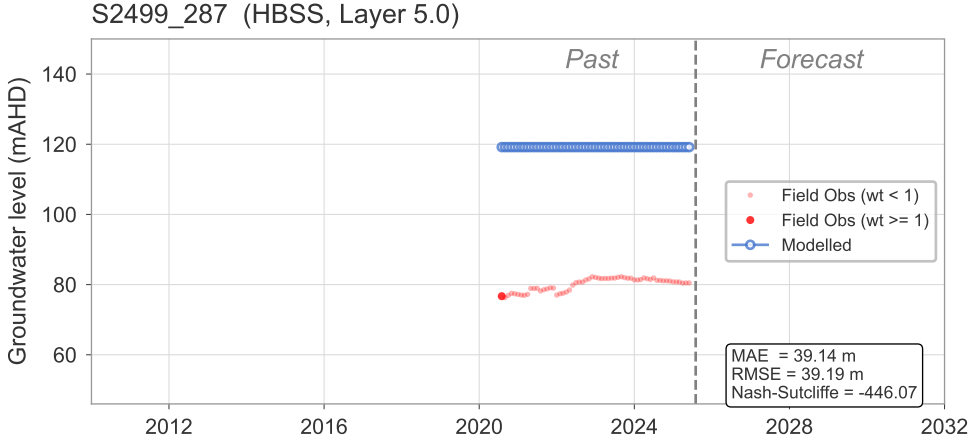

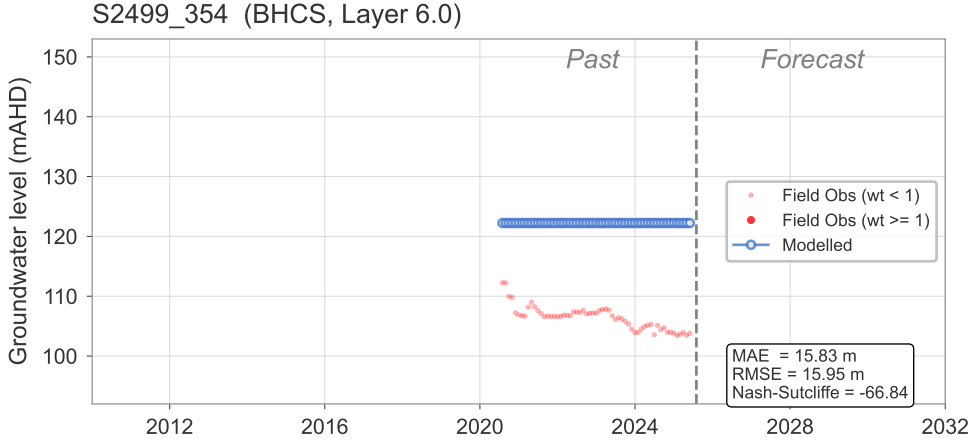

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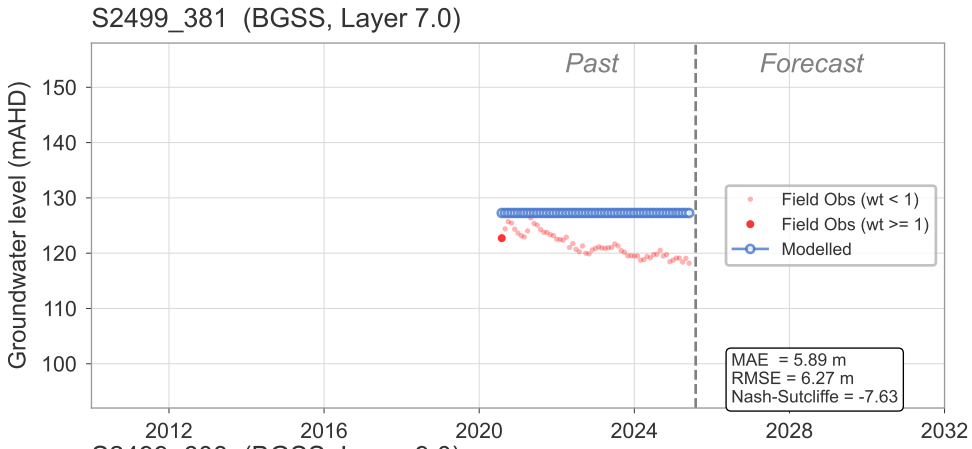

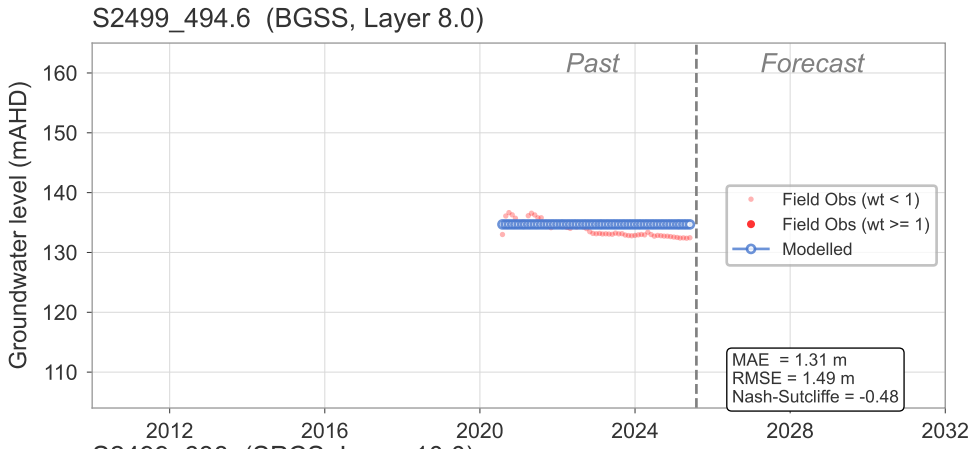

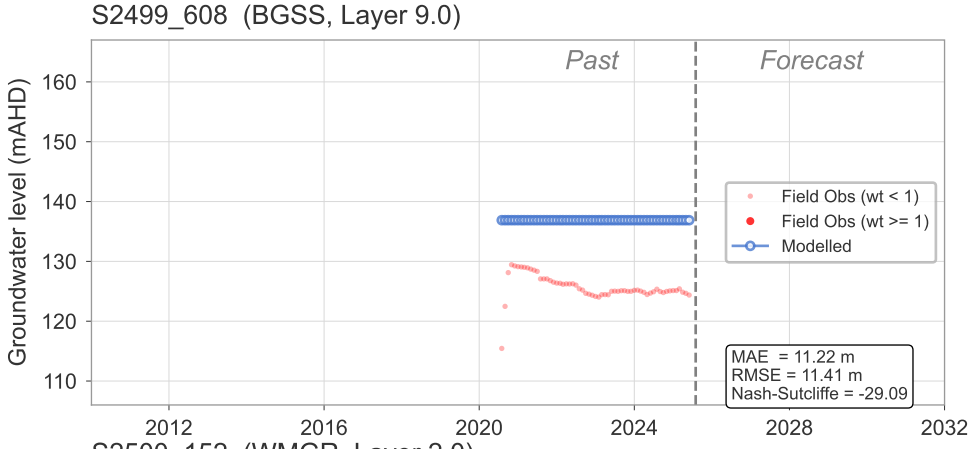

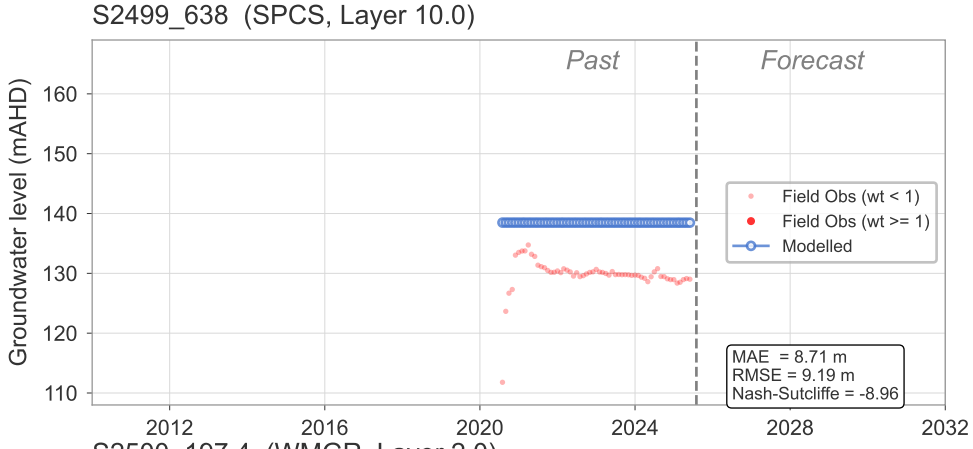

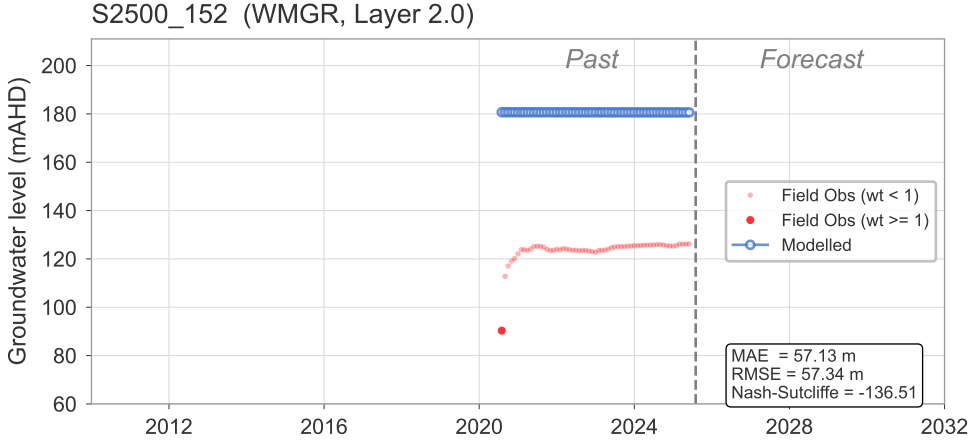

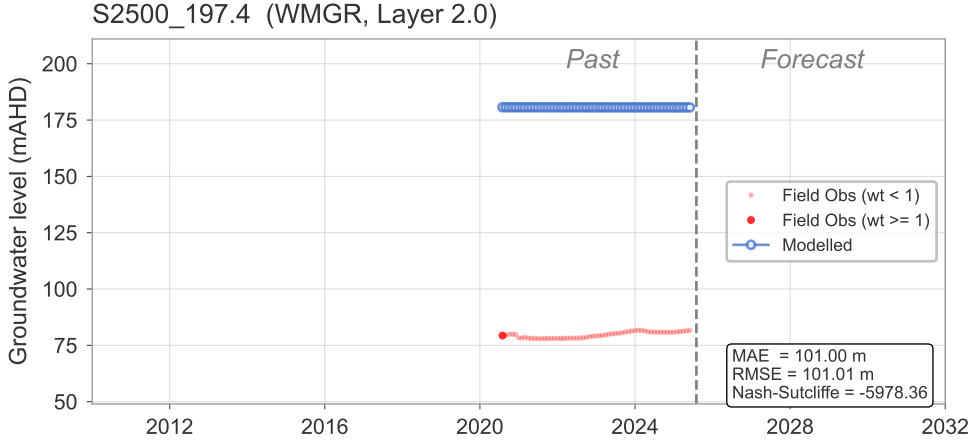

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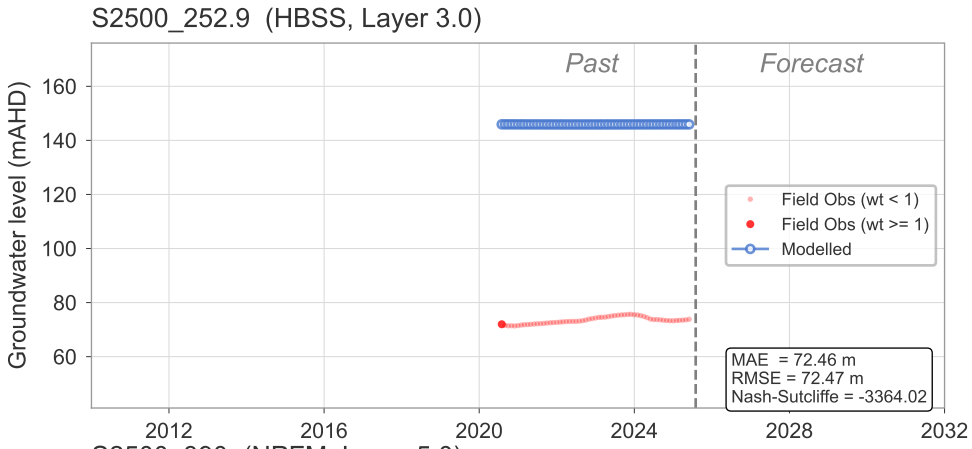
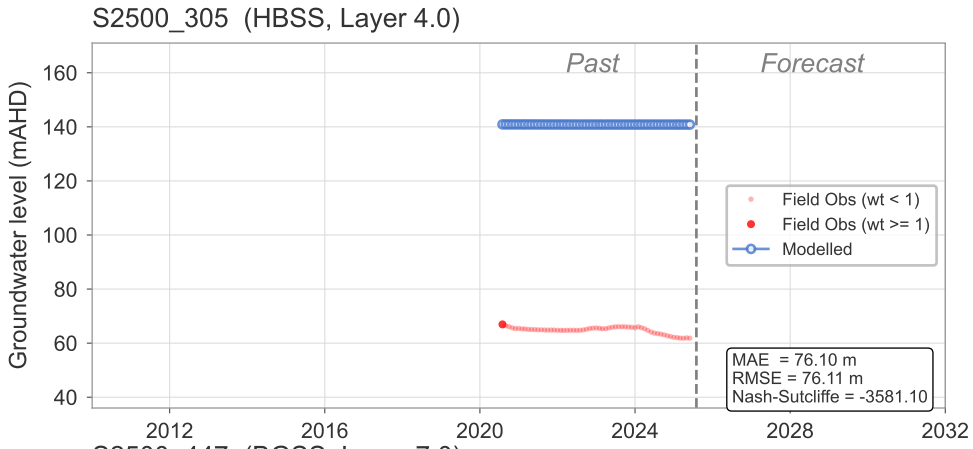
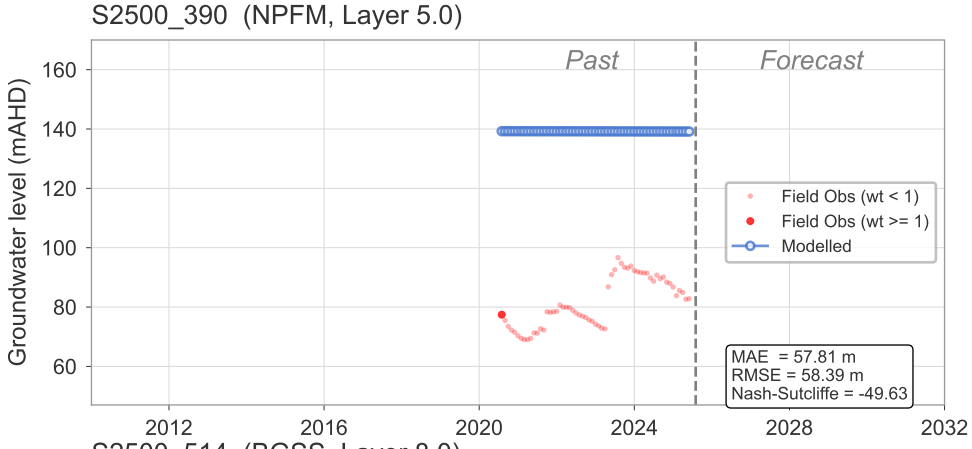
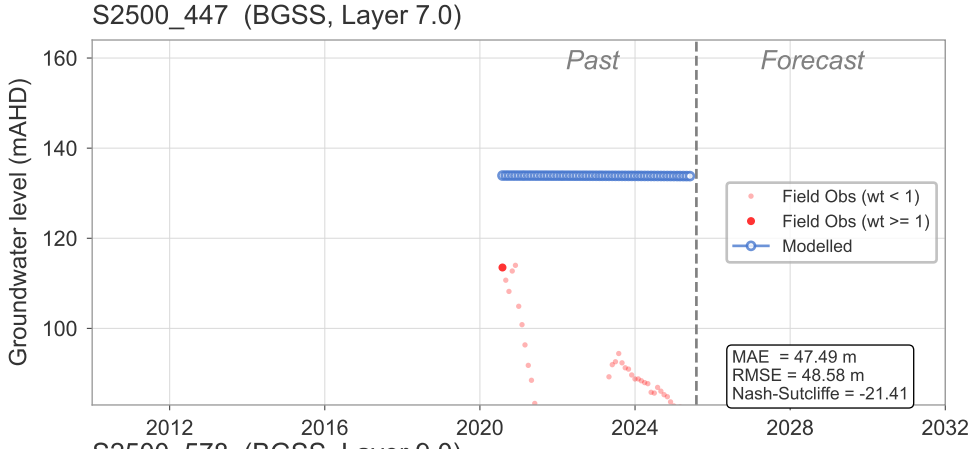
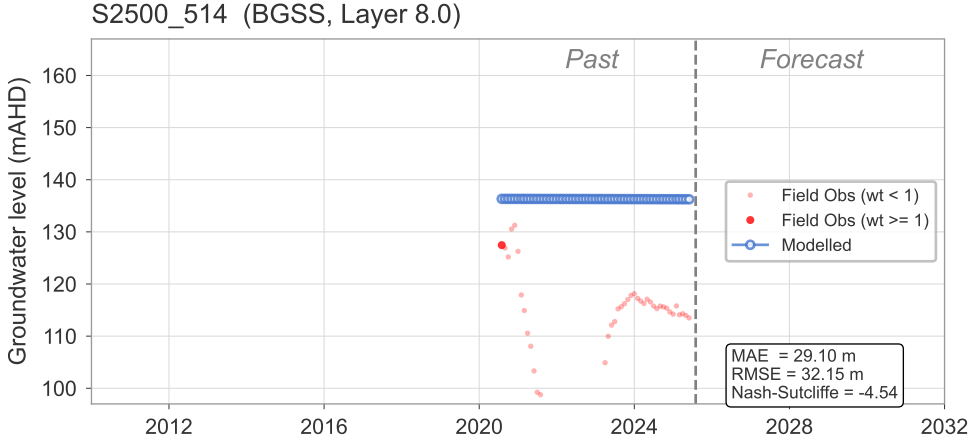
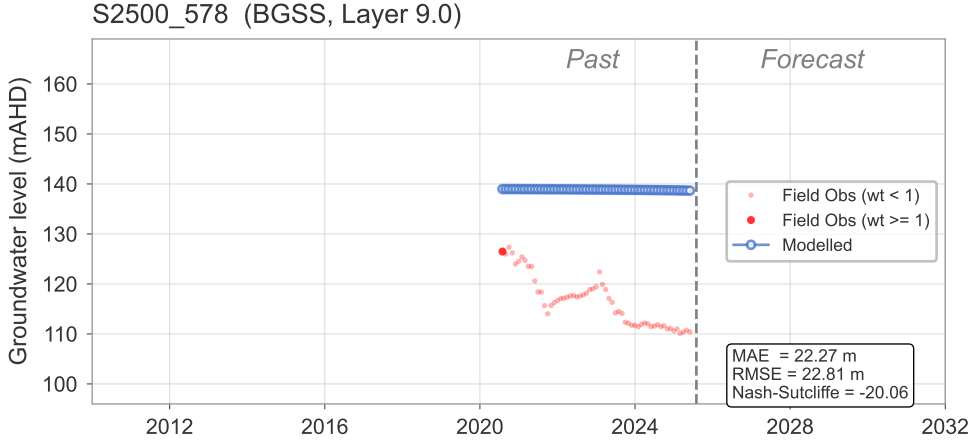




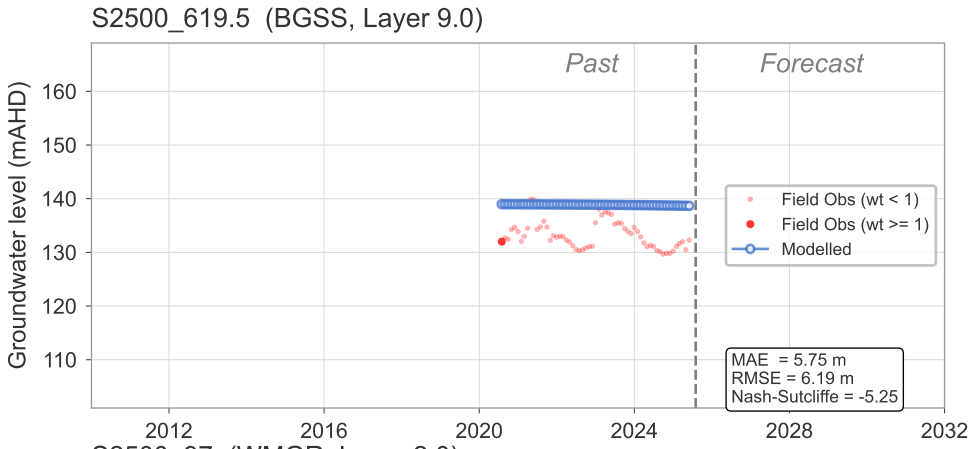


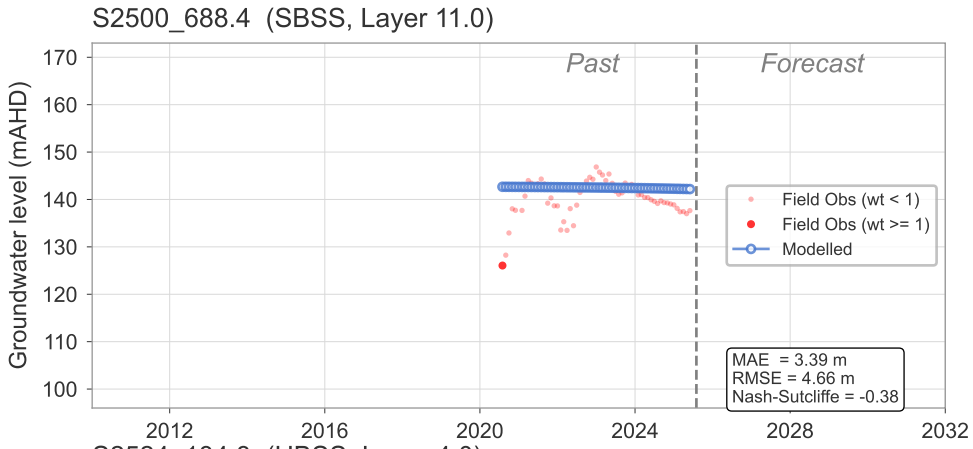


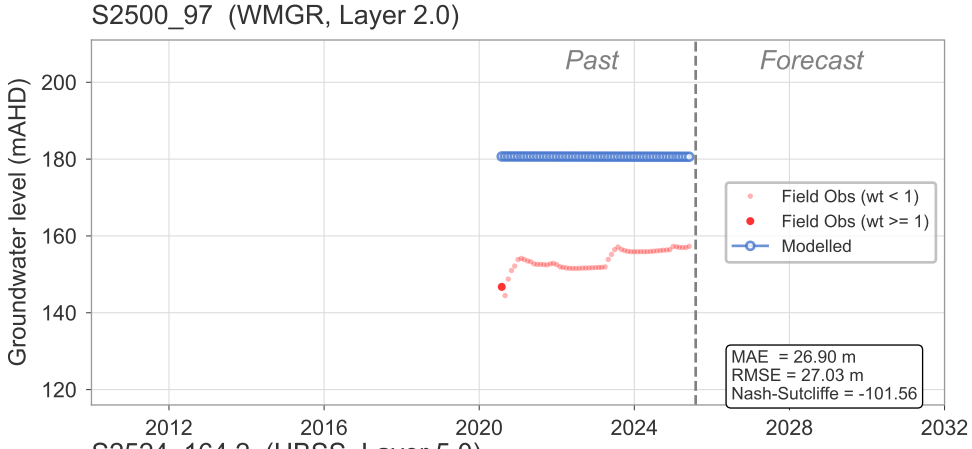


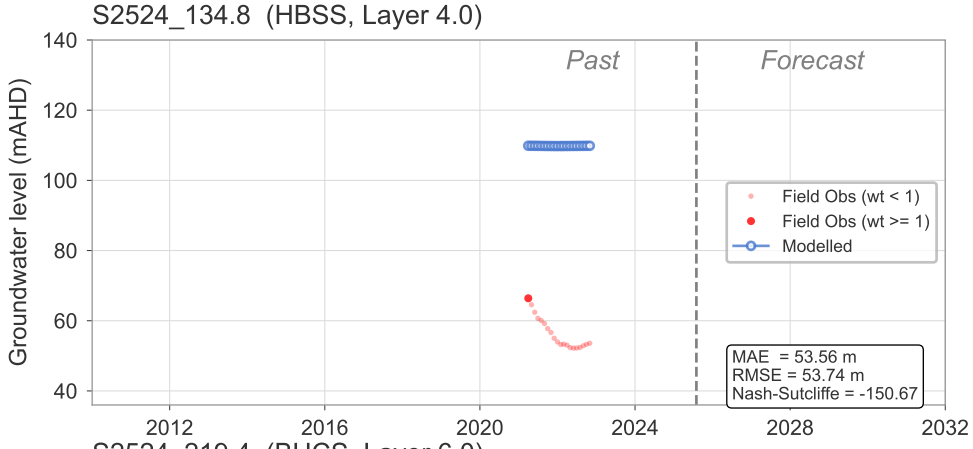


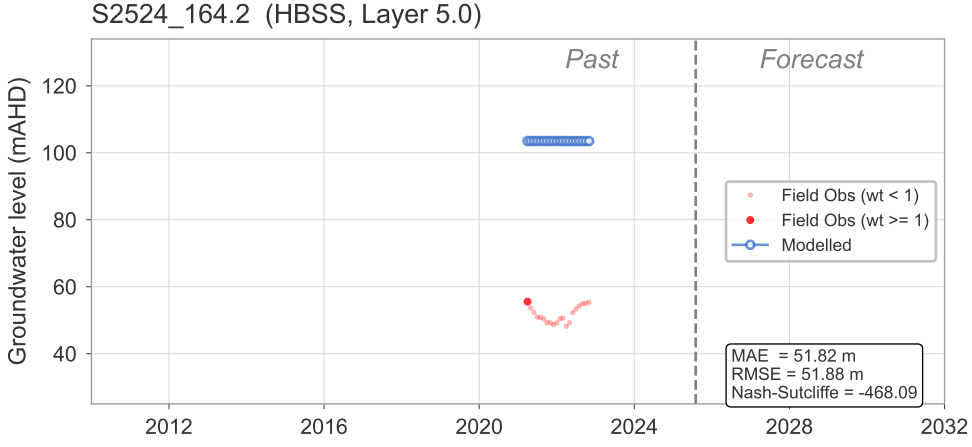
Modelled and observed groundwater hydrographs

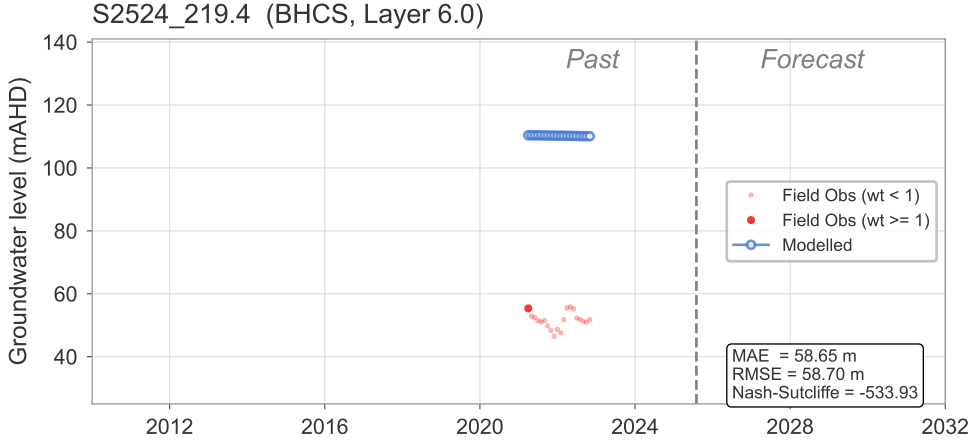












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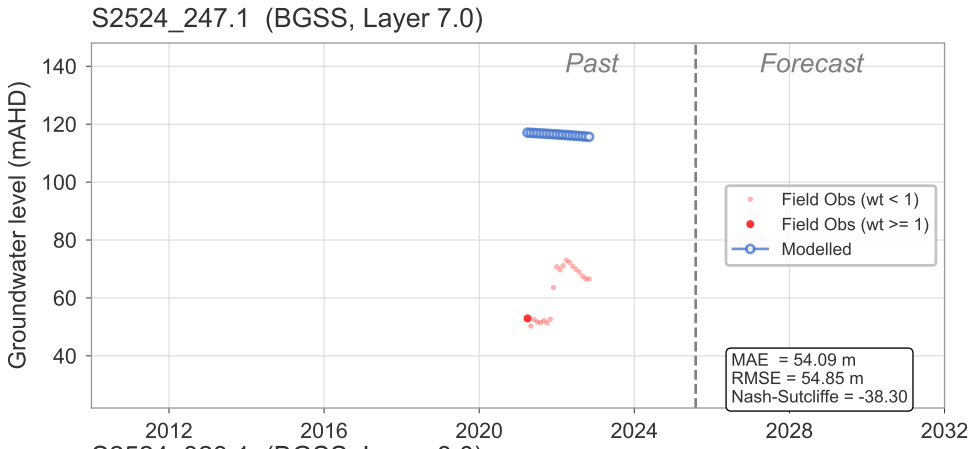

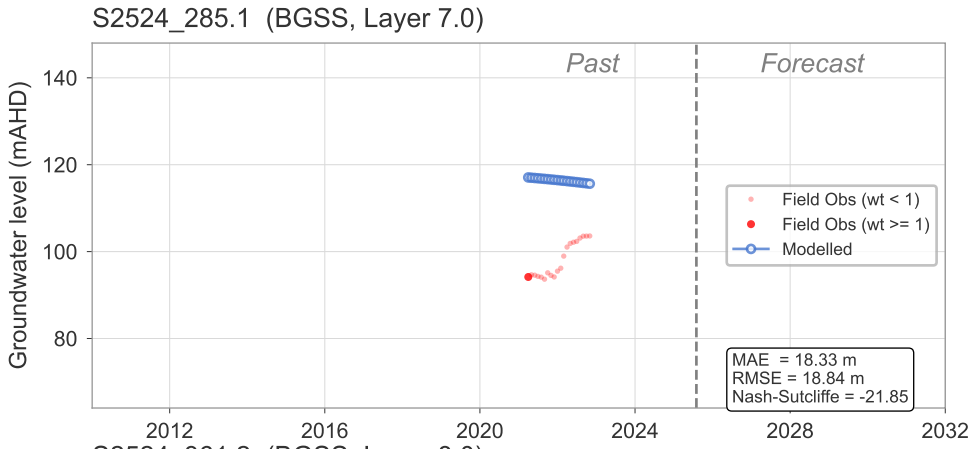

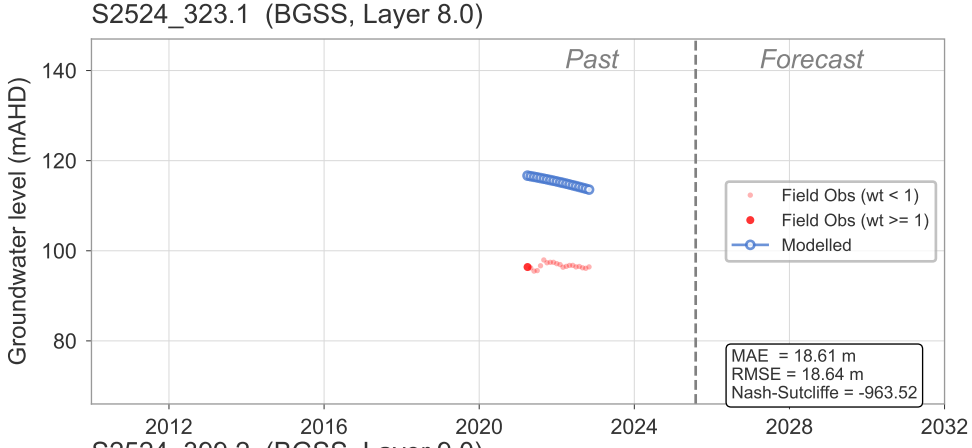

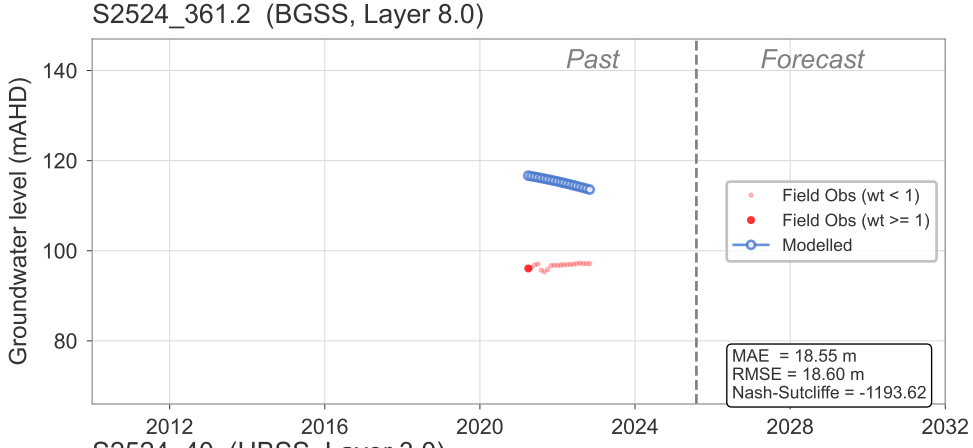

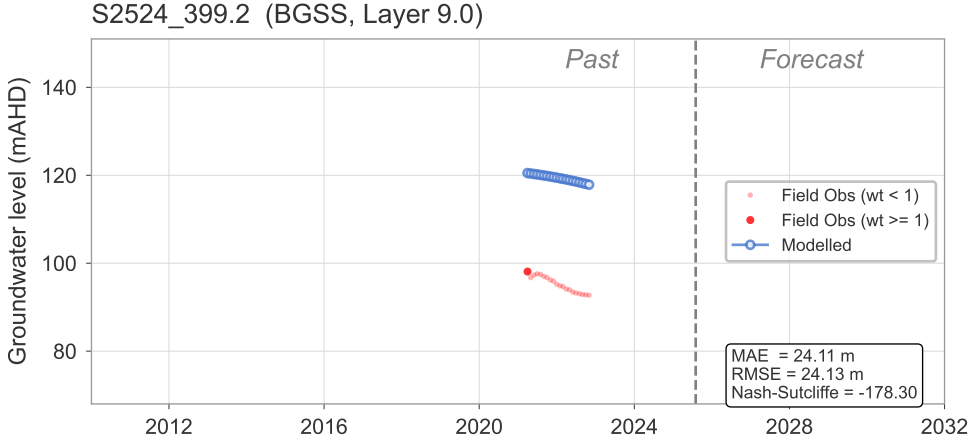

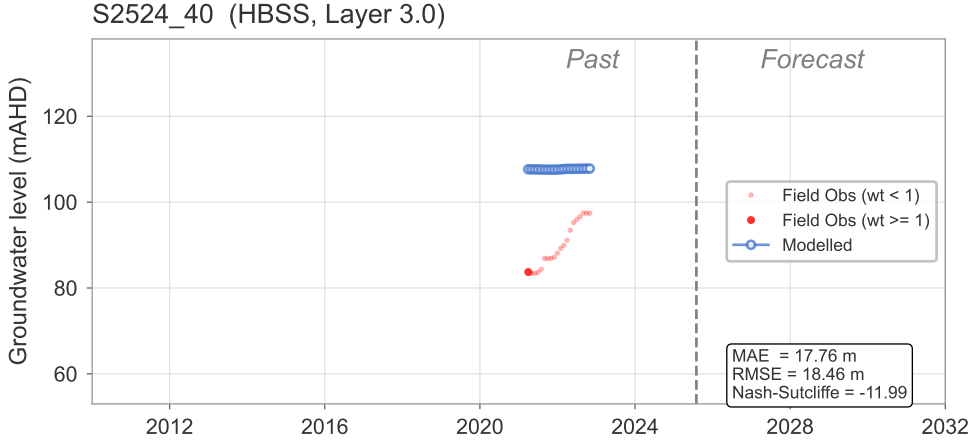

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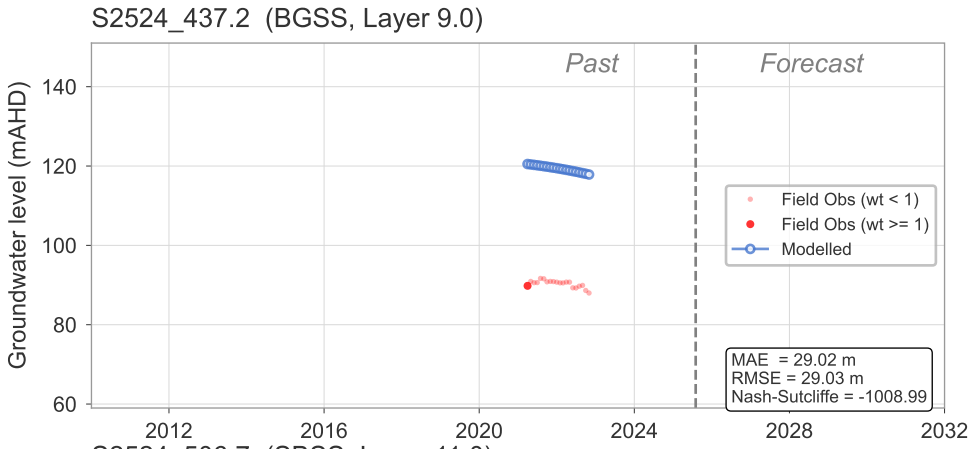

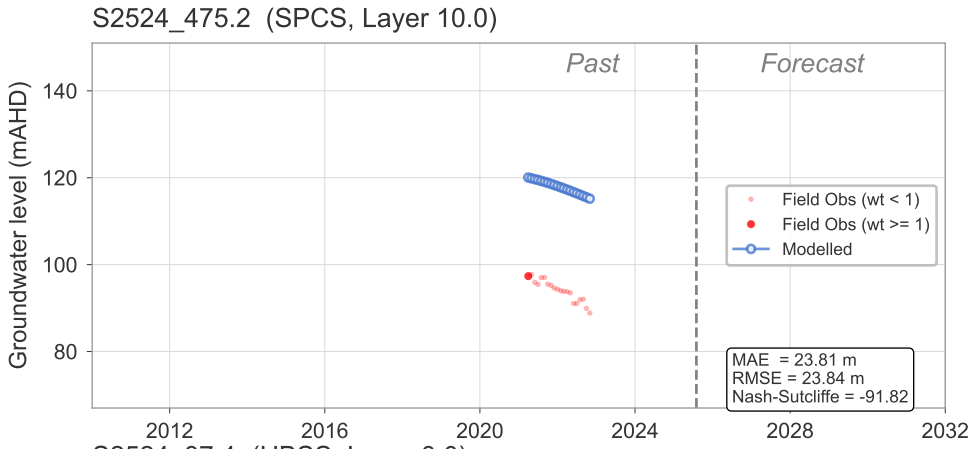

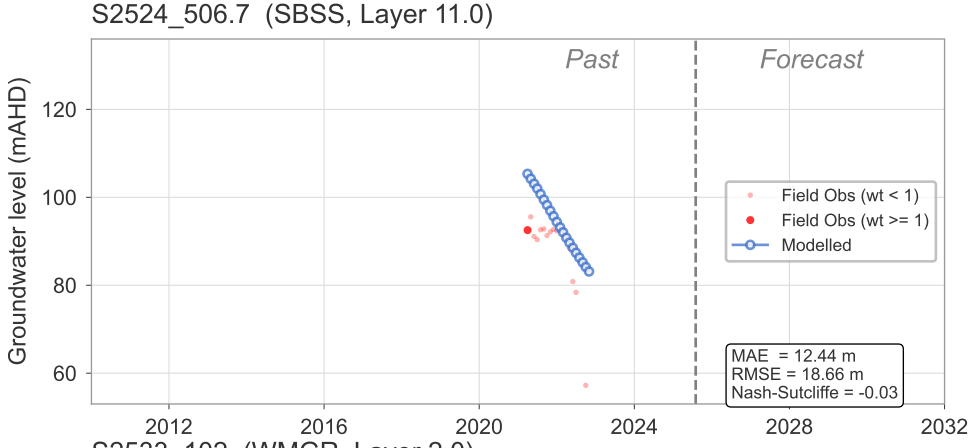

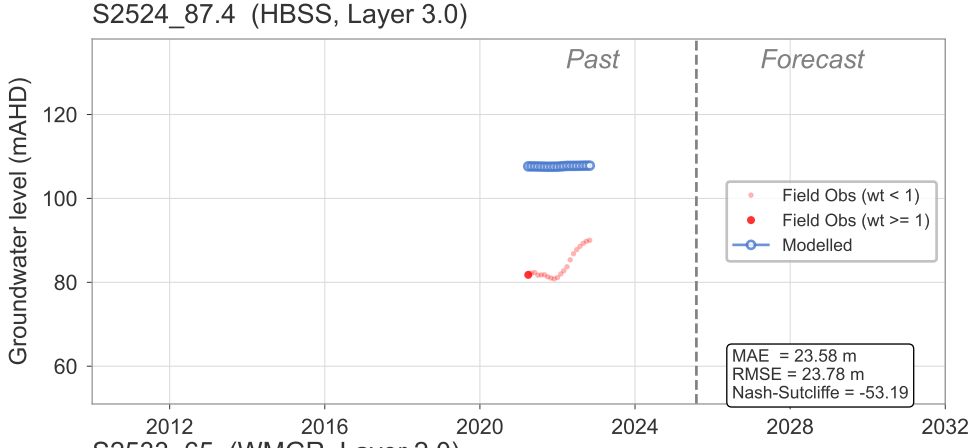

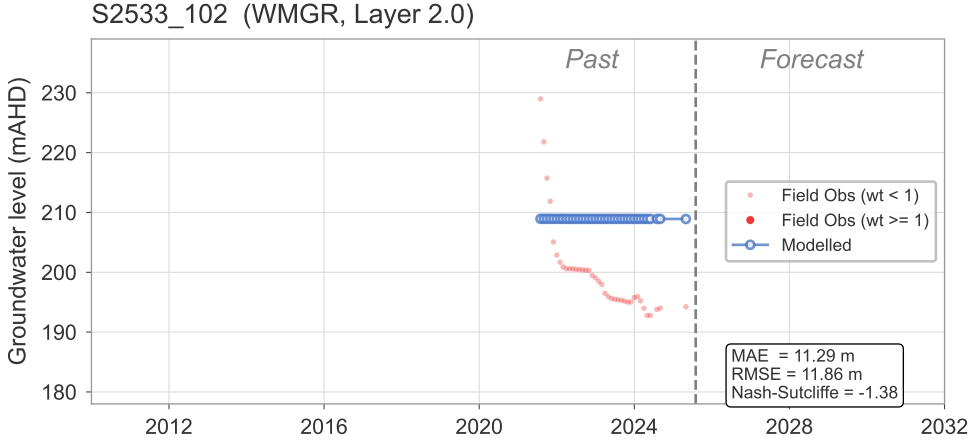

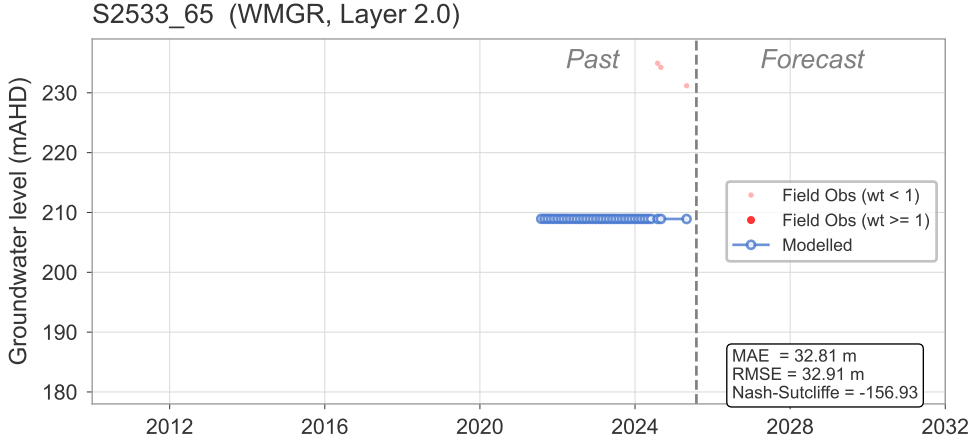

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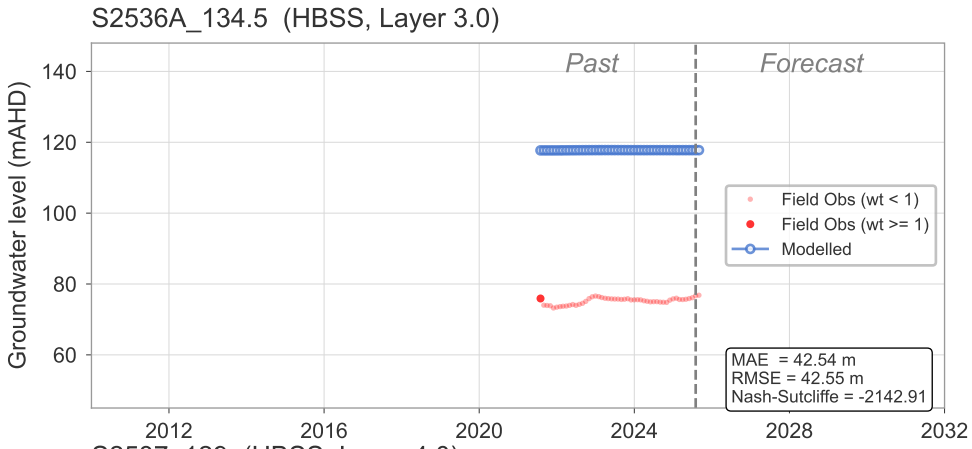

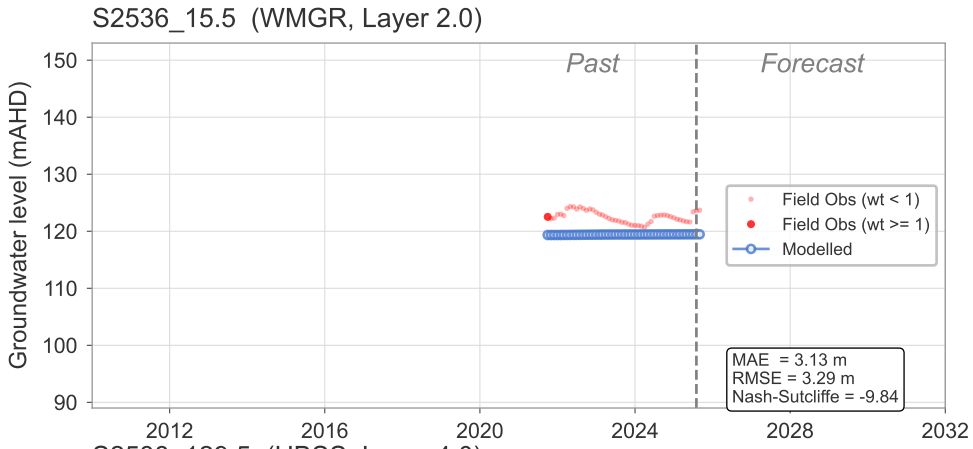

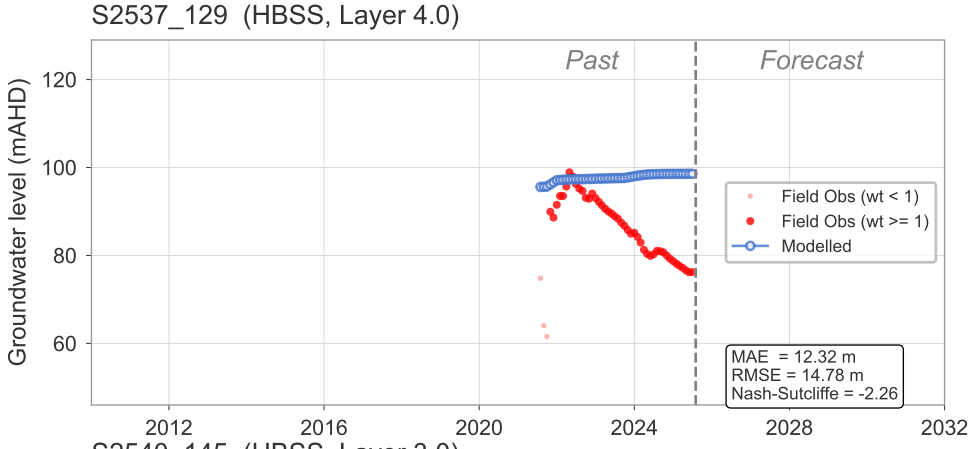

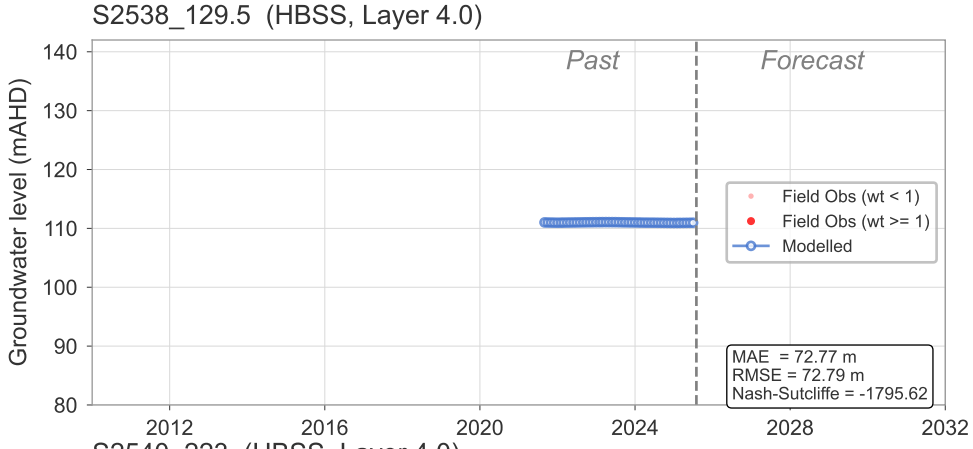

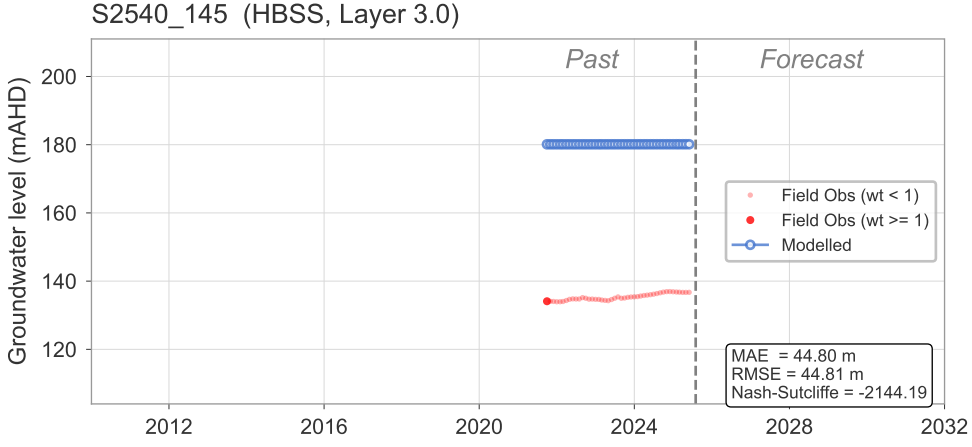

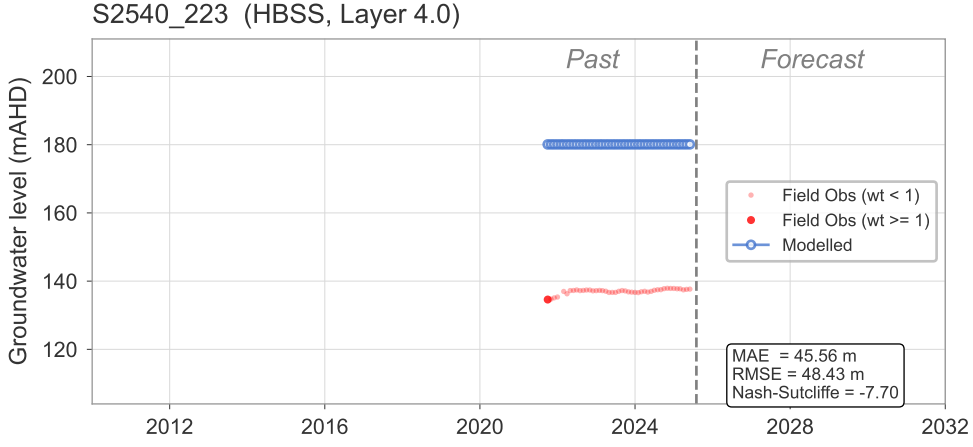

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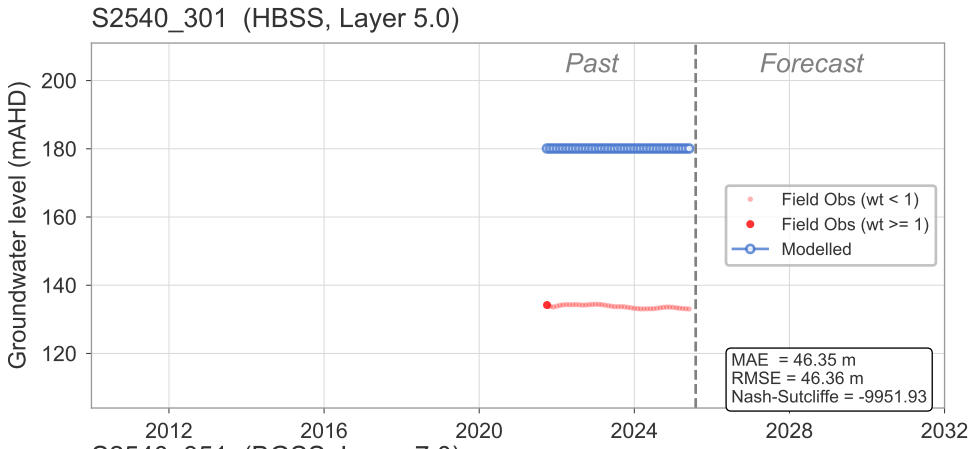

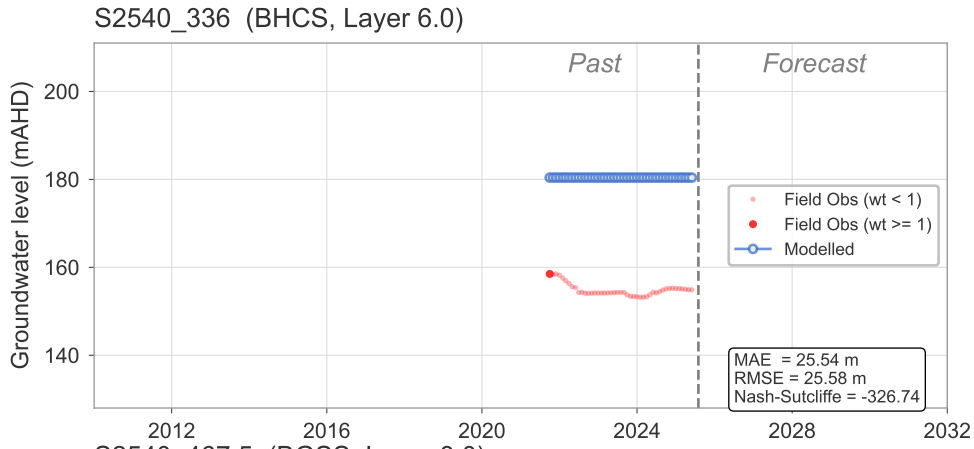

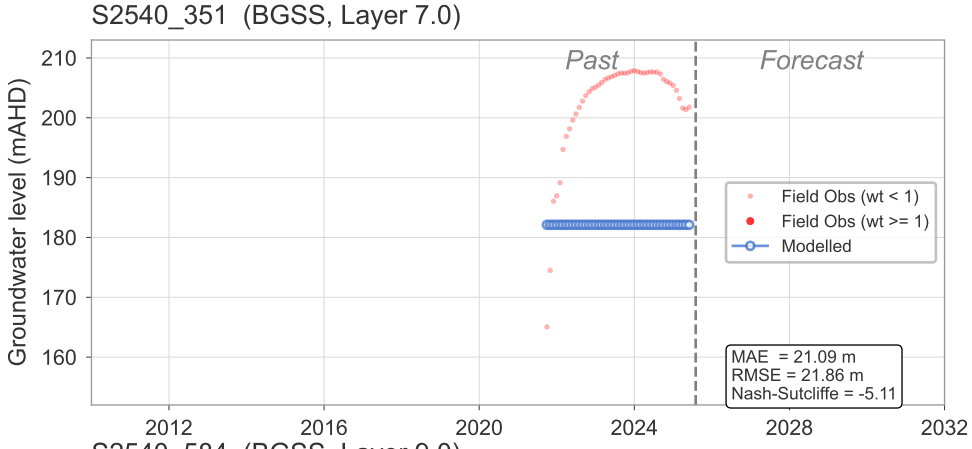

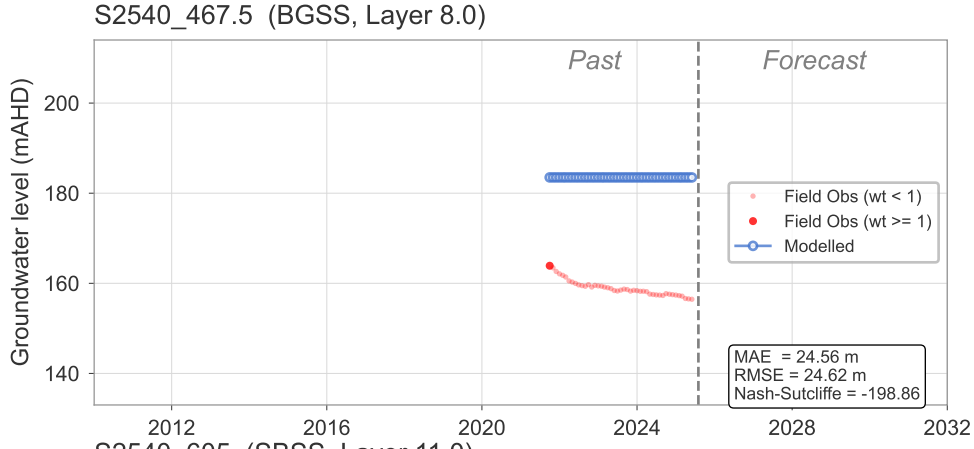

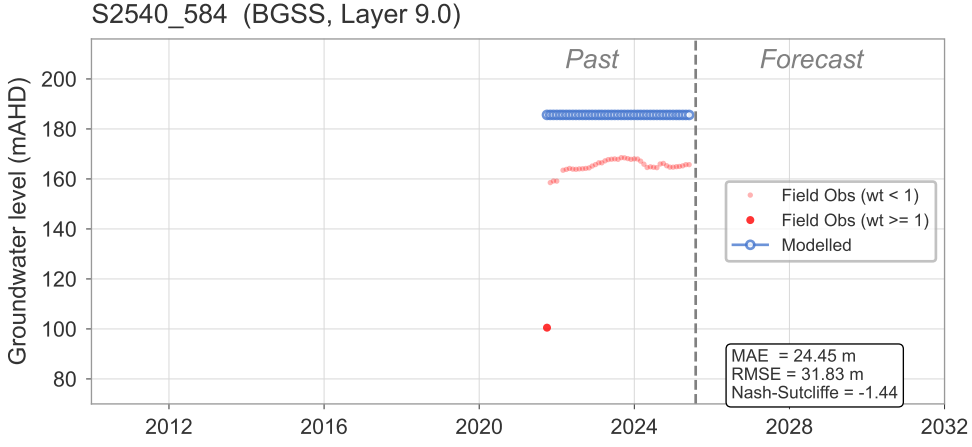

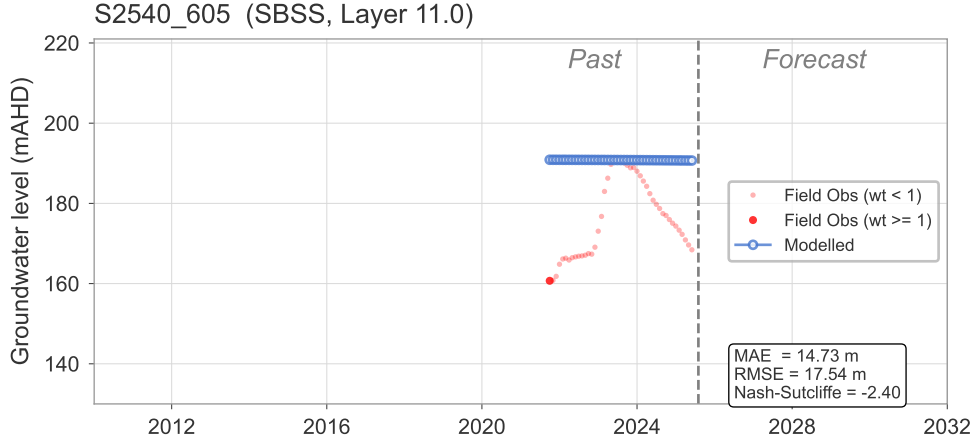

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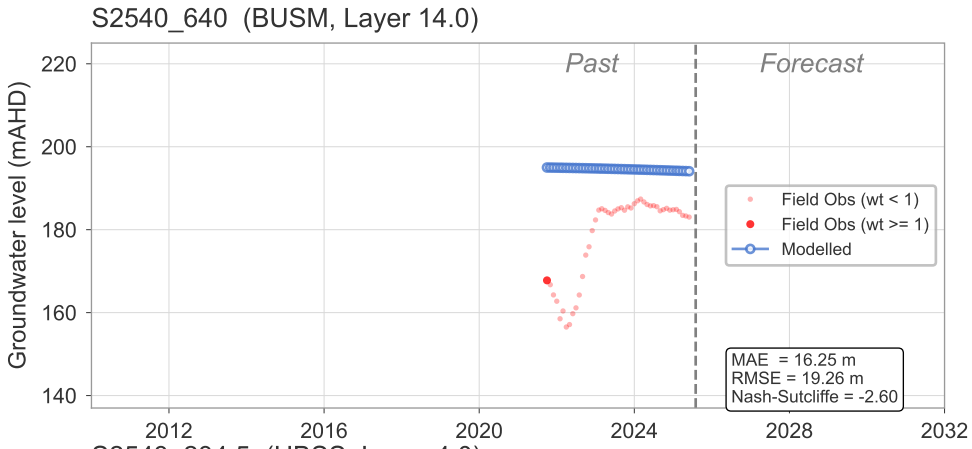

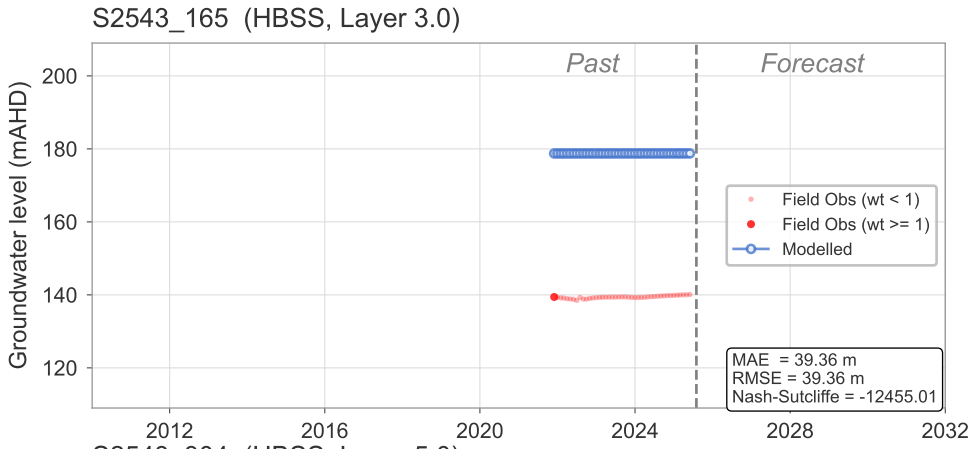

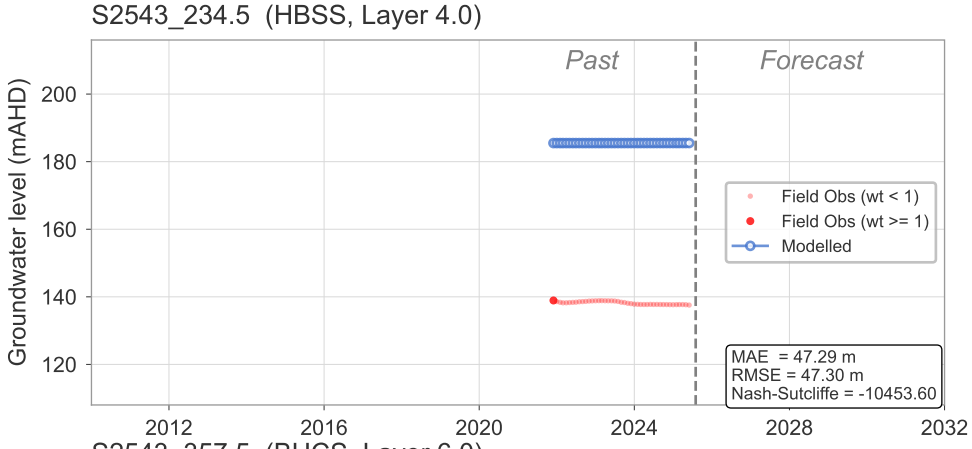

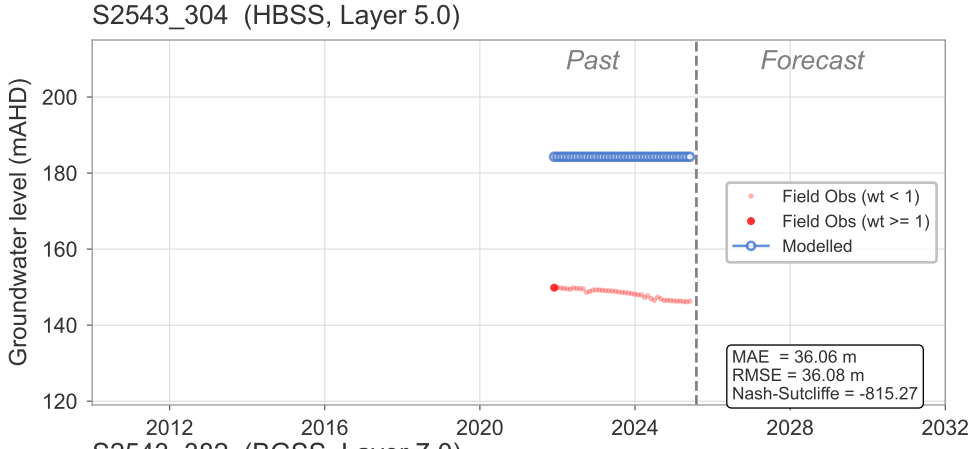

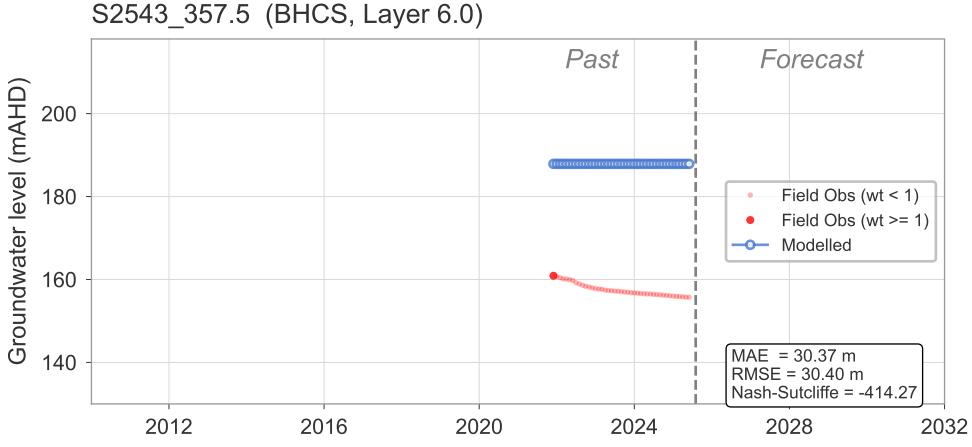

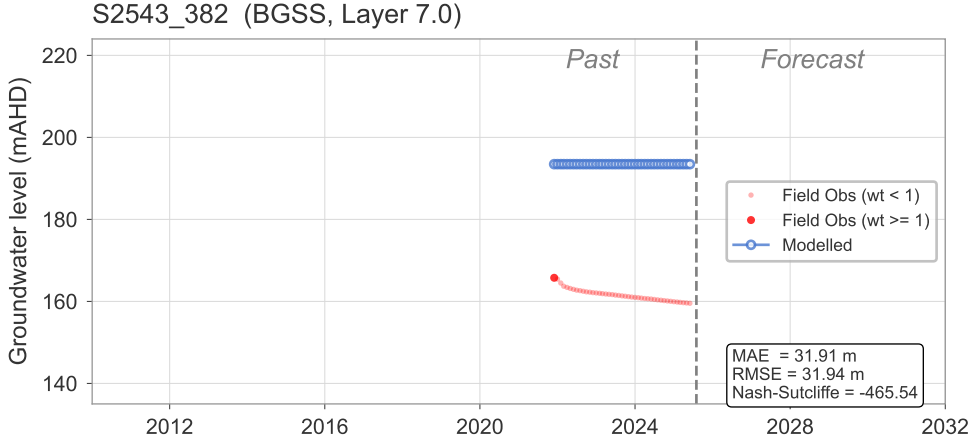

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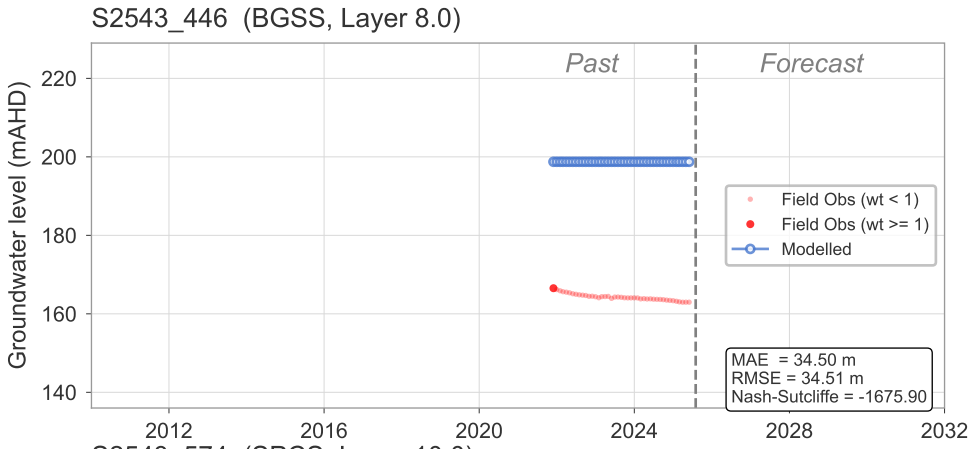
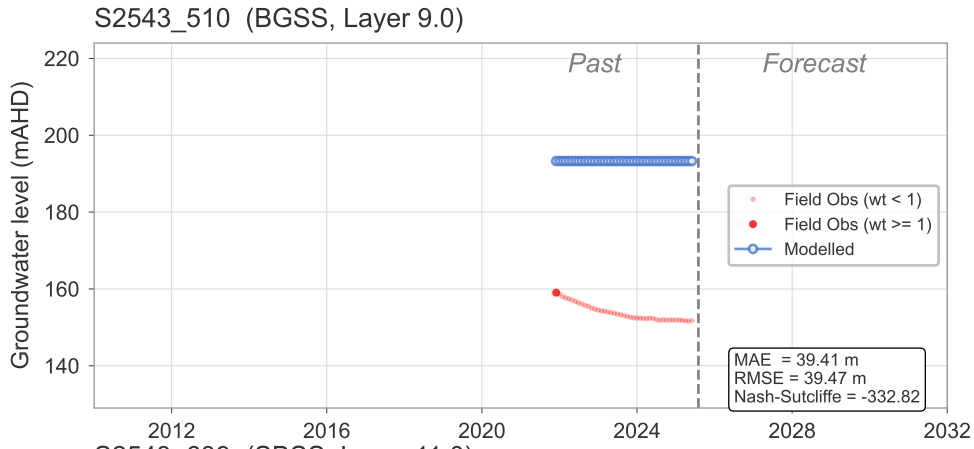
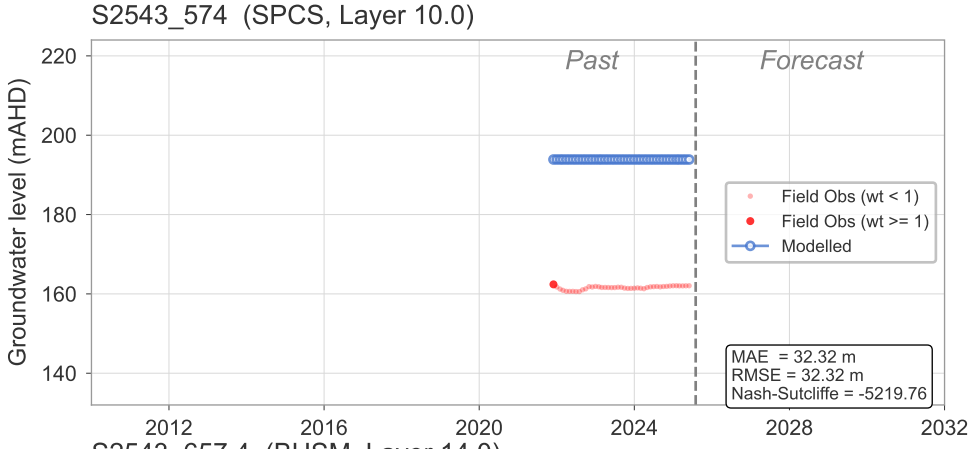
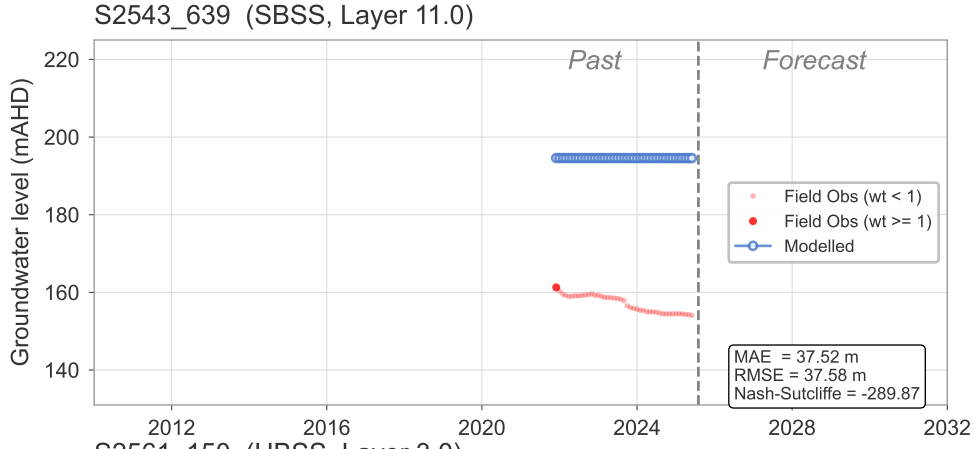
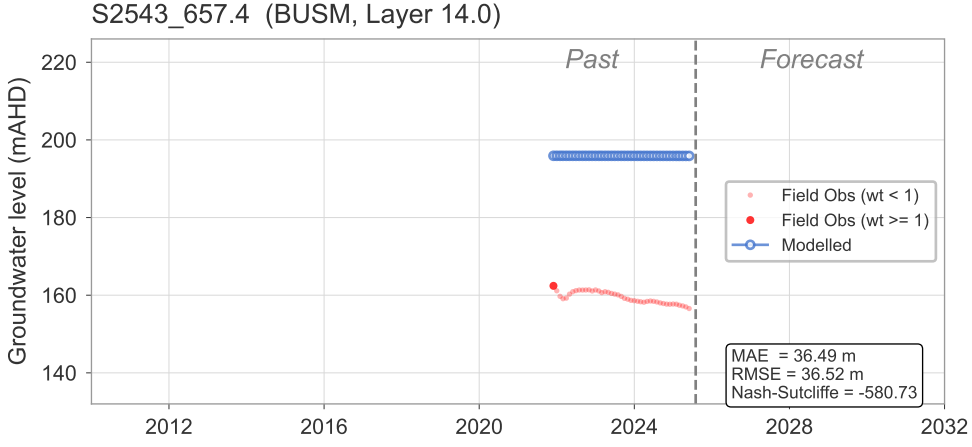
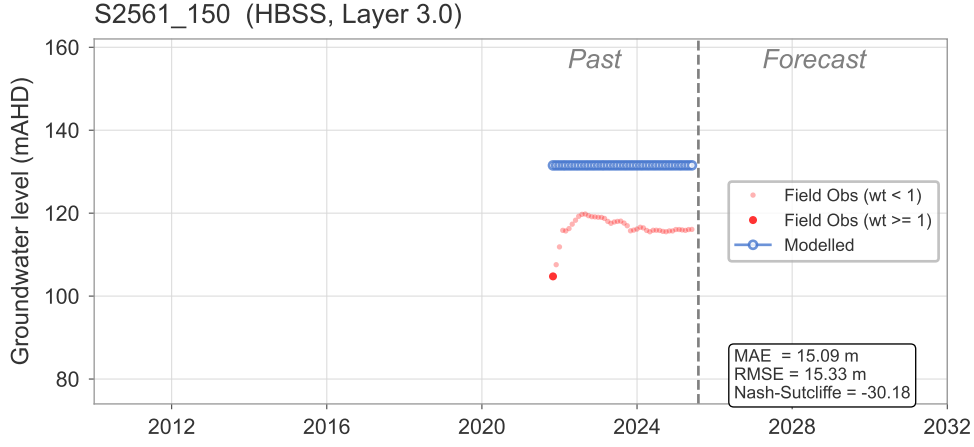




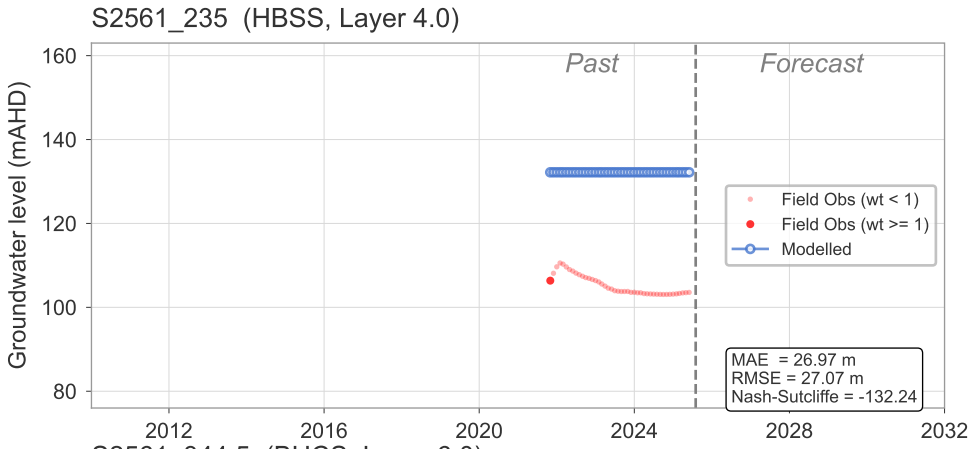


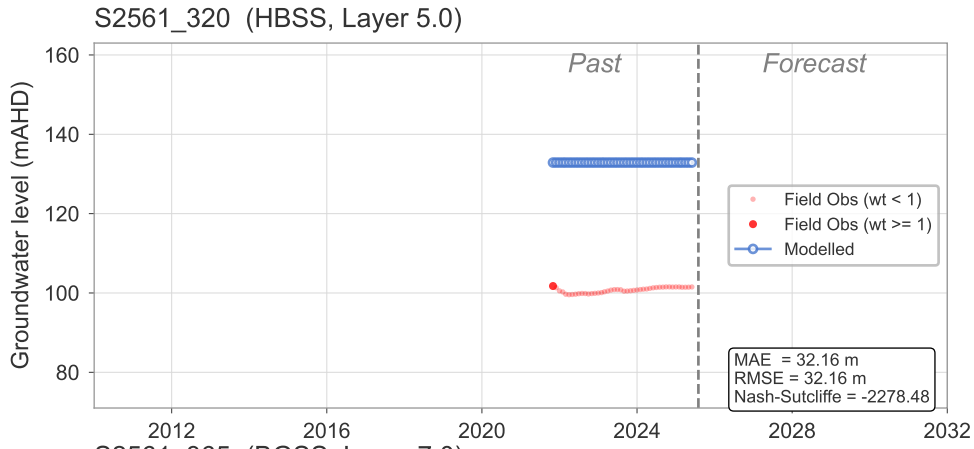


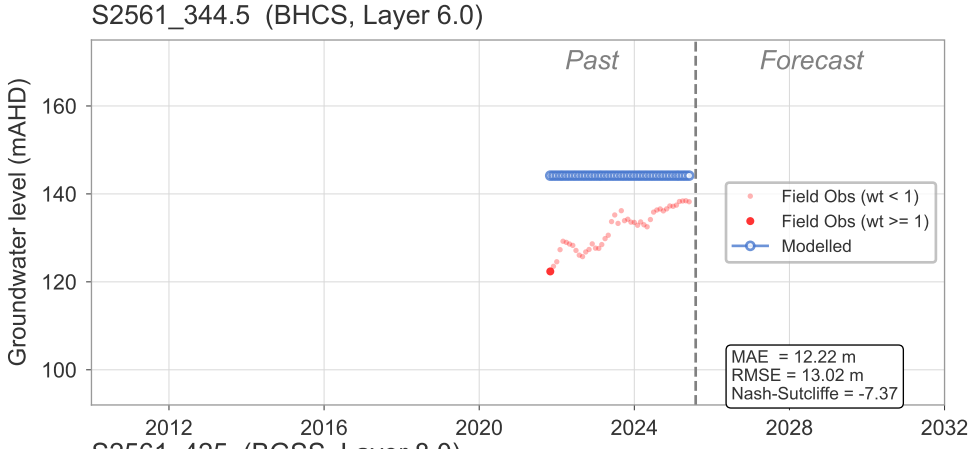


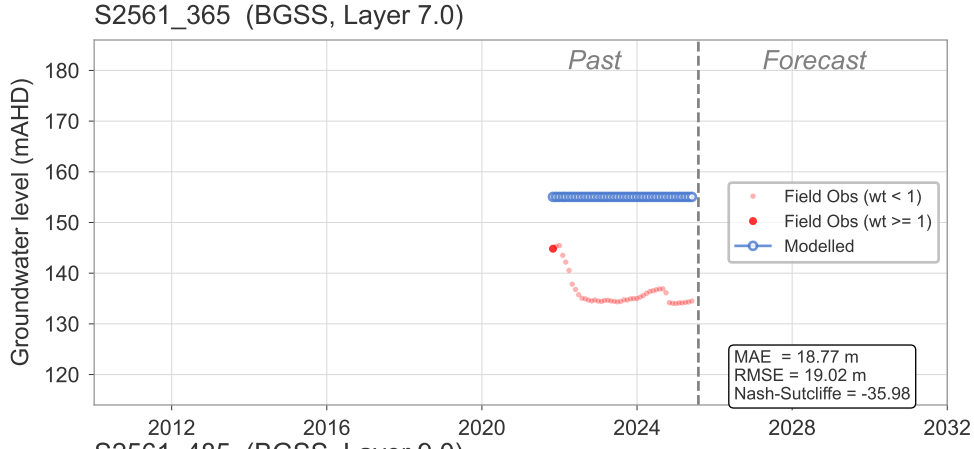


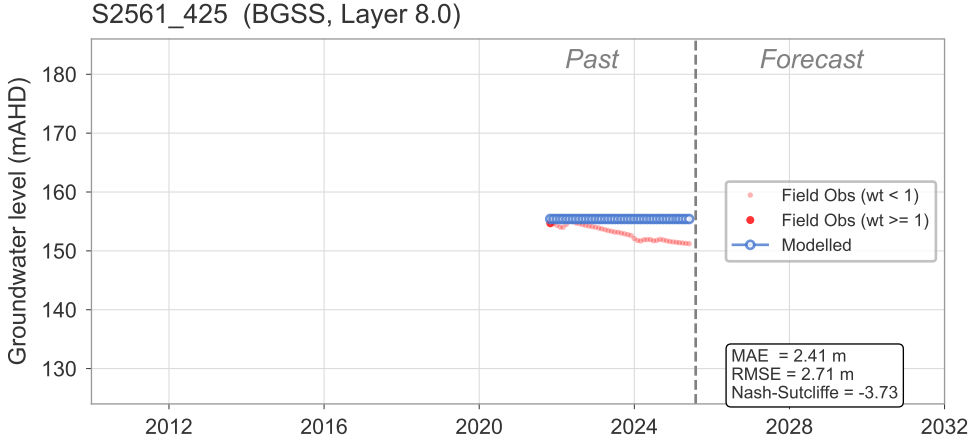
Modelled and observed groundwater hydrographs

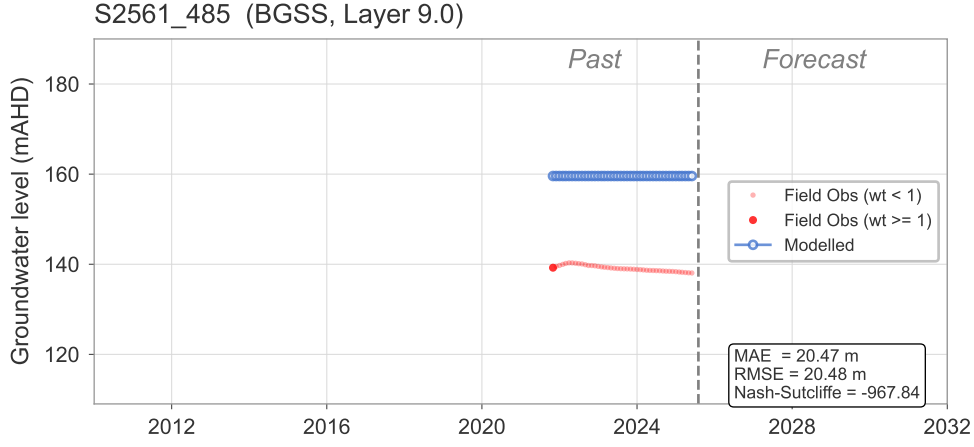












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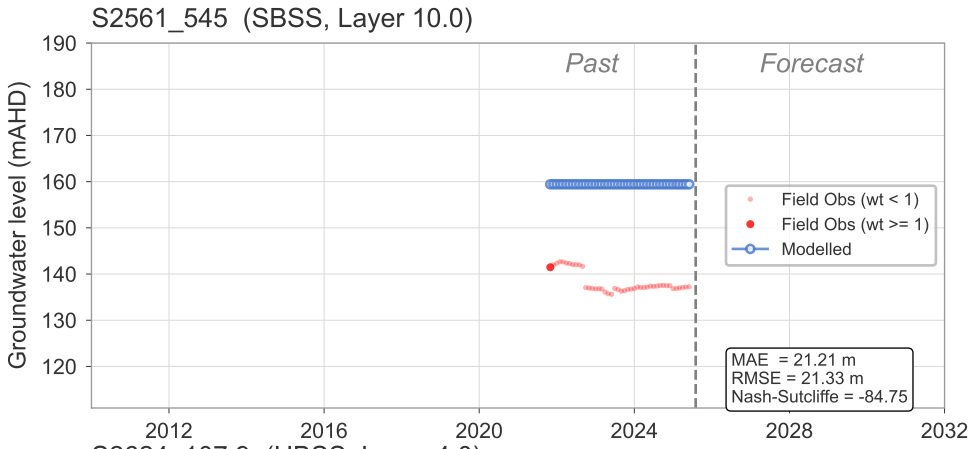

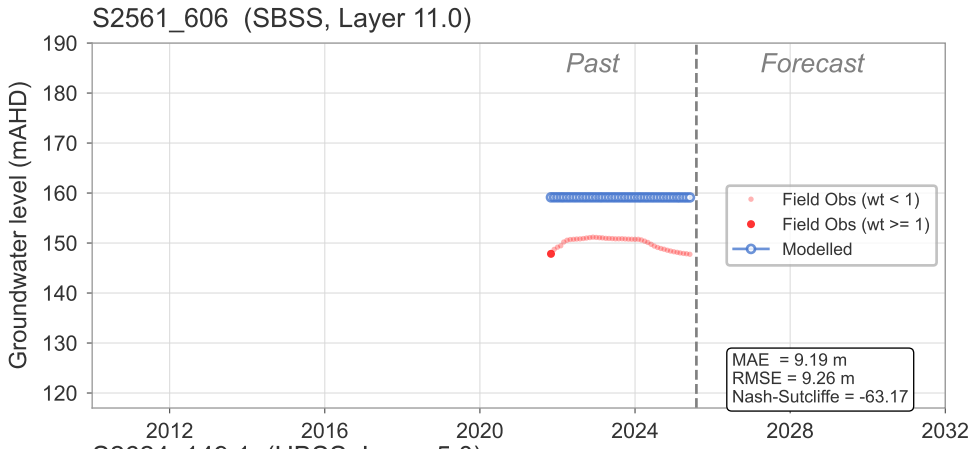

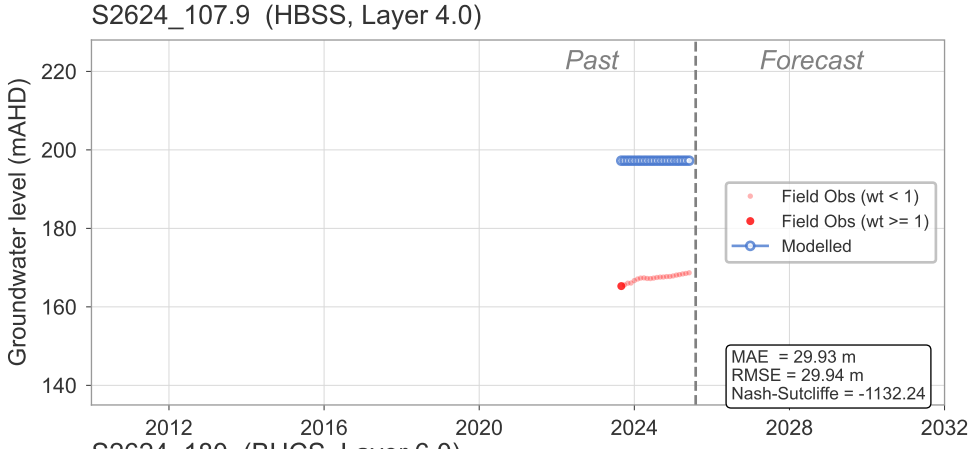

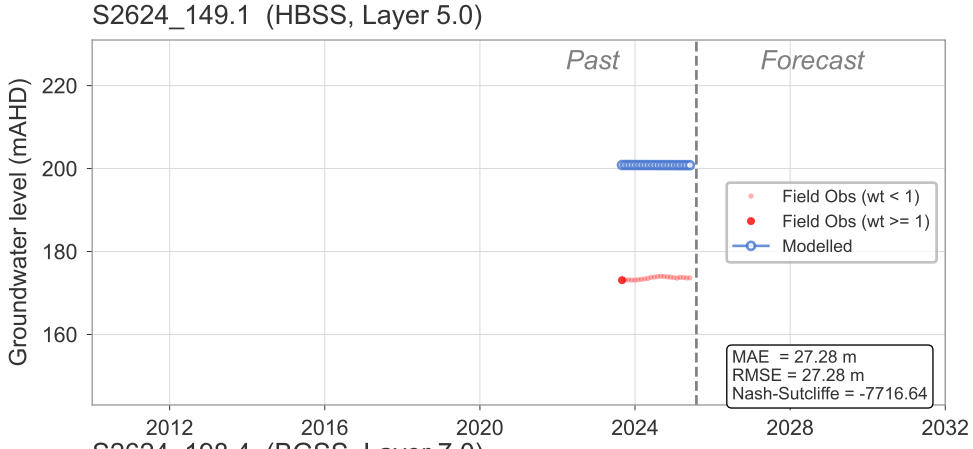

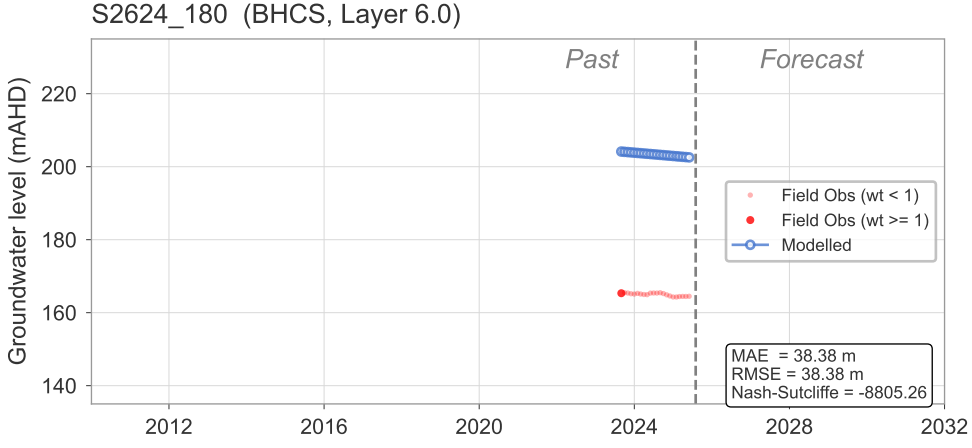

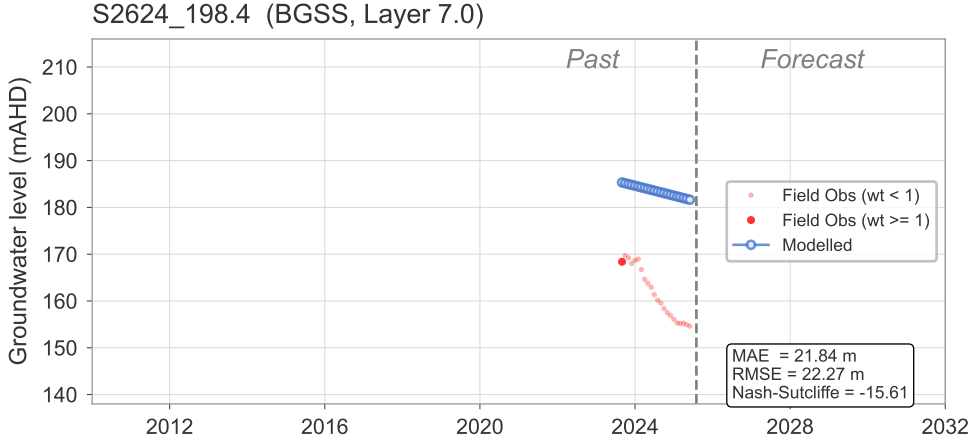

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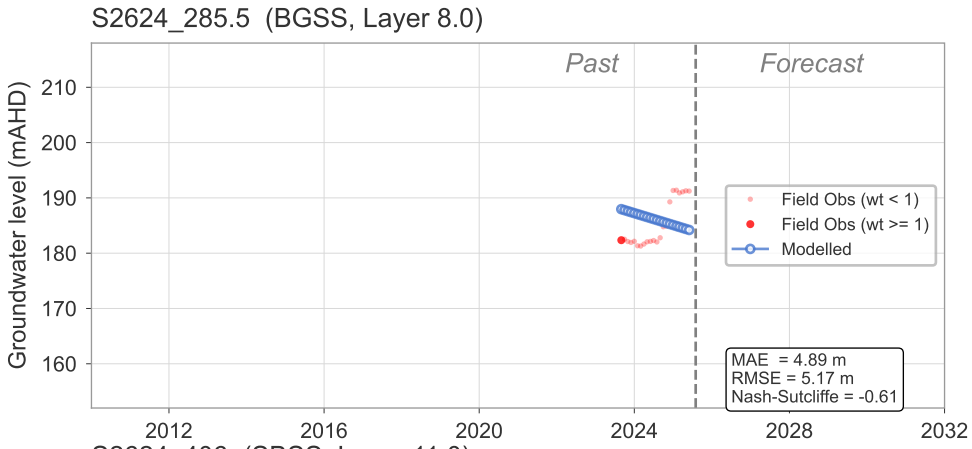
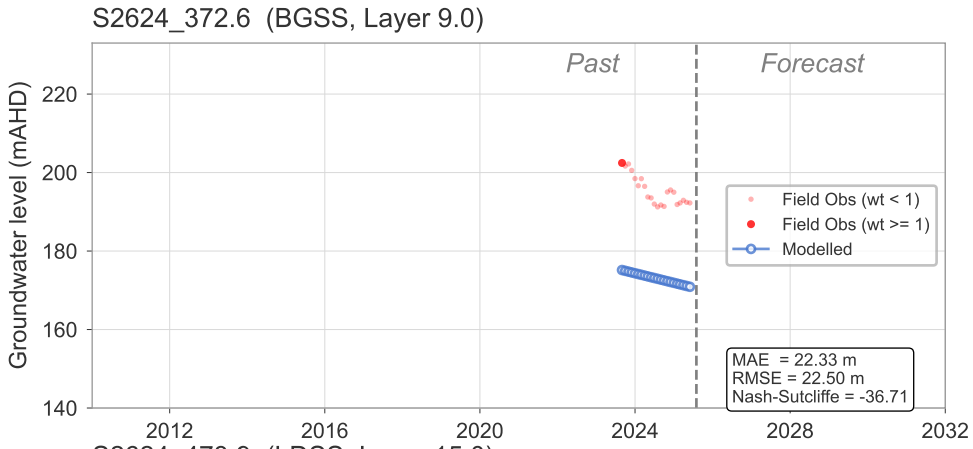
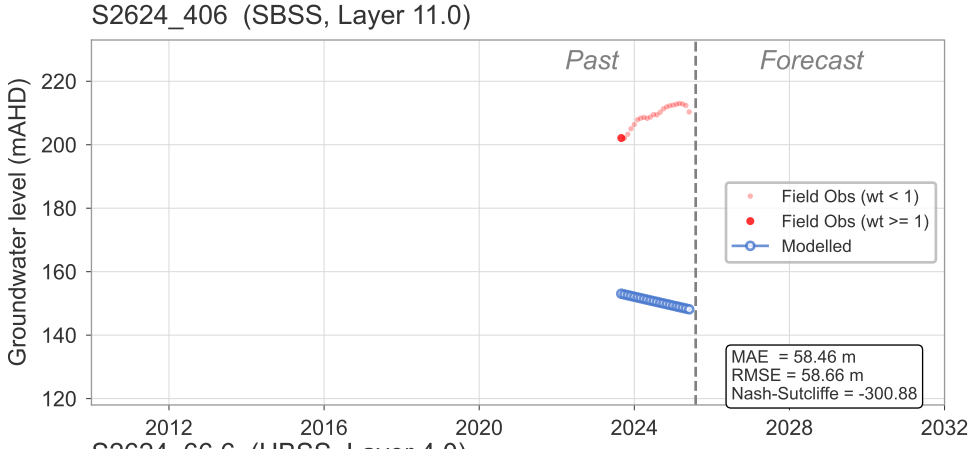
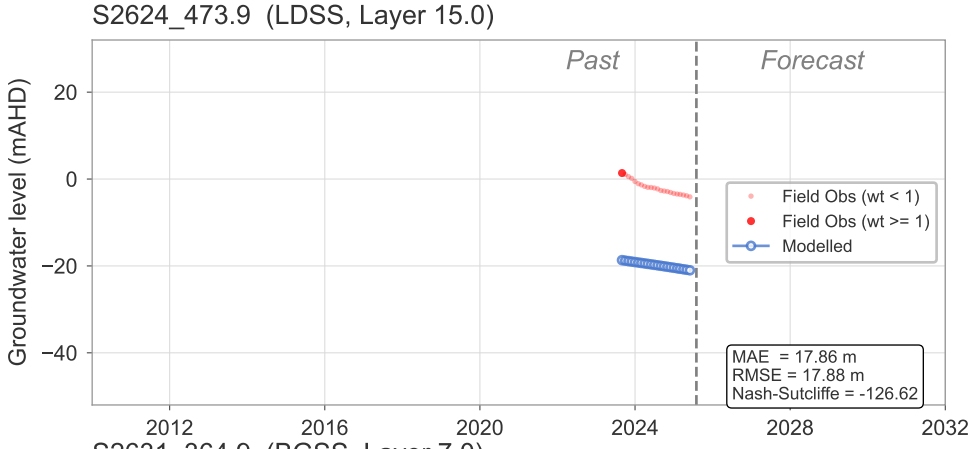
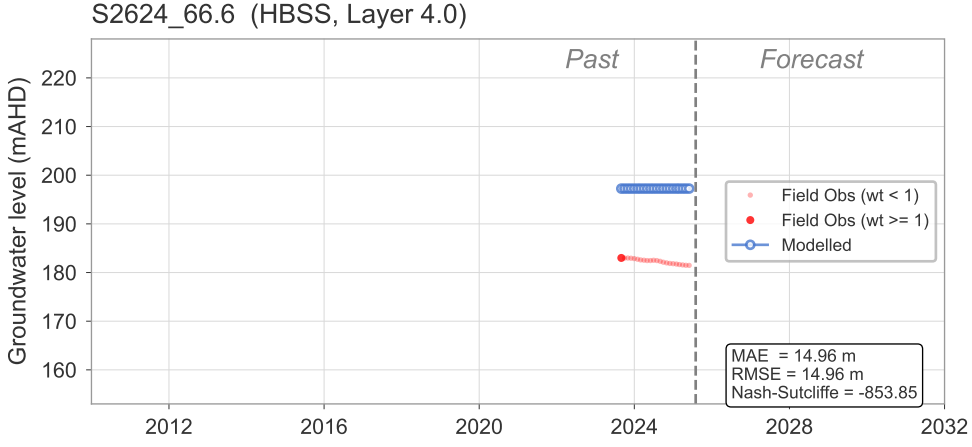
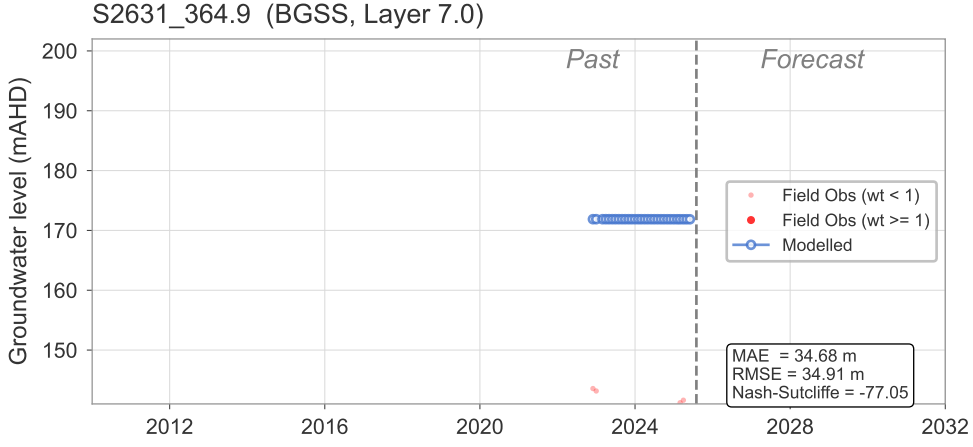




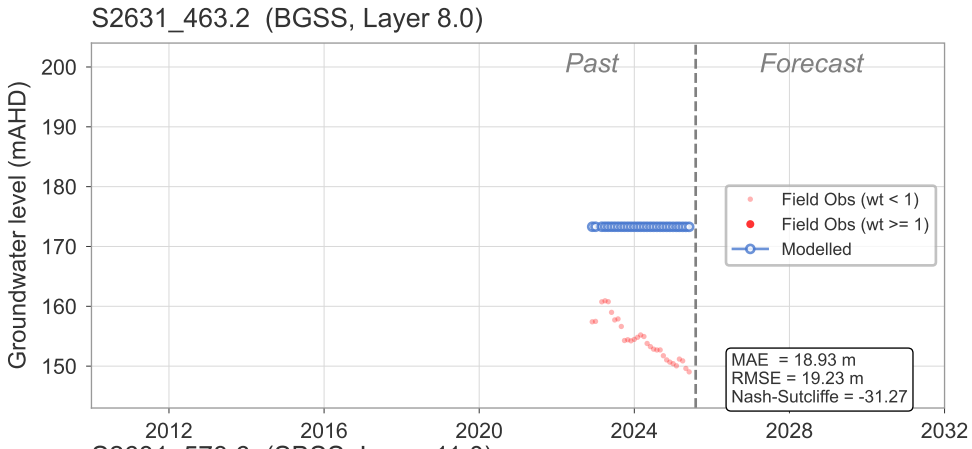


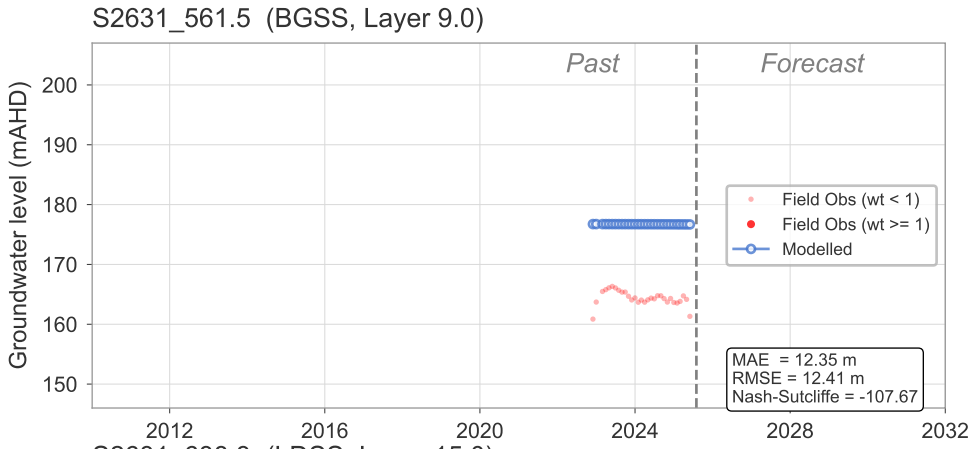


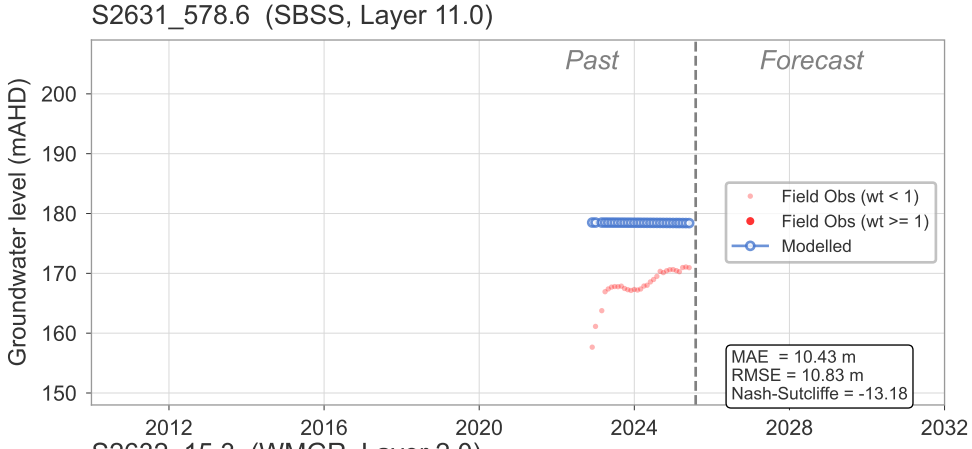


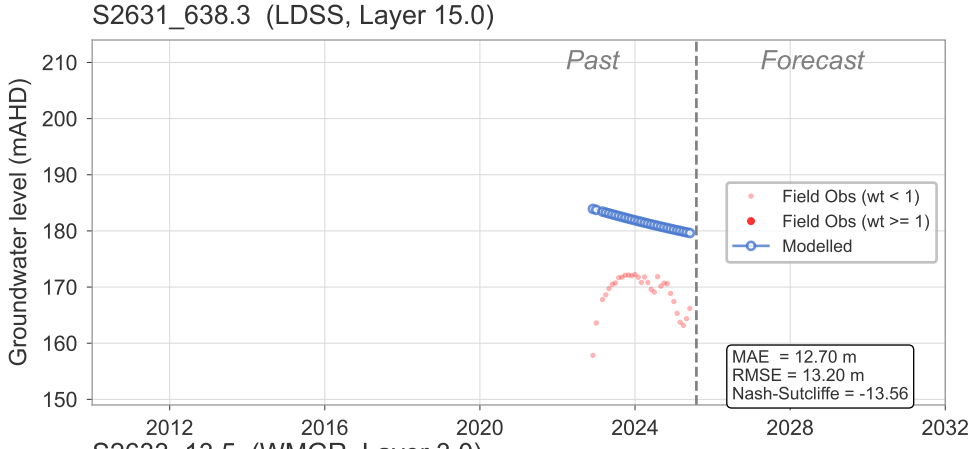


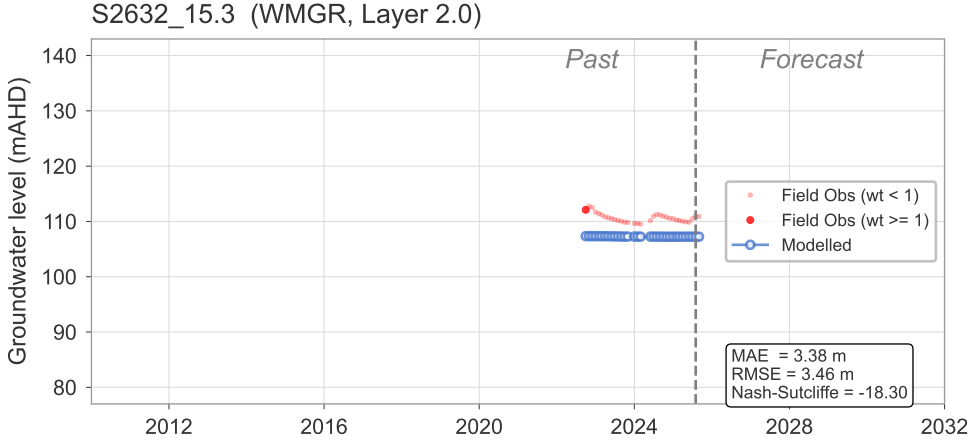
Modelled and observed groundwater hydrographs

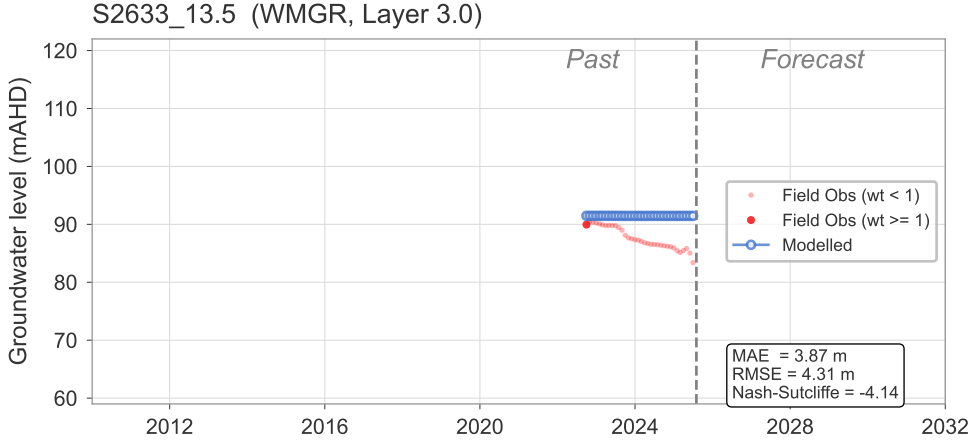




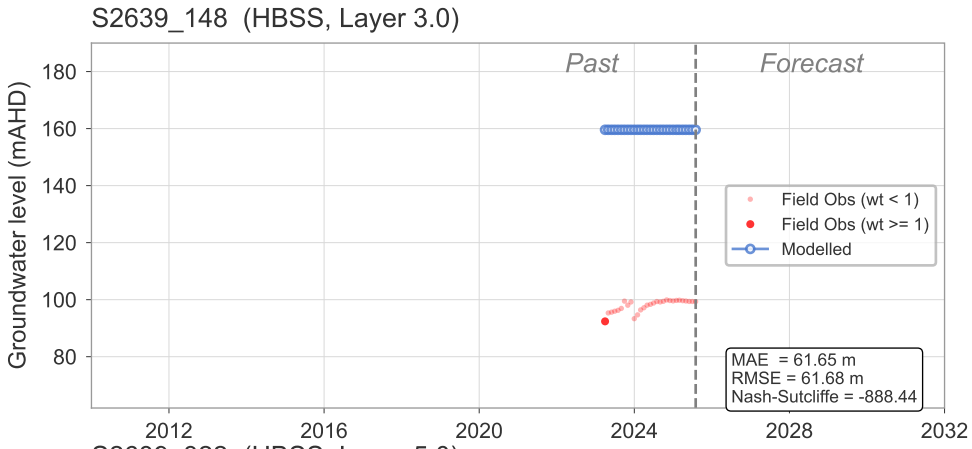


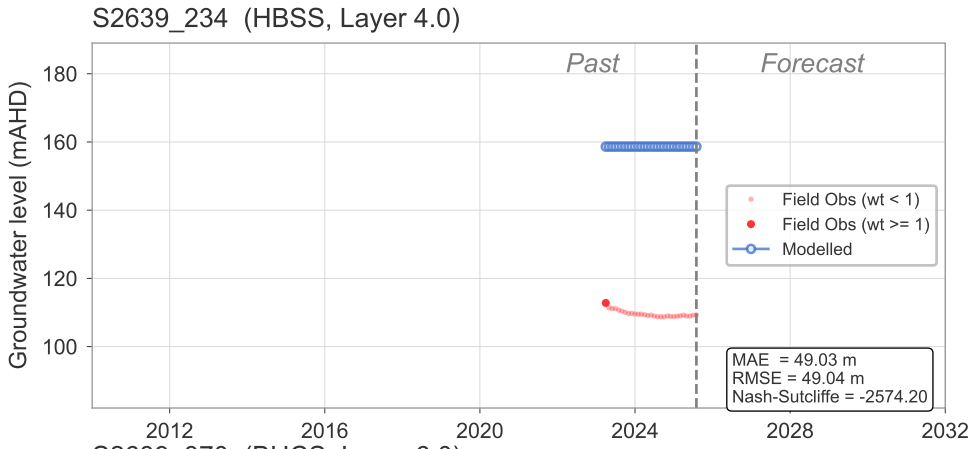


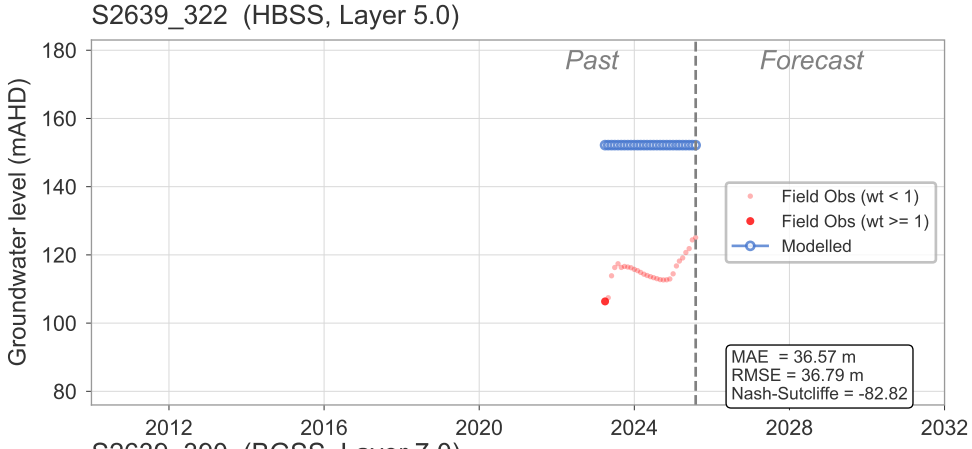


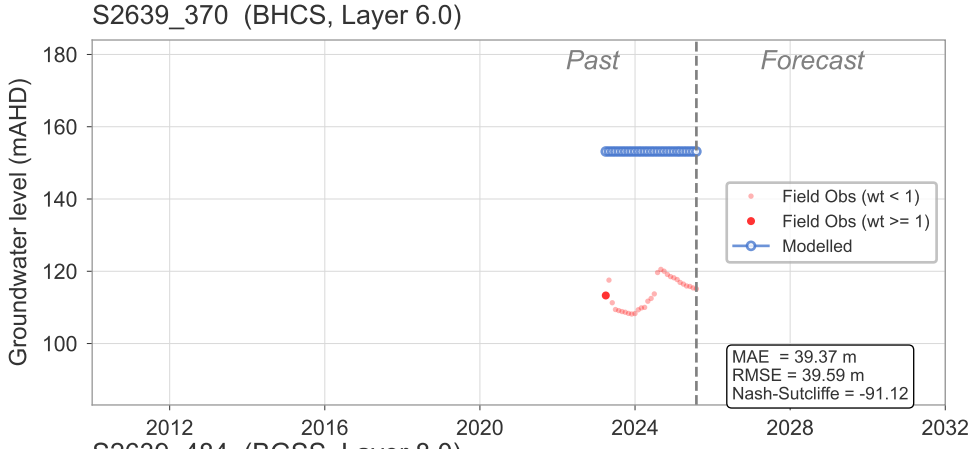


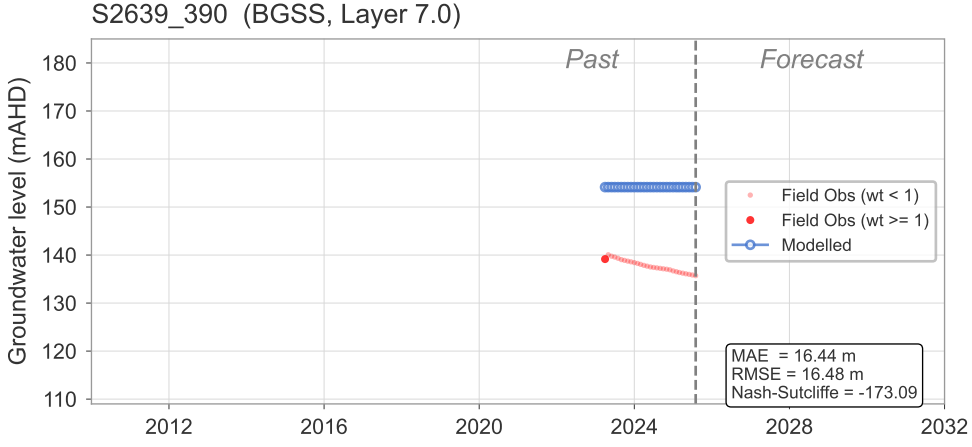
Modelled and observed groundwater hydrographs

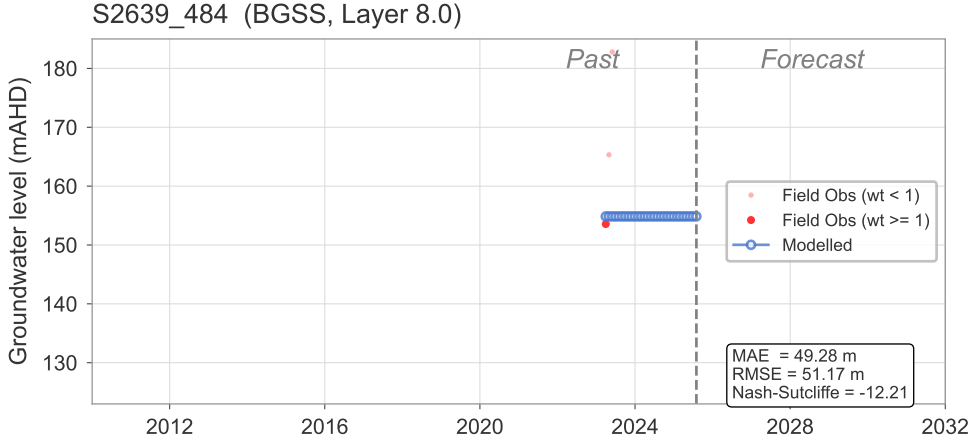




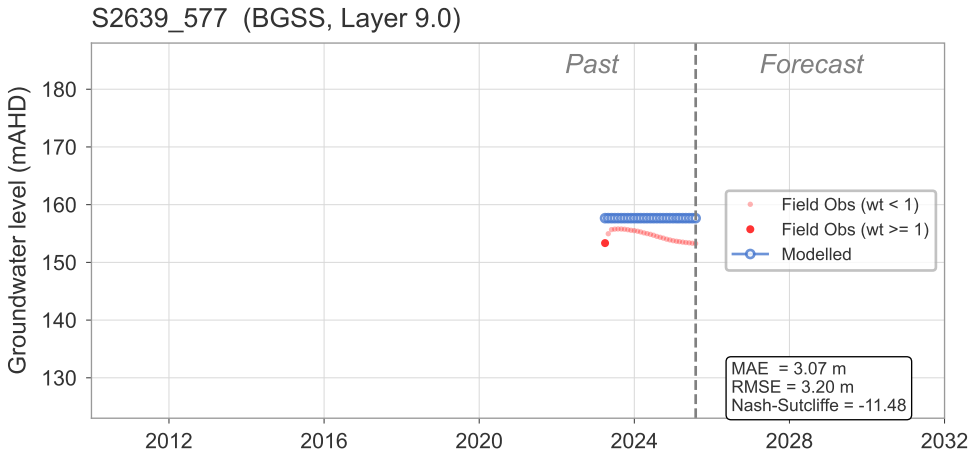








Modelled and observed groundwater hydrographs





APPENDIX D – Model optimised parameters

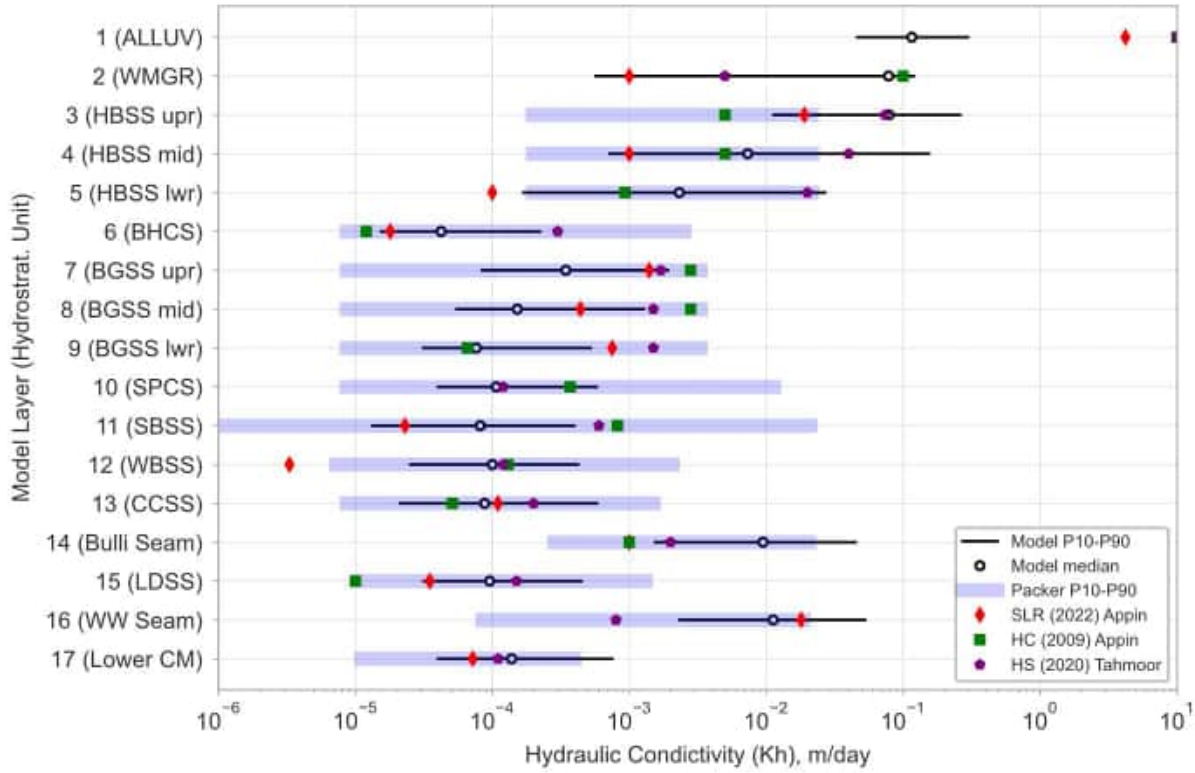
Summary of model optimised Kh parameter ranges

Model optimised parameter statistics

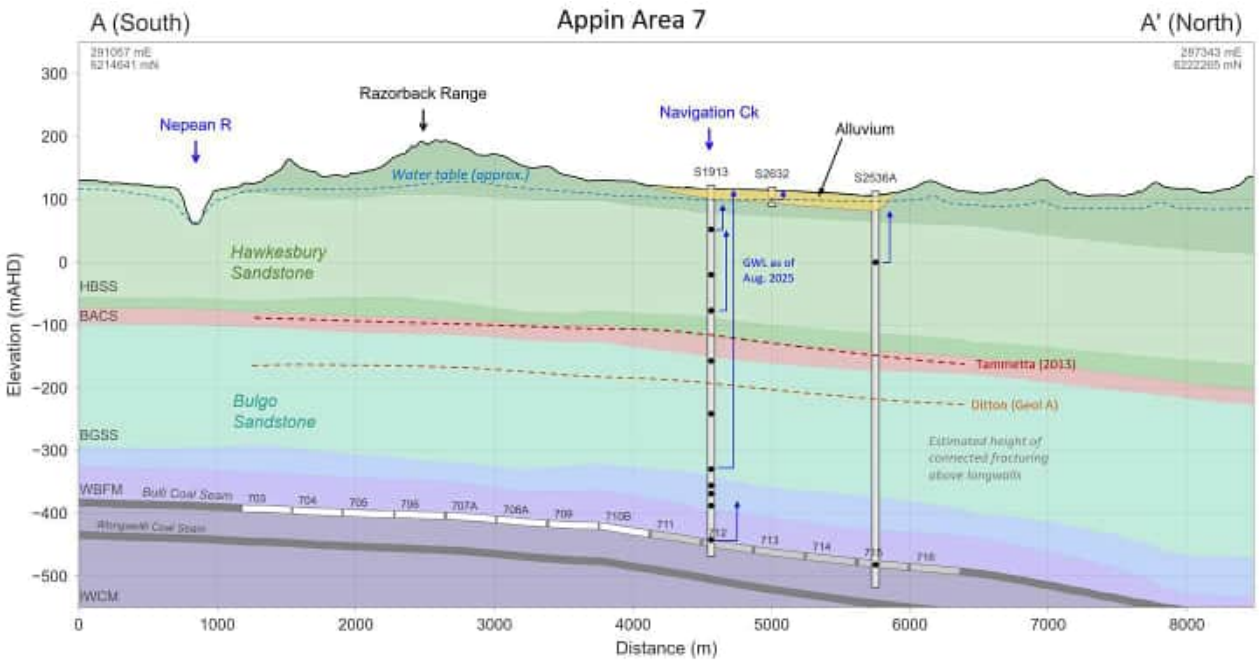
Layer	Unit	Kx (mean)	Kx (p10)	Kx (p50)	Kx (p90)	Kz (mean)	Kz (p10)	Kz (p50)	Kz (p90)	Kz/Kx (mean)	Sy (mean)	Sy (p10)	Sy (p50)	Sy (p90)	Ss (mean)	Ss (p10)	Ss (p50)
1	ALLUV	3.83E-01	4.62E-02	1.16E-01	2.97E-01	6.58E-02	8.96E-03	3.42E-02	1.38E-01	4.90E-01	6.73E-02	3.11E-02	5.84E-02	1.14E-01	2.06E-03	6.64E-04	1.11E-03
2	WMGR	6.64E-02	5.70E-04	7.83E-02	1.19E-01	1.62E-02	3.26E-05	1.09E-02	3.83E-02	5.30E-01	3.06E-02	1.55E-02	3.10E-02	4.31E-02	8.03E-04	9.04E-07	9.36E-04
3	HBSS upr	1.09E-01	1.13E-02	7.87E-02	2.61E-01	2.87E-02	2.59E-04	1.33E-02	7.77E-02	3.87E-01	6.19E-02	3.06E-02	5.92E-02	9.69E-02	6.32E-04	2.43E-06	6.92E-04
4	HBSS mid	4.37E-02	7.22E-04	7.33E-03	1.54E-01	7.91E-03	5.39E-06	7.59E-05	2.57E-02	1.25E-01	3.82E-02	1.44E-02	3.18E-02	7.38E-02	2.08E-04	2.77E-06	7.69E-06
5	HBSS lwr	1.48E-02	1.69E-04	2.32E-03	2.67E-02	1.20E-03	1.36E-06	2.26E-05	4.92E-04	8.94E-02	2.59E-02	1.31E-02	2.16E-02	4.36E-02	4.26E-05	7.24E-07	3.36E-06
6	BHCS	3.32E-03	1.54E-05	4.22E-05	2.23E-04	2.71E-04	1.77E-07	4.73E-07	2.45E-06	3.28E-02	1.52E-02	1.05E-02	1.31E-02	2.16E-02	1.59E-05	6.97E-07	2.15E-06
7	BGSS upr	2.15E-03	8.42E-05	3.44E-04	1.92E-03	1.36E-04	5.64E-07	4.64E-06	4.71E-05	7.48E-02	2.32E-02	1.23E-02	2.08E-02	3.79E-02	9.28E-06	6.62E-07	2.53E-06
8	BGSS mid	6.83E-04	5.32E-05	1.52E-04	1.28E-03	1.69E-05	3.25E-07	1.86E-06	1.61E-05	3.04E-02	2.02E-02	1.16E-02	1.72E-02	3.29E-02	3.07E-06	6.16E-07	2.02E-06
9	BGSS lwr	2.72E-04	3.13E-05	7.64E-05	5.22E-04	6.72E-06	2.55E-07	1.13E-06	1.09E-05	7.12E-02	1.74E-02	1.15E-02	1.56E-02	2.57E-02	2.86E-06	6.34E-07	2.12E-06
10	SPCS	2.42E-04	4.01E-05	1.07E-04	5.78E-04	3.31E-06	2.81E-07	1.08E-06	8.24E-06	4.33E-02	1.12E-02	8.35E-03	1.01E-02	1.56E-02	2.80E-06	6.24E-07	2.15E-06
11	SBSS	1.53E-04	1.34E-05	8.16E-05	3.95E-04	1.24E-05	5.86E-07	4.24E-06	2.79E-05	4.44E-01	1.53E-02	1.06E-02	1.37E-02	2.31E-02	2.73E-06	3.89E-07	2.02E-06
12	WBSS	1.66E-04	2.53E-05	1.00E-04	4.20E-04	3.34E-06	2.29E-07	1.01E-06	7.93E-06	5.30E-02	1.24E-02	5.99E-03	1.07E-02	2.18E-02	3.04E-06	7.47E-07	2.47E-06
13	CCSS	1.97E-04	2.12E-05	8.78E-05	5.82E-04	2.51E-06	2.21E-07	1.10E-06	5.62E-06	4.65E-02	1.54E-02	1.03E-02	1.35E-02	2.39E-02	4.09E-06	8.85E-07	3.62E-06
14	Bulli Seam	1.82E-02	1.55E-03	9.49E-03	4.48E-02	4.09E-04	1.90E-05	1.39E-04	9.83E-04	1.67E-01	1.78E-02	1.08E-02	1.54E-02	2.95E-02	2.95E-06	5.76E-07	2.13E-06
15	LDSS	1.93E-04	3.16E-05	9.56E-05	4.47E-04	3.27E-06	2.03E-07	9.48E-07	7.71E-06	5.22E-02	1.50E-02	1.03E-02	1.30E-02	2.33E-02	1.92E-06	3.11E-07	1.33E-06
16	WW Seam	2.10E-02	2.34E-03	1.13E-02	5.26E-02	2.29E-04	8.48E-06	7.80E-05	5.67E-04	6.47E-02	1.73E-02	1.13E-02	1.55E-02	2.66E-02	2.13E-06	2.82E-07	1.36E-06
17	Lower CM	3.03E-04	4.01E-05	1.38E-04	7.50E-04	4.54E-06	2.74E-07	1.77E-06	1.18E-05	4.89E-02	9.54E-03	5.40E-03	8.10E-03	1.56E-02	1.74E-06	3.46E-07	1.23E-06

Model optimised parameters: Previous modelling assessments

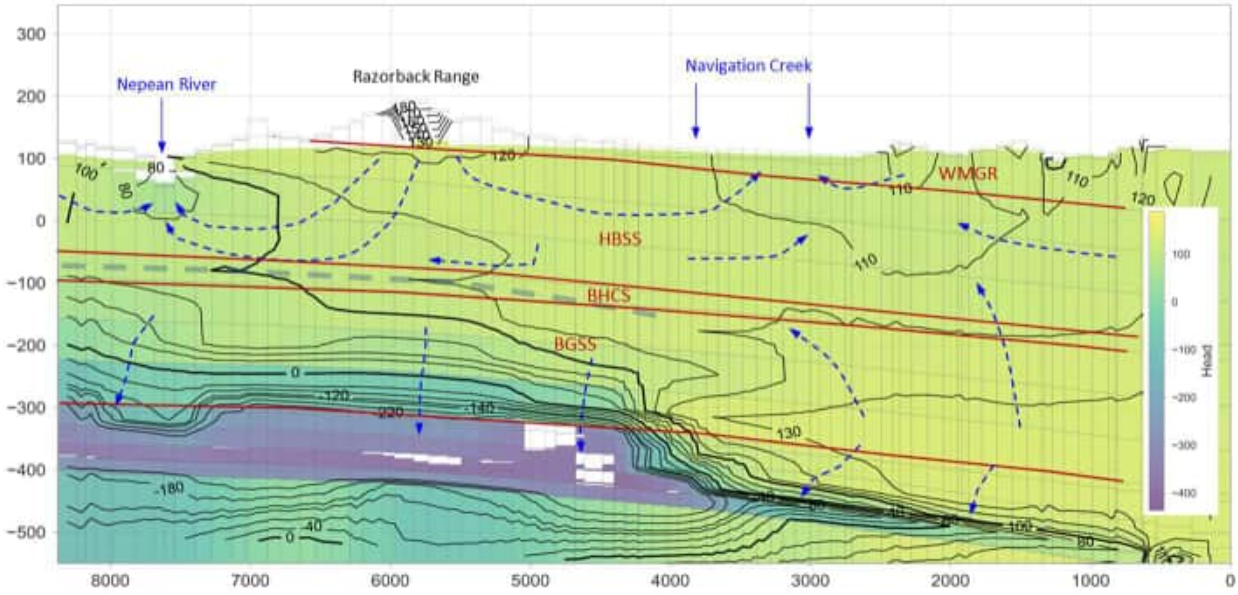
Layer	Unit	Kx_SLR_cal	Kz_SLR_cal	Kz/Kx_SLR_ca	Sy_SLR_cal	Ss_SLR_cal	Kx_HC_cal	Kz_HC_cal	Kx_Tah_cal	Kz_Tah_cal	Ss_Tah_cal	Sy_Tah_cal
1	ALLUV	4.20E+00	6.50E-02	1.50E-02	2.70E-01	3.00E-05	1.00E+01	1.00E+00	1.00E+01	3.00E-02	1.03E-04	1.14E-01
2	WMGR	1.00E-03	1.00E-05	1.00E-02	1.00E-02	1.00E-07	1.00E-01	1.00E-02	5.00E-03	2.80E-04	1.02E-06	1.06E-02
3	HBSS upr	1.90E-02	6.50E-04	3.30E-02	4.30E-02	1.00E-05	5.00E-03	8.50E-04	7.40E-02	8.00E-04	6.00E-06	1.80E-02
4	HBSS mid	1.00E-03	5.00E-04	5.00E-01	1.00E-02	2.60E-05	5.00E-03	8.50E-04	4.00E-02	8.00E-05	6.00E-06	1.10E-02
5	HBSS lwr	1.00E-04	1.20E-06	1.20E-02	1.20E-02	3.00E-06	9.30E-04	8.10E-05	2.00E-02	9.00E-05	6.00E-06	1.10E-02
6	BHCS	1.80E-05	6.10E-07	3.30E-02	9.40E-03	1.00E-07	1.20E-05	3.10E-06	3.00E-04	8.00E-06	6.00E-06	7.00E-03
7	BGSS upr	1.40E-03	1.70E-05	1.20E-02	1.30E-02	1.00E-07	2.00E-03	9.40E-05	1.70E-03	6.00E-06	6.00E-06	1.00E-02
8	BGSS mid	4.40E-04	1.80E-05	4.00E-02	1.30E-02	1.00E-06	2.80E-03	9.40E-05	1.50E-03	7.00E-06	7.00E-06	1.00E-02
9	BGSS lwr	7.50E-04	9.90E-06	1.30E-02	1.60E-02	1.00E-06	6.60E-05	1.00E-05	1.50E-03	7.00E-06	7.00E-06	1.00E-02
10	SPCS	7.30E-07	7.80E-08	1.00E-01	4.50E-03	1.00E-07	3.70E-04	3.00E-06	1.20E-04	1.04E-06	6.00E-06	2.50E-03
11	SBSS	2.30E-05	2.30E-07	1.00E-02	1.11E-02	2.55E-06	8.20E-04	1.10E-04	6.00E-04	4.00E-06	2.50E-06	6.00E-03
12	WBSS	3.30E-06	4.10E-08	1.20E-02	7.60E-03	1.00E-07	1.30E-04	6.00E-07	1.20E-04	1.00E-06	5.00E-06	2.00E-03
13	CCSS	1.10E-04	5.50E-07	4.80E-03	4.50E-03	5.00E-06	5.10E-05	3.50E-07	2.00E-04	8.00E-06	4.00E-06	6.00E-03
14	Bulli Seam	1.00E-03	5.60E-05	5.60E-02	9.00E-03	1.00E-07	1.00E-03	1.00E-04	2.00E-03	3.60E-07	7.00E-06	8.00E-03
15	LDSS	3.50E-05	3.50E-07	1.00E-02	7.30E-03	1.00E-07	1.00E-05	2.00E-06	1.50E-04	3.30E-07	2.50E-06	5.00E-03
16	WW Seam	1.80E-02	2.90E-03	1.60E-01	4.80E-03	1.00E-07			8.00E-04	3.70E-07	4.00E-06	5.00E-03
17	Lower CM	7.20E-05	2.60E-06	3.60E-02	2.10E-03	1.00E-06			1.10E-04	2.50E-06	1.00E-06	4.00E-03



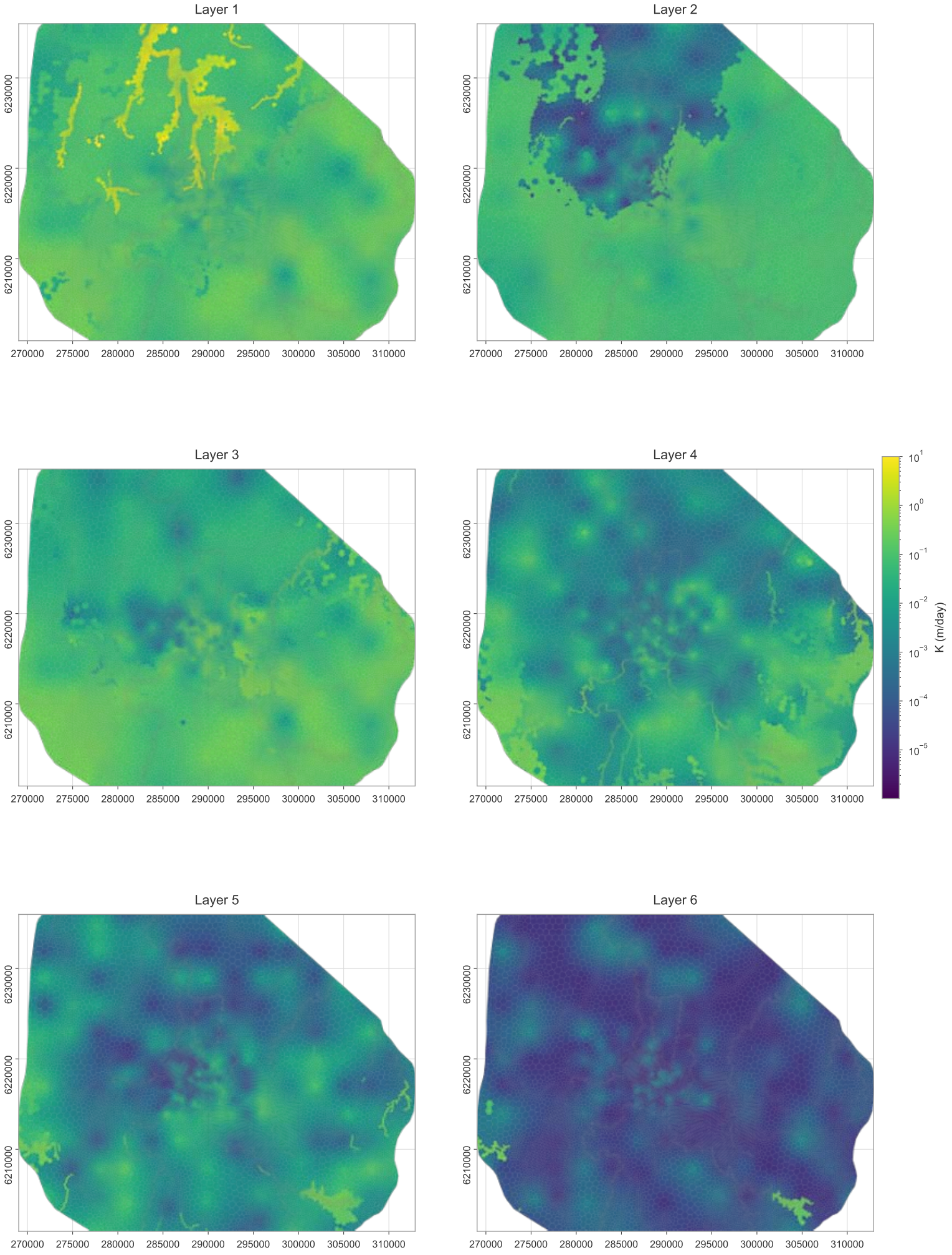
Hydrogeological cross section



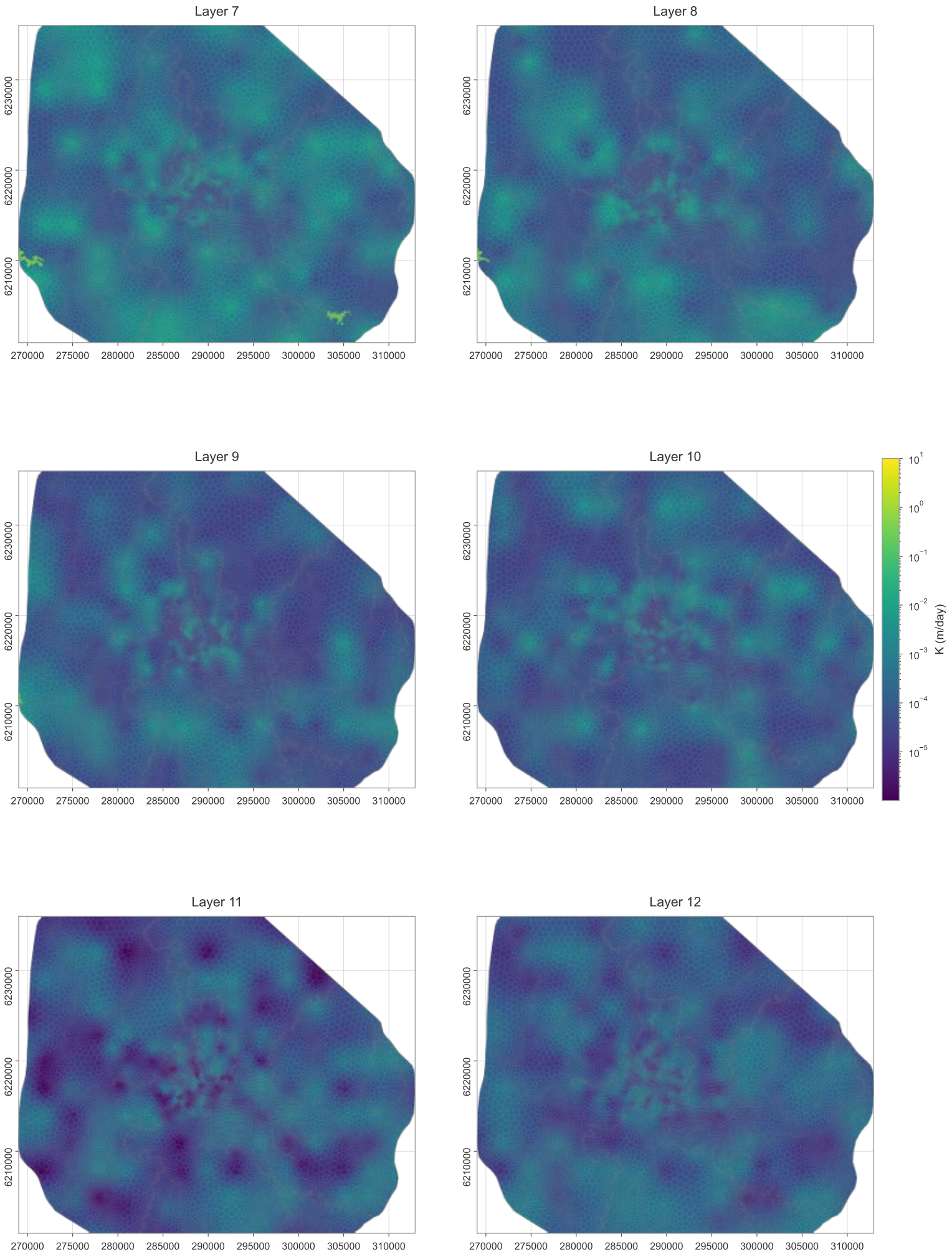
Equivalent cross section showing modelled heads as of June 2025 (SP73), annotated with groundwater flow directions



Hydraulic conductivity (horizontal) (Kh)



ap5b: NPF.k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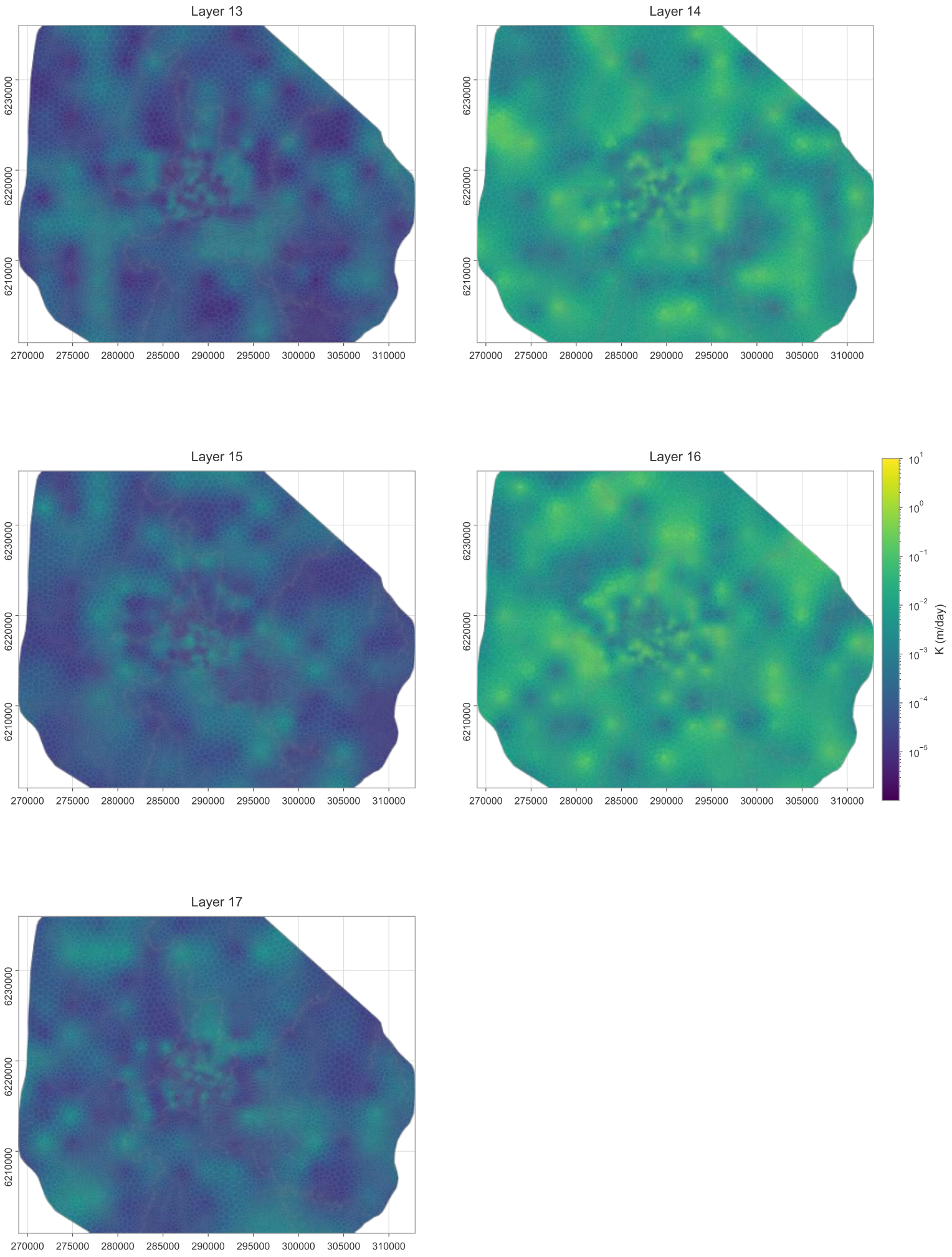
290000
295000
300000
305000
310000
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
K (m/day)

ap5b: NPF.k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Layer 14
Layer 15
Layer 16
Layer 17
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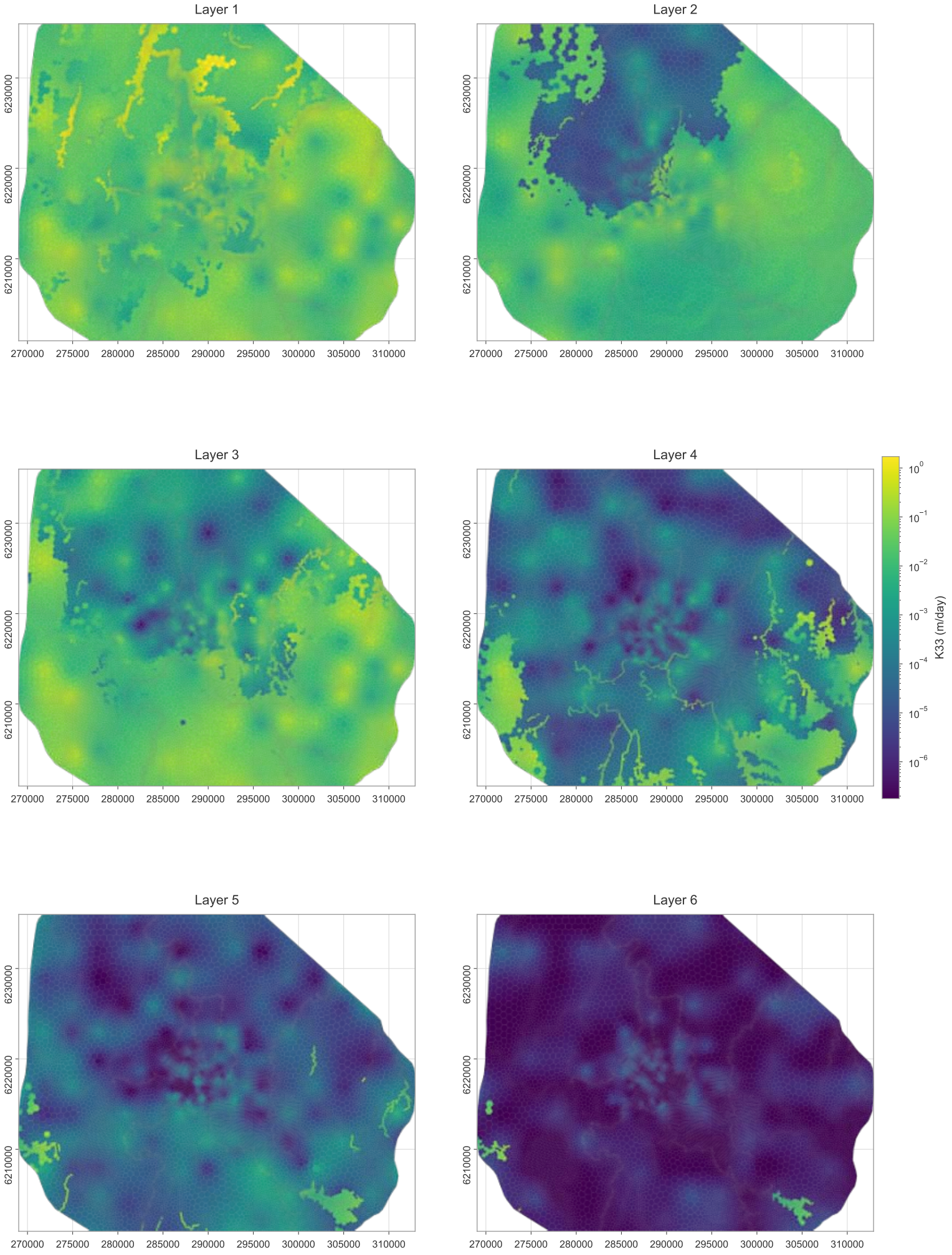
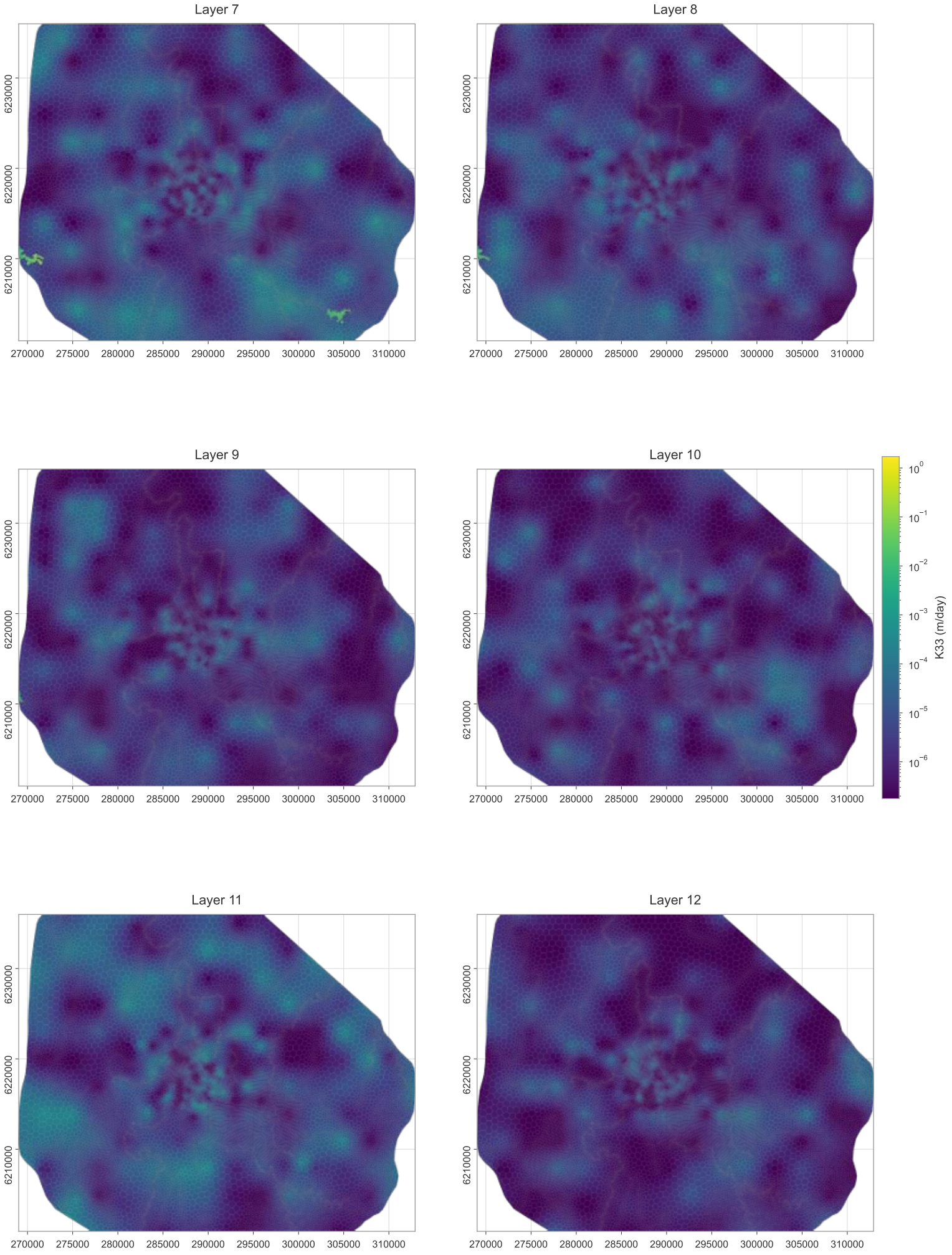
6210000
270000
275000
280000
285000
290000
295000
300000
305000
310000
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
K (m/day)

Hydraulic conductivity (vertical) (Kv)



ap5b: NPF.k33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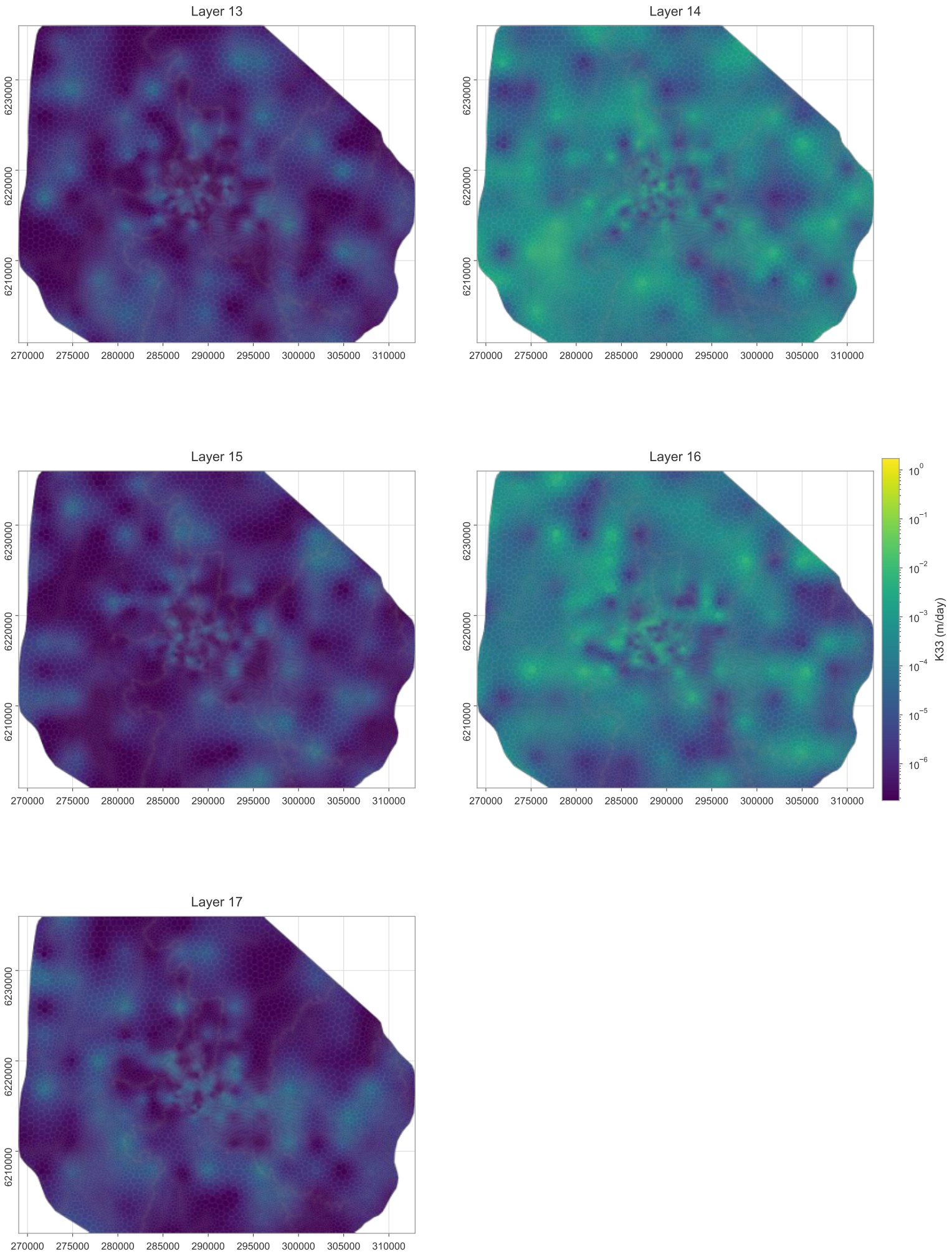
10^{-5}
10^{-6}
K33 (m/day)

ap5b: NPF.k33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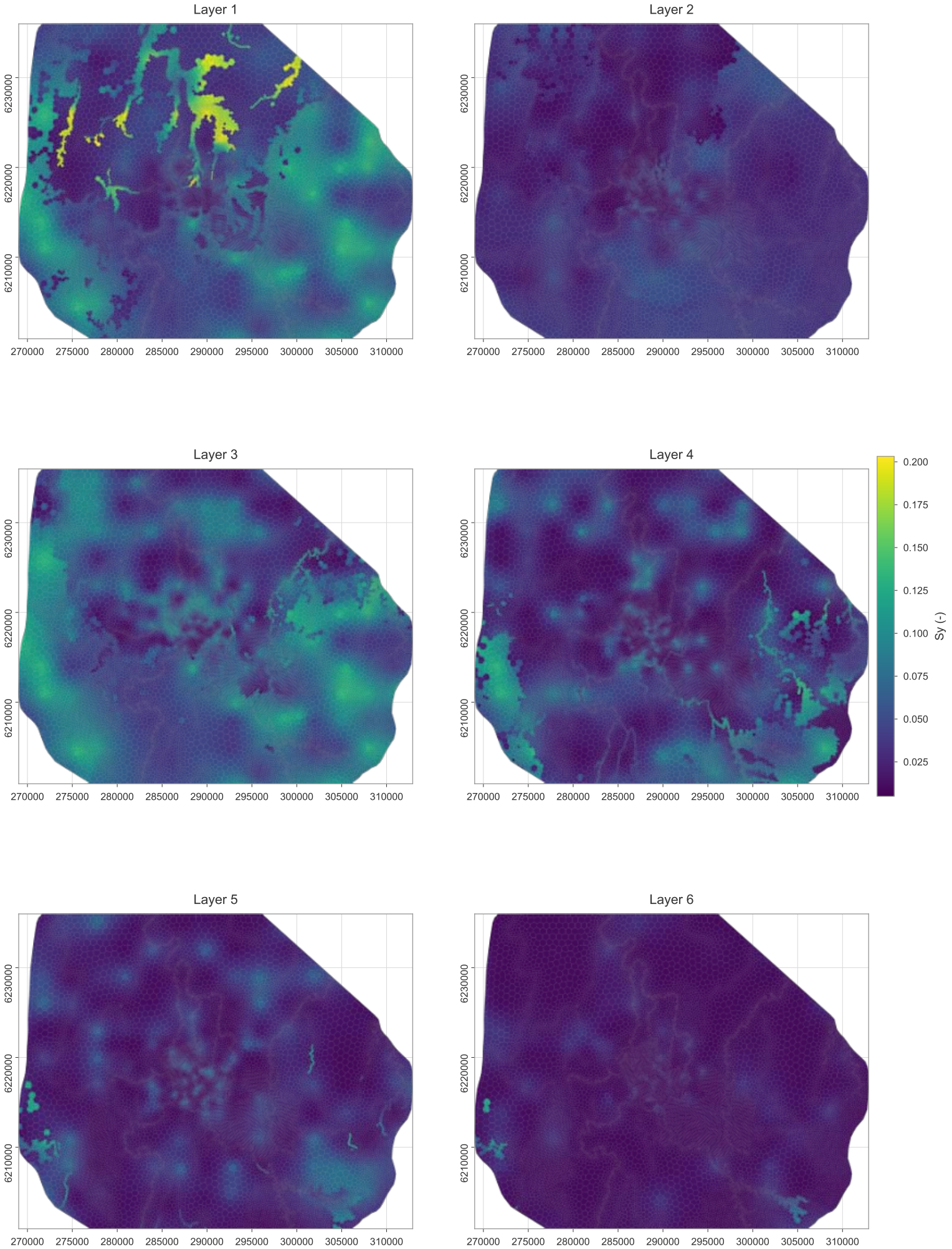
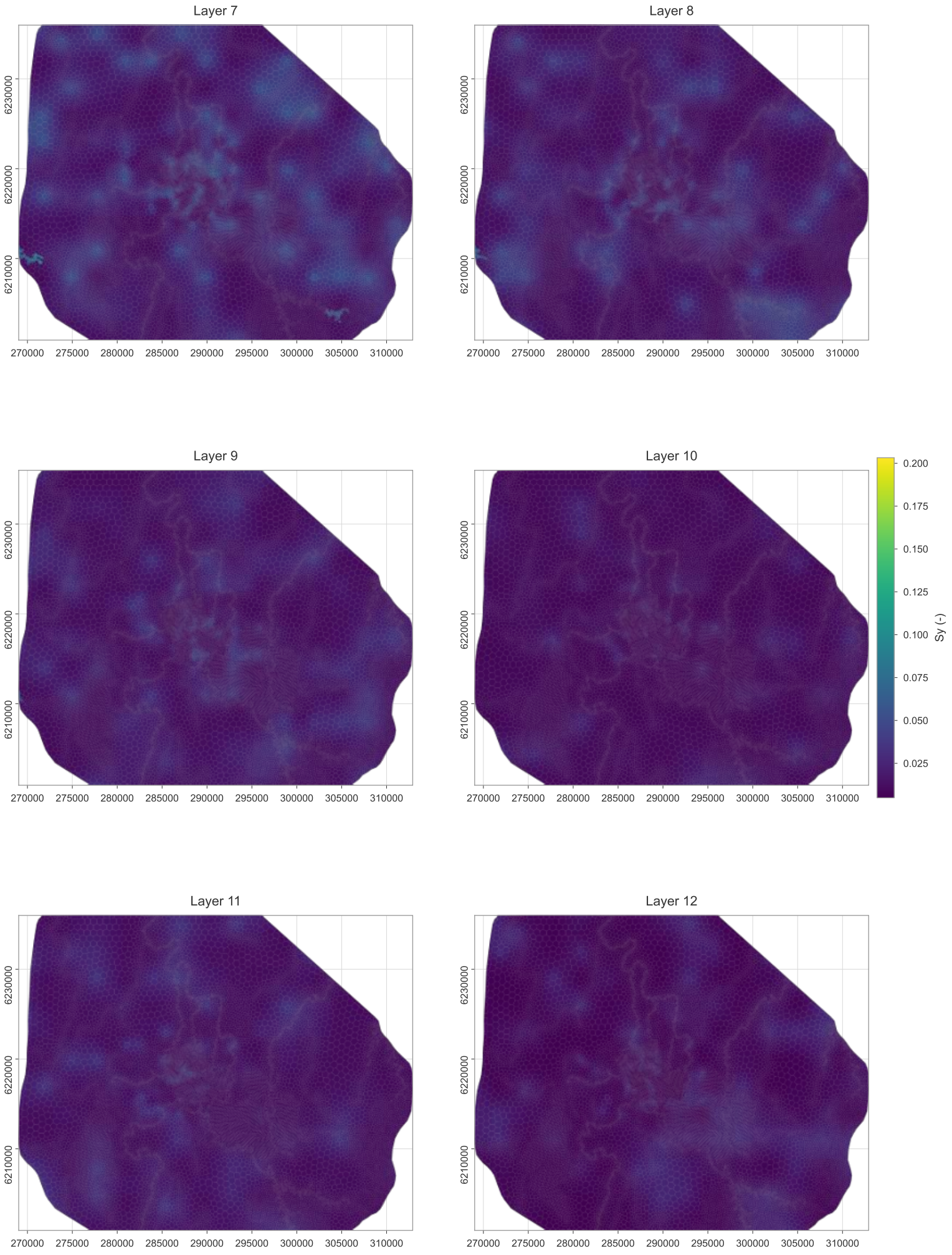
280000
285000
290000
295000
300000
305000
310000
K33 (m/day)
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}

Specific yield (Sy)



ap5b: STO.Sy (selected layers)



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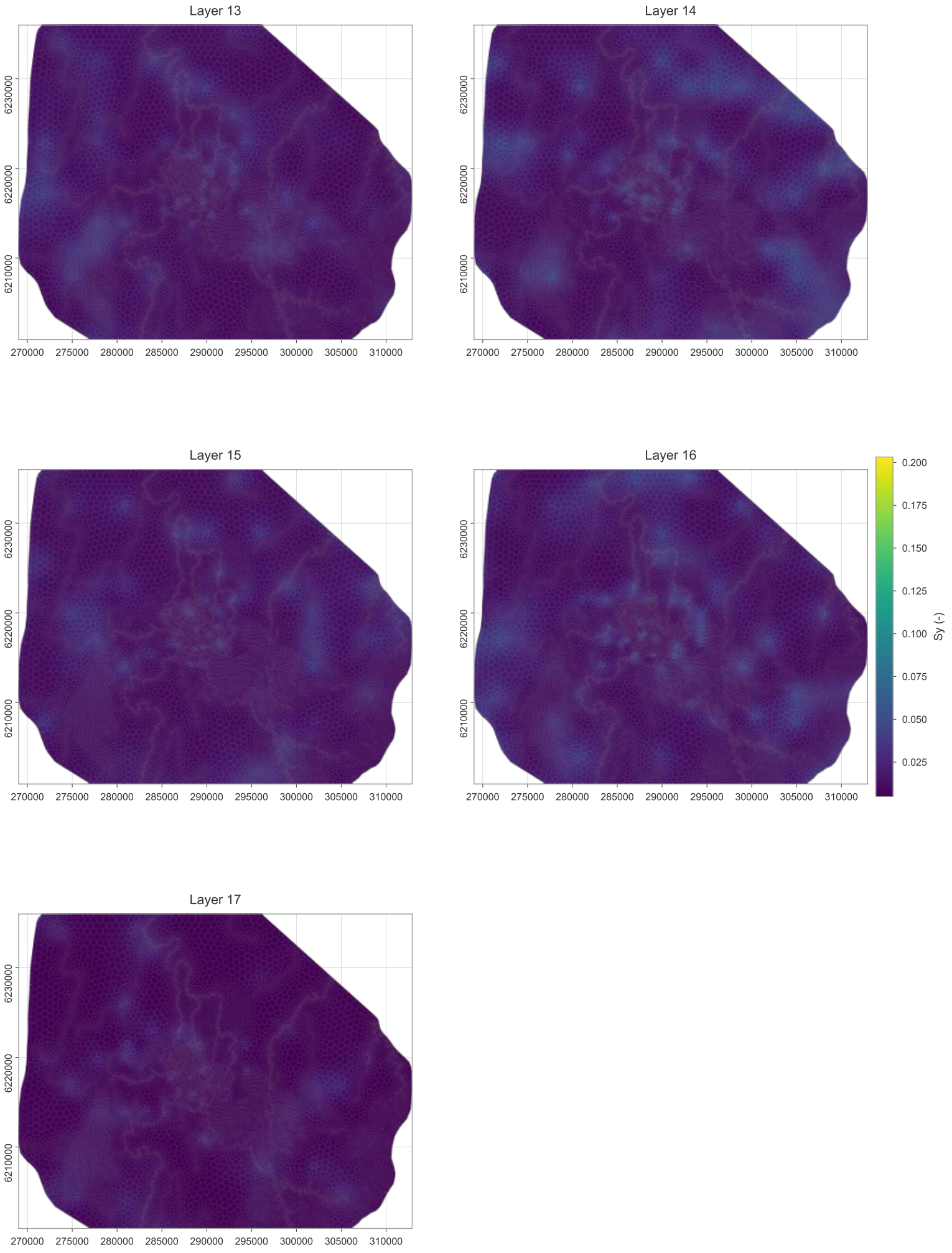

APPENDIX E – Recommended TARP thresholds

Recommended Trigger Action Response Plan (TARP) thresholds for groundwater drawdown related to mining at specified groundwater bores.

Tabe E1: Model predicted drawdown and recommended TARP triggers for private bores an groundwater monitoring bores

Effects due to Project and Cumulative (all mines) at the 90th, 95th and 99th percentile of model runs. Triggers set as follows:

TARP Level 1	30-day rolling median is greater than **P90** drawdown predictions or greater than 1.0 m of mining induced drawdown where predicted drawdown is less than 1 m
TARP Level 2	30-day rolling median is greater than **P95** predictions and 0.5m greater than level 1 values (to prevent trigger escalation due to natural water table variations where probabilities are closely distributed).
TARP Level 3	30-day rolling median is greater than **P99** predictions and 0.5m greater than level 2 values

Bore_ID	Owner	Change_Proj_P90	Change_Proj_P95	Change_Proj_P99	Change_Cumul_P90	Change_Cumul_P95	Change_Cumul_P99	Recommended_L1_TARP	Recommended_L2_TARP	Recommended_L3_TARP	Type
GW108907	private	0.00	0.00	0.00	5.12	5.41	7.25	5.1	5.6	7.2	Water Supply
GW105376	private	0.00	0.00	0.00	7.08	7.31	10.76	7.1	7.6	10.8	Water Supply
GW072874	private	0.00	0.00	0.00	9.17	9.45	12.80	9.2	9.7	12.8	Water Supply
GW102619	private	0.04	0.04	0.05	0.16	0.17	0.20	1.0	1.5	2.0	Irrigation
GW072196	private	0.07	0.08	0.09	0.78	0.81	0.90	1.0	1.5	2.0	Water Supply
GW100289	private	0.03	0.03	0.04	0.06	0.08	0.09	1.0	1.5	2.0	Water Supply
GW106675	private	0.06	0.07	0.08	0.83	0.91	0.99	1.0	1.5	2.0	Water Supply
GW112381	private	0.01	0.01	0.03	2.56	2.68	2.91	2.6	3.1	3.6	Water Supply
GW105574	private	0.00	0.01	0.02	3.67	4.09	4.63	3.7	4.2	4.7	Water Supply
GW107791	private	0.01	0.01	0.01	0.73	0.79	1.16	1.0	1.5	2.0	Water Supply
GW105531	private	0.81	0.93	1.04	4.21	4.40	4.82	4.2	4.7	5.2	Water Supply
GW026516	private	0.01	0.01	0.01	0.01	0.01	0.02	1.0	1.5	2.0	Irrigation
GW108990	private	0.00	0.00	0.00	0.24	0.30	0.35	1.0	1.5	2.0	Water Supply
GW062945	private	0.19	0.20	0.20	0.22	0.22	0.23	1.0	1.5	2.0	Water Supply
GW104766	private	0.16	0.16	0.17	0.18	0.19	0.20	1.0	1.5	2.0	Water Supply
GW105325	private	0.09	0.09	0.10	0.11	0.11	0.12	1.0	1.5	2.0	Other
S2536	ICHPL (Alluv)	0.20	0.22	0.22	0.78	0.80	0.85	1.0	1.5	2.0	Monitoring VWP
S2536A	ICHPL (HBSS)	0.00	0.00	0.00	9.85	10.30	12.34	9.8	10.3	12.3	Monitoring VWP
S1913	ICHPL (HBSS)	0.00	0.00	0.00	10.28	10.53	12.31	10.3	10.8	12.3	Monitoring VWP
S2500	ICHPL (HBSS)	2.08	2.24	0.29	4.72	5.07	5.43	4.7	5.2	5.7	Monitoring VWP
S2315	ICHPL (HBSS)	0.00	0.00	0.00	13.80	14.19	15.92	13.8	14.3	15.9	Monitoring VWP
S1954	ICHPL (HBSS)	0.02	0.02	0.00	0.93	1.18	1.32	1.0	1.5	2.0	Monitoring VWP
S1936	ICHPL (HBSS)	0.00	0.00	0.00	7.90	8.37	10.80	7.9	8.4	10.8	Monitoring VWP
S1941	ICHPL (HBSS)	0.02	0.02	0.01	19.57	20.10	21.23	19.6	20.1	21.2	Monitoring VWP
S2157	ICHPL (HBSS)	0.01	0.01	0.00	0.36	0.37	0.46	1.0	1.5	2.0	Monitoring VWP
S2632	ICHPL (WMGR)	0.18	0.24	0.27	8.33	8.89	10.41	8.3	8.9	10.4	Monitoring VWP
S2537	ICHPL (HBSS)	0.02	0.02	0.01	19.57	20.10	21.23	19.6	20.1	21.2	Monitoring VWP
S2538	ICHPL (HBSS)	0.00	0.00	0.00	8.13	9.02	11.18	8.1	9.0	11.2	Monitoring VWP

12.2 Appendix B – Appin Longwalls 712 to 716 Surface Water Impact Assessment (HGEO 2025b)

Illawarra Coal Holdings Pty Ltd

Appin Mine Extraction Plan

Surface Water Assessment
Longwall panels 712 to 716



HGEO Pty Ltd

Date: 9 October 2025

Project number: J21606

Report: D25298

DOCUMENT REGISTER

Revision	Description	Date	Comments
A	1st Draft	28/8/2025	
B	2nd Draft	17/9/2025	
C	Final	09/10/2025	

FILE

Https://hgeocomau.sharepoint.com/sites/HGEO/Shared Documents/Files/Client_Site/Appin_A7/Projects/J21606_Appin_LW712_716_Surface_Water/D25298_Appin_Mine_Extraction_Plan_Surface_Water_Assessment_RevC.docx

Cover photo: Razorback Range looking west from Menangle Road, March 2025.

QUALITY CONTROL

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ABBREVIATIONS

Abbreviation/Term	Meaning
AHD	Australian height datum
ANZG	The Australian and New Zealand Guidelines for Fresh and Marine Water Quality
BLR	Basic landholder rights
BSO	Bulli Seam Operations
DGVs	Default guideline values
DO	Dissolved oxygen
DPIE	Department of Planning, Industry and Environment
EA	Environmental Assessment
EC	Electrical conductivity
EP	Extraction Plan
EV	Environmental value
GM3	Gear M Illawarra Met Coal Pty Ltd
HBSS	Hawkesbury Sandstone
IPD	Impact pathway diagram
IPM	Incremental profile method
IESC	Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development
KFH	Key fish habitat
LW	Longwall
ML	Megalitres
NRAR	Natural Resources Access Regulator
ORP	Oxidation reduction potential
PEL	Petroleum Exploration Licence
PPL	Petroleum Production Lease
PPR	Preferred Project Report
RMZ	Risk Management Zone
SMP	Subsidence Management Plan

SUMMARY

Illawarra Coal Holdings Pty Limited (ICHPL), a wholly owned subsidiary of Gear M Illawarra Met Coal Pty Ltd (GM^3), operates Appin Mine, a longwall coal mine in the Southern Coalfield of New South Wales. ICHPL is preparing an Extraction Plan (EP) Application for Longwalls 712 to 716 (LW712 to LW716) in the Bulli Seam. This surface water assessment report provides information to support the EP Application which will be submitted to the Department of Planning, Housing and Infrastructure.

The study area for the surface water assessment encompasses the surface area that could be affected by subsidence due to mining of LW712 to LW716. This includes the area based on a 35° angle of draw from the longwall panels and the predicted additional 20 mm subsidence contour, and the area based on the 600 m boundary from the longwall panels which represents the minimum extent of valley-related effects. Downstream waterways are also considered.

The study area is located within the Hawkesbury-Nepean catchment but not within the Sydney Drinking Water Catchment. Land use in the area is predominantly rural residential with most rural properties used for grazing. Watercourses within the study area include Navigation Creek and its tributaries, and tributaries of Matahil Creek, Apps Gully and Foot Onslow Creek. The headwaters of these streams drain from the steep ridgeline of remnant bushland along Razorback Range in the west of the study area. Downstream waterways include the Nepean River, which is more than 2 km from the study area, as well as Racecourse Creek and Stonequarry Creek downstream of Apps Gully.

Streams within the study area are ephemeral and comprise disconnected pools that have naturally developed in bedrock in the upper reaches and alluvial soils in the lower reaches. The streams flow during and following periods of significant rainfall, periodically connecting the pools. The watercourses have been and continue to be subject to disturbance due to historic land clearance and current agricultural land use. This has resulted in fragmented riparian vegetation, elevated sediment and nutrient input, degraded water quality (including high salinity, iron, and manganese), and aquatic habitat of relatively limited value, although streams in the study area do support native aquatic plants, macroinvertebrates and fish. There are 278 farm dams within the study area, most of which intersect drainage lines and capture flows. This means the influence of watercourses in the study area on flow and water quality in the downstream Nepean River is likely to be minimal.

Surface water monitoring for the Project has already commenced to establish a baseline prior to the commencement of mining. Monitoring will continue throughout the mining of LW712 to LW716 and following the development of incremental subsidence. The surface water monitoring program includes; reference water chemistry and observation monitoring at one site, flow monitoring at two sites, water chemistry and observational monitoring at three sites, and observational monitoring at three sites within or in close proximity to the LW712 to LW716 study area.

Post-mining surface water monitoring will continue for a two-year period following the completion of longwall extraction for surface water flow, pool water level, and water quality monitoring at locations on the Nepean River and Foot Onslow Creek in accordance with the Extraction Plan Approval for Longwalls 709 to 711 and 905.

An assessment of potential impacts on surface water systems to predict potential impacts to surface water resources and associated receptors has indicated:

- There is a low risk of broadscale fracturing of creek beds within the study area. Some localised fracturing is possible within the longwall footprint, and creeks could experience a diversion of

stream flow (when flowing) and a reduction or loss of water holding capacity of pools. Previous observations suggest such impacts are unlikely, and no significant loss of catchment yield is anticipated. No fracturing is anticipated within the Nepean River.

- Longwall mining and associated fracturing of strata above the longwall panel (goaf) will result in groundwater depressurisation at the mined coal seam and within the fracture network, with the drawdown effect diminishing with height above the mine and with distance from the mine footprint. It is expected that depressurisation of upper aquifers, including the upper Hawkesbury Sandstone, will be relatively minor and in line with those observed during previous mining in Areas 7 and 9. Negligible drawdown is expected within the Wianamatta Group and Quaternary alluvium, including identified wetland areas. There is expected to be negligible flow losses from streams and pools due to groundwater drawdown. No drawdown related losses of flow are expected from the Nepean River.
- No large-scale adverse changes in ponding or scouring of the banks along the creeks as a result of subsidence induced tilt. There may be some small reversals in stream grade along the flatter sections of streams or in the locations of the existing farm dams and localised ponding could develop in these areas.
- No significant impacts on surface water quality are predicted to occur as a result of the extraction of LW712 to LW716. Subsidence is not expected to cause significant changes to flow regime or bank scouring.
- Reactivation of existing minor gas release zones or the development of new gas release zones along the Nepean River and creeks and tributaries could occur due to the mining of LW712 to LW716. Gas release reactivation is considered unlikely in the Nepean River which is more than 2 km from LW712 to LW716. Associated water quality effects from minor gas releases would be negligible.
- The likelihood of the occurrence or enhancement of ferruginous springs is considered to be low due to previous mining experience within the area, however, if this were to occur the effects are anticipated to be localised and minor.
- Impacts to farm dams due to the Project are considered unlikely based on mining under more than 300 farm dams in the region (with loss of water reported for only a small number of dams) and predicted subsidence impacts. However, where subsidence results in loss of water from dams due to cracking and/or tilt, these impacts will be managed and compensated in accordance with the Coal Mine Subsidence Compensation Act 2017 and/or an alternate water supply would be provided as required by Condition 14 of the BSO Project Approval (Compensatory Water Supply) in consultation with the landowner.

1. Introduction

Appin Mine is an underground mine located approximately 25 kilometres (km) north-west of Wollongong near the township of Douglas Park (Figure 1). The mine extracts hard coking coal for steel production and is owned and operated by Illawarra Coal Holdings Pty Limited (ICHPL), a wholly owned subsidiary of Gear M Illawarra Met Coal Pty Ltd (GM[3]). Mining operations are undertaken in accordance with Project Approval 08_0150 for the Bulli Seam Operations (BSO), granted on 22 December 2011 and subsequently modified in April 2015 (Mod 1), October 2016 (Mod 2), April 2022 (Mod 3), August 2024 (Mod 5), and October 2024 (Mod 6). Appin Mine has an approved production capacity of up to 10.5 million tonnes per annum of Run of Mine coal until 2041. ICHPL is currently extracting Longwall 711 in Appin Area 7.

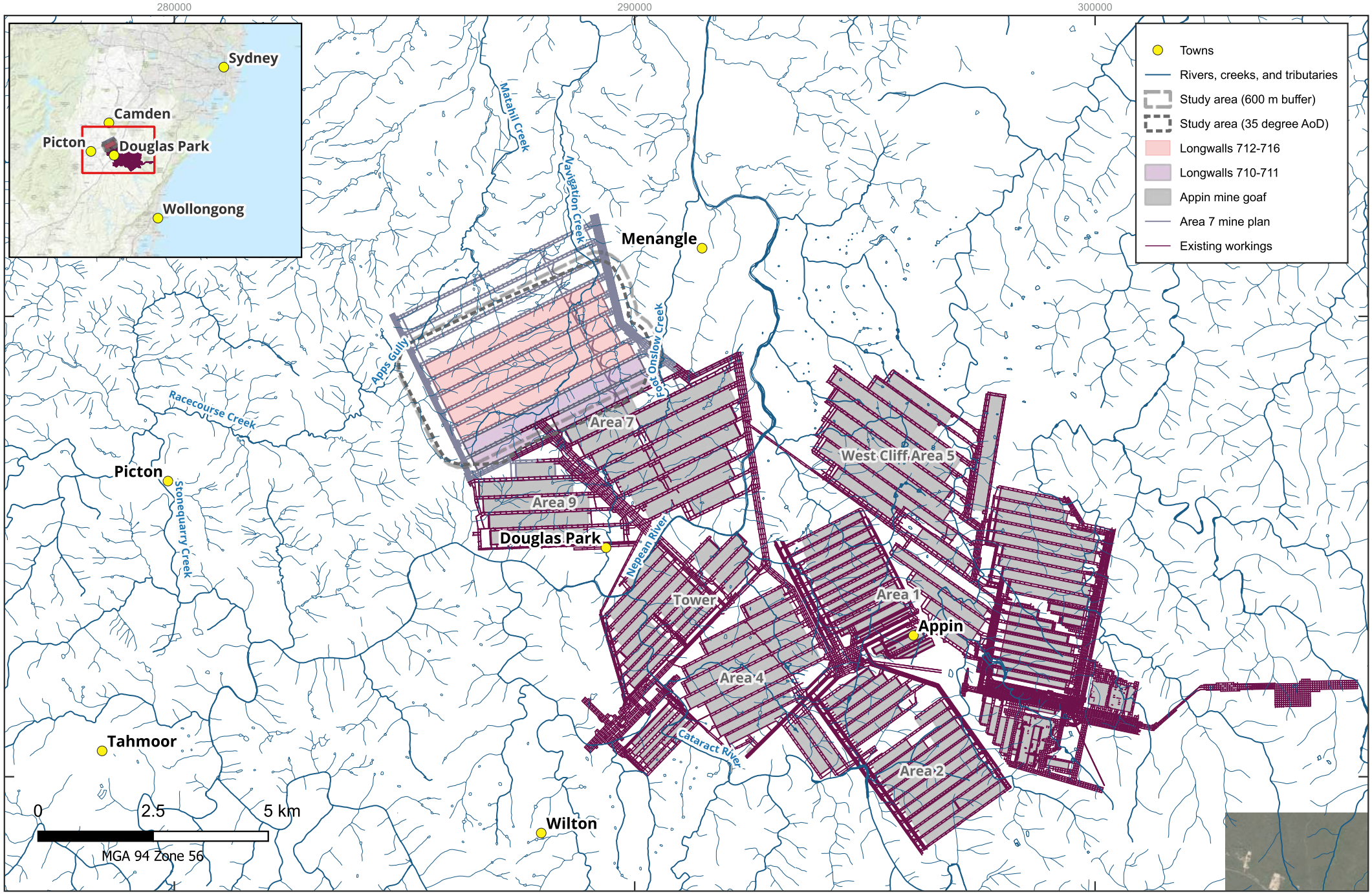
BSO Approval Schedule 3 Condition 5 requires that an Extraction Plan (EP) is prepared prior to commencement of secondary extraction. An EP is required to outline the proposed management, mitigation, monitoring, and reporting of potential impacts from the secondary extraction of approved longwalls at Appin Mine. ICHPL are currently seeking EP approval for Longwalls 712 to 716 (LW712 to LW716), which are a continuation of the current longwall series in Area 7 (the Project). This report presents a technical assessment of the potential surface water impacts of the Project and recommends management, mitigation, and monitoring strategies.

1.1 Appin Mine

Appin Mine is a longwall mine that extracts coal from the Bulli Seam within the Permian aged Illawarra Coal Measures. Mining is currently occurring in Area 7. Historically mining at Appin Mine has also occurred at Tower Colliery, Appin Area 1, Area 2, Area 3, Area 4 and Area 9, and West Cliff Mine (Figure 1). A summary of mining at Appin Mine is provided in Table 1.

Table 1 Summary of mining at Appin Mine

Mine Area	Longwall panels	Period of mining	Status
Tower	1 – 20	1978 – 2002	Historic mining
Appin Area 1	1 – 12	1969 – 1986	Currently used for underground mine water storage, transferred from current mining areas
Appin Area 2	12 – 29	1986 – 1997	Historic mining
Appin Area 3	301 – 302	1998 – 2007	Historic mining
Appin Area 4	401 – 408	1998 – 2007	Currently used for underground mine water storage, transferred from current mining areas
West Cliff Area 5	1 – 138	1983 – 2016	Historic mining, approved to 2041
Appin Area 7	701 - 711	2007 – Present	Active mining, approved to 2041
Appin Area 9	901 – 905	2016 – 2023	Active mining, approved to 2041



Appin Mine Extraction Plan Surface Water Assessment

Location map

Figure 1

file: Appin_SW.qgz

1.2 Project description

The Project to be assessed is the secondary extraction of longwall panels LW712 to LW716 in Appin Area 7 of the approved BSO. The location of the longwalls is shown in Figure 2.

Longwall panels LW712 to LW716 are approximately 4 km in length and 313 m wide (excluding the first workings). The thickness of the Bulli Seam within the extents of the longwalls varies between 3.0 m and 3.6 m. The proposed longwalls will mine the full seam thickness.

The floor of the Bulli Seam generally dips from the south-southeast to the north-northwest with an average grade across the mining area of approximately 3.0 % (i.e. 1 in 33). The proposed longwalls will be extracted towards the main headings, i.e. retreat mining from west to east (MSEC 2025).

The depths of cover to the Bulli Seam above LW712 to LW716 vary between 555 m and 800 m. The minimum depth of cover occurs along a tributary to Navigation Creek above the tailgate of LW712. The maximum depth of cover occurs along the Razorback Range above the western end of LW716.

1.3 Study area

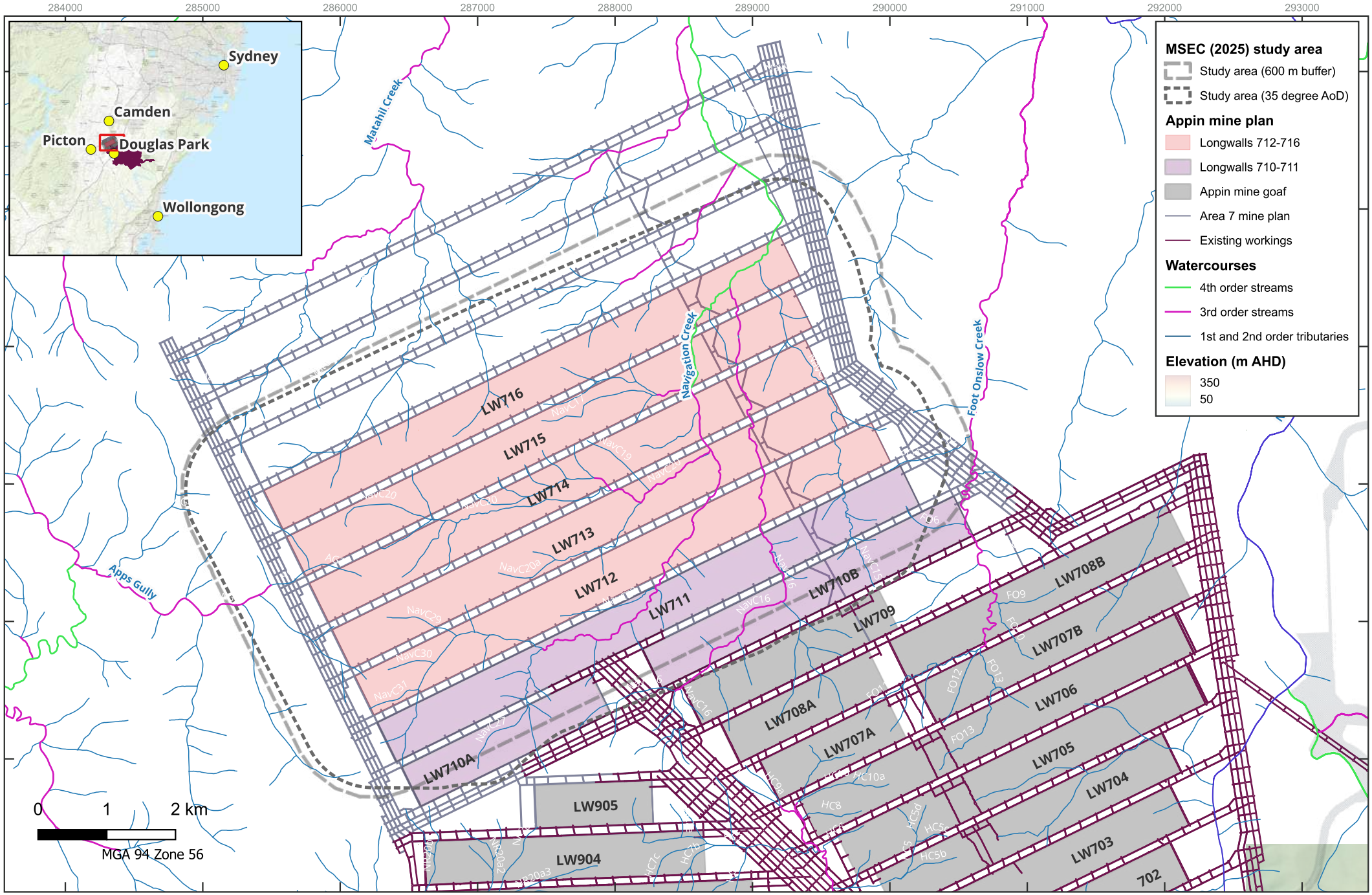
The study area for this assessment is based on the surface area that could be affected by the mining of the proposed LW712 to LW716. The subsidence impact assessment (MSEC 2025) considers two areas: the study area based on the 35° angle of draw and the study area based on the 600 m boundary (Figure 2).

The study area based on the 35° angle of draw represents the minimum extent for the assessments for the conventional ground movements, i.e. vertical subsidence and its associated effects, as recommended by the Resources Regulator for Subsidence Management Plan applications (Department of Mineral Resources 2003). It has been calculated by combining the areas bounded by the following limits:

- The 35° angle of draw line from the extents of the proposed LW712 to LW716; and
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour determined using the calibrated Incremental Profile Method (MSEC 2025).

The study area based on the 600 m boundary is the area within 600 m of the edge of longwall panels (Figure 2). It represents the minimum extent of the assessments for the valley-related effects. This distance is based on the recommendations from the Southern Coalfield Inquiry (Department of Planning 2008) for the risk management zones.

The study area for the surface water assessment is the outer extent of the study area based on the 35° angle of draw and the study area based on the 600 m boundary. The surface water assessment additionally includes downstream waterways including the Nepean River, Navigation Creek, Apps Gully, Racecourse Creek, Stonequarry Creek, Foot Onslow Creek, and Matahil Creek.



Appin Mine Extraction Plan Surface Water Assessment

Longwall layout and watercourses in the study area

Figure 2

file: Appin_SW.qgz

2. Relevant legislation, policy, guidelines, and conditions

2.1 BSO Project Approval

The BSO Project Approval requires preparation of an Extraction Plan (EP) for first and second workings within each longwall mining domain. The EP must incorporate a Water Management Plan which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on watercourses, and includes:

- Surface water impact assessment criteria, including trigger levels for investigating any potentially adverse impacts on water resources or water quality; and
- A program to monitor and report stream flows and assess any changes resulting from subsidence impacts.

The BSO Project Approval also includes subsidence impact performance measures for natural and built features. These are summarised in Table 2. The term negligible, used in Table 2, is defined in the BSO Project Approval as small and unimportant, such as to be not worth considering.

Table 2 Subsidence impact performance measures relevant to surface water

Natural or built feature	Performance measure
Nepean River	Negligible environmental consequences including: • negligible diversion of flows or changes in the natural drainage behaviour of pools; • negligible gas releases and iron staining; and • negligible increase in water cloudiness.
Other watercourses	No greater subsidence impact or environmental consequences than predicted in the Environmental Assessment (EA) and Preferred Project Report (PPR).
Farm dams	Always safe. Serviceability should be maintained wherever practicable. Loss of serviceability must be fully compensated. Damage must be fully repaired or fully compensated, or else the damaged built feature or damaged infrastructure component must be replaced.

2.2 Water sharing plan

The take of water from streams near Appin Mine is regulated under the Water Sharing Plan for the *Greater Metropolitan Region Unregulated River Water Sources 2023*. Water sharing plans are the primary legal framework for managing water access and sharing in NSW and are developed in accordance with the *Water Management Act 2000*. The plan area of the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2023 is located on the south-east coast of NSW and covers an area of approximately 32,500 km^2. The plan area includes the Hawkesbury River catchment to the north and west, the Shoalhaven River catchment to the south and south-west, and the rivers of the Illawarra and metropolitan Sydney.

The study area is predominantly located within the Mid Nepean River Weirs Water Source, with the western part of the study area located within the Stonequarry Creek Water Source. Water sources typically coincide with sub-catchment boundaries and are divided into management zones to enable detailed water access and trading rules to be specified. The Menangle Weir Management Zone is located along the Nepean River to the east of the study area upstream of Menangle Weir, and the Camden Weir Management Zone is located along the Nepean River to the north-east of the study area downstream of Menangle Weir.

2.3 NSW water quality and river flow objectives

The NSW Water Quality and River Flow Objectives were developed for all major fresh and estuarine surface water catchments across NSW. The NSW Water Quality Objectives include a range of water quality indicators that can be used to assess whether the current condition of our waterways supports the values and uses people want protected. The NSW River Flow Objectives set out goals for surface water flow management and identify how river flow can protect river health and water quality.

2.4 Australian and New Zealand Guidelines for Water Quality (ANZG)

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) (DCCEEW 2018) provide authoritative guidance on the management of water quality for natural and semi-natural water resources in Australia and New Zealand. The guidelines form part of the National Water Quality Management Strategy, which is a national approach to improving water quality in Australian waterways.

The ANZG provide water managers with tools and guidance to assess, manage and monitor the water quality. The ANZG aim to protect 'environmental values' (EVs), those values or uses of water that the community believes are important for a healthy ecosystem for public benefit, welfare, safety or health. These include, but are not limited to, protection of aquatic ecosystems, drinking water, primary and secondary recreation, visual amenity, agricultural water for irrigation, livestock and growing aquatic foods, industrial water, and cultural and spiritual values.

The ANZG provide guidance on the derivation of site-specific water quality guideline values, technically-derived numerical measures (e.g. concentrations) or descriptive statements to protect aquatic ecosystems and human water uses and values (e.g. irrigation, stock watering, recreation). The guideline values can be derived for a range of physico-chemical, biological, and habitat indictors.

Each of the EVs requires its own specific set of guideline values because the acceptable guideline values to support one type of EV may not be acceptable to maintain another EV. For example, the guideline values for pesticides required to protect fish and other fauna are usually lower than those required to protect irrigated crops. Another reason is that the indicators relevant to one EV may be different to those used for other EVs.

The ANZG includes default guideline values (DGVs) which can provide a generic starting point for assessing water quality. We recommend using DGVs for generic applications in the absence of more relevant guideline values (jurisdictional, site specific).

2.5 IESC Information Guidelines Explanatory Note on using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessment

The Explanatory Note on using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessment (IESC 2024) was developed by the Independent Expert Scientific Committee on Unconventional Gas Development and Large Coal Mining Development (IESC), a statutory body under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999.

The Explanatory Note provides guidance on the development of impact pathway diagrams (IPDs) to integrate and communicate the diverse information in the documentation of environmental impact assessment. IPDs are a conceptual model that illustrates how impacts of a proposed project are predicted to adversely affect water resources and related assets (receptors), the potential pathways of the impacts from sources to receptors, and how these pathways might interact with each other. When superimposed on maps of the project area, IPDs also indicate where such impacts might occur.

The pathways in IPDs are typically represented as linking consecutive categories of components (Figure 3), starting with drivers and ending in receptors, which in this context are surface water resources. The Explanatory Note presents some examples of IPDs from the mining literature which demonstrate that the terminology used for the different components of IPDs and the representation of IPDs is variable from project to project.

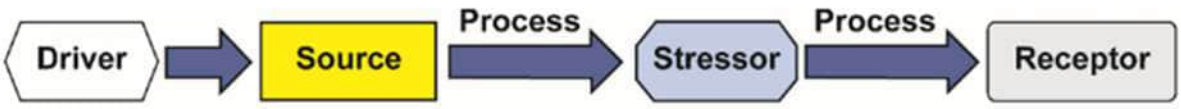


Figure 3 Typical components of an impact pathway diagram

3. Environmental setting

3.1 Topography

Appin Mine is located on the southern margins of the Cumberland Plain, which is characterised by low lying, gently undulating plains and hills. The mine is on the western periphery of the Woronora Plateau, as defined by the gorges and sandstone plateaus found to the east and the incised Nepean Gorge.

The surface elevations of the study area and surrounds are shown in Figure 2. Elevations within the study area range from 95 m AHD to 310 m AHD. The topographic high occurs in the west of the study area associated with Razorback Range. The terrain in this area is incised by tributaries that form the headwaters of Navigation Creek, Apps Gully, and Matahil Creek. Flatter plains occur in the east of the study area which generally fall towards the north. The lowest surface level occurs along Navigation Creek where it crosses the finishing (i.e. eastern) end of LW716.

3.2 Land use

Appin Mine is located within a predominantly rural and rural residential area with remnant vegetation occurring along ridgelines and urban development associated with the township of Douglas Park. Most rural properties in the area are used for grazing of native vegetation or modified pastures.

The AGL Camden Gas Project is located at the northern end of Appin Mine on Petroleum Production Lease (PPL) 1 to 6 and Petroleum Exploration Licence (PEL2). The Camden Gas Project commenced operations in 2001 and over the life of the project comprised 144 wells targeting the Bulli and Balgownie coal seams. AGL is currently in the process of ceasing production and decommissioning wells, with 112 wells reported to be decommissioned as of May 2023. AGL are authorised to extract groundwater for gas production in accordance with Water Access Licenses 24856 and 24736 and Works and Use Approvals 10WA112288 and 10WA112294 with a total allocation of 30 ML/year (15 ML allocated from the Sydney Basin Central Groundwater Source and 15 ML allocated from the Sydney Basin Nepean Groundwater Source) (SLR 2021).

3.3 Climate

ICHPL has been recording daily rainfall observations at Appin East, Appin North, Appin West and Ventilation Shaft No.6 since 2014. Longer term data are available at Bureau of Meteorology (BoM) climate stations in the vicinity of the mine, including Darkes Forest (068024), Cataract Dam (068016), Wedderburn (068159) and Douglas Park (068200). Climate data for this assessment were obtained from the Scientific Information for Landowners (SILO) database, which interpolates data from the BoM climate stations for grid cell locations. Data for the grid cell location between Douglas Park and Appin (Latitude -34.20 Longitude 150.75) for the period January 1890 to December 2024 were used for this assessment.

Appin Mine experiences moderate rainfall, with a mean annual rainfall of approximately 823 mm. Rainfall is generally evenly distributed throughout the year, with the highest mean rainfall in autumn and summer and the lowest in late winter/early spring. Severe drought conditions occurred across much of NSW during 2017 to 2019 including at Appin. The drought was followed by very wet weather in 2020 to 2022 with the development of prolonged La Niña conditions. Temperatures in the area range throughout the year from a mean maximum of 27.2°C in January to a mean minimum of 5.7°C in August. Long-term average annual evaporation at Appin is approximately 1443 mm.

3.4 Geology

Appin Mine is located within the Southern Coalfield of the Sydney Basin (Figure 4). The stratigraphy of the Southern Sydney Basin is shown in Figure 4, based on the Southern Coalfield 1:100,000 geological map (Moffitt 1999).

The Triassic Wianamatta Group is present at the surface of the study area and ranges in thickness from less than 10 m to 200 m at Razorback Range. Quaternary floodplain alluvium is mapped as occurring at the surface in the eastern part of the study area along Navigation Creek and its tributaries.

The Hawkesbury Sandstone (HBSS) underlies the Wianamatta Group within the study area. The HBSS comprises bedded sandstone units around 170 m thick (MSEC 2025), which are incised along the Nepean River. The HBSS is underlain by the Triassic sandstones, siltstones and claystones of the Narrabeen Group. This includes the Bulgo Sandstone, Scarborough Sandstone and Coal Cliff Sandstone, as well as the Bald Hill Claystone, Stanwell Park Claystone and Wombarra Claystone.

Permian aged Illawarra Coal Measures underlie the Narrabeen Group. The Illawarra Coal Measures consist of interbedded sandstone, shale and coal seams, with a thickness of approximately 200 m to 300 m. The Bulli Seam is the primary economic sequence of interest at Appin Mine. Within the study area the Bulli Seam is around 3.0 m to 3.6 m thick and around 555 m to 800 m below surface (MSEC 2025).

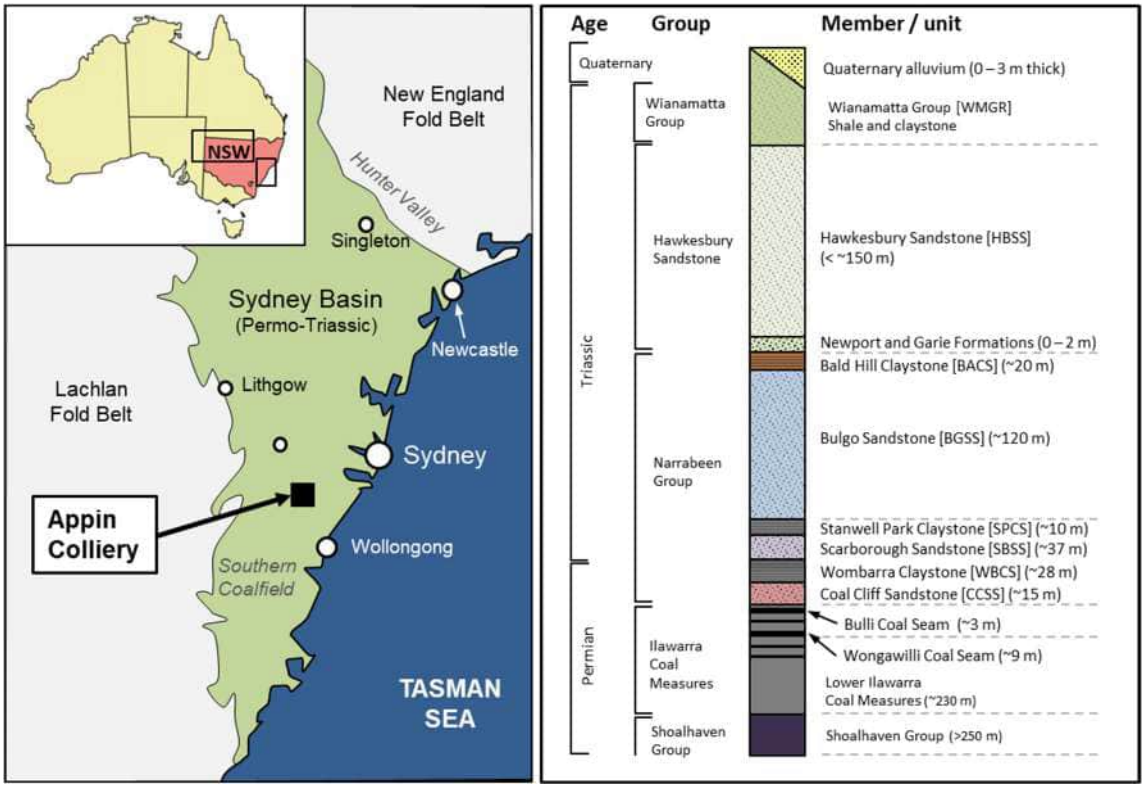


Figure 4 Stratigraphy

3.4.1 Structural geology

The Permian coal measures dip approximately 3 % in a north north-westerly direction, towards the Douglas Park syncline. There are no major geological structures (faults) mapped within the study area. Major geological structures in the surrounding region include the Nepean Fault Zone, O'Hares Fault and J-Line Fault.

Within the study area there are two NNW-SSE orientated zones of geological structure that cross the western ends of LW712 to LW716 and the eastern end of LW712 and possibly extend through the eastern ends of the other proposed longwalls. These zones comprise series of dykes with thicknesses up to approximately 3.5 m and minor faults with displacements up to approximately 3 m (MSEC 2025).

Elsewhere, minor faults with displacements up to approximately 1 m cross the proposed LW712 to LW716. Increased subsidence or localised irregular movements are not anticipated in these locations, as this was not observed when longwalls previously mined through similar geological structures in Appin Areas 7 and 9 (MSEC 2025).

3.5 Hydrogeology

The geology and hydrogeology of the area is illustrated in a south-north cross section in Figure 5. Three main groundwater systems occur in the study area:

1. Perched groundwater systems associated with fractures and bedding planes within the shallow sandstone and shale units of the Wianamatta Group and Hawkesbury Sandstone;
2. Shallow groundwater systems associated with layered water-bearing zones within the saturated Hawkesbury Sandstone; and
3. Deeper groundwater systems within the Narrabeen Group and Illawarra Coal Measures.

3.5.1 Perched groundwater systems

The Wianamatta Group and Hawkesbury Sandstone have perched water table zones associated with fractures and bedding planes within shallow sandstone and shale units. These zones may be ephemeral, have limited vertical flow, and be hydraulically disconnected from the deeper groundwater systems. Groundwater in the Wianamatta Group is moderately saline (median electrical conductivity 4,750 µS/cm) and suitable for short term irrigation and water for some stock (i.e. sheep and dairy cattle). Due to low yields the Wianamatta Group is not considered a productive groundwater source.

3.5.2 Shallow groundwater systems

The Hawkesbury Sandstone is the main groundwater source in the study area due to its regional extent and outcrop areas that receive rainfall recharge. It is a thick aquifer (approximately 155 m) with numerous high and low permeability horizons that provides baseflow contributions where incised along major rivers including the Nepean River. Due to the stratification of the sandstone sequences, groundwater flow within the Hawkesbury Sandstone is primarily horizontal with a slight downward component in the study area. Groundwater flow is generally in a northerly direction and locally influenced where intersected by rivers and private abstraction bores. The shallow depths and high yields make the aquifer ideal for private water supply bores, with the highest yielding bores associated with coarse sandstone units and/or fracture networks. The quality of groundwater in the Hawkesbury Sandstone is variable but in general brackish (median electrical conductivity 2,060 µS/cm) with a

neutral pH (median pH of 7.5) and suitable for short-term irrigation (due to elevated iron concentrations) and stock water.

3.5.3 Deeper groundwater systems

Deeper groundwater systems in the study area occur within the Narrabeen Group and the Illawarra Coal Measures. These units typically are of much lower permeability than the Hawkesbury Sandstone and produce low bore yields and poorer water quality.

The main water bearing unit of the Narrabeen Group is the confined Bulgo Sandstone. Groundwater flow in the Bulgo Sandstone is in a north-westerly direction through bedding planes, joints and fractures. Groundwater quality is moderately saline (median electrical conductivity 4,950 µS/cm), neutral (median pH 7.2) and suitable for short term irrigation and water for some stock (i.e. sheep and dairy cattle). Three low permeability aquitards occur within the Narrabeen Group which impede vertical flow within the unit. The Bald Hill Claystone, which is approximately 30 m thick in the study area, overlies the Bulgo Sandstone and interrupts the vertical groundwater flow from the overlying Hawkesbury Sandstone. The Stanwell Park Claystone, which is approximately 14 m thick, underlies the Bulgo Sandstone and limits the interaction of groundwater between the Bulgo Sandstone and the Scarborough Sandstone. The Wombarra Claystone, which forms the base of the Narrabeen Group, is approximately 26 m thick in the study area and impedes vertical flow to the Illawarra Coal Measures. Groundwater monitoring within the study area at S1913 indicates that groundwater heads at depth within the Narrabeen Group tend to be higher than those observed in the HBSS.

Groundwater occurrence within the Illawarra Coal Measures is associated with the more permeable coal seams. Groundwater is confined and flow is generally in a northerly direction. The coal seams outcrop to the east of Appin Mine along the Illawarra Escarpment. Prior to mining, groundwater heads in the Wongawilli Seam were around 1 to 5 m higher than the heads in Bulli Seam. On a regional scale, groundwater in the Bulli and Wongawilli seams flowed towards the north. Groundwater in the Narrabeen Group and Illawarra Coal Measures has been locally depressurised due to current and historical mining at Appin Mine and coal seam gas extraction for the Camden Gas Project.

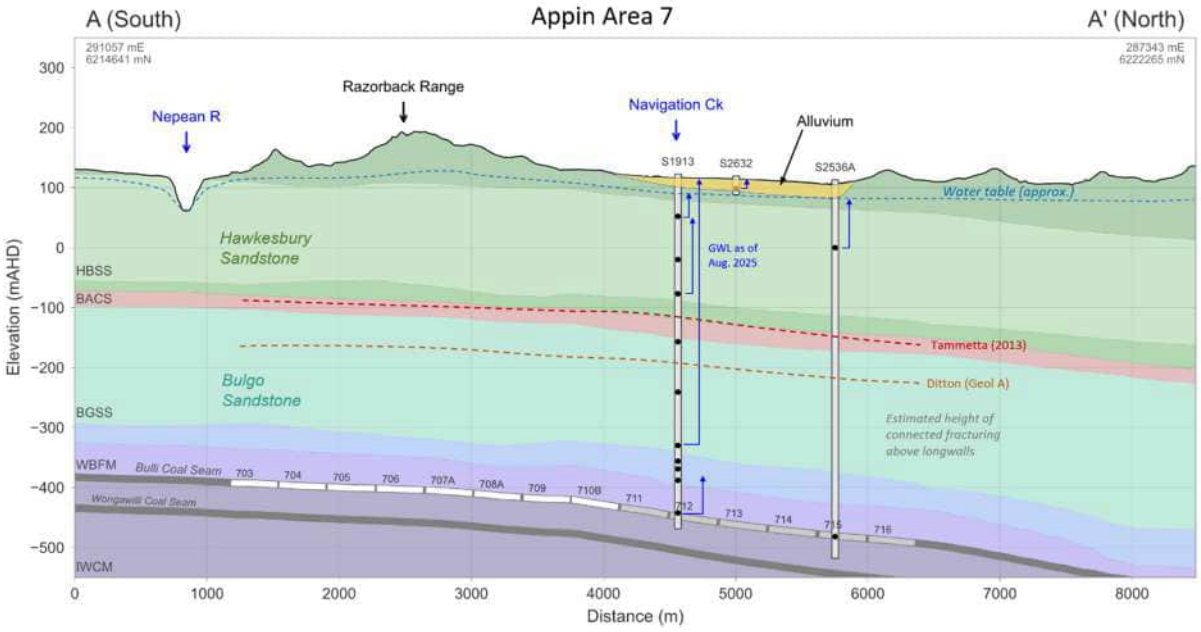


Figure 5 Hydrogeological cross section (N-S) through Appin Area 7 and Area 9

3.6 Surface water and drainage

3.6.1 Hydrological setting

Appin Mine is located within the Hawkesbury-Nepean and Georges River catchments (Figure 6). Major rivers in the area include the Nepean River, Stonequarry Creek, and the Cataract River in the Hawkesbury-Nepean catchment, and Georges River in the Georges River catchment. The rivers within the Appin Mine area generally flow in a northerly direction and have perennial flows influenced by dam releases and baseflow contributions from the incised HBSS. Summary details for each of the main rivers near the Project are included in Table 3.

3.6.1.1 Hawkesbury Nepean Basin

The study area is located within the Hawkesbury-Nepean basin, which covers an area of approximately 22,000 km^2 (DCCEEW 2024). Nepean River runs through Appin Mine between Tower and Areas 7 and 9 and tributaries of the Nepean River are located within the study area.

Flows within the Hawkesbury-Nepean basin are retained by large dams used to store water for Sydney's water supply. Major storages located upstream of the study area include Lake Nepean, Lake Avon, Lake Cordeaux, Lake Cataract and Lake Burragorang (Figure 6). These storages are located within the declared Sydney Drinking Water Catchment, although the study area itself is outside this area. The Hawkesbury-Nepean basin is considered an unregulated system as while the dams and weirs in the catchment capture water, they are not used to release water into the river downstream for extraction by users and so flows are not regulated.

Table 3 Major river systems near Appin Mine

River	Appin Mine Area	Catchment	Description
Nepean River	Area 7, Area 9 and Tower	Hawkesbury-Nepean	Flows in a general northerly direction. Flow is regulated by upstream weirs and is approximately 310 ML/day (at Maldon Weir).
Stonequarry Creek	Area 7	Hawkesbury-Nepean	Flows in a general southerly direction and joins the Nepean River near Maldon upstream of Appin Mine. Flow is regulated by upstream Warragamba Dam and is approximately 22 ML/day (at Picton).
Cataract River	Area 4 and Tower	Hawkesbury-Nepean	Flows in a northerly direction and joins the Nepean River between Tower and Area 9. Flow is regulated by upstream Cataract Dam and is approximately 92 ML/day (at Broughton Pass Weir).
Georges River	West Cliff	Georges River	Flows in a northerly direction. Flow is regulated by upstream Brennan's Creek Dam and is around 4.2 ML/day (at Brennans Creek Dam).

3.6.1.2 Sydney drinking water catchment

The Sydney Drinking Water Catchment (as declared within the meaning of the *Water NSW Act 2014* by s 6.60 of *State Environmental Planning Policy (Biodiversity and Conservation) 2021*) is located to the west, south and east of the study area (Figure 6). The catchment is a 16,000 km^2 area of land that supplies drinking water to the Sydney region and surrounding areas, and includes the Warragamba, Shoalhaven, Upper Nepean, Woronora, and Blue Mountains catchments. Historically mining has occurred within what is now the declared catchment area.

The Sydney Drinking Water Catchment includes areas of land identified as Special or Controlled Areas (in the *Sydney Water Catchment Management Act 1998*) that protect water quality (Figure 6). The Special Areas cover approximately 3,640 km^2 of mostly native bushland around the water storages and infrastructure that supply Sydney, the Illawarra, Blue Mountains, Southern Highlands and Shoalhaven regions. Public access and activities are restricted to protect water quality in these areas.

3.6.2 Nepean River

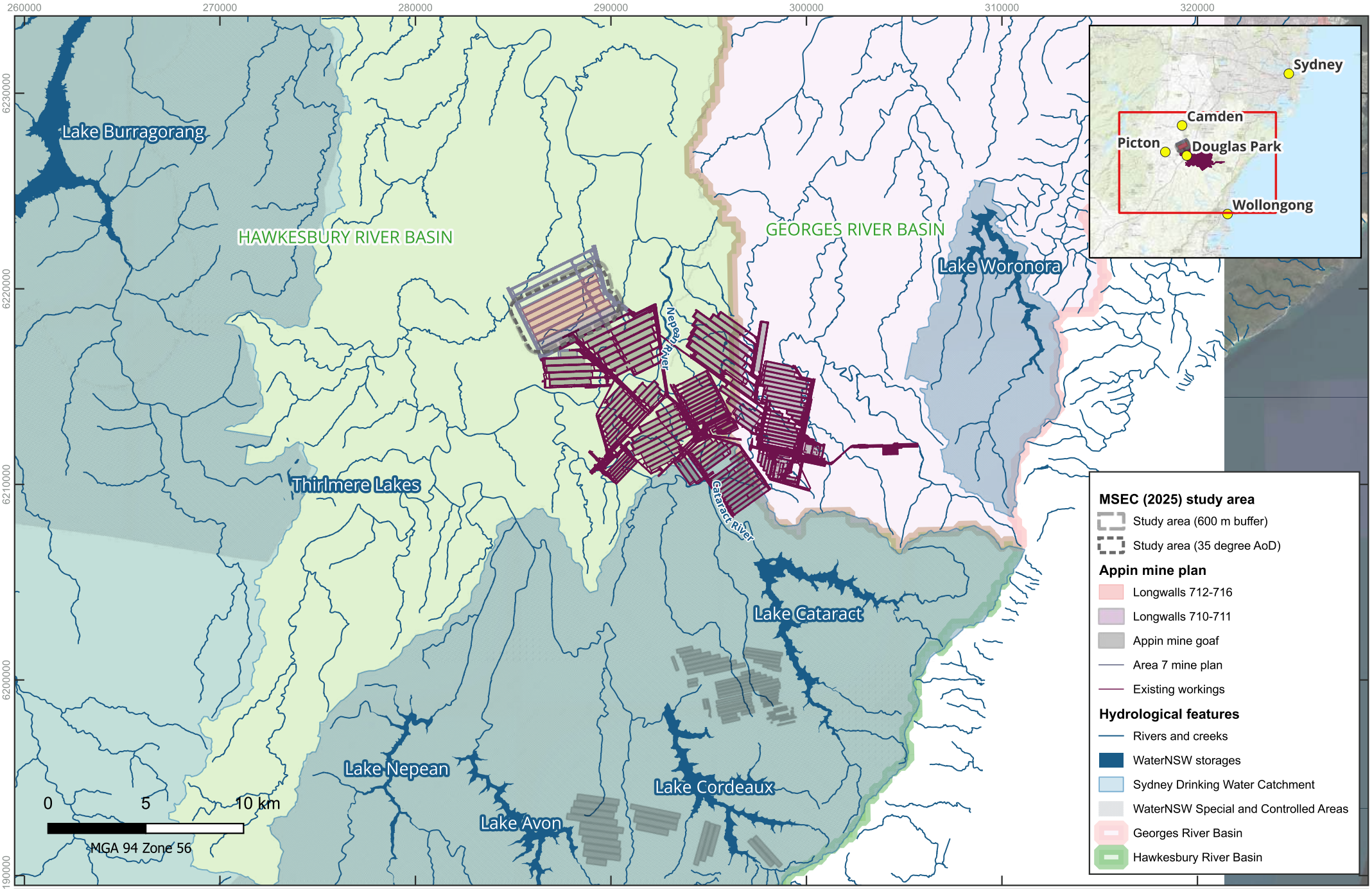
Nepean River runs past Appin Mine between Tower and Areas 7 and 9 and is located to the east and south of the study area, with the closest points approximately 2.2 km south of LW712 and 2.5 km east of LW712. Tributaries of the Nepean River, including Navigation Creek and Foot Onslow Creek are located within the study area. The headwaters of Matahil Creek and Apps Gully, also a tributary of the Nepean River, are located just within the study area.

Nepean River flows in a northerly direction, with a mean flow of around 310 ML/day (Maldon Weir) since 2010. Surface water flows in the Nepean River are derived from several sources including rainfall-runoff from natural, agricultural, and urban catchment areas, baseflow from perched aquifers and the regional Hawkesbury Sandstone groundwater system, and licensed discharges, including from Appin and Tahmoor Collieries. Rainfall-runoff from catchment areas contributes most flow in the Nepean River system. Flows vary greatly and are highly responsive to rain events due to the significant areas of catchment.

Natural flow within the Nepean River and associated watercourses including Stonequarry Creek and Cataract River has been significantly altered by dams and weirs. Natural catchment flows are retained by large storage dams upstream of Appin Mine for the purpose of water supply for Sydney. Smaller storages upstream of the study area include Maldon Weir on the Nepean River and Broughtons Pass Weir on Cataract River. Water in the catchment is also retained by numerous farm dams, some of which are located on tributaries of the Nepean River.

Nepean River is a ‘gaining river’ in terms of surface water - groundwater interaction, being situated in a well incised gorge that defines a regional low point in the piezometric surface. Water levels in the Nepean River and its tributaries are monitored using observations and measured benchmarks.

A significant portion of the Nepean River catchment has been cleared for urban development, agriculture, and industry. Runoff from urban areas, farms, and industrial areas, as well as licensed discharges, have contributed to degraded water quality within Nepean River.



Appin Mine Extraction Plan Surface Water Assessment

Hydrological setting

Figure 6

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3.6.3 Watercourses in the study area

Named watercourses within the study area and downstream include the Navigation Creek, and the upper tributaries of Apps Gully (a tributary of Racecourse Creek), Foot Onslow Creek, and Matahil Creek (Figure 2). The Nepean River is located more than 2 km from LW712 and is outside the study area.

The NSW Government's Strategic Review into the Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield (Department of Planning 2008) recommended that Risk Management Zones (RMZs) be applied to all streams of third order or above in the Strahler stream classification. The creeks that have third order sections within the study area are Navigation Creek, tributaries to Navigation Creek NavC14.5, NavC16, NavC17 and NavC20, Apps Gully and Foot Onslow Creek. A fourth order section of Navigation Creek is also located within the study area (Figure 2). The upper reaches of Navigation Creek, Apps Gully, and Matahil Creek commence along Razorback Range above the western ends of the proposed longwalls and are first and second order streams.

The third and fourth order streams within the study area occur as shallow channels in the surface soils, which have been derived from the Wianamatta Group, with some sandstone outcropping. The first and second order streams within the study area have more substantial incisions into the surface soils, with exposed sandstone in the bases and rock outcropping in the valley sides.

Streams within the study area are ephemeral, but pools have naturally developed along the lengths of these creeks within the surface soils and rock platforms. Flows have been altered by the numerous farm dams which intersect the drainage lines and capture flows (Figure 7) and therefore watercourses within the study area contribute only a small portion of total flows in the Hawkesbury-Nepean basin (<0.2%). Water quality is influenced by the land use and soils in the catchment, with nutrients associated with farming activities and salinity associated with the marine sediments of the Wianamatta Group shales.

Average existing gradients for the third and fourth order sections of streams within the study area are typically between 0.5 and 2 %. Gradients of the first and second order streams along Razorback Range typically vary between 10 and 30 %, while gradients for the lower reaches away from Razorback Range typically vary from less than 0.5 to 5 % (MSEC 2025).

3.6.3.1 Navigation Creek

Navigation Creek (Photo 1A, 1B, and 1C) directly overlies LW712 to LW716 and flows in a northerly direction. The Creek and four of its tributaries (i.e. NavC14.5, NavC16, NavC17 and NavC20) are third order streams within the study area. A fourth order section of Navigation Creek is also located within the study area (Figure 2).

Navigation Creek is approximately 5.1 km long within the study area, with 4.4 km overlying longwall panels (MSEC 2025). NAVC16 to the east of Navigation Creek (Photo 1D) is approximately 3.7 km long, with 1.9 km overlying longwall panels. NAVC17 and NAVC20 overlie longwall panels and are 0.27 and 1.1 km long, respectively. NAVC14.5 is outside the mining area but within the study area and is approximately 1.3 km long.

The headwaters of Navigation Creek drain from the steep ridgeline of remnant bushland in the west of the study area, however most of the Navigation Creek catchment is farmland (Photo 1A). The

catchment area of Navigation Creek to its confluence with the Nepean River is approximately 24.9 km^2. The study area comprises approximately 40% of the Navigation Creek catchment area.

Navigation Creek and its tributaries are ephemeral and likely only flow during periods of extended, moderate or high rainfall. They do not receive significant baseflow contributions from groundwater. The creek and tributaries have been highly modified through the construction of instream farm dams to capture and store water for livestock and agriculture (Photo 1E). The farm dams are well established and interrupt flow and cause ponding of water (Photo 1C). As most surface water flows from the upper reaches of Navigation Creek are likely to be captured by farm dams, the influence of this watercourse on flow and water quality in the Nepean River is likely to be minimal.

Observations of Navigation Creek and its tributaries indicate it is highly disturbed and in poor condition along most of its length. The creek is diverted through culverts under roads and driveways in many places (Photo 1F). Stream channels are often shallow and covered in grass (Photos 1A and 1E). In some locations stream banks are steep with minimal vegetation coverage or weeds and evidence of erosion and scouring (Photos 1B, 1D, and 1F). Some pools have naturally established along the stream, however most ponding of water is related to the presence of farm dams.

3.6.3.2 Apps Gully

Apps Gully is a third order tributary of Racecourse Creek and crosses the western margin of the study area. First and second order tributaries of Apps Gully drain from the west of Razorback Range and overlie the western extents of longwall panels 712, 713, 714 and 715. Apps Gully and its tributaries drain agricultural land as well as tracts of remnant vegetation on ridgelines. They are ephemeral streams that have been modified by farm dams which capture water and interrupt flow (Figure 7). They do not receive baseflow from groundwater but may receive interflow discharge from perched groundwater within the Wianamatta Formation following high rainfall periods.

Apps Gully and its tributaries flow in a general westerly direction and join Racecourse Creek to the west of the study area (Figure 2). Racecourse Creek also flows in a general westerly direction and joins Stonequarry Creek approximately 9.4 km downstream of the study area. Before joining Stonequarry Creek, Racecourse Creek flows around the northern perimeter of the township of Picton.

Stonequarry Creek is a tributary of the Nepean River and flows in a general southerly direction through the township of Picton. Flows in Stonequarry Creek are regulated by releases from upstream Warragamba Dam. Flooding in Picton can occur because of both ‘mainstream flooding’, break out of the main channel of Stonequarry Creek inundating the surrounding floodplain, as well as ‘overland flow’ caused when the runoff from local rain events exceeds the capacity of the local drainage network and makes its way to the creek (WMA Water 2021a). A Floodplain Risk Management Study and Plan was undertaken in 2021 (WMA Water 2021b) to manage the risk of flooding in Picton.

Stonequarry Creek joins the Nepean River just downstream of Maldon Weir, approximately 7.0 km downstream of the Racecourse Creek confluence and 6.8 km upstream of Appin Mine (Figure 6). Stonequarry Creek receives inflows from four main tributaries: Racecourse Creek from the east, Crawfords Creek from the north, and Cedar and Mathews Creek to the west of Picton. The catchment area of Stonequarry Creek to its confluence with the Nepean River is approximately 97.3 km^2. The study area is in the headwaters of the catchment and represents only a very small proportion (1.9%) of the total catchment area.



Photo 1 A) Navigation Creek downstream above longwall panel 716. B) Navigation Creek upstream above longwall panel 713. C) Navigation Creek downstream of longwall panel 716. D) NAVC16 above longwall panel 713. E) Tributary of Navigation Creek above longwall panel 713. F) Tributary of Navigation Creek above longwall panel 714 (Source: ICHPL).

3.6.3.3 Foot Onslow Creek

Foot Onslow Creek is a third order stream (Figure 2). First and second order tributaries of Foot Onslow Creek occur in the study area to the east of the longwall panels but do not directly cross the footprints of Longwalls 712 to 716. To the south of the study area, Foot Onslow Creek and its tributaries overlie previously extracted longwall panels 706, 707B, 708B, 709 and 710A (Photos 2A and 2B). Foot Onslow Creek flows in a general northerly direction to its confluence with the Nepean River approximately 3.7 km downstream of the study area. The catchment area of Foot Onslow Creek to its confluence with the Nepean River is approximately 8.5 km^2. The study area is in the headwaters of Foot Onslow Creek and represents a small proportion (13.3%) of the total catchment area.

Foot Onslow Creek and its tributaries are ephemeral and only flow during periods of extended, moderate or high rainfall. The creek and its tributaries drain agricultural land and farm dams have been constructed on many of the tributaries, interrupting flow and capturing water. Stantec Australia (2025) indicate that within the study area the creek contains several relatively large, deep pools that would be expected to persist through prolonged dry periods but at the time of inspection, there was no flow connectivity and standing pools were separated by sections of dry creek bed.

Foot Onslow Creek is highly disturbed and in poor condition. Stream banks are vegetated with grass or weeds or have steep to near vertical walls with evidence of significant scouring and erosion (Photo 2A). Stream bed material primarily consists of soft silt and clay with some sand and gravel bars and grass and reed growth in some locations (SLR 2021; Stantec Australia 2025).



Photo 2 Foot Onslow Creek (Source: SLR, 2021)

3.6.3.4 Matahil Creek

First and second order tributaries of Matahil Creek occur in the north of the study area overlying LW716. These tributaries drain in a northerly direction and join Matahil Creek approximately 900m downstream of the study area (Figure 2). Matahil Creek also flows in a general northerly direction and joins the Nepean River approximately 12.2 km downstream of the study area. The catchment area of Matahil Creek to its confluence with the Nepean River is approximately 45.3 km^2.

The study area is in the headwaters of the Matahil Creek catchment and represents only a small proportion (4.8%) of the total catchment area. The headwaters of Matahil Creek drain from remnant vegetation along ridgelines associated with Razorback Range however most of the Matahil Creek

catchment is farmland. Matahil Creek and its tributaries are ephemeral and like Navigation Creek, have been highly modified by farm dams which capture water and interrupt flow (Figure 7).

3.6.4 Receptors

Receptors associated with watercourses in the study area include wetlands and aquatic ecosystems that are located downstream and outside the study area, surface water users, and farm dams.

3.6.4.1 Wetlands

A study undertaken by Kingsford et al., (2004) mapped wetlands across New South Wales using a combination of classification of spectral classes of Landsat MSS and TM imagery and ancillary wetland information to create information classes of broad wetland groups (floodplain wetlands, freshwater lakes, saline lakes, reservoirs, estuarine wetlands and coastal lagoons and lakes). The mapping is shown in Figure 7 and indicates there are no wetlands in the study area. Mapped wetlands located downstream of the study area include reservoirs and floodplain wetlands along the Nepean River.

3.6.4.2 Aquatic ecosystems

Aquatic ecosystems within and downstream of the study area are detailed in the Stantec Australia (2025) report and summarised below.

The Nepean River supports significant and permanent aquatic habitat including extensive beds of submerged macrophytes in the shallower river edges, and large wood debris and boulders along the channel edge. Riparian vegetation is relatively undisturbed and provides a source of substantial in-stream woody debris, an important habitat for many species of aquatic fauna, including a number of species of native fish and aquatic macroinvertebrates. It is classified as Type 1 – Highly Sensitive Key Fish Habitat (KFH) (Type 1 – KFH) (Stantec Australia 2025).

Aquatic habitat provided by first, second, third and fourth order tributaries within the study area (including Navigation Creek and small sections of Foot Onslow Creek and Apps Gully) generally consists of a series of disconnected pools with connecting flow for short periods during and following rainfall. These watercourses have been and continue to be subject to disturbance due to historic land clearance and current agricultural land use. This has resulted in fragmented riparian vegetation, elevated sediment input and impaired water quality. They provide aquatic habitat of relatively limited value, though do support native aquatic plants, macroinvertebrates and fish. Third and fourth order sections of these drainage lines provide Type 1 – KFH to Type 2 – Moderately Sensitive KFH, while first and second order sections are not KFH (Stantec Australia 2025).

The threatened Macquarie perch (*Macquaria australasica*) occurs in the Nepean River upstream of the study area, though the presence of Maldon Weir appears to prevent access to the section adjacent to the study area and it is considered unlikely to occur in this section. The only records of the threatened Sydney Hawk dragonfly are in the Nepean River approximately 5 km upstream of the study area. These and other threatened species would be highly unlikely to occur in tributaries within the study area (Stantec Australia 2025).

3.6.4.3 Surface water users

The take of water from streams near Appin Mine is regulated under the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2023. The area is predominantly

located within the Mid Nepean River Weirs Water Source, with take from the Menangle Weir Management Zone located along the Nepean River upstream of Menangle Weir, the Camden Weir Management Zone located along the Nepean River downstream of Menangle Weir, and the Mid Nepean Catchment Management Zone which includes tributaries and farm dams located on third order or higher tributaries. The western part of the area is located within the Stonequarry Creek Water Source. A summary of unregulated river access licences in the water sources within the study area is provided in Table 4. Data on the location of individual unregulated river access licences is not available.

Extraction from tributaries may also occur under basic landholder rights (BLR), which do not require a licence. BLR includes water for domestic and stock purposes extracted from a water source fronting a landholder's property or from any aquifer underlying the land, harvestable rights, and native title rights. There are currently no extractions for native title rights in the Hawkesbury-Nepean catchment.

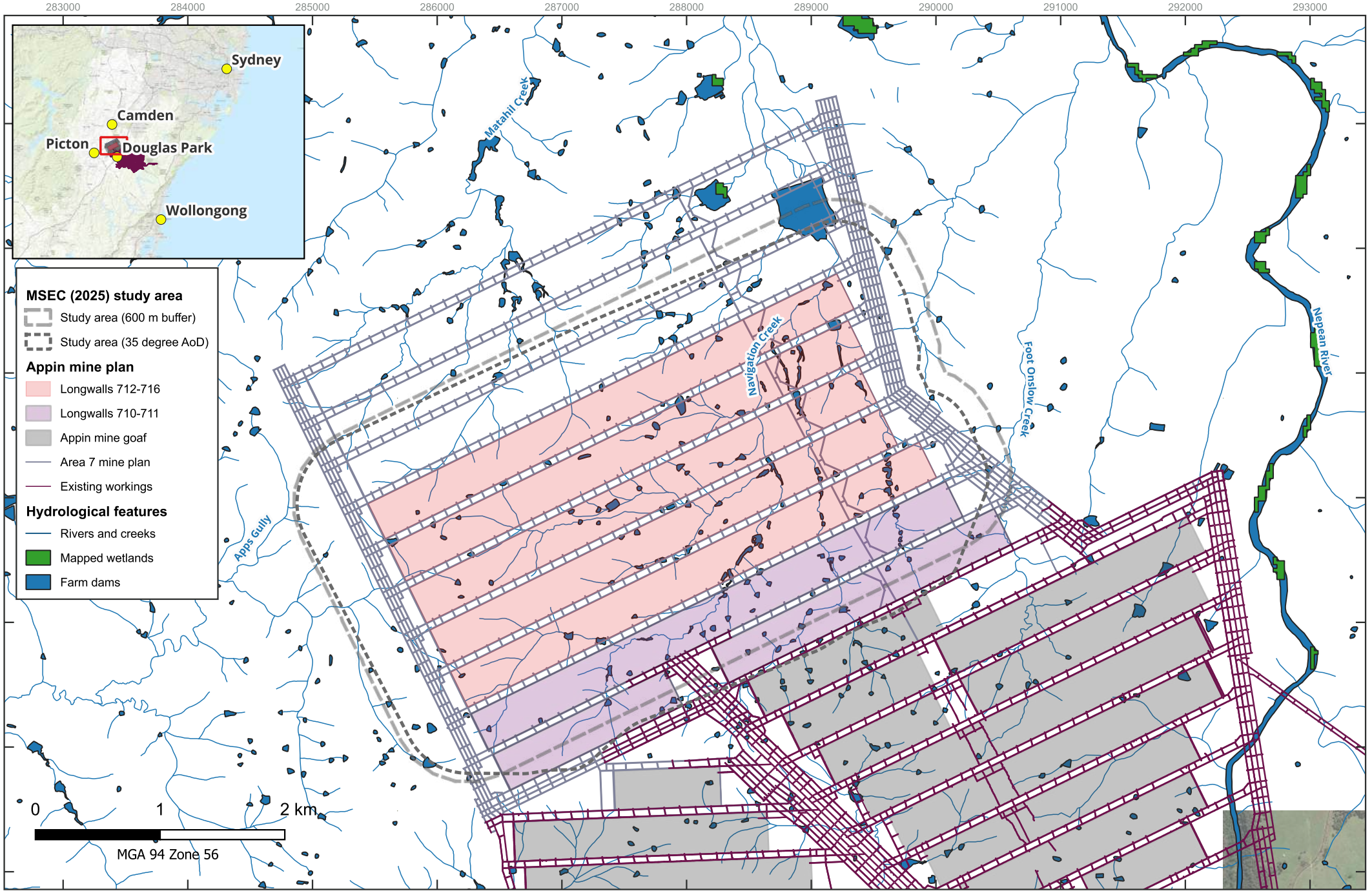
Table 4 Surface water entitlements

Water source	Management zone	Number of entitlements	Total share components (ML)	Min share (ML)	Max share (ML)
Mid Nepean River Weirs Water Source	Menangle Weir Management Zone	20	2939.0	2.0	1560.0
	Camden Weir Management Zone	25	3633.5	5.5	800.0
	Mid Nepean Catchment Management Zone	117	6150.0	0.0	1560.0
Stonequarry Creek	n/a	23	689.3	0.0	189.0

3.6.4.4 Farm dams

There are 278 farm dams located within the study area, 146 of which are located directly above the proposed longwalls. Being located within a predominantly rural and rural residential area, they are understood to be used for stock and domestic purposes. The locations of the farm dams are shown on Figure 7 and are generally located within natural streamlines. They are understood to be perched within weathered horizons of the Wianamatta Group shales and disconnected from the underlying aquifers of the Hawkesbury Sandstone. The dams are generally shallow, with the dam wall heights generally being less than 3 m and plan areas ranging between 28 m^2 and 16.7 ha. There are five dams with area greater than 5000 m^2 (MSEC 2025).

Unlicensed extraction from farm dams is permitted as a harvestable right. The take of water from a farm dam only requires an access licence when: the dam is located on a third order or higher stream, irrespective of the dam capacity or purpose; the dam exceeds the maximum harvestable right dam capacity for the property, which is a capacity that enables the landholder the ability to capture 10 per cent of the mean annual runoff from their property; or the dam is on a permanent (spring fed) first or second order stream. Licensed take from farm dams within the study area would be from the Mid Nepean Catchment Management Zone, which is summarised in Table 4.



Appin Mine Extraction Plan Surface Water Assessment

Receptors

Figure 7

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4. Baseline surface water conditions

4.1 Stream flow

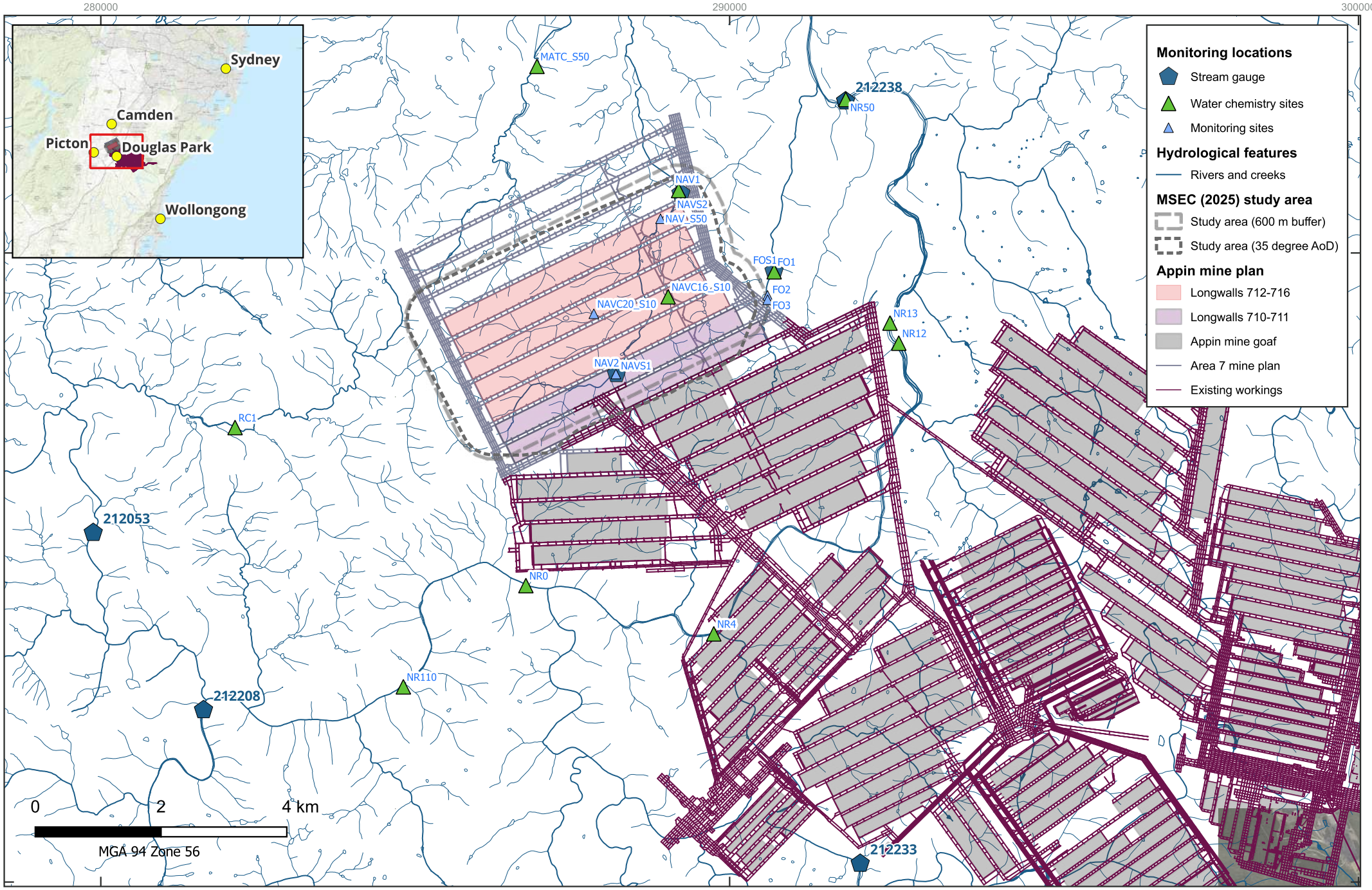
ICHPL conduct monitoring of stream flow at Navigation Creek within the study area and Foot Onslow Creek just outside the study area (Figure 8). Stream flow is also recorded every 15 minutes at four NSW government stream gauges on the major rivers in the vicinity of the study area. Two are on the Nepean River at Maldon and Menangle weirs, one is on the Cataract River at Broughtons Pass Weir, and one is on Stonequarry Creek at Picton (Figure 8). The gauging sites outside the study area provide for down-gradient monitoring of impacts and up-gradient control points. Baseline flow conditions at the gauging sites are summarised in Table 5. Flow in tributaries Navigation Creek and Foot Onslow Creek is very small compared to flow in Nepean River, Stonequarry Creek, and Cataract River.

Table 5 Stream gauges near Appin Mine and baseline flow conditions

Stream gauge location	Stream gauge ID.	Period of record	Median flow (ML/day)	Mean flow (ML/day)	Average annual no flow days
Nepean River at Maldon Weir	212208	26/07/1973 to present	22.5	377	1.68
Nepean River at Menangle Weir	212238	3/7/1990 to present	66.7	556	4.22
Cataract River at Broughtons Pass Weir	212233	31/12/1982 to present	3.19	137	148
Stonequarry Creek at Picton	212053	5/12/1990 to present	2.26	23.2	5.82
Navigation Creek^	NAVS1	7/9/2023 to present	0.000	0.073	347
Navigation Creek*	NAVS2	*Proposed site*	-	-	-
Foot Onslow Creek^	FOS1	6/9/2023 to present	0.079	0.330	16.5

n/a not applicable as these gauges record flows released from upstream storages
^ Data are based on short period of record since Sept 2023
*Proposed site

Observations of flow at monitoring sites across the Appin Mine Lease area also made every month (Table 6). Stream flow observations range from “no flow observed” to “trickle observed” to “surface flow observed”.



Appin Mine Extraction Plan Surface Water Assessment

Surface water monitoring locations

Figure 8

file: Appin_SW.qgz

Flow duration curves for streams near Appin Mine are shown in Figure 9. The data show that the Nepean River flows most days with less than five annual no-flow days on average. This is understood to be due to releases from upstream storages and contributions from baseflow from the Hawkesbury Sandstone aquifer. Stonequarry Creek at Picton similarly flows most days due to releases from Lake Burragorang (Warragamba Dam). Cataract River at Broughtons Pass Weir flows around 60% of days in the year when releases are made from upstream Cataract Dam.

Data for the short period of record since September 2023, during which rainfall was slightly above average, indicate Navigation Creek flowed less than 5% of days in the year whereas Foot Onslow Creek flowed more than 95% of days in the year.

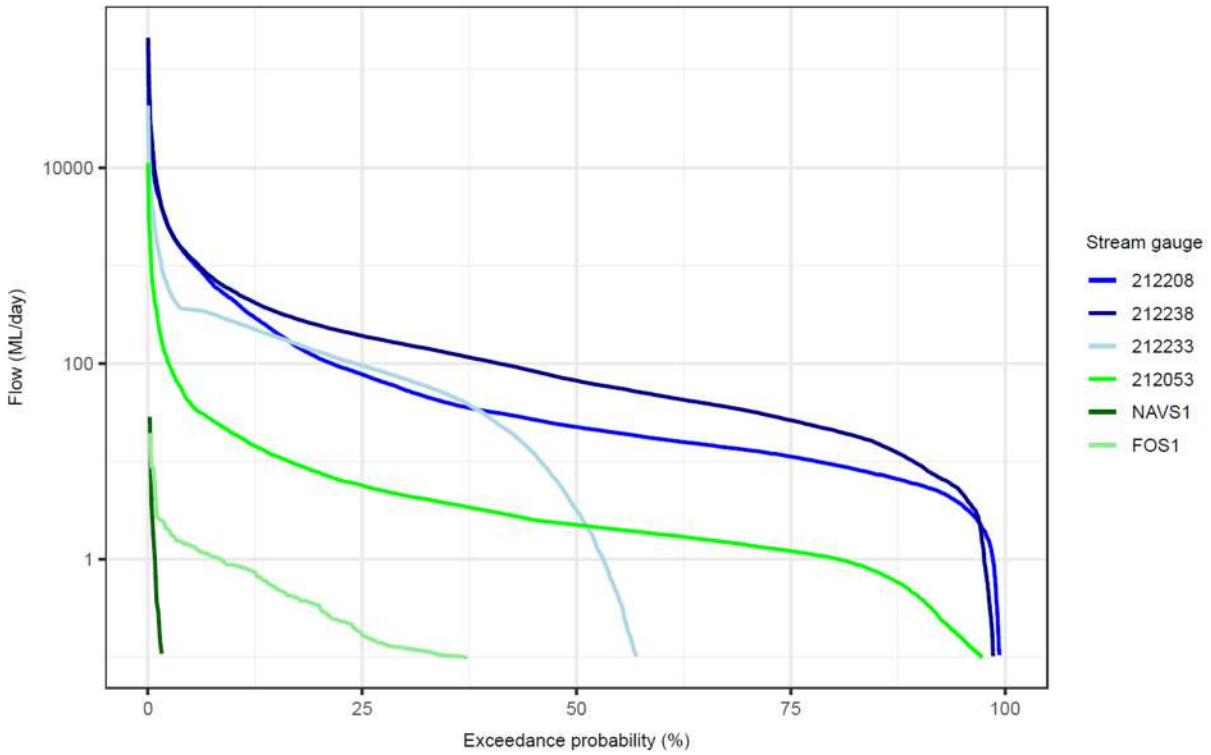


Figure 9 Flow duration curves for steams near Appin Mine

4.2 Pools

ICHPL has historically measured water levels in pools every month in accordance with Extraction Plan requirements for Area 7 and Area 9. Pool water levels are measured relative to a reference benchmark (nail) at the pool where possible. Where a benchmark cannot be installed at a site, semi-quantitative water level and flow observations are captured. Pool water levels are measured at the following locations within and near the study area:

- Nepean River – NR110, NR13 and NR0; and
- Racecourse Creek – RC1.

Water levels in pools on tributaries and the Nepean River near Appin Mine are shown as a time-series in Figure 10.

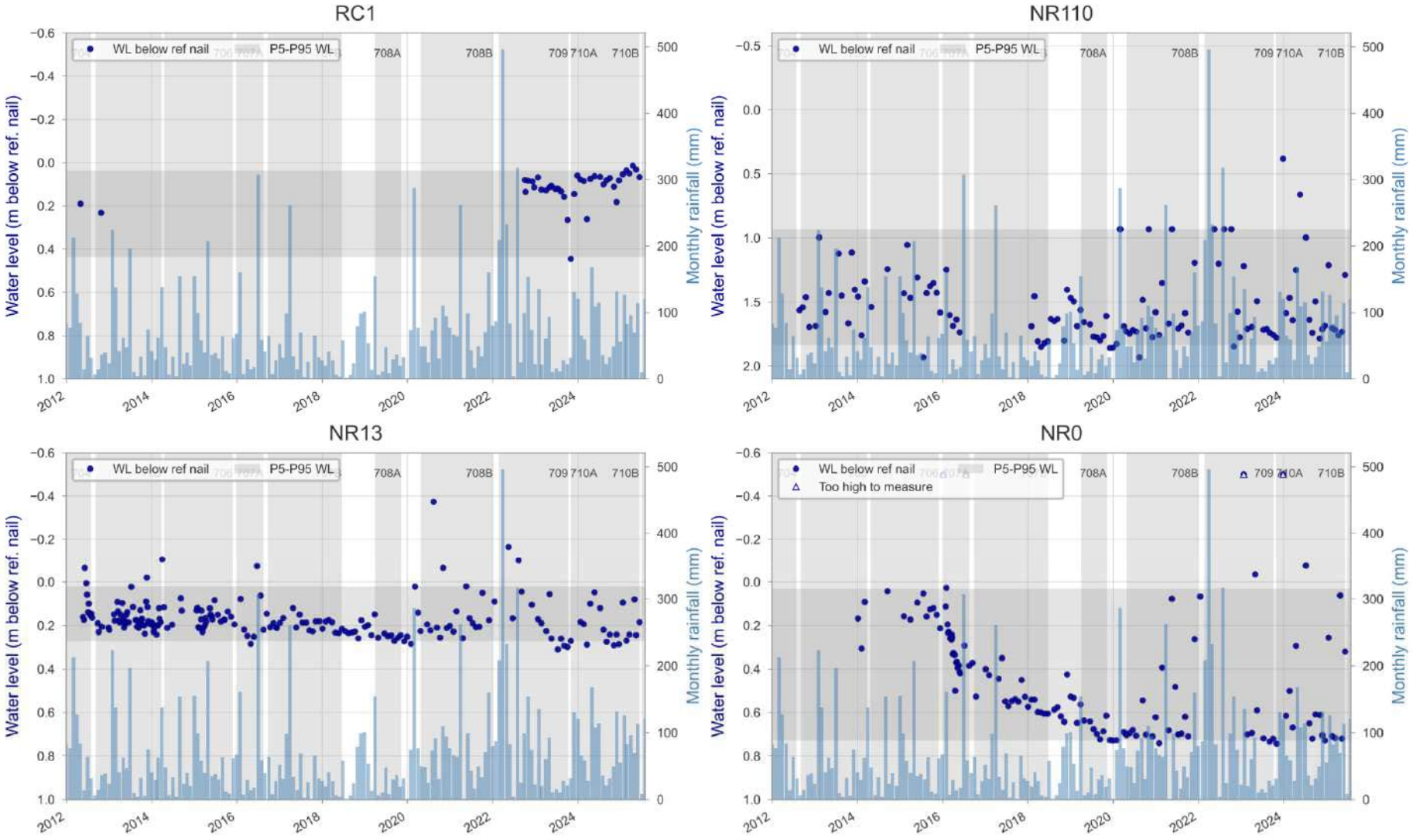


Figure 10 Pool water levels

4.3 Stream water quality

ICHPL has historically conducted surface water quality monitoring at numerous sites across the Appin Mine lease every month in accordance with the requirement of Extraction Plans for Area 7 and Area 9. Stream water quality monitoring sites are located within, upstream, and downstream of the study area (Figure 8) and include:

- Nepean River – NR110, NR0, NR4, NR12, NR13, NR50;
- Navigation Creek – NAV1, NAV2;
- Tributaries of Navigation Creek – NAVC20_S10, NAVC16_S10, NAV_S50;
- Foot Onslow Creek – FO1, FO2, FO3;
- Racecourse Creek – RC1; and
- Matahil Creek – MATC_S50.

Surface water quality monitoring has been carried out since before the start of mining in Area 7. Key parameters monitored include:

- Field parameters, including electrical conductivity (EC), pH, temperature, dissolved oxygen, oxidation reduction potential (ORP);
- General indicators, including laboratory EC, pH, dissolved oxygen, ORP, total suspended solids, dissolved organic carbon;
- Major ions, including calcium, magnesium, sodium, potassium, chloride, bicarbonate, sulfate, nitrate;
- Dissolved and total metals, including iron, manganese, aluminium, arsenic, barium, boron, copper, lead, lithium, manganese, nickel, selenium, strontium, zinc;
- Nutrients, including total nitrogen and total phosphorous;
- Hydrocarbon gases including methane, ethane, ethene, butane, butene, and phenols (only where targeted analysis of gas release is required).

Depth to water and observations of surface water flow and iron staining are also made at surface water quality monitoring sites. A summary of the surface water quality monitoring historically undertaken at Appin Mine is provided in Table 6.

Table 6 Historical surface water quality monitoring

Stream	Monitoring locations	Period of record	Frequency of monitoring	Parameters monitored*
Navigation Creek	NAV1	March 2010 to present	Monthly since Sept 2016	Field parameters, general indicators, major ions, metals, nutrients, depth to water, observations
	NAV2	Sept 2022 to present	Monthly	Observations
	NAVC20_S10	Feb 2025	Monthly	Observations

Stream	Monitoring locations	Period of record	Frequency of monitoring	Parameters monitored*
Tributaries of Navigation Creek	NAVC16_S10	March 2025	Monthly	Field parameters, general indicators, major ions, metals, nutrients, observations
	NAV_S50	March 2025	Monthly	Field parameters, observations
Foot Onslow Creek	FO1	March 2010 to present	Monthly since Sept 2016	Field parameters, general indicators, major ions, metals, nutrients, depth to water, observations*
	FO2	Sept 2022 to present	Monthly	Observations
	FO3	June 2023 to present	Monthly	Field parameters, observations
Racecourse Creek	RC1	Jan 2010 to present	Monthly since Sept 2022	Field parameters, general indicators, major ions, metals, nutrients, depth to water, observations
Matahil Creek	MATC_S50	September 2025 to present	Monthly	Field parameters, general indicators, major ions, metals, nutrients, observations
Nepean River	NR110	Jan 2012 to present	Monthly since Aug 2012	Field parameters, general indicators, major ions, metals, nutrients, depth to water, observations
	NR0	Jan 2010 to present	Monthly	Field parameters, general indicators, major ions, metals, nutrients, hydrocarbon gases, depth to water, observations
	NR4	Feb 2010 to present	Monthly	Field parameters, general indicators, major ions, metals, nutrients, depth to water, observations
	NR12	Jan 2012 to present	Monthly since June 2012	
	NR13	Feb 2012 to present	Monthly since June 2012	

Stream	Monitoring locations	Period of record	Frequency of monitoring	Parameters monitored*
	NR50	Jan 2010 to present	Monthly	

Note*: Field and laboratory parameters as listed in the Longwall 712-716 Water Management Plan

Surface water quality data for the study area are summarised in Table 7 and Table 8. Figure 11 shows the electrical conductivity (EC) and pH of surface water in streams and tributaries within and near the study area. Surface water in the Nepean River both upstream and downstream of the study area is fresh whereas surface water in Navigation Creek, Racecourse Creek, and Foot Onslow Creek is brackish and elevated compared to the default guidelines values for EC for upland river systems in southeast Australia (DCCEEW 2018). As shown in the piper plot in Figure 12, the salinity of surface waters in the tributaries is distinct from surface waters in the Nepean River and dominated by sodium and chloride ions related to the underlying Wianamatta Group shales, which are of marine origin. The quality of water in the Nepean River is predominantly influenced by releases from the large water storages upstream. High variation in salinity over time is observed for the tributaries, which is typical of ephemeral creeks with higher salinity generally associated with low flows.

The pH of surface waters in the region, including both the Nepean River and tributaries, is elevated compared to the default guidelines values for pH for upland river systems in southeast Australia (DCCEEW 2018). The pH reflects the land use in the catchment being predominately farmland with inputs of nitrogen and phosphorus related to livestock and fertiliser use (Table 8).

Concentrations of total iron and manganese in surface waters are elevated for the tributaries compared to the Nepean River (Figure 13). There were no observations of iron staining at any of the monitoring locations during the monitoring period.

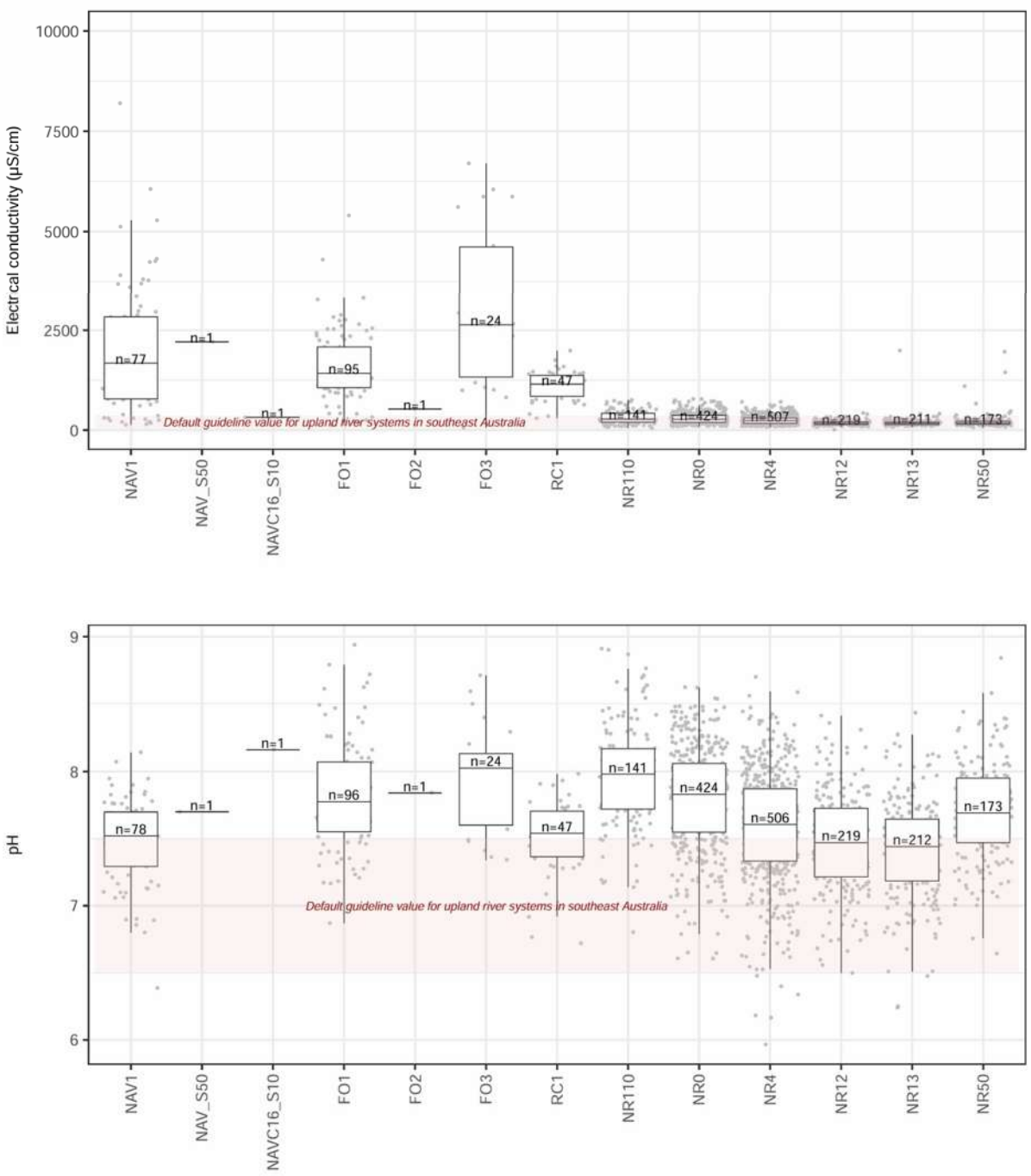


Figure 11 Electrical conductivity and pH of surface waters near Appin Mine

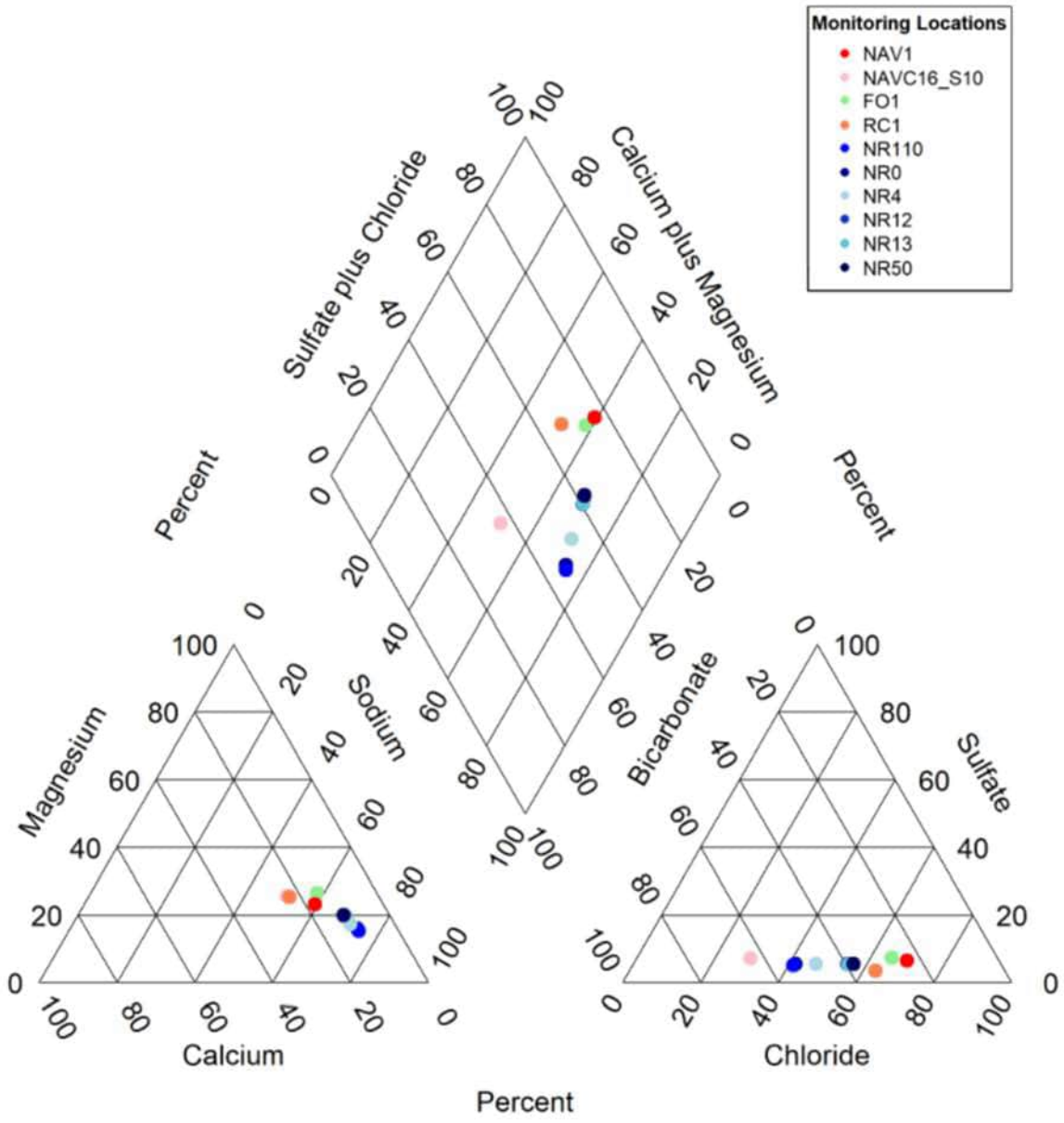


Figure 12 Piper plot for surface water sites near Appin Mine

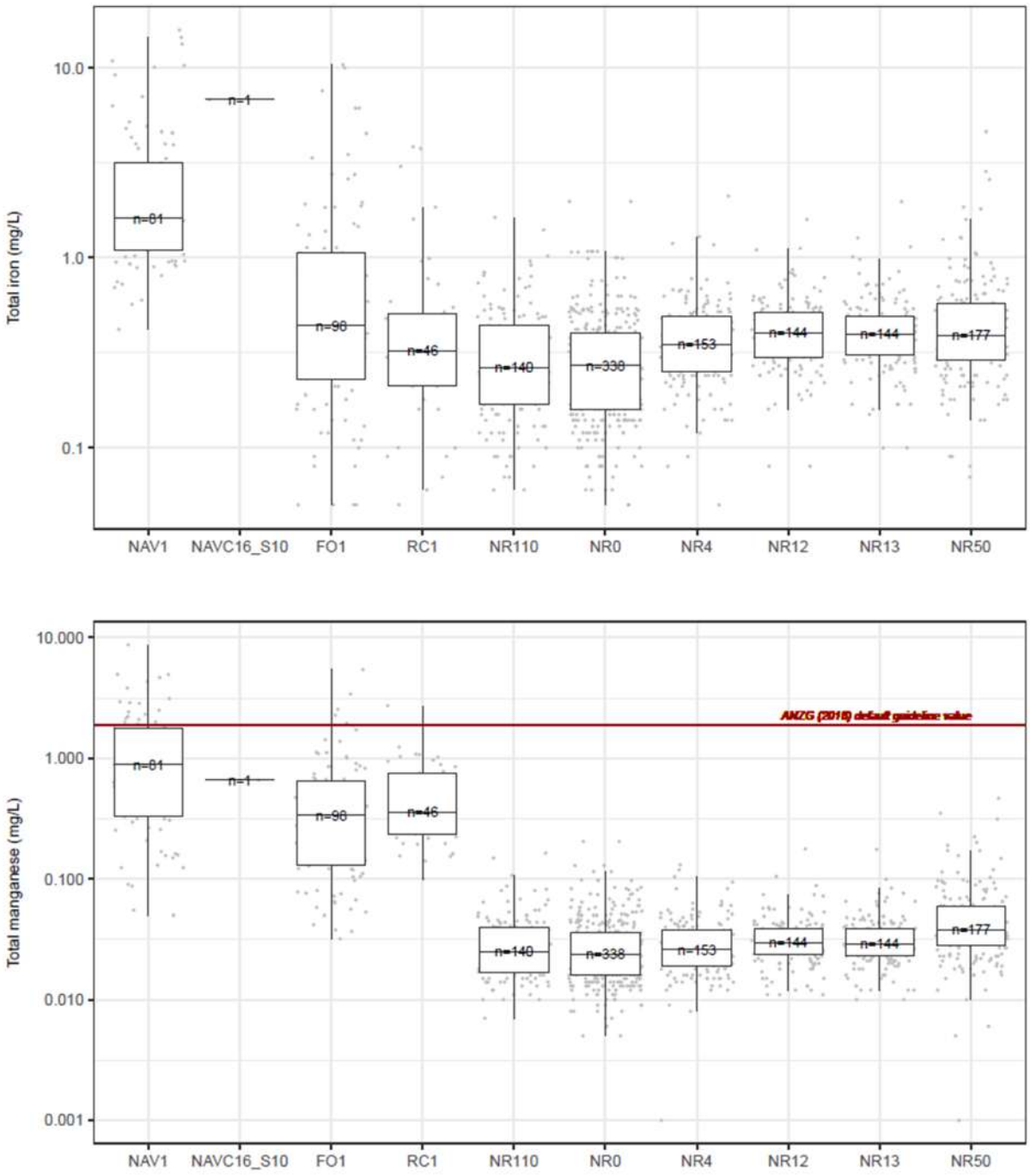


Figure 13 Total iron and total manganese in surface waters near Appin Mine

Table 7 Field water quality data (medians)

Stream		Navigation Creek and tributaries			Foot Onslow Creek			Racecourse Creek	Nepean River					
Parameter	Units	NAV1	NAV_S50	NAVC16_S10	FO1	FO2	FO3	RC1	NR0	NR110	NR12	NR13	NR4	NR50
Number of samples	n	77	1	1	95	1	24	47	424	141	219	211	507	173
Electrical Conductivity	µS/cm	1955	2210	315	1581	527	2979	1105	303	319	178	187	247	217
pH	pH units	7.5	7.7	8.16	7.8	7.8	8.0	7.5	7.8	8.0	7.5	7.4	7.6	7.7
Redox potential	mV	98	121	135	173	246	169	195	219	182	218	221	270	192
Dissolved Oxygen	%	43.7	29.1	76.5	76.5	84.7	80.7	46.0	90.9	91.2	87.5	86.4	88.4	86.6
Temperature	°C	16.3	22.1	22.51	17.5	16.7	17.8	16.0	17.8	17.9	18.4	18.7	17.4	18.4

* Results are laboratory data
na not available

Table 8 Laboratory analytical data (medians)

Stream		Navigation Creek and tributaries		Foot Onslow Creek	Racecourse Creek	Nepean River					
Parameter	Units	NAV1	NAVC16_S10	FO1	RC1	NR0	NR110	NR12	NR13	NR4	NR50
Electrical Conductivity	µS/cm	2099	329	1671	1107	311	318	179	179	235	195
Total Dissolved Solids	mg/L	1214	381	962	611	178	181	105	106	136	114
pH	pH units	7.8	7.7	8.0	7.7	7.7	7.6	7.2	7.2	7.5	7.3
Suspended Solids	mg/L	44.3	156	33.4	11.2	6.4	6.7	5.7	5.9	6.4	8.2
Dissolved Organic Carbon	mg/L	12.0	17.0	9.1	5.8	12.3	8.8	5.1	5.3	12.8	7.2
Aluminium	mg/L	0.074	0.560	0.118	0.062	0.050	0.055	0.061	0.061	0.062	0.060
Arsenic	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	0.076	na	0.150	0.166	0.175	0.020	0.020	0.021	0.020	0.094
Boron	mg/L	0.050	na	0.050	0.050	0.130	na	na	na	na	0.125
Copper	mg/L	<0.001	0.003	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Stream		Navigation Creek and tributaries		Foot Onslow Creek	Racecourse Creek	Nepean River					
Parameter	Units	NAV1	NAVC16_S10	FO1	RC1	NR0	NR110	NR12	NR13	NR4	NR50
Iron	mg/L	0.734	0.430	0.131	0.104	0.181	0.185	0.251	0.248	0.226	0.255
Lead	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lithium	mg/L	0.002	<0.001	0.011	<0.001	0.059	0.052	0.017	0.017	0.035	0.015
Manganese	mg/L	0.991	0.325	0.401	0.453	0.012	0.012	0.015	0.015	0.013	0.024
Nickel	mg/L	<0.001	0.003	<0.001	<0.001	0.004	0.004	0.002	0.002	0.003	0.002
Selenium	mg/L	<0.010	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium	mg/L	0.280	na	0.296	0.201	0.101	0.021	0.024	0.024	0.024	0.024
Zinc	mg/L	0.008	<0.005	0.008	0.012	0.008	0.008	0.006	0.006	0.008	0.007
Aluminium	mg/L	0.389	4.170	0.684	0.423	0.106	0.124	0.118	0.122	0.132	0.149
Iron	mg/L	2.920	6.800	1.097	0.606	0.320	0.346	0.436	0.435	0.399	0.519
Manganese	mg/L	1.309	0.656	0.553	0.542	0.031	0.032	0.033	0.033	0.032	0.054
Total Nitrogen as N	mg/L	1.660	na	0.800	na	0.430	0.388	0.443	0.370	0.390	0.397
Total Phosphorus as P	mg/L	0.278	0.370	0.069	0.043	0.030	0.031	0.023	0.019	0.019	0.027

na not available

5. Surface water impact assessment

5.1 Impact pathway diagram

An impact pathway diagram (IPD) (IESC, 2024) has been developed to show how the Project is predicted to adversely affect surface water resources (Figure 14). The diagram shows the potential pathways from the sources of impact to the receptors, and how these pathways interact. The sources of impact are discussed in more detail in Section 5.2. The potential pathways and predicted impacts on surface water resources and associated receptors are discussed in Section 5.3.

5.2 Sources of impact

An unavoidable consequence of longwall mining is subsidence, which can cause surface and sub-surface cracking, buckling, dilation and tilting. Subsidence has the potential to result in a range of impacts on surface water systems and related assets. To predict subsidence associated with the extraction of LW712 to LW716, Mine Subsidence Engineering Consultants (MSEC) used the Incremental Profile Method (IPM) calibrated to observations and measurements above previously mined longwalls at Appin (MSEC 2025). The main findings of the MSEC report are summarised below. More detail is provided in the MSEC (2025) subsidence assessment report.

Longwall mining involves dewatering which has the potential to cause depressurisation of groundwater systems, which can impact on connected surface water systems and related assets. Groundwater depressurisation associated with the extraction of LW712 to LW716 is assessed using a numerical groundwater model, which has been calibrated using groundwater monitoring observations at Appin Mine and surrounding areas (HGEO 2025). The main findings of the HGEO report are summarised below. More detail is provided in the HGEO (2025) groundwater assessment report.

5.2.1 Predicted subsidence

The maximum predicted total subsidence effects due to the mining of LW712 to LW716 are 1450 mm vertical subsidence, 6.5 mm/m tilt (i.e. 0.65 % or 1 in 154), 0.07 km^{-1} hogging curvature (i.e. minimum radius of curvature of 14 km) and 0.14 km^{-1} sagging curvature (i.e. minimum radius of curvature of 7 km). The maximum predicted strains (excluding valley-related effects) are 1.0 mm/m tensile and 1.6 mm/m compressive based on the 95 % confidence levels (MSEC 2025).

The predicted subsidence effects for the Nepean River due to the mining of LW712 to LW716 are less than 5 mm vertical subsidence, less than 5 mm upsidence, and less than 5 mm closure (MSEC 2025). While the river could experience very low levels of vertical subsidence or valley-related effects, it is not predicted to experience measurable tilts, curvatures or strains.

The maximum predicted values of total vertical subsidence, tilt and curvature for the third order sections of Navigation Creek, Navigation Creek tributaries, Apps Gully and Foot Onslow Creek are provided in Table 9. Maximum predicted subsidence for Navigation Creek, Navigation Creek tributaries, Apps Gully and Foot Onslow Creek ranges from 90 mm to 1,450 mm. The maximum predicted tilt for the creeks and tributaries within the study area is 6.5 mm/m (i.e. 0.65 % or 1 in 154).

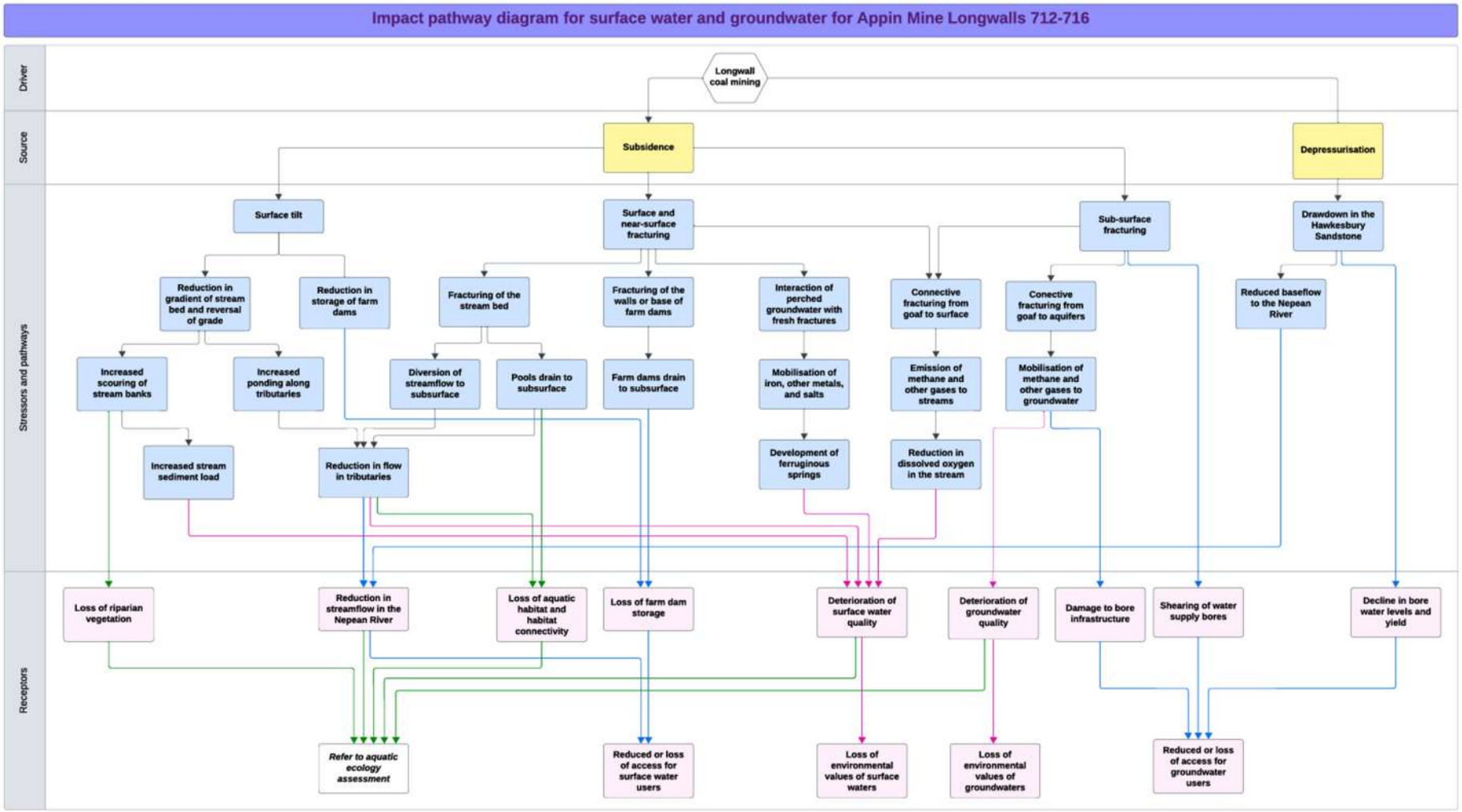


Figure 14 Impact pathway diagram

Fracturing is expected to occur where the creeks and tributaries are located directly above the mining area. Impacts can also occur outside the mining area, with minor and isolated fracturing occurring at distances up to approximately 400 m outside the longwalls, as previously observed at Appin Mine and elsewhere in the Southern Coalfield.

Table 9 Maximum predicted subsidence in watercourses in the study area

Stream	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Navigation Creek	1450	6.5	0.07	0.14
NAVC14.5	90	<0.5	<0.01	<0.01
NAVC16	1400	6.5	0.06	0.12
NAVC17	1300	5.0	0.06	0.11
NAVC20	1350	6.0	0.06	0.12
Apps Gully	1100	4.0	0.04	0.07
Foot Onslow Creek	100	1.0	<0.01	<0.01

5.2.2 Predicted groundwater depressurisation

The Groundwater Impact Assessment (HGEO 2025) provides estimates of groundwater depressurisation and drawdown at the water table using a numerical groundwater model.

Longwall mining and associated fracturing of strata above the longwall panel (goaf) will result in depressurisation at the mined coal seam and within the fracture network, with the drawdown effect diminishing with height above the mine and with distance from the mine footprint. Depressurisation will be greatest within the zone of connected fracturing which is estimated to extend approximately to the base of the Bald Hill Claystone based on the empirical model of Tammetta (2013).

There is expected to be negligible flow losses from streams and pools due to groundwater drawdown across the study area. Drawdown at the water table is expected to be minor, and creeks within the study area are ephemeral and largely disconnected from the regional groundwater system. The Nepean River is located more than 2 km from the LW712 to LW716 mining area, and well beyond the extent of drawdown within the upper Hawkesbury Sandstone. This is in line with groundwater monitoring observations which show minor drawdown within the upper Hawkesbury Sandstone within the mining footprint, with positive hydraulic gradients maintained towards the Nepean River and no detected loss of flow (HGEO 2023, 2025).

5.3 Impact assessment

Subsidence due to longwall mining can lead to surface tilt, surface fracturing, sub-surface fracturing, and connective fracturing from the goaf to the surface. Mine dewatering can cause depressurisation of overlying groundwater systems. These stressors have the potential to impact on surface water resources and associated receptors.

The Project does not involve any direct abstraction of surface water from watercourses. Streams in the study area are not intended to be relocated or reinstated, and no instream structures are proposed. The Project includes minor activities on the land surface consisting of monitoring activities, rehabilitation, and associated access tracks within the study area.

Monitoring of subsidence as well as surface water and groundwater systems has occurred throughout the mining of longwall panels 701 to 711 in Appin Area 7 in accordance with the Extraction Plan - Water Management Plan (South32 Illawarra Metallurgical Coal 2022) and therefore the impacts of longwall mining in this area are well understood. The potential impacts on surface water resources and associated receptors based on the predictions of subsidence and groundwater depressurisation are shown in Figure 14 and discussed below.

5.3.1 Stream flow and pools

5.3.1.1 Nepean River

The Nepean River is located more than 2 km from the study area. Subsidence predictions for the Nepean River indicate very low levels of vertical subsidence or valley-related effects, and no measurable tilts, curvatures or strains. It is unlikely, therefore, that the Nepean River would experience adverse physical impacts due to mining-induced movements from LW712 to LW716. No impacts to water levels in the Nepean River have been observed during mining in Appin Areas 7 and 9 (HGEO 2024).

5.3.1.2 Watercourses and pools in the study area

Surface tilt

Subsidence can lead to tilting of the land surface. Where mining-induced tilts oppose and are greater than the natural drainage line gradients that exist before mining, this can lead to a reduction in the gradient of the stream bed and reversal of the stream grade, and an increase in ponding. Other potential impacts of tilting on watercourses can include creation or alteration of riffle and pool sequences, changes in flooding, and bank instability and loss. Changes in stream flow and ponding have the potential to reduce flows and impact on aquatic habitat and downstream water users. Scouring and erosion of the stream banks has the potential to lead to loss of riparian vegetation and increased instream sediment load resulting in degradation of water quality (discussed in Section 5.3.2).

The maximum predicted tilt for the creeks and tributaries within the study area is 1 in 154. This is generally less than the average existing gradients of the creeks which vary between 1 in 200 and 1 in 50 for the third and fourth order sections, between 1 in 200 and 1 in 20 for the first and second order sections away from Razorback Range, and between 1 in 10 and 1 in 3 for the steeper first and second order sections of the streams along Razorback Range (MSEC 2025). There are small reductions in the existing stream grades predicted along Navigation Creek and some of its tributaries upstream of the main gates of the proposed longwalls. There are possible small reversals in stream grade along the flatter sections of the streams or in the locations of the existing farm dams (MSEC 2025).

So, while it is unlikely that there would be large-scale adverse changes in the levels of ponding or scouring of the banks along the creeks and tributaries within the study area, it is possible that localised increased ponding could develop along the tributaries due to mining-induced tilt. Localised ponding is most likely to develop in the east of the study area where the existing grades are small, and upstream of the chain pillars and the edges of the mining area (MSEC 2025).

The potential impacts of increased ponding and scouring of the drainage lines, therefore, are expected to be minor and localised. A significant loss of surface water yield from the catchment due to ponding along tributaries is not predicted, nor is a significant degradation of water quality due to scouring and erosion of stream banks. Impacts resulting from changes in surface water flows due to mining-induced tilt are expected to be small in comparison with those which occur during natural flooding conditions (MSEC 2025).

Surface fracturing

Subsidence that occurs under watercourses can cause fracturing of the streambed and banks, movements of joint and bedding plates in the streambed, uplift and buckling of strata in the streambed, and dilation and the development of bed separation within the top 10 m to 20 m of the bedrock. Fracturing in bedrock has been observed due to previous longwall mining in the Southern Coalfield where the tensile strains have been greater than 0.5 mm/m or where the compressive strains have been greater than 2 mm/m (MSEC 2025). These physical impacts can cause diversion of surface water flow to the dilated strata below and drainage of pools. These changes have the potential to reduce downstream flows and the continuity of flow between pools during low flows.

In the Southern Coalfield, substantial surface cracking has occurred in watercourses within the Upper Nepean, Avon, Cordeaux, Cataract, Bargo, Georges and Woronora catchments, including Flying Fox Creek, Wongawilli Creek, Native Dog Creek and Waratah Rivulet. The usual sequence of events has been subsidence-induced cracking within the streambed, followed by significant dewatering of permanent pools and in some cases complete absence of surface flow. The NSW Threatened Species Scientific Committee (2005) noted that if the water body is in an area where the coal seam is less than approximately 100 to 120 m below the surface, longwall mining can cause the water body to lose flow permanently. However, if the coal seam is deeper than approximately 150 m, the water loss may be temporary unless the area is affected by severe geological disturbances such as strong unless the area is affected by severe geological disturbances such as strong faulting. In most cases, surface waters lost to the sub-surface re-emerge downstream. The ability of the water body to recover is dependent on the width of the crack, the surface gradient, the substrate composition and the presence of organic matter. An already-reduced flow rate due to drought conditions or an upstream dam or weir will increase the impact of water loss through cracking. Within the study area, the depth to the coal seam is between 550 and 800 m and there are no significant faults. Any water loss would therefore be expected to be temporary. Additionally, the bed of most streams in the study area comprises alluvial and silty materials rather than bedrock, with bedrock substrates confined to the upper reaches.

The creeks and tributaries within the study area, including the third and fourth order sections, are predicted to experience a maximum conventional tensile strain of 1.0 mm/m and a maximum predicted compressive strain due to valley-related effects of 7 mm/m based on the 95% confidence level. Fracturing could therefore develop along the creeks and tributaries that are located directly above the mining area. Impacts may also occur outside the mining area, with minor and isolated fracturing occurring at distances up to approximately 400 m outside the longwalls, as previously observed at Appin Mine and elsewhere in the Southern Coalfield (MSEC 2025).

Within Appin Area 7 (LW701 to LW710A), 19.4 km of streams have been directly mined beneath, including the upper reaches of Foot Onslow Creek. Measured movements above these panels have recorded 1450 mm of subsidence, 9.0 mm/m tilt, 3.0 mm/m tensile strain and 6.0 mm/m compressive strain, however, there has been no reported fracturing which has resulted in surface water flow diversions (MSEC 2025). Nevertheless, mining beneath tributaries in other parts of the Southern

Coalfield has resulted in fracturing of stream beds, and there is potential that this may occur within the study area.

Fracturing of the stream bed may lead to a diversion of surface water flow to the dilated strata below and a reduction in stream flow. The creeks and tributaries within the study area are ephemeral and, therefore, surface water flows only occur during and for short periods after rain events. During heavy rainfall, losses to fractures are expected to be limited. Losses to fractures may be more significant during low flows. Although fracturing along streams in the study area may occur, it is unlikely that there would be a significant loss of surface water yield from the catchment.

There are a limited number of standing pools along tributaries within the study area. While there is potential for surface fracturing to result in loss of water in some pools, previous experience at Appin suggests that losses are unlikely. Any such reductions in water level has the potential to result in loss of aquatic habitat and a reduction in the continuity of flow between pools during low flows. The impacts of these potential in aquatic habitat and habitat connectivity are discussed in the Stantec Australia (2025) aquatic ecology assessment.

5.3.2 Water quality

5.3.2.1 Scour and erosion

Subsidence can lead to tilting of the land surface and changes in stream grade. This can result in bank instability and loss, increased rates of erosion or scour, and a subsequent increase in sedimentation and deterioration of water quality in the stream. The water quality impacts may include an increase in turbidity, a reduction in dissolved oxygen (DO), and an increase in salinity, iron oxides, and manganese.

As discussed in Section 5.2.1, small reductions in existing stream grades and small reversals in stream grade may occur along Navigation Creek and its tributaries, particularly along the flatter sections of the streams or where instream farm dams are located (MSEC 2025). Minor scouring and erosion of stream banks may occur due to changes in stream grade, however the impacts are expected to be short-term, minor, and localised and are not expected to result in any significant impacts to water quality.

5.3.2.2 Saline ferruginous springs

Subsidence can result in the development of saline ferruginous springs along stream banks. These springs have the potential to increase concentrations of iron, manganese, and salts in the stream, causing degradation of water quality and localised precipitation of iron oxyhydroxides (iron staining).

Saline ferruginous springs can develop where streams are underlain by Wianamatta Group shales, which are marine sediments with elevated concentrations of salts, iron, and manganese. Saline ferruginous springs induced by longwall mining have been observed in the Southern Coalfield in sub-catchments of the Cataract and George's rivers related to mining of Appin Longwall 21 B in 1996 and Westcliff Longwall 5A2 (Ecoengineers 2008).

Mining of previous longwalls within Appin Area 7 and 9 has not resulted in any observed ferruginous springs in the walls of the Nepean River or tributaries (Ecoengineers 2014; Geoterra 2016; HGEO 2024) and it is considered unlikely that springs will develop due to the proposed mining. Should a spring develop, it is anticipated that only localised changes in water quality would occur.

5.3.2.3 Gas emissions

Longwall mining can result in fracturing of the strata above the extracted coal seam and/or relative movement of strata along pre-existing joint planes. This can lead to the liberation of methane and other gases from sub-surface strata to overlying streams. Gas emissions within waterways can cause a small reduction in dissolved oxygen (DO) due to microbiological consumption of dissolved methane by natural aerobic bacteria within the water column in close proximity to the gas release site. This degradation of water quality has the potential to impact aquatic biota and cause dieback of aquatic and riparian vegetation. Such dieback is rare and has only occurred in one location in the Southern Coalfield (Stantec Australia 2025).

Substantial studies have been undertaken into the properties of gas within rock strata. Gas is found in most rocks and can exist in three different states – free gas, dissolved gas in water, and adsorbed gas. Analyses of gas compositions indicate that the near-surface strata are the direct and major source of gas rather than the extracted coal resource. The most likely source of gas is the Hawkesbury Sandstone. As rocks in the near-surface strata experience compression in response to valley closure movements, free or adsorbed gas can be released, typically exiting the stream bed through new or existing fractures or joints (Ecoengineers 2008).

Gas emissions have typically occurred within deep river valleys, although some gas emissions have also been observed in creeks (Ecoengineers 2008). Approximately fifty gas release zones have been observed along the Nepean River during the mining of longwalls in Areas 7 and 9 (Ecoengineers 2014; Geoterra 2016). Reactivation of existing gas release zones or the development of new gas release zones along the Nepean River could occur due to the mining of the Longwalls 712 to 716 (MSEC 2025). Gas releases may result in localised minor changes in water quality, including reductions in DO, however considering the typically large flows in the Nepean River (310 ML/day on average), these localised changes are not expected to result in significant impacts on aquatic biota. Previous monitoring of water quality in the Nepean River during mining has not observed a reduction in dissolved oxygen related to gas emissions (Ecoengineers 2014; Geoterra 2016; HGEO 2024). No impacts on aquatic biota have been observed in the Nepean River associated with gas releases observed during extraction of previous Appin Area 7 and 9 longwalls (Stantec Australia 2025).

Gas emissions have also been observed in creeks and tributaries during mining in Area 5, including in Ousedale Creek and Elladale Creek (Ecoengineers 2014). Due to the ephemeral nature of the creeks and tributaries in the study area, any gas emissions to waterways are unlikely to be significant other than where standing pools or instream storages occur.

5.3.3 Farm dams

5.3.3.1 Surface tilt

Mining-induced tilts can affect the water levels around the perimeters of farm dams, with the freeboard (the vertical distance between the crest of the embankment and the reservoir water surface) increasing on one side and decreasing on the other. Tilt can reduce the storage capacity of farm dams by causing them to overflow or can affect the stability of the dam walls.

The maximum predicted tilt for farm dams in the study area is 0.65 % and predicted changes in freeboard are small, varying from less than 25 mm to 275 mm (MSEC 2025). It is therefore unlikely that farm dams in the study area would experience adverse impacts on the storage capacities due to these small changes in freeboard.

5.3.3.2 Surface fracturing

The farm dams located directly above the proposed mining area could experience cracking in the bases or their walls due to the mining-induced curvatures and strains. This has the potential to result in loss of stored water to the dilated strata below and a loss of water supply for the landholder.

There is extensive experience of mining directly beneath farm dams in the Southern Coalfield, which indicates that the incidence of impacts on these features is low. Farm dams are commonly constructed with cohesive materials in the bases and walls which can absorb the conventional subsidence movements typically experienced in the Southern Coalfield without the development of substantial cracking. Non-conventional movements can result in localised cracking and deformations at the surface and, where coincident with farm dams, could result in impacts (MSEC 2025).

ICHPL has mined directly beneath more than 300 farm dams in Appin Areas 3, 4, 7 and 9 and West Cliff Area 5. Loss of water was reported for only a small number of dams. Similarly, Tahmoor Mine has mined Longwalls 22 to 32 and Longwalls W1 to W4 beneath approximately 112 dams with only one farm dam known to have experienced damage (MSEC 2025).

6. Surface water monitoring program

Surface water monitoring for the Project has already commenced to establish a baseline prior to the commencement of mining. Monitoring will continue throughout the mining of LW712 to LW716 and following the development of incremental subsidence. The surface water monitoring network for the Project is shown on Figure 15.

A Water Management Plan (WMP) will be prepared in consultation with Biodiversity Conservation and Science Directorate, WaterNSW, and Department of Planning, Industry and Environment (DPIE) Water in accordance with Condition 5(h) of Schedule 3 of the BSO Approval. The Water Management Plan will include details of the surface water and groundwater monitoring recommended in this assessment to identify at risk surface water and groundwater features and characteristics associated with longwall mining for the Project and to manage the potential impacts and/or environmental consequences of mining on watercourses and aquifers.

Monitoring and reporting of subsidence is also undertaken in accordance with an approved Subsidence Management Plan (SMP).

6.1 Surface water flow and pool water level monitoring

The risk of significant loss of stream flow and water holding capacity of pools due to creek bed fracturing is considered low. Nevertheless, there is potential that ephemeral streams in the study area could experience fracturing of the stream bed resulting in loss of stream flow during low flows and a reduction or loss of water holding capacity of pools. This potential impact will be monitored by:

- Routine inspection of creek lines for signs of fracturing;
- Continuous monitoring of stream flow;
- Monitoring water levels in pools every month; and
- Observations of stream flow and water levels in pools every month.

Post-mining monitoring of sites in the Nepean River and Foot Onslow Creek will continue for a period of two years after the completion of Longwall 711 in accordance with the Extraction Plan for Longwalls 709 to 711 and 905.

Monitoring of flows will be undertaken at two sites (NAVS1 and NAVS2) in Navigation Creek within the study area for Longwalls 712 to 716.

Observations of flow will additionally be made at all monitoring locations within and near the study area, including on Navigation Creek (NAV_S50, Nav16_S10, NAV20_S10), Racecourse Creek (RC1), and Matahil Creek (MATC_S50) (Table 10). Due to the ephemeral nature of creeks within the study area, continuous flow monitoring is problematic. No suitable pools for automated monitoring have been identified on creeks within or near the study area. Monitoring of water levels in pools relative to a reference benchmark will be undertaken at observational sites where it is possible to do so.

The potential impact of creek bed fracturing on stream flows will also be monitored via regular inspection for the presence of fracturing in the stream bed and observation of water levels within pools.

A Trigger Action Response Plan (TARP) has been developed to assess the need for management and remediation based on the monitoring results (refer to Section 7). In the unlikely event of a significant impact to stream pools within ephemeral watercourses, remediation would be conducted where remediation is technically feasible and necessary.

6.2 Surface water quality monitoring

Baseline surface water quality monitoring for the Project has already commenced to establish a baseline prior to the commencement of mining and is discussed in Section 4.3. Monitoring is occurring in creeks within and near the study area including in Navigation Creek, tributaries of Navigation Creek, Racecourse Creek, and Matahil Creek. Surface water quality monitoring will continue throughout the mining of LW712 to LW716 and following the development of incremental subsidence in accordance with the program in Table 10.

An established control site at Racecourse Creek (a tributary of the Nepean River) is utilised to allow for a more quantitative understanding of any effects in the Nepean River which may be related to creeks outside the mining area, and provide a means of ensuring that the TARPs for the established impact sites are reasonable and not triggered by upstream effects unrelated to the mining of the proposed longwalls.

6.3 Observational monitoring of watercourse condition

Implementation of observational monitoring of watercourse condition is recommended prior, during, and following mining of the proposed longwalls. Assessment should include:

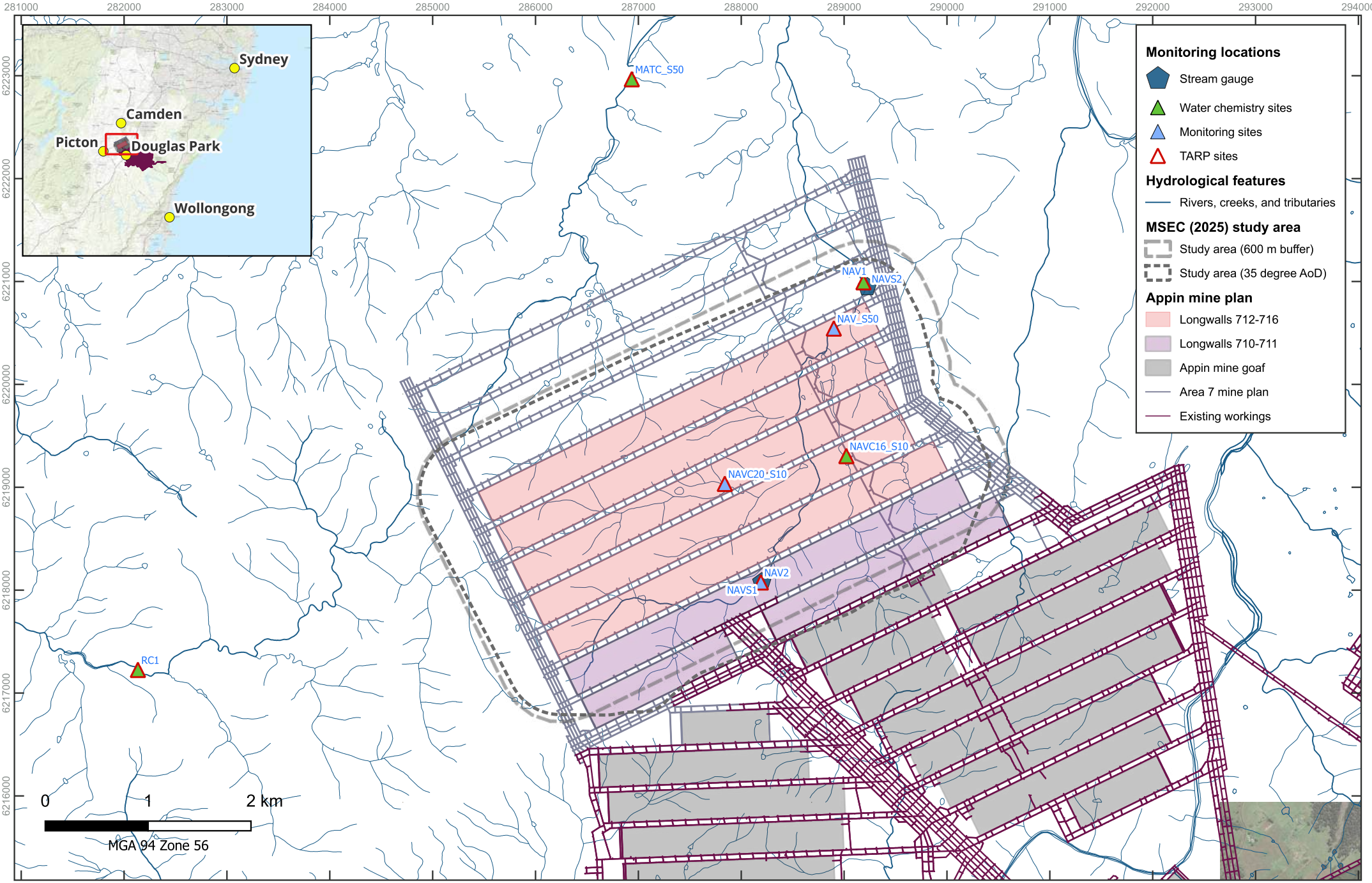
- Erosion/sedimentation compared with baseline;
- Signs of impacts (e.g. cracking, vegetation changes, increased erosion, changes in water colour etc);
- Impacts determined from comparing photo points taken prior to, during and post mining;
- Iron or salinity staining (e.g. orange or white staining in water or on banks/seeps);
- Water cloudiness; and
- Evidence of springs.

Observational monitoring will be undertaken along Navigation Creek, tributaries of Navigation Creek, and Matahil Creek within the study area annually (where access permits), with photo points at the surface water monitoring locations in Table 10.

A reference site will be maintained in a similar ephemeral creek to assist in distinguishing natural and mining induced changes. Monitoring has previously been undertaken at a historical monitoring site within Racecourse Creek (RC1) and will be continued for this purpose noting that a short length of Apps Gully upstream is located within the study area.

Table 10 Surface water monitoring program for the Project

Stream	Monitoring locations	Commencement of monitoring	Frequency of monitoring	Parameters monitored
Navigation Creek	NAV1	March 2010	Monthly	Stream flow gauging and water level (at upstream site NAVS2), field parameters, general indicators, major ions, metals, nutrients observations
	NAV2	Sept 2022	Monthly	Stream flow gauging and water level (NAVS1), observations
Tributaries of Navigation Creek	NAVC20_S10	Feb 2025	Monthly	Observations
	NAVC16_S10	March 2025	Monthly	Field parameters, general indicators, major ions, metals, nutrients, observations
	NAV_S50	March 2025	Monthly	Observations
Matahil Creek	MATC_S50	September 2025	Monthly	Field parameters, general indicators, major ions, metals, nutrients, observations
Racecourse Creek	RC1	Jan 2010	Monthly	Field parameters, general indicators, major ions, metals, nutrients, depth to water, observations



Appin Mine Extraction Plan Surface Water Assessment

Surface water monitoring network for the Project

Figure 15

file: Appin_SW.qgz

7. Management and mitigation strategies

7.1 Streams

BSO Approval Condition 1, Schedule 3 stipulates that there should be negligible diversion of surface water flows or changes in the natural drainage behaviour of pools in the Nepean River. In relation to other watercourses, there should be no greater subsidence impact or environmental consequences than predicted in the Environmental Assessment and PPR. The term “negligible” is defined within the Project Approval as “small and unimportant, such as not to be worth considering”.

Impacts to the Nepean River, Navigation Creek, Foot Onslow Creek, Apps Gully, Matahil Creek, and other tributaries due to the Project are predicted to be negligible or unlikely, and therefore it is unlikely that mitigation measures will be required. Nevertheless, a Trigger Action Response Plan should be developed as part of the WMP to monitor and manage potential impacts to surface water systems within the Longwall 712 to 716 study area.

The TARP should specify trigger levels for flow and water quality and the management actions to be taken. The triggers should be based on flow and water quality data collected before mining commences (baseline period).

It is recommended that the TARP for flow is developed using a similar approach to Dendrobium Method B: This method compares the change in the percentage of cease to flow days over a period with the change at reference sites. A three-tiered approach to setting trigger levels could be used, with a Level 1 trigger of ≥+5%, a Level 2 trigger of ≥+10%, and a Level 3 trigger of ≥+20% change in cease to flow days between the pre- and post-mining period at the gauge site beyond that observed at the reference site. This method is considered appropriate for the Project as the creeks in the study area are ephemeral and flow is highly modified. At sites where no flow data are available, observations of flow/no-flow could be compared. RC1 could be used as a reference site given that its catchment is mostly outside the mining area. WaterNSW operates a flow gauge on Stonequarry Creek at Picton (WaterNSW site 212053) which could be used as an additional flow reference site. However, it is noted that Stonequarry Creek flows most of the time and therefore differs in its flow characteristics to the ephemeral watercourses within the study area.

The TARP for water chemistry could be developed using the approach in the WMP for LW710 to LW711. This method involves comparing water quality data with data for baseline and reference sites. TARP trigger thresholds are based on deviations from the baseline mean (mean + 3 sd for EC and mean – 3 sd for pH and dissolved oxygen) and the duration of the threshold exceedance. TARP thresholds for NAV1are presented in Appendix 1. TARP thresholds for NAV2 and NAVC16_S10 should be calculated prior to mining within 400 m of the monitoring site to maximise the period of baseline. The Project includes associated minor activities on the land surface consisting of monitoring activities, rehabilitation and associated access tracks within the study area. These access tracks and rehabilitation areas will be managed with best practice runoff controls which comply with the ‘Blue Book’ (Managing Urban Stormwater: Soils and Construction Vol.1, 4th edition and Vol.2E Mines and Quarries) to minimise the risk of adverse impacts to water quality of downstream areas. Water quality monitoring in downstream waterways will also be undertaken. With appropriate controls in place, it is considered that these surface activities will have minimal impacts to surface water quality.

7.2 Farm dams

Impacts to farm dams due to the Project are considered unlikely based on mining under more than 300 farm dams in the region (with loss of water reported for only a small number of dams) and predicted subsidence impacts (MSEC 2025). However, where subsidence results in loss of water from dams due to cracking and/or tilt, these impacts will be managed and compensated in accordance with the *Coal Mine Subsidence Compensation Act 2017* and/or an alternate water supply would be provided as required by Condition 14 of the BSO Project Approval (Compensatory Water Supply) in consultation with the landowner.

8. REFERENCES

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DCCEEW (2024) Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2023, Background and changes

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Moffitt RS (1999) Southern Coalfield Regional Geology 1:100k, 1st edition

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SLR (2021) Appin Mine Extraction Plan surface water assessment, Longwalls 709 to 711 and 905

South32 Illawarra Metallurgical Coal (2022) Longwalls 709 to 711 and 905 Water Management Plan

Stantec Australia (2025) Appin Longwalls 712 to 716 Extraction Plan – Aquatic Ecology Assessment

WMA Water (2021a) Stonequarry Creek (Picton) Flood Study Update Vol. 1 and 2

WMA Water (2021b) Stonequarry Creek (Picton) Floodplain Risk Management Study and Plan

APPENDIX 1 – Water chemistry TARP trigger levels

TARP thresholds for Longwalls 712-716

Location	NAV1	NAV2	NAVC16_S10
Watercourse	Navigation	Navigation	Navigation
EC [mean] (µS/cm)	2565	TBC#	TBC#
EC [mean+1SD]	4508		
EC [mean+2SD]	6451		
pH [mean]	7.6		
pH [mean-1SD]	7.2		
pH [mean-2SD]	6.8		
DO [mean] (%)	27.8		
DO [mean-1SD]	6.4		
DO [mean-2SD]	0**		
TDS [mean] (mg/L)	1470		
TDS [mean+1SD]	2594		
TDS [mean+2SD]	3718		
Fe_tot [mean] (mg/L)	5.1		
Fe_tot [mean+1SD]	11.1		
Fe_tot [mean+2SD]	17.1		
Mn_tot [mean] (mg/L)	1.8		
Mn_tot [mean+1SD]	2.8		
Mn_tot [mean+2SD]	3.8		

TARP thresholds to be calculated prior to mining within 400 m to maximise baseline

** Assigned zero value where mean - 2SD is < 0.