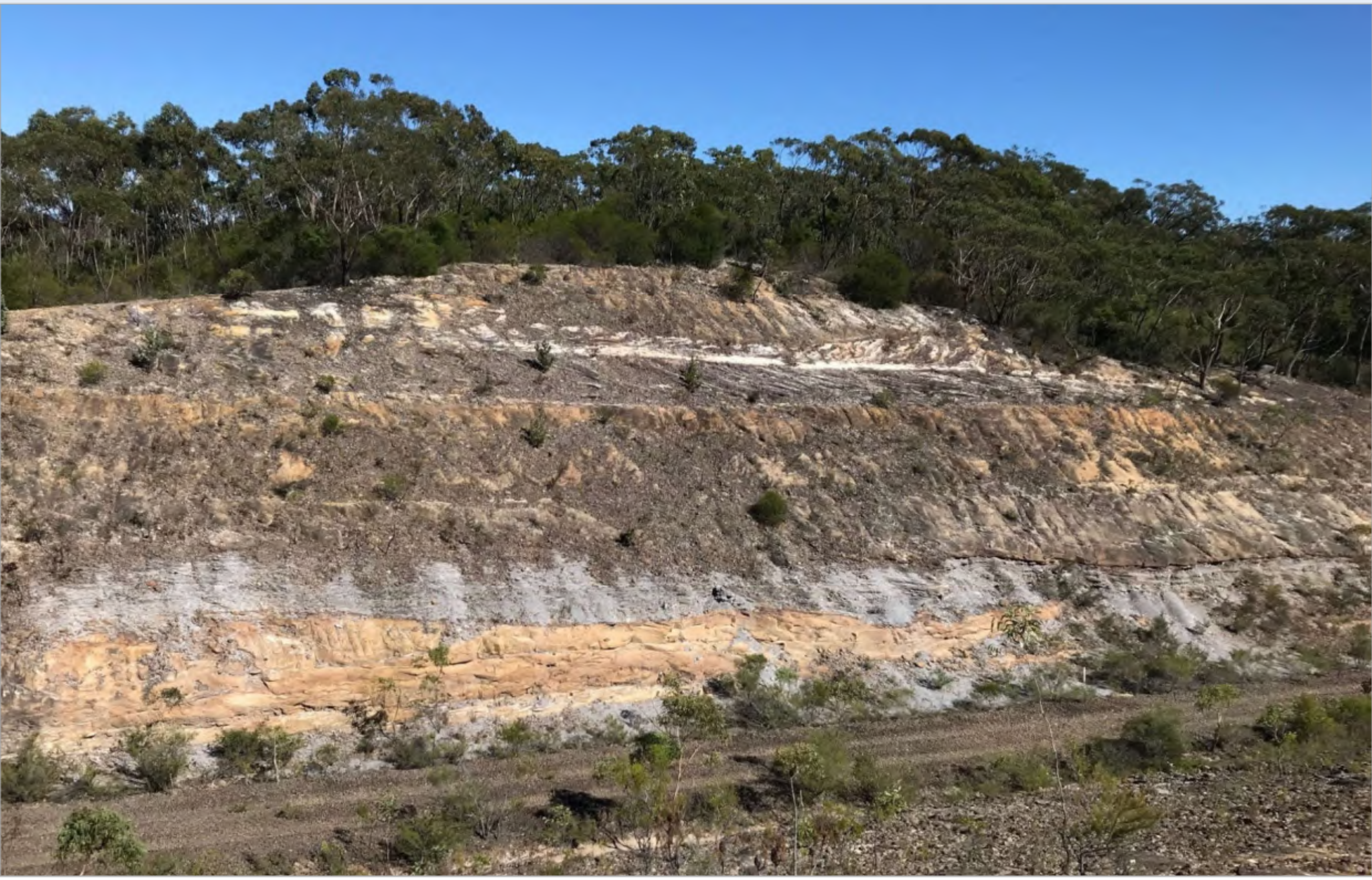
South32 - Illawarra Metallurgical Coal

DENDROBIUM MINE

End of Panel Groundwater Assessment for Longwall 19 (Area 3A)



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EXECUTIVE SUMMARY

This report provides an assessment of the hydrogeological effects of Longwall 19 extraction in Area 3A at Dendrobium Mine, as required under the conditions of mining approval. Extraction of Longwall 19 commenced on 20/6/2022 and was completed on 29/3/2023. The longwall is located to the south of Longwall 8 which was completed in December 2012. Longwall 19 has a total length of 1661 m and a width of 305 m including first workings with a maximum cutting height of 3.9 m. The depth of cover ranges between 287 m and 369 m.

The mean total mine inflow during Longwall 19 extraction was 12.0 ML/day which represents a 32% increase compared with the previous longwall. The increase is primarily due to the very high rainfall during the longwall extraction period and the previous two years. The net mine water balance is dominated by pumping from Area 3B (72 % of total), with Area 3A representing only 6.5 % of inflows. No anomalous inflow due to intersecting water-bearing structures such as faults or dykes was reported during the extraction of Longwall 19. Analysis of tritium and radiocarbon in mine inflow indicates that modern water contributes between 5 and 10% of mine inflow.

Groundwater salinity (as indicated by Electrical Conductivity – EC) shows a general increase with depth below the surface. A declining trend in EC is reported in two monitoring bores (S2314_30m and S2001_63m). Trends identified in previous EOP reports have resolved or proved spurious as more data has been collected. Therefore, it is recommended that S2314_30m and S2001_63m be resampled in late 2023 and reviewed in the next EOP report.

Mining of Longwall 19 resulted in continued depressurisation of the target coal seam and overlying strata in general agreement with numerical model predictions. Importantly, for piezometers installed in the barrier zone between Lake Avon and Area 3B, observed groundwater drawdown is generally less than predicted. As expected, the greatest depressurisation is within the Wongawilli Coal Seam and deeper strata and decreases with height above the seam.

Piezometers installed after longwall extraction indicate significant depressurisation throughout all strata and throughout the Hawkesbury Sandstone (HBSS) in most holes. Holes drilled above extracted longwalls provide evidence for groundwater perching and recovery in the years following mining, particularly over the last two years of higher-than-average rainfall. Drawdown in the HBSS reduces with distance and is typically negligible at distances greater than 1.2 km from the goaf footprint.

Piezometers installed along the barrier zone between Lake Avon and extracted longwalls in Area 3B show declines in piezometric heads to levels below contemporaneous water levels in Lake Avon and changed in strata permeability due to mine subsidence. Seepage losses from Lake Avon are estimated to be in the range 0.09 to 0.89 ML/day as at the end of Longwall 18 and the maximum southern extent of mining in Area 3B.

1. INTRODUCTION

Illawarra Metallurgical Coal (IMC) operates the Dendrobium underground coal mine, located approximately 12 km west of Wollongong (NSW) in the Southern Coalfield (Figure 1). IMC is required under the conditions of mining approval to submit regular reviews of the local hydrological data, including groundwater level and quality, and potential seepage losses from stored water.

IMC operates an extensive network of groundwater monitoring sensors (piezometers), groundwater sampling pumps and down-hole geotechnical instruments. Groundwater data from more than 950 active piezometers at 181 monitoring bores is updated monthly via telemetry or collected by IMC field teams.

This End of Panel (EoP) assessment reviews groundwater level and quality monitoring data up to one month after the completion of Longwall 19 (cumulative). Data are assessed against baseline and impact criteria defined in the Trigger Action Response Plan (TARP) which forms part of the Subsidence Management Plan for Area 3A (South32, 2020a) and the Groundwater management plans contained therein.

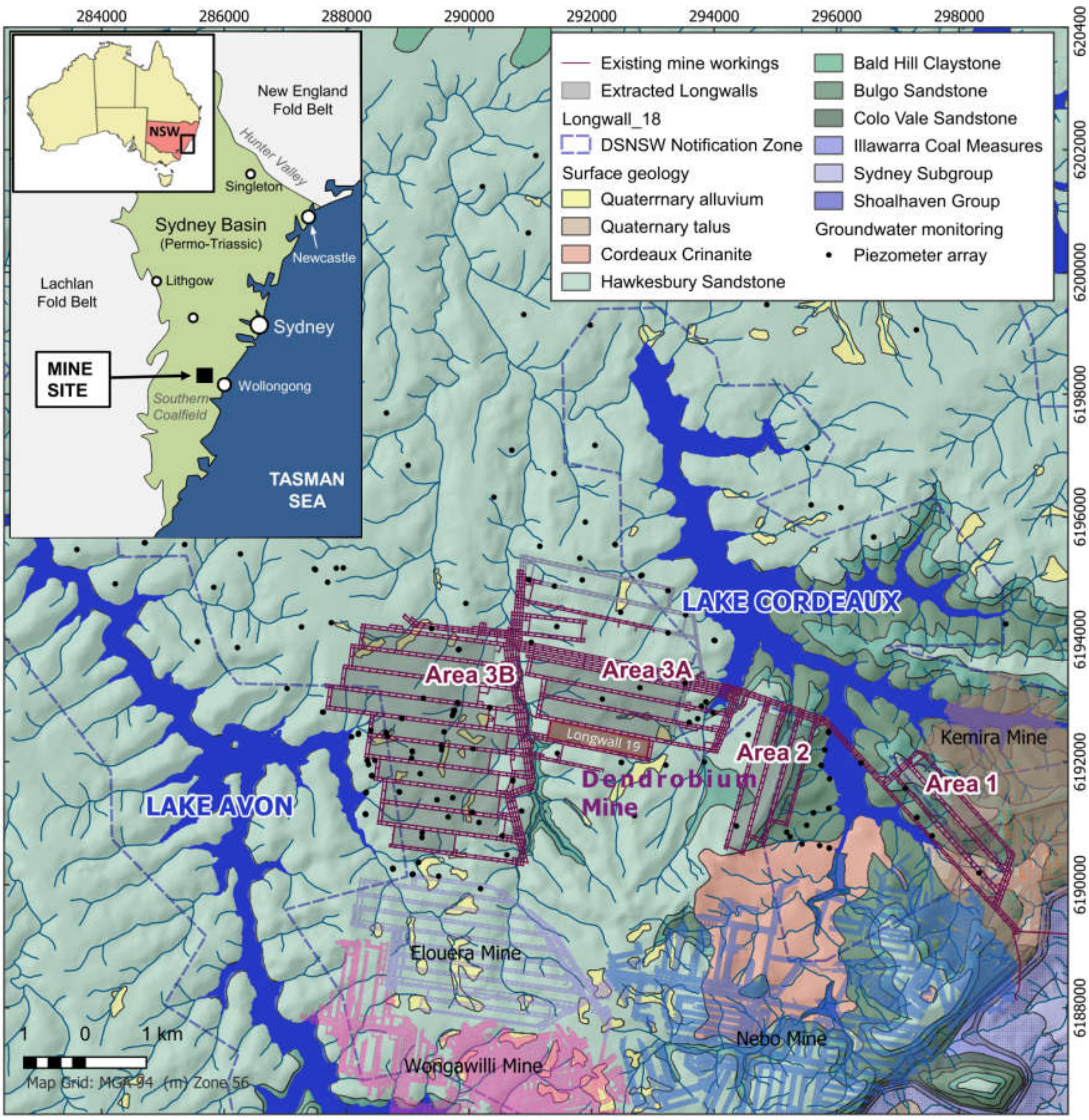

Figure 1. Location of Dendrobium Mine and surface geology

1.1 Longwall 19

Longwall mining at Dendrobium has been carried out in three designated areas: Area 1 (east of Lake Cordeaux), Area 2 (west of Lake Cordeaux), and Area 3 (between Lake Cordeaux and Lake Avon) which is divided into sub areas 3A, 3B and 3C. Mining in Area 3B was completed in May 2022, after which mining resumed in Area 3A with Longwall 19. Extraction of Longwall 19 commenced on 20/6/2022 and was completed on 29/3/2023. The longwall is located to the south of Longwall 8 which was completed in December 2012. Longwall 19 has a total length of 1661 m and a width of 305 m including first workings with a maximum cutting height of 3.9 m. The depth of cover ranges between 287 m and 369 m.

At Dendrobium Mine, coal is extracted from the Wongawilli Seam. Previous workings in the Wongawilli Seam are located to the south at Elouera and Nebo, and to the east at Kemira. The overlying Bulli Seam was mined previously at Mt Kembla to the east of and partially overlapping Area 1.

1.2 Regulator feedback on previous EOP report

The NSW Department of Planning and Environment (DPE) provided comments from the Environment and Heritage Group (EHG) and WaterNSW in relation to the Longwall 18 End of Panel groundwater monitoring review. Table 1 summarises comments (except for minor editorial remarks) and makes reference to sections of this report that are relevant to each comment. Note that a more detailed response has been provided to DPE by IMC:

Table 1. Government agency comments from previous EOP report (groundwater)

Comment	Response
[EHG] notes the inconsistency in conclusions regarding a lack of groundwater aquifer impacts. Reference was made to lack of clarity in representing piezometric head data at sensors where pressure head is zero or close to zero.	Groundwater hydrographs are presented with respect to piezometric (total) head and pressure head in Appendix B. As with previous EOP reports, piezometric head data for sensors at which pressure head is less than 2 m are indicated with a dashed line. Section 3.2 discusses depressurisation impacts from mining including sensors that indicate zero or near-zero pressure head.
[EHG] considers the groundwater model to be poorly calibrated. Reviews for the Longwall 19A SMP identified significant censoring of relevant data. Adequacy of the groundwater model needs to be addressed	Details regarding the groundwater model are provided in Watershed Hydrogeo (2020). The groundwater model is updated and peer-reviewed for each SMP application; EHG comments will be addressed in the next model update report. All data reviewed in this report and used in the model are provided in electronic format.
WaterNSW: There is lack of comprehensive interpretation of water quality in the context of groundwater levels monitoring and modelling (observed changes in hydraulic gradients, hydraulic conductivities, estimates of groundwater travel time) for assessment of seepage from the lake.	Additional comment is made in relation to groundwater quality and seepage adjacent to Lake Avon. Electrical conductivity timeseries data are discussed in Section 3 and presented in Appendix C.

1.3 Hydrogeology

Dendrobium Mine is located within the Southern Coalfield which is one of the five major coalfields that lie within the Sydney Geological Basin. The stratigraphy of the Southern Sydney Basin is shown in Figure 2. The Basin is primarily a Permo-Triassic sedimentary rock sequence, underlain by undifferentiated sediments of Carboniferous and Devonian age. The Bulli and Wongawilli Coal Seams are the primary target seams in the top part of the Illawarra Coal Measures. The Coal Measures are overlain by Triassic sandstones, siltstones and claystones of the Narrabeen Group and the Hawkesbury Sandstone (HBSS). The HBSS is the dominant outcropping formation across the mine area, but lower stratigraphic units (Bald Hill Claystone (BHCS), Narrabeen Group) are exposed in deeply incised parts of Wongawilli Creek and along the south-eastern shores of Lake Cordeaux.

The hydrogeology of the area is described in previous groundwater assessments associated with Dendrobium Mine (e.g. Coffey, 2012; HydroSimulations, 2016; Parsons Brinckerhoff, 2014), and summarised below.

Three main groundwater systems are recognised:

1. Perched groundwater systems associated with swamps and shallow sandstone. These may be ephemeral and/or disconnected from the deeper groundwater systems.
2. Shallow groundwater systems: layered water-bearing zones within the saturated HBSS; and
3. Deeper groundwater systems within the Narrabeen Group and the Illawarra Coal Measures.

Recharge to the aquifer systems is primarily from rainfall infiltration through outcropping formations, generally the HBSS in the western half of the Dendrobium mine area and the Bulgo Sandstone (BGSS) in the eastern half. There will be some recharge from the Reservoirs and streams to host formations at times of high-water level and creek flooding.

Strong topographic relief and recharge drive vertical groundwater flow near the ground surface, but at depth the alternation of aquifers and aquitards promotes horizontal groundwater flow at the base of permeable units. In general, groundwater flow in shallow systems is strongly influenced by local topographical features such as streams and lakes, whereas deeper groundwater systems are influenced by regional topographic and drainage patterns (Toth, 2009). Regional groundwater flow in the deeper sandstone units (pre-development) is predominantly northwest, towards the Nepean River system and away from the Illawarra escarpment.

Discharge from the (shallow) groundwater systems occurs naturally at the surface to creeks and to the reservoir as baseflow and seeps, and by evapotranspiration through vegetation. Along the escarpment to the south-east of Dendrobium Mine, groundwater discharge appears as seeps in cliff faces at the junction of formations with contrasting permeability.

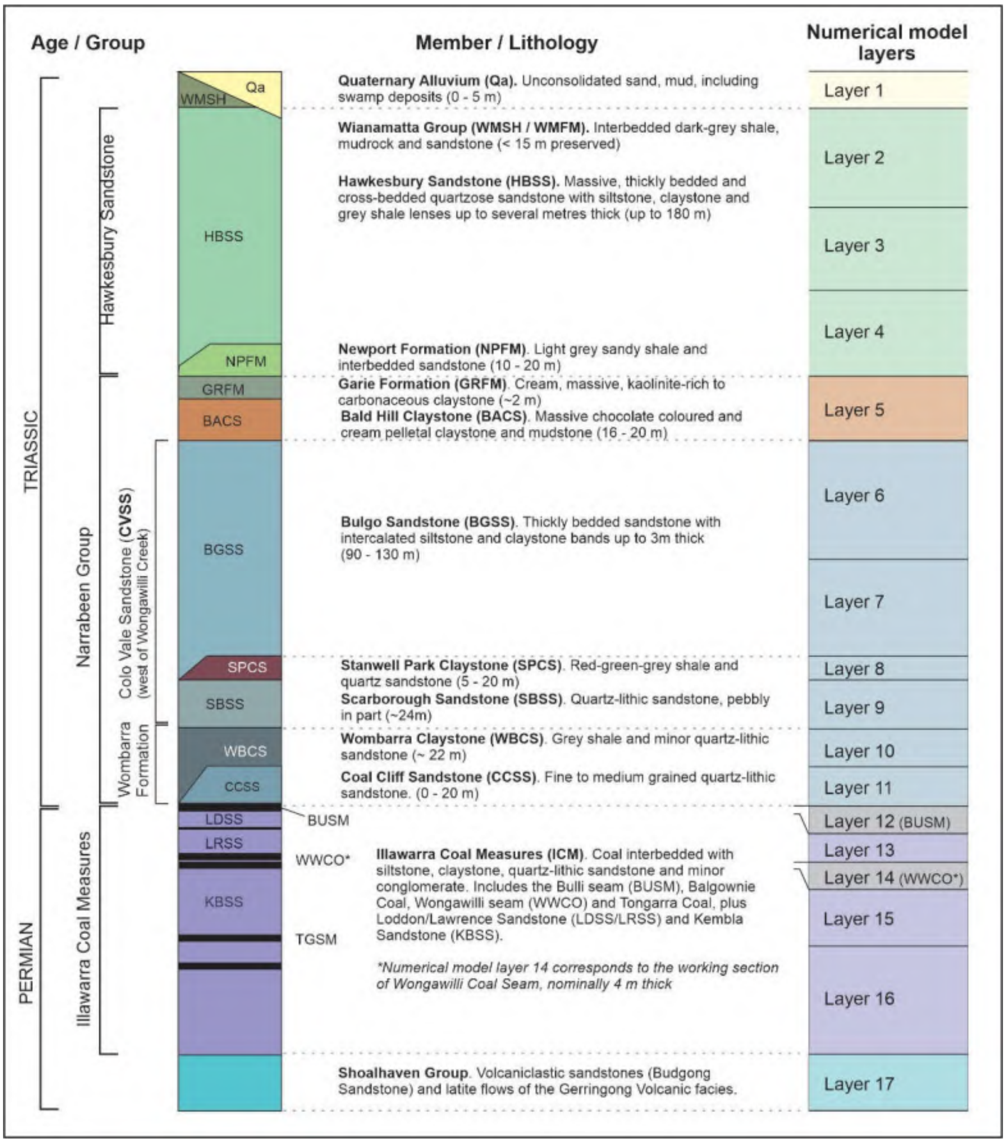

Figure 2. Generalised stratigraphy of the Southern Coalfield

1.4 Effects of mining

Extraction of coal using longwall methods commonly results in ground subsidence and associated deformation and fracturing of overlying strata (Peng and Chiang, 1984; Whittaker and Reddish, 1989). Fracturing is most intense and vertically connected immediately above the collapsed longwall (goaf), and grades upwards through zones of less fractured strata (Booth, 2002). Fracturing of the overburden can cause significant changes in aquifer characteristics such as permeability and storage, and potentially can provide pathways for vertical groundwater movement between shallow groundwater and surface water systems and underground mines (Advisian, 2016; McNally and Evans, 2007). The height to which vertically connected (and free-draining) fracture networks extend above the mined seam is therefore important in assessing potential impacts of longwall mining on groundwater and surface water systems.

Several authors have 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 & Merrick 2014. 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 impact models. It is important to note that the terms used by the authors are not equivalent; Tammetta refers to the "height of desaturation" (more precisely, complete depressurisation); Ditton and Merrick refer to a "zone of continuous cracking" (Zone A), and Mills refers to a zone of large downward movement (Zone 2).

The Independent Expert Panel for Mining in the Catchment (IEPMC) was established in 2018 to provide advice to government on impacts of mining activities in the Greater Sydney Water Catchment Special Areas, with a focus on risks to quantity of water (IEPMC, 2019a, 2019b). In relation to hydrogeological impacts and height of fracturing, the Panel considers that:

"*…changes in ground behaviour and fracturing, permeability and the lateral extent of affected areas occur gradationally rather than as step changes. The so-called 'fractured zone' is a misnomer. Fracturing still develops above this zone and may be connected. Due largely to the different interests and focus of geoscience and engineering disciplines, zones defining mining-induced rock deformation do not necessarily align with zones defining groundwater response to mining.*

Adhikary *et al.* (2020) reviewed strata-caving mechanics and the observations of Tammetta (2013) and developed empirical equations defining upper and lower bound estimates for the height of connected fracturing. The equations are functions of the effective panel width (W') and height of mining (t) only. The authors propose that the upper and lower bounds could be used to define possible ranges of fracturing heights in probabilistic modelling, and that the upper bound should be used as a conservative assumption in deterministic studies[1]. Modelling indicated that subsidence above wide or super-critical[2] panels would be accommodated by fracturing to the surface; however, the authors emphasise that the seam to surface fracturing does not imply seam to surface connection. In addition, rock mass dilation may result in sudden and complete piezometric pressure drops throughout overlying strata that are independent of (and beyond) the connected fracture network. Initial piezometric pressure loss may recover to various degrees depending on the fracture network, recharge rate, and aquitard integrity including the presence of self-healing clay-rich aquitards. Those conclusions are consistent with observations at Dendrobium as summarised in this report.

Since 2018 IMC has carried out targeted investigations into the height of fracturing and groundwater conditions above completed longwalls at Dendrobium Mine. Investigation holes have been drilled above existing Longwalls 12 to 18 in Area 3B and Longwalls 6 and 7 in Area 3A, allowing assessment of effects above longwalls of different width. The main findings of the investigation are summarised in Section 3.2.1.

1.5 Numerical groundwater impact model

Regional numerical modelling by Coffey (Coffey, 2012) supported the *Area 3B Subsidence Management Plan* (SMP) application and subsequent approval. The model has been revised and updated several times since 2012 to better represent subsidence fracturing and to allow assessment of shallow groundwater within swamps and baseflow to streams (HydroSimulations, 2016). The current model was developed by Watershed Hydrogeo (2020) using MODFLOW-USG. The model includes historical mining at Dendrobium and surrounding mines.

[1] Note that for Area 3B, the lower and upper bounds of Adhikary *et al.* (2020) are 199 – 387 m. Those values bracket or contain estimates based on Mills 2011 (305 m), Tammetta 2013 (351 – 377 m) and Ditton & Merrick 2014 (216 – 258 m; Geol-A95).

[2] Adhikary *et al.* (2020) define critical and super-critical width, in the absence of site-specific data, as $W/d \geq 1.2$ and ≥ 1.4, where W is the effective panel width and d is the depth of cover (seam top to ground surface). For longwalls in Area 3B W/d ranges from 0.74 to 1.12 (sub-critical).

The vertical extent of layers used to simulate the regional groundwater systems in the latest numerical model are shown in Figure 2. An East-West cross section showing the modelled stratigraphy is presented in Figure 3.

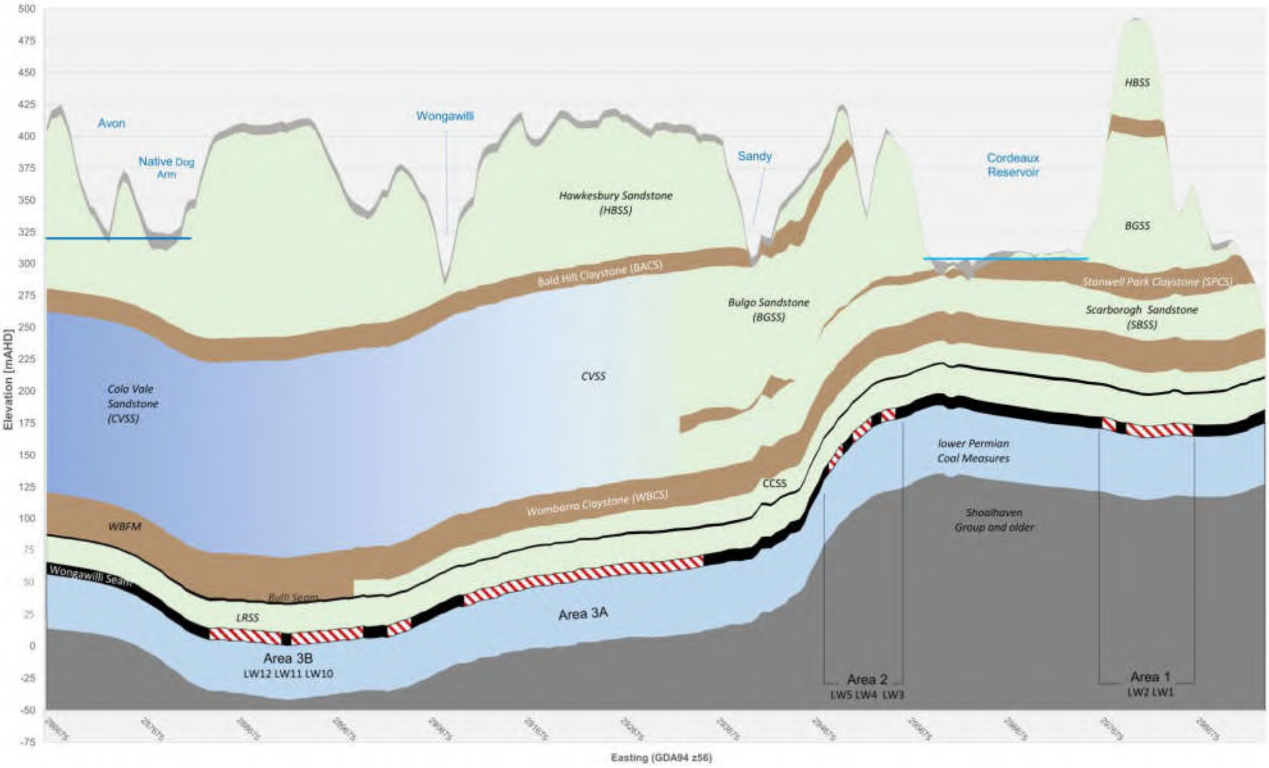

Figure 3. Geological cross-section (east-west) through Dendrobium Mine

2. MONITORING DATA

This section presents the monitoring data available for the groundwater assessment and supports the discussion of the observed hydrological behaviour presented in Section 3.

2.1 Management Plan

Groundwater monitoring at Dendrobium Mine is conducted in accordance with the "Dendrobium Colliery Area 3B SMP Groundwater Management Plan" (South32, 2012) and the Area 3A Subsidence Management Plan (South32, 2020b). The aims of the Groundwater Management Plan are to:

- Monitor groundwater levels and quality, commencing at least one year prior to mining affecting the system.
- Project potential groundwater changes during mining (short term) and post-mining (long term) with particular attention to the effect of changes to groundwater regime, impact on the catchment yield and interaction with the stored waters.
- Identify hydraulic characteristics of overlying and intercepted groundwater systems and determine changes to groundwater systems due to coal extraction and dewatering operations.
- Report any pumping tests and groundwater/surface water simulation studies; and
- Collect water level data from relevant groundwater-monitoring locations.

2.2 Groundwater monitoring network

The groundwater-monitoring locations for Areas 3A and 3B are shown in Figure 4. A list of all monitoring bores installed at Dendrobium is included in Appendix A. There are approximately 180 active monitoring bores located across the Dendrobium mine lease, containing over 950 piezometers, excluding those that are decommissioned or no longer monitored.

2.3 Deep groundwater levels

Deep groundwater levels are monitored using one or more piezometers installed within monitoring bores. Monitoring bores typically have an index number with an 'S' prefix such as S2314, within which piezometers may be installed at multiple depth levels (e.g., S2314_128m). In most cases, the piezometers are vibrating wire piezometers (VWP) that are fully grouted into the bore hole. The sensors contain a sensitive diaphragm that deforms in response to subtle changes in pore pressure that are transmitted through the connected pores of the grout from the adjacent geological strata. VWP sensors are commonly used in deep mining and geotechnical applications where the strata permeability is low and conventional (standpipe) piezometers are impractical (Contreras et al., 2008; Mikkelson and Green, 2003).

Standpipe piezometers, consisting of a slotted open casing, are best suited to monitoring of relatively shallow groundwater systems within moderate to high permeability strata (e.g., swamp sediments and shallow HBSS). Automated loggers record groundwater pressures each hour (typically). The recorded data are subsequently converted to fluid pressure head (m) and potentiometric head (mAHD).

Deep groundwater responses to mining are assessed primarily through the use of time-series hydrographs for multi-level piezometer sites (VWPs). Most VWPs at Dendrobium suffer from electromagnetic noise which causes spurious spikes in the data records. Noisy data are filtered and removed where practical. Hydrographs and analysis are presented in Section 3.1.

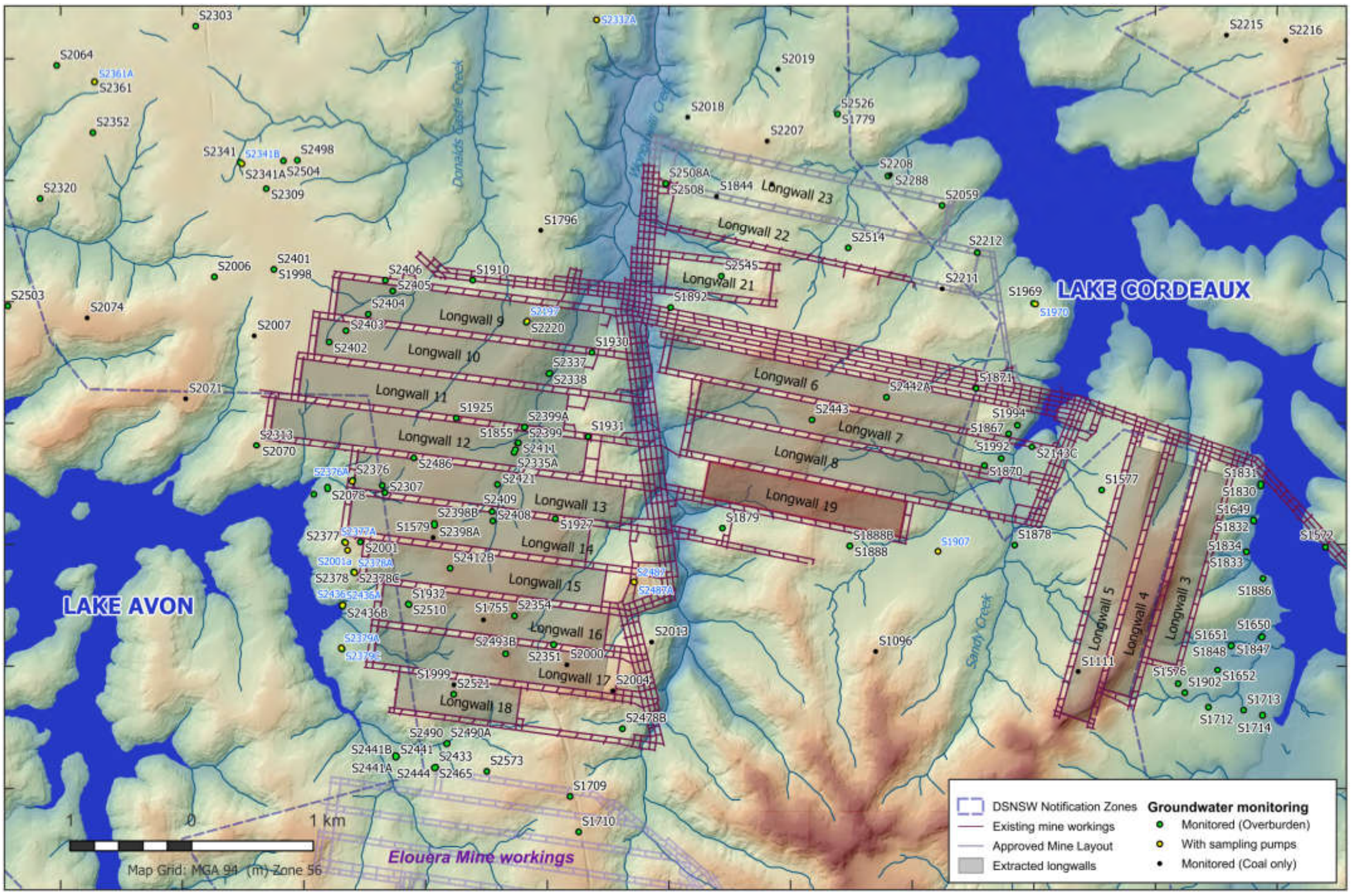

Figure 4. Deep groundwater monitoring network around Areas 2, 3A and 3B

Hydrographs are plotted in terms of ***piezometric head*** (mAHD) and ***pressure head*** (m H_2O). Piezometric head can be thought of as the theoretical level to which water would rise in a bore that is open to an aquifer at a given elevation and is calculated by adding the measured pore pressure (at the VWP, expressed in m of water) to the elevation of the sensor (in m AHD). The potentiometric head in a confined aquifer system can be (and often is) different to the water table elevation at the same location.

Hydrographs presented in this assessment include surface water hydrographs for the nearest water supply reservoir (Lake Cordeaux for Area 3A and Lake Avon for Area 3B hydrographs). Note also that individual hydrograph traces are presented as dotted lines at times when the pressure head is below a threshold of 2 m. The ***pressure head*** is the absolute pore pressure at the sensor expressed in m of water. When the pressure head is below that threshold it is an indication that the rock matrix is approaching complete depressurisation at the location of the sensor and, given the uncertainty in pressure measurements, may be totally or partially desaturated. Both piezometric and pressure head hydrographs are presented in Appendix B.

Assessment of the spatial distribution of piezometric head and pressure drawdown over the reporting period is carried out using annotated and coloured symbols on a map. ***Drawdown*** (in metres) is simply the difference in potentiometric head between a reference date and the end of the current reporting period.

In this assessment the groundwater drawdown reference date is November 2009, immediately prior to the start of mining at Area 3A. This date was selected because very few piezometers were operational in Area 3B prior to 2009. The following procedure was used to calculate groundwater drawdown.

- Piezometric head and pressure head data were tabulated from the Dendrobium VWP database. Data were reduced to daily observations using a median of sub-daily data.
- The median head at each operational sensor was obtained for the last 3 months of the recently completed longwall and the last three months of Longwall 5 (ending in November 2009). This approach is used to capture sensors with records that fall slightly short of the end of panel.
- The average head was calculated for each of five subunits: middle HBSS, lower HBSS, upper BGSS, lower BGSS and SBSS. This allows piezometric heads to be compared at bore locations where sensors are set at inconsistent depths. The subunits also correspond to the subunits used in the regional numerical model, allowing direct comparison with model predictions.
- For bores that were installed after 2009, the piezometric head in 2009 was spatially interpolated from sensors within each subunit that were active at that time (using kriging).
- Drawdown was calculated for each subunit as the difference between median heads at the end of the recently completed longwall and the end of Longwall 5 (either observed or interpolated).
- Where one or more of the sensors in the subunit recorded less than 1 m of pressure head (assumed to be near desaturation), the drawdown is recorded as a minimum. Those locations are highlighted on the relevant spatial plots.
- Sensor data for decommissioned or damaged bores are not extrapolated. Locations that have been decommissioned, damaged or for which data are otherwise unavailable at the time of reporting are not included in analysis.

Spatial plots are presented and discussed in Section 3.3.

2.4 Mine water balance

All movements of water via pumping stations are monitored and controlled in real-time through the System Control and Data Acquisition (SCADA) system and used to calculate a daily mine Water Balance. The Water Balance is an accurate measure of all water that enters, circulates and leaves the mine, including via air moisture and coal moisture content. Mine water seepage (groundwater inflow), which cannot be directly measured, is determined by mass balance for each goaf and is therefore known to a reasonable accuracy. Key metrics of the Mine Water Balance are reported against Trigger Action Response Plan (TARP) levels to Dams Safety NSW monthly.

In this assessment, the estimated groundwater inflow component of the mass balance is presented as time-series hydrographs and compared with rainfall trends and model predictions. Analysis of water balance trends for the reporting period is presented in Section 3.

2.5 Groundwater chemistry

Groundwater chemistry sampling sites relevant to this assessment are shown in Figure 4 (yellow symbols). Currently there are eight sampling bores in Area 3B containing 20 individual sampling pumps screened within the Hawkesbury and Balgo Sandstone. Most sampling sites are located between the mined and planned longwalls of Area 3B and the eastern shore of Lake Avon. The SBSS is monitored at two locations: S1886 (Area 2) and S1870 (Area 3C).

In addition to samples collected from bores, groundwater samples are routinely collected from underground workings, inter-seam boreholes and flooded adjacent mine workings, as described in the *Underground Water Sampling and Analysis Procedure* (DENP0048). Water is analysed for chemistry (major and minor ions), and isotopes of carbon and hydrogen. Monthly water samples are taken from the main discharge points of the mine and from completed longwall panels. The results of the sampling are reviewed each month and reported to Dams Safety NSW. More than 3,400 water samples have been collected and analysed at Dendrobium Mine since 2004 (including > 1100 tritium analyses), providing an extensive database for ongoing assessment and a basis for chemically characterising waters from various sources.

In this assessment, average field electrical conductivity (EC), is used as a general indicator of water quality (salinity). Water salinity varies according to its source (see Figure 5) and, in general, groundwater salinity tends to increase with the depth below the surface; groundwater in the HBSS tends to be relatively fresh (average EC ~ 170 μS/cm) whereas mine seepage water is distinctly more brackish (average EC of seepage in Areas 3A and 3B ~ 2200 μS/cm). Beneficial water use categories based on the ANZECC water quality guidelines (ANZECC, 2000) are shown for reference only. Groundwater quality is assessed further in Section 3.5.

Samples collected from bores can sometimes be influenced by drilling water, residual grout or bentonite leachate from the construction of the piezometer. Typically, this is indicated by elevated or anomalous EC, pH, sulfate, or Ca/Na ratios. Samples that are highly affected by grout or bentonite are excluded from assessment; however, some samples may show subtle effects.

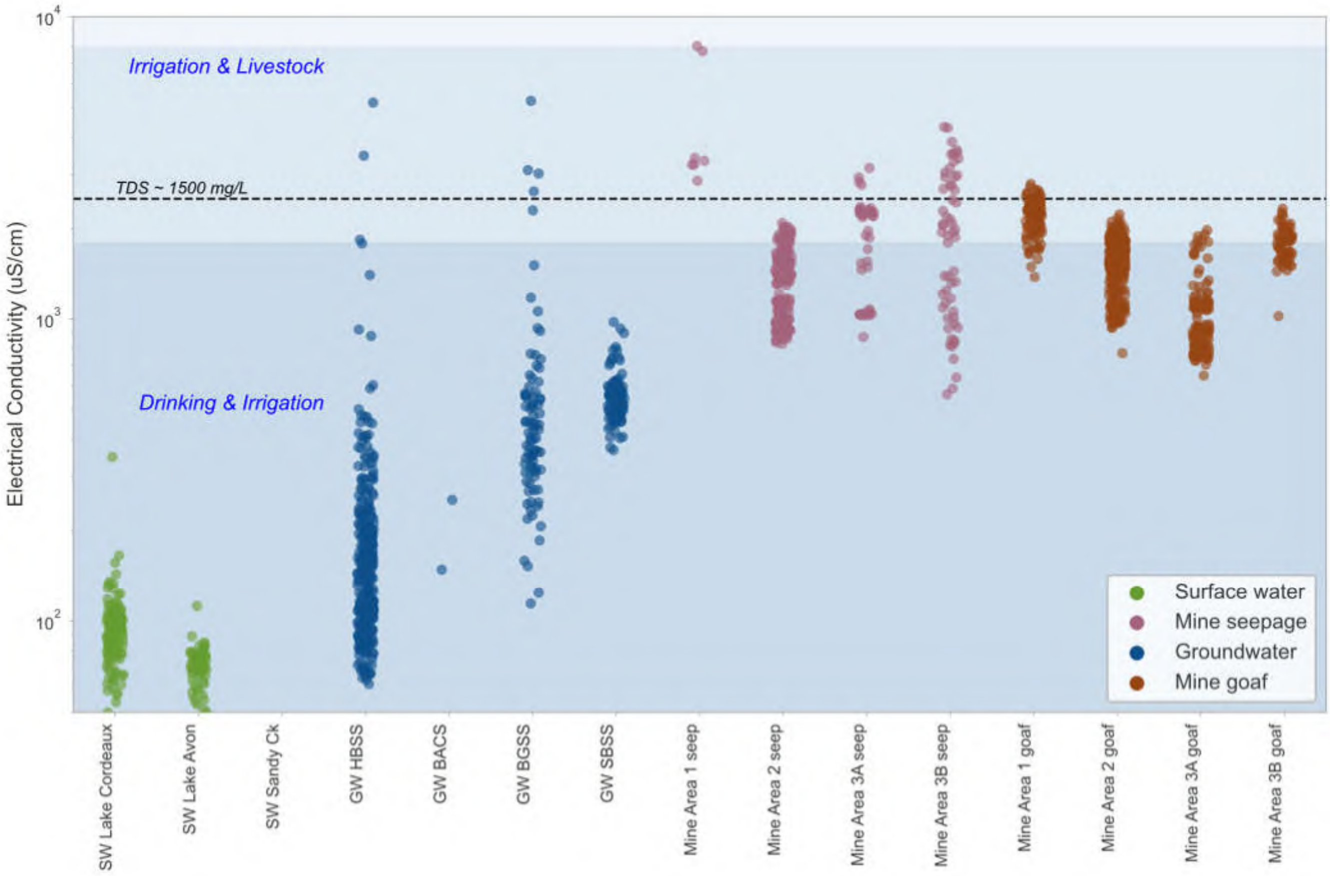

Figure 5. Strip plot of Electrical Conductivity of surface water, groundwater and mine inflow.

3. ASSESSMENT OF GROUNDWATER RESPONSE TO MINING

3.1 Mine water balance

Table 2 presents mine inflow statistics as indicated from the net water balance for each Area for the period over which Longwall 19 was extracted (20/6/2022 to 29/3/2023). The water balance for each area over previous longwalls is shown in Figure 6. Continuous timeseries plots of mine inflow compared with the cumulative rainfall residual curve are shown in Figure 7and Figure 8. The cumulative rainfall residual is the cumulative deviation of observed daily rainfall from the daily rainfall mean (~3.1 mm per day). The curve trends downward during prolonged dry periods (e.g., during the severe 2017-2019 drought), and upward during prolonged wet periods (e.g., the 2020-2022 La Nina events). Groundwater recharge processes are often correlated with rainfall residual trends.

Table 2. Dendrobium Mine Inflow during the Extraction of Longwall 19 (in ML/day)

STATISTIC	AREA 1	AREA 2	AREA 3A	AREA 3B	AREA 3C	TOTAL
Longwall 19 (mean)	0.44	2.14	0.78	8.62	1.31	11.97
Longwall 19 (max)	2.15	6.64	8.15	10.69	2.67	20.21

The mean total mine inflow during Longwall 19 extraction was 12.0 ML/day which represents a 32% increase compared with the previous longwall. The increase is primarily due to the very high rainfall during the longwall extraction period and the previous two years, with Figure 7 showing that total mine inflow has recently declined as a result of drier conditions in 2023. The net mine water balance is dominated by pumping from Area 3B (72 % of total), with Area 3A representing only 6.5 % of inflows. It is likely that some of the water reporting to Area 3B and 3C is derived from up-gradient areas such as Area 3A during high inflow periods. No anomalous inflow due to intersecting water-bearing structures such as faults or dykes was reported during the extraction of Longwall 19.

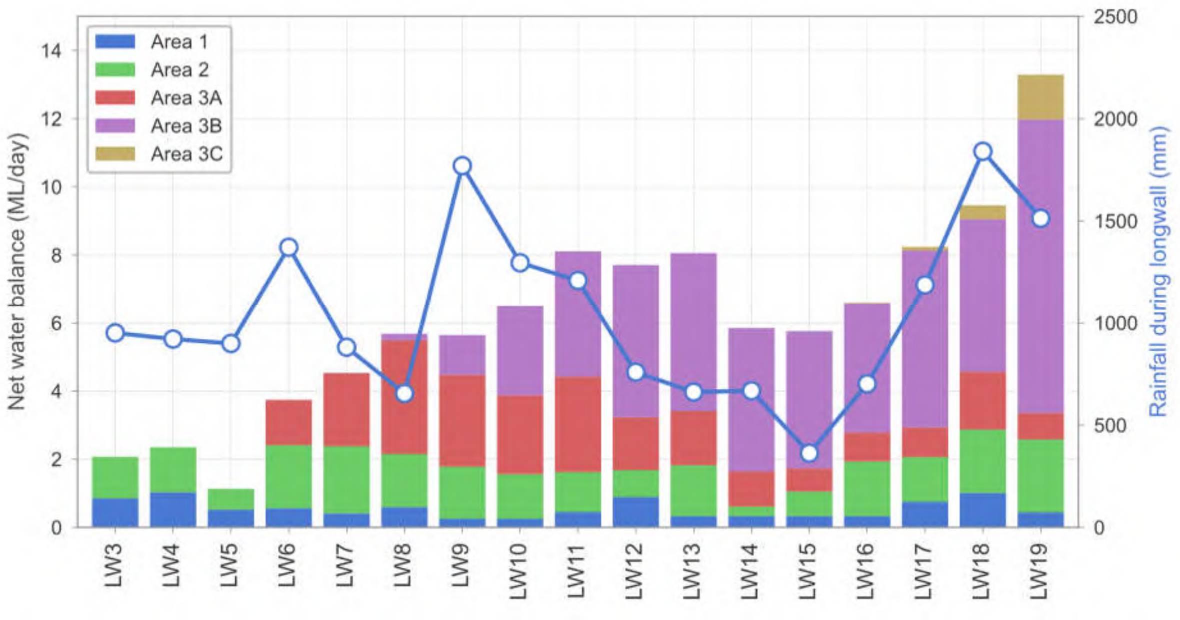

Figure 6. Net mine water balance during longwall extraction periods

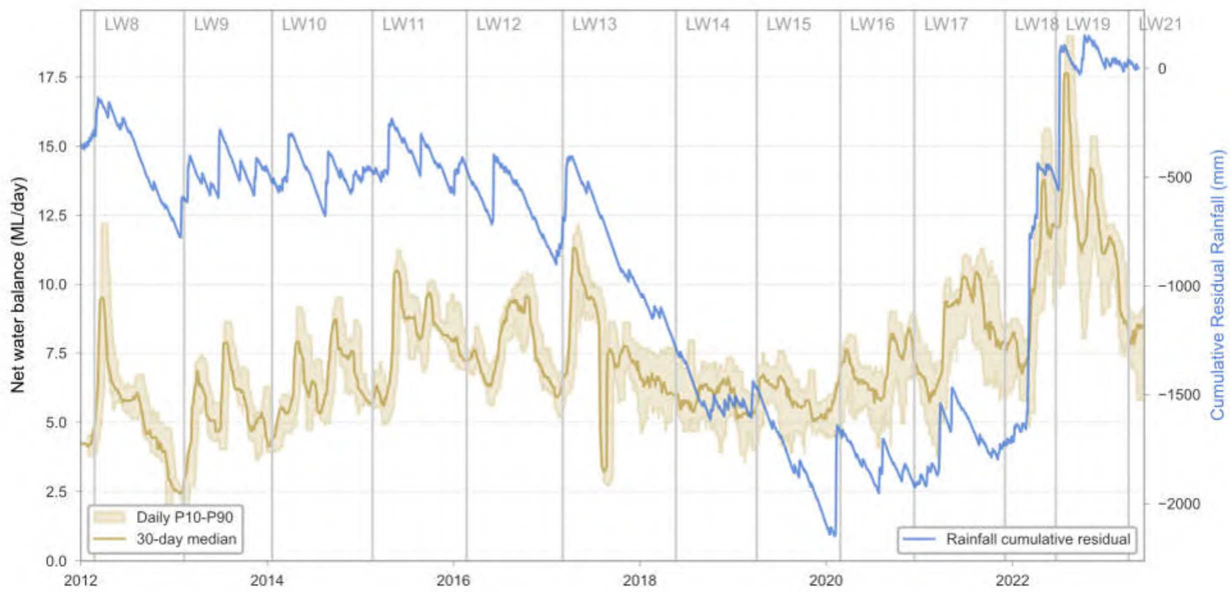

Figure 7. Groundwater inflow from water balance for all mine areas (ML/day)

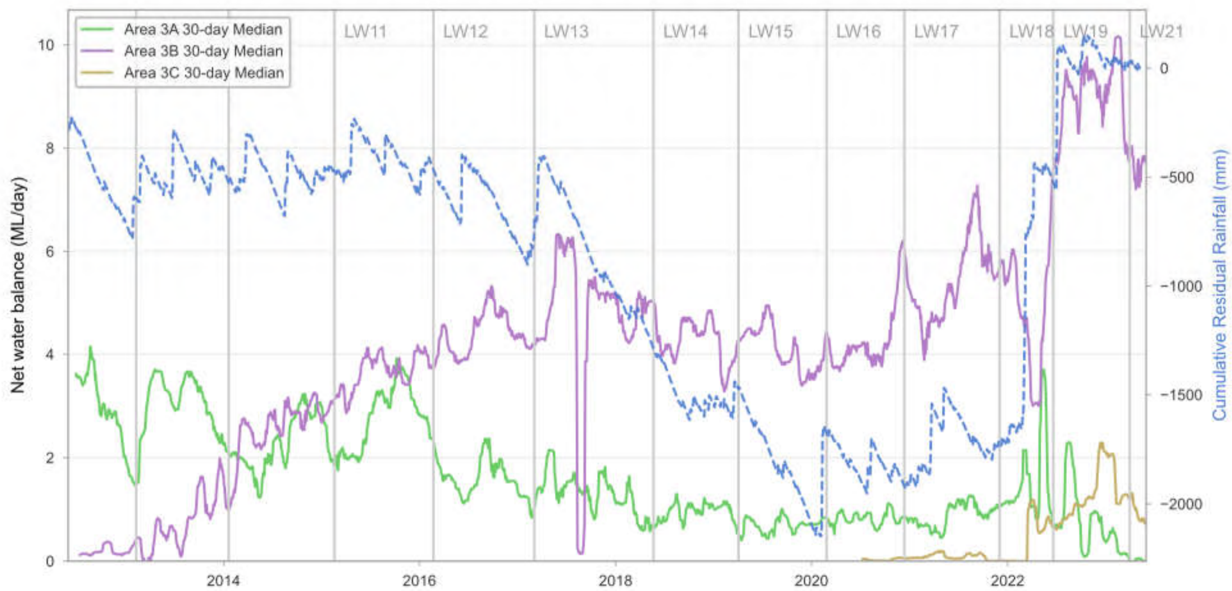

Figure 8. Groundwater inflow to the mine for Areas 3A, 3B and 3C (ML/d)

3.1.1 Estimates of the surface water component of mine inflow

The correlation of inflow peaks with periods of high rainfall implies that there is a rainfall (or surface water) induced component to mine inflow. Two approaches are used to assess the proportion of mine inflow that may be attributed to rainfall or surface water:

1. Baseflow separation approach, whereby the volume related to the inflow peaks is estimated as a fraction of the total inflow for a given period. Baseflow is a concept from stream flow hydrology whereby the baseflow represents the groundwater discharge component of flow, as opposed to the ‘quick flow’ component of rainfall runoff represented by the hydrograph peaks (in this case peaks in mine inflow following rain events).

2. Isotopic tracer approach, whereby tracers of modern water (tritium and radiocarbon) are used to detect and estimate the proportion of rainfall or surface water in mine inflow samples.

The two approaches assess surface water input in different ways and will not necessarily yield similar results. The baseflow separation approach estimates the inflow component related to high rainfall events. Those events result in a rise in groundwater levels or piezometric head (within porous rock and fracture networks) which drive transient increases in mine inflow. However, the water itself may be largely derived from the release of (old) groundwater storage[3] unless there are direct and rapid pathways between the surface and the goaf.

3.1.2 Water balance baseflow separation

An example of base-flow separation analysis is shown in Figure 9 for the total mine water balance data. The daily water balance data (grey circles) is highly variable due to the nature of pumping cycles in the underground mine and the trend is best represented as a 30-day moving average (the purple line). The moving average clearly defines peaks in net mine inflow following large rainfall events, with a two to three-month delay. The most recent peak is associated with the very high rainfall in 2022. Much of the rainfall response in the total mine water balance is driven by the Area 2 water balance which is known to be dominated by rainfall response; however, rainfall response signals are also evident in the Area 3B water balance.

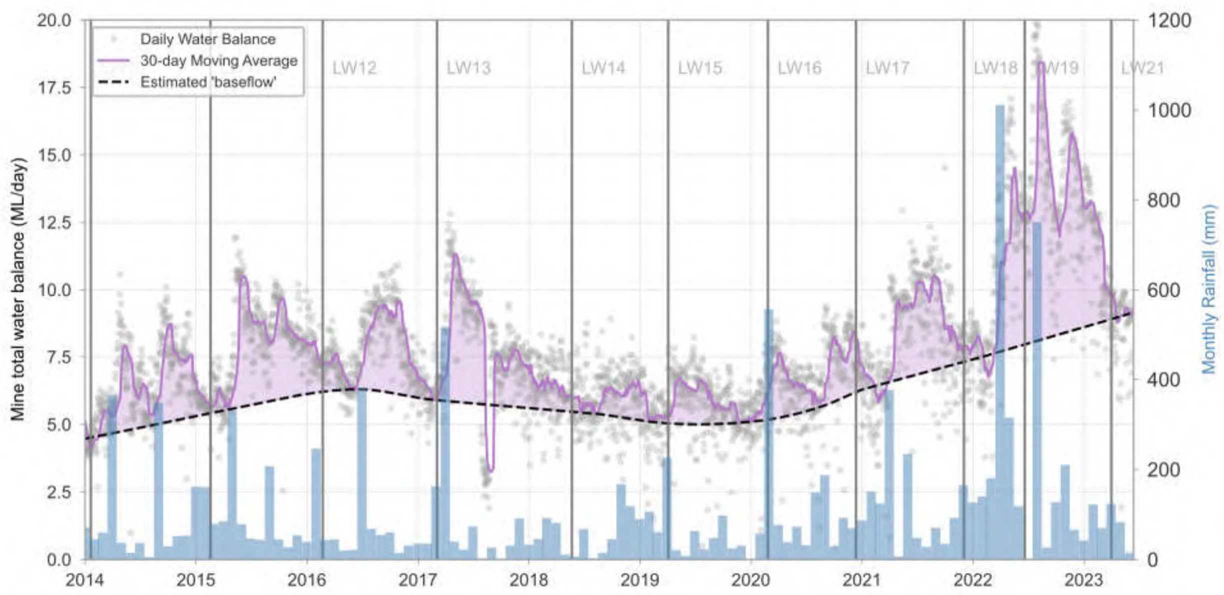

Figure 9. Estimate of potential surface water component of the total mine water balance

Applying digital stream baseflow separation filters to the water balance data is problematic due to the high variability of the data (including negative values) and significant lag times. Therefore, the baseflow component has been approximated by interpolating between troughs in the 30-day moving average water balance. The potential rainfall-induced inflow component is defined by the difference between the two curves (purple shading). Note that the estimate will include peaks caused by

[3] Note that the volume of groundwater storage above the longwall footprint alone is significant. Unconfined or drainable groundwater storage would be in the order of 7 GL per longwall (assuming an average longwall goaf area of 610,000 m2, a Specific Yield of 3% averaged over all strata and an average saturated thickness of 370 m). Confined or elastic storage would be small in comparison; in the order of 20 ML (assuming a Specific Storage coefficient of around 10^{-6} m^{-1}; David *et al.* 2017). At the average mine inflow rate per longwall, complete drainage of the column (ignoring lateral groundwater flow) would take in the order of 20 years. Old groundwater storage release is likely to dominate mine inflow for many years.

variations in pumping (for operational reasons) and therefore may over-estimate the rainfall-induced component.

Using this method, the rainfall-induced component of inflow for the whole mine has averaged **~20%** since the start of Longwall 12. The apparent contribution during Longwall 19 was 39% up from 16% for the previous longwall, again due to the high rainfall in 2022.

3.1.3 Tritium in mine inflow

The modern water component in mine inflow is monitored by analysing tritium in samples collected from goaf inflow and development seepage water samples. The results are reported monthly to Dams Safety NSW. Tritium is an isotope of hydrogen (^3H), generated in the atmosphere through interactions with cosmic rays and through past atmospheric nuclear weapons testing (Clark, 2015). Tritium is incorporated into water molecules in rainfall and enters groundwater systems through recharge (rainfall and stream-bed infiltration). Tritium decays exponentially according to its half-life (12.32 years) and is typically only detectable in surface water samples and in groundwater that recharged within 4 to 5 half-lives (50 to 70 years). Detection of tritium above deep groundwater baseline levels in mine inflow samples would indicate a component of modern water in the sample (as it does for samples from Area 2).

Tritium is widely assumed to be a conservative tracer in that it is not significantly sorbed or otherwise retarded during groundwater transport (e.g. Cendón et al., 2014; Štamberg et al., 2014). However, a review by ANSTO (2018), commissioned by South32, concluded that tritium may undergo diffusive exchange with (and therefore loss to) zones of older groundwater. While the effect has not been quantified in terms of typical groundwater pathways at Dendrobium, it is important to consider when assessing tritium results. Despite possible diffusive losses, tritium remains an important and unambiguous indicator of modern water when tritium is detected above baseline levels.

A timeseries plot of tritium in groundwater samples from the underground mine and Lake Avon is shown in Figure 10. Tritium in samples collected from the Area 3B goaf outflow is typically within or close to baseline concentrations in deep groundwater, as defined by the 95th percentile (P95) level for samples collected from the Scarborough Sandstone (shaded area below 0.2 TU in Figure 10). This implies a very low modern contribution to mine inflow in Area 3B. The median tritium content in Area 3B has increased slightly since 2020 but remains below 0.2 TU. Samples from Areas 2 and 3A are typically slightly higher than in Area 3B, ranging up to approximately 0.5 and implying a higher proportion of modern water. Estimates of modern water content based on simple binary mixing using the most recent 12 tritium samples for each mining area are ~ 6% for Area 3B, 16% for Area 3A, 24% for Area 2 and ~13% for Area 1. Those estimates imply a flow weighted mean for the whole mine of **~10%** modern water. That estimate should be regarded as an underestimate due to potential diffusive losses as discussed above.

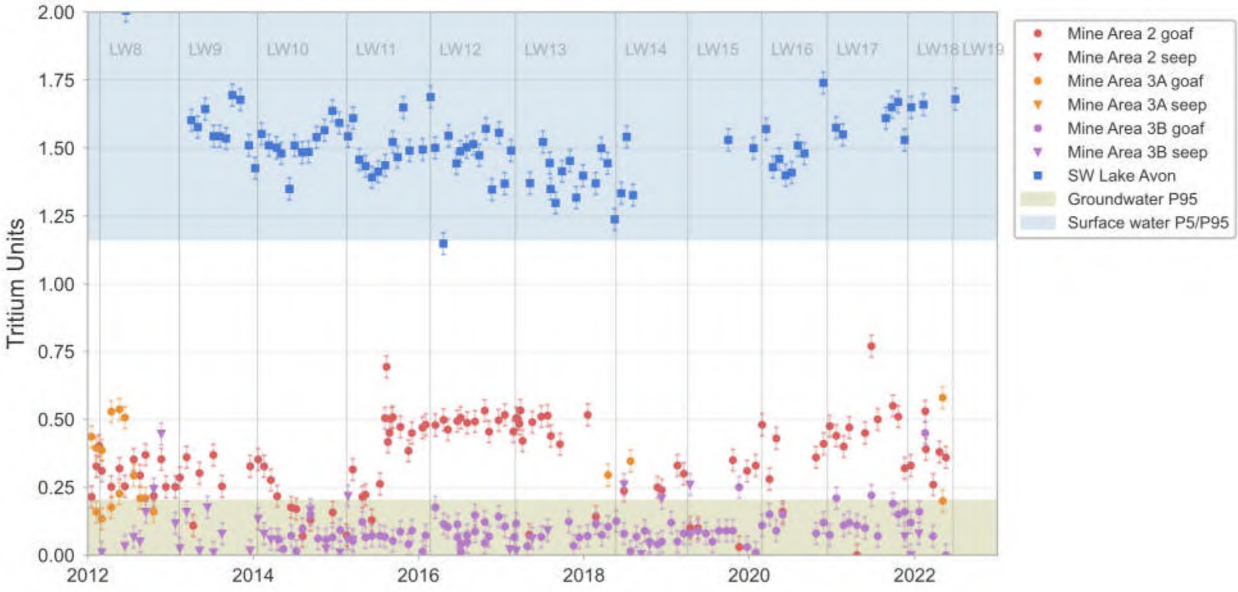

Figure 10. Tritium concentration in water samples from Area 3B

3.1.4 Radiocarbon (14C) in mine inflow

Carbon-14 (14C) has been analysed in mine water, groundwater and surface water samples since 2020 as an additional indicator of modern water. 14C is a radioactive isotope of carbon with a half-life of 5,730 years. It is a widely used tracer for groundwater movement up to 30,000 years old. 14C is produced in the atmosphere and becomes part of the carbon cycle through uptake of plants and respiration and oxidation of the soil zone. Surface water and rainfall infiltrating into the ground contain small amounts of carbon dioxide derived from the air. Leaving the atmosphere, the water comes in contact with the soil pores in which the partial pressure of carbon dioxide from vegetation (root-respiration) is much higher. As water reaches the water table, the ^{14}C starts decaying and result in a decline in $^{14/12}C$ ratio over time. Providing there are no other sources and sinks of carbon and the initial concentration is known, the groundwater age or residence time can be calculated in terms of years before present (Clark and Fritz 1997). Many groundwater samples comprise a mixture of waters of different ages such that, in practice, it is more useful to characterise samples in terms of their percentage modern carbon (pMC) content which is related to the mean residence time of the mixture. In addition, underground samples will contain a high proportion of old, isotopically “dead” carbon derived from dissolution of carbonate minerals and therefore may underestimate contributions from modern water. As with tritium, 14C analysis and reporting by ANSTO can take up to a year due to high demand.

A timeseries of pMC for all sample results is shown in Figure 11. Sample location prefixes are SW = surface water, GW = groundwater (bore sample), Wk = adjacent mine workings (specifically Nebo Mine workings used for water supply). Underground samples are collected from goaf pumping stations or dams (“goaf”) or from seeps or drippers encountered during development of roadways. Samples collected from the Area 3B goaf outflow tank (DWS203) have low pMC (median 1.8%) which, together with low corresponding tritium concentrations, implies that inflow to Area 3B is dominated by deep, old groundwater sources with a very small proportion of modern water. Samples from Area 3A and Area 2 have median pMC values of 4.8% and 3.9%, slightly higher than Area 3B and consistent with tritium results. In contrast, samples of shallow groundwater from the Hawkesbury Sandstone (HBSS) have a significantly higher (and variable) modern carbon content due to contributions recharge within the last 30,000 years.

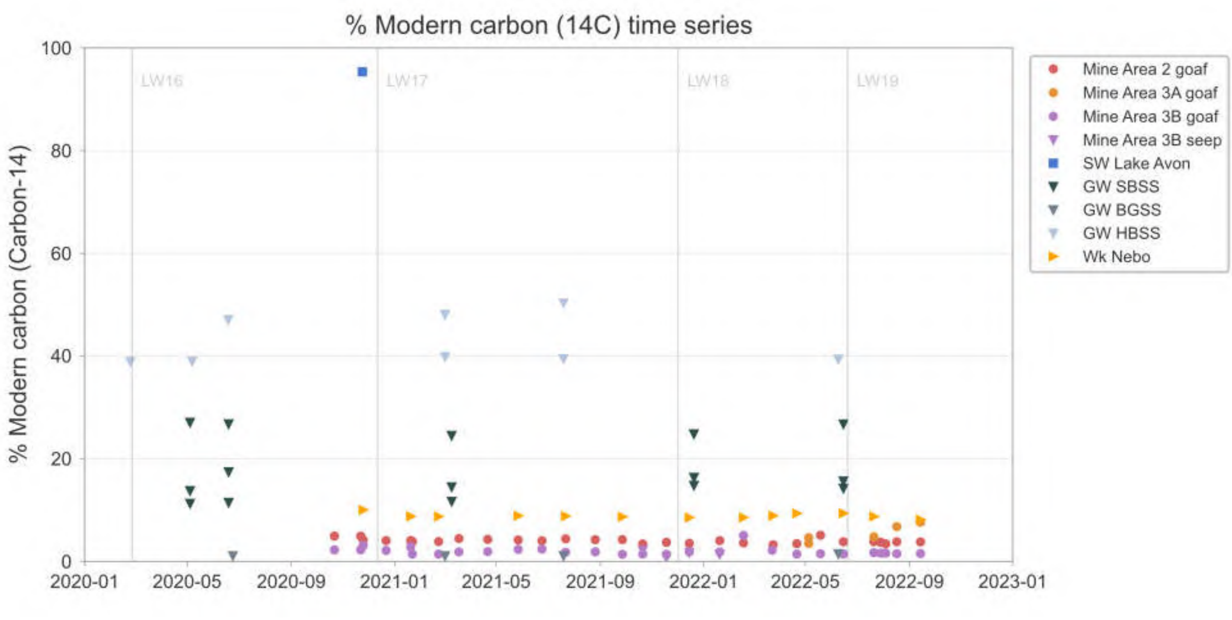

Figure 11. Timeseries of % modern carbon in mine water samples

3.2 Deep groundwater levels – time-series hydrographs

Groundwater hydrographs for all active VWP arrays are presented in Appendix B (Piezometric head and pressure head hydrographs). Overall trends and notable observations are summarised in the following subsections according to their proximity to mine workings.

No monitoring bores are located directly above Longwall 19. The nearest VWP arrays to Longwall 19 are S1907 (328 m), S1888 (149 m) and S1879 (215 m).

3.2.1 Strata above mined longwalls

Piezometer cables in bores located above the footprint of a longwall are usually sheared or the sensors rendered inoperable by ground movements associated with mining and there is rarely a continuous record of groundwater pressures after the longwall has passed the monitoring location. Therefore, it is useful to consider groundwater monitoring data from locations above longwalls in two groups:

1. Baseline monitoring of groundwater levels as the longwall approached the monitoring location (until the cables shear).

2. Monitoring established over the goaf following the passage of the longwall. Since 2018, new piezometer arrays have been installed over previously mined longwalls 6 and 7 in Area 3A and Longwalls 12 to 18 in Area 3B. In addition, piezometers have been installed above mined longwalls to monitor specific swamps and watercourses.

Prior to being mined beneath:

Review of hydrographs from piezometers installed above longwalls prior to being mined beneath show evidence of depressurisation at the coal seams before mining started at Area 3A and years before mining started in Area 3B (Appendix B). Depressurisation of most overlying strata is apparent from the start of mining at Area 3A, and the rate of depressurisation increased as mining moved to Area 3B, and with every successive longwall in Area 3B. Depressurisation is generally greater in the deeper formations. Transient pressure *increases* are also common as the longwall approaches or passes nearby the monitoring site and these reflect compression and relaxation of the strata as the subsidence wave passes (Booth, 2002). Piezometer cables typically shear when the longwall passes within 10 m of the location, but at some sites shearing has occurred when the longwall was up to 660 m away (e.g., S1929).

The most recent example of depressurisation in piezometers directly mined under is in S2521 which is located above Longwall 18. The VWP array shows sharp depressurisation in the Bulgo Sandstone from early January 2022, to near zero pressure head at 237 m. Depressurisation is apparent in the lower Hawkesbury sandstone, but not in the shallow Hawkesbury sensors which may record perching above low permeability claystone layers.

After being mined beneath:

IMC has carried out investigation drilling above extracted Longwalls in Areas 3A and 3B (HGEO, 2020a, 2020b, 2021a). The most recent drilling and re-installation was above Longwall 18 (S2521). The work was completed early in 2023 and the results are currently under review. These investigations provide a good understanding of fracturing and depressurisation above extracted longwalls at Dendrobium. The height of fracturing investigation report was reviewed by Professor Bruce Hebblewhite (2020). The main findings are summarised below:

- In both Areas 3A and 3B, mining-induced fracturing, including high-angle fracturing is highly variable but appears to extend to the surface. The density of fracturing generally decreases with height above the goaf, with anomalous fracturing within the Bald Hill Claystone and below 120 m above the goaf. On average, the density of fracturing above the 249 m wide longwalls is less than that above the 305 m wide longwalls (although the profiles are variable).

- All holes drilled above extracted longwalls show a significant increase in horizontal permeability throughout the profile. Packer tests indicate an increase in permeability of 2 to 3 orders of magnitude relative to pre-mining conditions. At the centreline of Longwall 12 (S2420) there is an anomalous zone of apparently unaffected (near median) permeability in the upper CVSS and Bald Hill Claystone (BACS). Above the pillar zone between Longwall 11 and Longwall 12, packer tests indicate distinctly lower post-longwall permeability than the centreline holes throughout all strata.

- VWPs installed after longwall extraction indicate significant depressurisation throughout all strata, with near-zero pressure heads recorded in most piezometers. Complete depressurisation is recorded throughout the HBSS in most holes drilled above goaf. However, holes in both areas show positive and increasing pressure heads in some sensors in the upper CVSS, BACS and HBSS, indicating localised perching and recovery of groundwater levels within those strata. This effect is particularly noticeable over the last three years in response to higher-than-average rainfall where significant recovery and perching is apparent above:

    - Longwall 6 (S2442A)
    - Longwall 7 (S2443)
    - Longwall 9 (S2405, S2404, S2220 – where piezometric head in the lower HBSS has now recovered to above the level of Wongawilli Creek)
    - Longwall 10 (S2402, S2403, S2337, S2338)
    - Longwall12 (S2411, S2420, S2335A)

- Longwall 13 (S2421)
- Longwall 17 (S2493)

In the context of previous models for fracturing above extracted longwalls, it is interpreted that the height of fracturing (and depressurisation) is highly variable but extends to the surface in Areas 3A and 3B and likely also in Areas 1 and 2. However, observations of localised perching and recovery above extracted longwalls are inconsistent with complete desaturation (draining) to the surface as predicted by Tammetta (2013). This suggests that the zone of highly connected and free-draining fracturing extends to approximately 220 to 250 m above the goaf (approximately to the base of the BACS in Areas 3A and 3B.

3.2.2 Area 3B: Strata outside mined longwalls

In this section, data from piezometers located outside the current mined longwall footprint are reviewed (excluding the Avon monitoring bores which are discussed below). These include bores installed north and northwest of Area 3. Refer to hydrographs in Appendix B.

The nearest VWP arrays to Longwall 19 are S1907 (328 m), S1888 (149 m) and S1879 (215 m). S1888 records a rapid depressurisation in most strata from 16/7/2023 as Longwall 19 approached within 265 m of the bore, including in the lower Hawkesbury sandstone. S1879 records depressurisation in the Bulgo Sandstone starting 1/12/2022 when Longwall 19 was at a distance of 505 m, with more rapid depressurisation starting on 6/2/2023 as the longwall passed adjacent to the bore.

Piezometers located to the north and west, and within 1 km of Area 3 (S1910, S1892, S1998 / S2401, S2006, S2007, S1969) show a gradual decline in groundwater pressures in most strata with the rate of decline increasing with depth and proximity to the longwall. Those observations are consistent with the gradual expansion of a drawdown cone away from the mine and are in line with numerical modelling predictions. The most strongly affected strata are within 500 m of extracted longwalls (S1910, S1892). At S2006 (1 km west of Longwall 9) piezometric head deceased to their lowest level in most strata towards the end of Longwall 14 and have shown recovery in within the HBSS and upper BGSS since Longwall 14 which continued during Longwall19.

Monitoring bores installed northwest of Area 3B show that drawdown is minor at distances greater than 1.2 to 1.5 km from Area 3B. At S2341 (1.2 km), there is some evidence for depressurisation in the deeper sandstone strata; however, all sensors show piezometric head at an elevation corresponding to the HBSS. Similar piezometric levels are observed at S2352 (2.3 km), S2342 (2.6 km), S2345 (3.5 km) and S2340 (4.7 km). At those relatively distant locations, piezometric head within the HBSS is typically above 320 m AHD (and above the level of Lake Avon), whereas levels within the BGSS and SBSS have heads < 300 m AHD and display broadly hydrostatic profiles, with evidence for some depressurisation in deeper strata since Longwall 16. This condition has not significantly changed during the extraction of Longwall 19.

3.2.3 Avon reservoir bores

A series of monitoring bores was installed along the barrier zone between Lake Avon reservoir and Area 3B to characterise the strata permeability before and/or after mining of adjacent longwall panels and to provide ongoing groundwater monitoring. Holes are typically re-drilled and tested following extraction of the adjacent longwall(s). Those observations provide critical information to allow more accurate calculation and modelling of potential seepage losses from the reservoir(s) to the mine. Results of drilling, permeability testing and monitoring have been reported as the investigation has expanded, and hole re-drilling has been completed. Hydrographs for all Avon Dam series monitoring bores are included in Appendix B.

In summary, piezometers in the Lake Avon barrier zone show widespread depressurisation of all strata in response to mining in Area 3B, as predicted in numerical groundwater models (Watershed Hydrogeo, 2020). Groundwater levels at the base of the HBSS were likely near or just above the lake level prior to mining and have declined to be below the lake level. Several piezometers show evidence for recovery in piezometric level between 2020 and 2022 corresponding to the very high rainfall during that period (e.g., at S2313, S2314, S2379, S2435, S2436), with a slight decline during 2023 due to dryer conditions. The observed levels imply hydraulic gradients away from the lake and towards the mine adjacent to extracted longwalls (see also Figure 19); however, gradients remain towards the lake beyond the influence of the extracted longwalls. Perched aquifers are apparent in upper parts of the HBSS which can persist after mining.

A plot of model predicted piezometric head versus observed head at piezometers adjacent to Lake Avon as of the end of Longwall 19 is shown in Figure 12. The plot shows that, for 58% of piezometers, observed head is similar to, or higher than, the numerical model prediction. Therefore, the model predictions remain generally accurate as of Longwall 19 or tend to slightly over-estimate groundwater drawdown adjacent to Lake Avon.

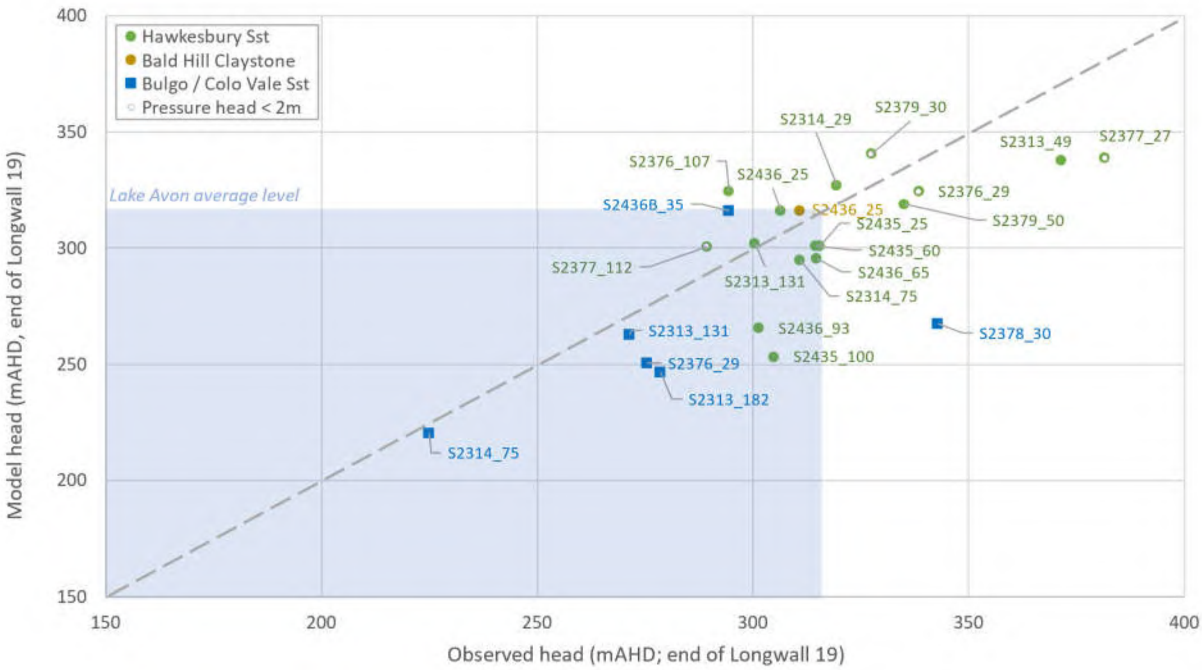

Figure 12. Modelled versus observed piezometric head for Avon Dam monitoring sites.

Hydraulic gradients away from the lake imply groundwater flow from the lake to the mine and seepage loss from the lake. The rate of seepage loss is governed by the hydraulic gradient and permeability (measured and expressed as hydraulic conductivity) of the intervening strata which has been tested prior to mining (at most sites) and following extraction of longwalls. Estimates of seepage loss have been calculated using several approaches, including regional and local scale numerical models (see Section 3.4.3, below)

3.2.4 Potentially transmissive geological structures

Geological structures such as faults and fracture zones have the potential to form conduits for groundwater flow to the mine and transmit drawdown to receptors distant from the mine. The permeability structure of faults is related to the internal structure, rock type, the prevailing stress regime and post-movement mineralisation of the fault zone (Bense et al., 2013). A geological assessment, including mapped and potential structures was carried out prior to mining in Area 3B (BHP Billiton, 2013). The geology between Avon Reservoir and Area 3B mine workings was further assessed by South32 (2018) and the geology associated with Longwall 19A in 2022.

In relation to Longwall 19, there are two igneous dykes mapped within the Wongawilli Coal Seam within the longwall footprint (Figure 13). The dykes are not mapped at ground level as outcrop, nor associated with surface lineaments. At the western end of Longwall 19, two mapped surface lineaments intersect the longwall footprint and extend towards Wongawilli Creek. The lineaments are associated with a pervasive West-Norwest trending joint pattern in the Hawkesbury Sandstone. During the extraction of Longwall 19 there were no anomalous inflows or changes in groundwater chemistry associated with mining through or beneath the mapped structural features (Section 3.1).

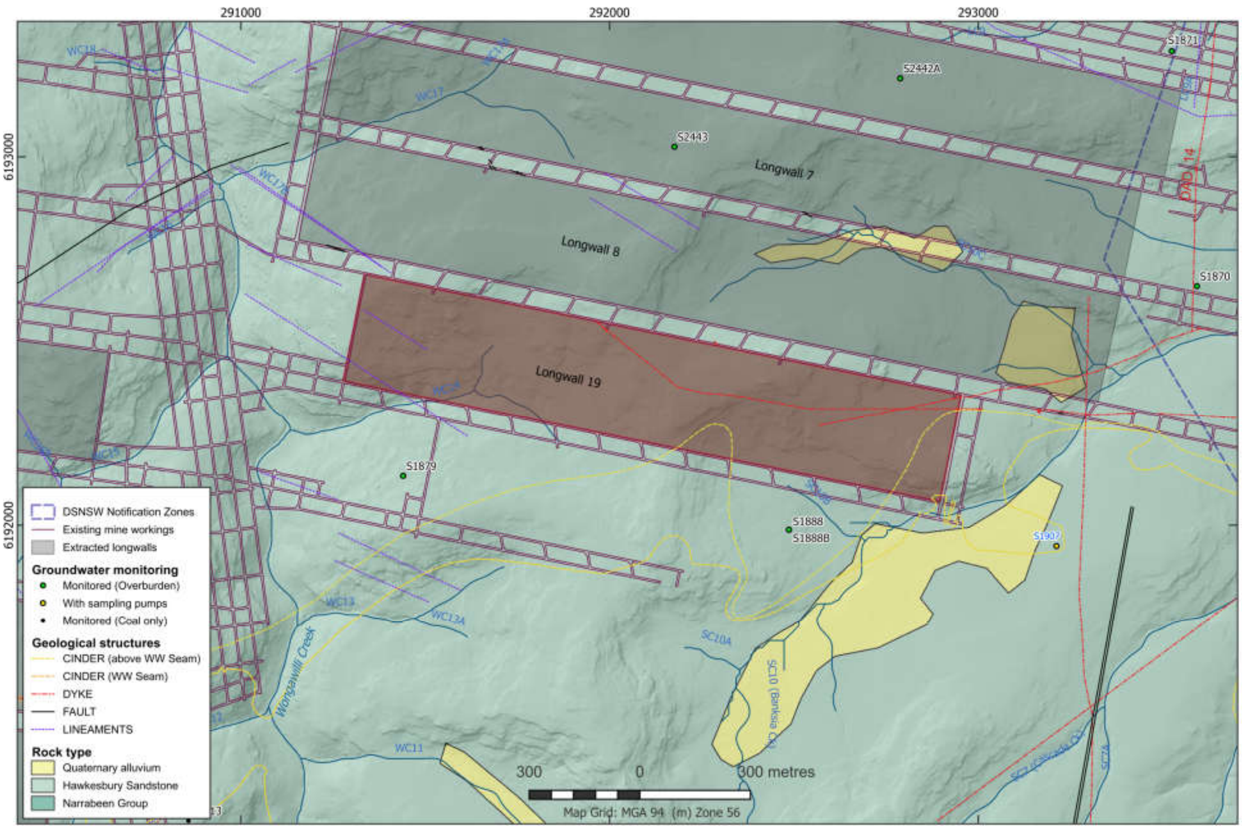

Figure 13. Surface geology and mapped structural features near Longwall 19

SRK (2020) assessed faults and surface lineaments above and around Dendrobium Mine. The assessment included analysis of mine subsidence data (LiDAR) to determine if surface subsidence is controlled by or reactivates mapped surface lineaments. The study identified several very minor linear anomalies directly above mined longwall panels in Area 3B, with none identified in Areas 2 or 3A. The study concluded that the potential for reactivation of lineaments extending outside the planned mining areas was assessed as low. A separate study HGEO (2020c) assessed of the spatial relationship between piezometric response in vibrating wire piezometers (anomalous drawdown compared with predictions) and proximity to known or inferred geological structures. The study concluded that anomalous drawdown responses are not correlated with mapped structural features. This is consistent with the observations in the underground mine that large inflows of groundwater are typically not associated with mapped linear features such as igneous dykes and faults, and with experience elsewhere in the Southern Coalfield (Doyle, 2007; Tonkin and Timms, 2015).

3.2.5 Elouera Fault

The Elouera Fault is located to the south of Area 3B, between Longwall 18 and Elouera Mine Longwall 8. The fault trends approximately east-west and broadly parallel to the northern tributary to Native Dog Creek (NDT1). The Elouera Fault is of particular interest with respect to the extraction of Longwall 18. A detailed investigation of the Elouera fault was carried out prior to development of Longwall 18, the results of which are provided in separate reports (HGEO, 2022, 2020d).

The Elouera Fault zone is a complex fault comprising three distinct but (structurally) connected fault zones and several splay structures. The main fault plane dips to the south at between 53 and 63° (based on recent drilling) and offsets the Wongawilli Seam by up to 40 m (downfaulted to the south). The fault trace is projected to intersect the surface on the northern slopes of the NDT1 valley. Drilling has identified the fault within the CVSS and drilling at Swamp 35b intersected a fault zone likely associated with Elouera Fault within the lower part of the HBSS. Several lineaments trending sub-parallel to the fault are apparent in Lidar topographic data; however, the fault has not been identified in surface outcrop.

In respect of groundwater effects related to the fault, the following is noted:

- No anomalous mine inflow was associated with intersecting structures such as dykes or faults during or following extraction of Longwall 18.
- In piezometers located within the fault plane (S2441B and S2465), groundwater pressures change in unison with piezometers located in immediately adjacent strata on both sides of the fault relative to Longwall 18 (Figure 14, Figure 15). There is no anomalous drawdown within the fault core, indicating that the fault is not anomalously conductive along the fault plane (which passes close to Longwall 18).
- At S2490, located 65 m south of the projected fault trace and at a similar distance from Swamp 35b, depressurisation is apparent in the Colo Vale sandstone. No drawdown is apparent in piezometers within the Hawkesbury Sandstone (Figure 16).
- Time-Domain Reflectometry (TDR) cables are installed in two inclined boreholes that intersect the Elouera Fault, S2441B and S2465. The cables were installed to identify reactivation movement on the fault plane due to mining effects. As of the most recent data acquisition (1/5/2023) slight anomalies are noted towards the base of S2441B (205 m); however, there are no anomalies associated with the main fault plane.

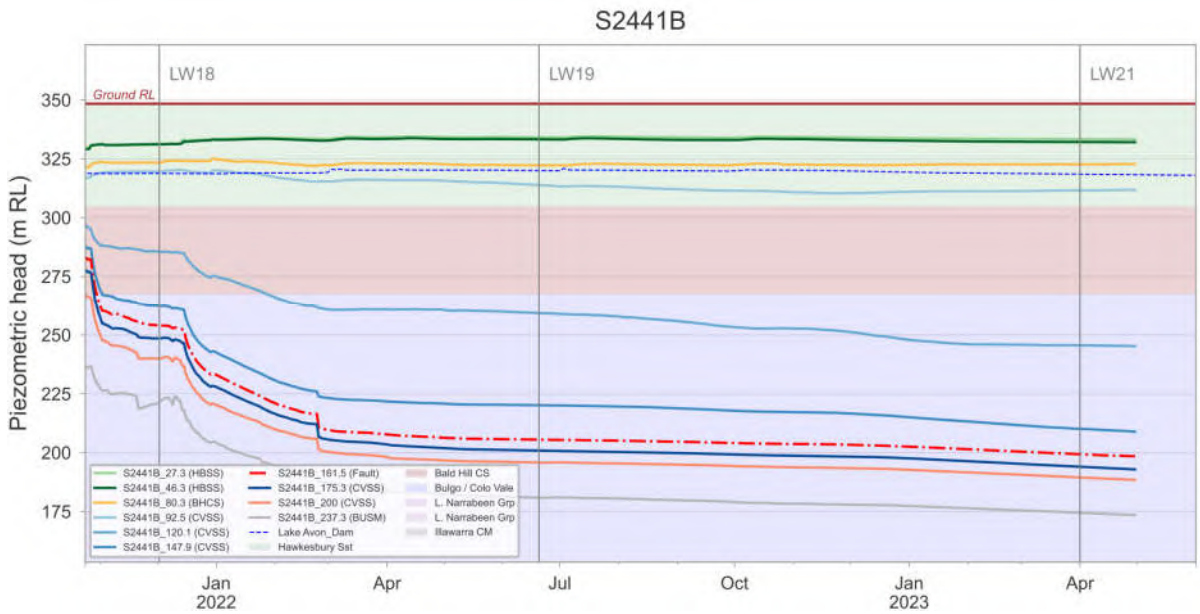

Figure 14. Groundwater hydrograph for Elouera fault monitoring bore S2441B (Site 1)

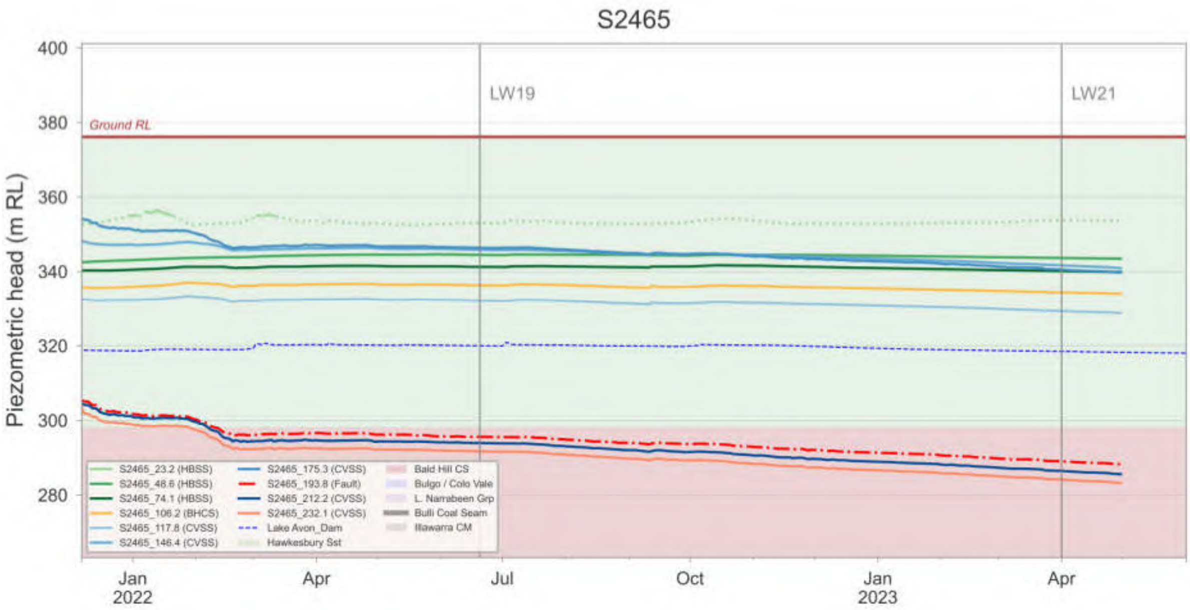

Figure 15. Groundwater hydrograph for Elouera fault monitoring bore S2465 (Site 2)

Figure 16. Groundwater hydrograph for Elouera fault monitoring bore S2490 (Site 3)

3.3 Deep groundwater levels – spatial patterns

The spatial distribution of piezometric heads and drawdown in piezometric head due to mining is shown in the following figures:

1. Bores where there are one or more sensors within the HBSS that record near-zero pressure head (assumed to be desaturated; Figure 17).

2. The change (drawdown) in average piezometric head between the end of Longwall 5 (November 2009) and the end of Longwall 19 (Figure 18 to Figure 22); and

3. The piezometric head in the lower HBSS relative to the Lake Avon FSL and recent lake levels as of the end of Longwall 19 (Figure 19).

For piezometers that ceased operation within the last two years, or where there are gaps in the data, values have been extrapolated (or interpolated) as appropriate. Piezometers that have been inactive for 2 years or more are excluded from the analysis. It should be noted that calculations of drawdown since 2009 are subject to uncertainty because of the inconsistency in the depths of sensors within each geological unit between monitoring bores.

3.3.1 Spatial distribution in groundwater drawdown

Maps of observed and estimated drawdown are shown for subunits within the HBSS, BGSS (and stratigraphic equivalent within the CVSS), and the SBSS. Analysis concentrates on the Triassic sandstone formations since those units are most relevant to connected surface water processes; drawdown in the Wongawilli and Bulli coal seams is shown in time series plots (hydrographs). The coal seams, being typically more permeable than the host coal measures and overlying Narrabeen Group, depressurise well in advance of mining, defining a broad zone of drawdown around current mining areas that overlaps with residual drawdown from neighbouring historic mines.

Analysis of drawdown in the HBSS focusses on the lower 70 m of the formation (lower HBSS). Comparison of drawdown in the upper and middle parts of the formation is problematic and potentially misleading (an underestimate) because of the number of sensors within desaturated strata. The number of sensors that record zero or near-zero (< 2 m H_2O pressure head) is shown in Figure 17. It is common for bores located above extracted longwalls to show near-zero pressure head conditions in multiple sensors implying drawdown of head below those sensors. The typical depth to water on the plateau areas prior to mining was in the order of 25 to 30 m. Therefore, sensors that are at less than 15 m depth are plotted separately (as green symbols) since it is more likely that those sensors would be desaturated under natural conditions.

Within the lower HBSS, maximum drawdown exceeding 45 m is observed in piezometer arrays above and immediately surrounding extracted longwalls. However, review of individual hydrographs (Appendix A) indicates that most strata above extracted longwalls are depressurised with evidence for perched aquifers forming above low-permeability horizons. Therefore, drawdown values above extracted longwalls should be considered as minima. Drawdown in the HBSS reduces rapidly away from the mined longwalls. Bores at which a groundwater increase is recorded relative to 2009 (“negative drawdown”) are shown as zero. Several piezometers record groundwater recovery relative to the baseline due to the high rainfall between 2020 and 2022, with many piezometers showing a slight decline in 2023 as a result of drier conditions.

Piezometric head in the lower HBSS compared with the water level in Lake Avon is shown in Figure 19. Several bores located between extracted longwalls in Area 3B and Lake Avon record piezometric heads that are below the current lake level, consistent with a gradient away from the reservoir as described previously. It should be noted that some bores contain sensors at higher stratigraphic levels that record piezometric head above the lake level (e.g., S2313_49 m) and therefore the hydraulic gradient within the barrier zone varies with both location and elevation. In addition, there is evidence for minor perched water tables persisting in some sensors. Bores at which no colour symbols are shown are those for which recent data were unavailable at the time of reporting (< 90 days before the end of the Longwall).

Observations of piezometric head in the BGSS are mainly restricted to near the extracted and planned longwalls (Figure 20 and Figure 21). Drawdown exceeding 100 m is estimated at several bores (e.g., S1932, S2421). Drawdown decreases away from the mined areas such that less than 30 m of drawdown is estimated at distances of 1.2 km or more north of Area 3B (S2341, S2006).

Significant depressurisation is expected in the BGSS (and units below) due to subsidence-related fracturing extending upwards from the goaf into these units.

The SBSS (Figure 22) is depressurised in the vicinity of the mined areas. As with the BGSS, estimated drawdown decreases to the northwest with distance from Area 3B; however, depressurisation of ~79 m is observed to the northeast (S2059) due to residual drawdown from neighbouring mines.

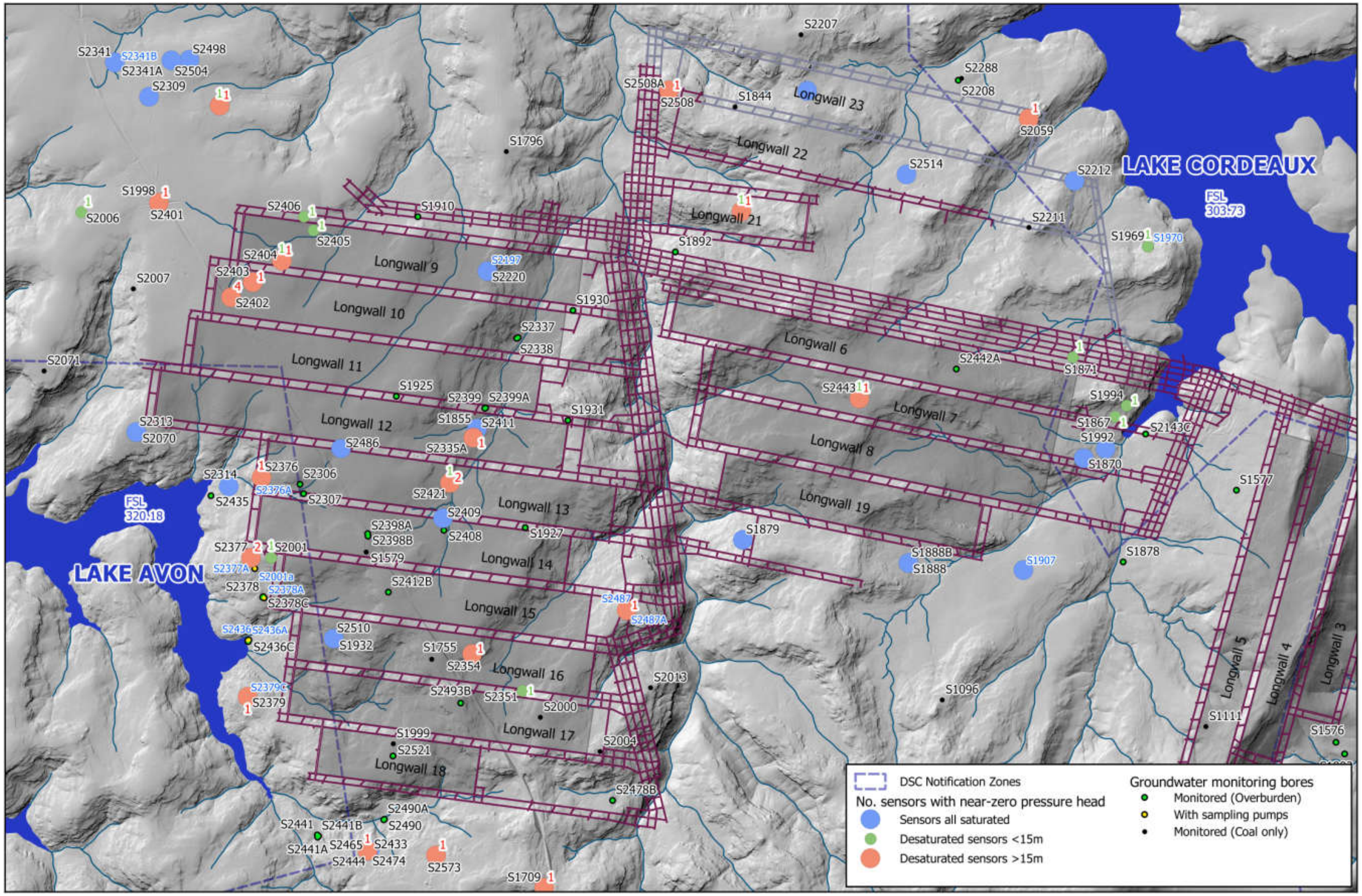

Figure 17. Sensors recording desaturated conditions in the Hawkesbury Sandstone (2023)

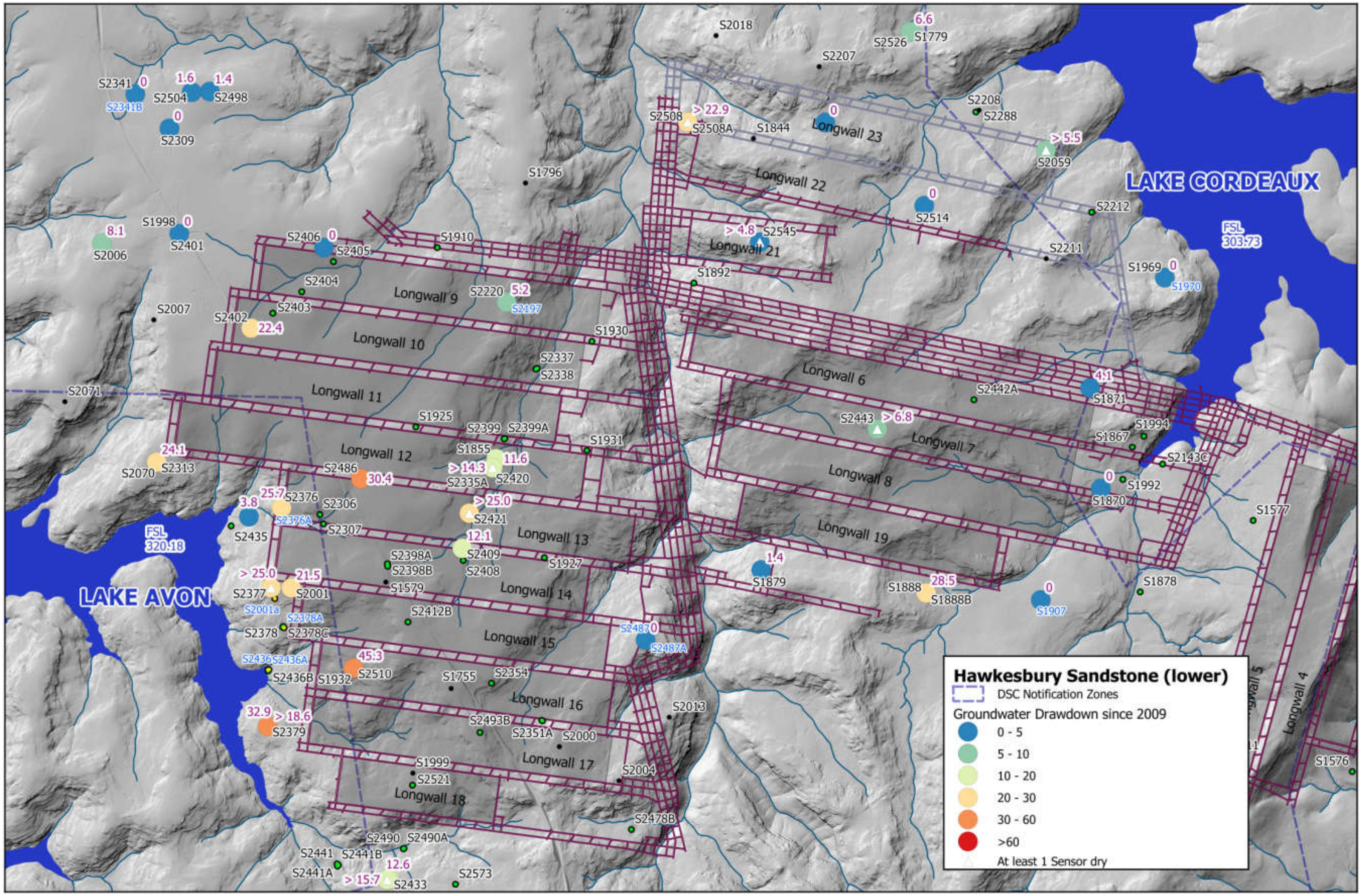

Figure 18. Drawdown in piezometric head in the lower Hawkesbury Sandstone (2009-2023)

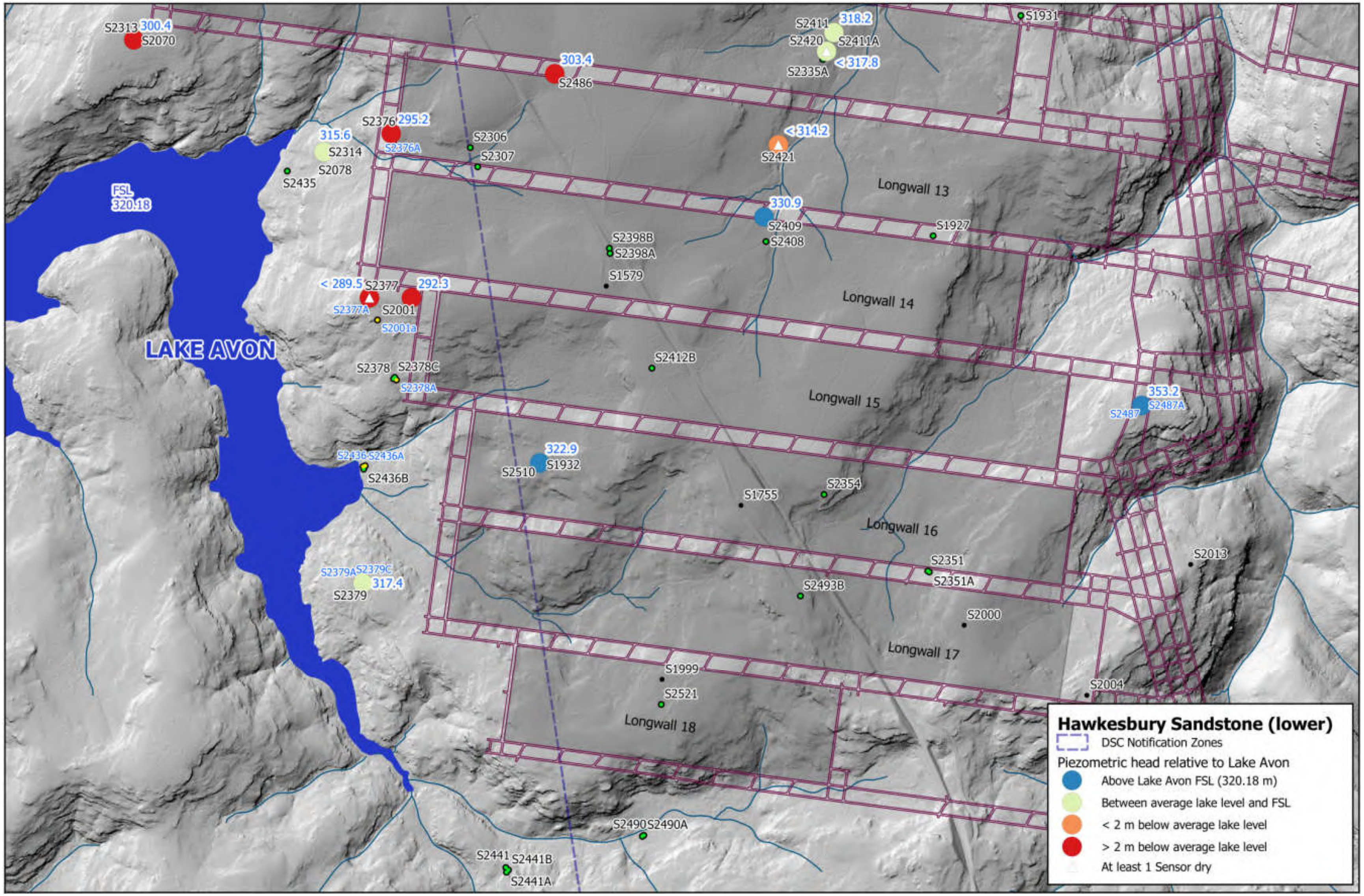

Figure 19. Piezometric head in the lower Hawkesbury Sandstone relative to Lake Avon (2023)

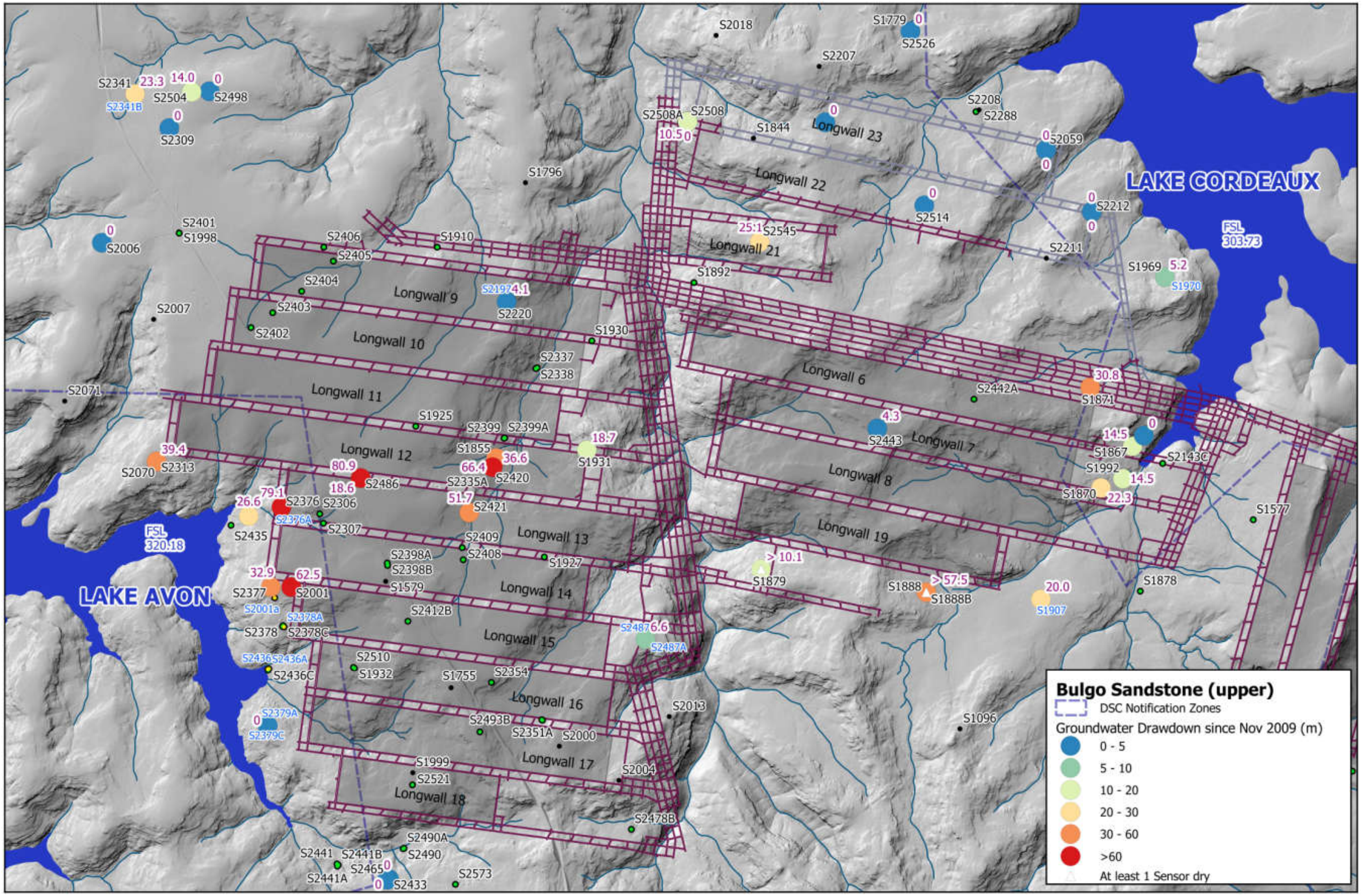

Figure 20. Drawdown in piezometric head in the upper Bulgo Sandstone (2009-2023)

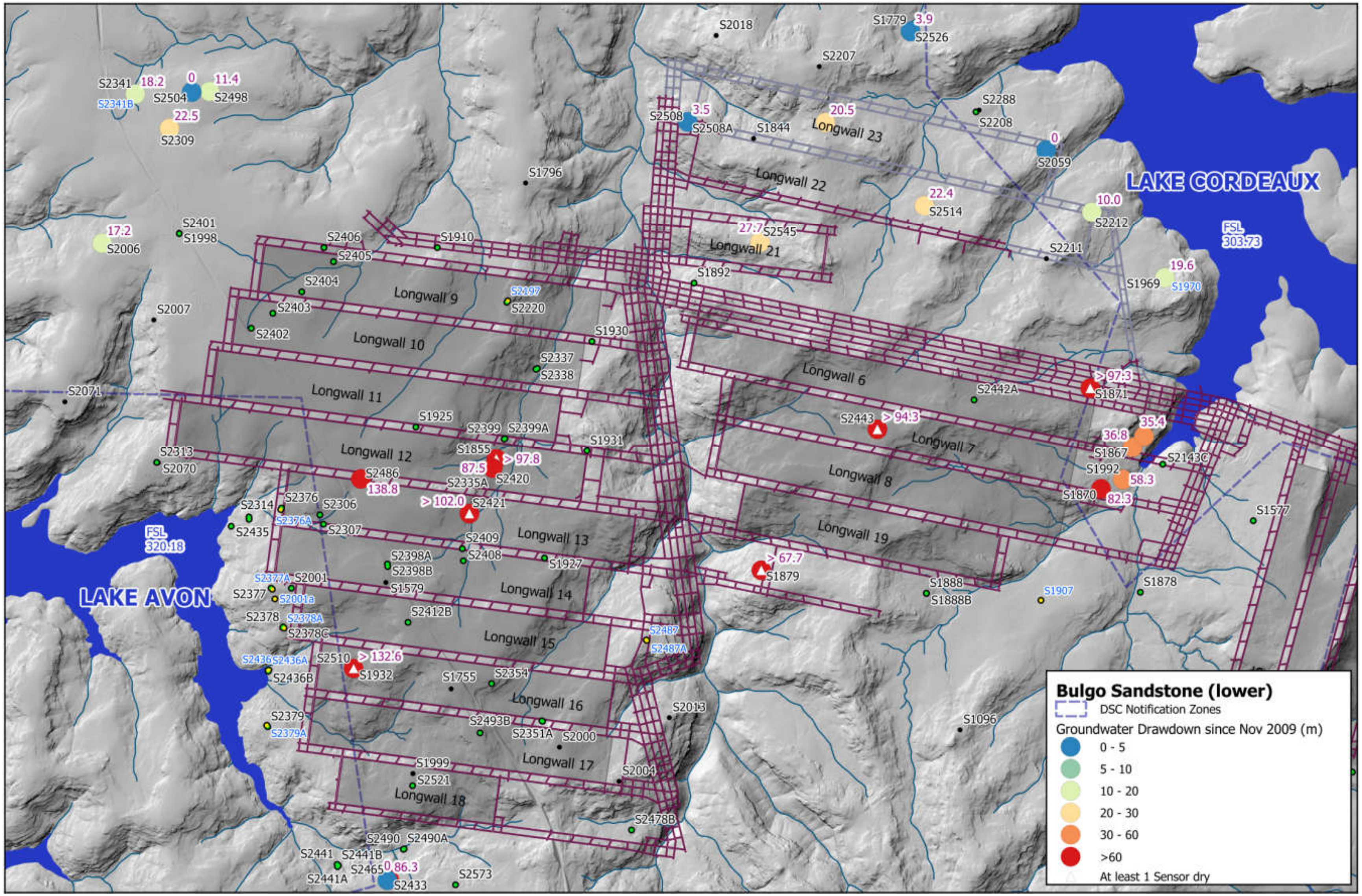

Figure 21. Drawdown in piezometric head in the lower Bulgo Sandstone (2009-2023)

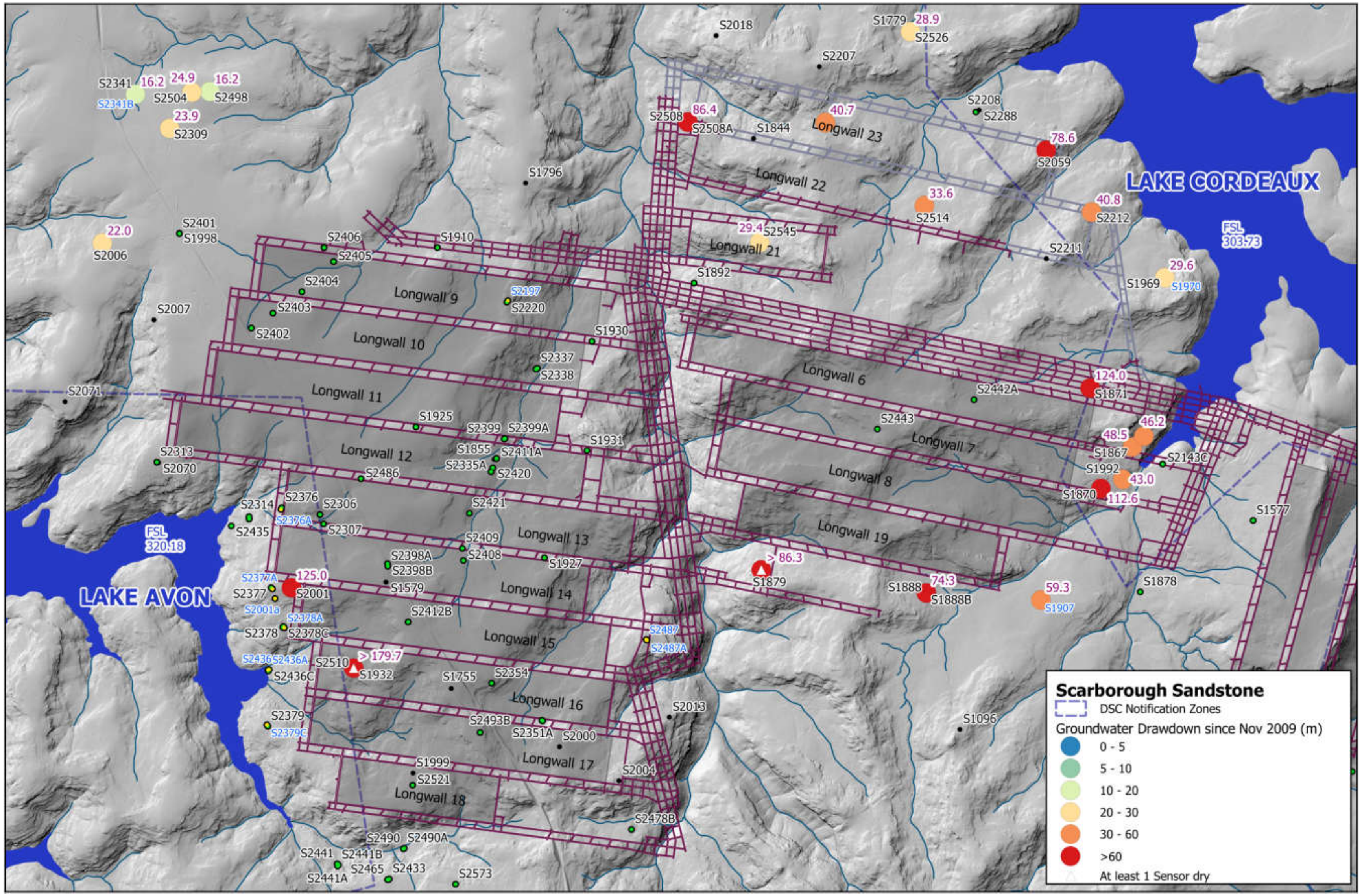

Figure 22. Drawdown in piezometric head in the Scarborough Sandstone (2009-2023)

3.4 Comparison with model predictions

3.4.1 Deep groundwater levels

In this section observed deep groundwater levels are compared with those predicted in the most recent groundwater impact model for Dendrobium Mine (Watershed Hydrogeo, 2020). The comparison was carried out by extracting the predicted heads at representative sensors as of the end of Longwall 19 from the original model output files (provided to HGEO by Watershed Hydrogeo) and plotting those heads against the observed heads (as presented in Section 3.3). It is therefore an independent assessment of the ongoing accuracy of the groundwater model predictions.

Figure 23 is a plot of the modelled and observed heads as of the end of Longwall 19. The data are coloured according to the formation, and bores that are located adjacent to Lake Avon are highlighted with concentric circles (holes, S2313, S2314, S2376, S2377, S2378, S2379, S2435, S2436, and holes S2001, S2194). Data from an accurate and well-calibrated model should cluster along the diagonal 1:1 line. Points plotting below the line indicate that observed heads are higher than predicted (i.e., the model over-predicts drawdown and is conservative), while points that plot above the line indicate that the model under-predicts drawdown at those locations. In previous reviews, sensors with near-zero pressure head were not plotted (since for "dry" piezometers the apparent piezometric head is simply the sensor elevation rather than an observed groundwater level). In this review data for sensors with near-zero pressure head (< 2m) are plotted as hollow triangles.

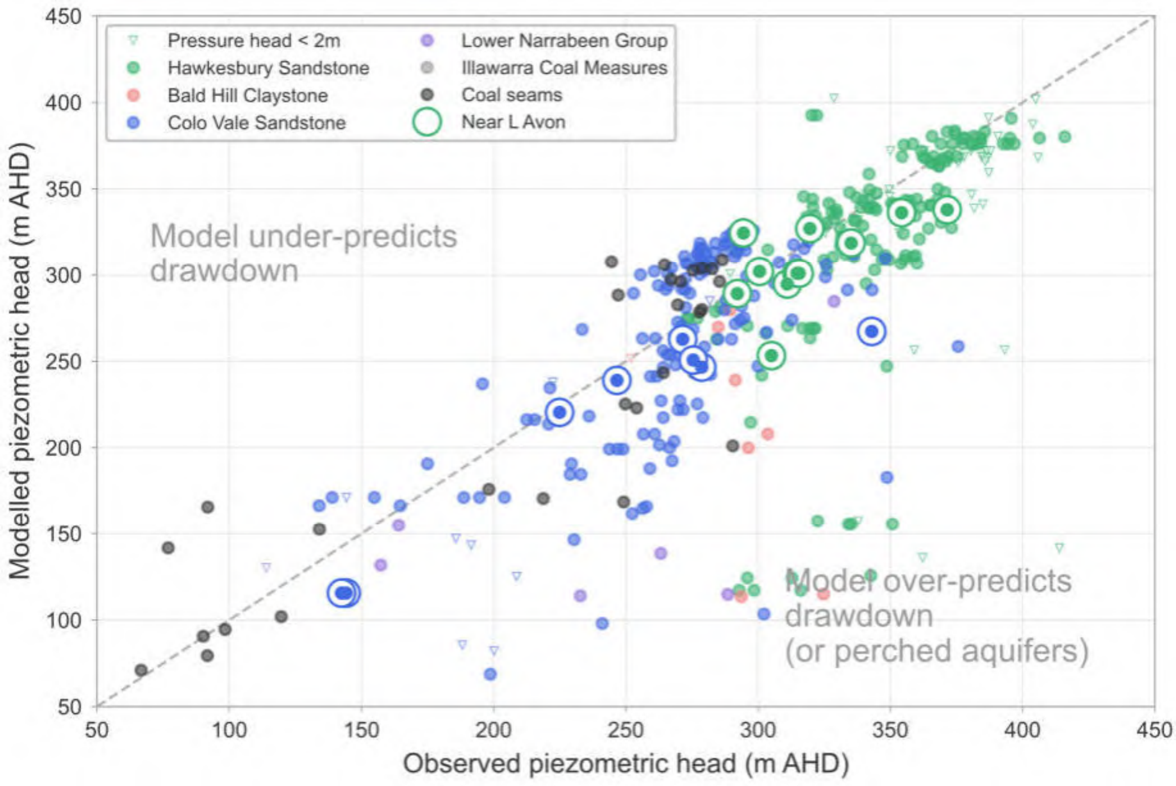

Figure 23. Observed versus model predicted heads at the end of Longwall 19

The following are concluded from the comparison in Figure 23:

- 65% of the observed-modelled piezometric head pairs plot below the 1:1 line indicating that the model is mostly conservative with respect to predicted groundwater drawdown impacts. This is a similar proportion to the previous longwall assessment period.

- Model predictions for piezometers in the HBSS plot close to the 1:1 line, particularly those in the range 280 to 350 m head, corresponding to the elevation range for watercourses in Area 3B.

- Model and observed heads for piezometers within the HBSS adjacent to Lake Avon plot close to the 1:1 line. Observed heads within this barrier zone are therefore generally in line with model predictions.

3.4.2 Mine water balance

Figure 24 is a plot of the modelled and observed groundwater inflow to the Dendrobium underground mine during the extraction of Longwalls 6 to 19. The numerical model is set up with stress periods corresponding to the originally planned longwall start and end dates and calibrated with groundwater monitoring and inflow data up to 2020. The plot shows that the model predictions match observed mine inflows closely over most of the timeseries. During the severe drought of 2017-2019 mine inflows declined relative to predictions; whereas heavy rains during 2022 resulted in a mine inflow peak that exceeded predictions for several months. The latter departure is reasonable since the rainfall in 2022 was much higher than any year in the model calibration data set, and not anticipated in the prediction rainfall scenarios. Nevertheless, the model continued to provide a reasonable and slightly conservative estimate of mine inflow for long-term average rainfall conditions.

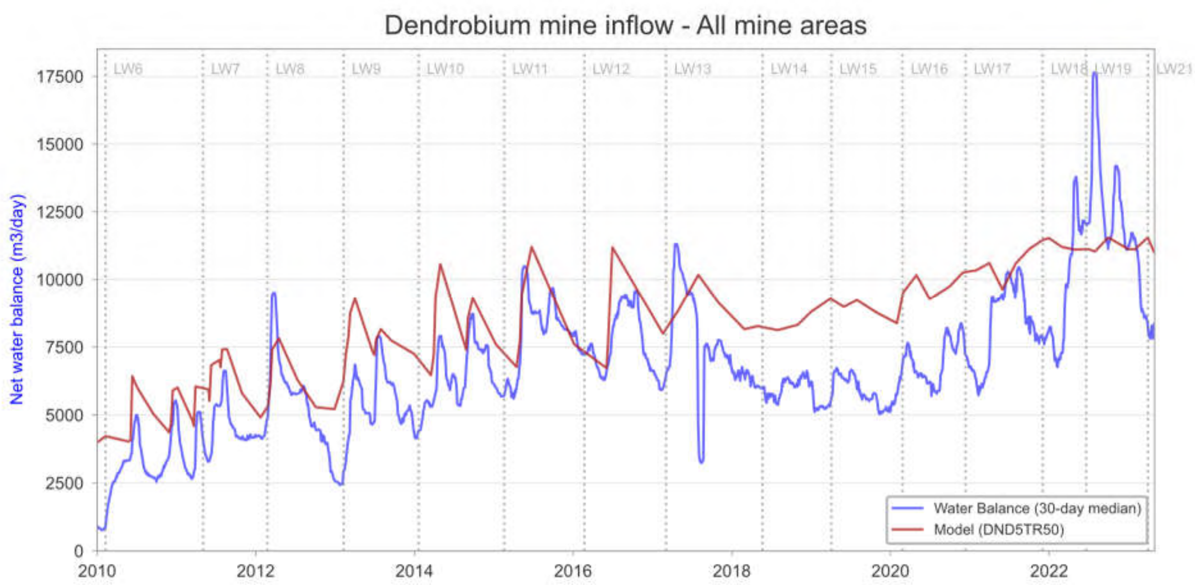

Figure 24. Observed versus model predicted mine groundwater inflow.

3.4.3 Seepage loss from Lake Avon

The actual rate of seepage loss from Lake Avon cannot be measured directly and can only be estimated by calculation (using for example, Darcy's Law) or by numerical modelling. All estimates rely on assumptions relating to the permeability and hydraulic head distribution within the sandstone barrier zone between the lake and the mine.

Forecast estimates of the net loss (seepage) from Lake Avon to of the end of Longwall 18, based on the regional groundwater model range between **0.09 and 0.45 ML/day** (Watershed Hydrogeo, 2020). This loss comprises induced leakage from, and reduced seepage to, the Lake, relative to pre-mining conditions. The estimated range is within the tolerable loss limit of 1 ML/day prescribed by Dams Safety NSW (DSC, 2014).

A local-scale numerical model was used to assess potential changes to seepage losses from lake Avon as a result of measured changes in permeability in the barrier zone between Area 3B and the lake (HGEO, 2021b). The model was last revised in August 2021 to include testing of strata permeability at location AD8 (S2379) following part extraction of Longwall 17. Note that drilling of additional monitoring bores between Longwall 18 and Lake Avon was not possible due to steep and inaccessible terrain. The revised model estimated a seepage loss of **~0.89 ML/day** adjacent to Longwalls 12 to 18 (to the southern extent of the Native Dog Creek inlet). The slightly higher estimate from the local-scale model reflects the conservative assumptions used, such as uniform steady state flow towards the mine and complete desaturation above the longwall goaf.

3.5 Groundwater chemistry

Previous reviews have shown that there is no clear spatial pattern in the distribution of groundwater quality in HBSS and BGSS bores. Time series plots of groundwater salinity measured using electrical conductivity (EC) and pH for samples collected from monitoring bores in Areas 2, 3A, and 3B are presented in Appendix C; the most recent results and trends are summarised in Table 3. Adverse trends are identified where recent samples define a consistent freshening trend (decreasing EC). Such trends in bores located adjacent to water storage reservoirs may indicate migration of fresh surface waters towards the mine. Despite efforts to avoid the use of drilling additives during the installation of sampling pumps, it is still common for samples collected in the first few months or years following installation to be tainted by bentonite, cement grout or other compounds. Influence from grout or bentonite typically manifests as high EC and anomalously high pH (>8.5 to 11), making it difficult to discern background groundwater trends (e.g., S1870_160m, S2436_90m).

Two other sampling pumps are identified in this report as yielding samples with possible freshening trends: S2314_30m (Figure 25) and S2001_63m. Trends identified in previous EOP reports have resolved or proved spurious as more data has been collected. Therefore, it is recommended that S2314_30m and S2001_63m be resampled in late 2023 and reviewed in the next EOP report. The sample from S2314_30m should be submitted for analysis of tritium and radiocarbon to allow identification of trends in modern water content.

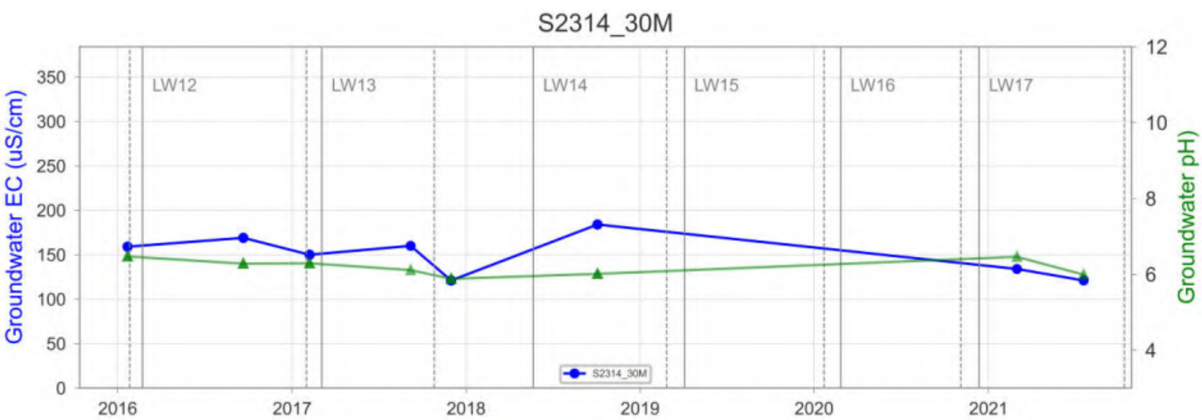

Figure 25. Timeseries plot of EC and pH for samples collected from S2314_30m

Table 3. Summary of EC measurements at monitoring bores

Bore ID	Depth (m)	Unit	Samples	Last sample	EC (µS/cm)	pH	Comment / trends
S1870	10m	HBSS	5	21/07/2021	67	5.68	No adverse trends
S1870	16.5m	HBSS	5	21/07/2021	74	5.81	No adverse trends
S1879	10m	HBSS	2	15/10/2019	75	4.60	Insufficient data
S1879	58m	HBSS	2	15/10/2019	233	6.60	Insufficient data
S1888	7.3m	HBSS	3	21/12/2021	82	6.55	No adverse trends
S1888	10m	HBSS	1	16/10/2019	102	5.54	Insufficient data
S1907	10m	HBSS	1	02/03/2020	74	6.09	Insufficient data
S1907	23.5m	HBSS	1	02/03/2020	77	6.24	Insufficient data
S1934	55m	HBSS	13	12/09/2022	114	6.16	No adverse trends
S1970	43m	HBSS	15	21/04/2021	86	5.90	Sparse data since 2014
S2001	63m	HBSS	7	14/12/2021	123	5.97	EC lower than previous
S2313	54m	HBSS	7	14/06/2022	80	5.20	No adverse trends
S2314	30m	HBSS	8	19/07/2021	121	5.99	Declining EC since 2019
S2314	75m	HBSS	15	28/04/2023	126	6.23	No adverse trends
S2361	70m	HBSS	3	01/07/2021	1830	6.86	Increasing EC
S2365	70m	HBSS	1	01/07/2021	292	6.85	Insufficient data
S2376	30m	HBSS	2	15/02/2022	506	7.34	Insufficient data
S2376	102m	HBSS	2	15/02/2022	147	6.63	Insufficient data
S2377	34m	HBSS	3	19/07/2021	79	5.07	No adverse trends
S2377	113m	HBSS	4	19/07/2021	84	5.51	No adverse trends
S2378	29m	HBSS	2	26/08/2022	97	6.02	Insufficient data
S2378	89m	HBSS	5	26/08/2022	154	6.29	No adverse trends
S2379	47m	HBSS	5	10/05/2023	82	5.16	No adverse trends
S1879	200m	BGSS	2	15/10/2019	639*	8.74	Insufficient data
S1907	167m	BGSS	1	02/03/2020	868*	11.10	Insufficient data
S1970	109m	BGSS	14	21/04/2021	309*	8.99	Sparse data since 2014
S2313	138m	BGSS	7	14/06/2022	111	5.90	No adverse trends
S2313	194m	BGSS	7	14/06/2022	504	8.02	Initially high EC, no trend since
S2314	128m	BGSS	15	28/04/2023	348	7.46	Initially high EC, no trend since
S2341A	228m	BGSS	1	02/08/2018	1400	7.36	Insufficient data
S2376	169m	BGSS	2	15/02/2022	523	7.46	Insufficient data
S2379	128m	BGSS	5	10/05/2023	479	7.83	No adverse trends
S2436	35m	BGSS	10	28/04/2023	137	6.39	Sparse data since 2014
S2436	90m	BGSS	10	28/04/2023	476	7.77	Initially high EC, no trend since
S1870	160m	SBSS	5	21/07/2021	264*	9.87	Declining EC since 2015
S1886	22m	SBSS	44	19/04/2023	440	7.67	No adverse trends
S1886	30m	SBSS	44	19/04/2023	554	7.94	No adverse trends
S1886	38m	SBSS	44	19/04/2023	565	8.11	No adverse trends

Note: * Grey shading = Results likely affected by bentonite pack near pump intake; Orange shading = declining EC trend.

4. CONCLUSION

The following conclusions are made with respect to the assessment of groundwater conditions following the completion of Longwall 19:

- The mean total mine inflow during Longwall 19 extraction was 12.0 ML/day which represents a 32% increase compared with the previous longwall. The increase is primarily due to the very high rainfall during the longwall extraction period and the previous two years. The net mine water balance is dominated by pumping from Area 3B (72 % of total), with Area 3A representing only 6.5 % of inflows. No anomalous inflow due to intersecting water-bearing structures such as faults or dykes was reported during the extraction of Longwall 19.
- Isotopic tracers of modern water (tritium and 14C) indicate that modern water contributes in the order of ~5% to ~10% of inflow to the mine.
- Groundwater salinity (as indicated by electrical conductivity – EC) shows a general increase with depth below the surface. A declining trend in EC is reported in two monitoring bores (S2314_30m and S2001_63m). Trends identified in previous EOP reports have resolved or proved spurious as more data has been collected. Therefore, it is recommended that S2314_30m and S2001_63m be resampled in late 2023 and reviewed in the next EOP report.
- Mining of Longwall 19 resulted in continued depressurisation of the target coal seam and overlying strata in line with numerical model predictions. Importantly, for piezometers installed in the barrier zone between Lake Avon and Area 3B, observed head is similar to, or higher than, the numerical model prediction. Therefore, the model predictions are generally accurate as of Longwall 19 or tend to over-estimate groundwater drawdown.
- Piezometers installed after longwall extraction indicate significant depressurisation throughout all strata and throughout the Hawkesbury Sandstone (HBSS) in most holes. Holes drilled above extracted longwalls provide evidence for groundwater perching and recovery in the years following mining. Drawdown in the HBSS reduces with distance and is typically negligible at distances greater than 1.2 km from the goaf footprint.
- Piezometers installed along the barrier zone between Lake Avon and extracted longwalls in Area 3B show declines in piezometric heads to levels below contemporaneous water levels in Lake Avon and changes in strata permeability due to mine subsidence. Seepage losses from Lake Avon are estimated to be in the range 0.09 to 0.89 ML/day as at the end of mining in Area 3B. The estimates are within the tolerable loss limit of 1 ML/day prescribed by Dams Safety NSW and supported by the low and consistent levels of tritium and 14C in mine inflow water in Area 3B.
- The Elouera Fault is located to the south of Area 3B, between Longwall 18 and Elouera Mine Longwall 8. IMC carried out a detailed hydrogeological investigation of the fault prior to Longwall 18 which concluded that the fault was unlikely to form a conduit to flow. Subsequent monitoring during Longwall 19 confirms this to be the case.

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APPENDIX A: List of monitoring bores

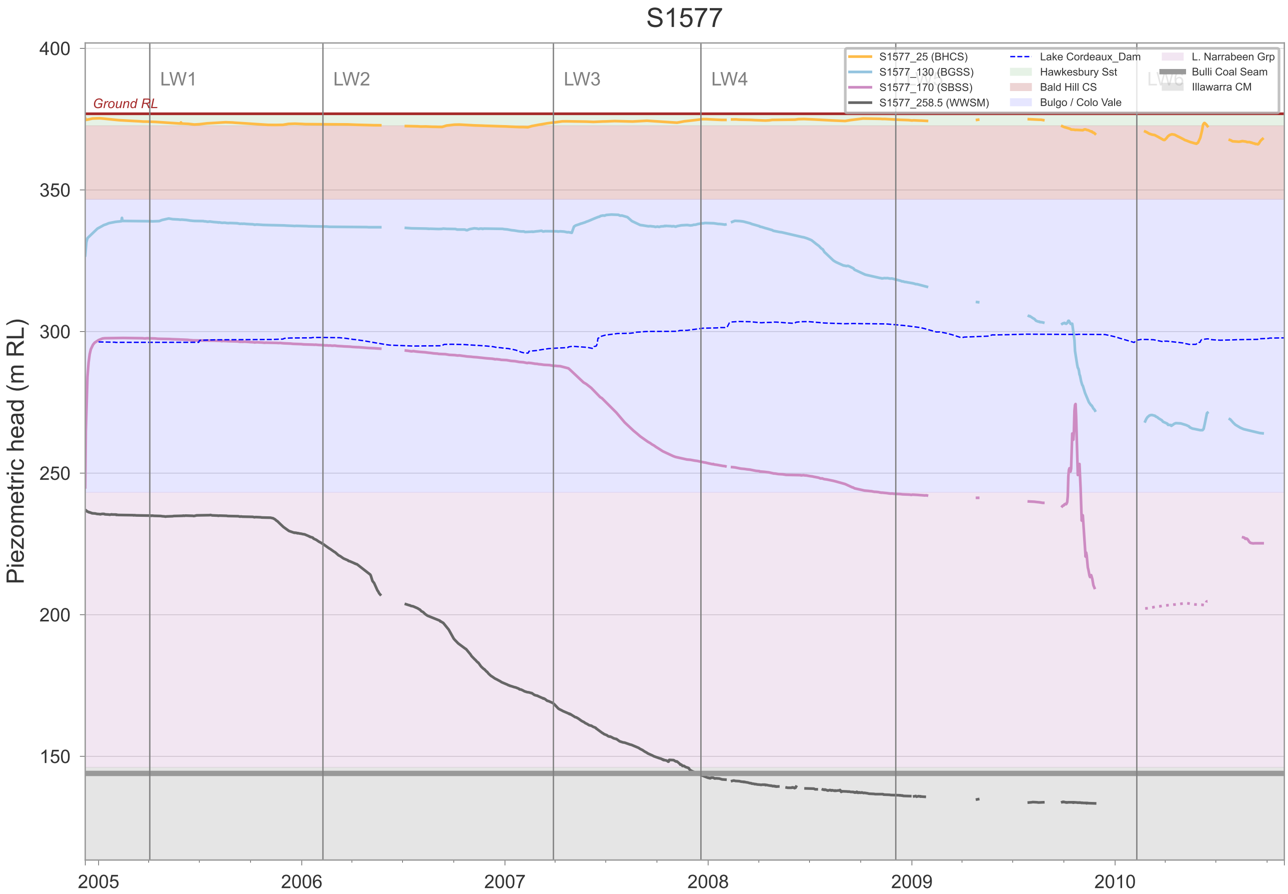
Dendrobium groundwater monitoring bores

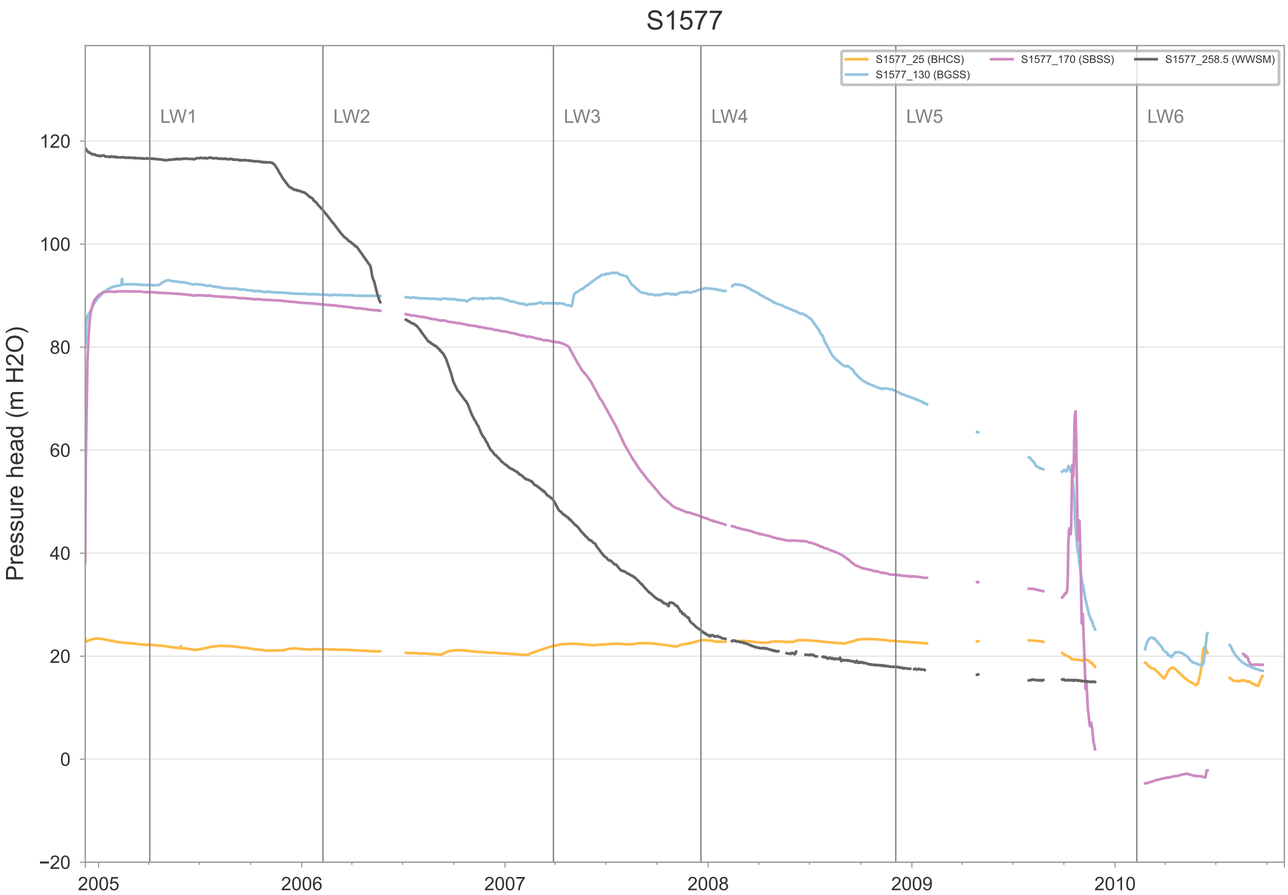
Bore ID	Alt_Name	MGA_mE	MGA_mN	Col_RL	Mine_Area	Sensors	First_record	Last_record	Years	%with_data
S1577	Dendrobium DDH 38	294558.0	6192446.6	376.9	Den 2	4	8/12/2004	23/09/2010	5.8	81.3
S1647B	Dendrobium 45 A to C	297312.3	6191093.7	360.1	Den 1	7	21/07/2005	21/02/2011	5.6	83.6
S1709	DC Elouera DDH 8	290186.4	6189934.4	434.3	Den Other	8	1/03/2005	24/05/2023	18.2	66.5
S1710	DC Elouera DDH 9	290258.0	6189645.7	432.5	Den Other	4	20/05/2005	23/05/2023	18	90.2
S1719	DC Dendrobium DDH 56	291202.0	6193277.0	413.6	Den 3A	1	16/06/2005	18/02/2010	4.7	91.9
S1739	DC Dendrobium DDH 62	289683.6	6191798.7	423.7	Den 3B	1	3/09/2005	19/01/2019	13.4	71.4
S1755	DC Dendrobium DDH64	289475.4	6191380.2	433.3	Den 3B	2	11/01/2006	24/04/2020	14.3	73.8
S1758	Dendrobium DDH 65	288586.6	6193106.9	408.8	Den 3B	2	27/01/2006	10/06/2014	8.4	72.1
S1796	Dendrobium DDH 69	289946.6	6194587.4	398.6	Den 3B	1			0	
S1800	Dendrobium DDH 70	289933.4	6193996.5	392.5	Den 3B	2	26/04/2006	31/08/2011	5.3	90.4
S1844	Dendrobium DDH 76	291391.1	6194868.8	375.6	Den 3C	2	23/08/2006	29/04/2023	16.7	71.1
S1845	Dendrobium DDH 77	291464.0	6193770.0	399.7	Den 3A	2	29/11/2006	4/01/2010	3.1	90.6
S1848	Dendrobium DDH 79	295620.7	6191166.3	315.5	Den 2	6	6/09/2006	18/04/2023	16.6	100
S1855	Dendrobium DDH 82	289746.5	6192833.2	366.6	Den 3B	2	12/12/2006	27/07/2016	9.6	88.8
S1867	ED Dendrobium DDH 84	293792.6	6192912.5	346.0	Den 3A	11	21/03/2007	30/04/2023	16.1	94.2
S1870	ED Dendrobium DDH 85	293593.2	6192648.2	351.5	Den 3A	12	3/02/2007	11/02/2023	16	89.5
S1871	ED Dendrobium DDH 86	293525.0	6193287.1	375.6	Den 3A	12	18/02/2007	30/04/2023	16.2	91.8
S1878	ED Dendrobium DDH 91	293842.3	6191994.3	337.1	Den 3A	11	25/04/2007	7/02/2020	12.8	95.2
S1879	ED Dendrobium DDH 92	291440.3	6192133.4	379.7	Den 3A	12	8/06/2007	30/04/2023	15.9	83.3
S1885	ED Dendrobium DDH 93	291504.4	6192667.9	420.0	Den 3A	12	8/06/2007	17/05/2012	4.9	91
S1886	ED Dendrobium PDH 94	295883.8	6191719.6	307.5	Den 2	1	23/03/2007	19/04/2023	16.1	90
S1888	ED Dendrobium DDH 96	292486.5	6191987.4	381.3	Den 3A	8	1/06/2007	30/04/2023	15.9	74.5
S1889	ED Dendrobium DDH 97	292244.8	6192980.4	435.4	Den 3A	8	3/06/2007	10/08/2011	4.2	92
S1890	ED Dendrobium DDH 98	292637.3	6192490.5	407.1	Den 3A	8	1/08/2007	7/08/2012	5	100
S1892	ED Dendrobium DDH 99	291014.1	6193952.0	356.1	Den 3A	8	8/08/2008	4/04/2022	13.7	47.3
S1902	ED Dendrobium DDH 100	295241.3	6190779.8	343.1	Den 2	4	4/10/2007	19/04/2023	15.5	87.8
S1907	ED Dendrobium DDH 103	293212.2	6191943.1	371.9	Den 3A	8	26/01/2008	30/04/2023	15.3	89.5
S1908	ED Dendrobium DDH 104	288925.9	6193601.4	405.7	Den 3B	8	17/05/2008	1/05/2014	6	79.6
S1910	EDEN105	289387.4	6194176.3	377.2	Den 3B	8	30/08/2008	5/03/2019	10.5	76.5
S1911	EDEN106	288802.8	6192549.4	405.2	Den 3B	12	16/05/2008	24/05/2017	9	96.7
S1914	EDEN107	289370.0	6192511.9	414.5	Den 3B	7	30/04/2008	10/08/2017	9.3	79.4
S1925	ED Dendrobium DDH 108	289251.6	6193041.1	416.7	Den 3B	8	5/08/2008	30/06/2022	13.9	88.4
S1926	ED Dendrobium DDH 109	289660.4	6193444.9	409.0	Den 3B	8	28/08/2008	8/08/2014	5.9	96.3
S1927	ED Dendrobium DDH 110	290066.0	6192211.0	414.8	Den 3B	8	17/05/2008	23/01/2017	8.7	88.9
S1929	ED Dendrobium DDH 111	290010.6	6193398.1	337.7	Den 3B	8	28/08/2008	8/08/2014	5.9	97
S1930	ED Dendrobium DDH 112	290367.3	6193582.9	353.1	Den 3B	12	17/06/2008	10/06/2021	13	83.4
S1931	ED Dendrobium DDH 113	290335.6	6192889.9	396.4	Den 3B	9	12/08/2008	30/04/2023	14.7	79.7
S1932	ED Dendrobium DDH 114	288863.3	6191505.4	396.1	Den 3B	11	1/09/2008	10/03/2020	11.5	89.8
S1934	ED Dendrobium DDH 115	292128.0	6192398.0	427.5	Den 3A	4	31/07/2009	20/11/2022	13.3	96.6
S1969	EDEN118	293998.1	6193985.7	368.5	Den 3C	11	24/09/2009	30/04/2023	13.6	65.7
S1992	EDEN119	293732.1	6192706.8	339.1	Den 3A	8	11/05/2009	30/04/2023	14	95
S1994	EDEN120	293865.2	6192982.4	345.5	Den 3A	8	14/01/2009	30/04/2023	14.3	68.6
S1995	EDEN121	288212.4	6193662.3	404.5	Den 3B	2	12/06/2009	28/01/2014	4.6	65.6
S1998	EDEN122	287750.6	6194273.1	410.5	Den 3B	2	12/06/2009	15/01/2020	10.6	63.5
S1999	EDEN123	289232.8	6190843.7	406.4	Den 3B	2	11/07/2009	20/04/2021	11.8	83.9
S2000	EDEN124	290161.4	6191011.2	442.0	Den 3B	2	11/07/2009	9/06/2021	11.9	74.4
S2001	EDEN125	288462.6	6192020.0	413.9	Den 3B	10	7/08/2009	9/04/2023	13.7	96.6
S2002	EDEN126	288633.4	6194222.1	400.0	Den 3B	2	21/07/2009	19/02/2012	2.6	85.3
S2003	EDEN127	290571.1	6192478.0	409.4	Den 3B	2	4/08/2009	1/03/2014	4.6	10.8
S2004	EDEN128	290538.5	6190794.8	443.5	Den 3B	2	16/11/2011	22/07/2021	9.7	0
S2006	EDEN129	287263.2	6194204.3	409.1	Den 3B	10	25/07/2009	6/03/2023	13.6	76.6
S2007	EDEN130	287590.8	6193718.9	405.8	Den 3B	2	18/06/2009	17/08/2022	13.2	69.5
S2009	EDEN131	287828.2	6193092.0	402.5	Den 3B	10	10/08/2009	24/03/2016	6.6	24.1
S2013	EDEN134	290857.7	6191198.2	399.7	Den 3B	2	22/07/2009	16/08/2022	13.1	69.4
S2059	EDEN148	293245.7	6194795.1	380.8	Den 3C	11	17/08/2011	30/04/2023	11.7	64.3
S2070	EDEN150	287619.3	6192813.2	414.7	Den 3B	2	16/05/2013	23/05/2023	10	81.8
S2078	EDEN154	288190.0	6192451.9	342.0	Den 3B	2	21/06/2010	13/03/2017	6.7	96.7
S2192	S2192	289826.7	6193848.7	389.3	Den 3B	6	25/03/2013	18/11/2014	1.7	34.8
S2194	S2194	288514.9	6190978.8	371.1	Den 3B	11	14/04/2013	1/04/2018	5	98.8
S2208	S2208	292801.1	6195037.3	344.0	Den 3C	8	20/12/2014	31/10/2020	5.9	99.8
S2211	S2211	293247.0	6194106.0	397.7	Den 3C	2	3/10/2013	1/05/2023	9.6	94.5
S2212	S2212	293534.8	6194402.9	369.2	Den 3C	10	12/10/2013	30/04/2023	9.5	98.7
S2220	S2220 (AQ5)	289827.2	6193830.7	388.1	Den 3B	3	13/11/2014	30/04/2023	8.5	99.9
S2303	Dend S2303	287109.8	6196268.1	411.7	Den 3B	7	14/02/2016	7/01/2023	6.9	93.5
S2306	Swamp Bore 3 (adjacent)	288643.3	6192483.7	395.5	Den 3B	4	17/09/2015	19/06/2022	6.8	95.1
S2307	Swamp Bore 4	288665.9	6192424.6	394.5	Den 3B	4	16/09/2015	19/06/2022	6.8	95.6
S2309	Dendrobium S2309_R	287689.9	6194933.2	412.0	Den 3D	10	16/07/2015	30/04/2023	7.8	97.5

Bore ID	Alt_Name	MGA_mE	MGA_mN	Col_RL	Mine_Area	Sensors	First_record	Last_record	Years	%with_data
S2312	Dendrobium S2312	284450.1	6196150.7	409.4	Den 3D	10	13/08/2015	30/04/2023	7.7	84.4
S2313	Avon 1	287609.0	6192815.5	415.3	Den 3B	3	1/11/2015	30/04/2023	7.5	93.9
S2314	Avon 2	288193.5	6192470.3	342.4	Den 3B	3	14/11/2015	30/04/2023	7.5	94.9
S2321	Dend S2321	284710.0	6195575.5	411.0	Den 3D	2	13/08/2016	30/04/2023	6.7	98.7
S2325	Dend S2325	283596.2	6195466.7	433.5	Den 3D	8	6/09/2016	30/04/2023	6.6	96.5
S2333	Dend s2333 (D-A3C-14-12)	290697.1	6197087.4	310.9	Den 3C	10	9/10/2016	30/04/2023	6.6	96.5
S2335	WC21Project Hole1Site 2	289725.4	6192748.7	372.6	Den 3B	5	19/10/2016	12/11/2016	0.1	96
S2335A	WC21Project Hole1Site 2	289727.0	6192755.0	370.1	Den 3B	6	5/09/2017	30/04/2023	5.7	97.9
S2336	WC21Hole2,Site2	289721.9	6192758.1	372.4	Den 3B	2	21/10/2016	20/07/2017	0.7	81.3
S2337	WC21Project Hole1Site 5	290021.0	6193411.9	336.1	Den 3B	3	25/11/2016	23/12/2022	6.1	93.9
S2338	WC21Hole2,Site5	290012.2	6193406.7	336.1	Den 3B	3	25/11/2016	23/12/2022	6.1	93.9
S2340	D-A5-25	285468.1	6197978.9	396.9	Den 3D	9	8/12/2016	30/04/2023	6.4	89.9
S2341	D-A5-28	287473.5	6195149.8	401.6	Den 3D	10	8/12/2016	30/04/2023	6.4	99.9
S2341A	D-A5-28A	287489.0	6195138.2	402.6	Den 3C	4	22/12/2016	30/04/2023	6.4	96.4
S2342	D-A5-12	287953.2	6196755.8	403.2	Den 3D	10	24/12/2016	30/04/2023	6.3	98.6
S2345	D-A5-19	285356.8	6196094.9	402.0	Den 3D	12	30/04/2017	11/01/2023	5.7	94.4
S2348	D-A5-17	286450.5	6196461.9	396.3	Den 3D	13	12/08/2017	6/02/2023	5.5	70.4
S2351	S14-04	290049.6	6191178.2	402.8	Den 3B	2	1/09/2017	1/05/2023	5.7	78.9
S2352	D-A5-6	286264.6	6195393.3	408.8	Den 3C	10	27/04/2017	22/02/2023	5.8	76.6
S2354	S14_05	289730.9	6191413.7	424.6	Den 3B	1	6/09/2017	30/04/2023	5.6	95.4
S2355	A5_S85_DBH	288136.2	6194877.8	396.6	Den 3C	5	5/08/2017	24/05/2023	5.8	100
S2357	A5-S100_DBH	286809.6	6196991.8	394.0	Den 3C	4	29/07/2017	4/05/2023	5.8	70
S2359	D-A5-5	285354.6	6195547.7	403.6	Den 3C	10	12/08/2017	30/04/2023	5.7	67.7
S2361	A5_S109_DBH	286277.9	6195810.7	402.4	Den 3C	4	24/06/2017	25/05/2023	5.9	77.1
S2362	A5_S110_DBH	285772.9	6195823.0	399.9	Den 3C	4	24/06/2017	28/12/2022	5.5	88.4
S2364	A5_S103_DBH	285982.8	6196782.1	395.0	Den 3C	4	14/11/2017	18/06/2021	3.6	68.4
S2365	A5_101/102_DBH	286042.3	6196448.9	399.2	Den 3C	5	5/09/2017	24/05/2023	5.7	82.7
S2366	A6_S113_DBH	291865.1	6200199.1	358.6	Den 3D	4	23/05/2018	16/07/2021	3.2	100
S2367	A6_S117_DBH	291630.7	6199726.5	356.1	Den 3D	4	23/05/2018	16/07/2021	3.2	100
S2370	D-A5-2	285554.8	6196642.7	375.6	Den 3C	10	13/05/2018	18/09/2020	2.4	61.2
S2371	A6_S116_DBH	291977.5	6199135.2	351.2	Den 3C	4	23/05/2018	16/07/2021	3.2	100
S2372	A6_S115_DBH	291576.9	6198891.4	373.5	Den 3C	4	23/05/2018	16/07/2021	3.2	100
S2373	A6_S112_DBH	292043.2	6200899.2	359.0	Den 3C	4	7/10/2017	16/07/2021	3.8	100
S2374	A6_S83_DBH	291114.8	6201461.1	324.4	Den 3C	4	24/05/2018	16/07/2021	3.1	100
S2376	Avon 6	288400.4	6192527.0	367.8	Den 3B	3	6/10/2017	23/05/2023	5.6	88.1
S2377	Avon 3	288333.4	6192020.4	408.2	Den 3B	3	2/06/2018	1/05/2023	4.9	98.3
S2378	Avon 4	288407.4	6191770.9	379.3	Den 3B	4	15/11/2017	9/11/2022	5	55.7
S2379	Avon 5	288312.9	6191140.5	356.6	Den 3B	4	17/07/2018	21/04/2023	4.8	40.3
S2398	LW14_1	289073.2	6192164.3	420.2	Den 3B	8	11/05/2018	15/08/2018	0.3	100
S2398B	LW14-1 post extraction Redrill	289070.9	6192172.6	418.0	Den 3B	8	8/03/2019	31/07/2021	2.4	99.2
S2399	LW12_1	289810.5	6192965.1	355.1	Den 3B	8	4/05/2018	9/08/2022	4.3	68.6
S2401	Den01b_R1	287752.2	6194264.9	411.1	Den 3B	6	17/11/2018	23/05/2023	4.5	84.1
S2402	Den01b_R2	288207.8	6193666.6	403.4	Den 3B	6	7/07/2018	23/05/2023	4.9	83.8
S2403	Den01b_R3	288345.1	6193761.1	400.7	Den 3B	6	17/11/2018	23/05/2023	4.5	85.8
S2404	Den01b_R4	288528.6	6193896.8	396.2	Den 3B	6	23/11/2018	22/05/2023	4.5	85.7
S2405	Den01b_R5	288729.5	6194087.6	386.1	Den 3B	6	18/11/2018	23/05/2023	4.5	85.9
S2406	Den01b_R6	288669.1	6194176.5	396.6	Den 3B	6	18/11/2018	23/05/2023	4.5	85.9
S2408	GW14-2	289552.1	6192193.4	398.1	Den 3B	7	4/10/2018	29/11/2022	4.2	87.7
S2409	GW14-3	289546.1	6192269.7	394.6	Den 3B	6	4/10/2018	30/04/2023	4.6	94.2
S2411	LW12_2	289761.1	6192837.7	364.0	Den 3B	8	6/07/2018	21/03/2023	4.7	99.5
S2412	LW15-1	289201.1	6191807.4	427.3	Den 3B	8	13/05/2018	17/06/2019	1.1	97
S2412B	GW15-1	289201.6	6191803.7	425.2	Den 3B	8	19/12/2019	30/04/2023	3.4	94.1
S2420	LW12-3	289738.4	6192780.0	367.8	Den 3B	8	3/10/2018	30/04/2023	4.6	90.6
S2421	LW13-1	289590.4	6192492.2	381.8	Den 3B	8	9/02/2019	30/04/2023	4.2	84.6
S2433	Elouera 2-1	289082.0	6190172.9	375.7	Den 3B	10	19/12/2021	30/04/2023	1.4	94.4
S2435	AD7	288080.8	6192411.6	328.2	Den 3B	3	21/11/2018	30/04/2023	4.4	91.9
S2436	AD8	288313.8	6191499.7	320.3	Den 3B	5	4/12/2018	30/04/2022	3.4	97.3
S2438		287944.9	6197535.1	399.3	Den 3C	9	24/11/2018	30/04/2023	4.4	98.1
S2441	Elouera1-1	288752.5	6190268.4	347.6	Den 3B	9	18/12/2021	13/12/2022	1	99.7
S2441B	Elouera1-3	288760.7	6190260.9	348.4	Den 3B	10	24/10/2021	30/04/2023	1.5	99.8

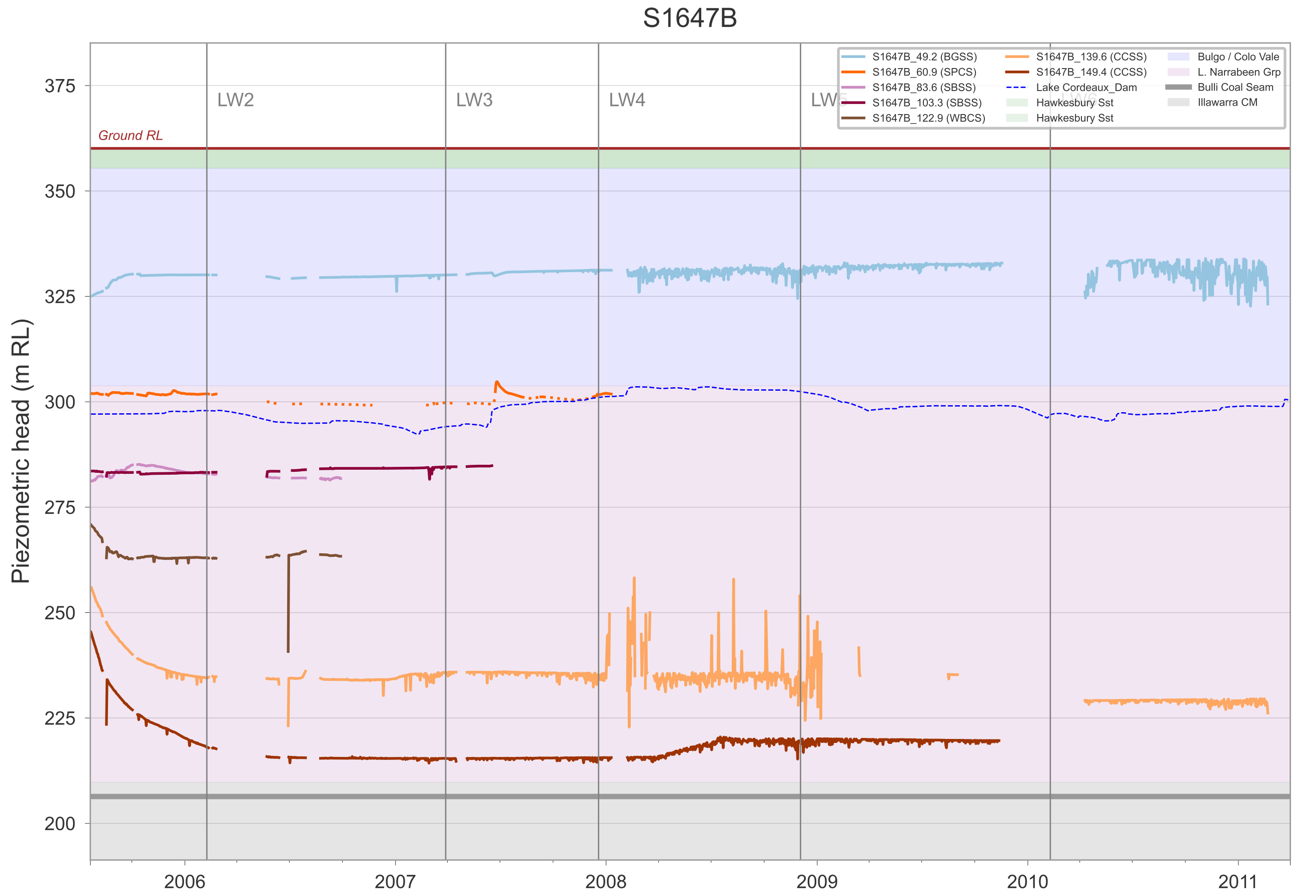
APPENDIX B: Groundwater hydrographs

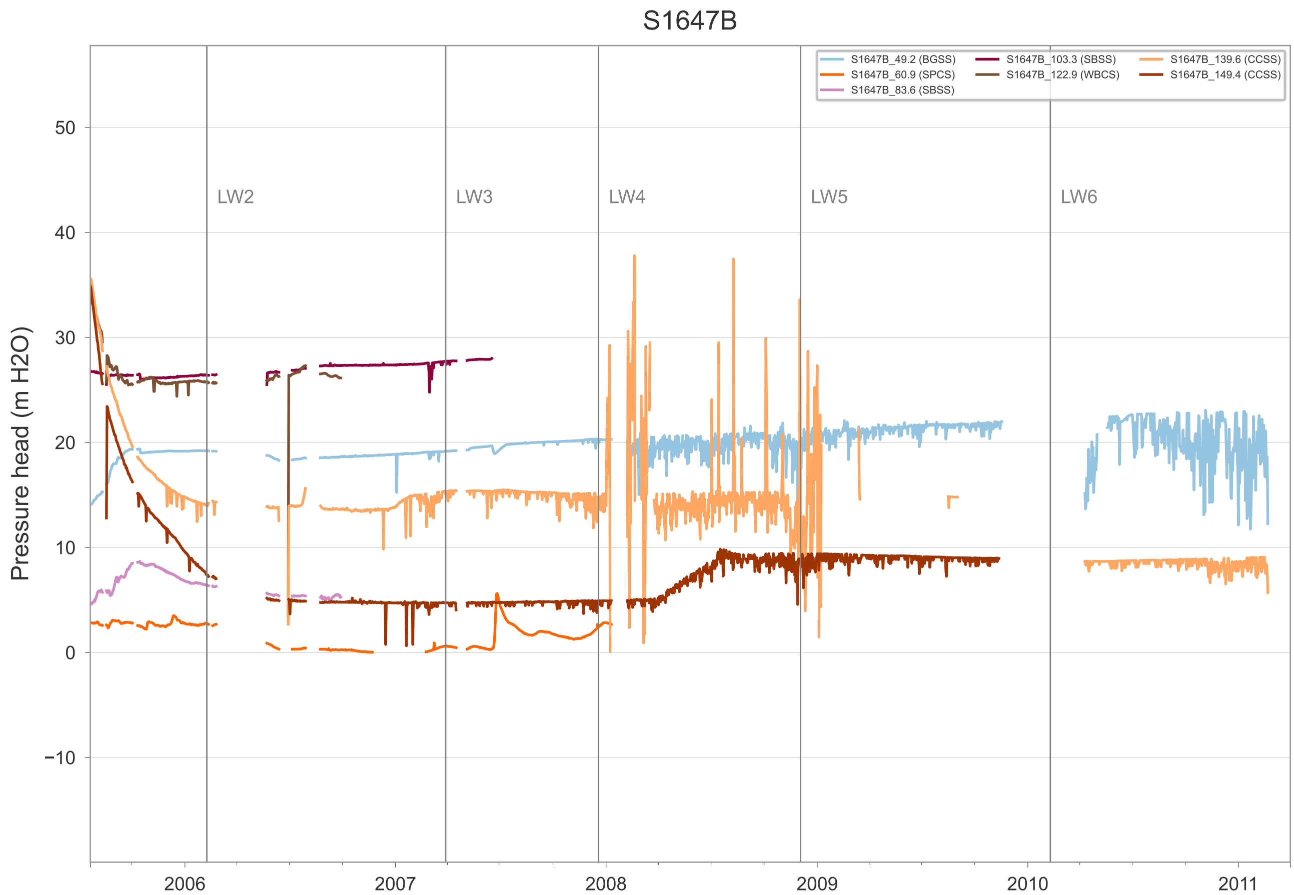
Groundwater hydrographs



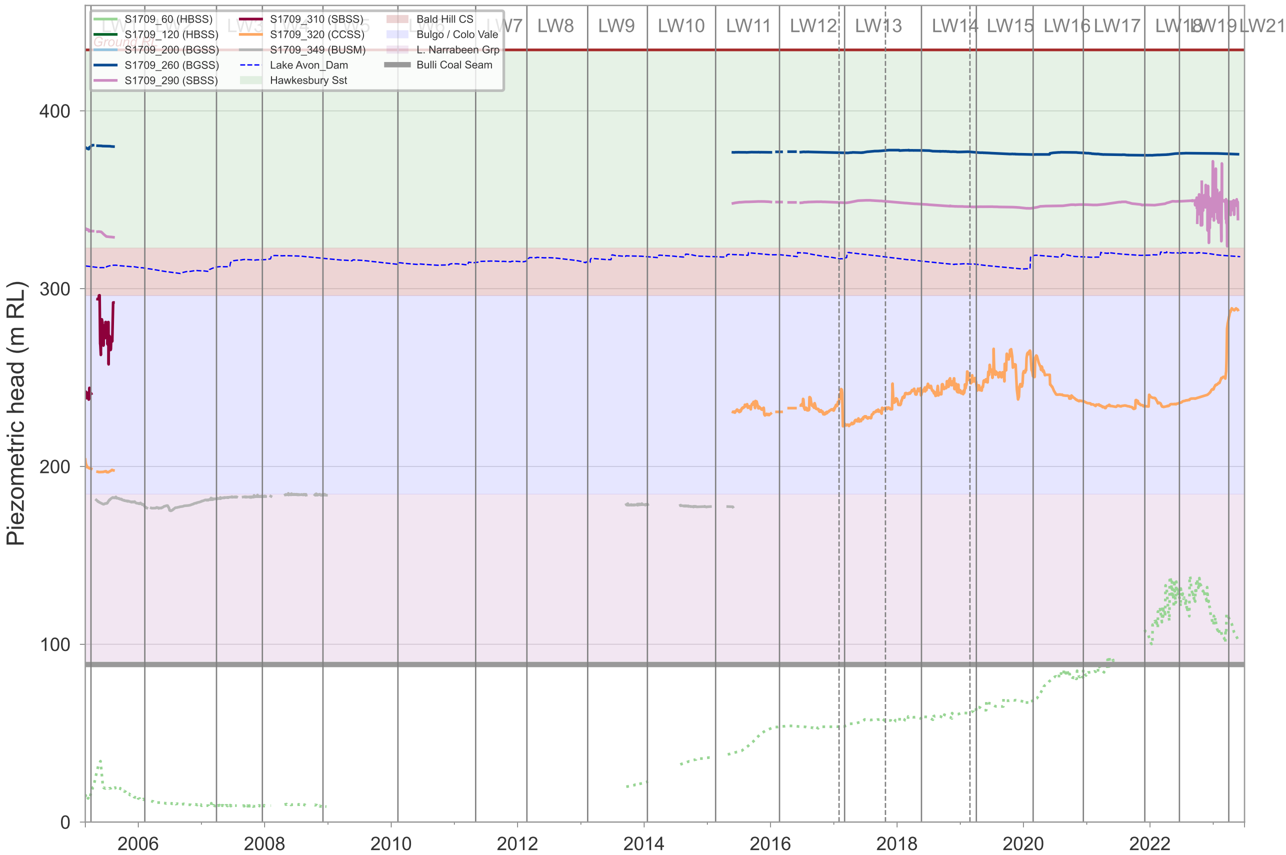


Groundwater hydrographs



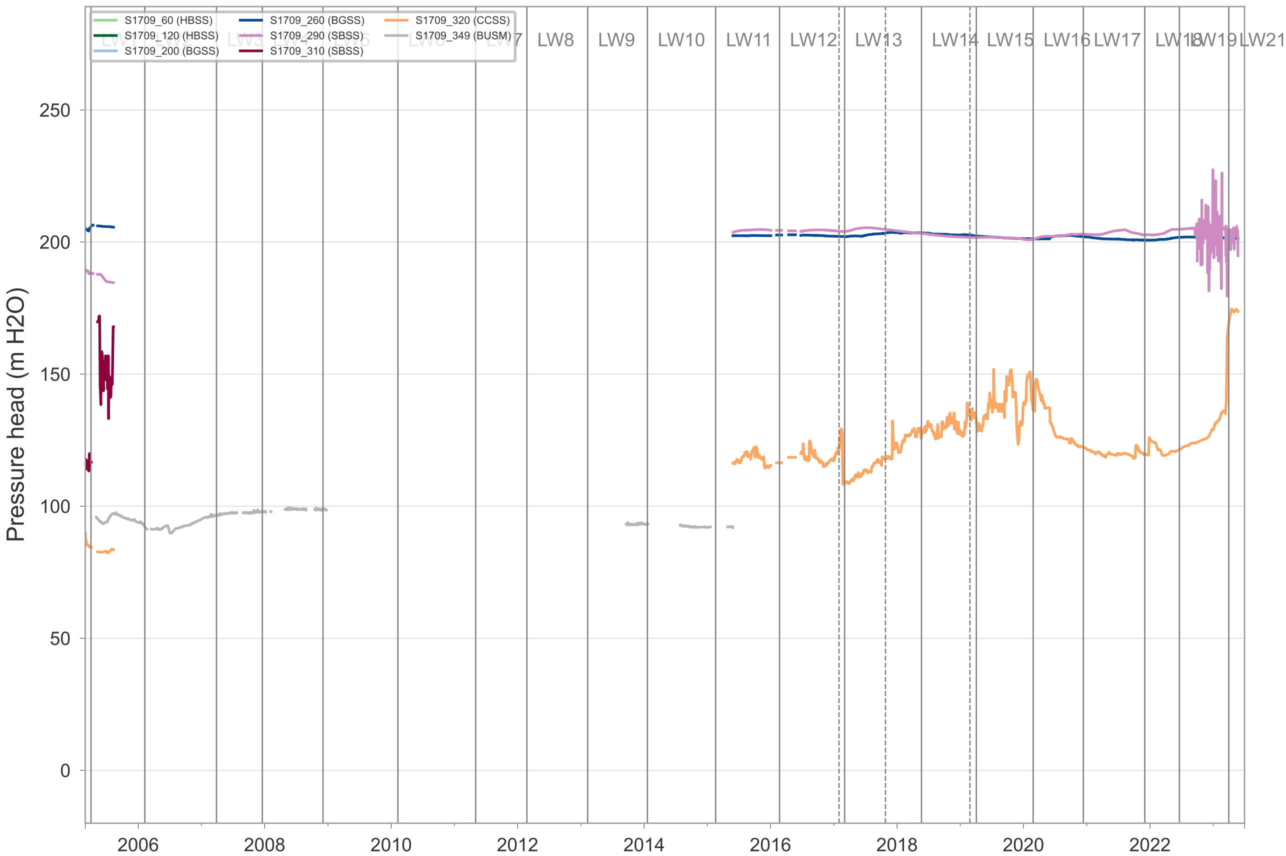


S1709



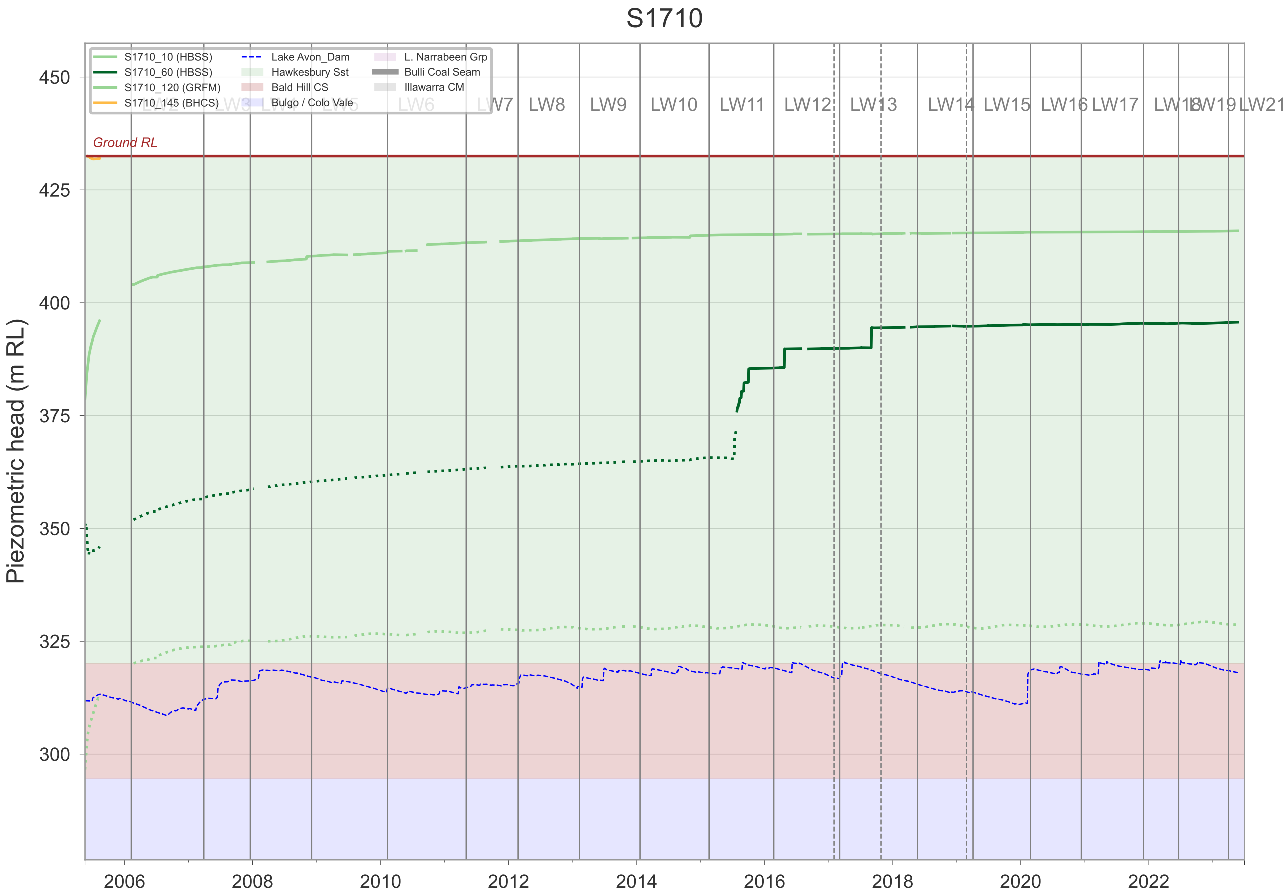
S1709_60 (HBSS)
S1709_120 (HBSS)
S1709_200 (BGSS)
S1709_260 (BGSS)
S1709_290 (SBSS)
S1709_310 (SBSS)
S1709_320 (CCSS)
S1709_349 (BUSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Piezometric head (m RL)
0
100
200
300
400
2006
2008
2010
2012
2014
2016
2018
2020
2022

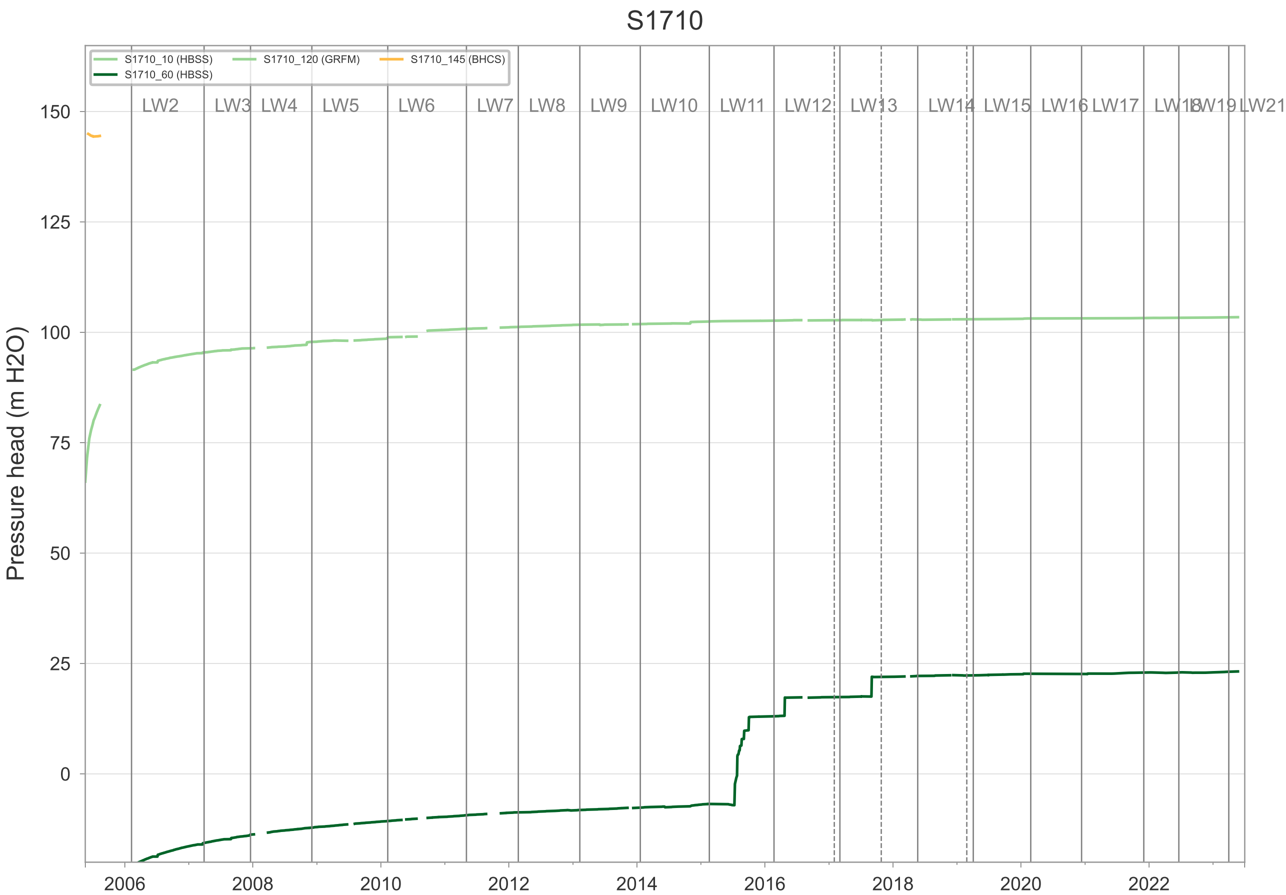
S1709

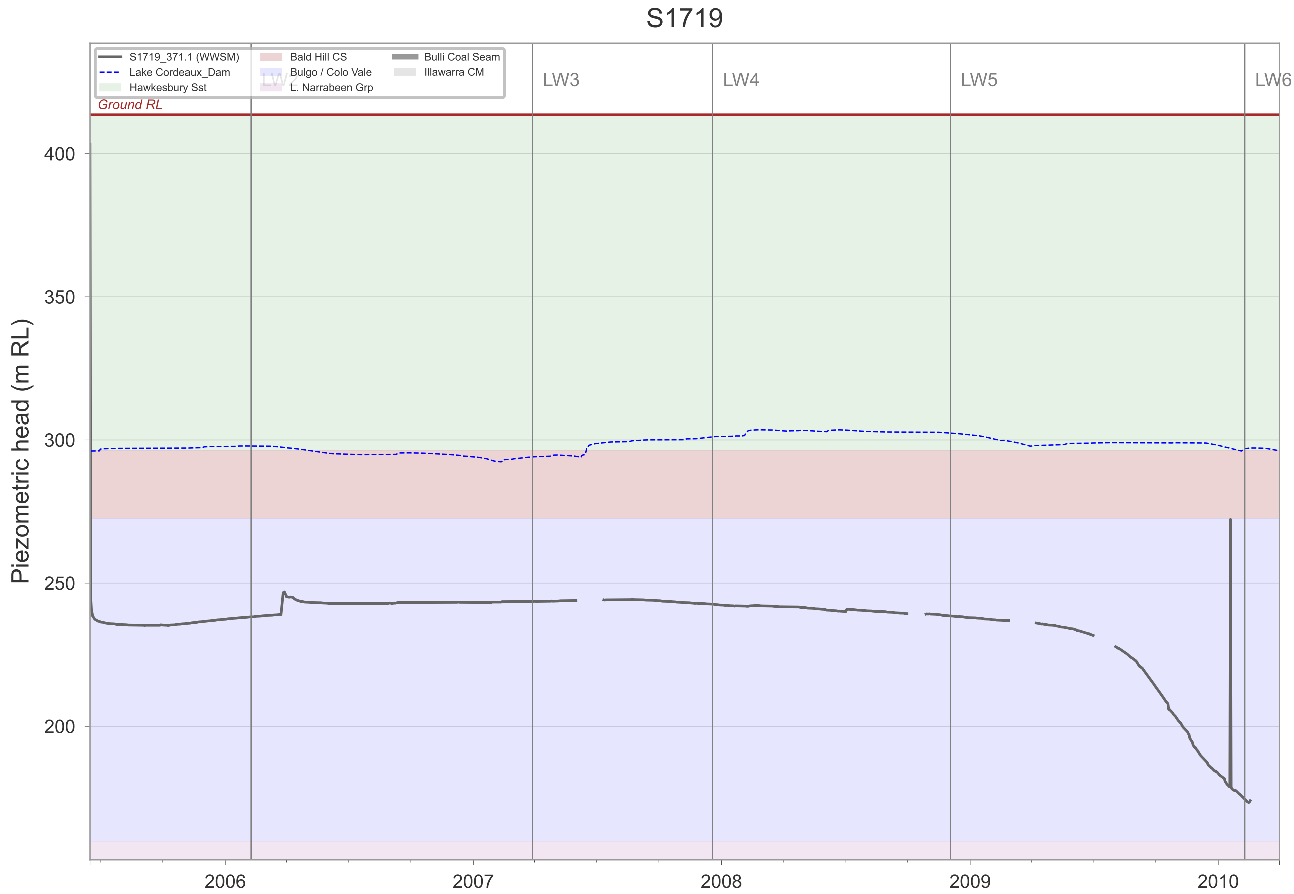


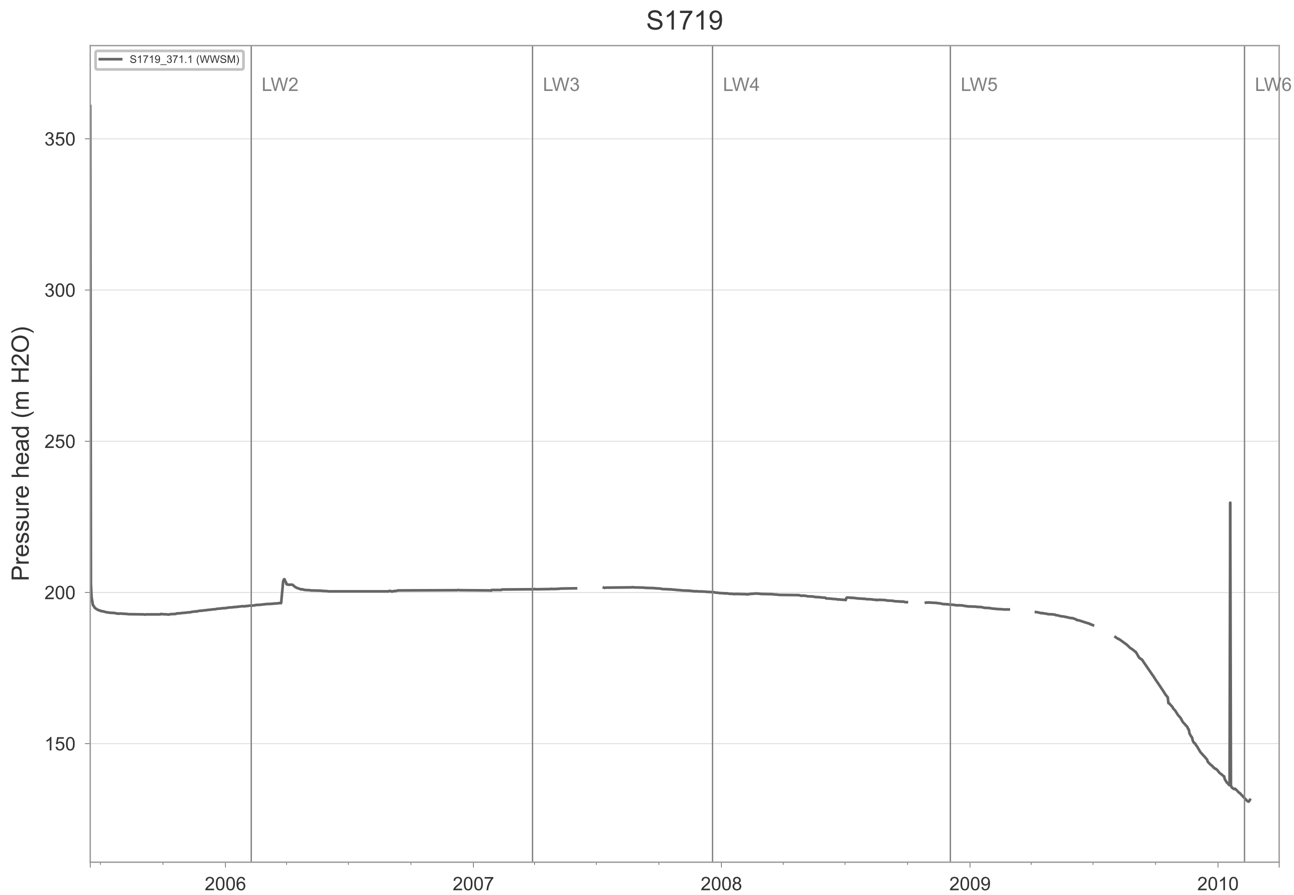
S1709_60 (HBSS)
S1709_120 (HBSS)
S1709_200 (BGSS)
S1709_260 (BGSS)
S1709_290 (SBSS)
S1709_310 (SBSS)
S1709_320 (CCSS)
S1709_349 (BUSM)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Pressure head (m H2O)
0
50
100
150
200
250
2006
2008
2010
2012
2014
2016
2018
2020
2022

Groundwater hydrographs

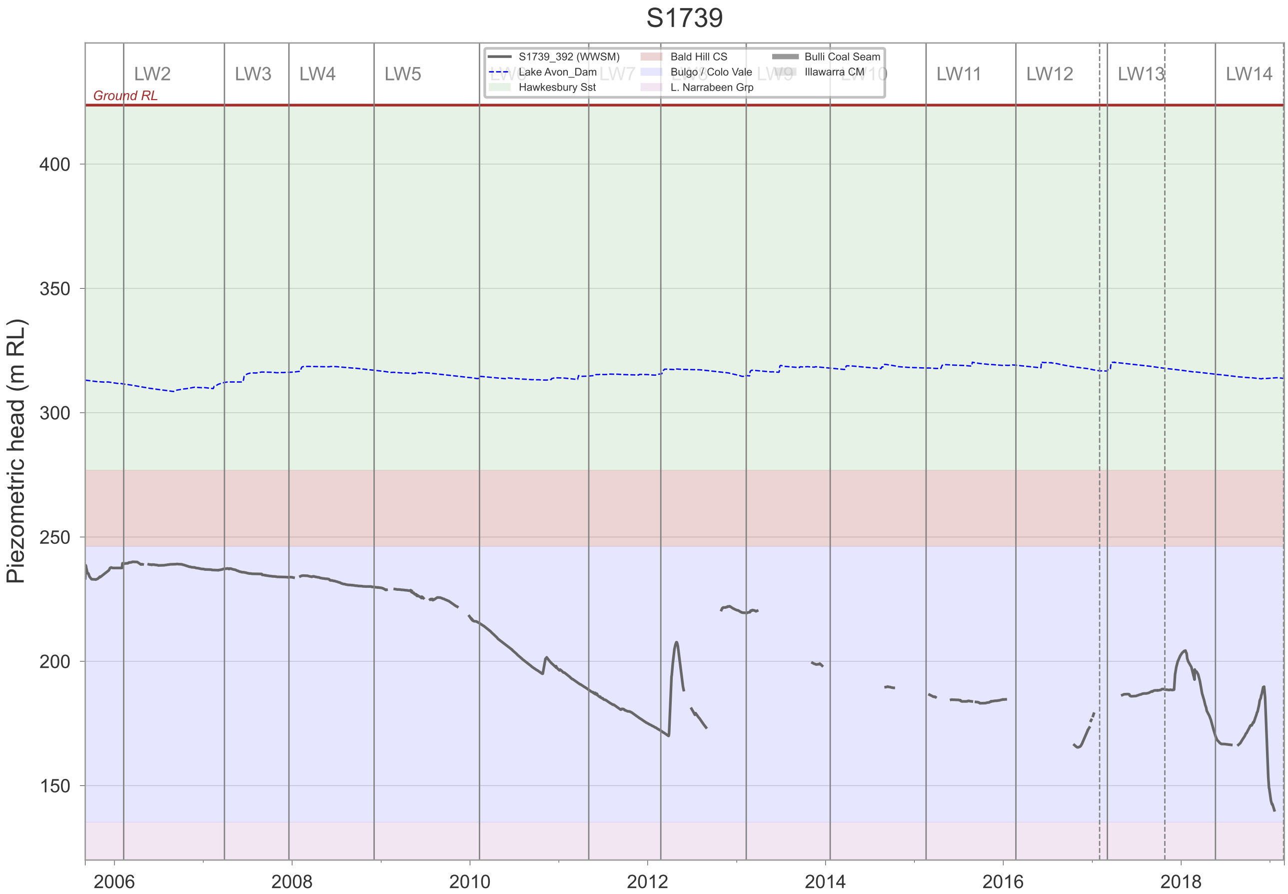


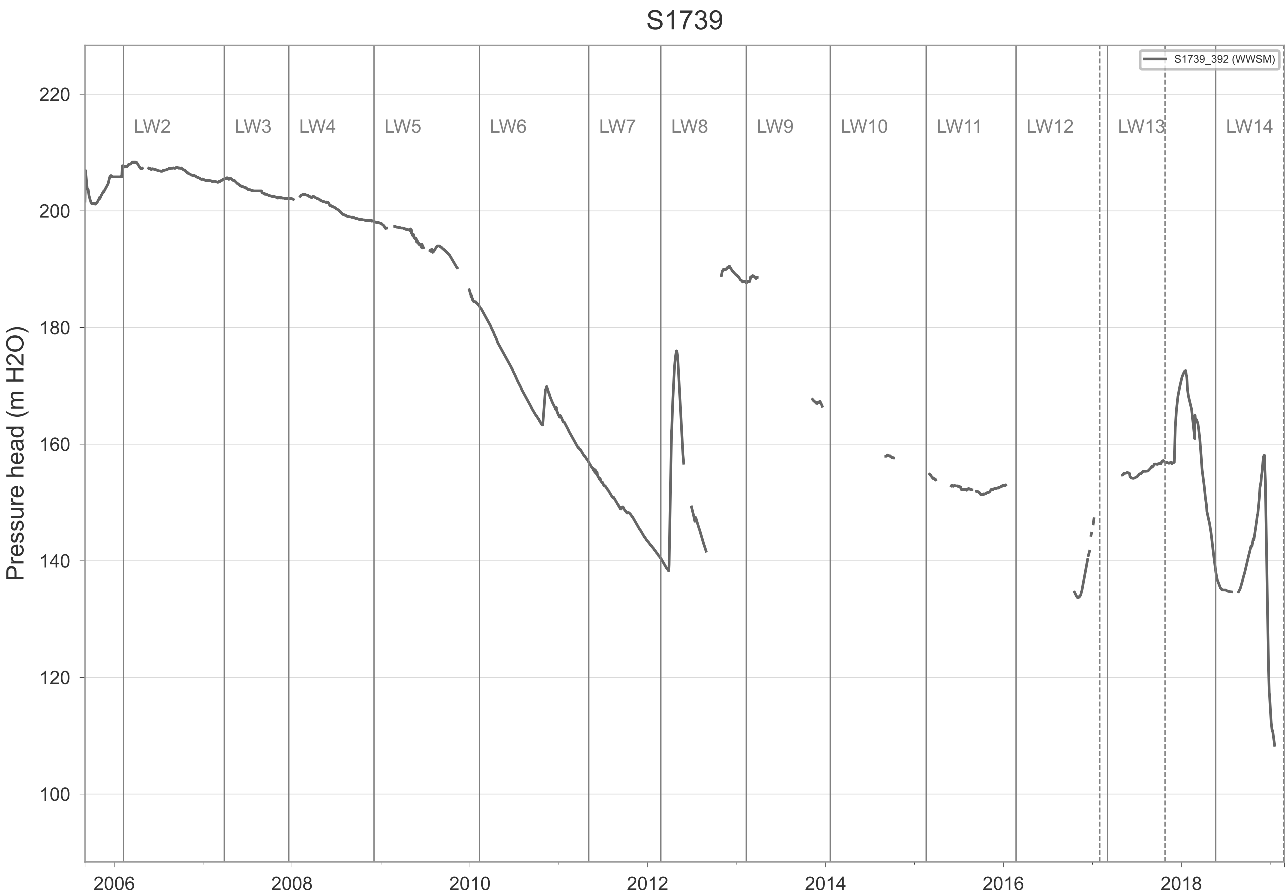


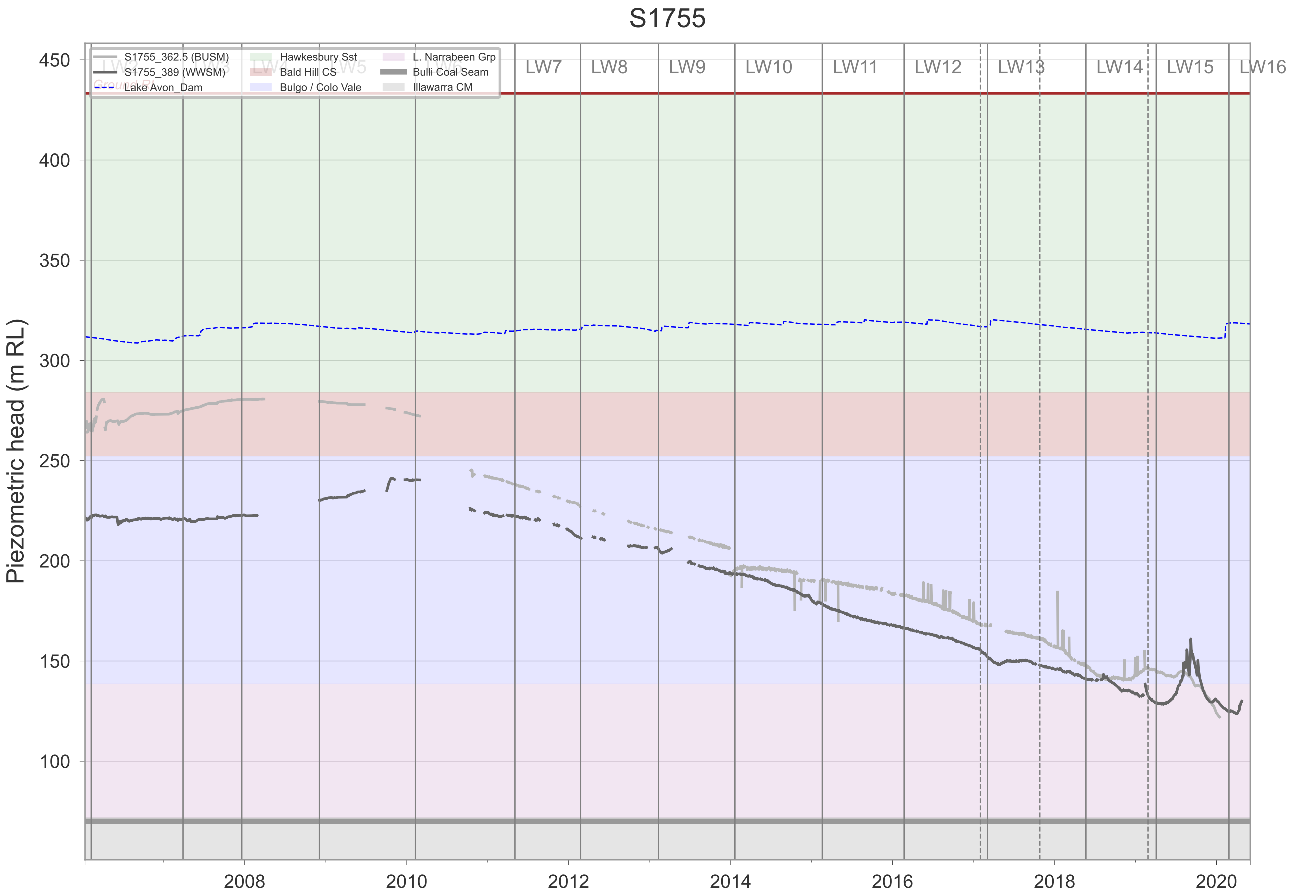

S1719
S1719_371.1 (WWSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Ground RL
LW3
LW4
LW5
LW6
Piezometric head (m RL)
400
350
300
250
200
2006
2007
2008
2009
2010

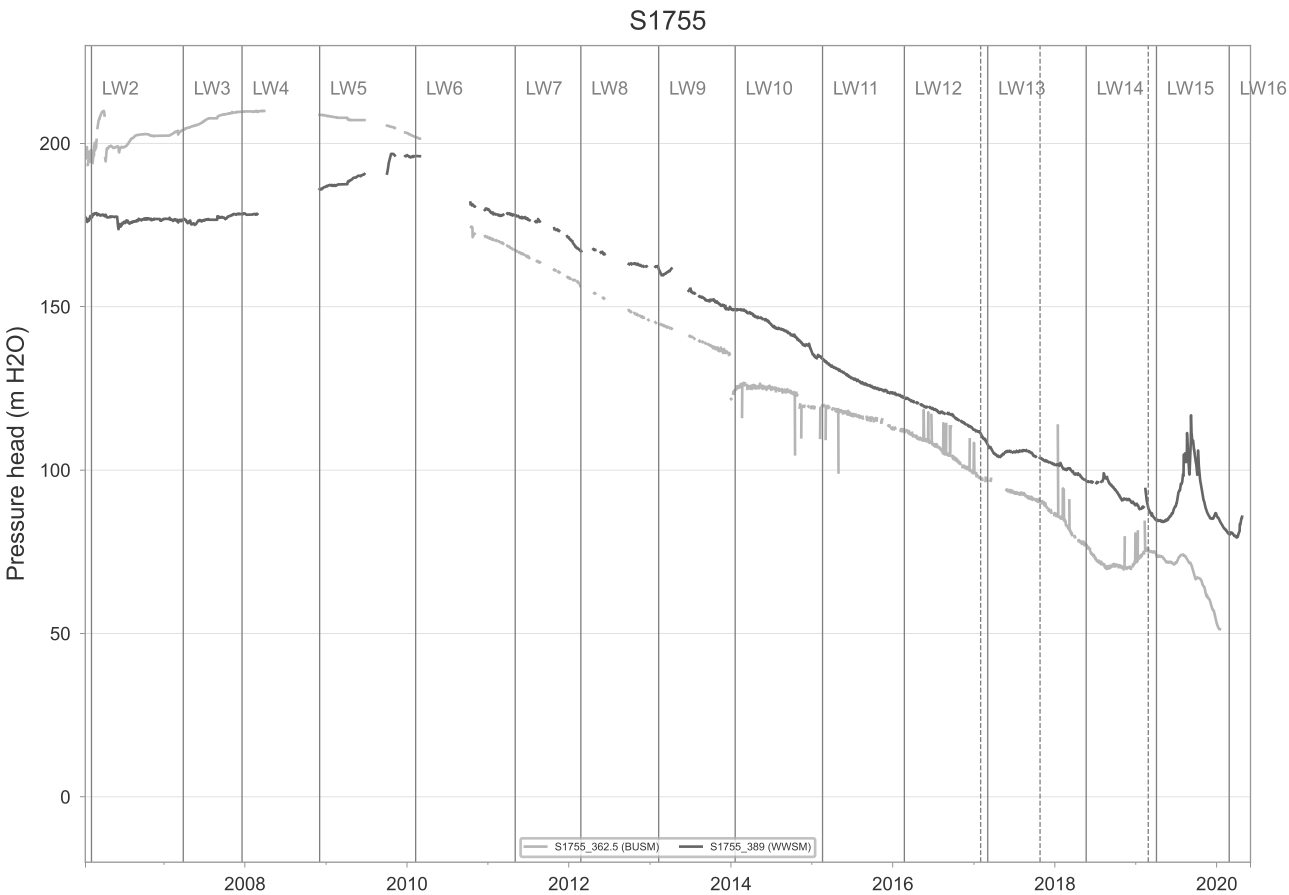

S1719
S1719_371.1 (WWSM)
LW2
LW3
LW4
LW5
LW6
Pressure head (m H2O)
350
300
250
200
150
2006
2007
2008
2009
2010

Groundwater hydrographs

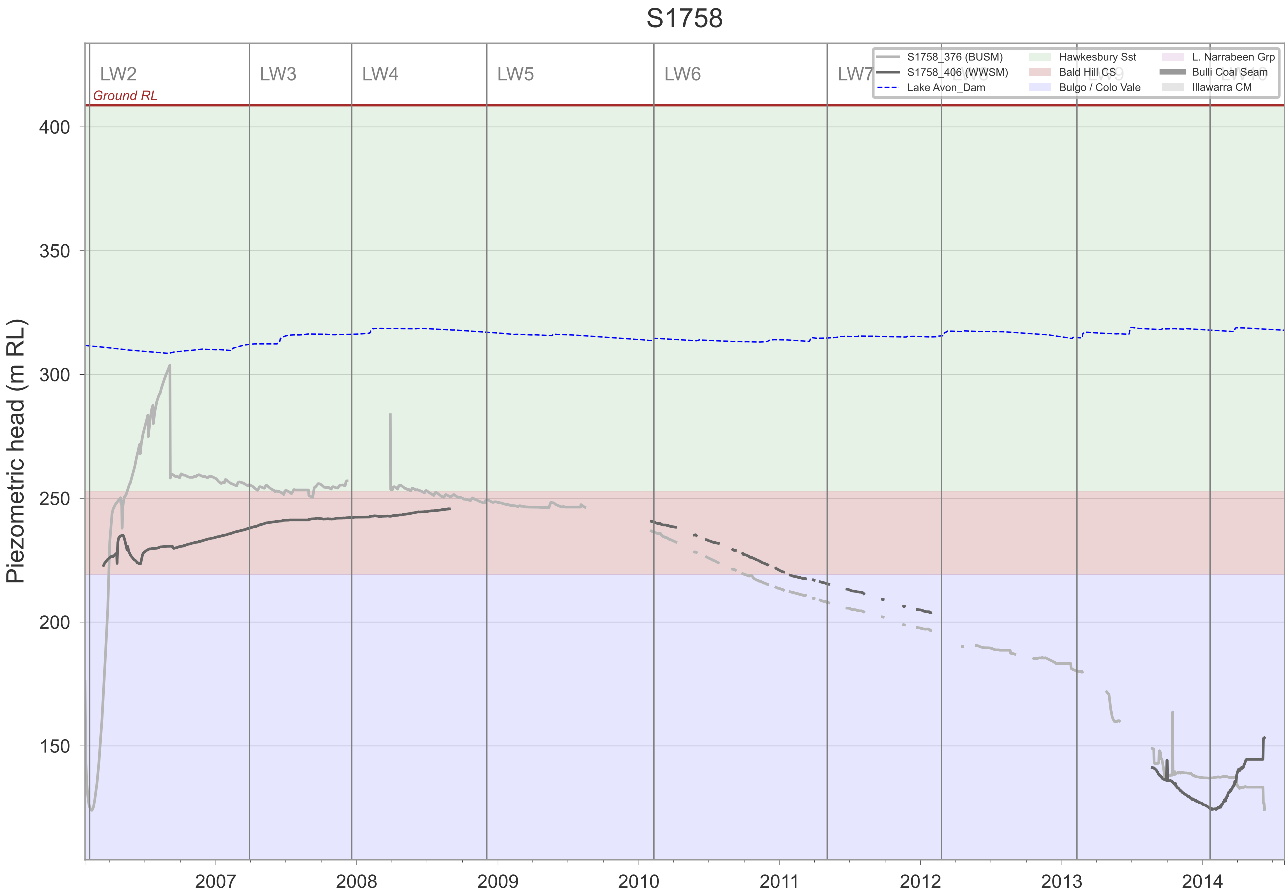


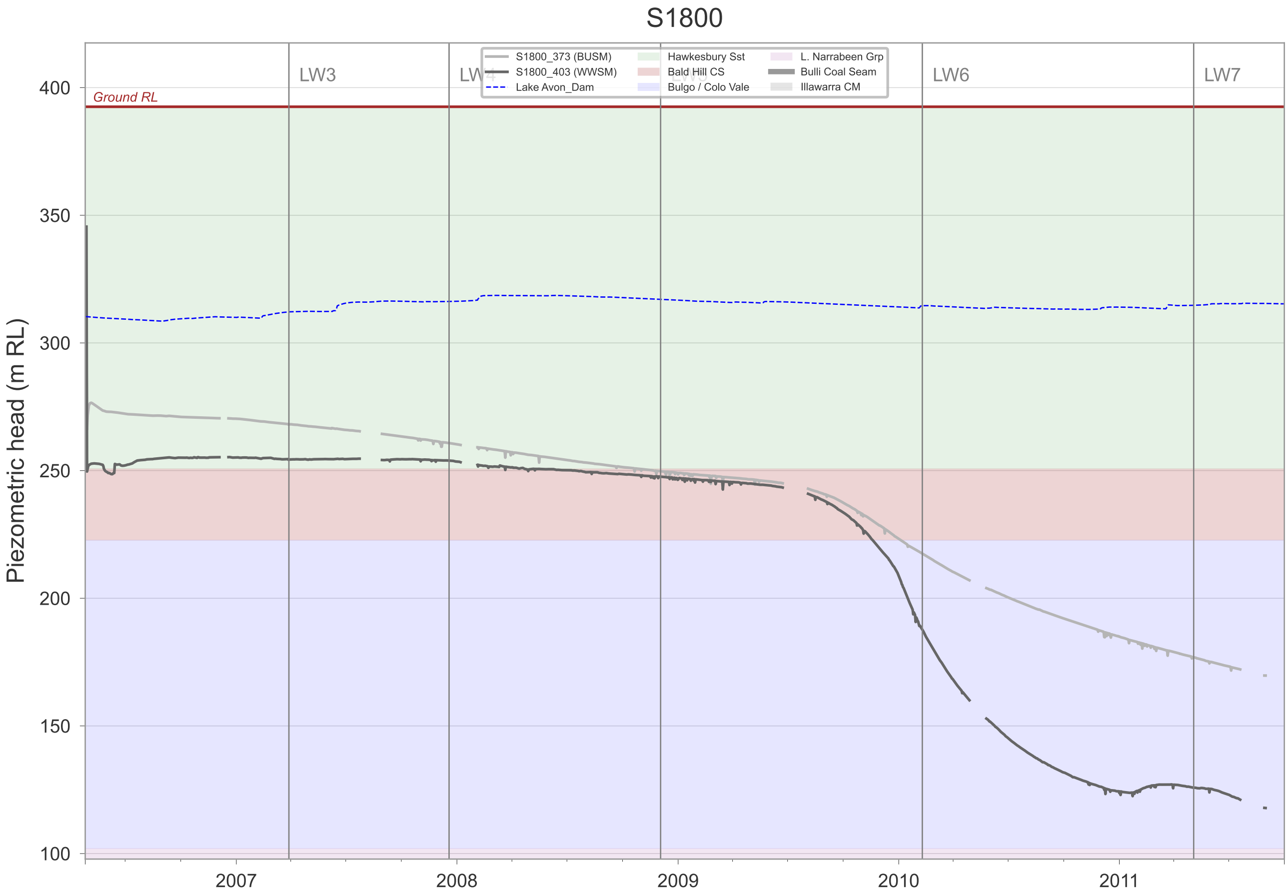


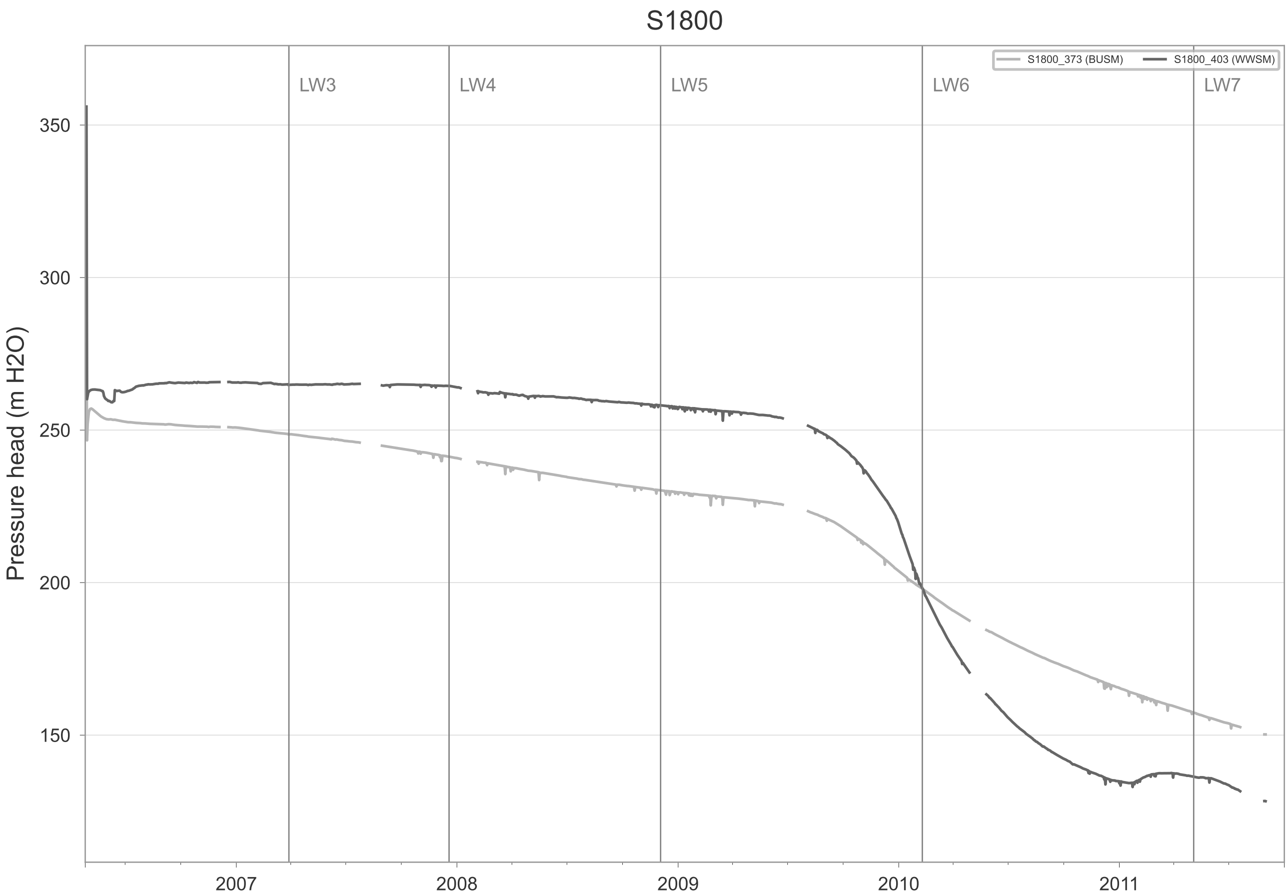

S1755
Piezometric head (m RL)
S1755_362.5 (BUSM)
S1755_389 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
450
400
350
300
250
200
150
100
2008
2010
2012
2014
2016
2018
2020

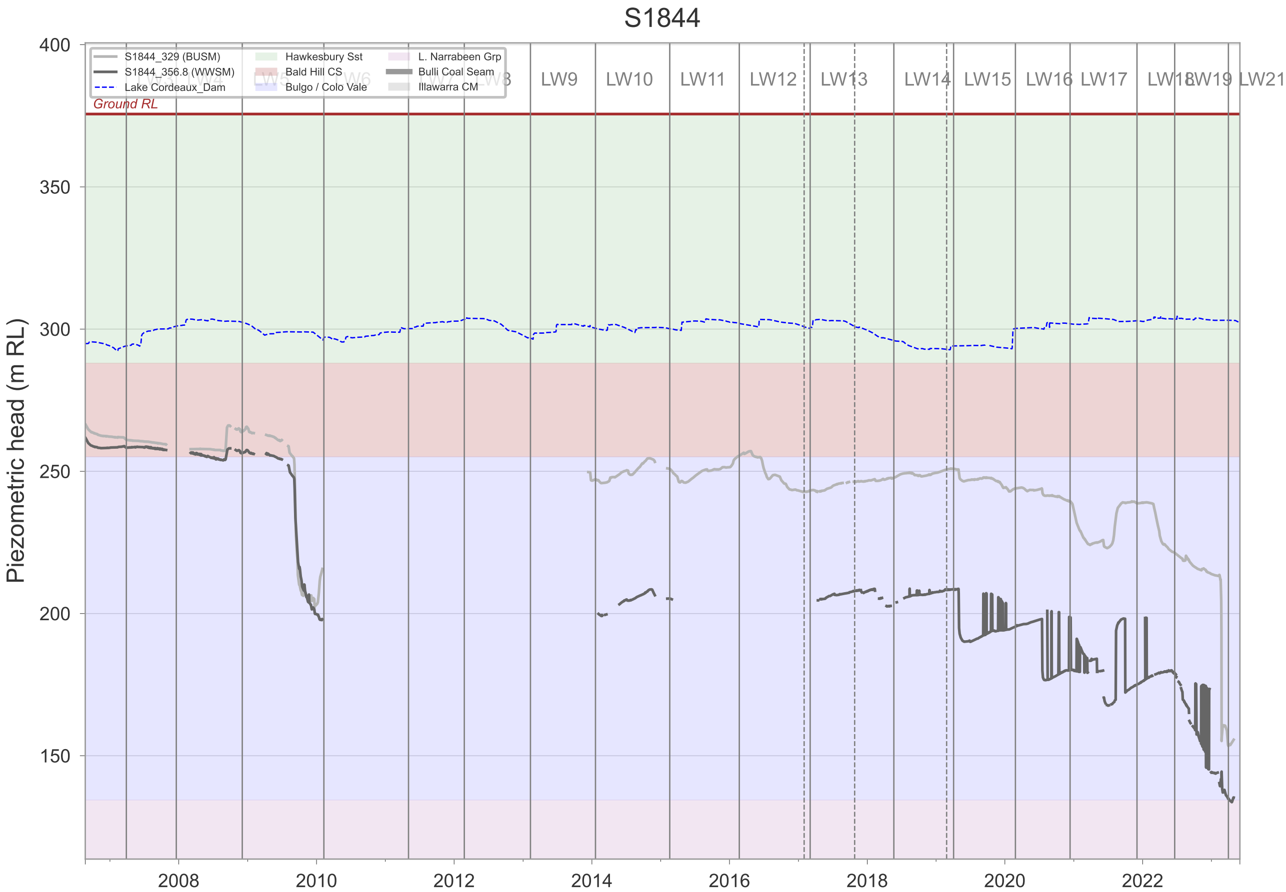

S1755
Pressure head (m H2O)
LW2
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
200
150
100
50
0
S1755_362.5 (BUSM)
S1755_389 (WWSM)
2008
2010
2012
2014
2016
2018
2020

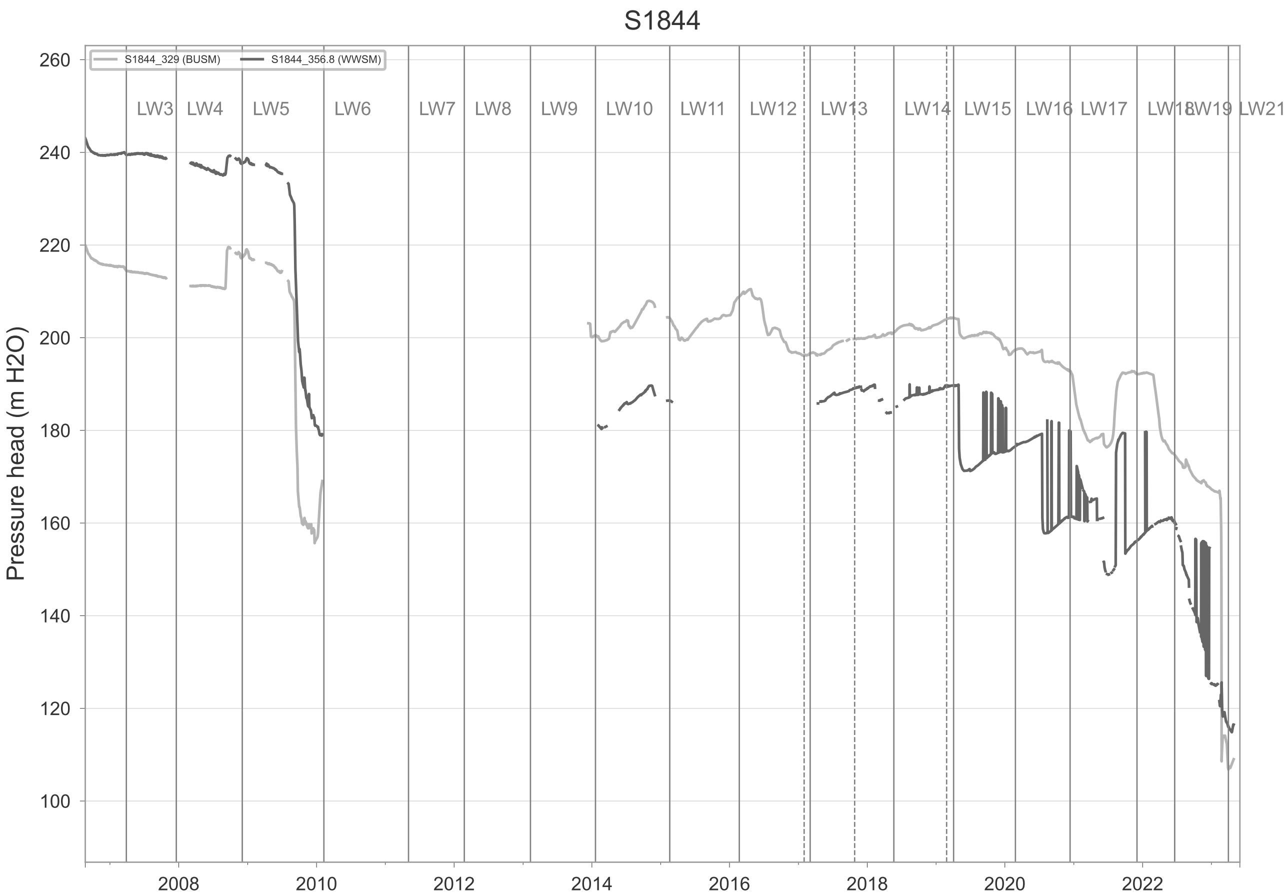
Groundwater hydrographs

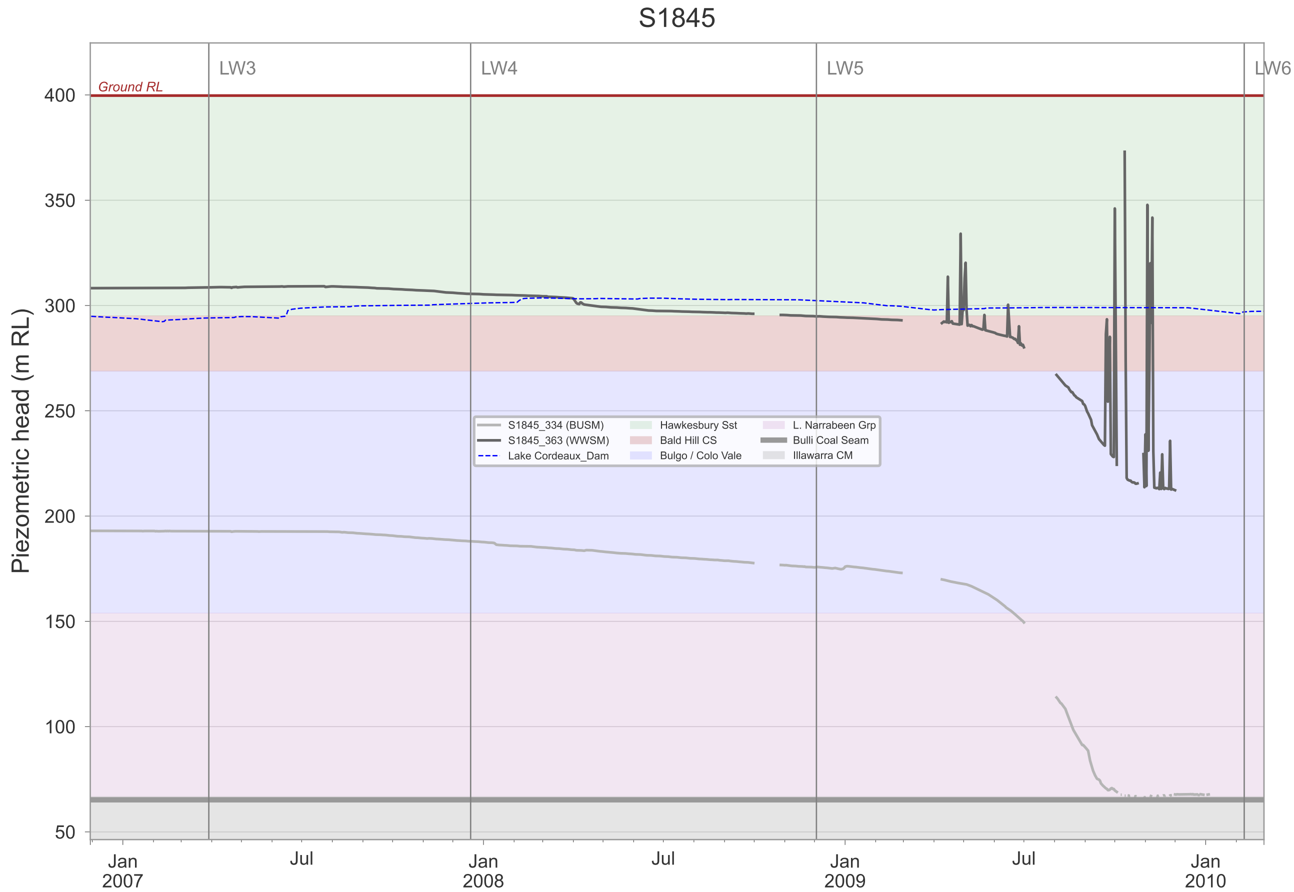


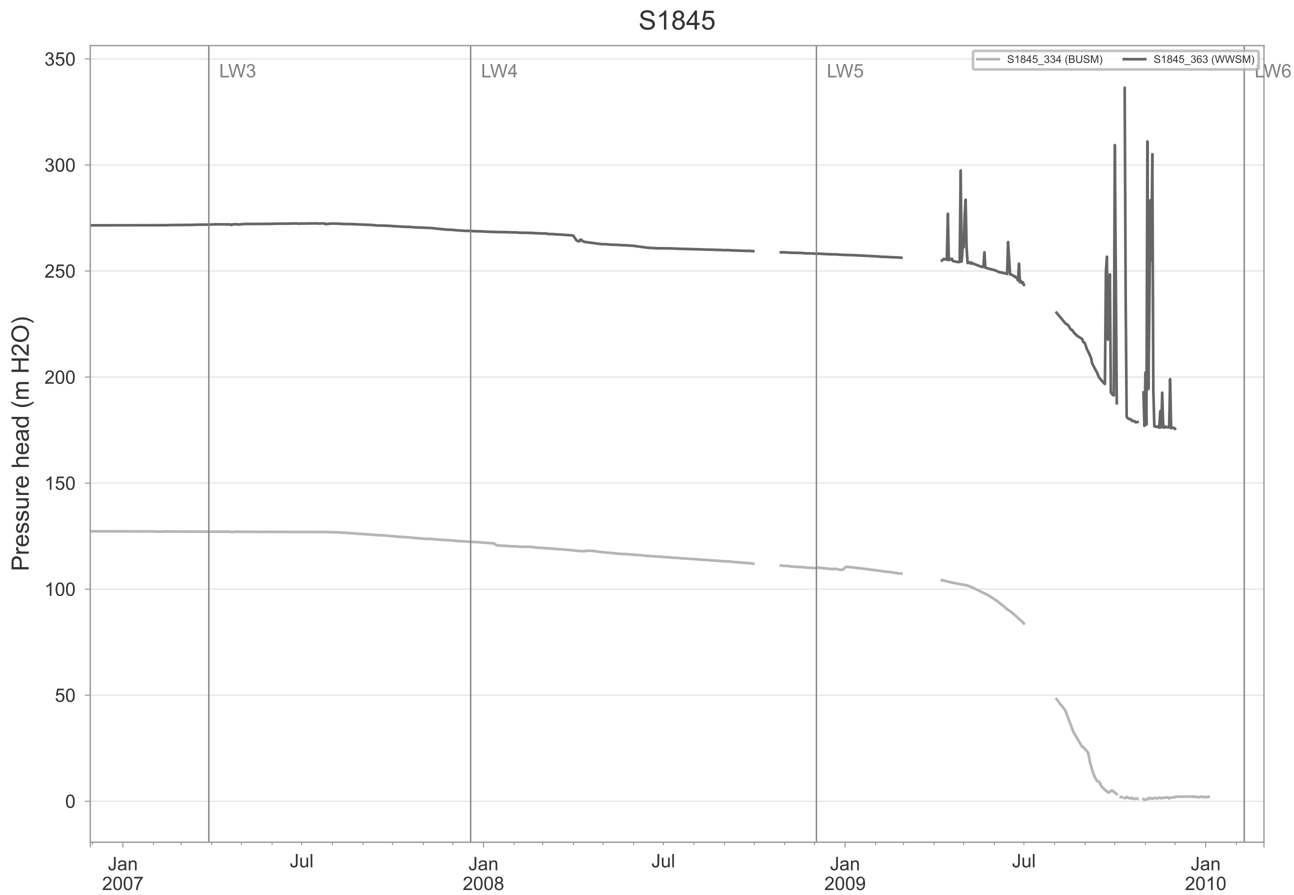

S1800
Piezometric head (m RL)
Ground RL
LW3
LW6
LW7
S1800_373 (BUSM)
S1800_403 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
100
150
200
250
300
350
400
2007
2008
2009
2010
2011

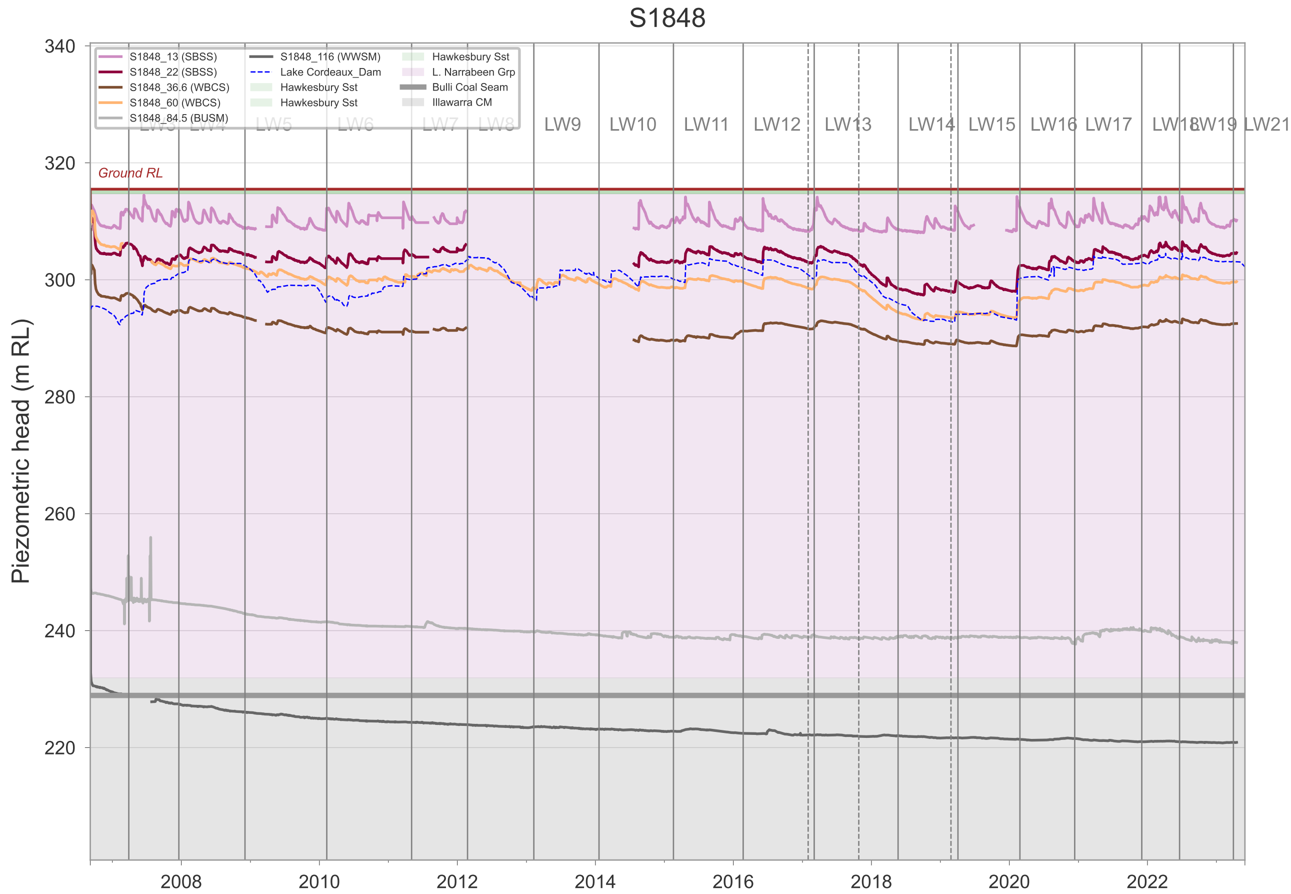

S1800
Pressure head (m H2O)
S1800_373 (BUSM)
S1800_403 (WWSM)
LW3
LW4
LW5
LW6
LW7
150
200
250
300
350
2007
2008
2009
2010
2011

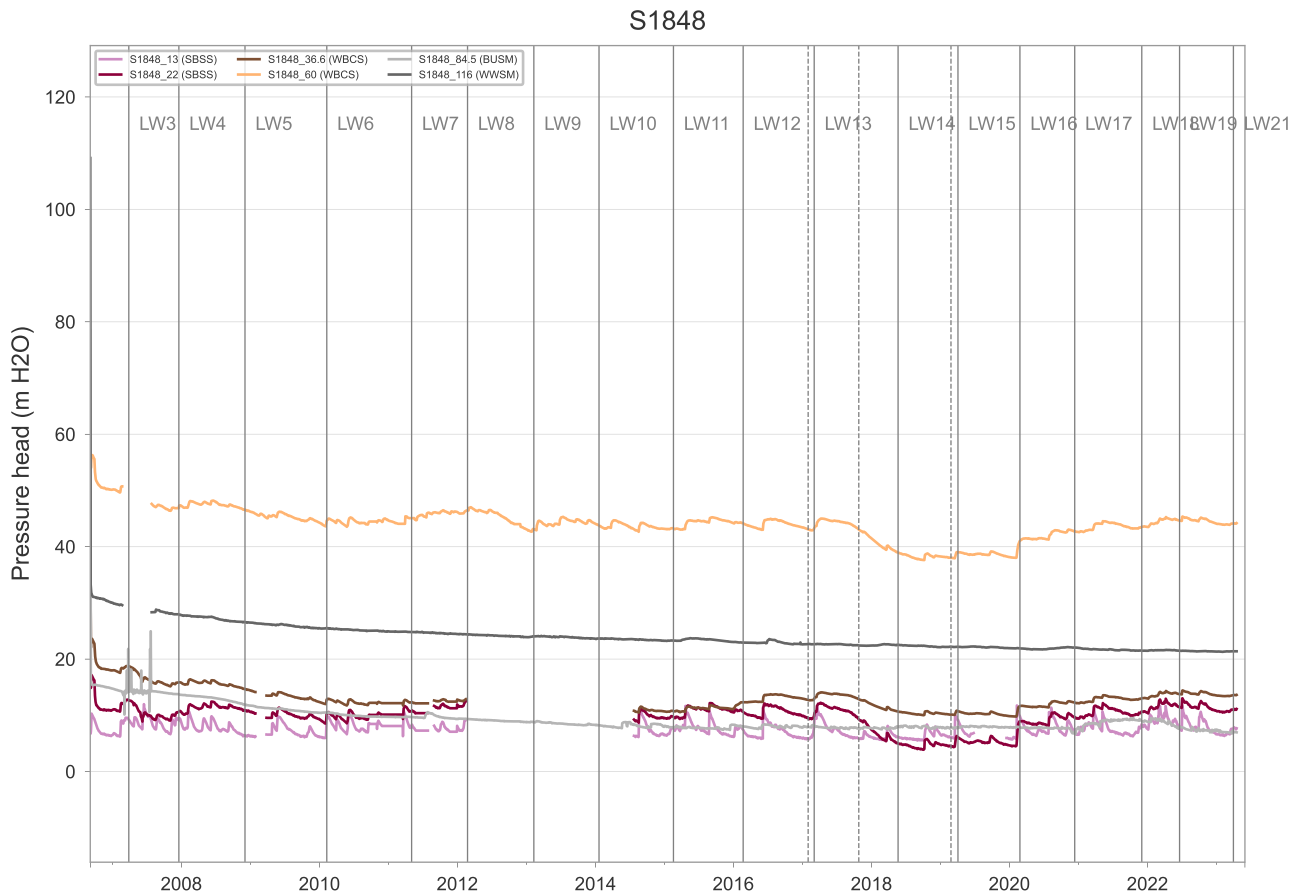

S1844
S1844_329 (BUSM)
S1844_356.8 (WWSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Ground RL
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Piezometric head (m RL)
400
350
300
250
200
150
2008
2010
2012
2014
2016
2018
2020
2022


S1844
S1844_329 (BUSM)
S1844_356.8 (WWSM)
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Pressure head (m H2O)
260
240
220
200
180
160
140
120
100
2008
2010
2012
2014
2016
2018
2020
2022

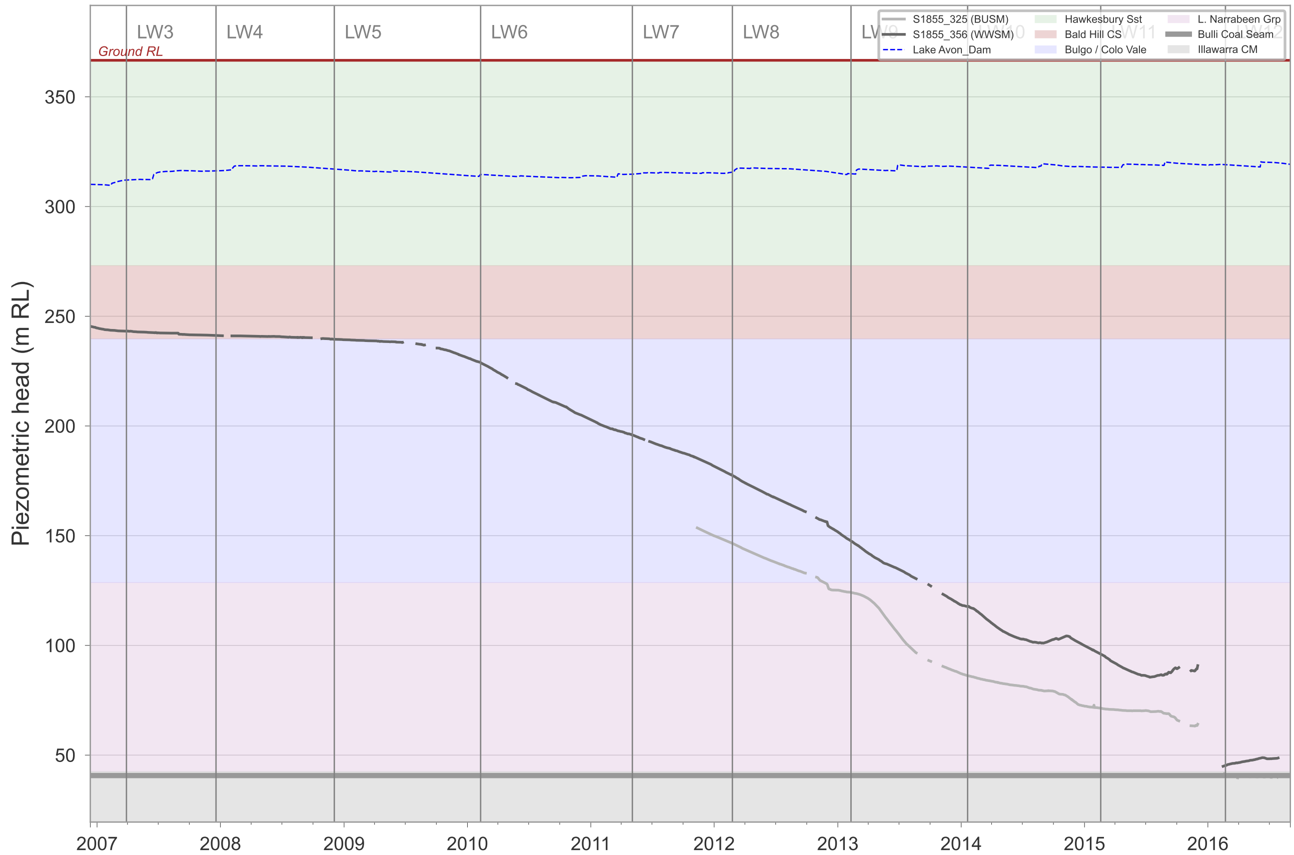

S1845
LW3
LW4
LW5
LW6
Ground RL
Piezometric head (m RL)
400
350
300
250
200
150
100
50
S1845_334 (BUSM)
S1845_363 (WWSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Jan 2007
Jul
Jan 2008
Jul
Jan 2009
Jul
Jan 2010


S1845
LW3
LW4
LW5
LW6
S1845_334 (BUSM)
S1845_363 (WWSM)
Pressure head (m H2O)
350
300
250
200
150
100
50
0
Jan 2007
Jul
Jan 2008
Jul
Jan 2009
Jul
Jan 2010

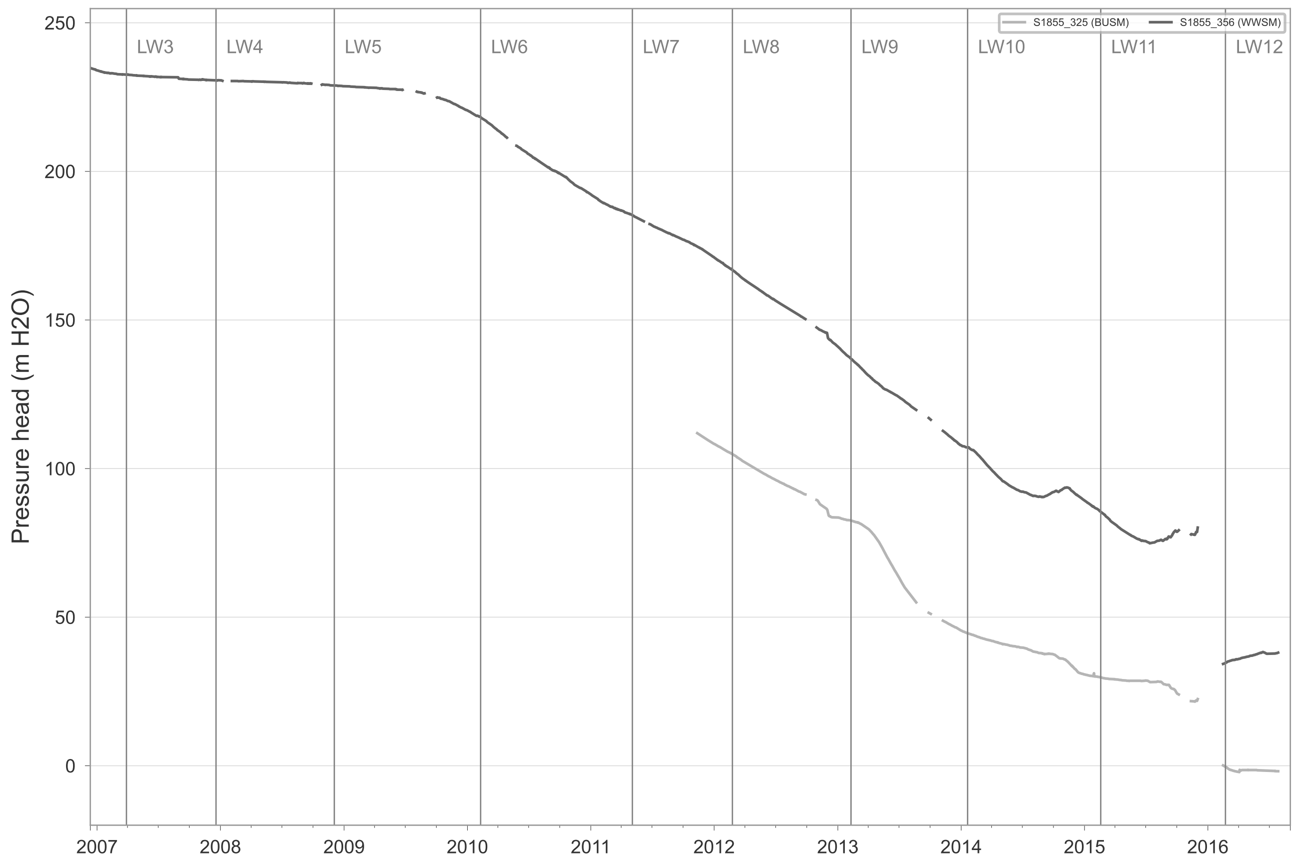

S1848
S1848_13 (SBSS)
S1848_22 (SBSS)
S1848_36.6 (WBCS)
S1848_60 (WBCS)
S1848_84.5 (BUSM)
S1848_116 (WWSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Hawkesbury Sst
Hawkesbury Sst
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Ground RL
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Piezometric head (m RL)
340
320
300
280
260
240
220
2008
2010
2012
2014
2016
2018
2020
2022

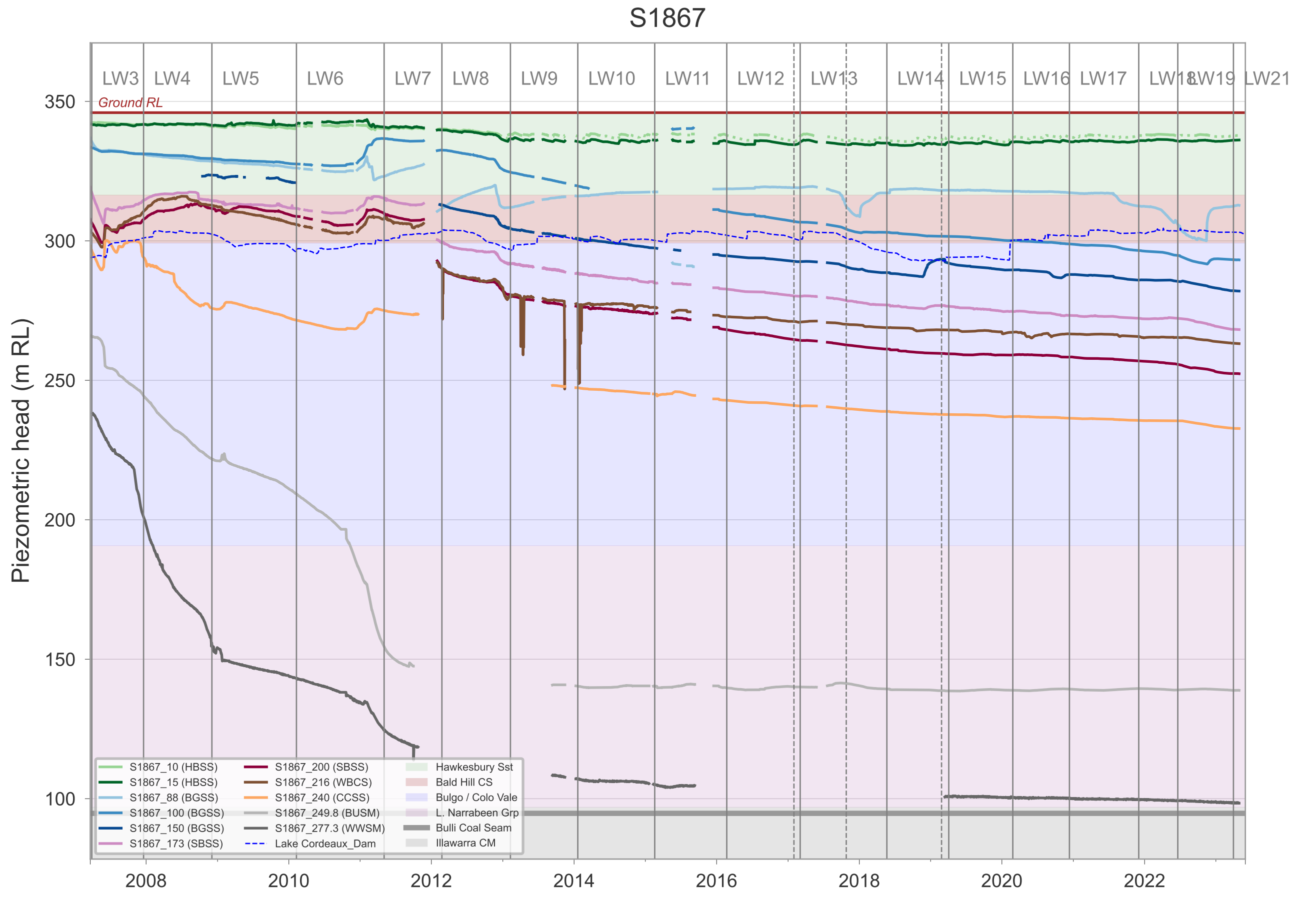

S1848
S1848_13 (SBSS)
S1848_22 (SBSS)
S1848_36.6 (WBCS)
S1848_60 (WBCS)
S1848_84.5 (BUSM)
S1848_116 (WWSM)
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Pressure head (m H2O)
120
100
80
60
40
20
0
2008
2010
2012
2014
2016
2018
2020
2022

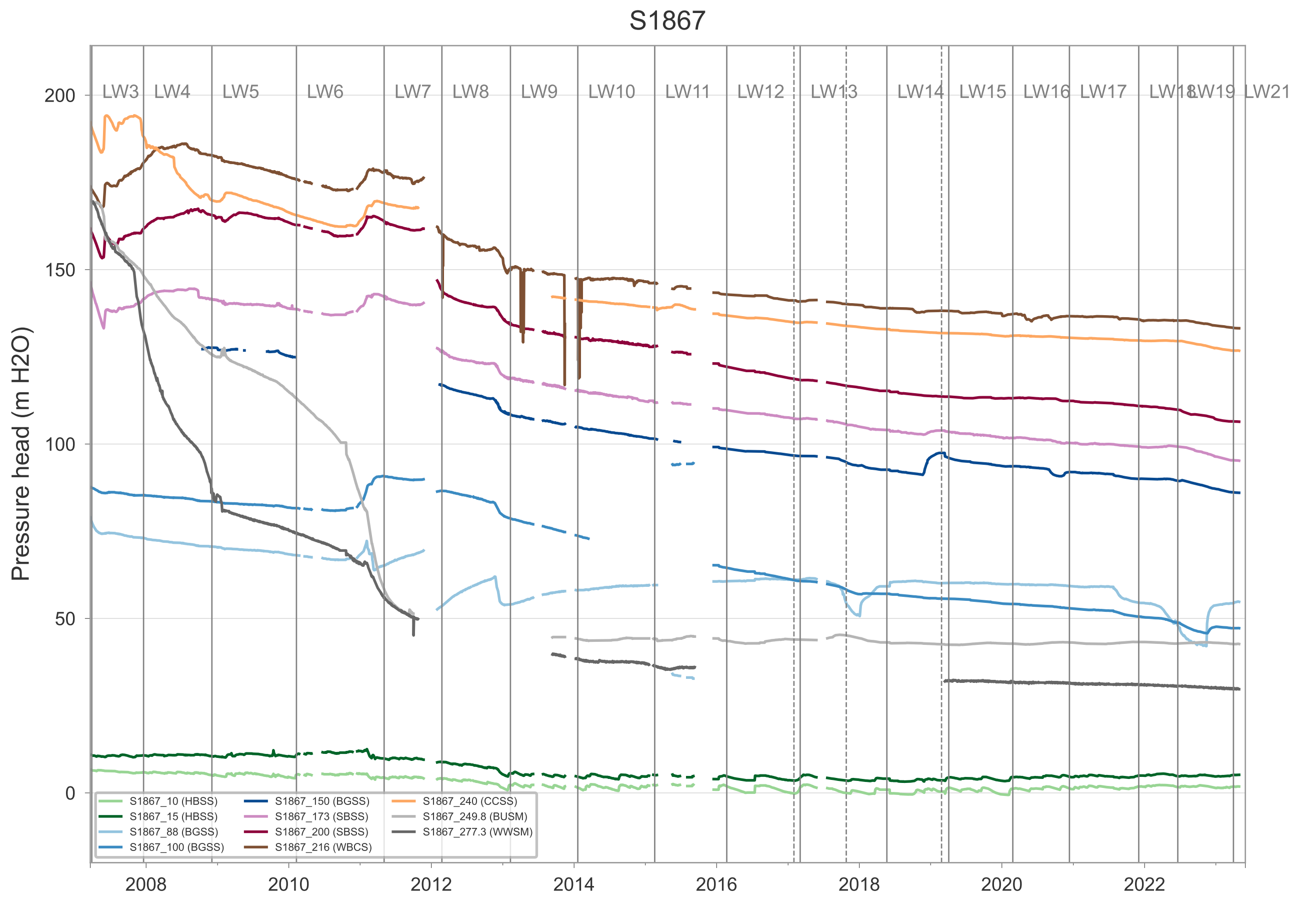
S1855

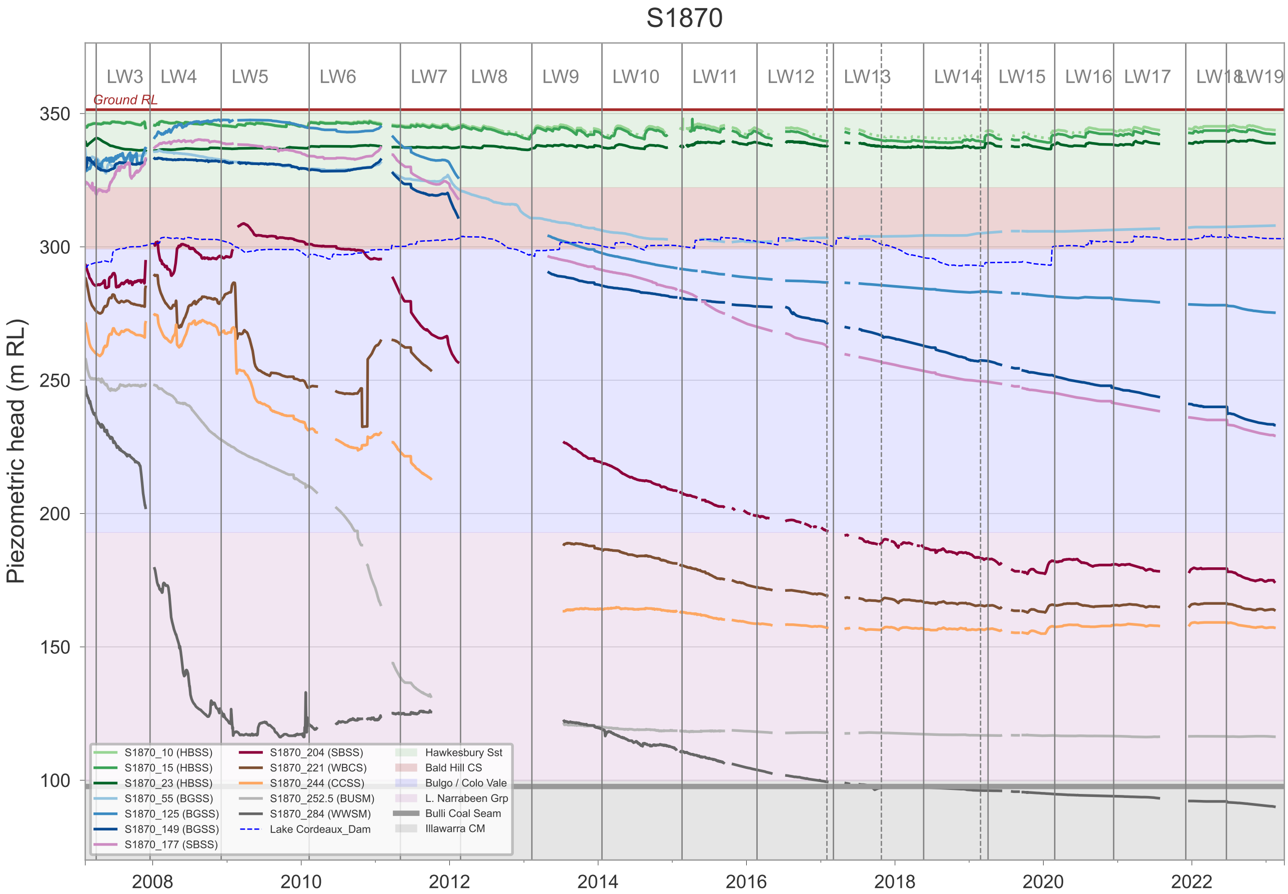

S1855_325 (BUSM)
S1855_356 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Ground RL
LW3
LW4
LW5
LW6
LW7
LW8
Piezometric head (m RL)
350
300
250
200
150
100
50
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

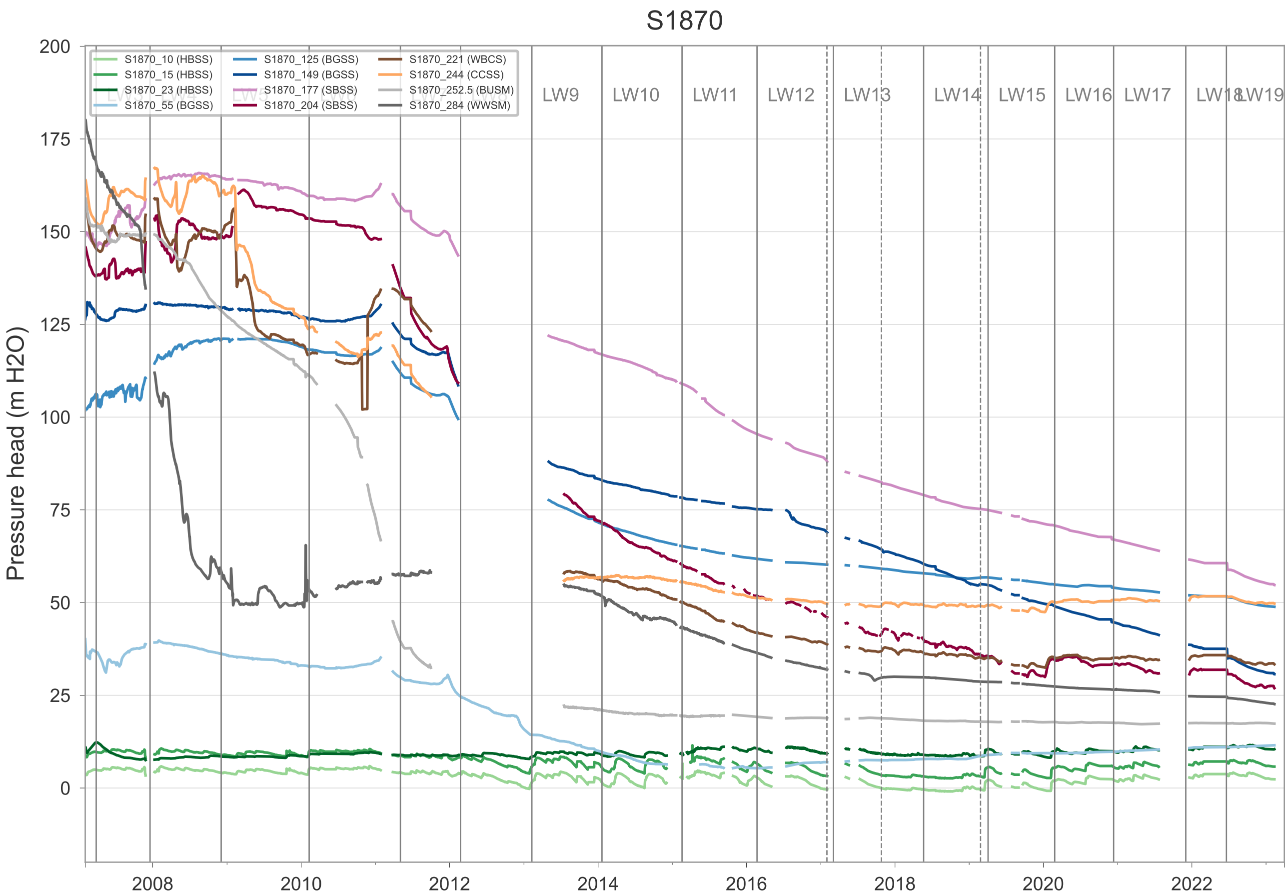
S1855

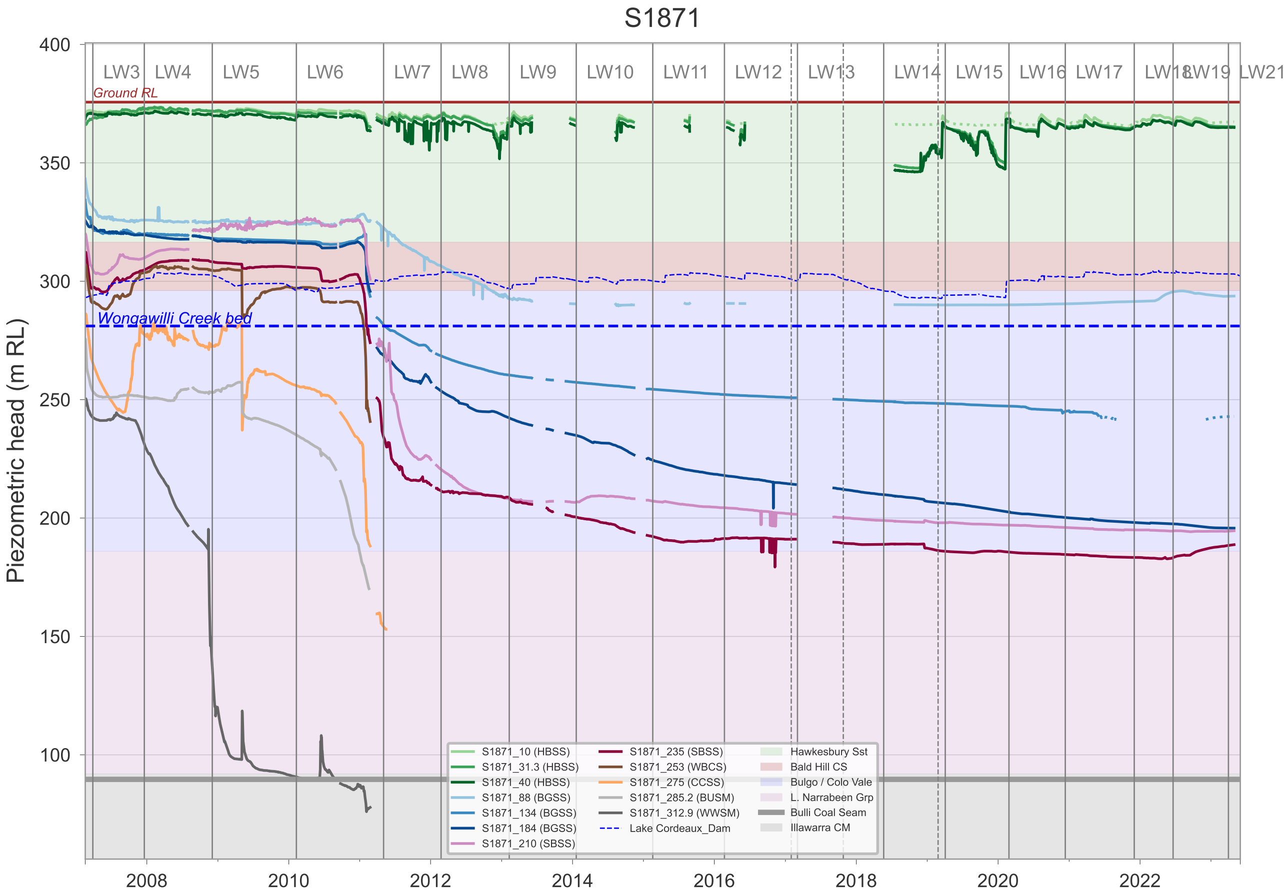

S1855_325 (BUSM)
S1855_356 (WWSM)
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
Pressure head (m H2O)
250
200
150
100
50
0
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

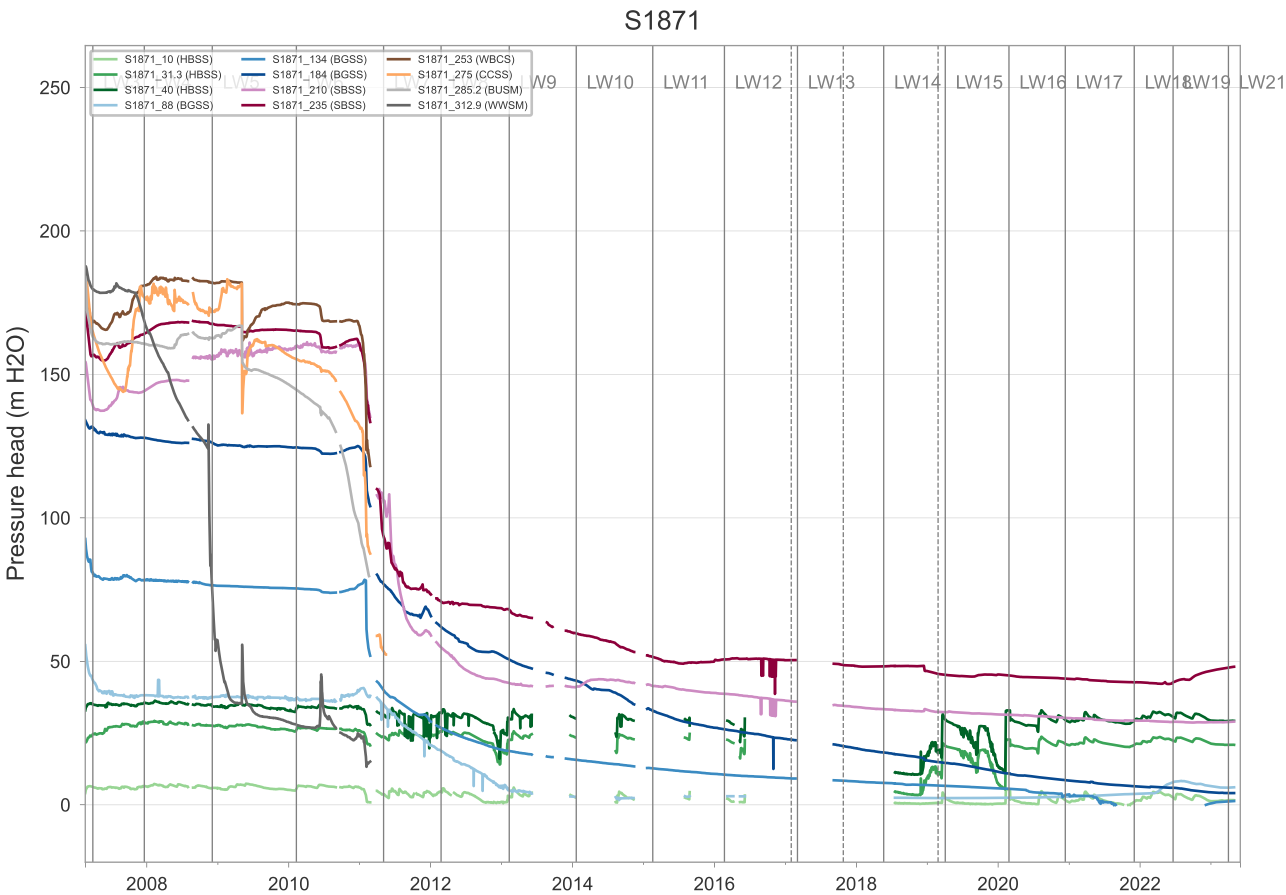

S1867
LW3 LW4 LW5 LW6 LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19 LW21
Ground RL
Piezometric head (m RL)
350
300
250
200
150
100
2008
2010
2012
2014
2016
2018
2020
2022
S1867_10 (HBSS)
S1867_15 (HBSS)
S1867_88 (BGSS)
S1867_100 (BGSS)
S1867_150 (BGSS)
S1867_173 (SBSS)
S1867_200 (SBSS)
S1867_216 (WBCS)
S1867_240 (CCSS)
S1867_249.8 (BUSM)
S1867_277.3 (WWSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM

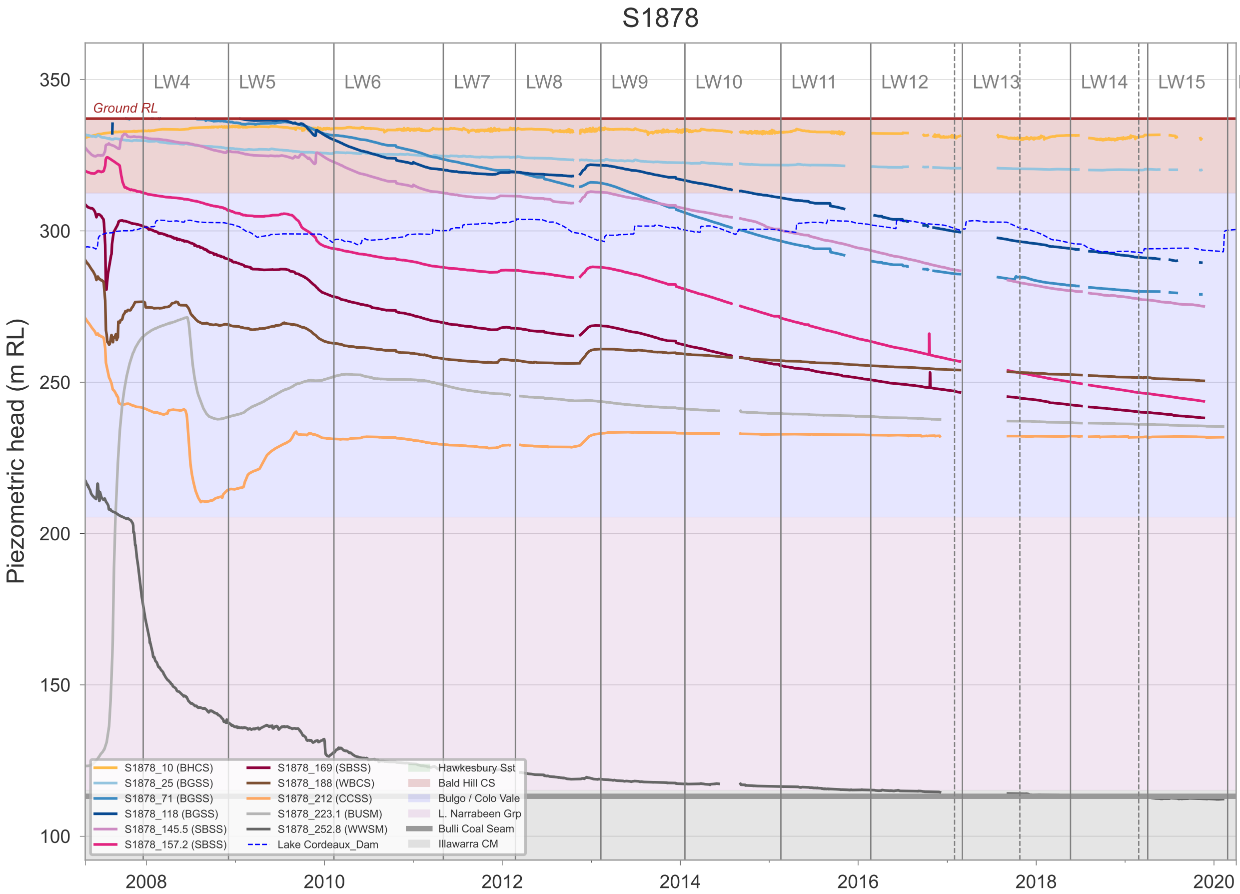

S1867
LW3 LW4 LW5 LW6 LW7 LW8 LW9 LW10 LW11 LW12 LW13 LW14 LW15 LW16 LW17 LW18 LW19 LW21
Pressure head (m H2O)
200
150
100
50
0
2008
2010
2012
2014
2016
2018
2020
2022
S1867_10 (HBSS)
S1867_15 (HBSS)
S1867_88 (BGSS)
S1867_100 (BGSS)
S1867_150 (BGSS)
S1867_173 (SBSS)
S1867_200 (SBSS)
S1867_216 (WBCS)
S1867_240 (CCSS)
S1867_249.8 (BUSM)
S1867_277.3 (WWSM)

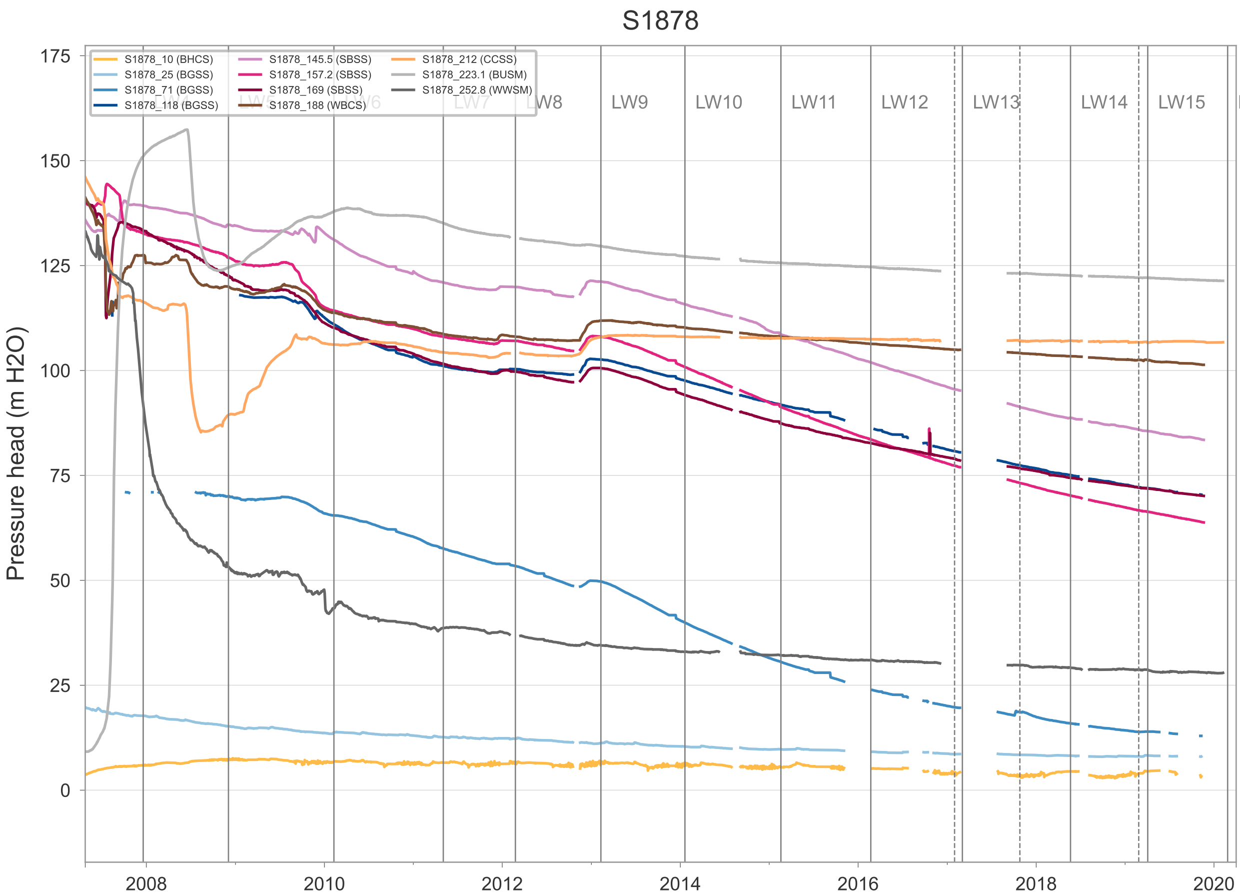

S1870
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Ground RL
Piezometric head (m RL)
350
300
250
200
150
100
2008
2010
2012
2014
2016
2018
2020
2022
S1870_10 (HBSS)
S1870_15 (HBSS)
S1870_23 (HBSS)
S1870_55 (BGSS)
S1870_125 (BGSS)
S1870_149 (BGSS)
S1870_177 (SBSS)
S1870_204 (SBSS)
S1870_221 (WBCS)
S1870_244 (CCSS)
S1870_252.5 (BUSM)
S1870_284 (WWSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM


S1870
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Pressure head (m H2O)
200
175
150
125
100
75
50
25
0
2008
2010
2012
2014
2016
2018
2020
2022
S1870_10 (HBSS)
S1870_15 (HBSS)
S1870_23 (HBSS)
S1870_55 (BGSS)
S1870_125 (BGSS)
S1870_149 (BGSS)
S1870_177 (SBSS)
S1870_204 (SBSS)
S1870_221 (WBCS)
S1870_244 (CCSS)
S1870_252.5 (BUSM)
S1870_284 (WWSM)

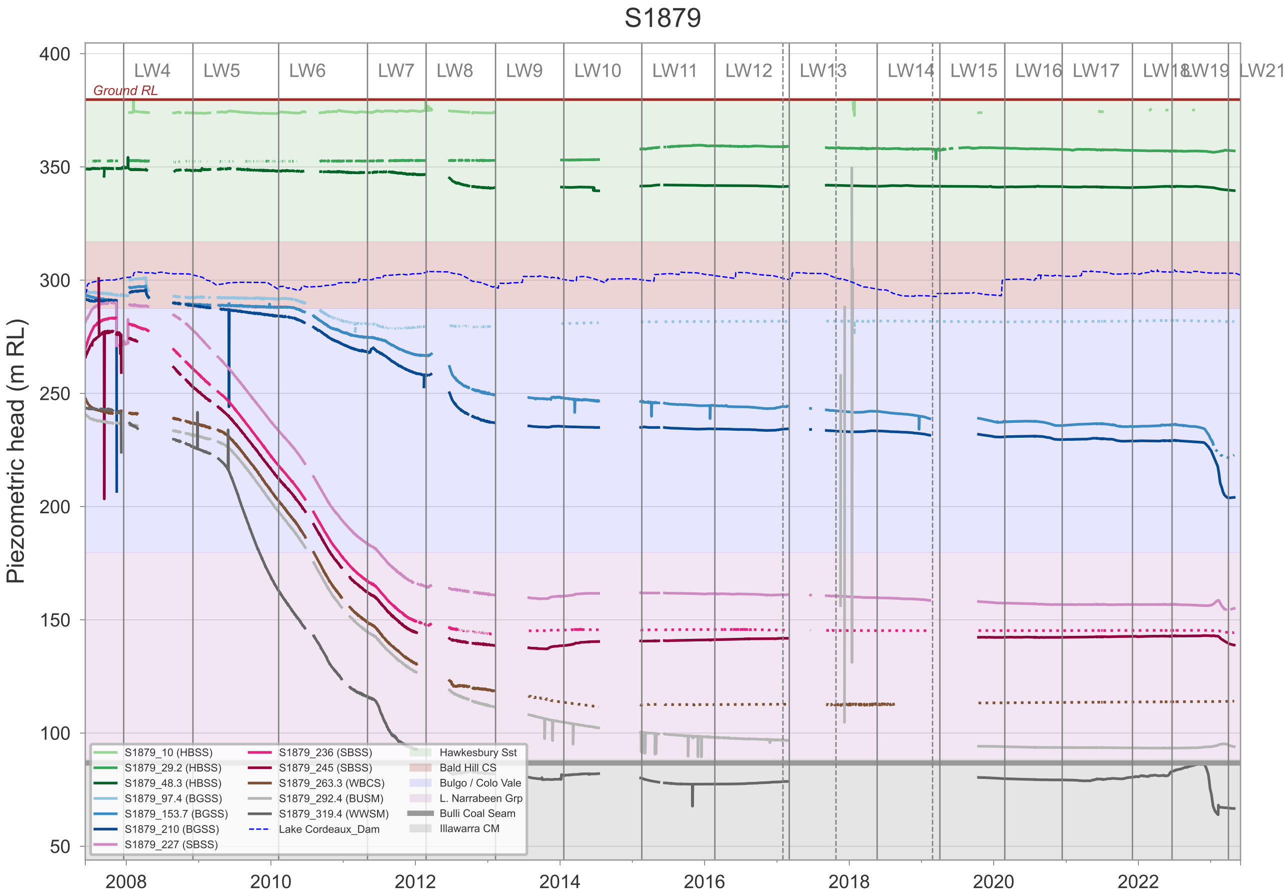

S1871
Piezometric head (m RL)
400
350
300
250
200
150
100
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Ground RL
Wongawilli Creek bed
2008
2010
2012
2014
2016
2018
2020
2022
S1871_10 (HBSS)
S1871_31.3 (HBSS)
S1871_40 (HBSS)
S1871_88 (BGSS)
S1871_134 (BGSS)
S1871_184 (BGSS)
S1871_210 (SBSS)
S1871_235 (SBSS)
S1871_253 (WBCS)
S1871_275 (CCSS)
S1871_285.2 (BUSM)
S1871_312.9 (WWSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM

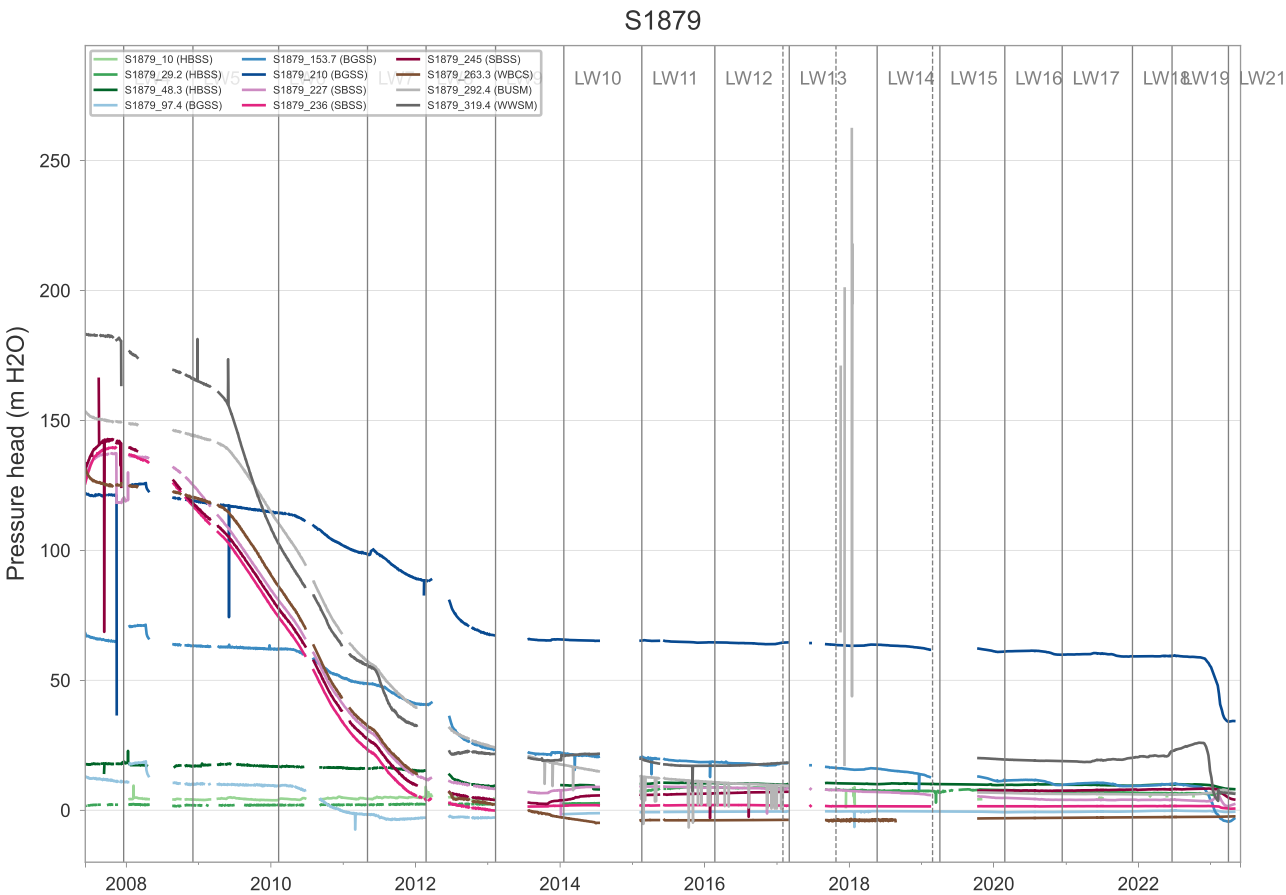

S1871
Pressure head (m H2O)
250
200
150
100
50
0
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
2008
2010
2012
2014
2016
2018
2020
2022
S1871_10 (HBSS)
S1871_31.3 (HBSS)
S1871_40 (HBSS)
S1871_88 (BGSS)
S1871_134 (BGSS)
S1871_184 (BGSS)
S1871_210 (SBSS)
S1871_235 (SBSS)
S1871_253 (WBCS)
S1871_275 (CCSS)
S1871_285.2 (BUSM)
S1871_312.9 (WWSM)


S1878
Piezometric head (m RL)
Ground RL
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
S1878_10 (BHCS)
S1878_25 (BGSS)
S1878_71 (BGSS)
S1878_118 (BGSS)
S1878_145.5 (SBSS)
S1878_157.2 (SBSS)
S1878_169 (SBSS)
S1878_188 (WBCS)
S1878_212 (CCSS)
S1878_223.1 (BUSM)
S1878_252.8 (WWSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM


S1878
Pressure head (m H2O)
S1878_10 (BHCS)
S1878_25 (BGSS)
S1878_71 (BGSS)
S1878_118 (BGSS)
S1878_145.5 (SBSS)
S1878_157.2 (SBSS)
S1878_169 (SBSS)
S1878_188 (WBCS)
S1878_212 (CCSS)
S1878_223.1 (BUSM)
S1878_252.8 (WWSM)
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16

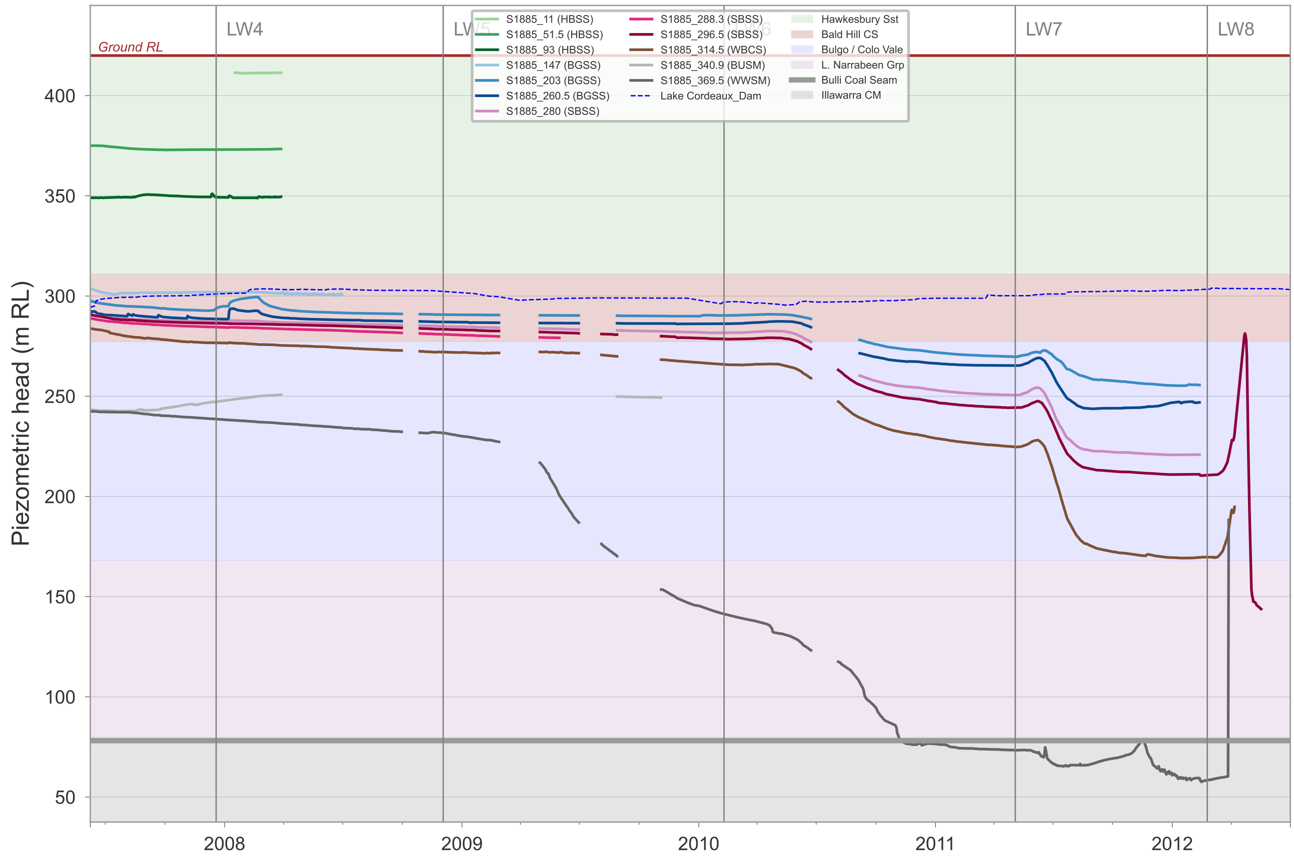
Groundwater hydrographs



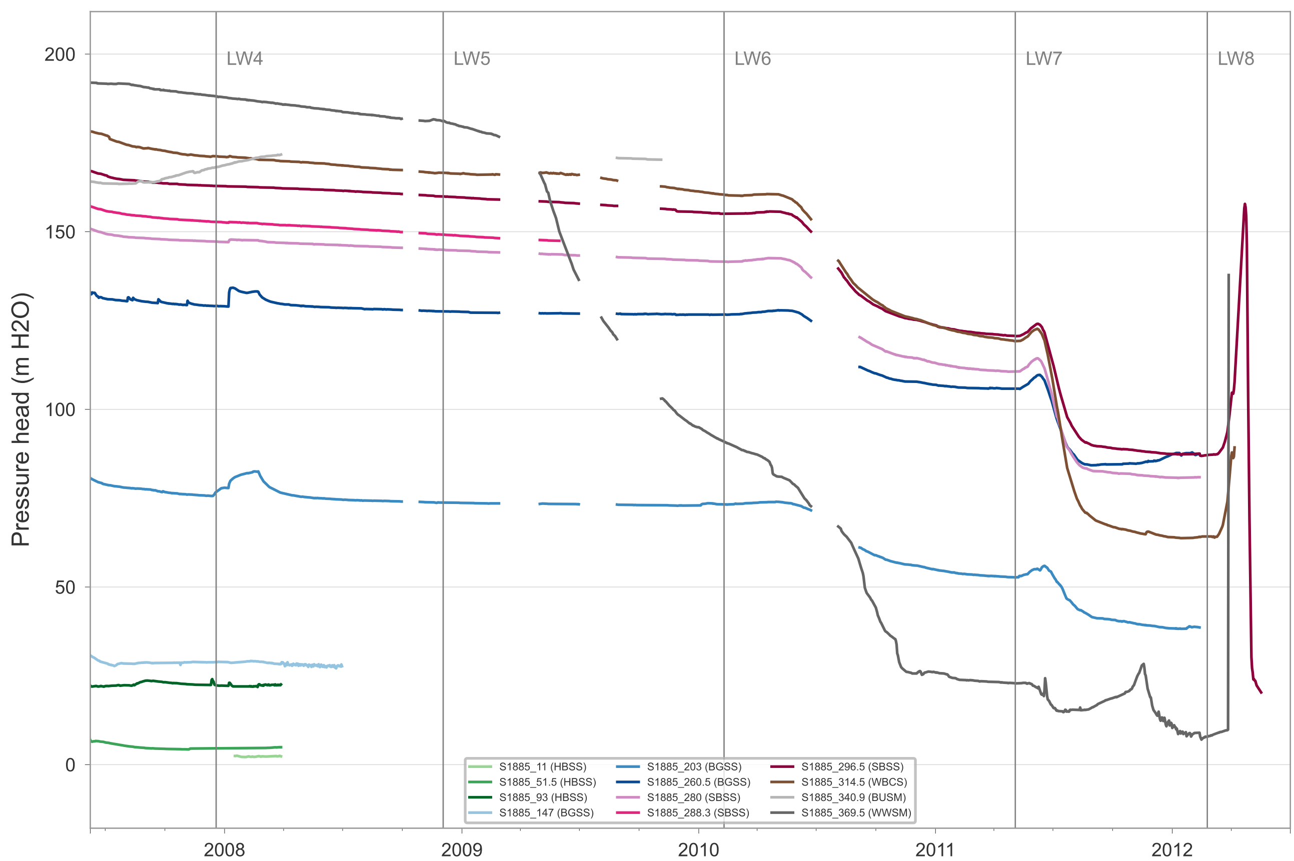


Groundwater hydrographs

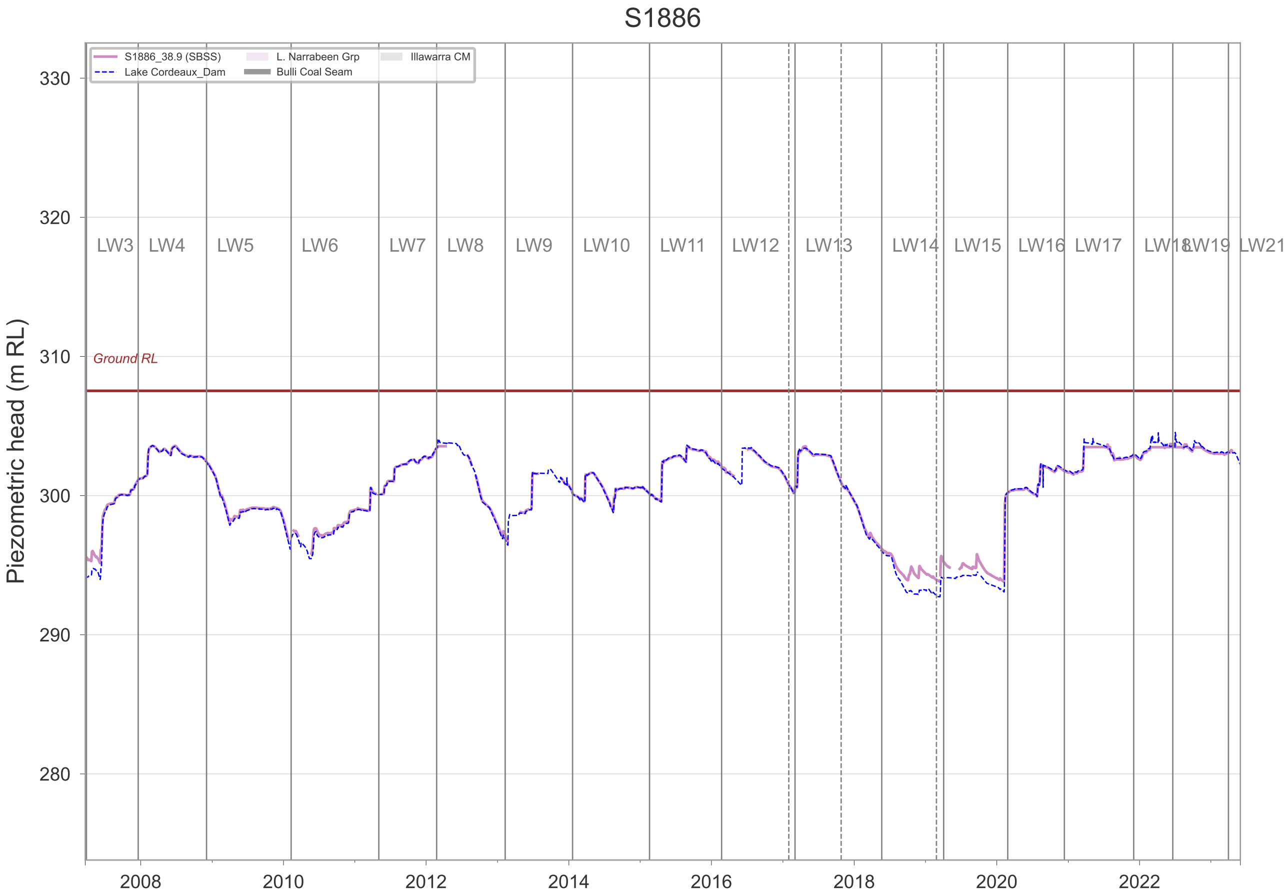
S1885

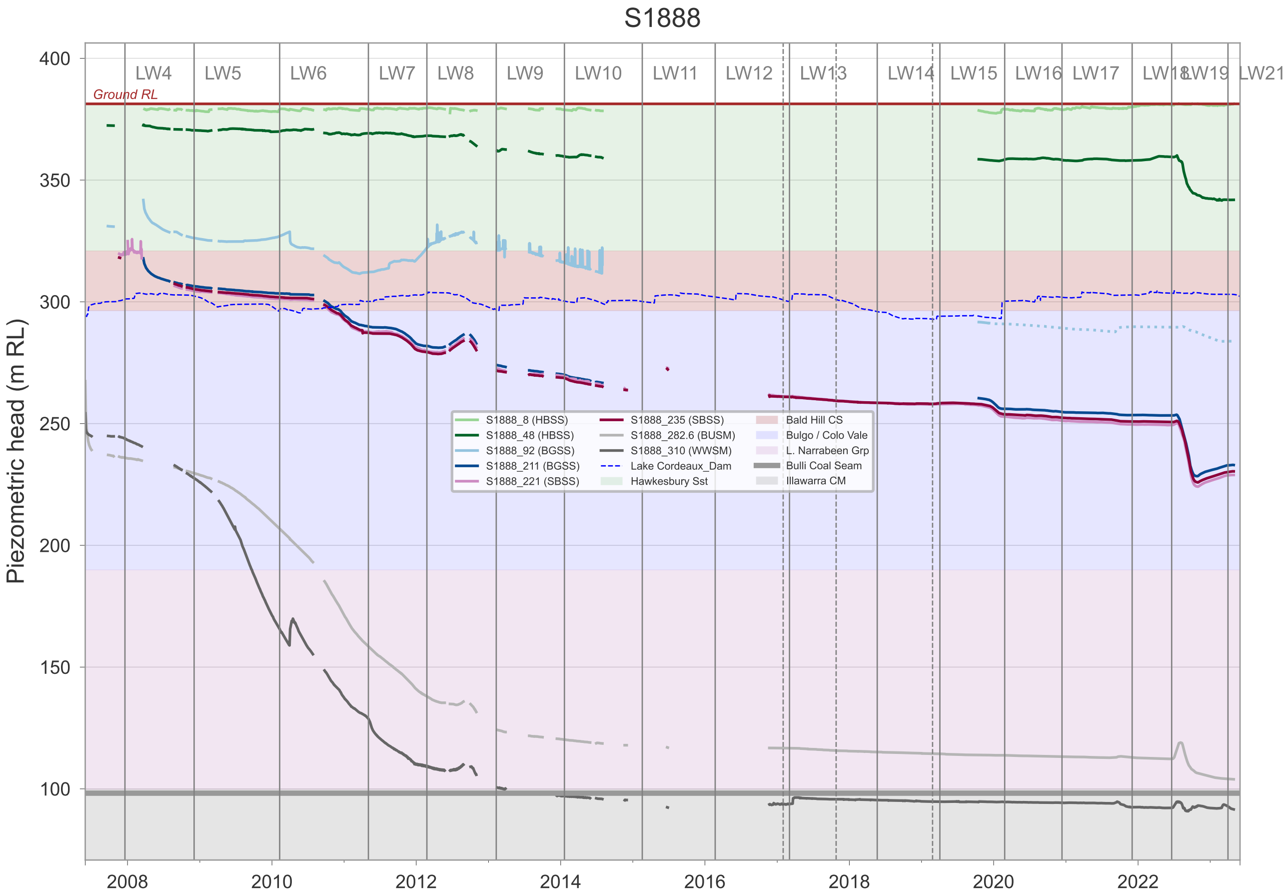


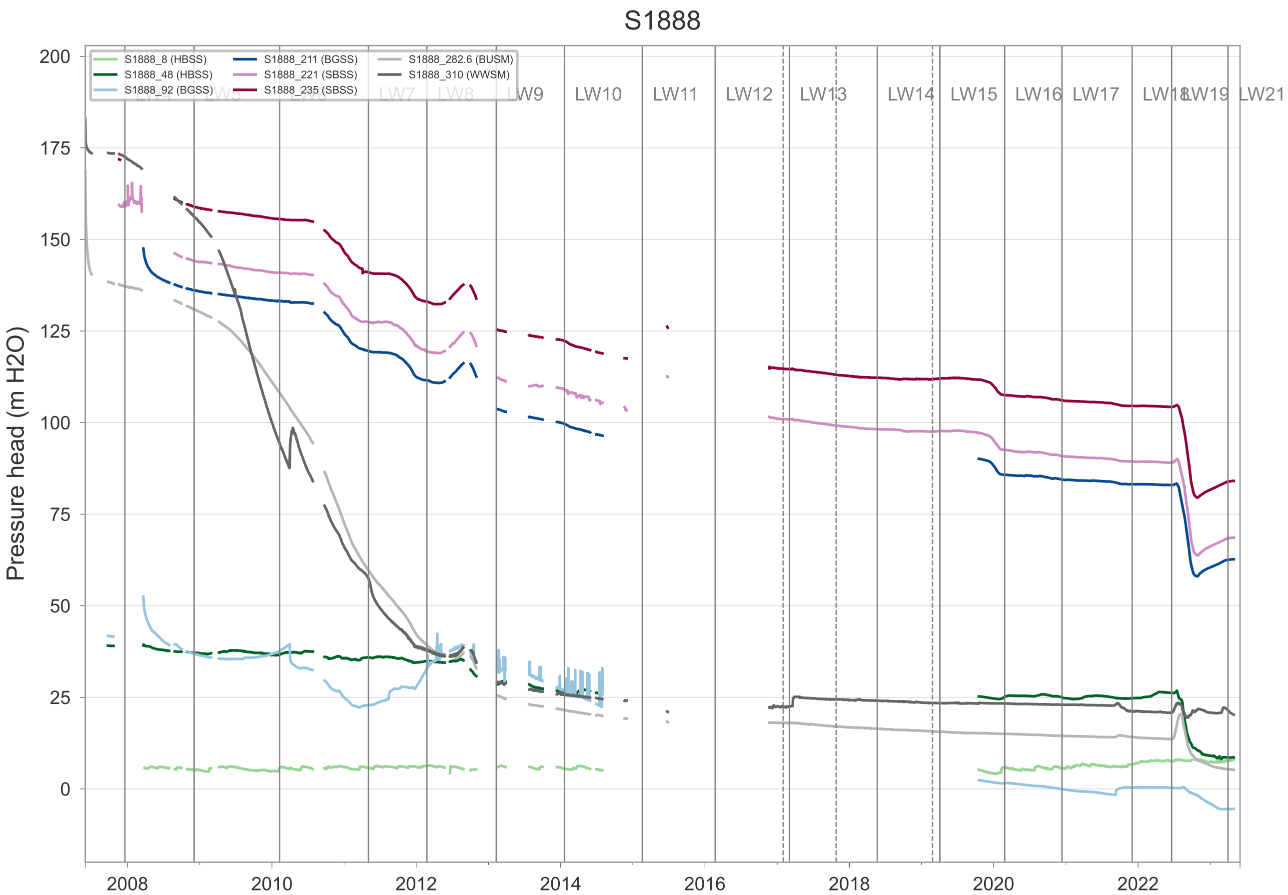
S1885



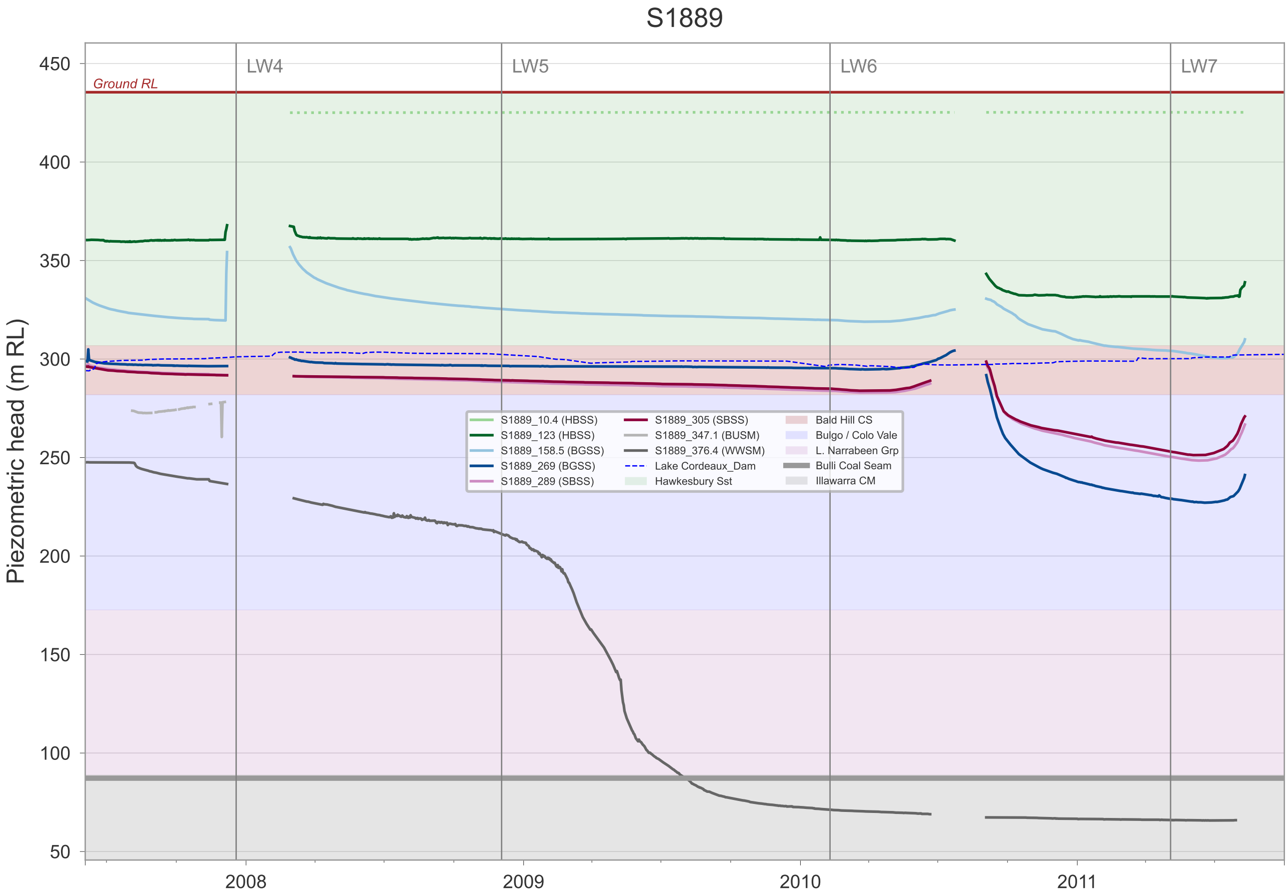
Groundwater hydrographs

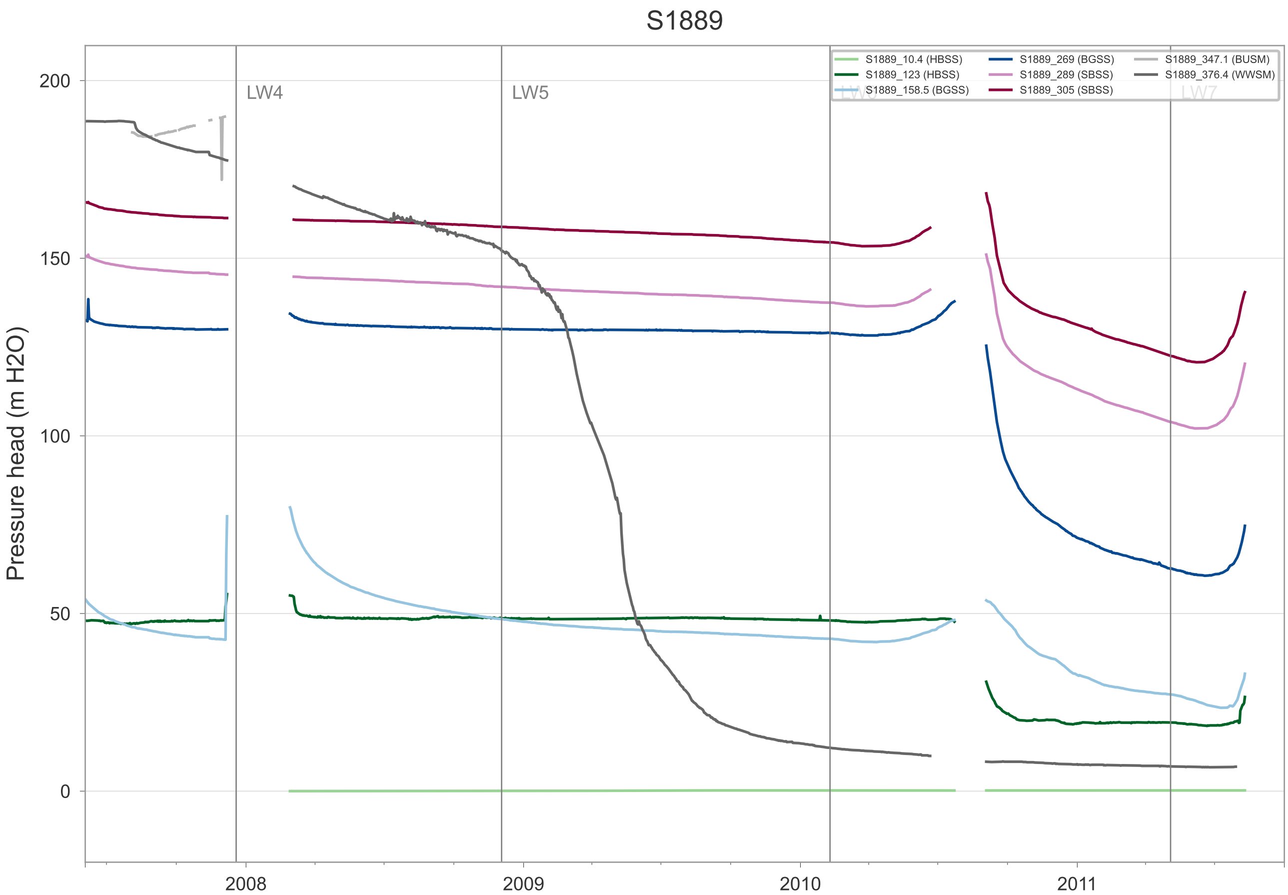



S1888
Piezometric head (m RL)
Ground RL
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
S1888_8 (HBSS)
S1888_48 (HBSS)
S1888_92 (BGSS)
S1888_211 (BGSS)
S1888_221 (SBSS)
S1888_235 (SBSS)
S1888_282.6 (BUSM)
S1888_310 (WWSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
400
350
300
250
200
150
100
2008
2010
2012
2014
2016
2018
2020
2022

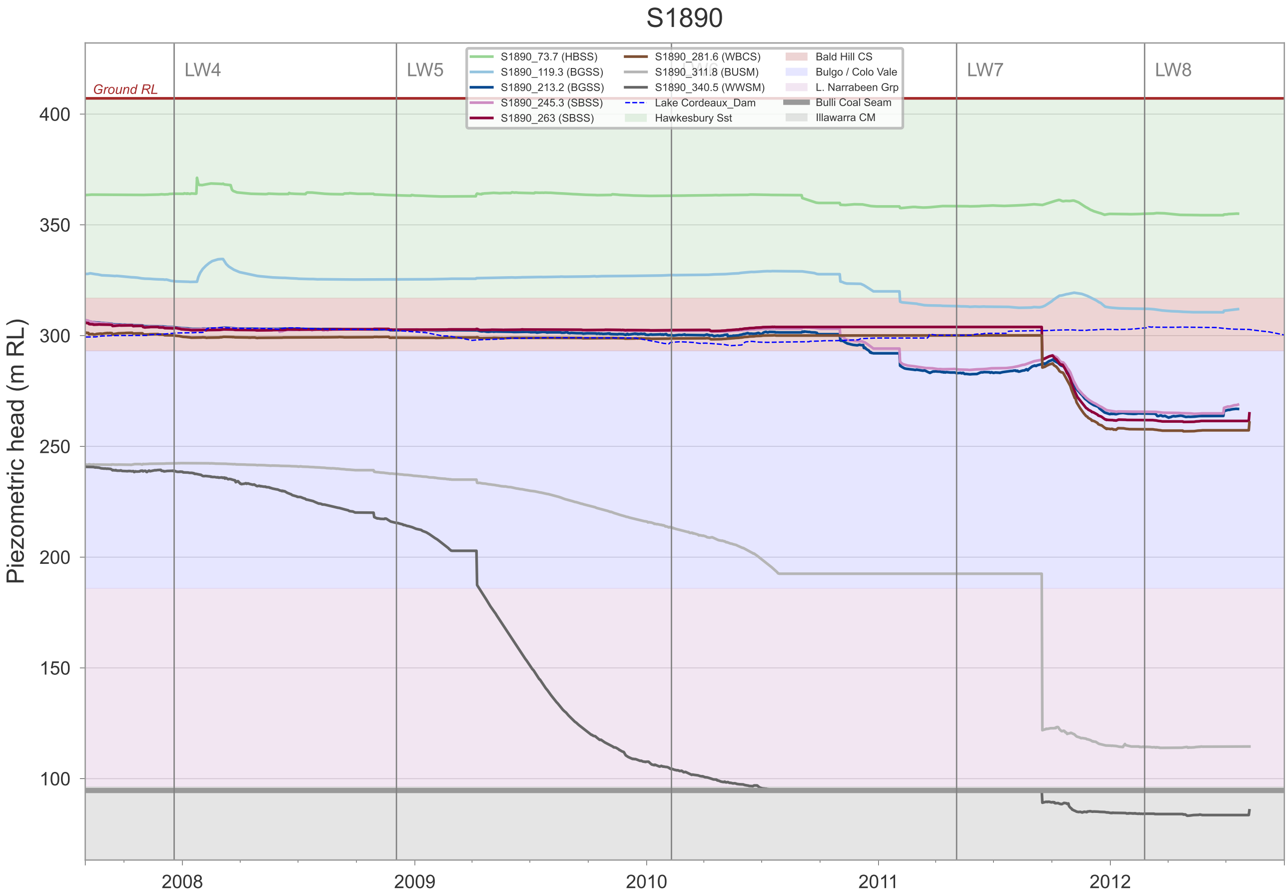

S1888
Pressure head (m H2O)
S1888_8 (HBSS)
S1888_48 (HBSS)
S1888_92 (BGSS)
S1888_211 (BGSS)
S1888_221 (SBSS)
S1888_235 (SBSS)
S1888_282.6 (BUSM)
S1888_310 (WWSM)
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
200
175
150
125
100
75
50
25
0
2008
2010
2012
2014
2016
2018
2020
2022

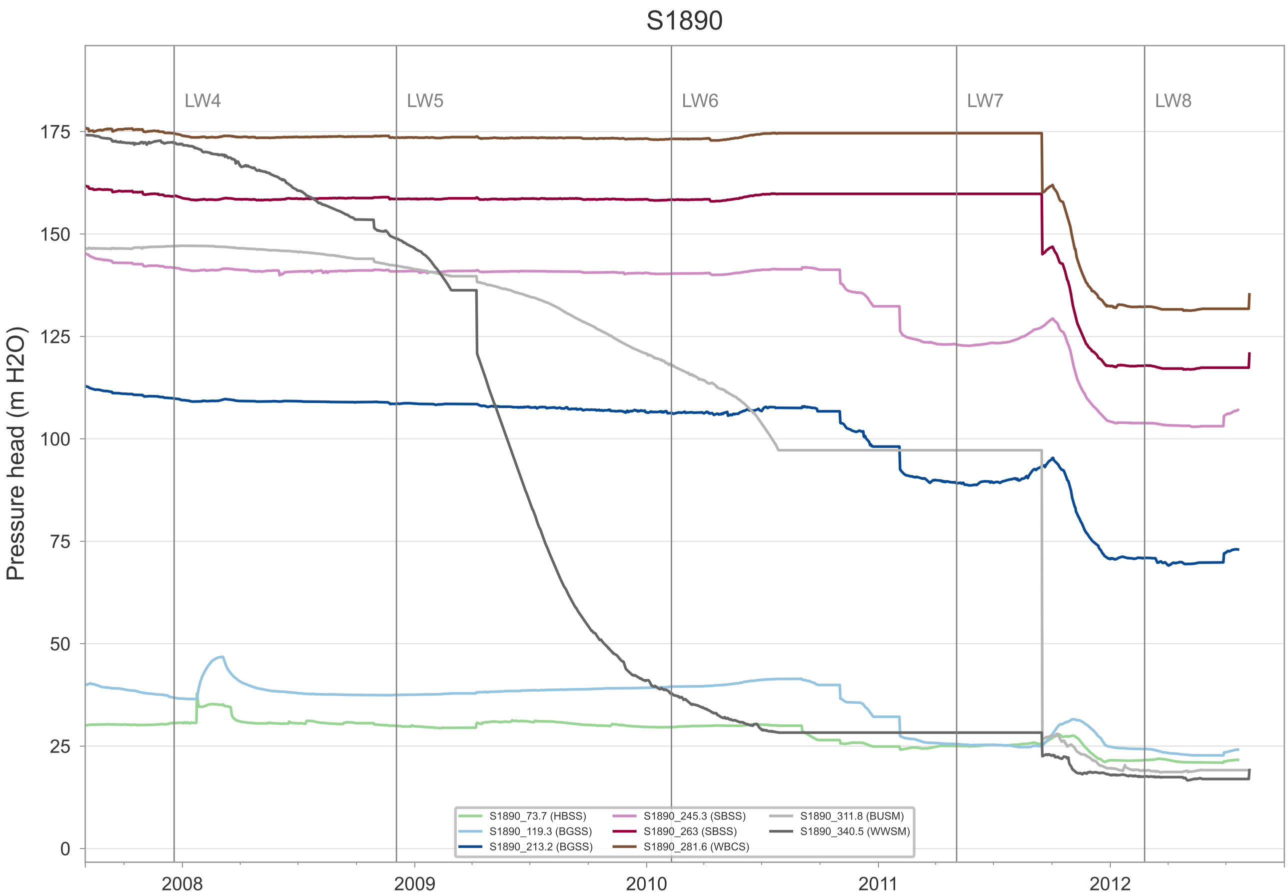
Groundwater hydrographs



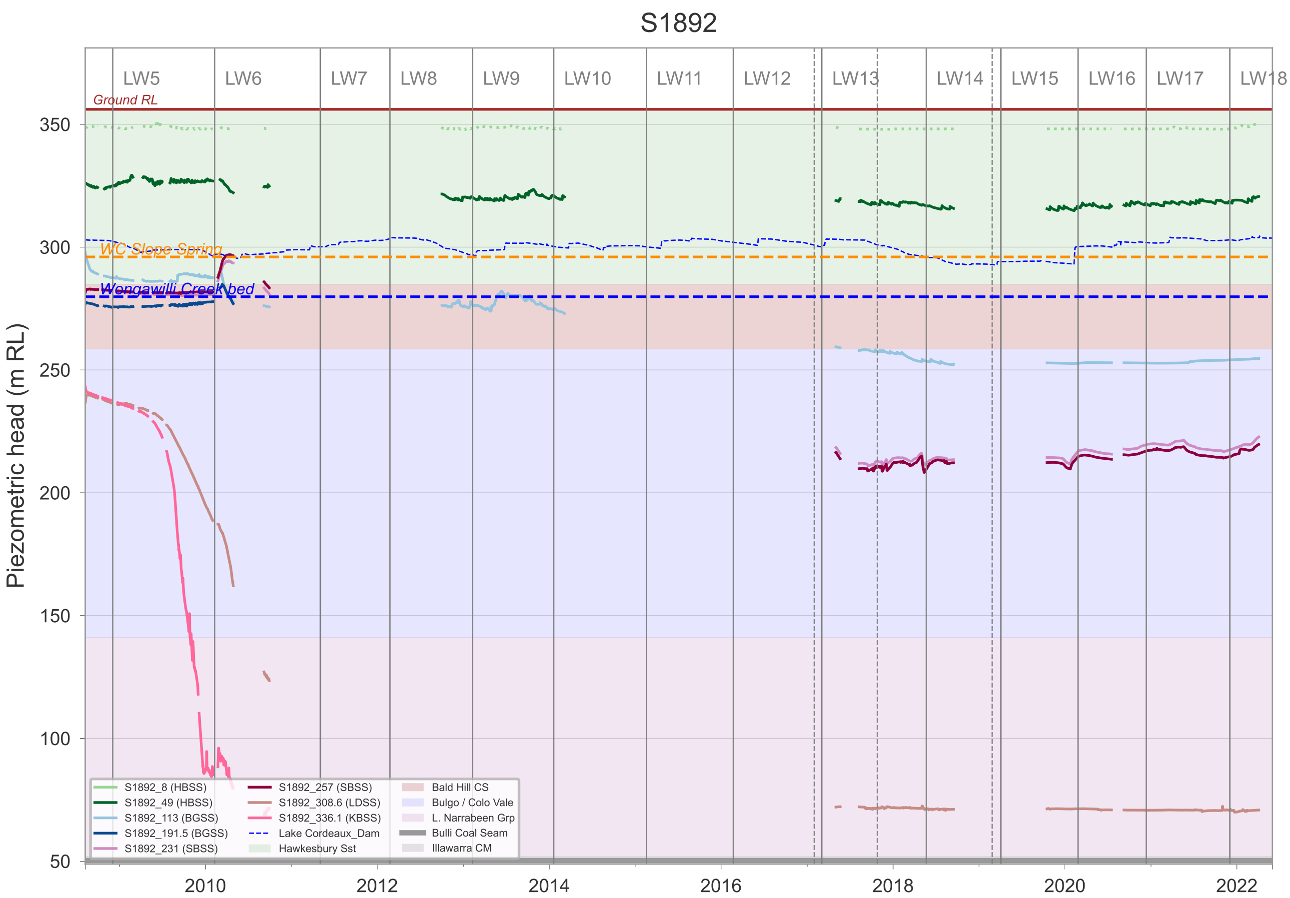


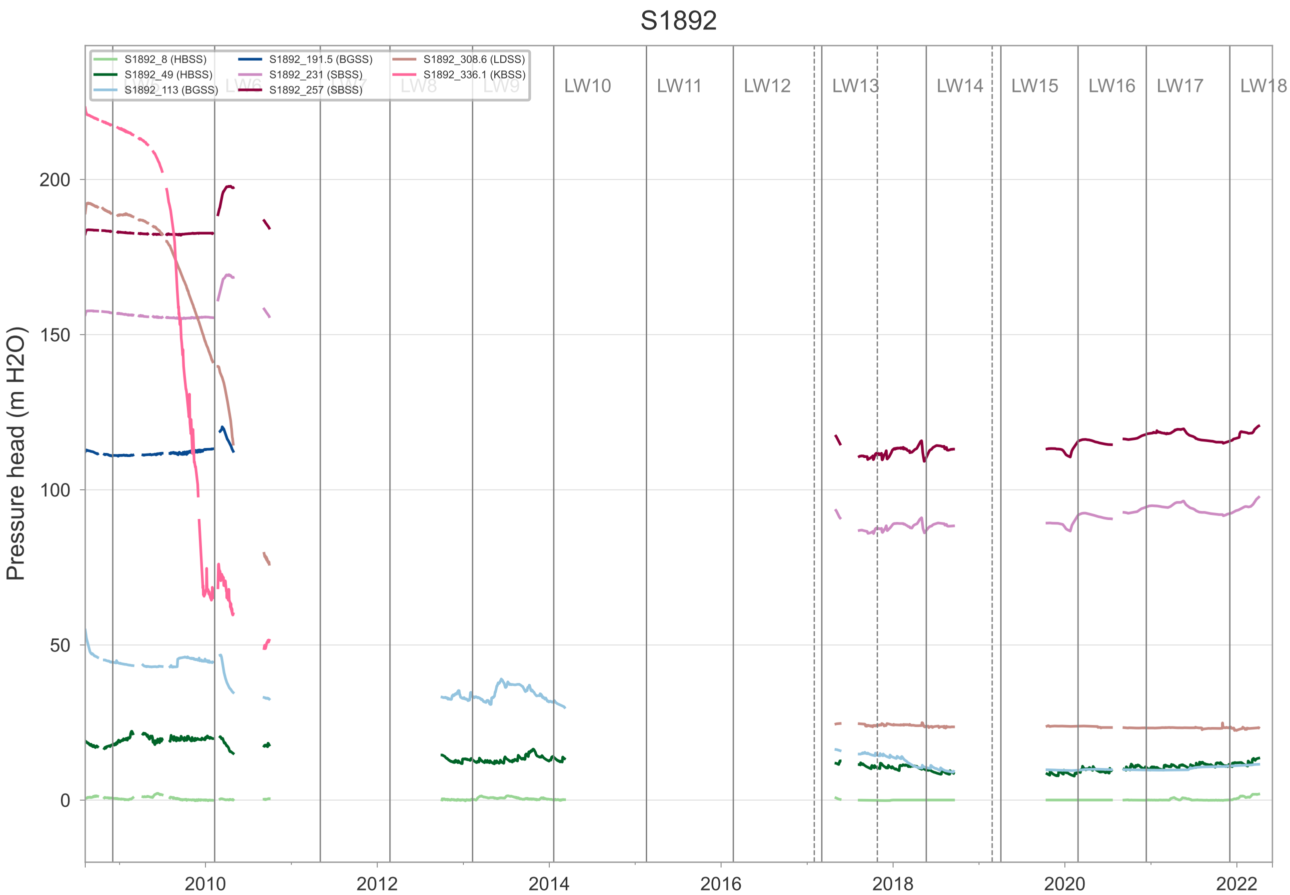
Groundwater hydrographs

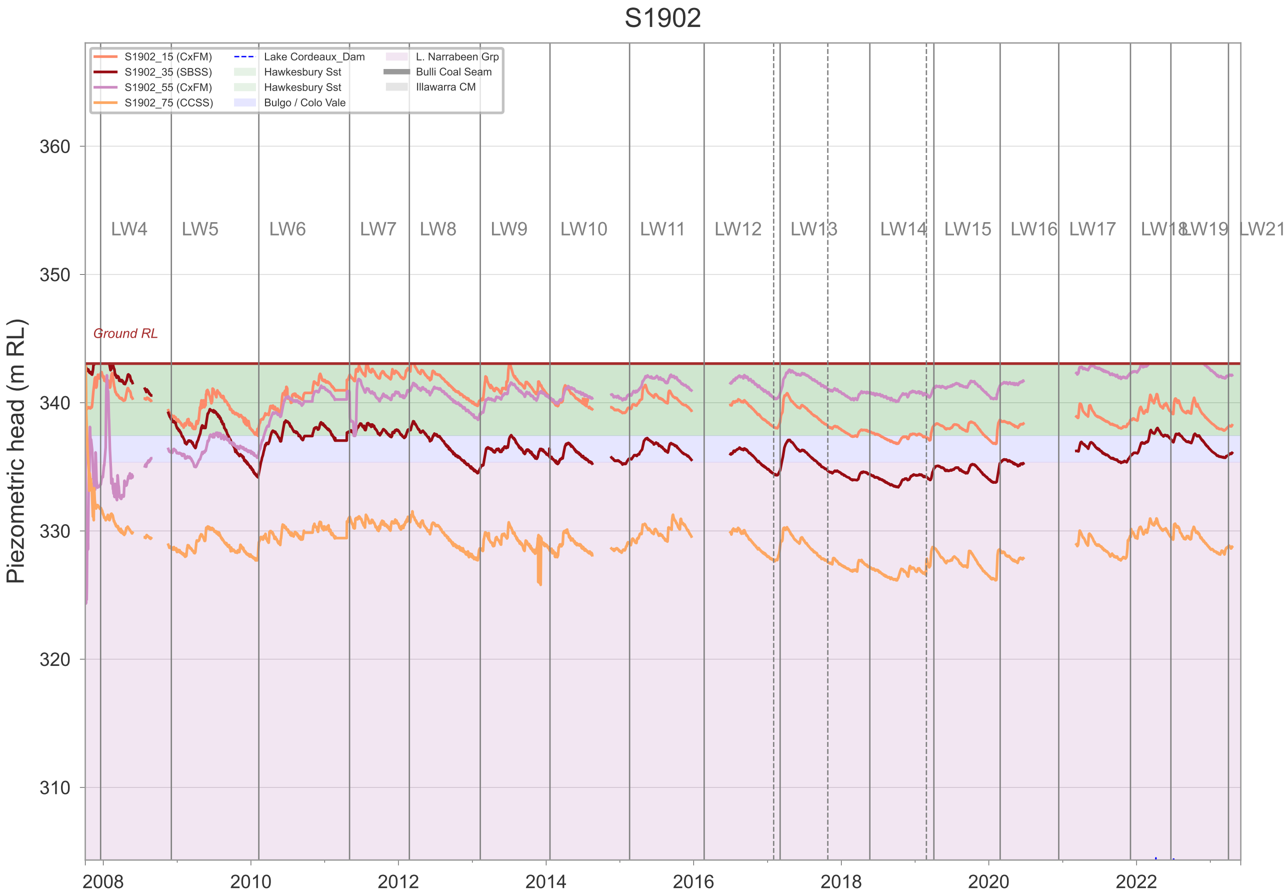


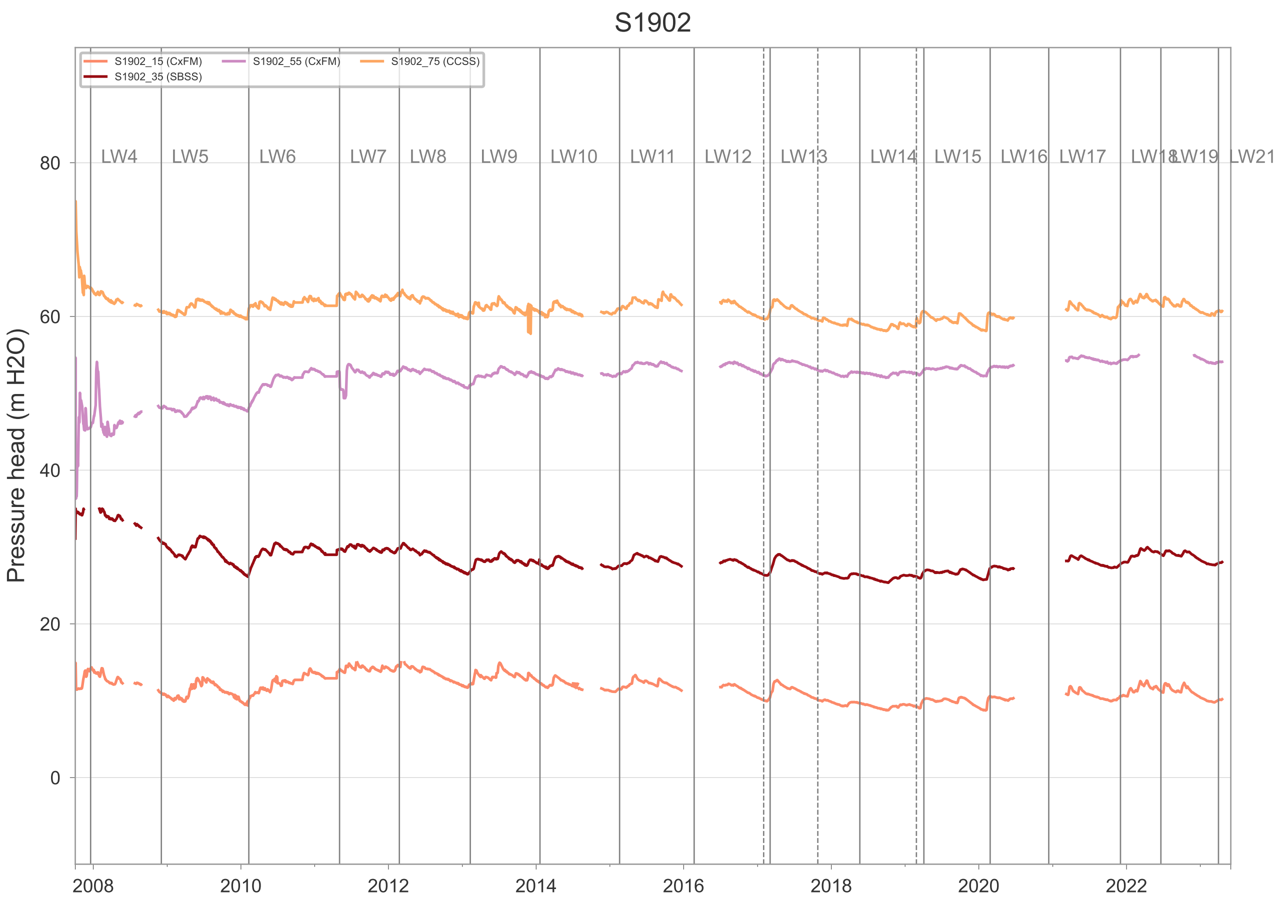


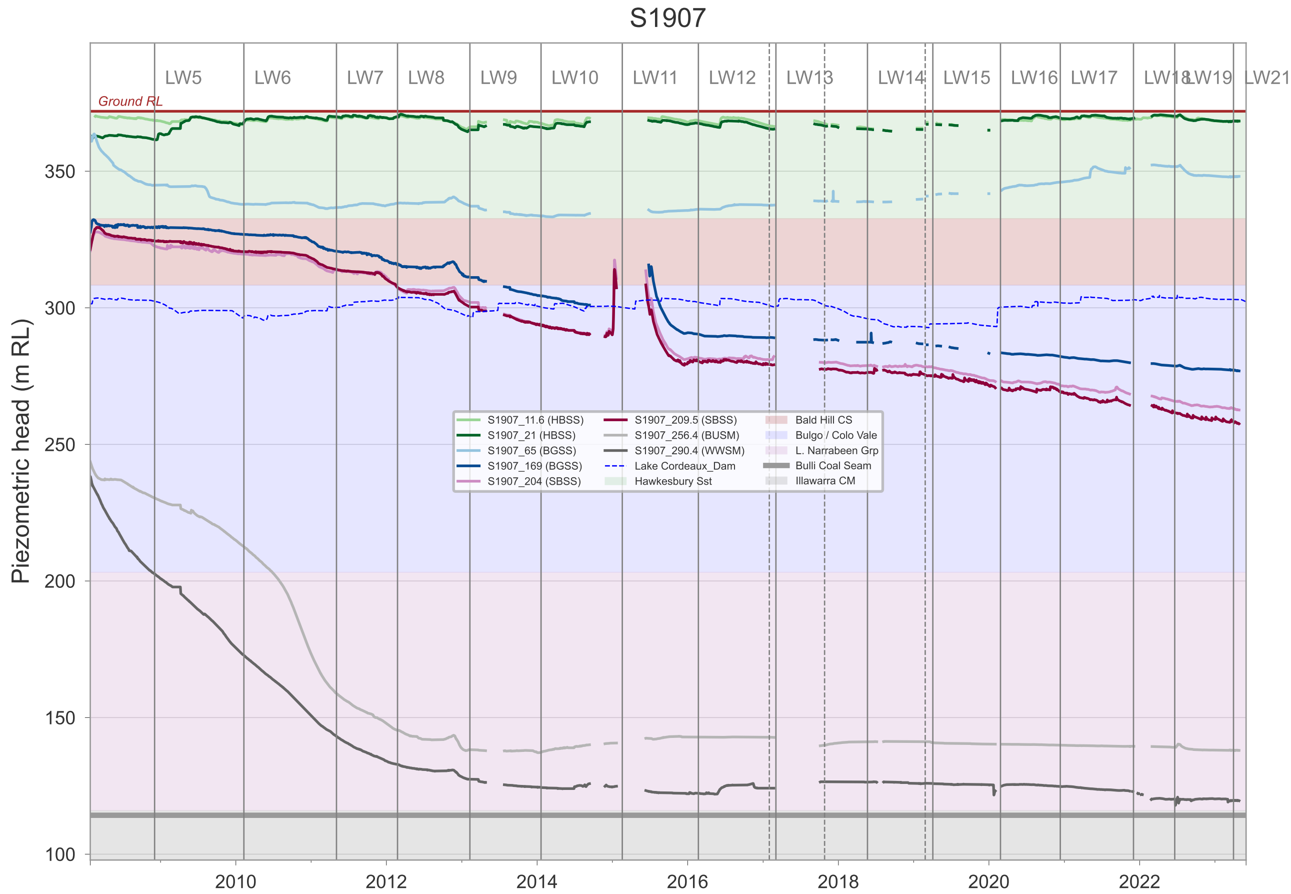
Groundwater hydrographs

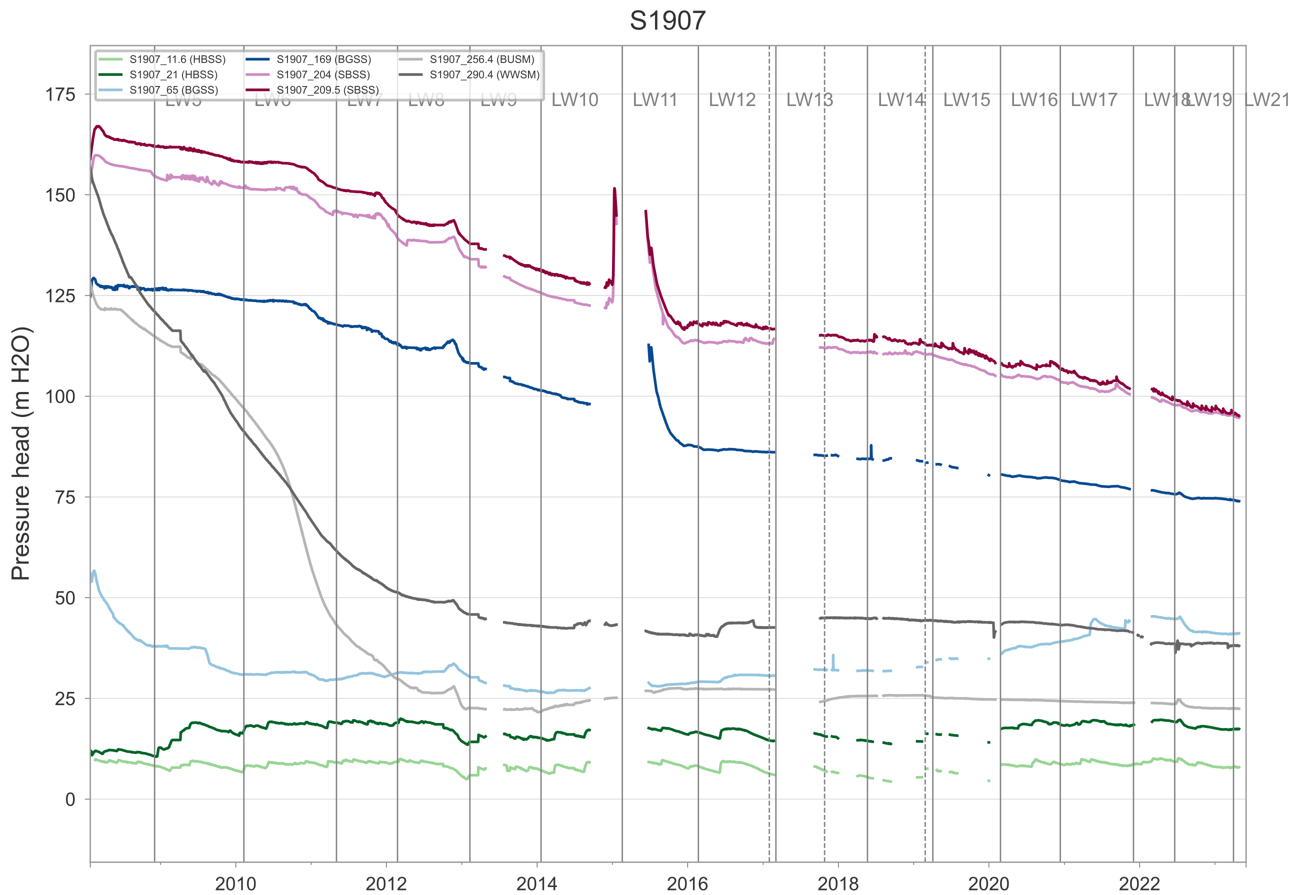




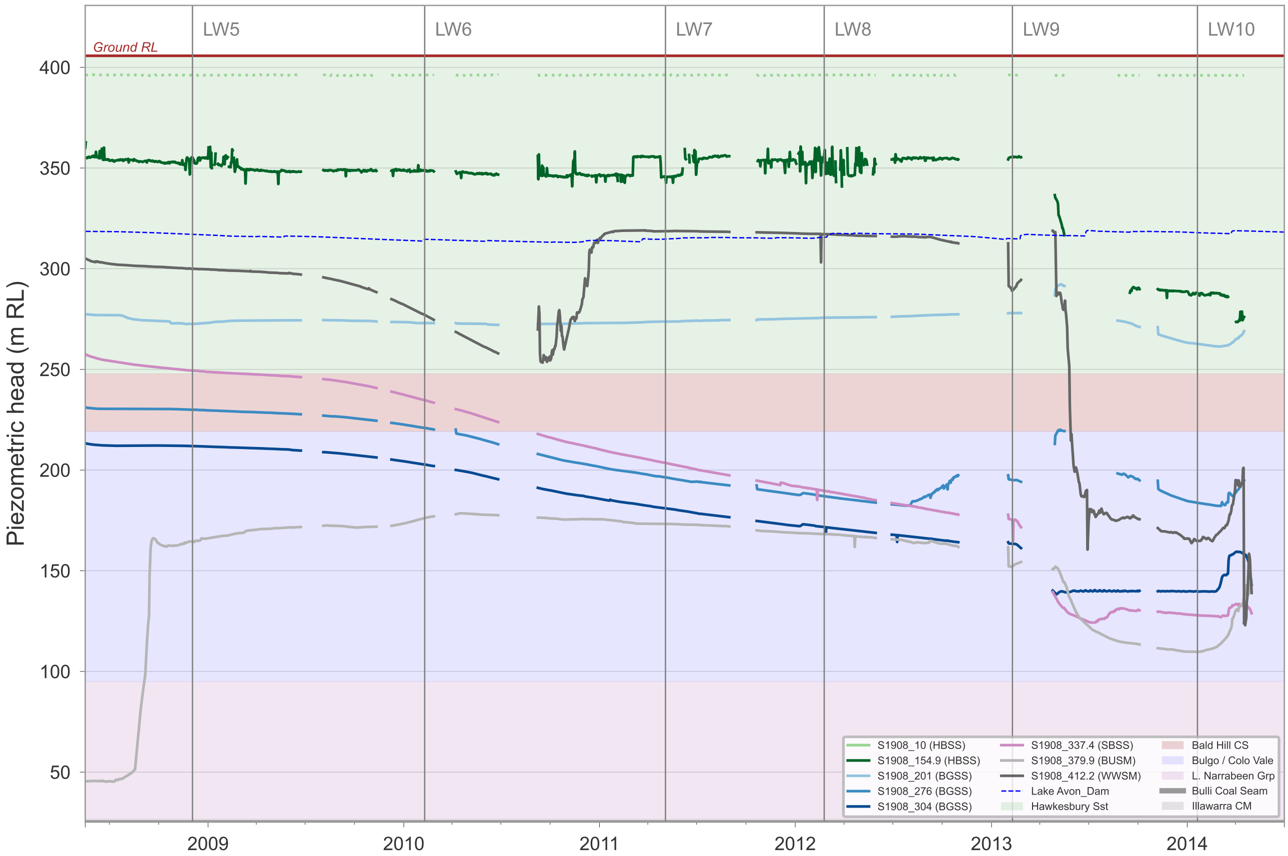

S1902
S1902_15 (CxFM)
S1902_35 (SBSS)
S1902_55 (CxFM)
S1902_75 (CCSS)
Lake Cordeaux_Dam
Hawkesbury Sst
Hawkesbury Sst
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Ground RL
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Piezometric head (m RL)
360
350
340
330
320
310
2008
2010
2012
2014
2016
2018
2020
2022


S1902
S1902_15 (CxFM)
S1902_35 (SBSS)
S1902_55 (CxFM)
S1902_75 (CCSS)
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Pressure head (m H2O)
80
60
40
20
0
2008
2010
2012
2014
2016
2018
2020
2022

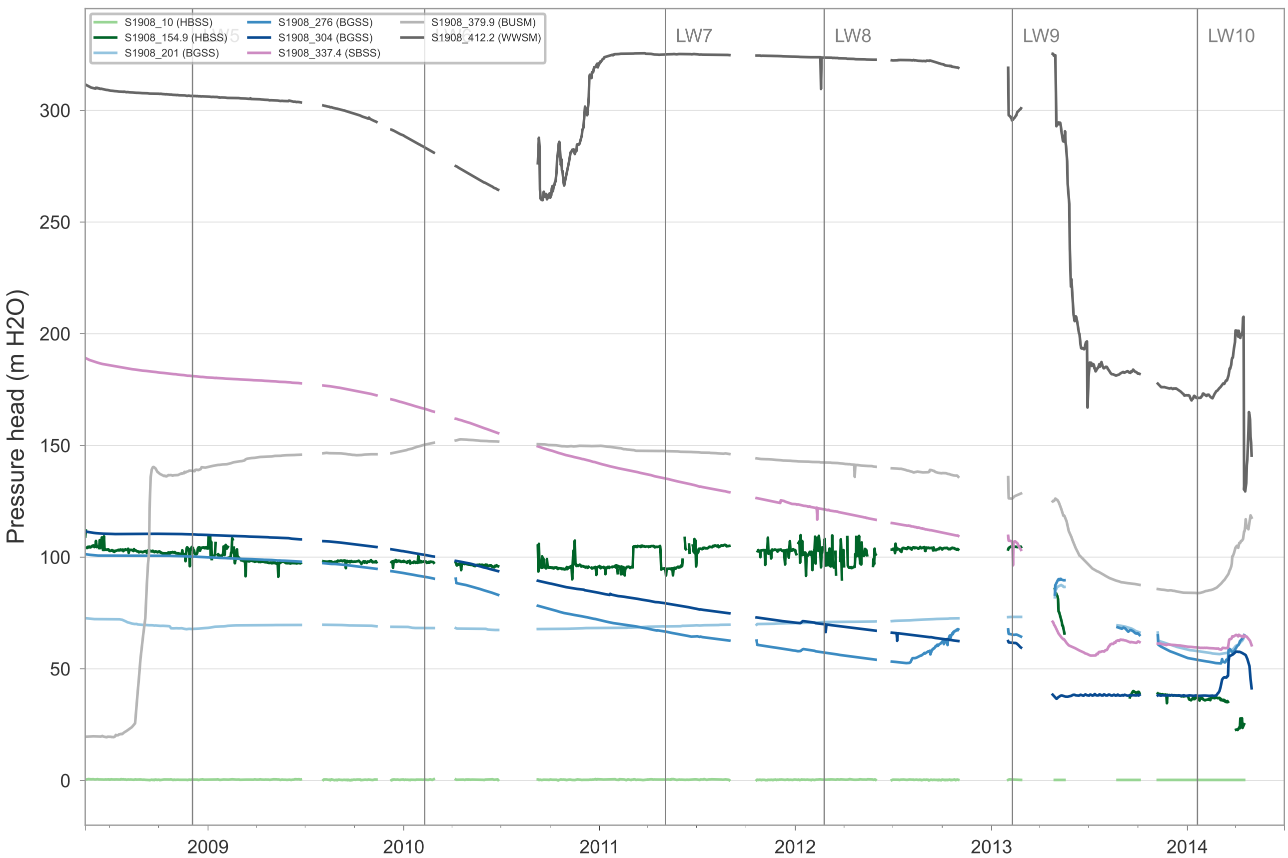

S1907
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Ground RL
Piezometric head (m RL)
S1907_11.6 (HBSS)
S1907_21 (HBSS)
S1907_65 (BGSS)
S1907_169 (BGSS)
S1907_204 (SBSS)
S1907_209.5 (SBSS)
S1907_256.4 (BUSM)
S1907_290.4 (WWSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM

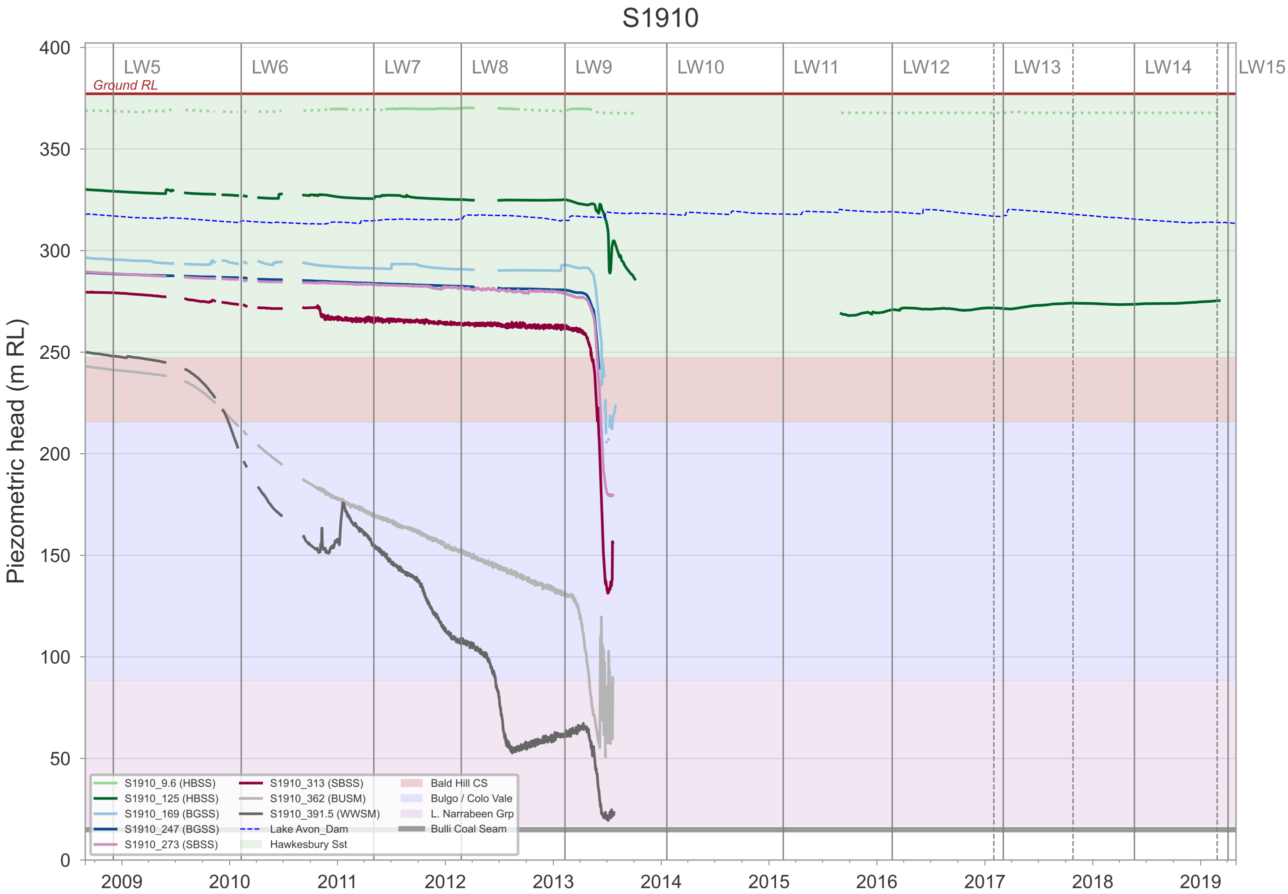

S1907
S1907_11.6 (HBSS)
S1907_21 (HBSS)
S1907_65 (BGSS)
S1907_169 (BGSS)
S1907_204 (SBSS)
S1907_209.5 (SBSS)
S1907_256.4 (BUSM)
S1907_290.4 (WWSM)
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Pressure head (m H2O)

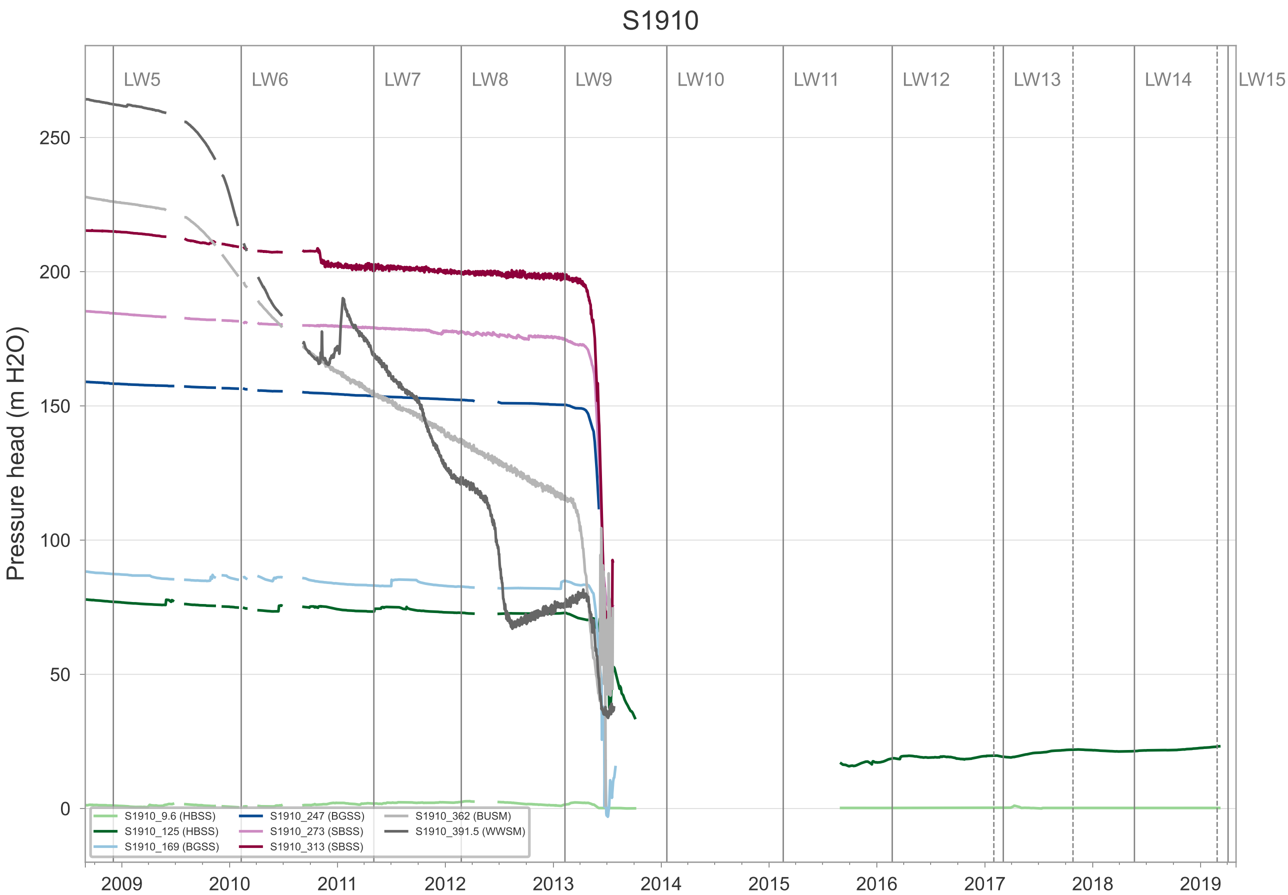
S1908

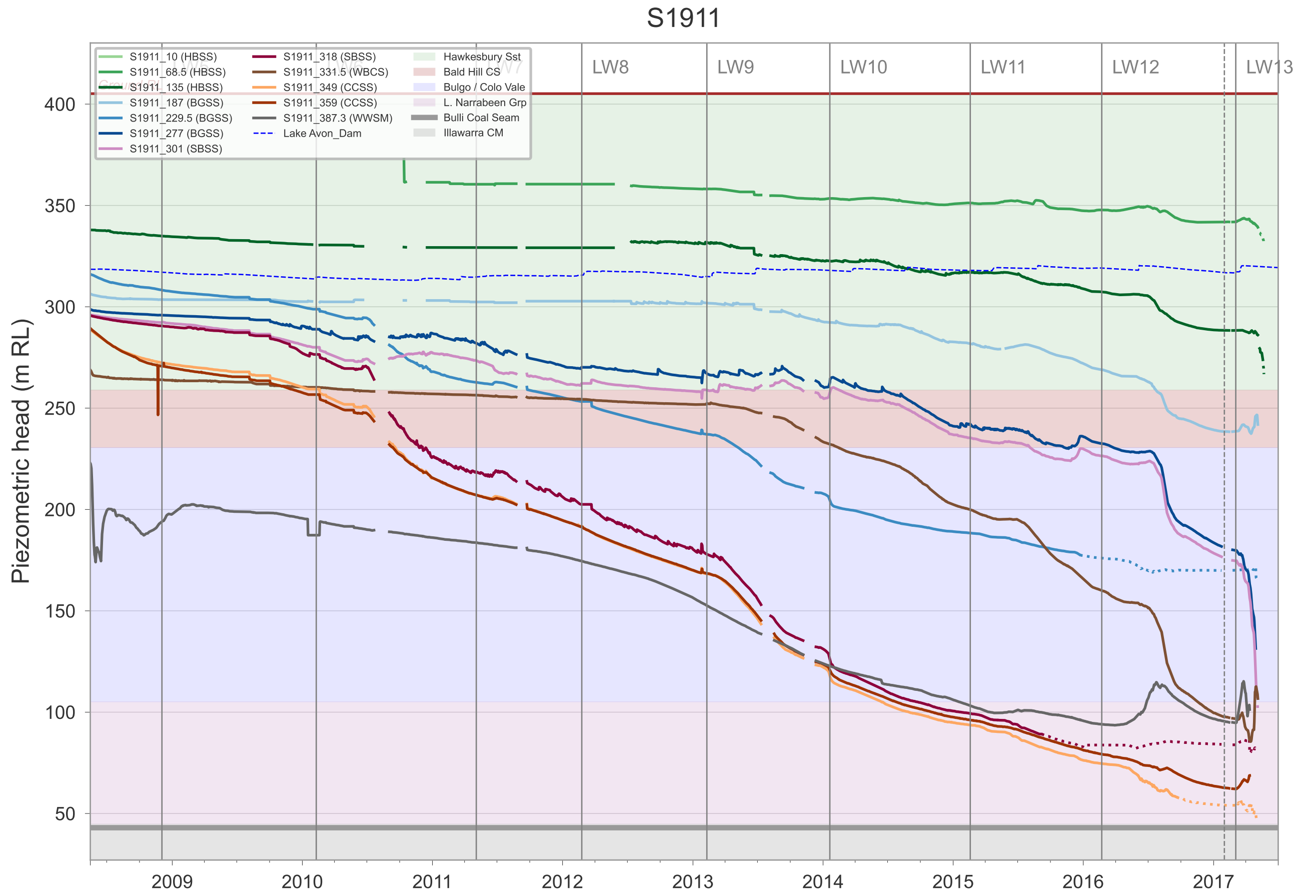

LW5
LW6
LW7
LW8
LW9
LW10
Ground RL
Piezometric head (m RL)
400
350
300
250
200
150
100
50
2009
2010
2011
2012
2013
2014
S1908_10 (HBSS)
S1908_154.9 (HBSS)
S1908_201 (BGSS)
S1908_276 (BGSS)
S1908_304 (BGSS)
S1908_337.4 (SBSS)
S1908_379.9 (BUSM)
S1908_412.2 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM

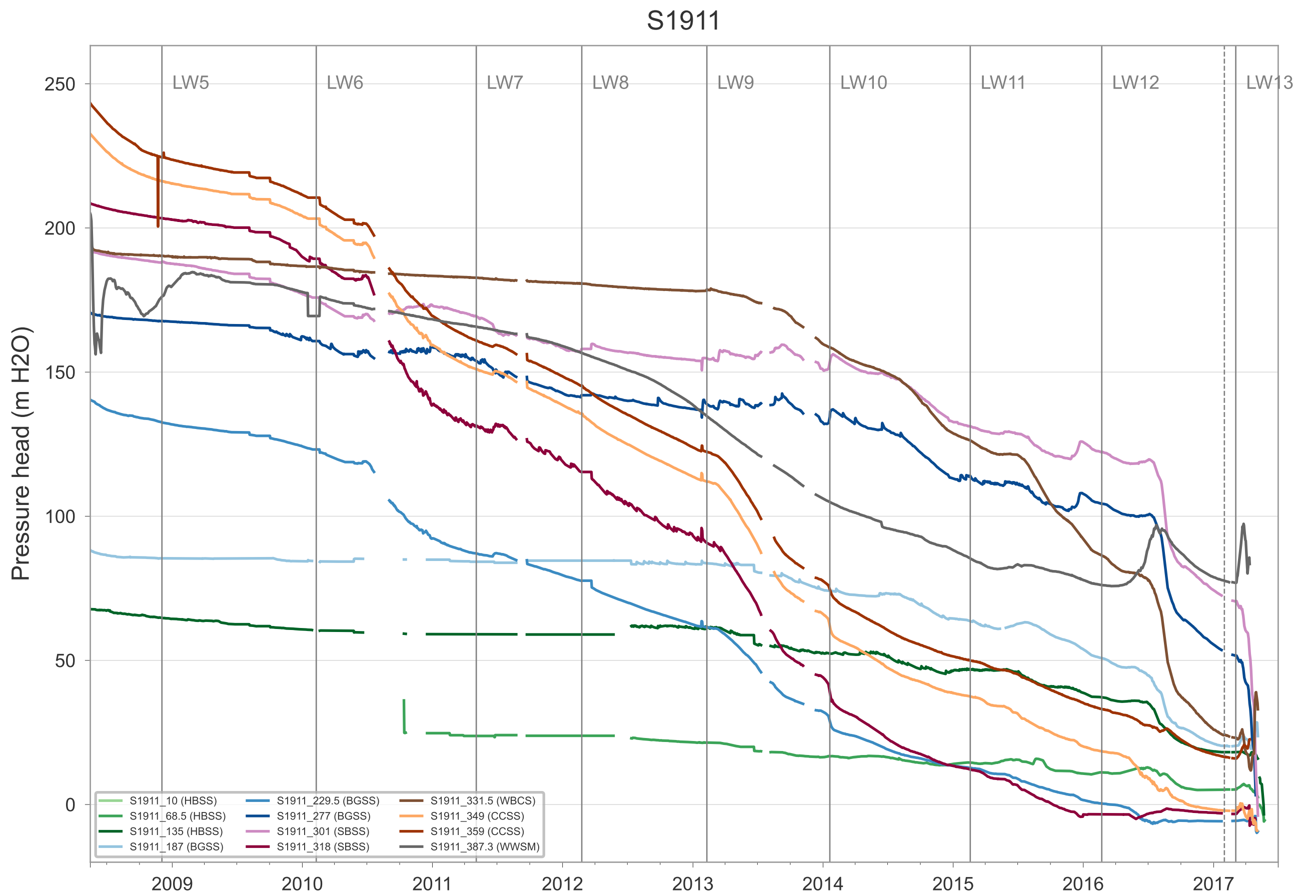
S1908

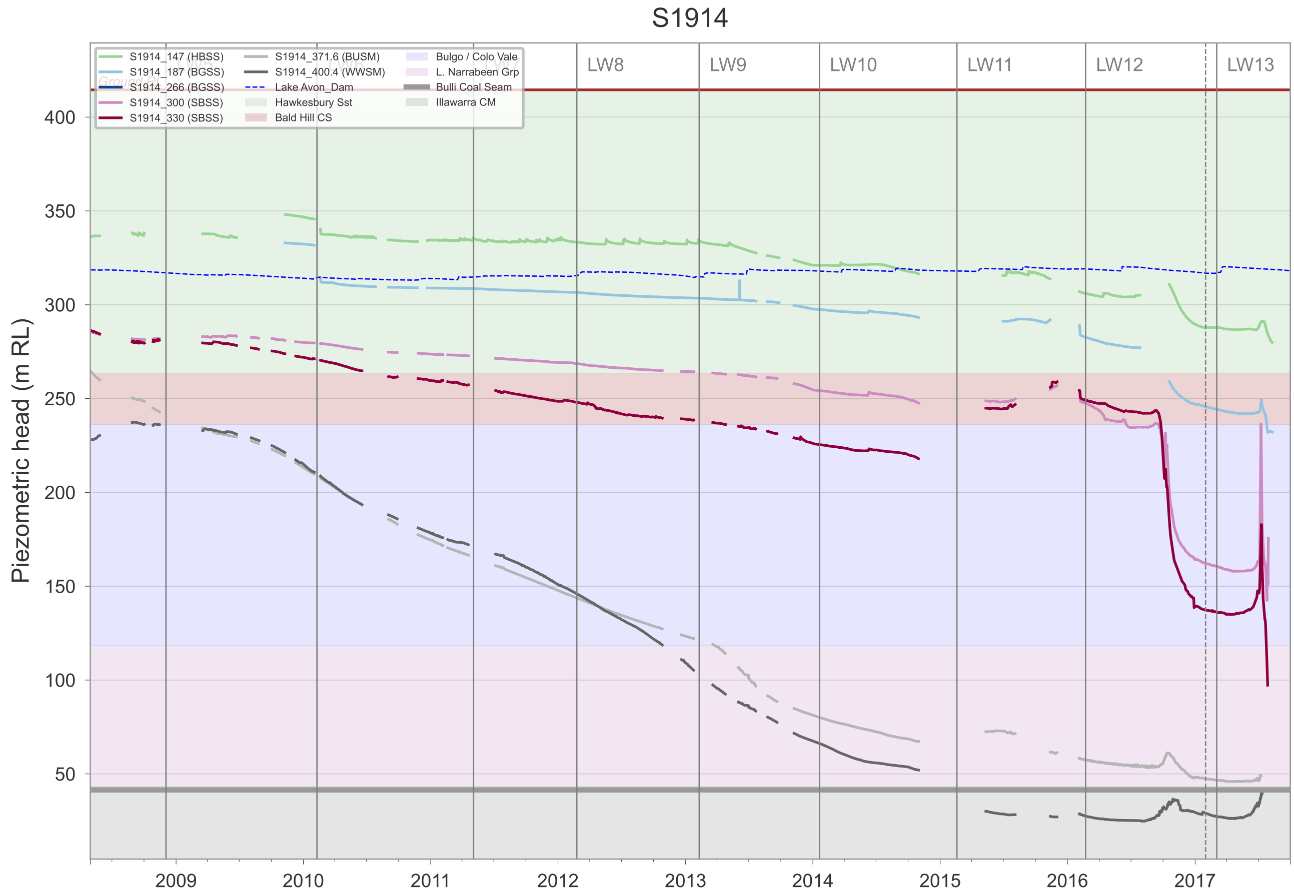

S1908_10 (HBSS)
S1908_154.9 (HBSS)
S1908_201 (BGSS)
S1908_276 (BGSS)
S1908_304 (BGSS)
S1908_337.4 (SBSS)
S1908_379.9 (BUSM)
S1908_412.2 (WWSM)
LW7
LW8
LW9
LW10
Pressure head (m H2O)
300
250
200
150
100
50
0
2009
2010
2011
2012
2013
2014

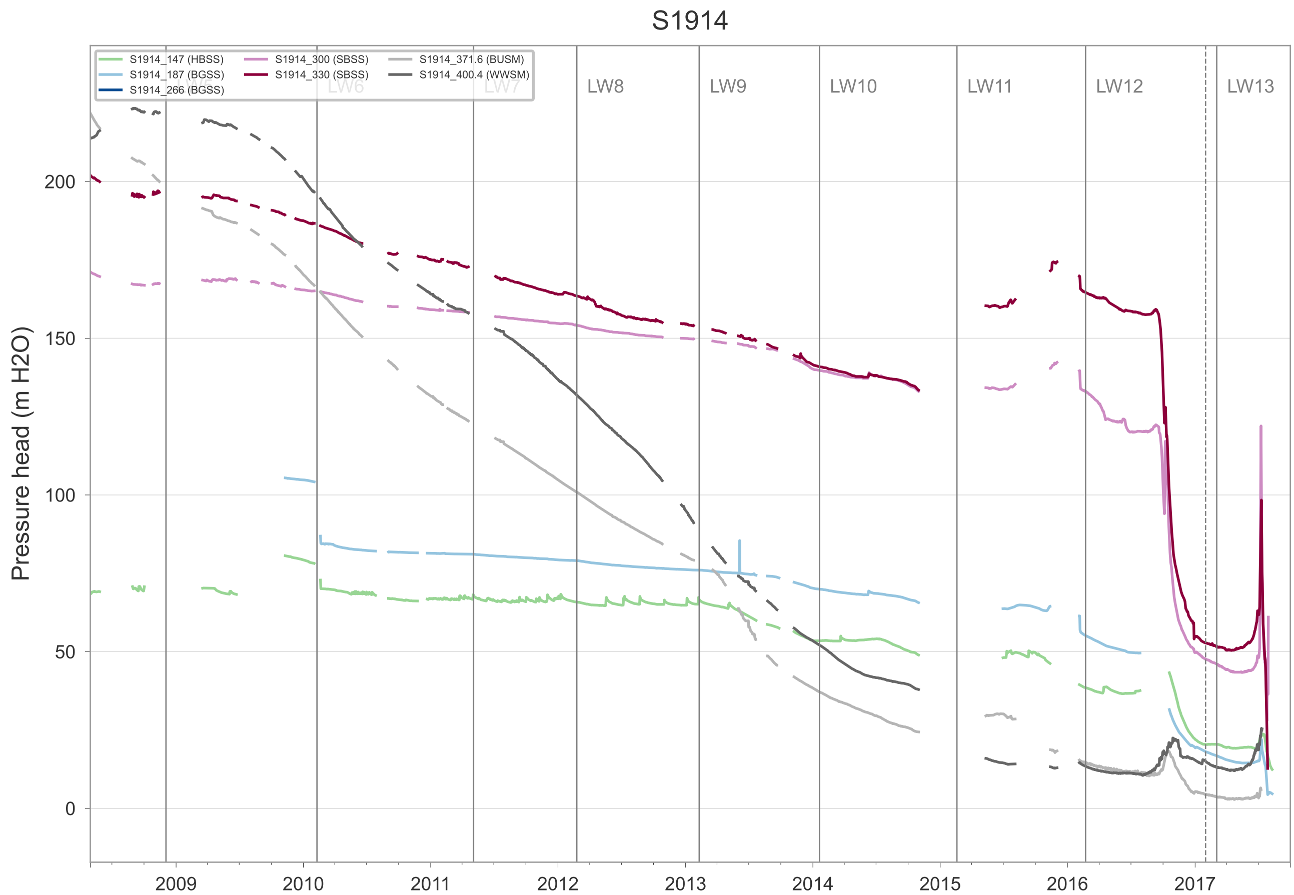

S1910
Piezometric head (m RL)
Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
400
350
300
250
200
150
100
50
0
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
S1910_9.6 (HBSS)
S1910_125 (HBSS)
S1910_169 (BGSS)
S1910_247 (BGSS)
S1910_273 (SBSS)
S1910_313 (SBSS)
S1910_362 (BUSM)
S1910_391.5 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam


S1910
Pressure head (m H2O)
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
250
200
150
100
50
0
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
S1910_9.6 (HBSS)
S1910_125 (HBSS)
S1910_169 (BGSS)
S1910_247 (BGSS)
S1910_273 (SBSS)
S1910_313 (SBSS)
S1910_362 (BUSM)
S1910_391.5 (WWSM)

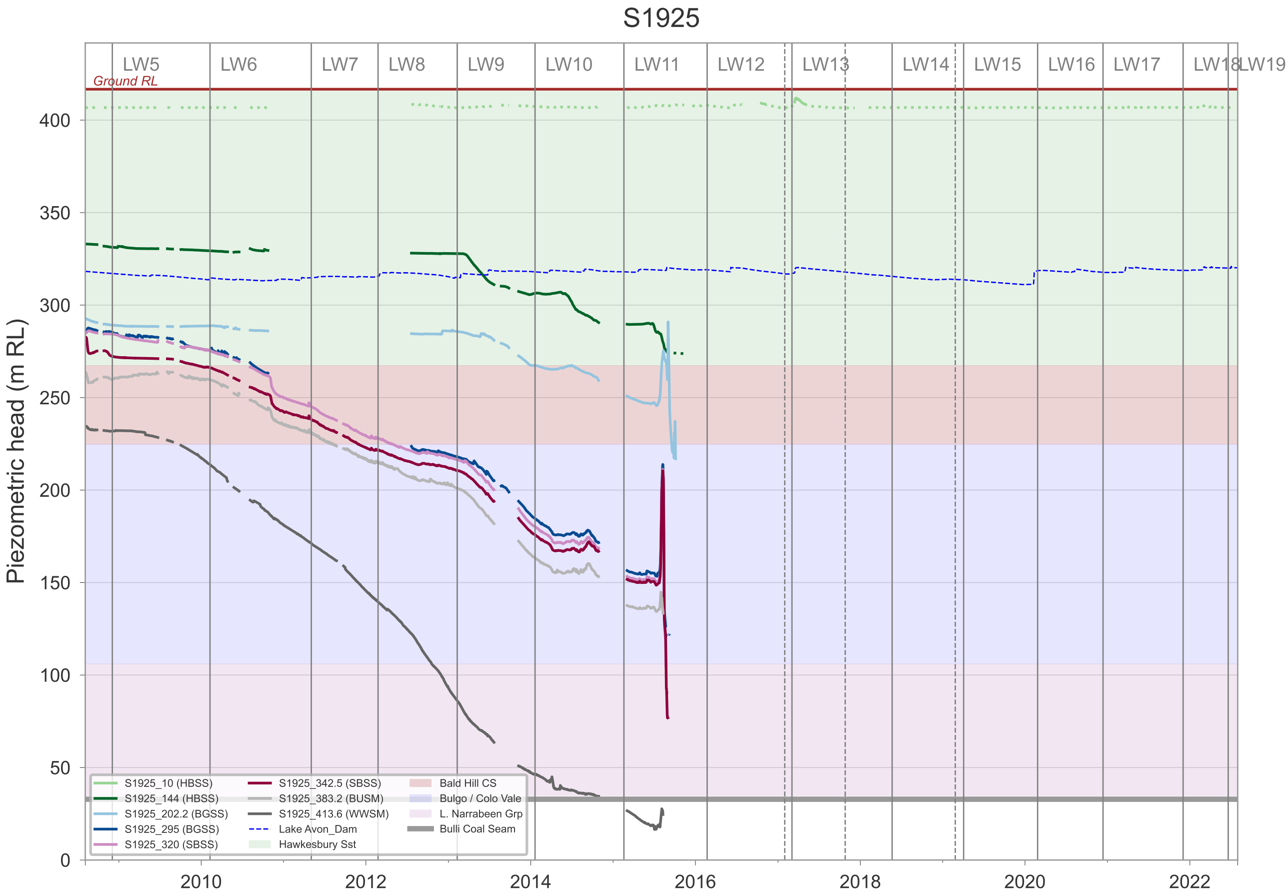

S1911
Piezometric head (m RL)
400
350
300
250
200
150
100
50
2009
2010
2011
2012
2013
2014
2015
2016
2017
LW8
LW9
LW10
LW11
LW12
LW13
S1911_10 (HBSS)
S1911_68.5 (HBSS)
S1911_135 (HBSS)
S1911_187 (BGSS)
S1911_229.5 (BGSS)
S1911_277 (BGSS)
S1911_301 (SBSS)
S1911_318 (SBSS)
S1911_331.5 (WBCS)
S1911_349 (CCSS)
S1911_359 (CCSS)
S1911_387.3 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM

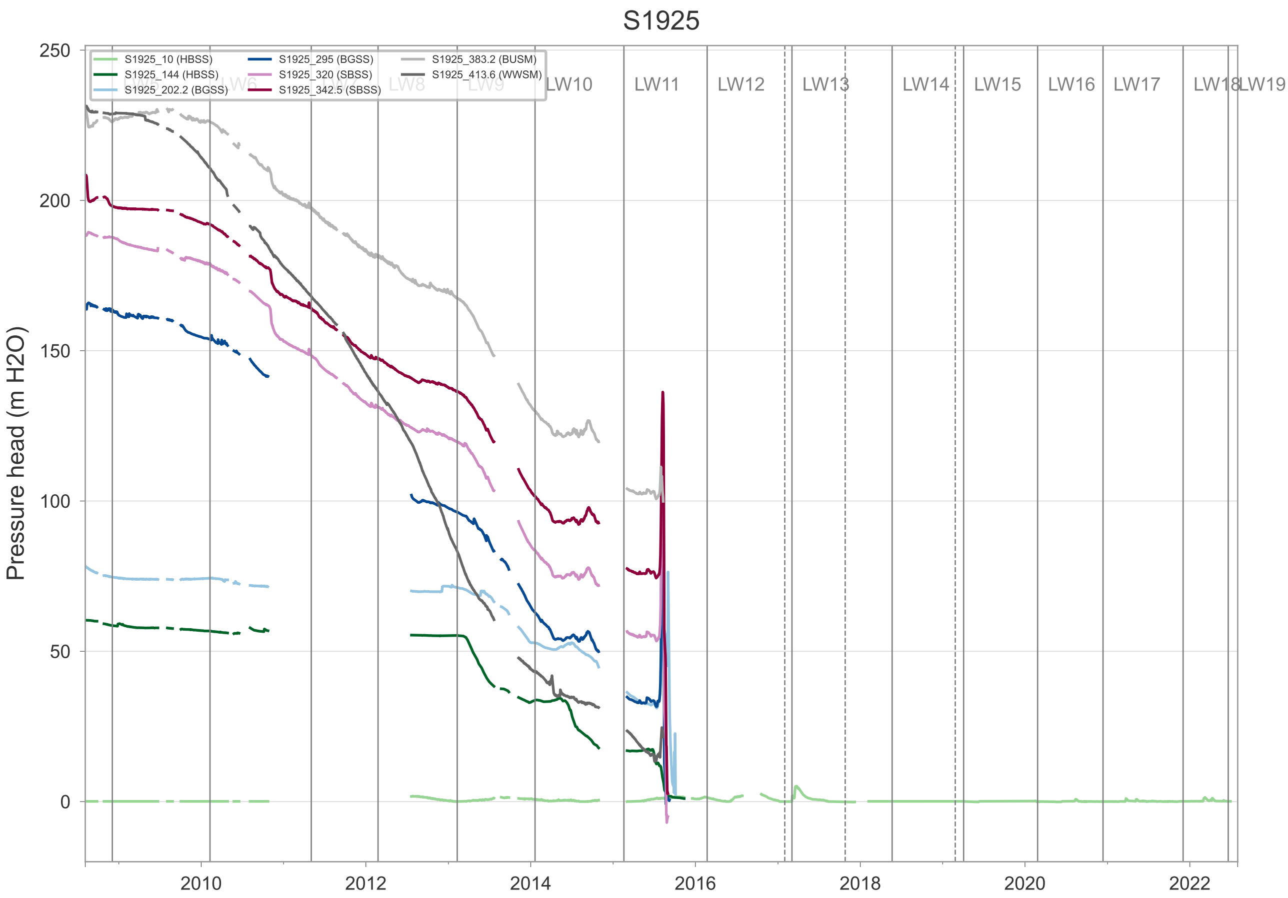

S1911
Pressure head (m H2O)
250
200
150
100
50
0
2009
2010
2011
2012
2013
2014
2015
2016
2017
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
S1911_10 (HBSS)
S1911_68.5 (HBSS)
S1911_135 (HBSS)
S1911_187 (BGSS)
S1911_229.5 (BGSS)
S1911_277 (BGSS)
S1911_301 (SBSS)
S1911_318 (SBSS)
S1911_331.5 (WBCS)
S1911_349 (CCSS)
S1911_359 (CCSS)
S1911_387.3 (WWSM)

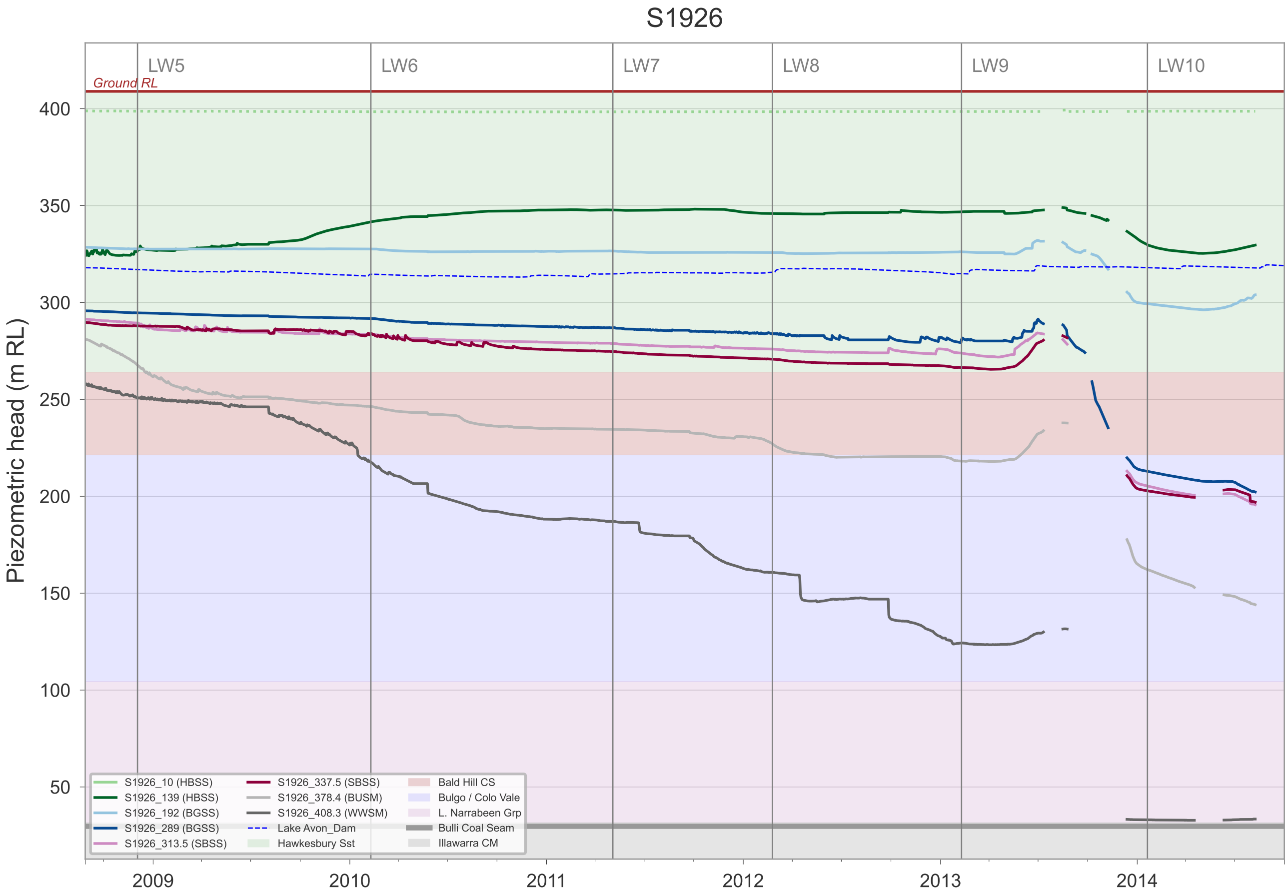

S1914
S1914_147 (HBSS)
S1914_187 (BGSS)
S1914_266 (BGSS)
S1914_300 (SBSS)
S1914_330 (SBSS)
S1914_371.6 (BUSM)
S1914_400.4 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
LW8
LW9
LW10
LW11
LW12
LW13
Piezometric head (m RL)
400
350
300
250
200
150
100
50
2009
2010
2011
2012
2013
2014
2015
2016
2017

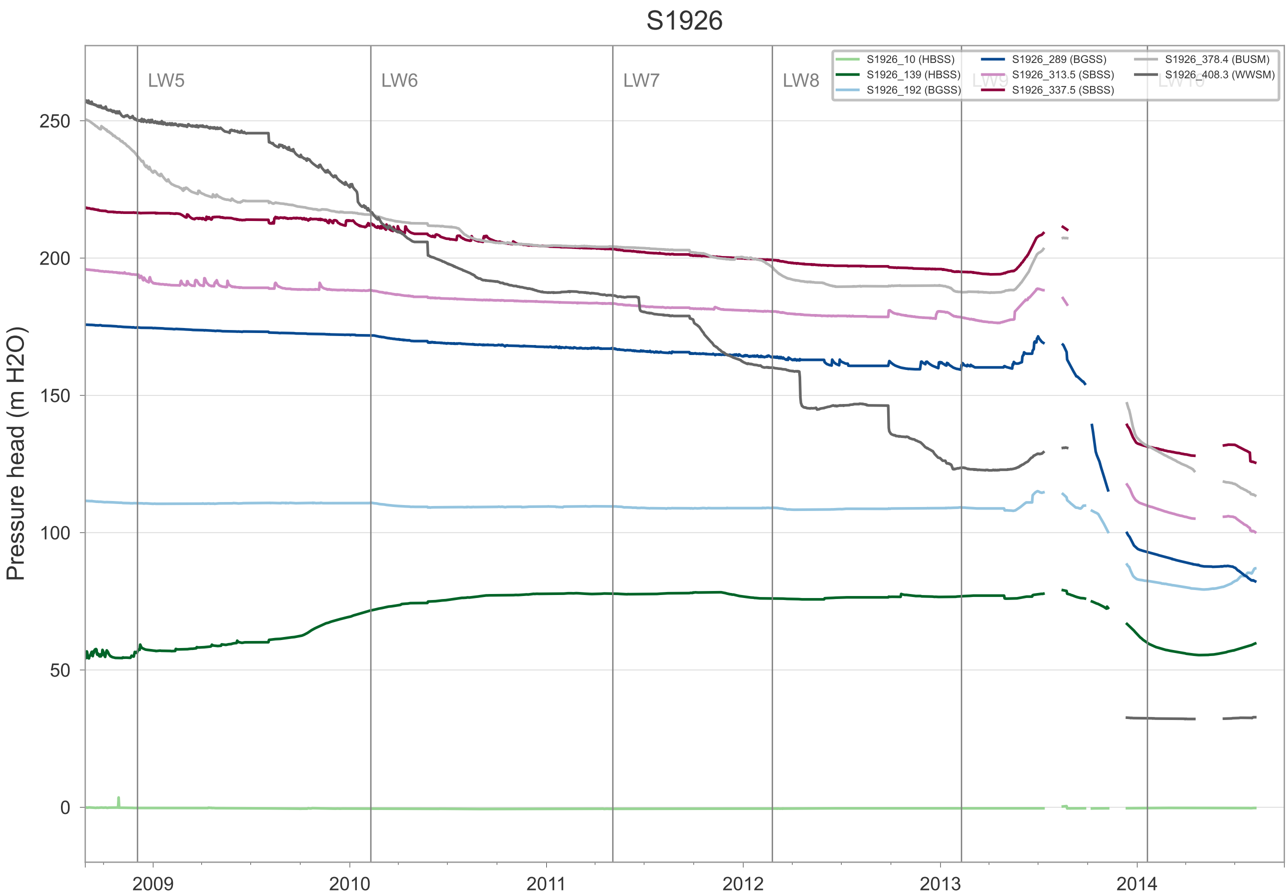

S1914
S1914_147 (HBSS)
S1914_187 (BGSS)
S1914_266 (BGSS)
S1914_300 (SBSS)
S1914_330 (SBSS)
S1914_371.6 (BUSM)
S1914_400.4 (WWSM)
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
Pressure head (m H2O)
200
150
100
50
0
2009
2010
2011
2012
2013
2014
2015
2016
2017

Groundwater hydrographs

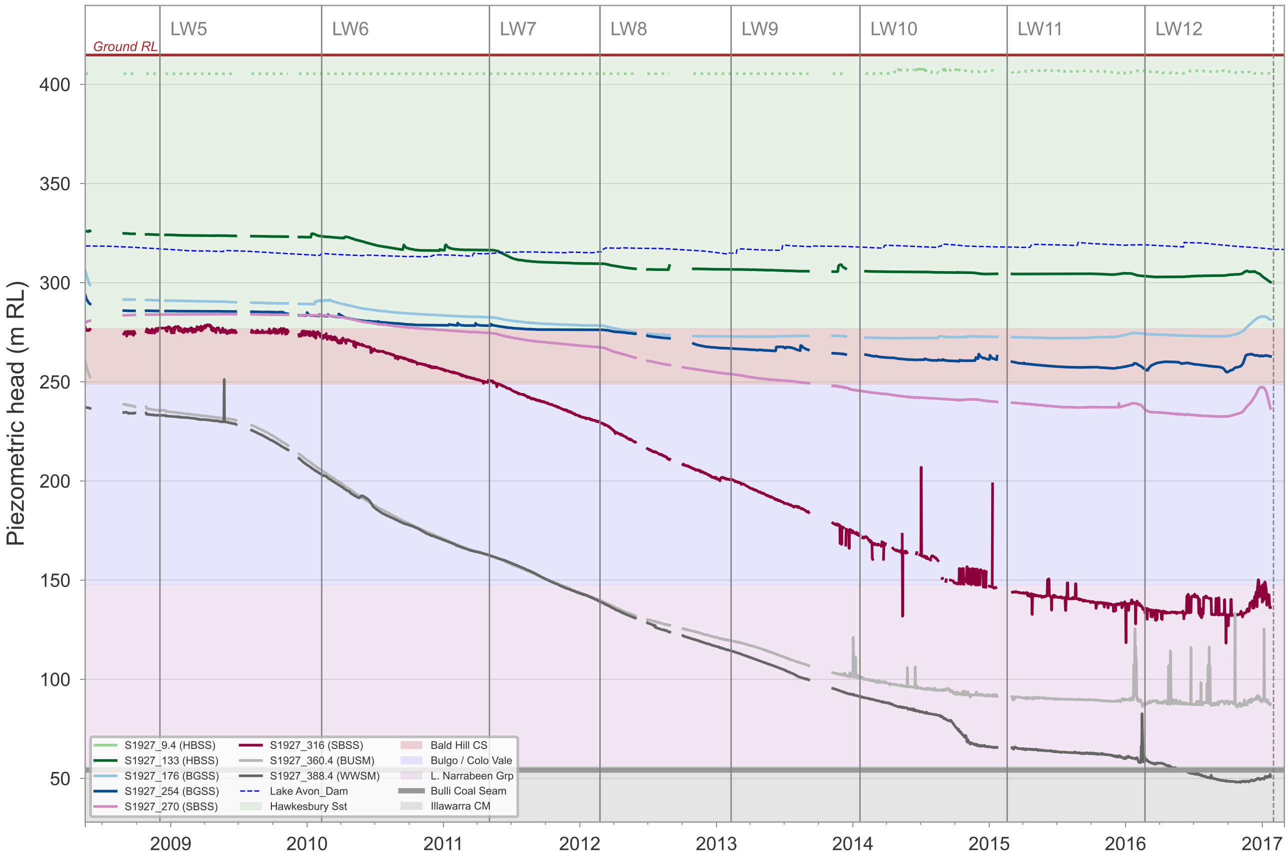





S1926
LW5
LW6
LW7
LW8
LW9
LW10
Ground RL
Piezometric head (m RL)
400
350
300
250
200
150
100
50
2009
2010
2011
2012
2013
2014
S1926_10 (HBSS)
S1926_139 (HBSS)
S1926_192 (BGSS)
S1926_289 (BGSS)
S1926_313.5 (SBSS)
S1926_337.5 (SBSS)
S1926_378.4 (BUSM)
S1926_408.3 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM

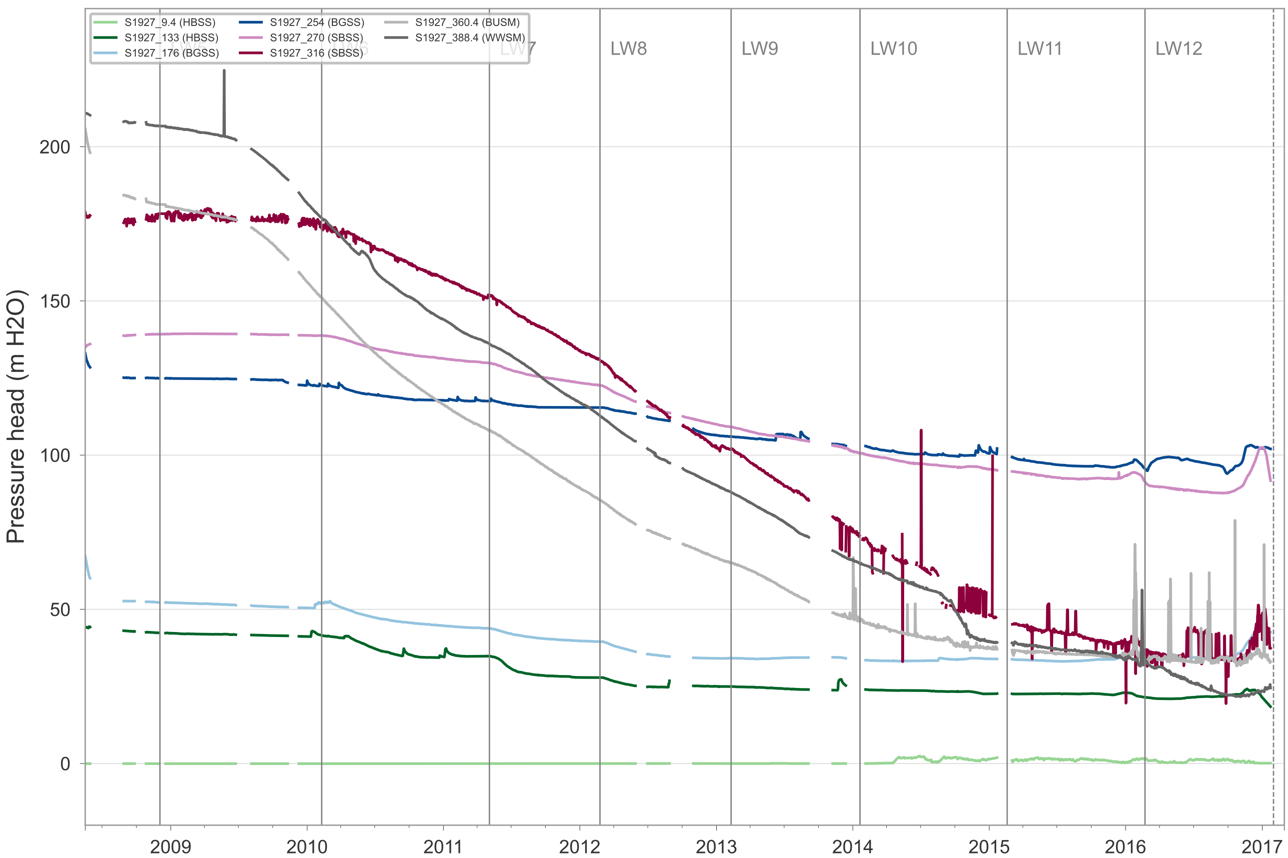

S1926
LW5
LW6
LW7
LW8
Pressure head (m H2O)
250
200
150
100
50
0
2009
2010
2011
2012
2013
2014
S1926_10 (HBSS)
S1926_139 (HBSS)
S1926_192 (BGSS)
S1926_289 (BGSS)
S1926_313.5 (SBSS)
S1926_337.5 (SBSS)
S1926_378.4 (BUSM)
S1926_408.3 (WWSM)

S1927

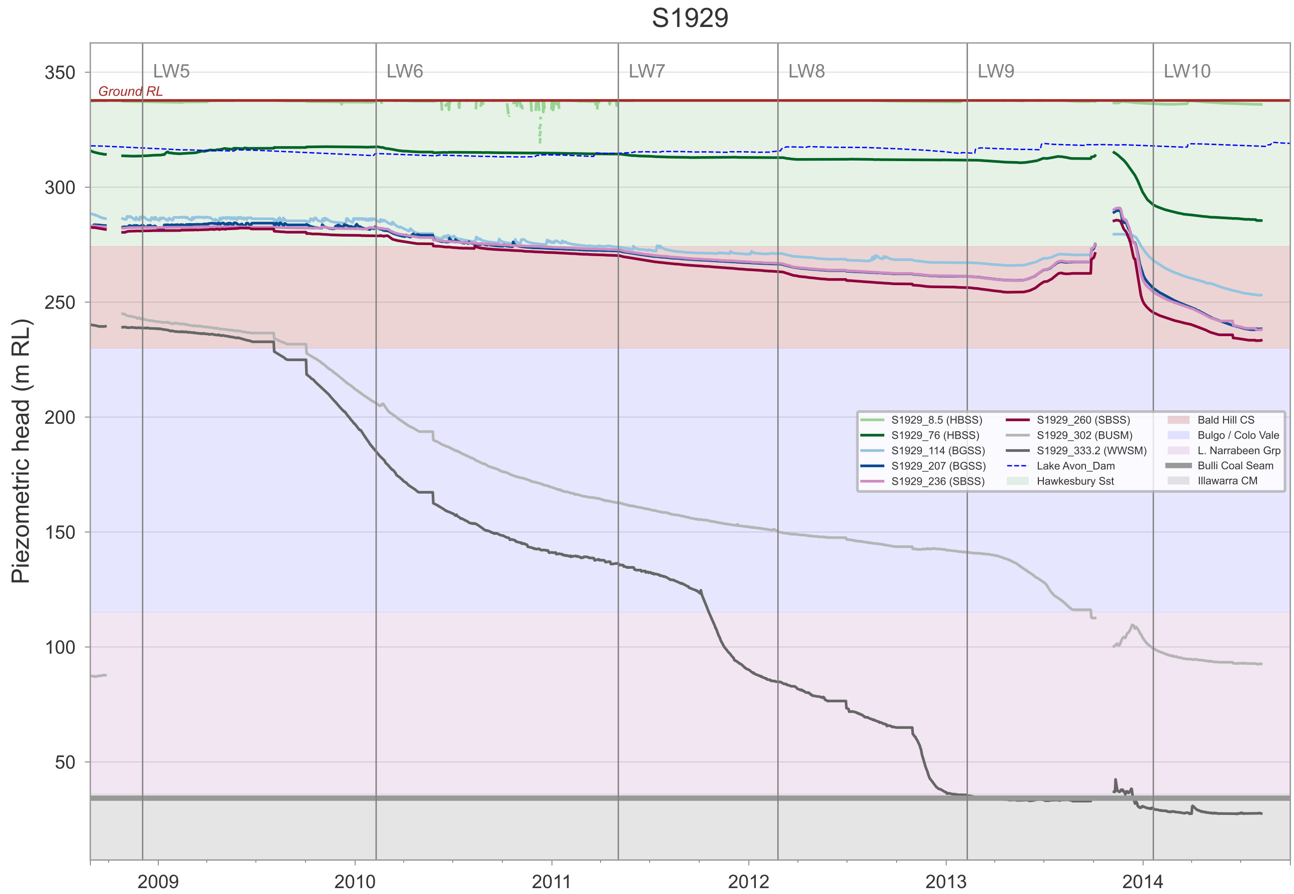


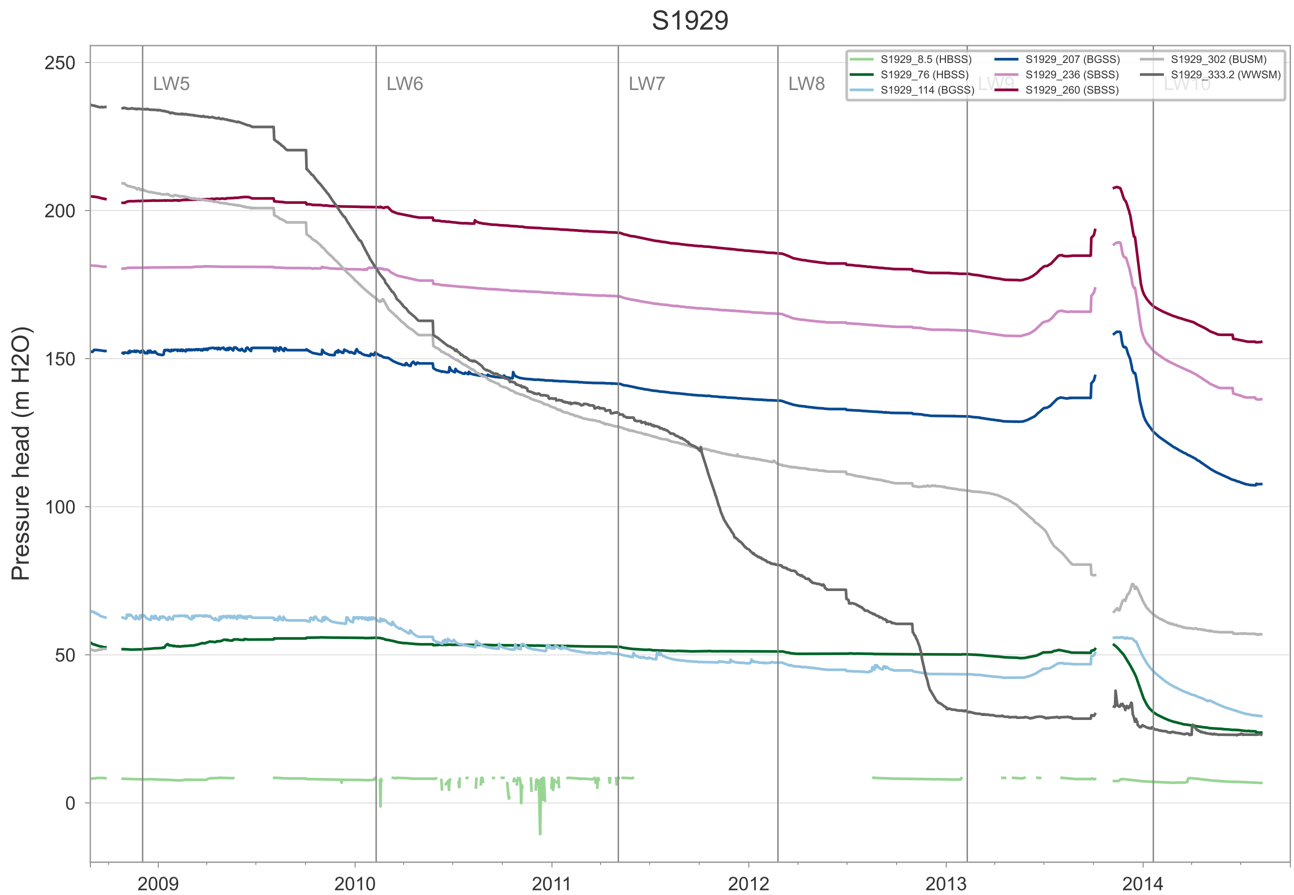
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
Ground RL
Piezometric head (m RL)
400
350
300
250
200
150
100
50
2009
2010
2011
2012
2013
2014
2015
2016
2017
S1927_9.4 (HBSS)
S1927_133 (HBSS)
S1927_176 (BGSS)
S1927_254 (BGSS)
S1927_270 (SBSS)
S1927_316 (SBSS)
S1927_360.4 (BUSM)
S1927_388.4 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM

S1927

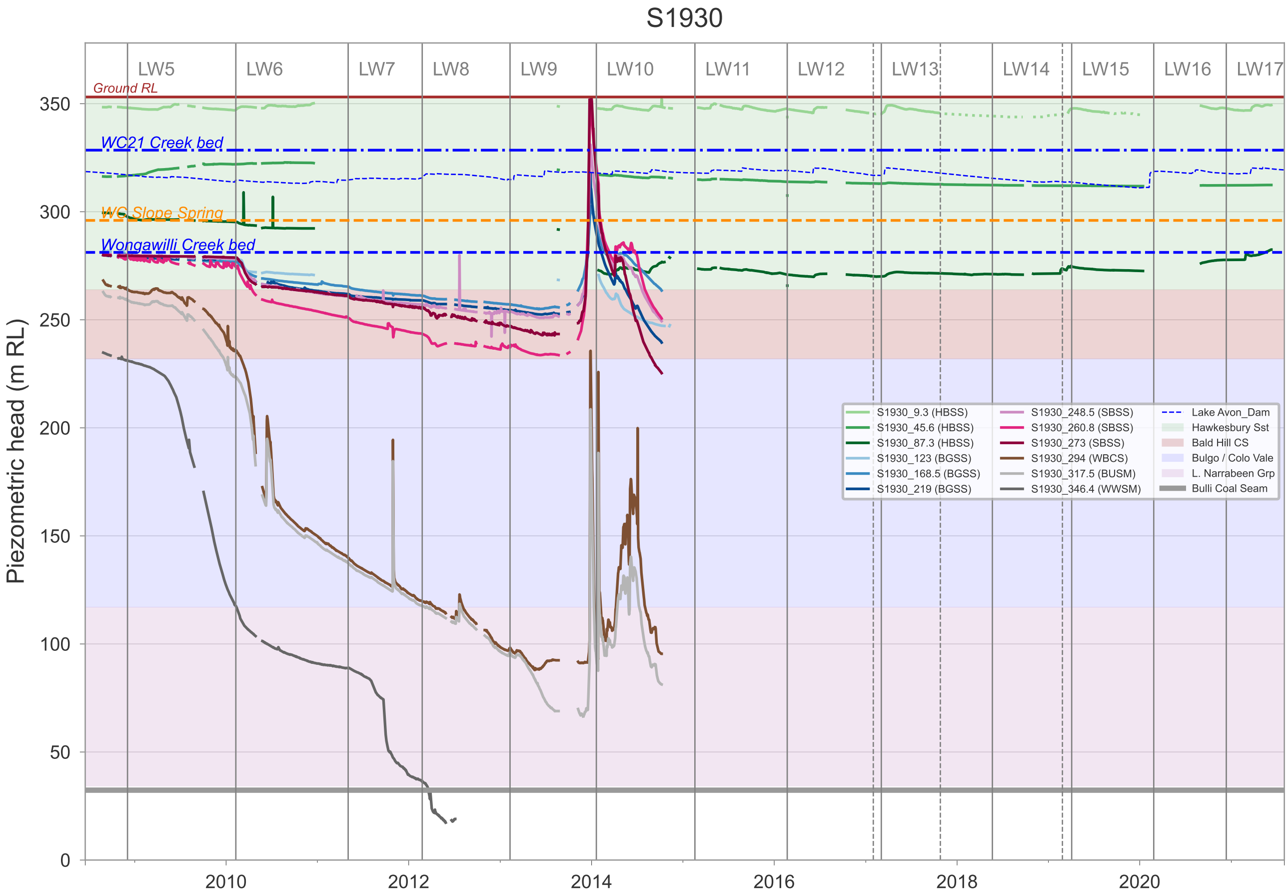


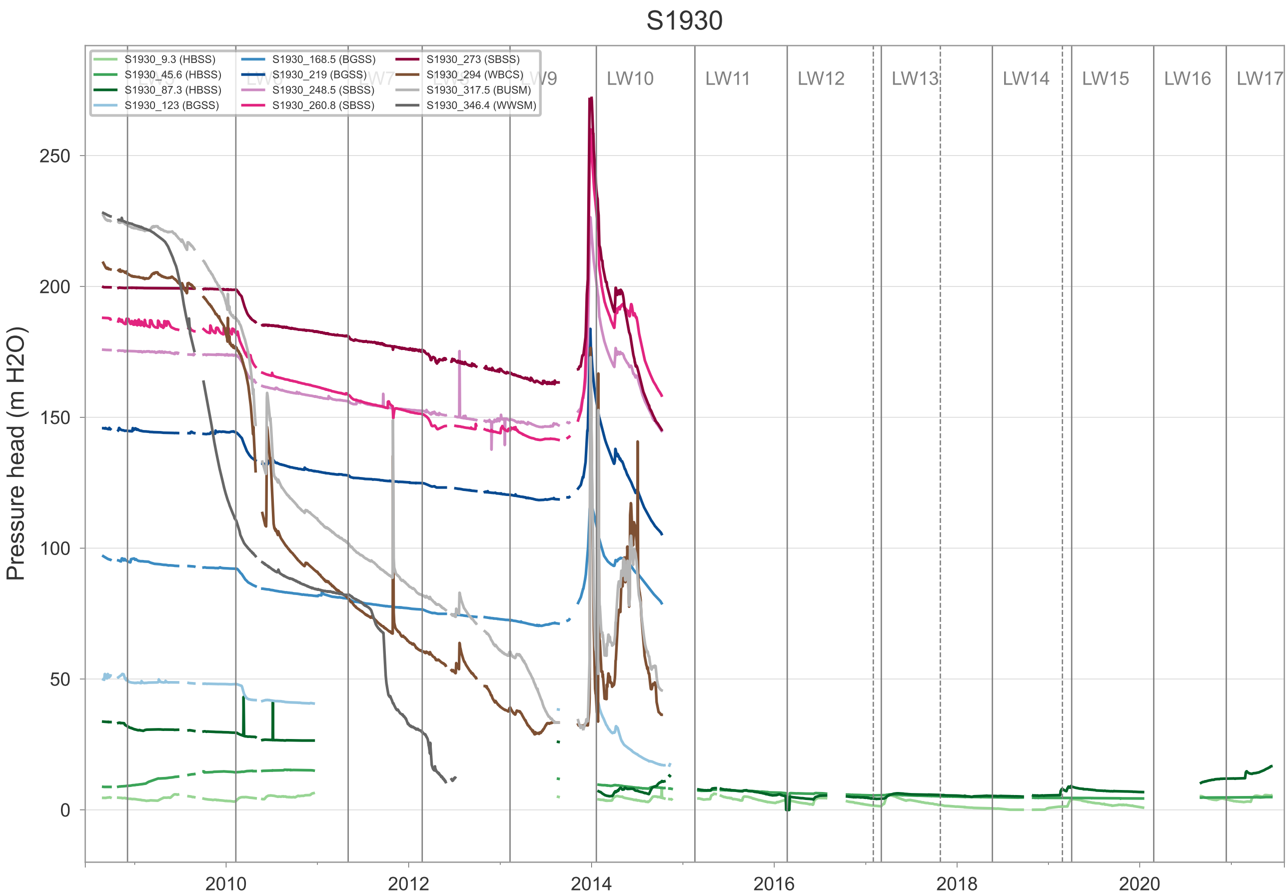
S1927_9.4 (HBSS)
S1927_133 (HBSS)
S1927_176 (BGSS)
S1927_254 (BGSS)
S1927_270 (SBSS)
S1927_316 (SBSS)
S1927_360.4 (BUSM)
S1927_388.4 (WWSM)
LW8
LW9
LW10
LW11
LW12
Pressure head (m H2O)
200
150
100
50
0
2009
2010
2011
2012
2013
2014
2015
2016
2017


S1929
Piezometric head (m RL)
Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
S1929_8.5 (HBSS)
S1929_76 (HBSS)
S1929_114 (BGSS)
S1929_207 (BGSS)
S1929_236 (SBSS)
S1929_260 (SBSS)
S1929_302 (BUSM)
S1929_333.2 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
2009
2010
2011
2012
2013
2014

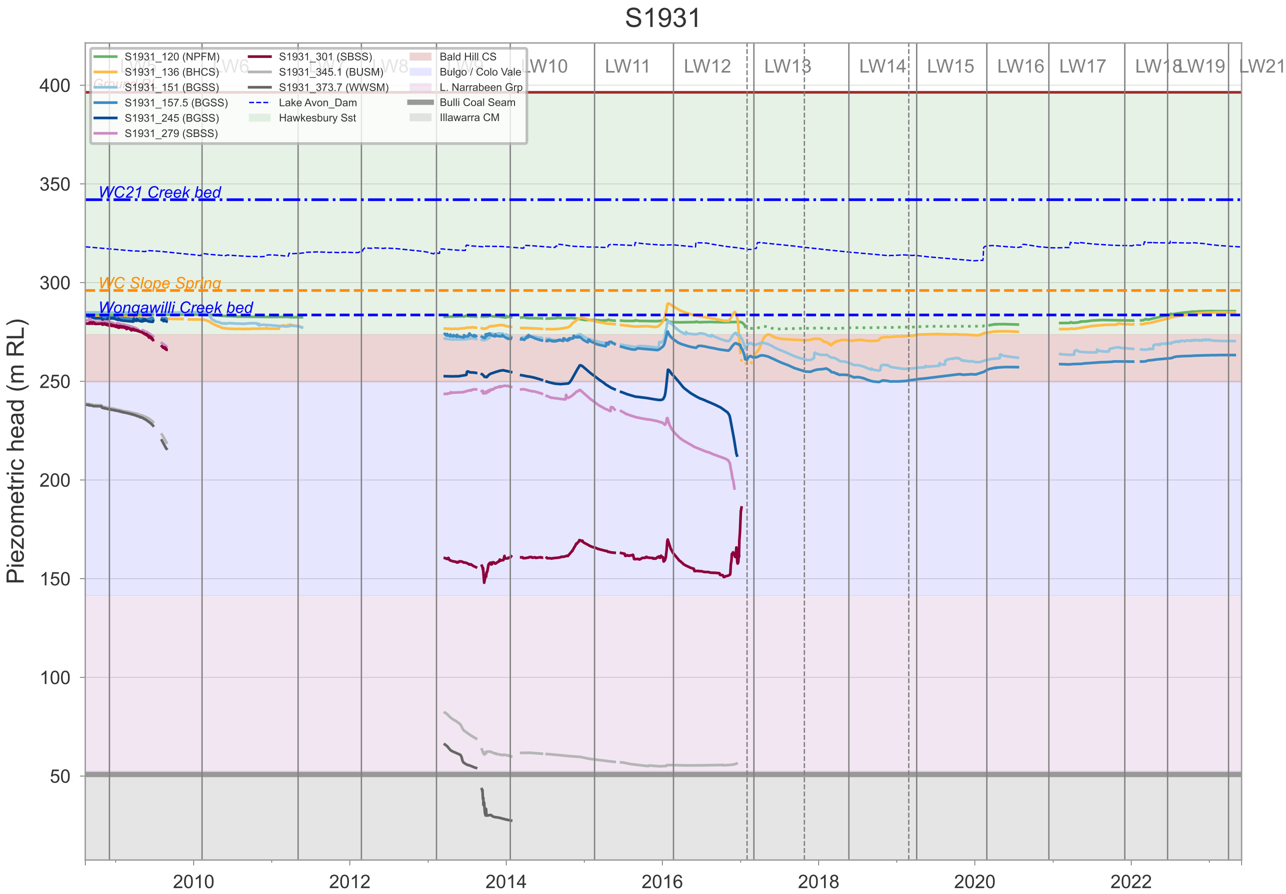

S1929
Pressure head (m H2O)
LW5
LW6
LW7
LW8
S1929_8.5 (HBSS)
S1929_76 (HBSS)
S1929_114 (BGSS)
S1929_207 (BGSS)
S1929_236 (SBSS)
S1929_260 (SBSS)
S1929_302 (BUSM)
S1929_333.2 (WWSM)
2009
2010
2011
2012
2013
2014

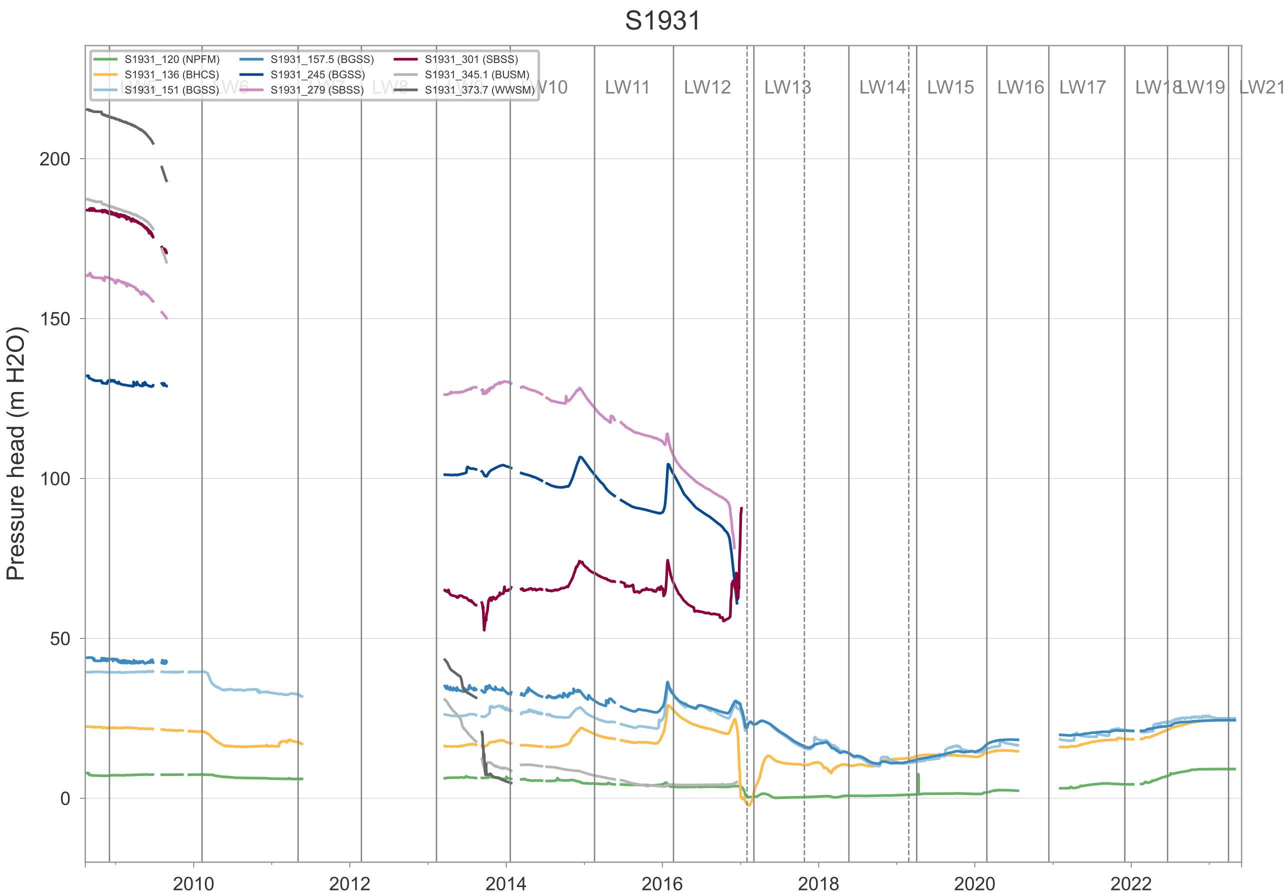
Groundwater hydrographs

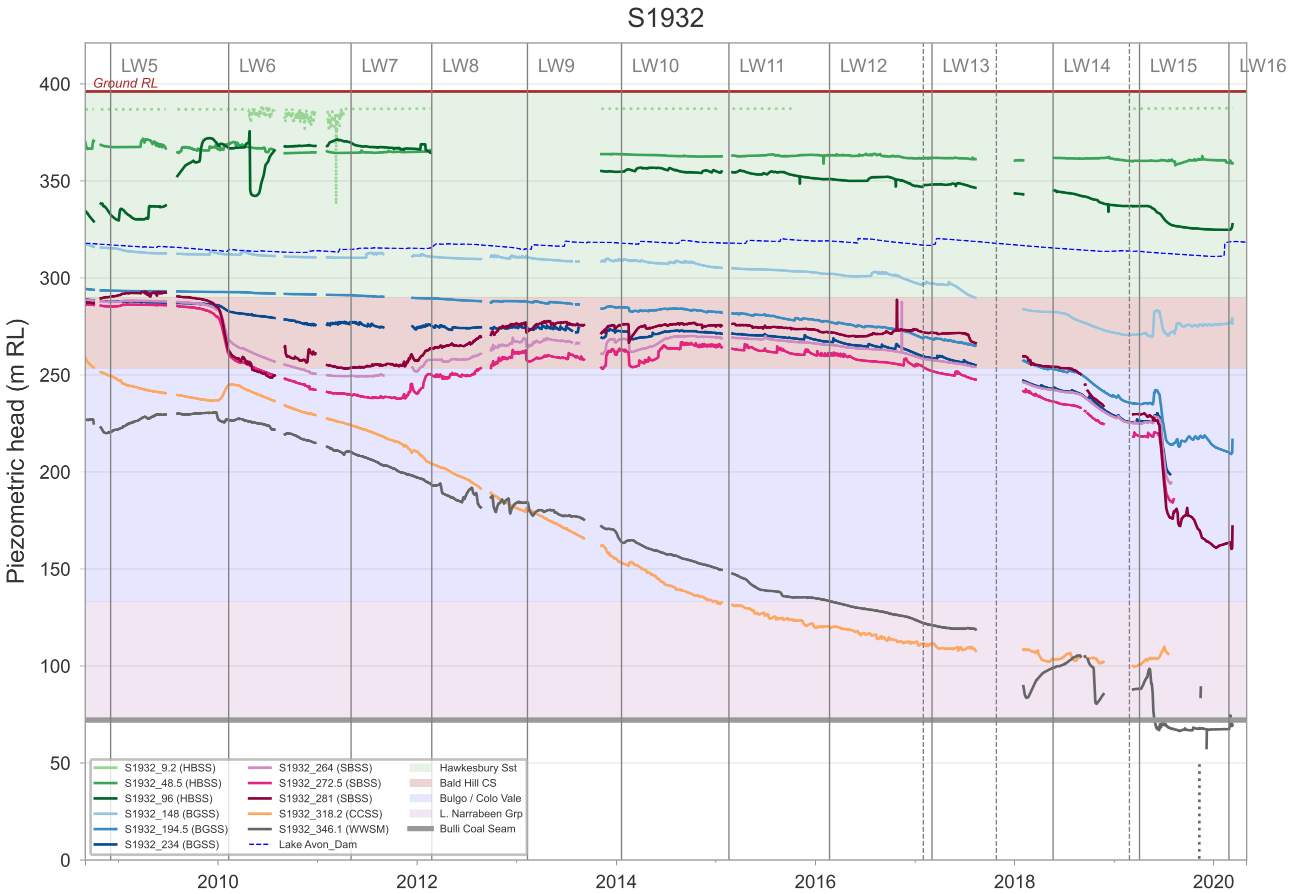


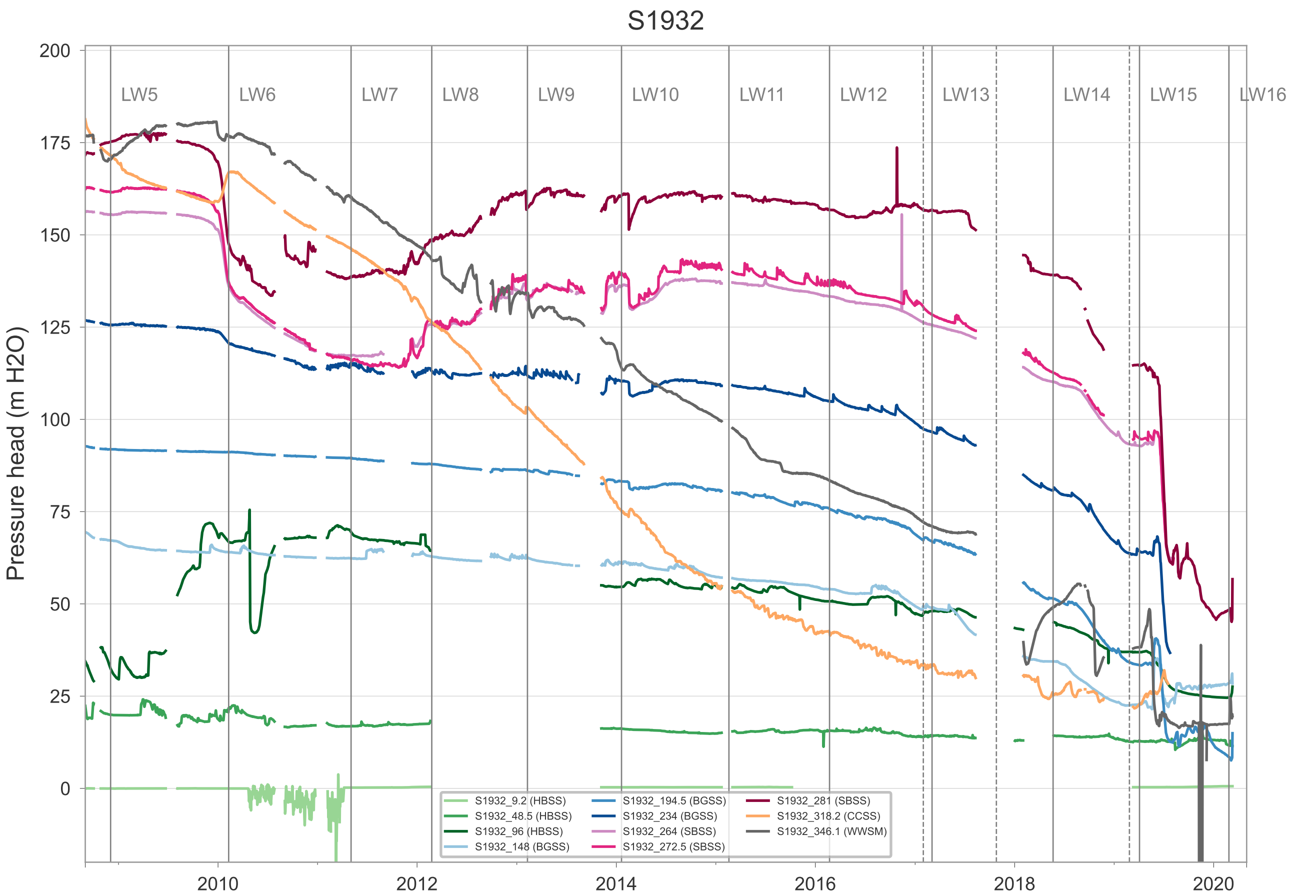


Groundwater hydrographs

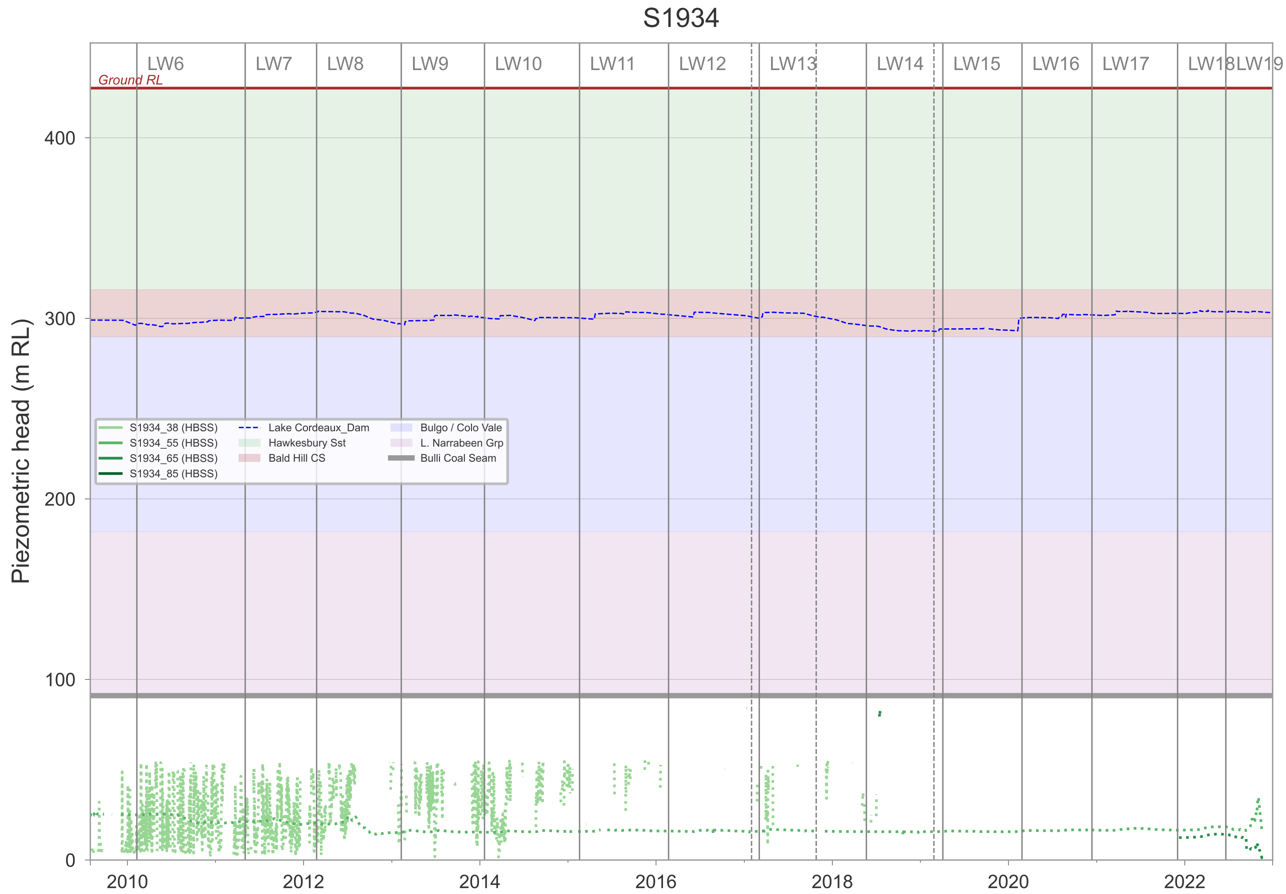


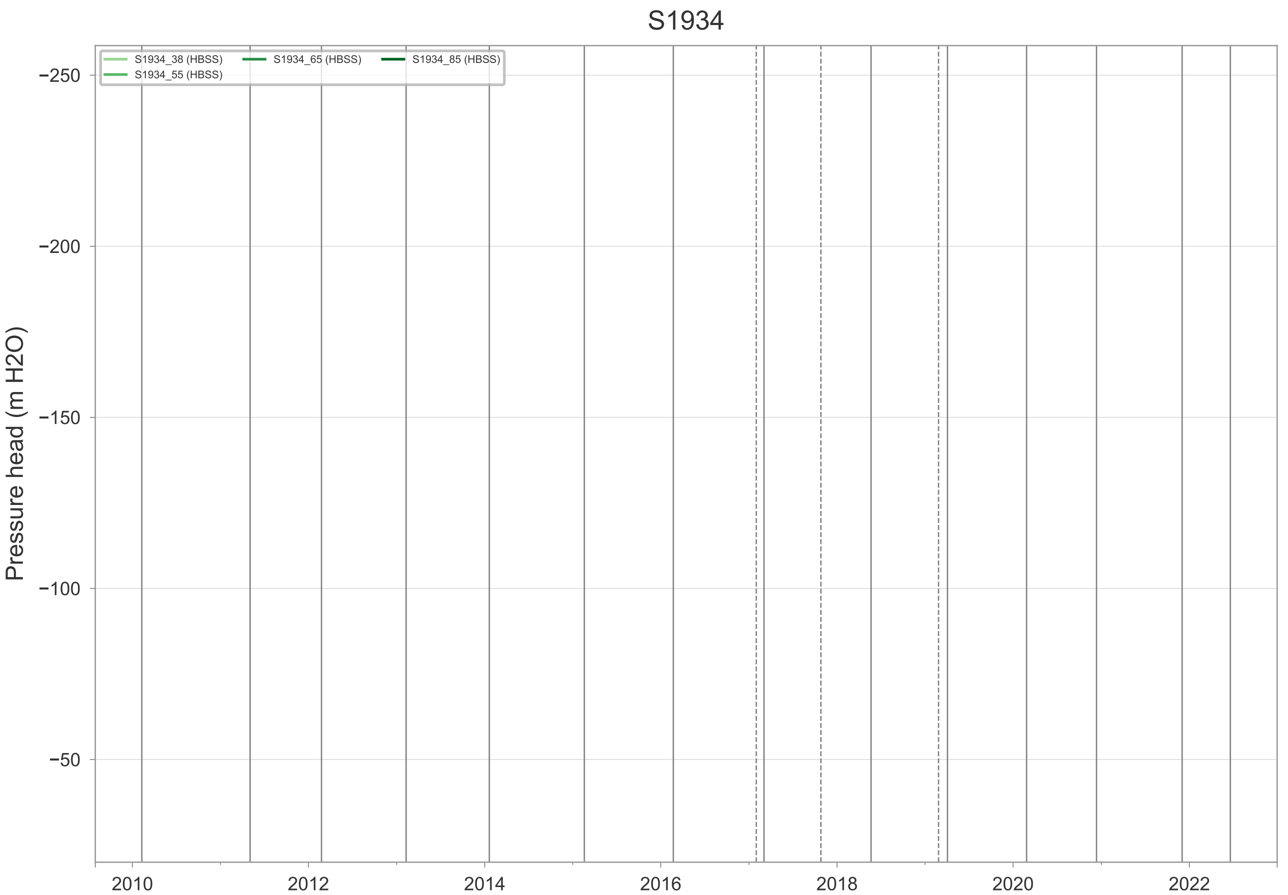



S1932
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
Ground RL
Piezometric head (m RL)
S1932_9.2 (HBSS)
S1932_48.5 (HBSS)
S1932_96 (HBSS)
S1932_148 (BGSS)
S1932_194.5 (BGSS)
S1932_234 (BGSS)
S1932_264 (SBSS)
S1932_272.5 (SBSS)
S1932_281 (SBSS)
S1932_318.2 (CCSS)
S1932_346.1 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
2010
2012
2014
2016
2018
2020

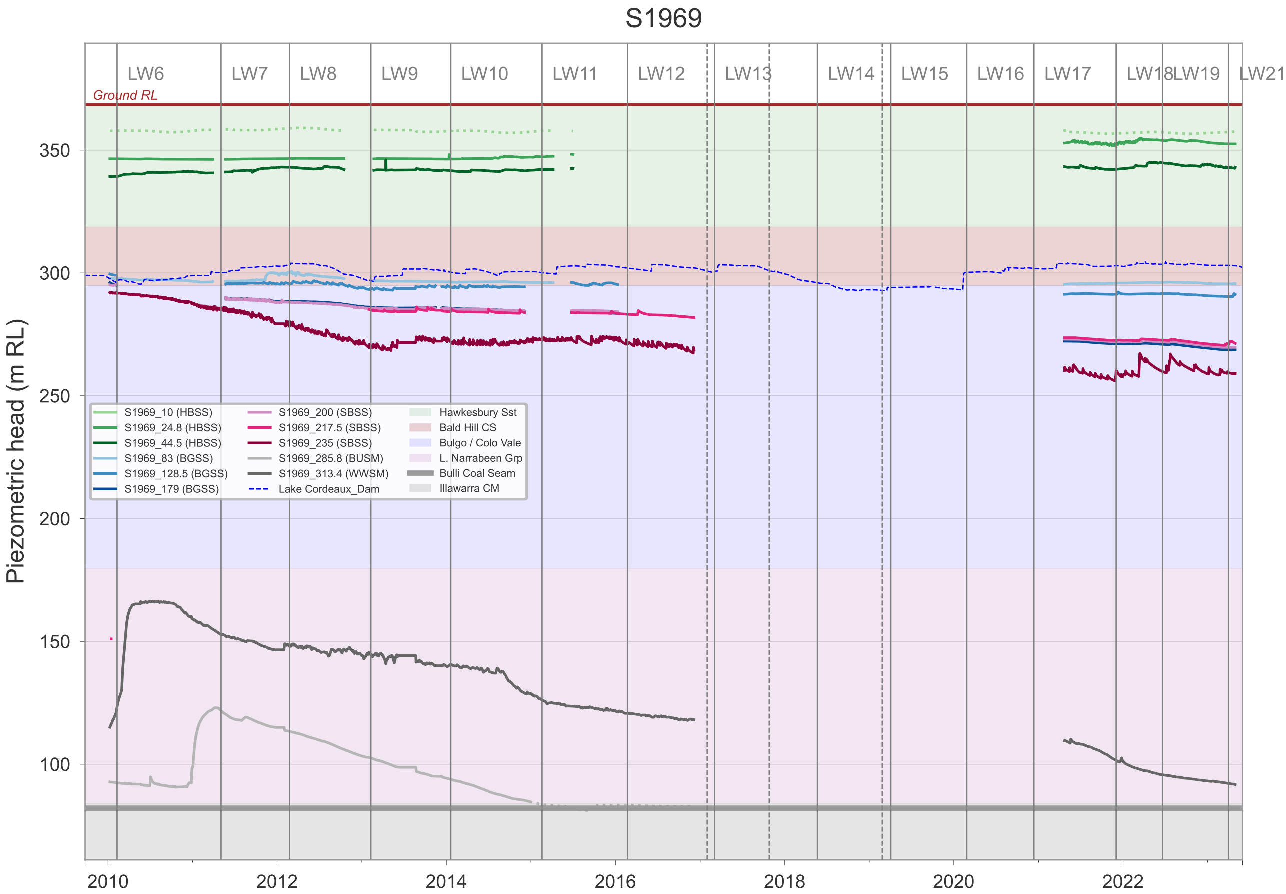

S1932
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
Pressure head (m H2O)
S1932_9.2 (HBSS)
S1932_48.5 (HBSS)
S1932_96 (HBSS)
S1932_148 (BGSS)
S1932_194.5 (BGSS)
S1932_234 (BGSS)
S1932_264 (SBSS)
S1932_272.5 (SBSS)
S1932_281 (SBSS)
S1932_318.2 (CCSS)
S1932_346.1 (WWSM)
2010
2012
2014
2016
2018
2020

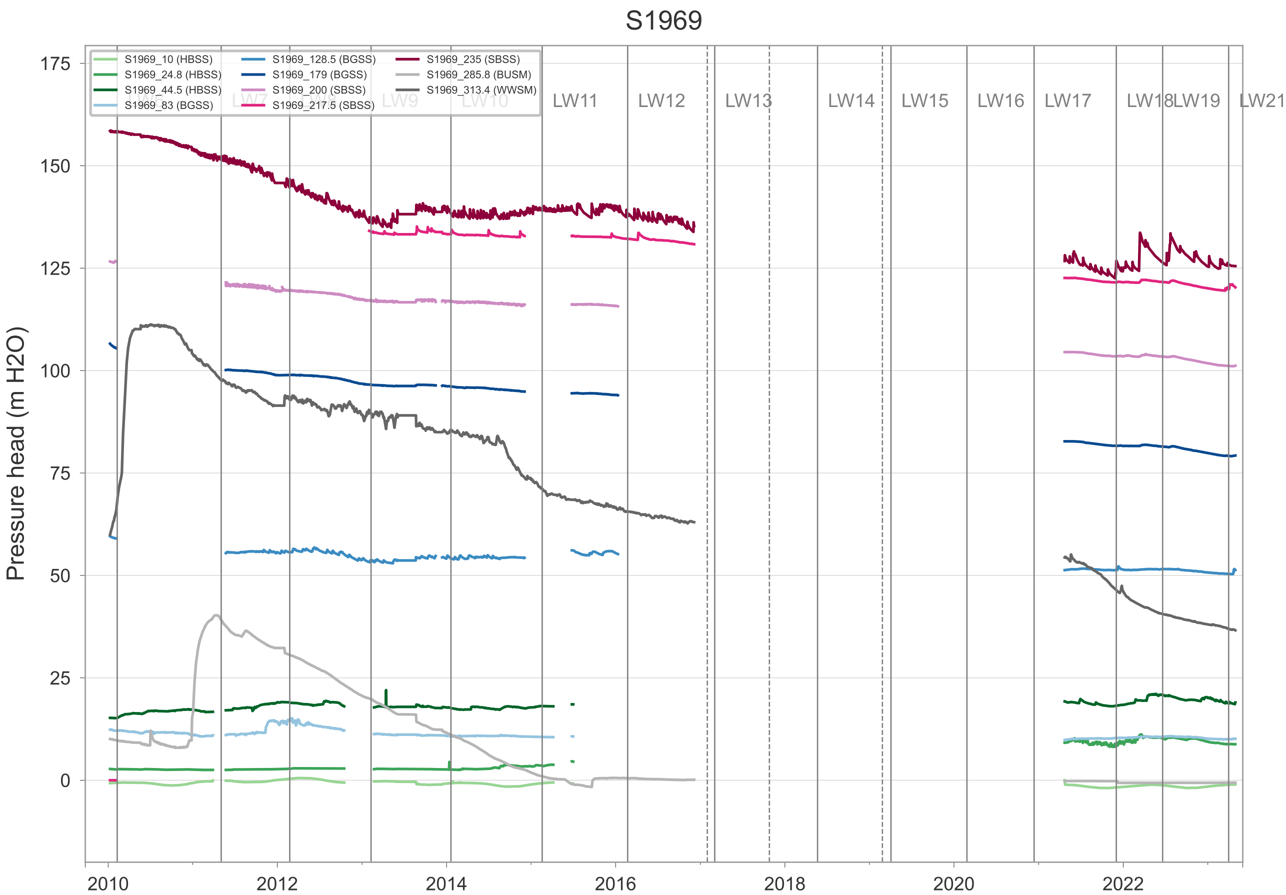
Groundwater hydrographs

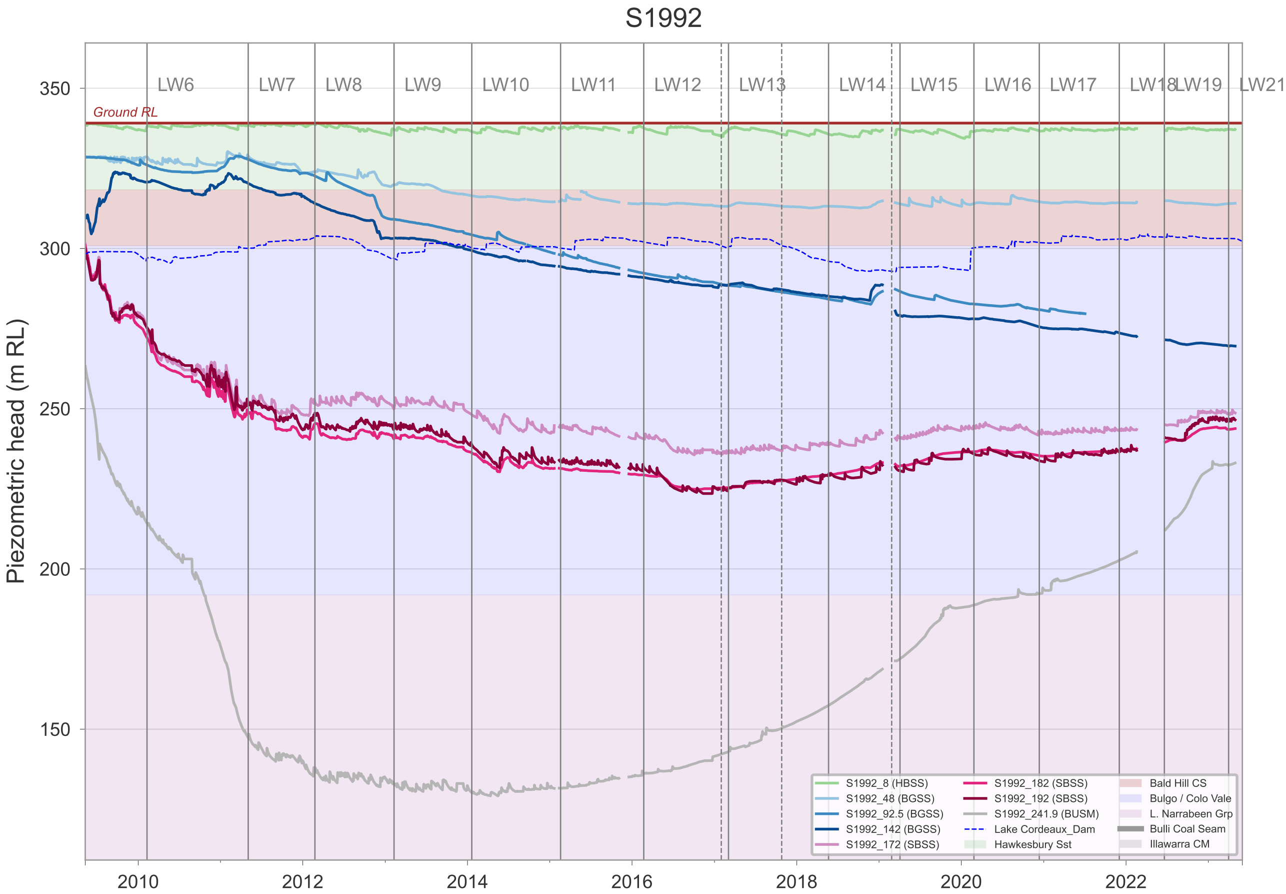


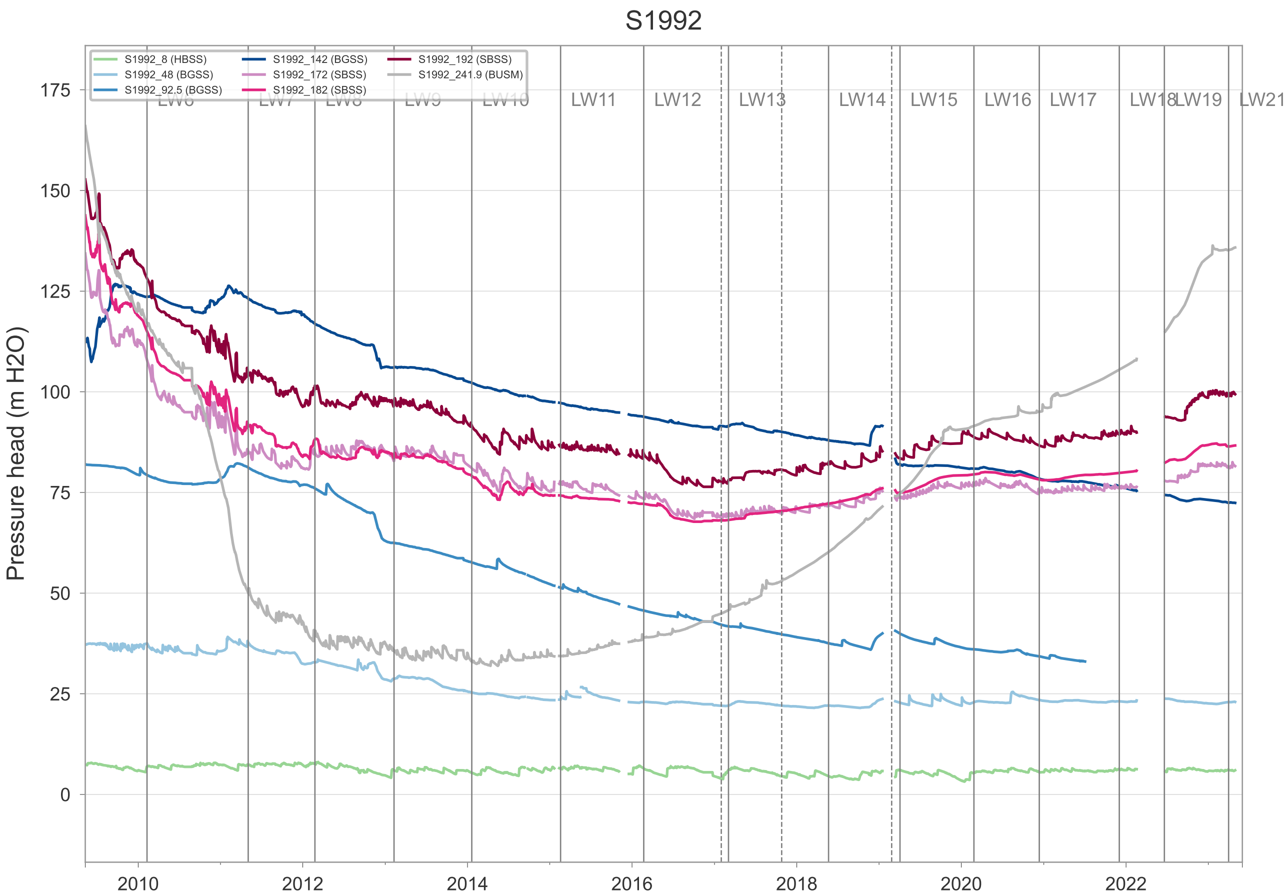


Groundwater hydrographs

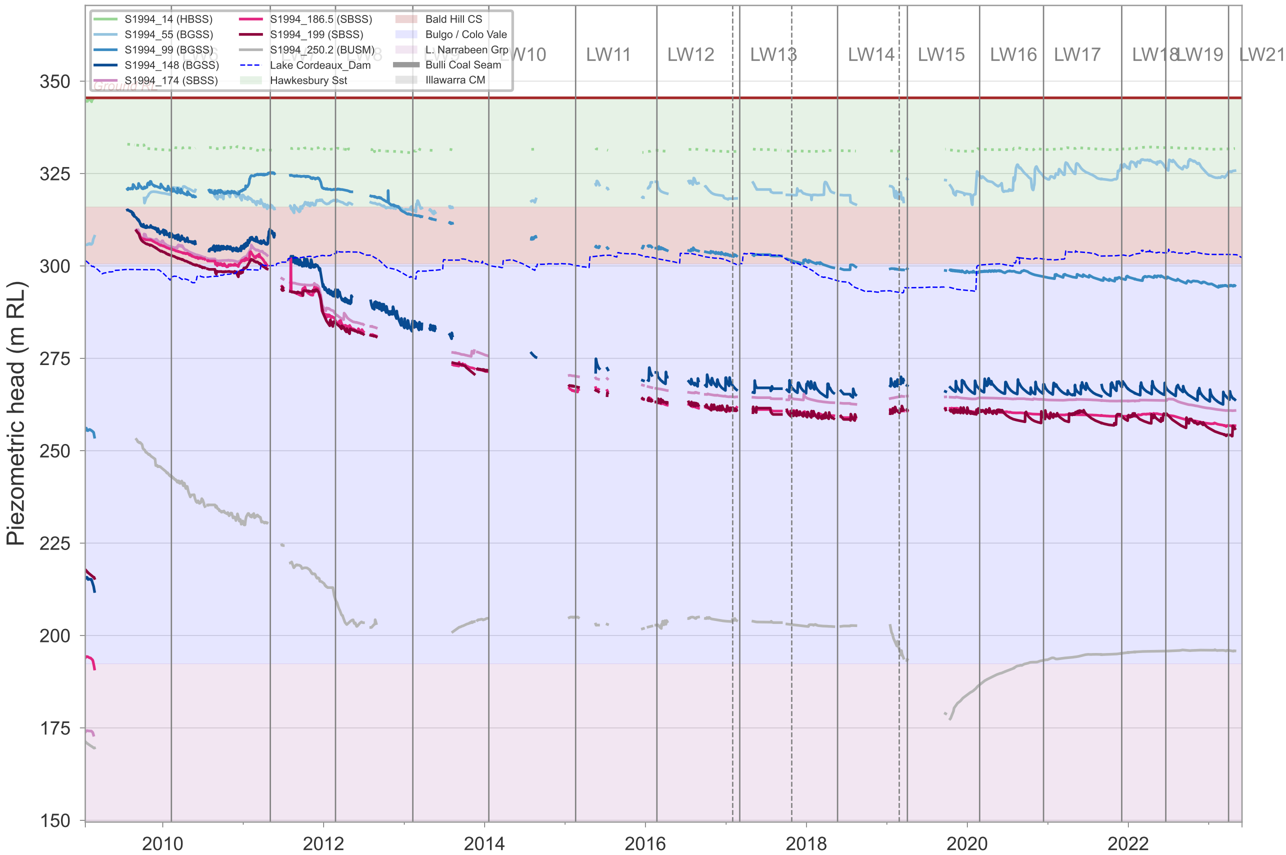




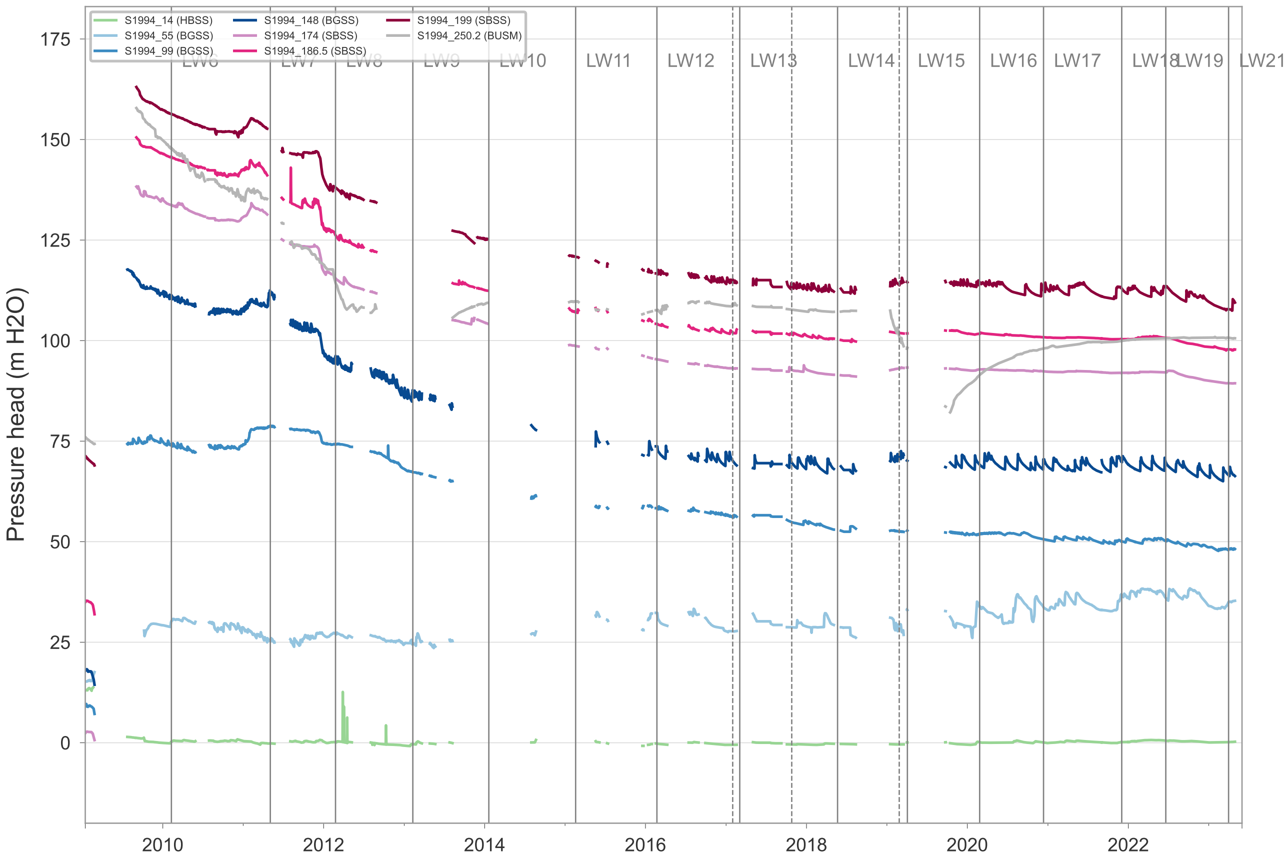

S1992
Piezometric head (m RL)
Ground RL
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
S1992_8 (HBSS)
S1992_48 (BGSS)
S1992_92.5 (BGSS)
S1992_142 (BGSS)
S1992_172 (SBSS)
S1992_182 (SBSS)
S1992_192 (SBSS)
S1992_241.9 (BUSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM


S1992
Pressure head (m H2O)
S1992_8 (HBSS)
S1992_48 (BGSS)
S1992_92.5 (BGSS)
S1992_142 (BGSS)
S1992_172 (SBSS)
S1992_182 (SBSS)
S1992_192 (SBSS)
S1992_241.9 (BUSM)
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21

S1994

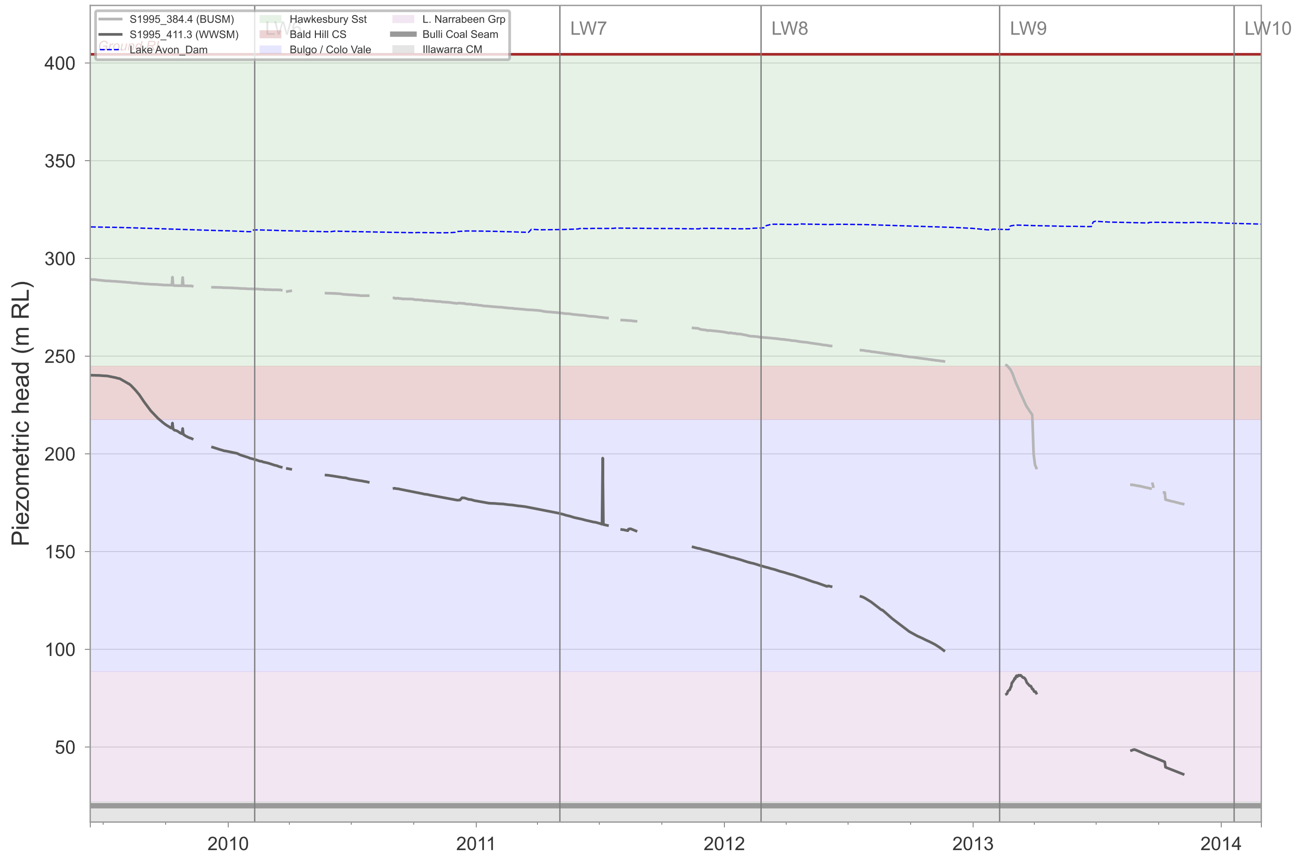

S1994_14 (HBSS)
S1994_55 (BGSS)
S1994_99 (BGSS)
S1994_148 (BGSS)
S1994_174 (SBSS)
S1994_186.5 (SBSS)
S1994_199 (SBSS)
S1994_250.2 (BUSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Piezometric head (m RL)
350
325
300
275
250
225
200
175
150
2010
2012
2014
2016
2018
2020
2022

S1994

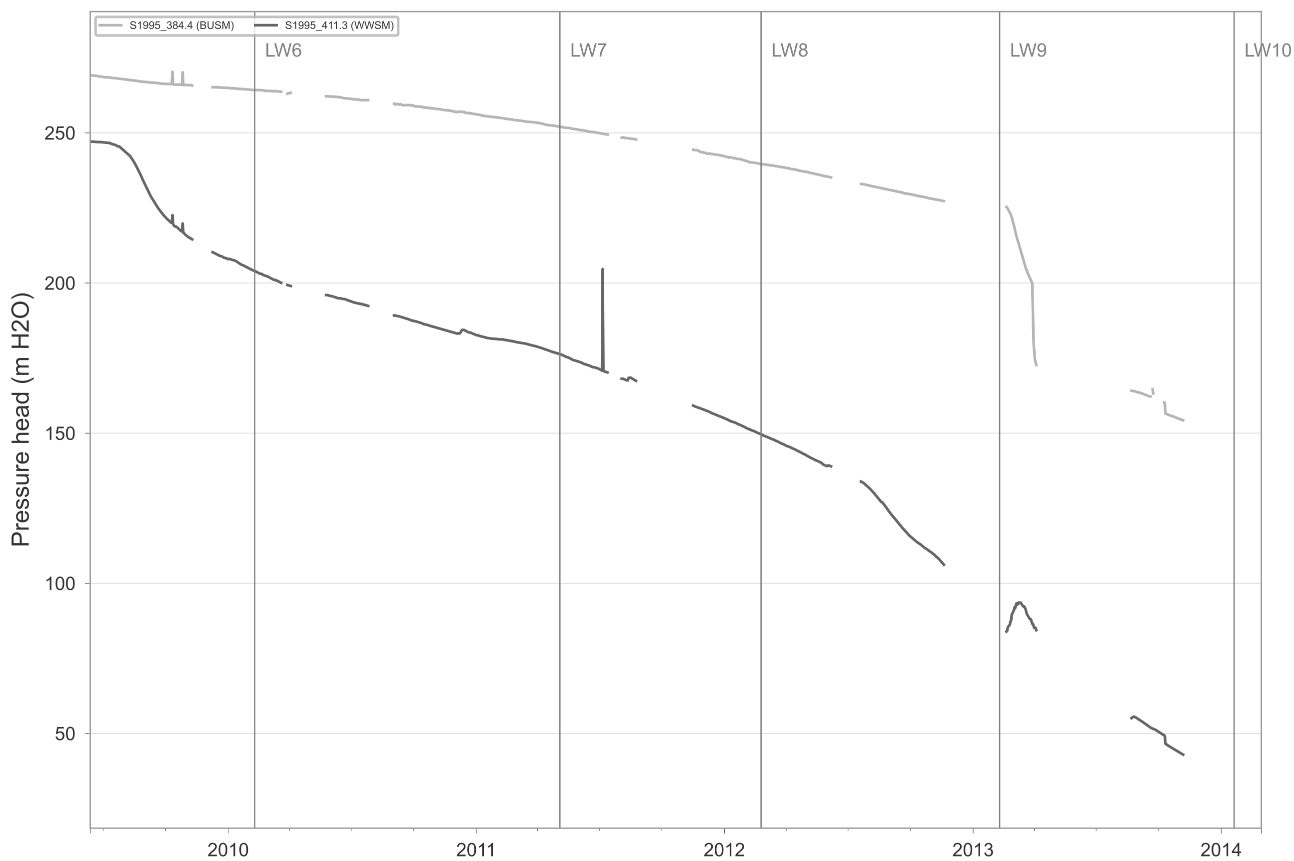

S1994_14 (HBSS)
S1994_55 (BGSS)
S1994_99 (BGSS)
S1994_148 (BGSS)
S1994_174 (SBSS)
S1994_186.5 (SBSS)
S1994_199 (SBSS)
S1994_250.2 (BUSM)
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Pressure head (m H2O)
175
150
125
100
75
50
25
0
2010
2012
2014
2016
2018
2020
2022

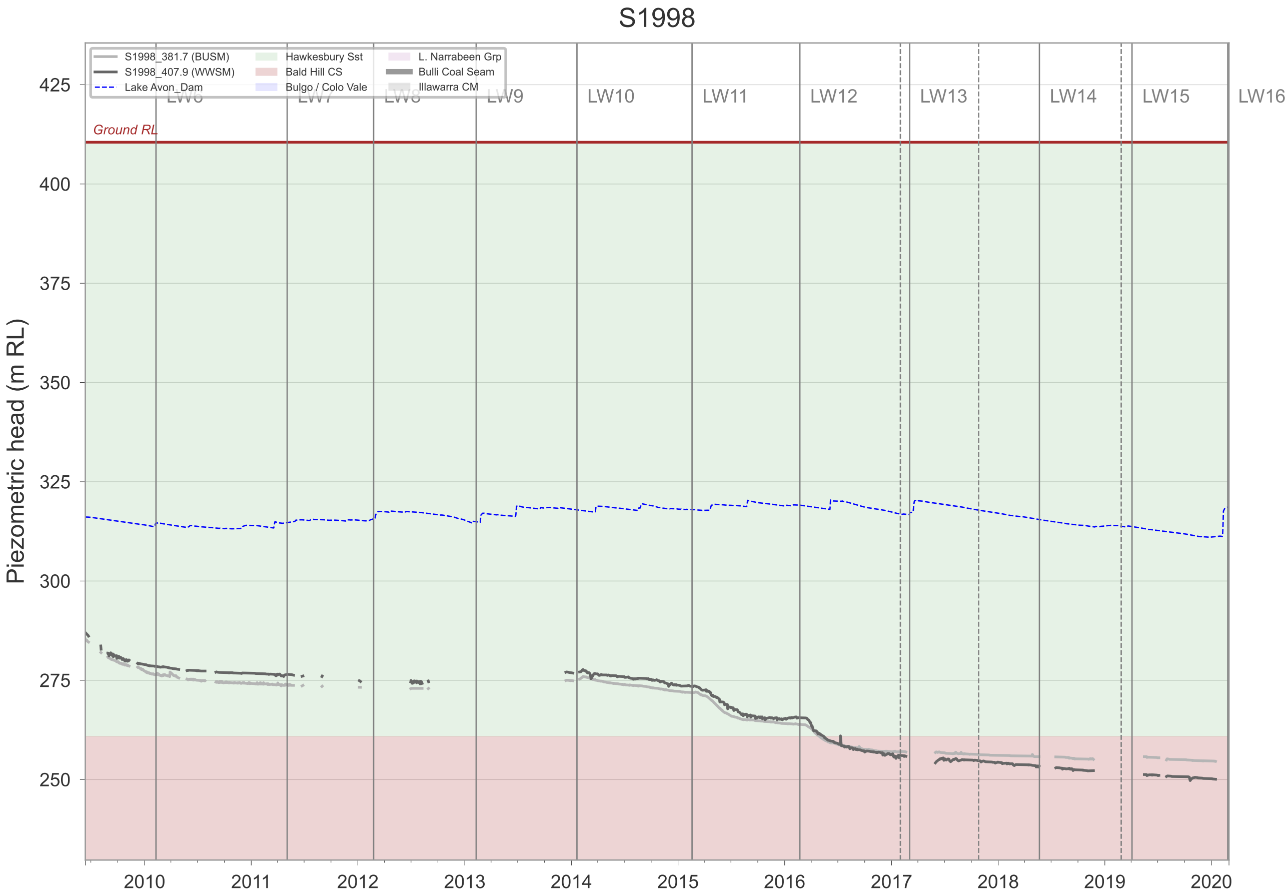
Groundwater hydrographs

S1995

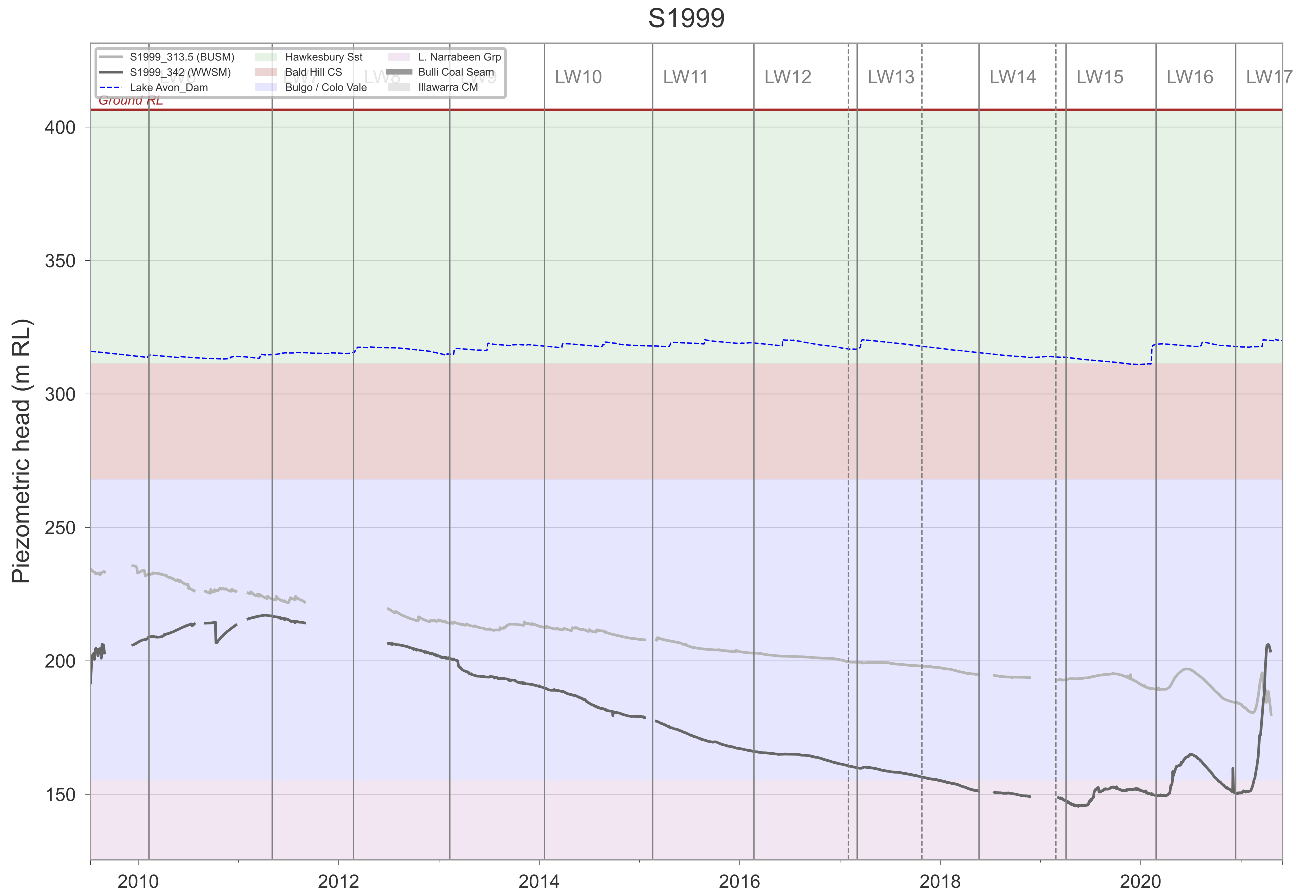


S1995



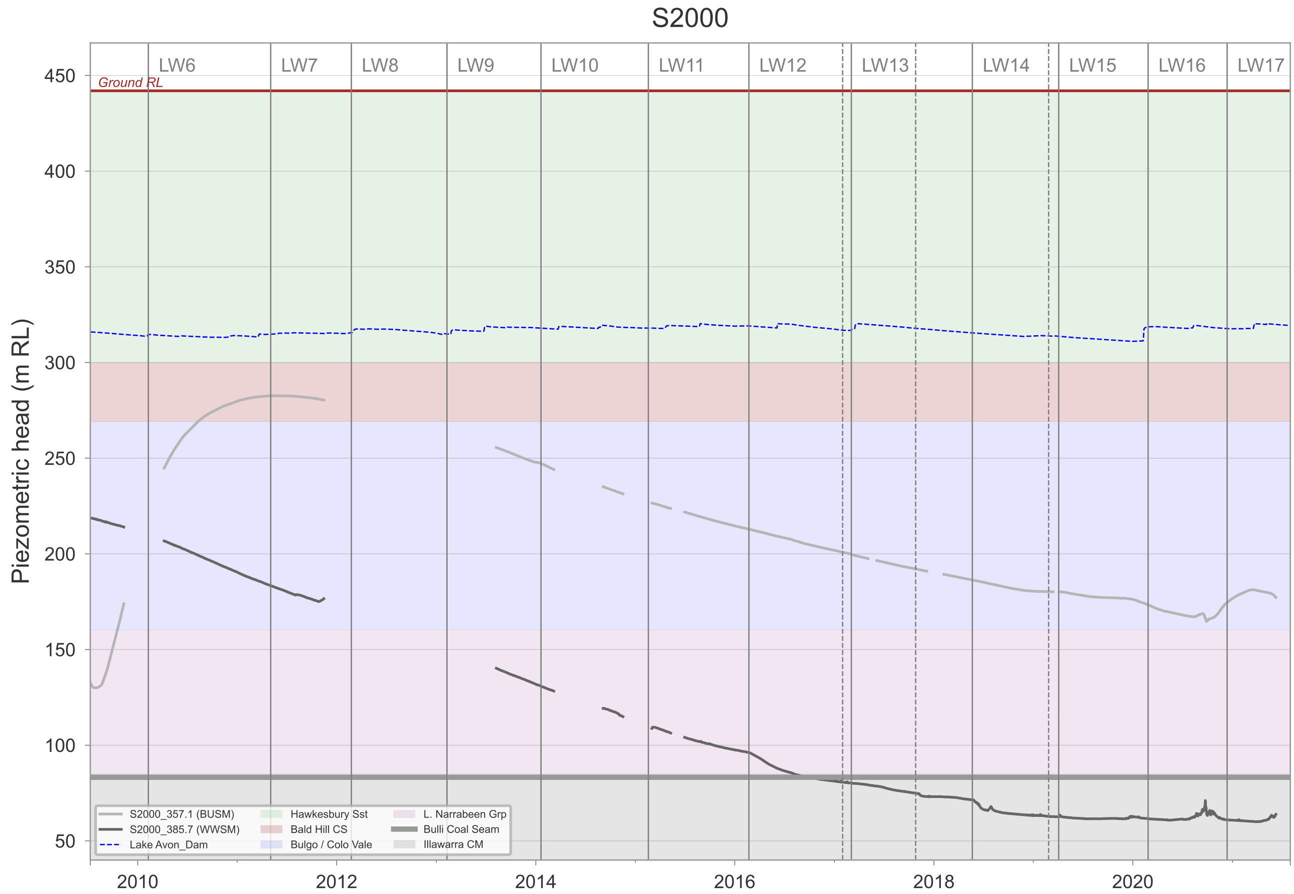

S1998
S1998_381.7 (BUSM)
S1998_407.9 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Ground RL
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
Piezometric head (m RL)
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

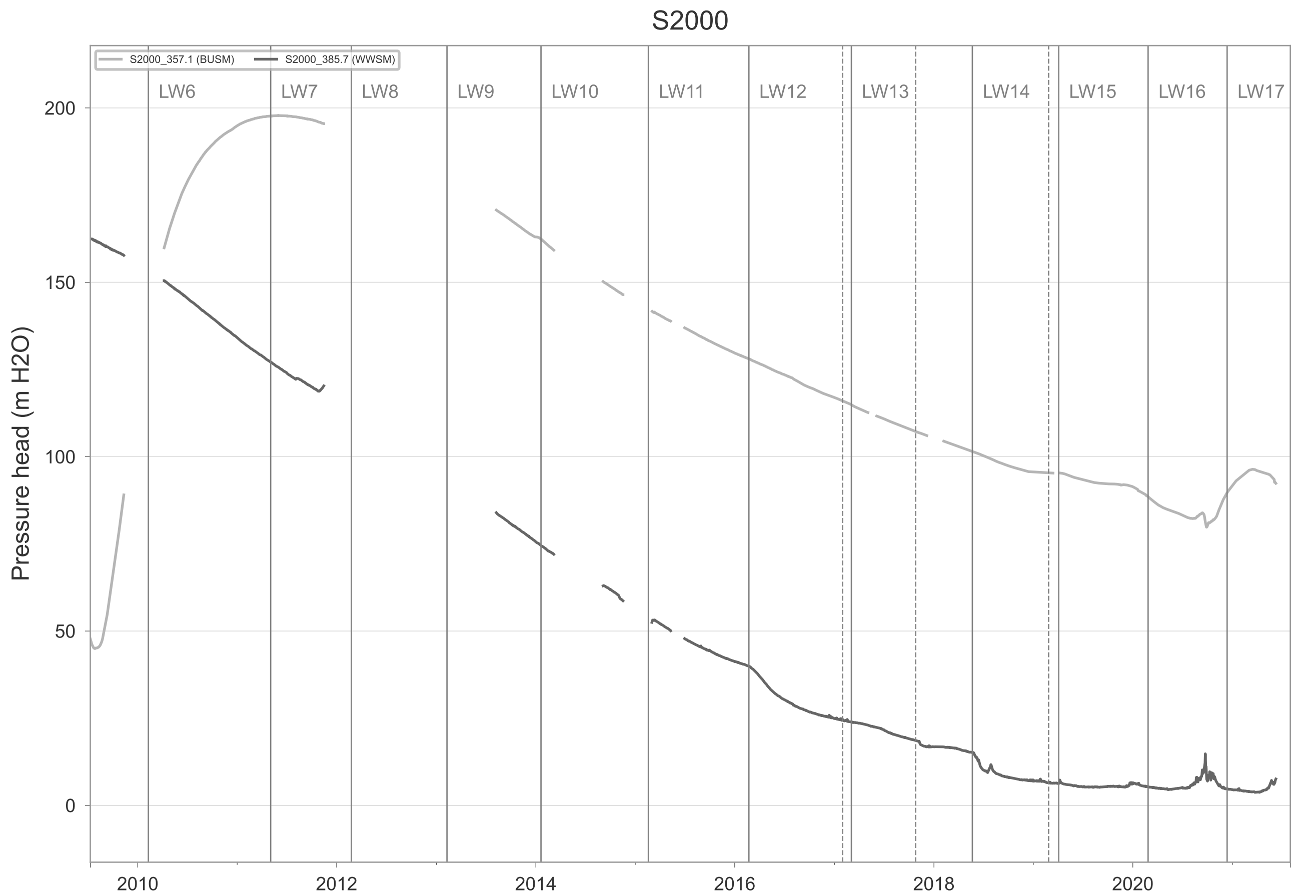

S1998
S1998_381.7 (BUSM)
S1998_407.9 (WWSM)
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
Pressure head (m H2O)
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

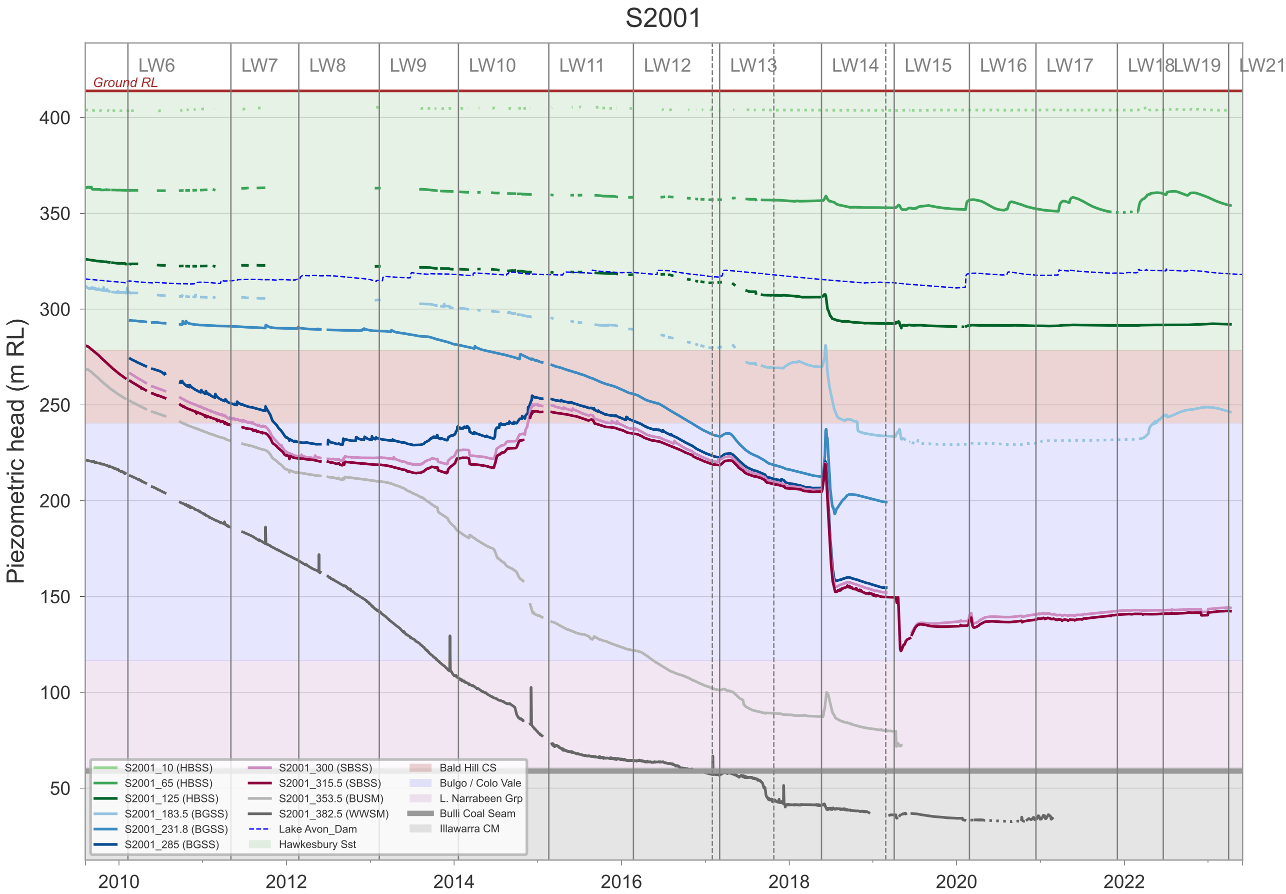

S1999
S1999_313.5 (BUSM)
S1999_342 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Ground RL
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Piezometric head (m RL)
400
350
300
250
200
150
2010
2012
2014
2016
2018
2020

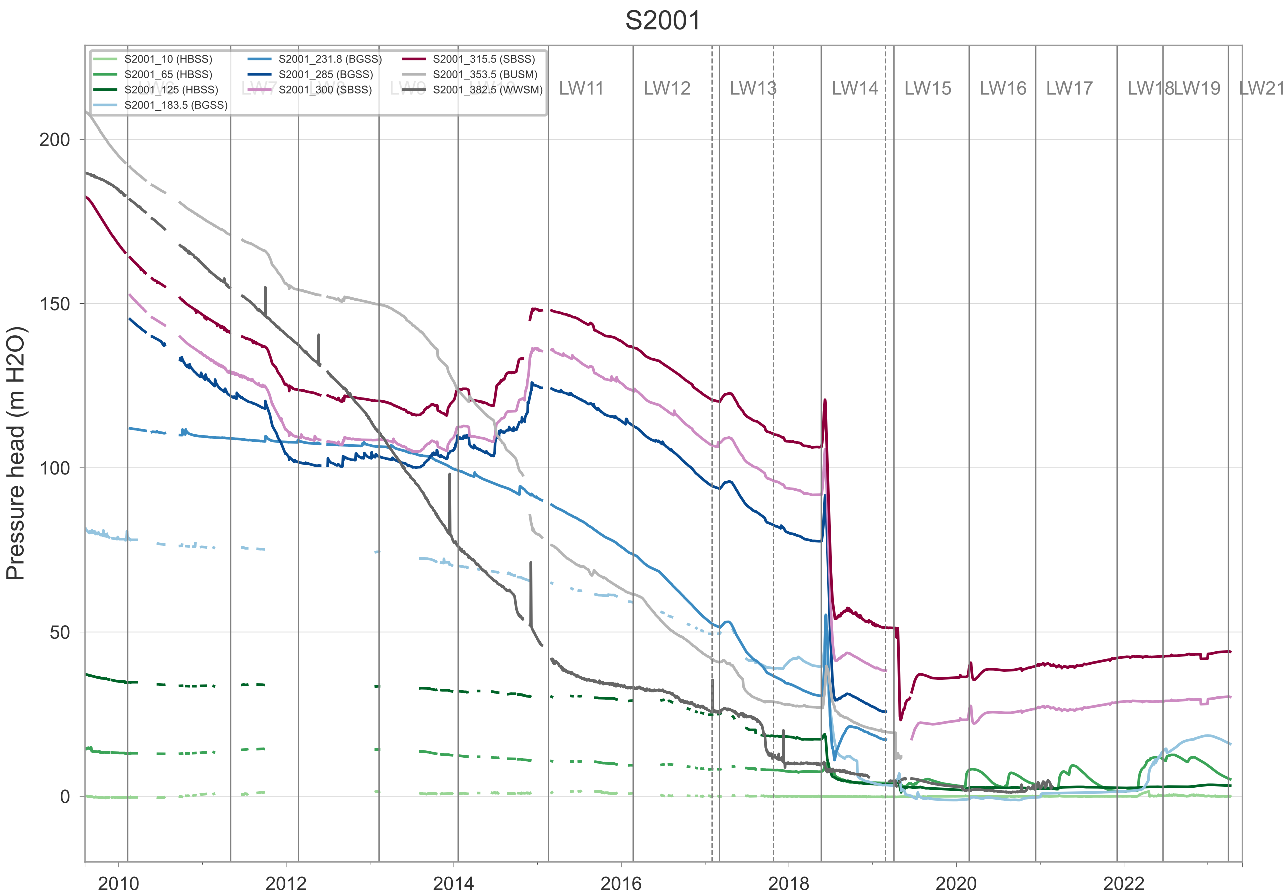

S1999
S1999_313.5 (BUSM)
S1999_342 (WWSM)
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
Pressure head (m H2O)
160
140
120
100
80
2010
2012
2014
2016
2018
2020

Groundwater hydrographs

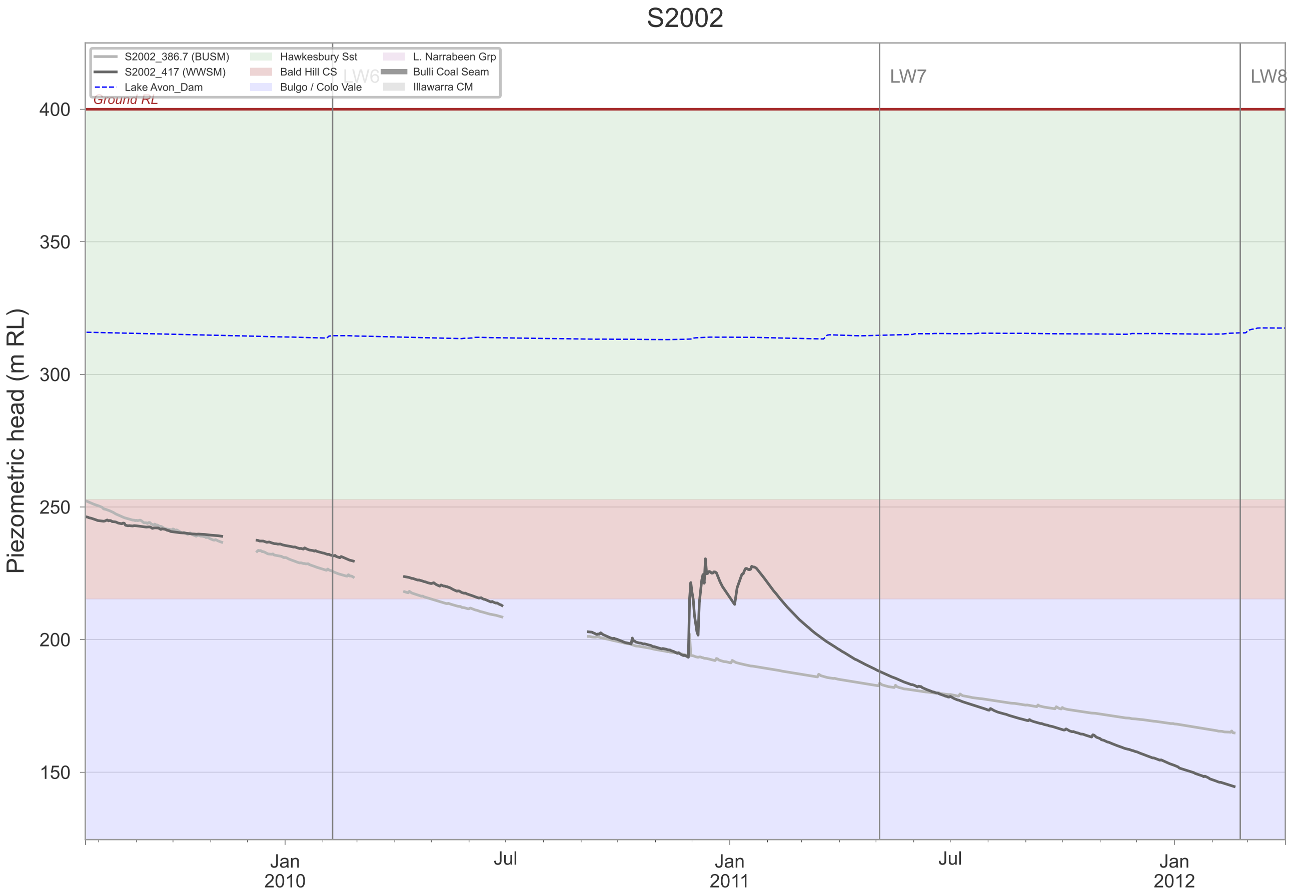


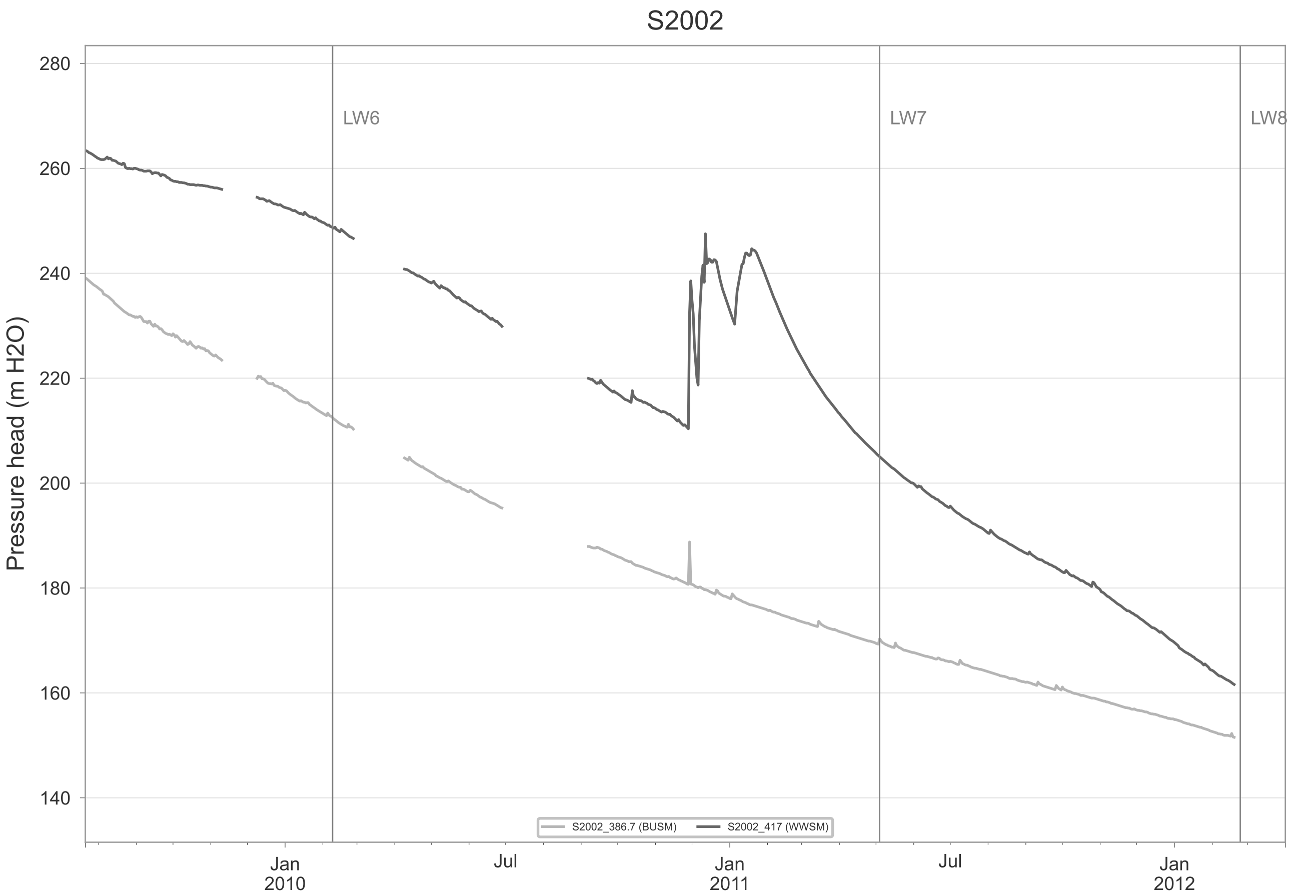



S2001
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Ground RL
Piezometric head (m RL)
400
350
300
250
200
150
100
50
2010
2012
2014
2016
2018
2020
2022
S2001_10 (HBSS)
S2001_65 (HBSS)
S2001_125 (HBSS)
S2001_183.5 (BGSS)
S2001_231.8 (BGSS)
S2001_285 (BGSS)
S2001_300 (SBSS)
S2001_315.5 (SBSS)
S2001_353.5 (BUSM)
S2001_382.5 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM

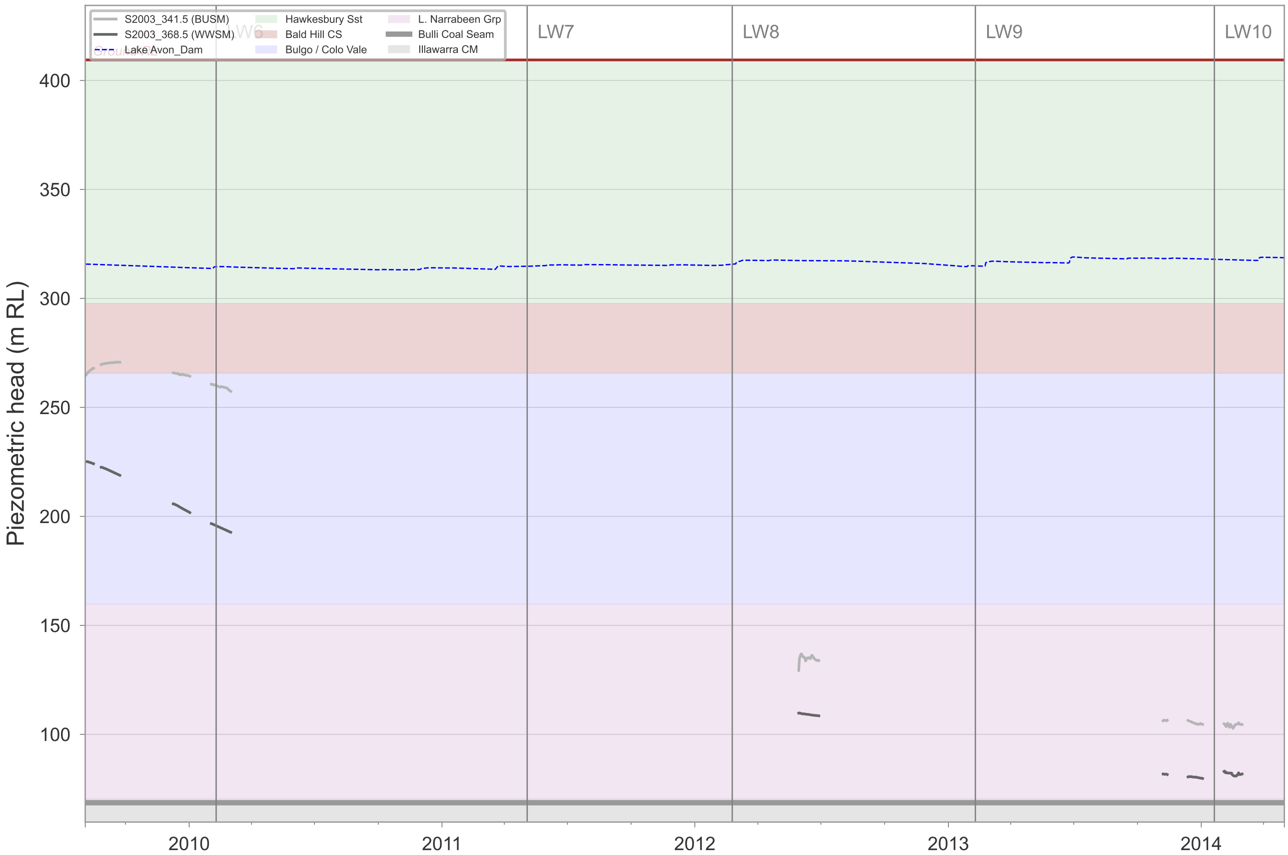

S2001
S2001_10 (HBSS)
S2001_65 (HBSS)
S2001_125 (HBSS)
S2001_183.5 (BGSS)
S2001_231.8 (BGSS)
S2001_285 (BGSS)
S2001_300 (SBSS)
S2001_315.5 (SBSS)
S2001_353.5 (BUSM)
S2001_382.5 (WWSM)
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Pressure head (m H2O)
200
150
100
50
0
2010
2012
2014
2016
2018
2020
2022

Groundwater hydrographs

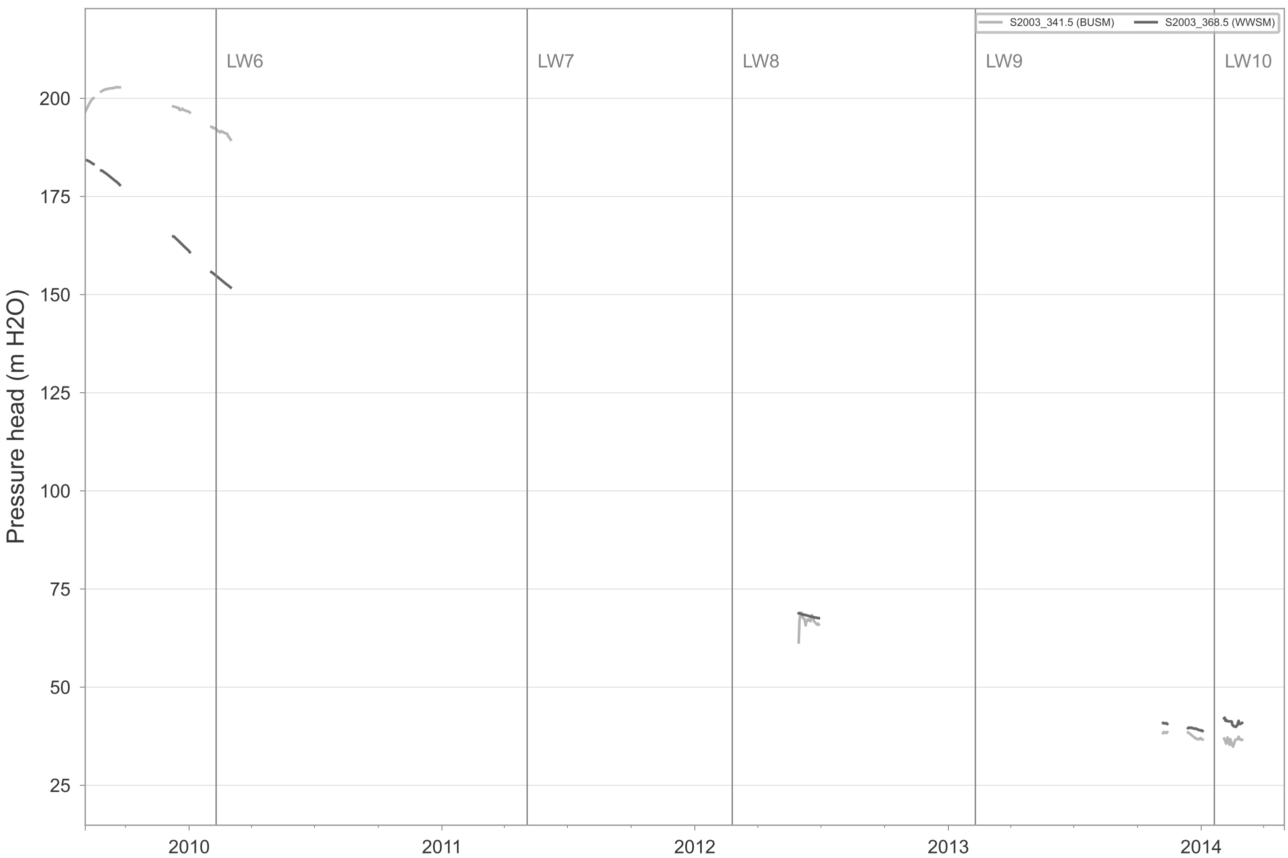


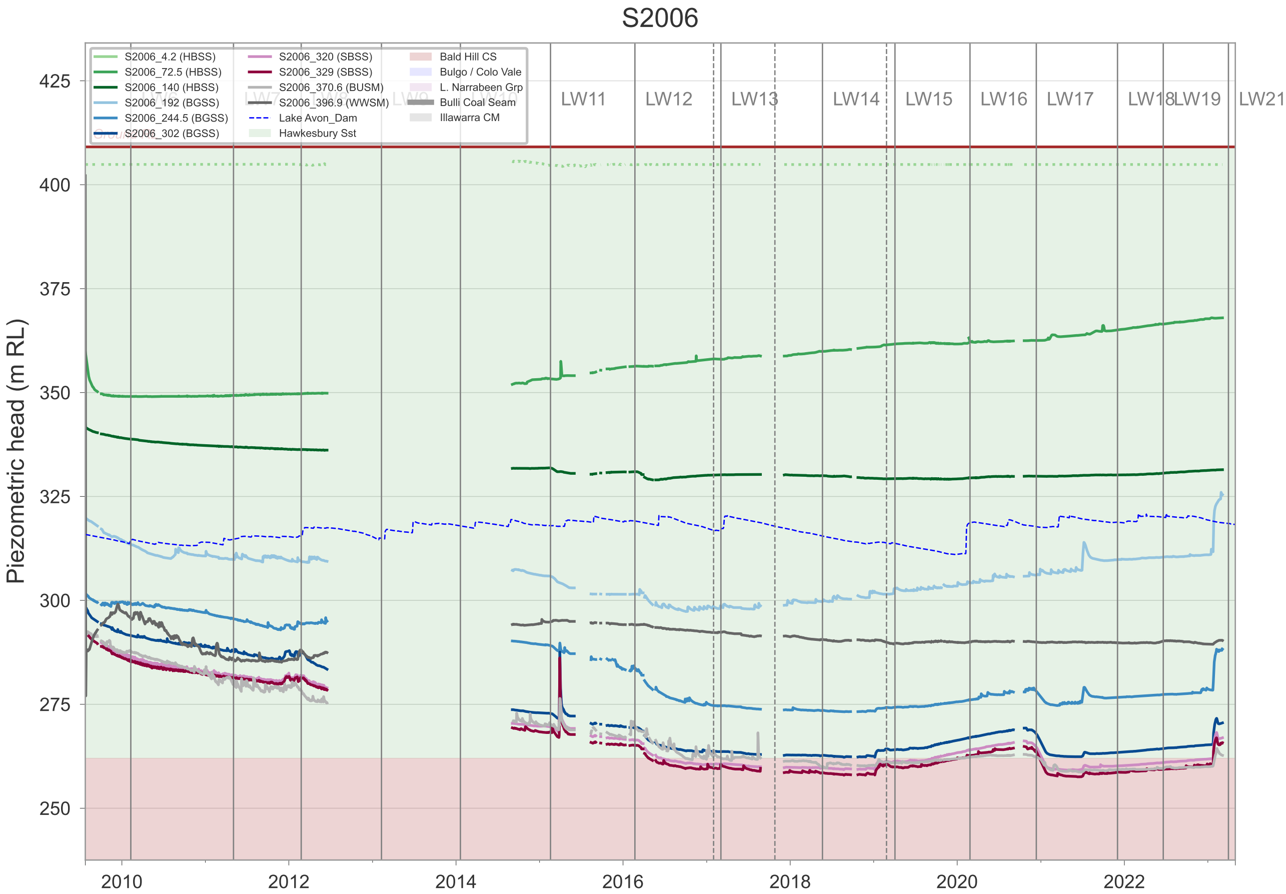


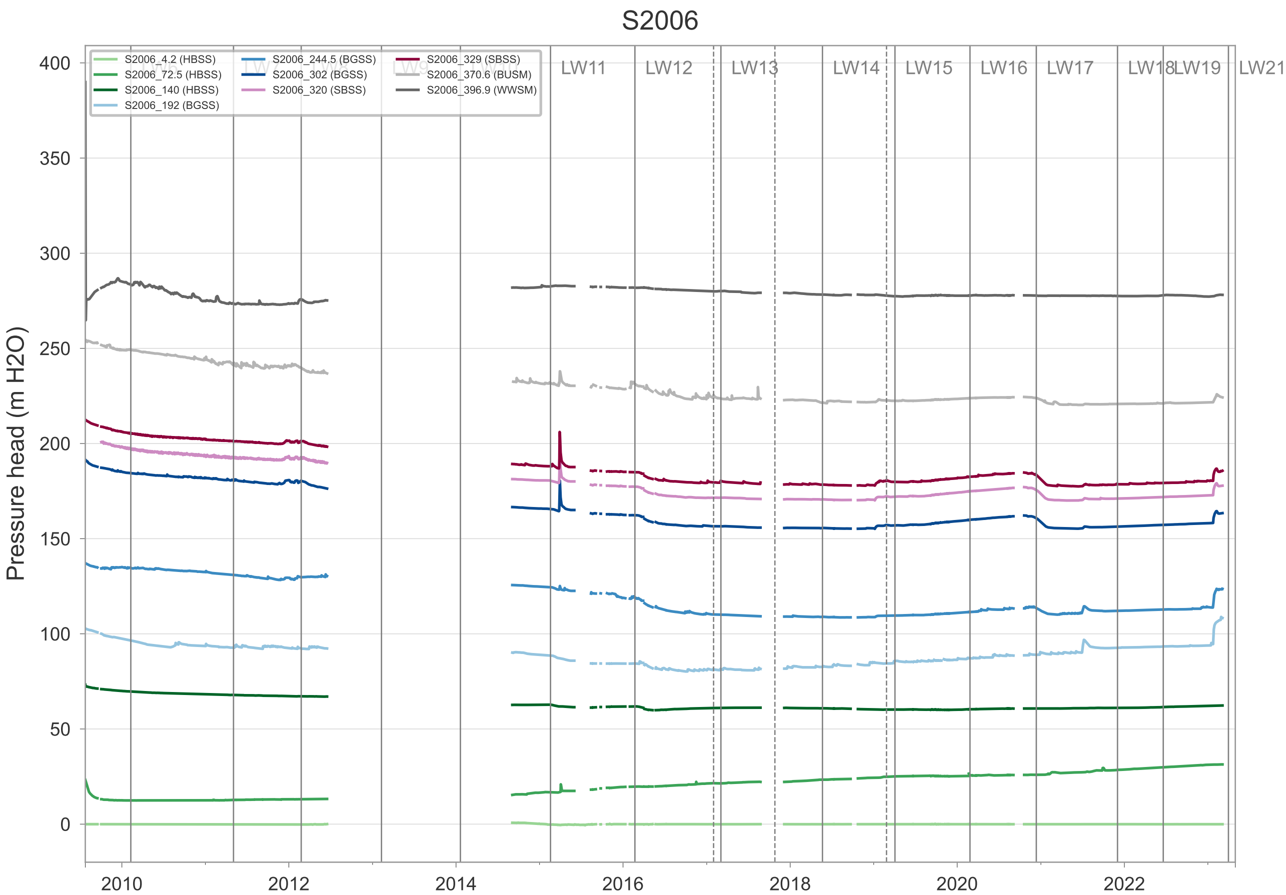
S2003


S2003_341.5 (BUSM)
S2003_368.5 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
LW6
LW7
LW8
LW9
LW10
Piezometric head (m RL)
400
350
300
250
200
150
100
2010
2011
2012
2013
2014

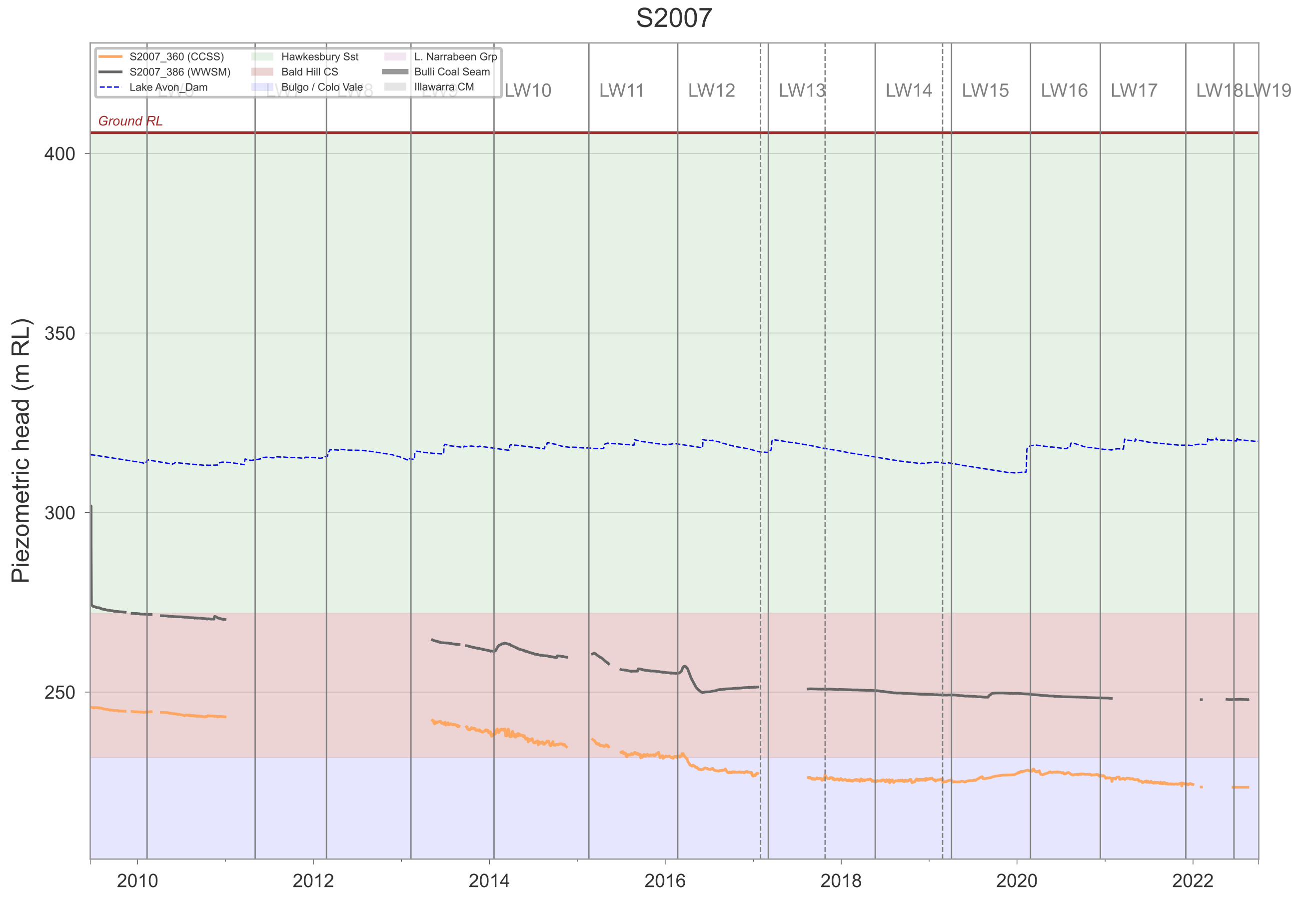
S2003

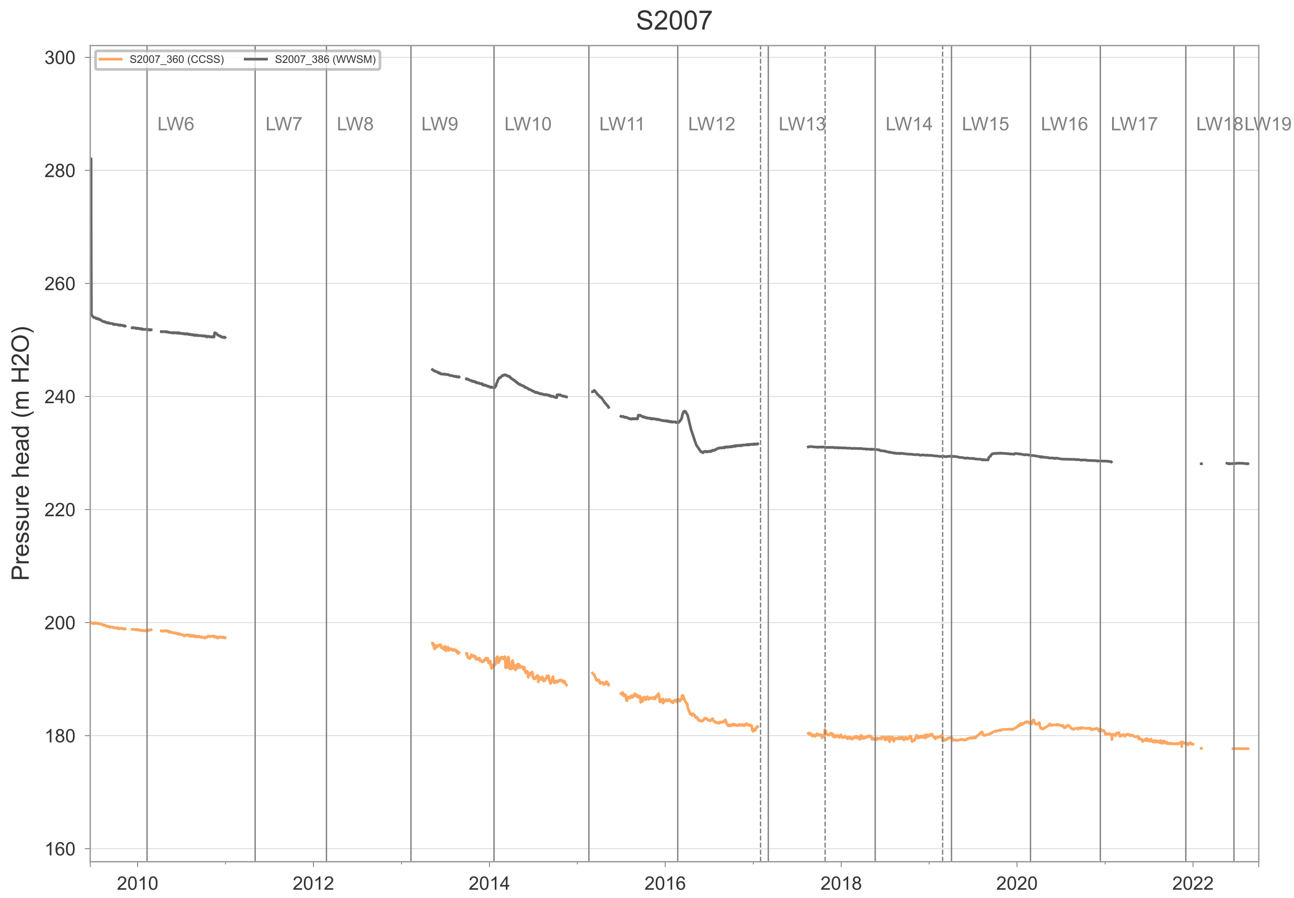

S2003_341.5 (BUSM)
S2003_368.5 (WWSM)
LW6
LW7
LW8
LW9
LW10
Pressure head (m H2O)
200
175
150
125
100
75
50
25
2010
2011
2012
2013
2014


S2006
Piezometric head (m RL)
S2006_4.2 (HBSS)
S2006_72.5 (HBSS)
S2006_140 (HBSS)
S2006_192 (BGSS)
S2006_244.5 (BGSS)
S2006_302 (BGSS)
S2006_320 (SBSS)
S2006_329 (SBSS)
S2006_370.6 (BUSM)
S2006_396.9 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
425
400
375
350
325
300
275
250
2010
2012
2014
2016
2018
2020
2022

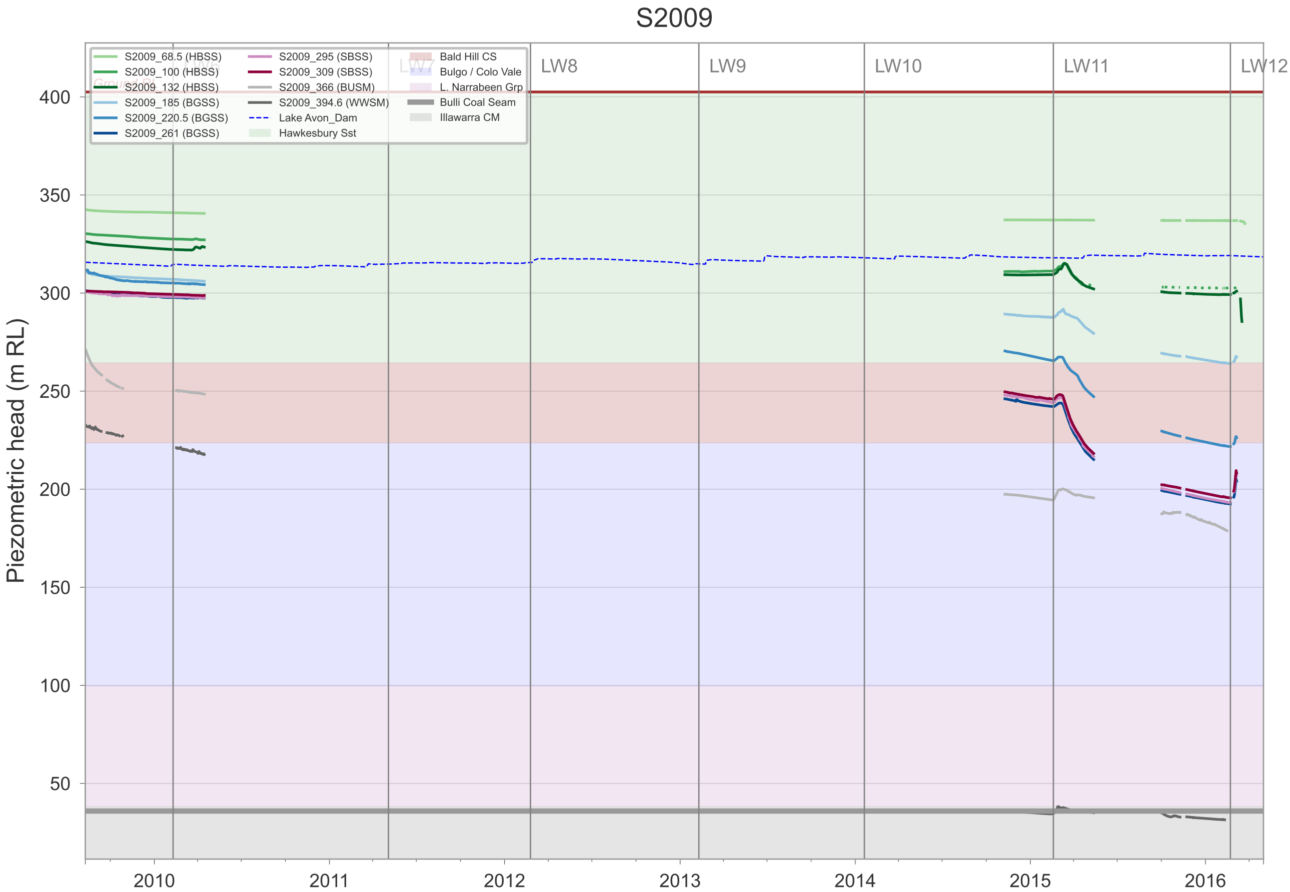

S2006
Pressure head (m H2O)
S2006_4.2 (HBSS)
S2006_72.5 (HBSS)
S2006_140 (HBSS)
S2006_192 (BGSS)
S2006_244.5 (BGSS)
S2006_302 (BGSS)
S2006_320 (SBSS)
S2006_329 (SBSS)
S2006_370.6 (BUSM)
S2006_396.9 (WWSM)
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
400
350
300
250
200
150
100
50
0
2010
2012
2014
2016
2018
2020
2022

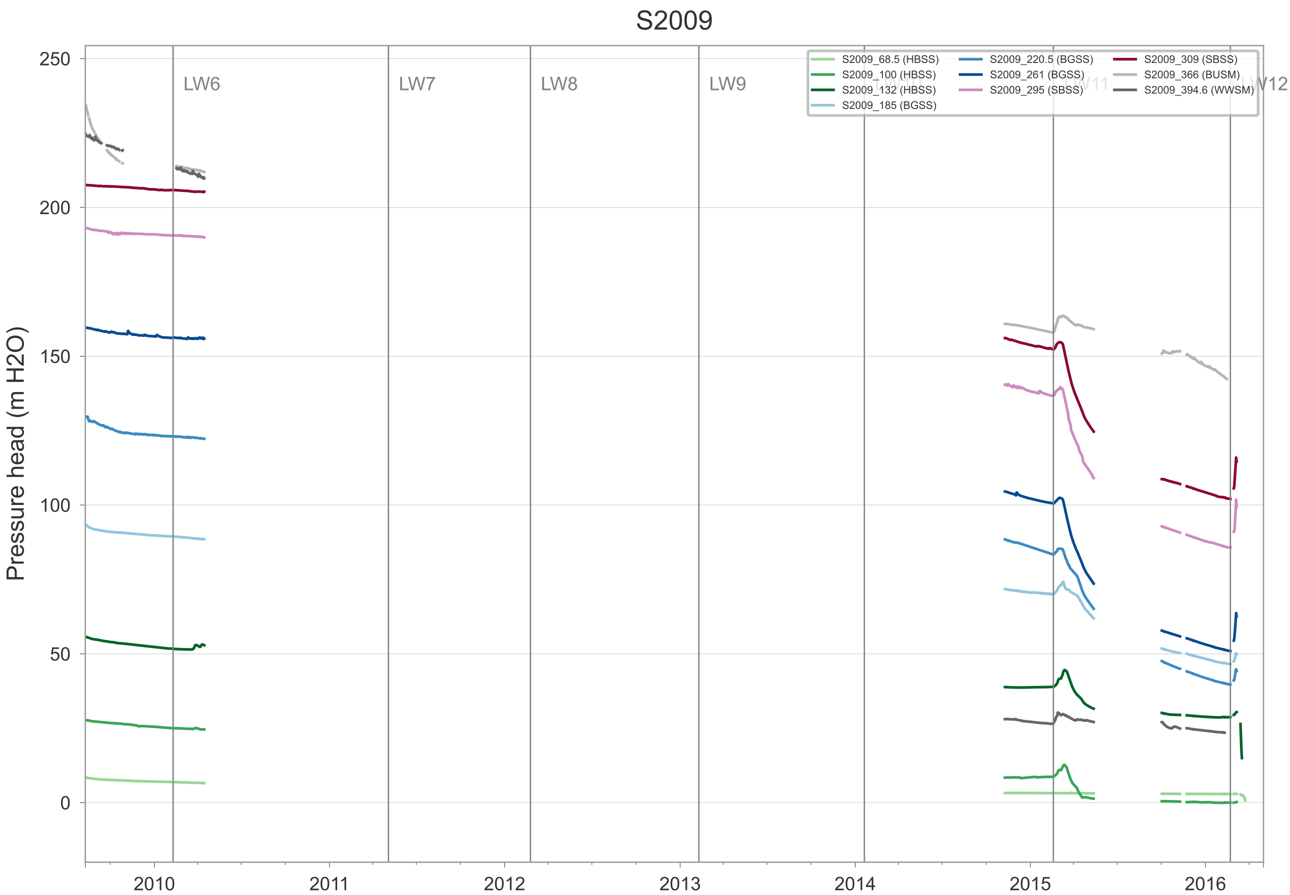
Groundwater hydrographs

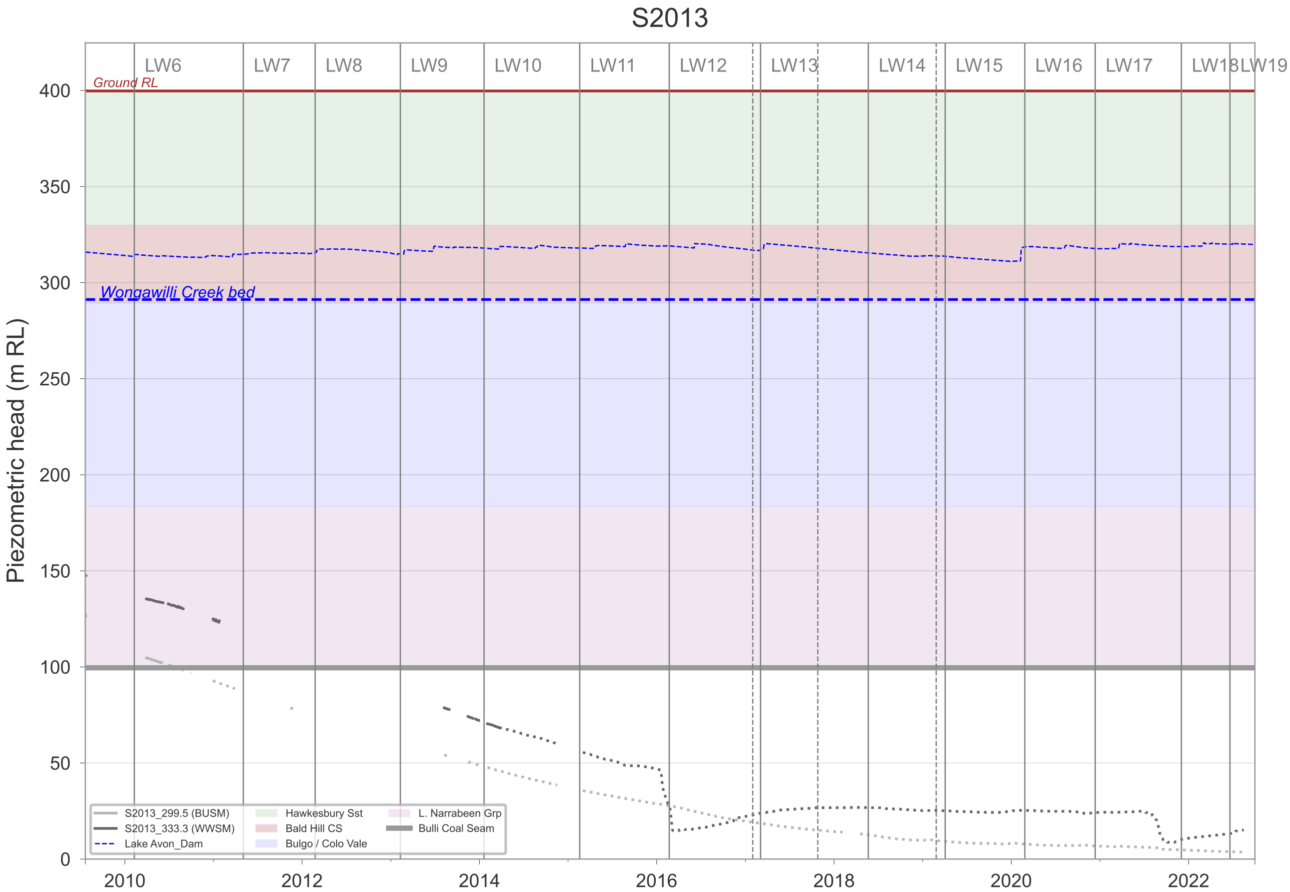


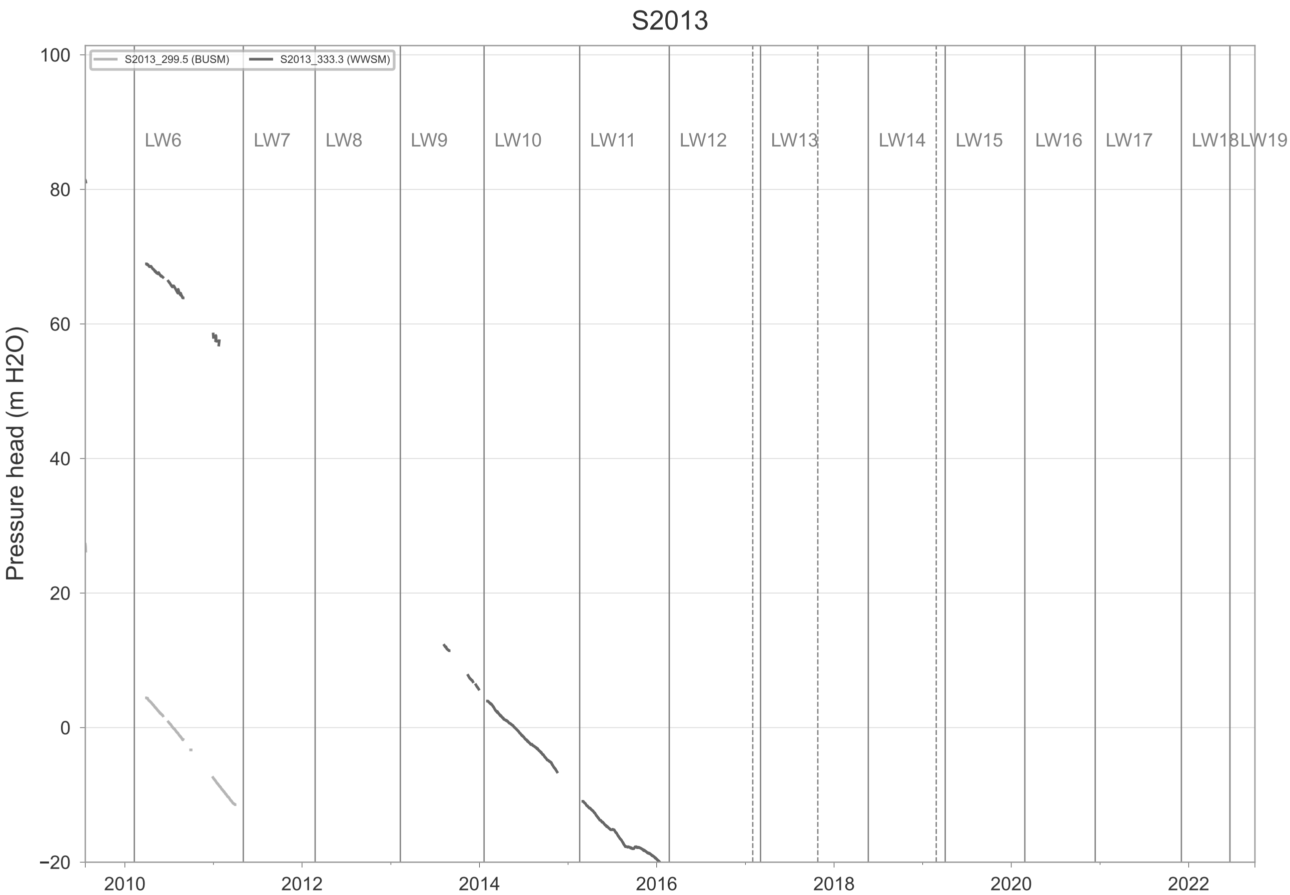


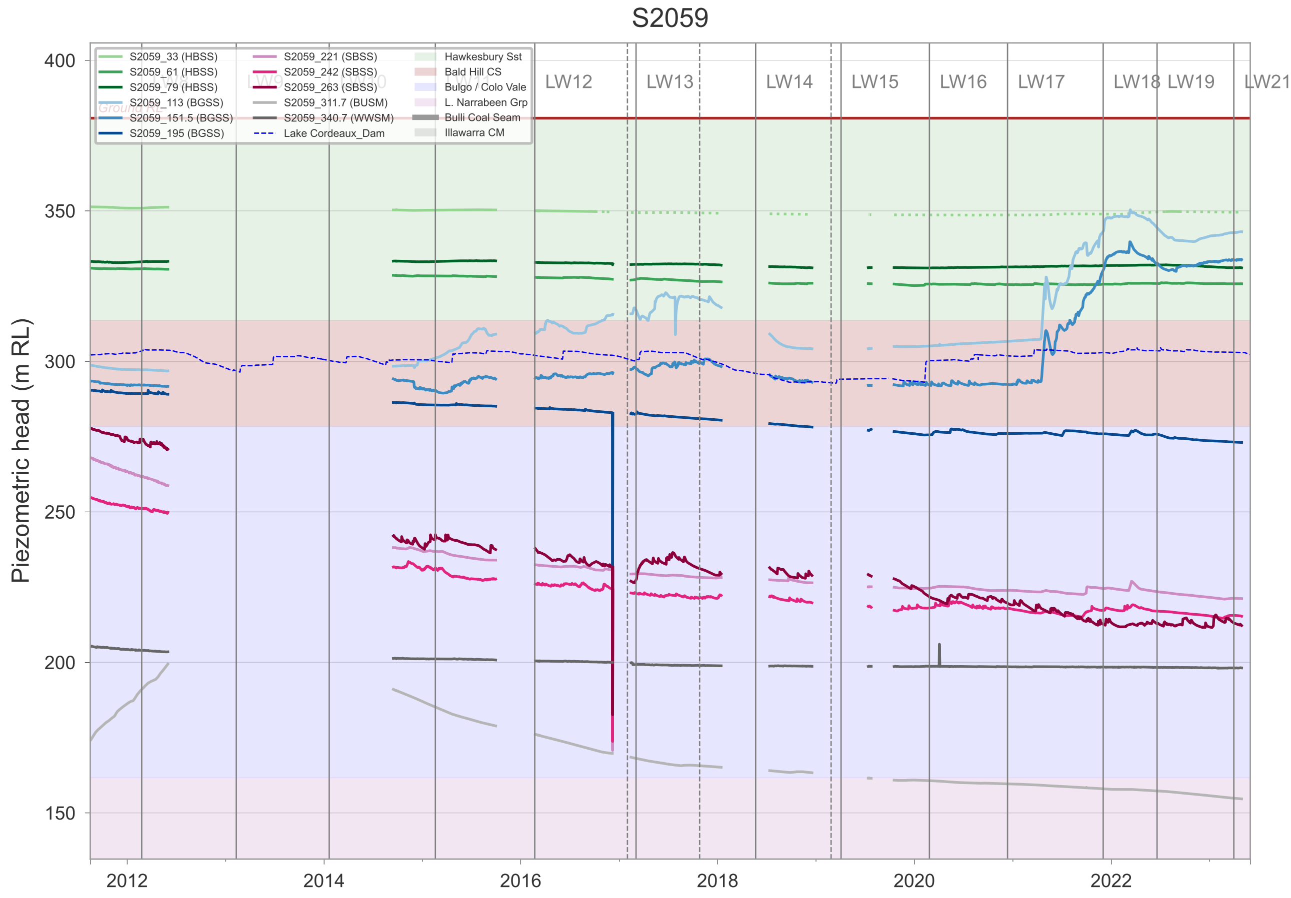
Groundwater hydrographs

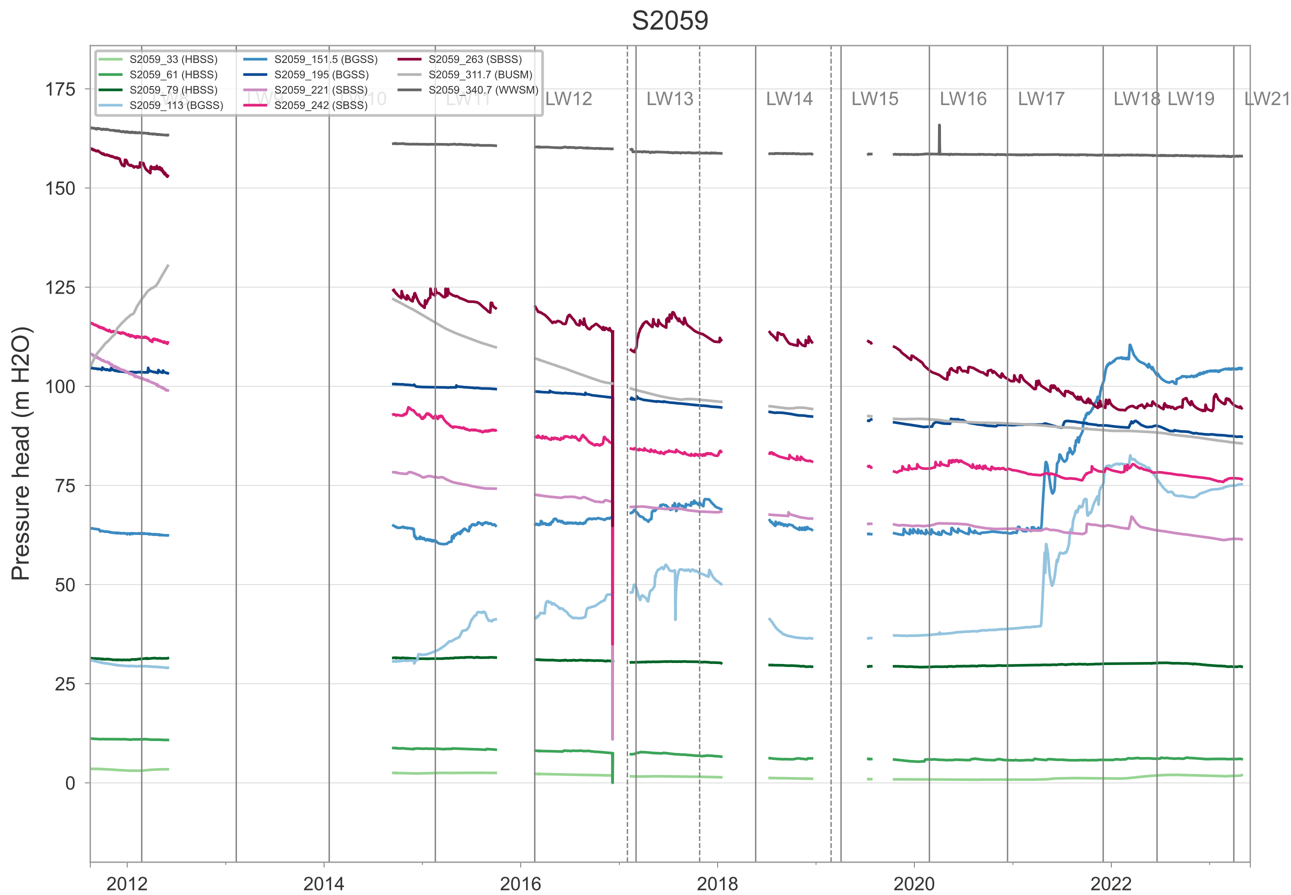


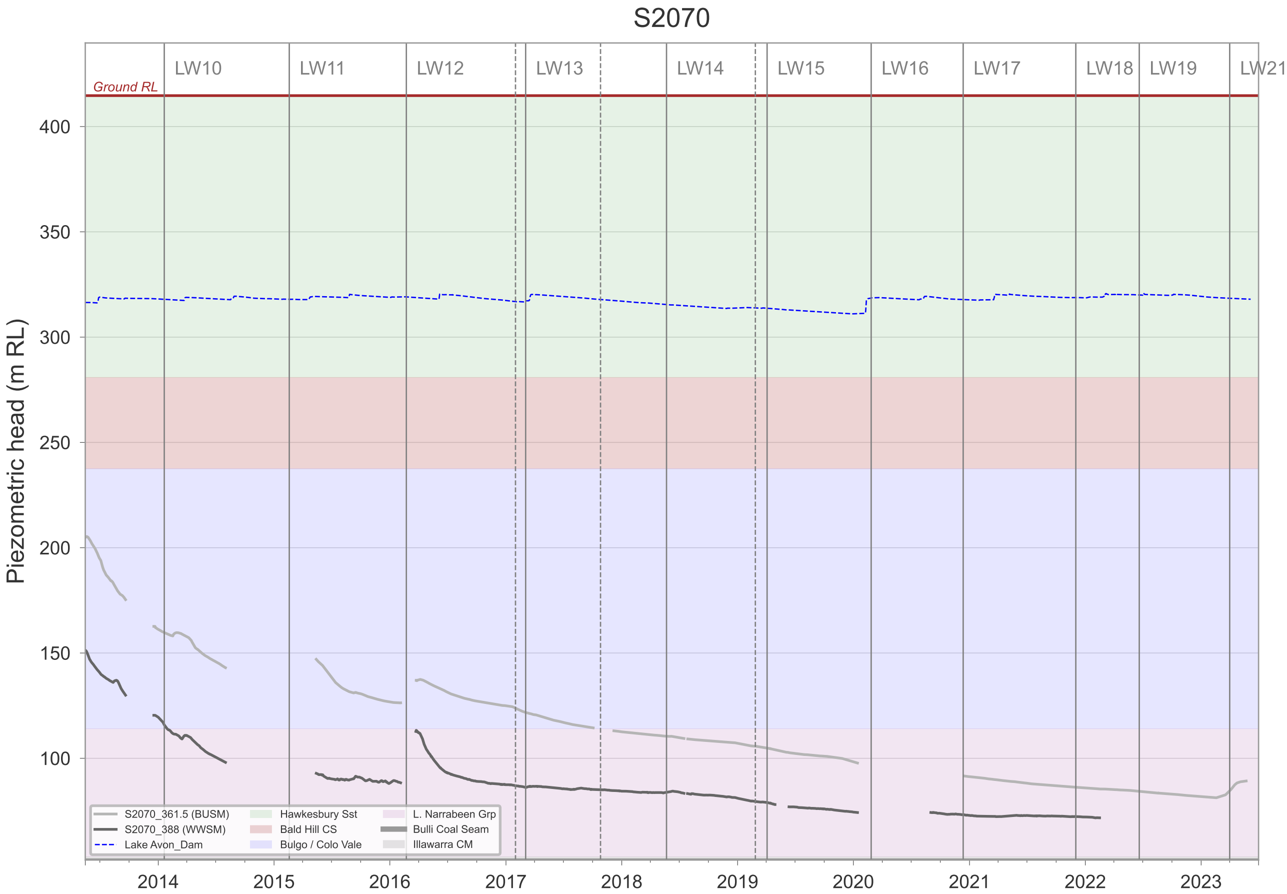


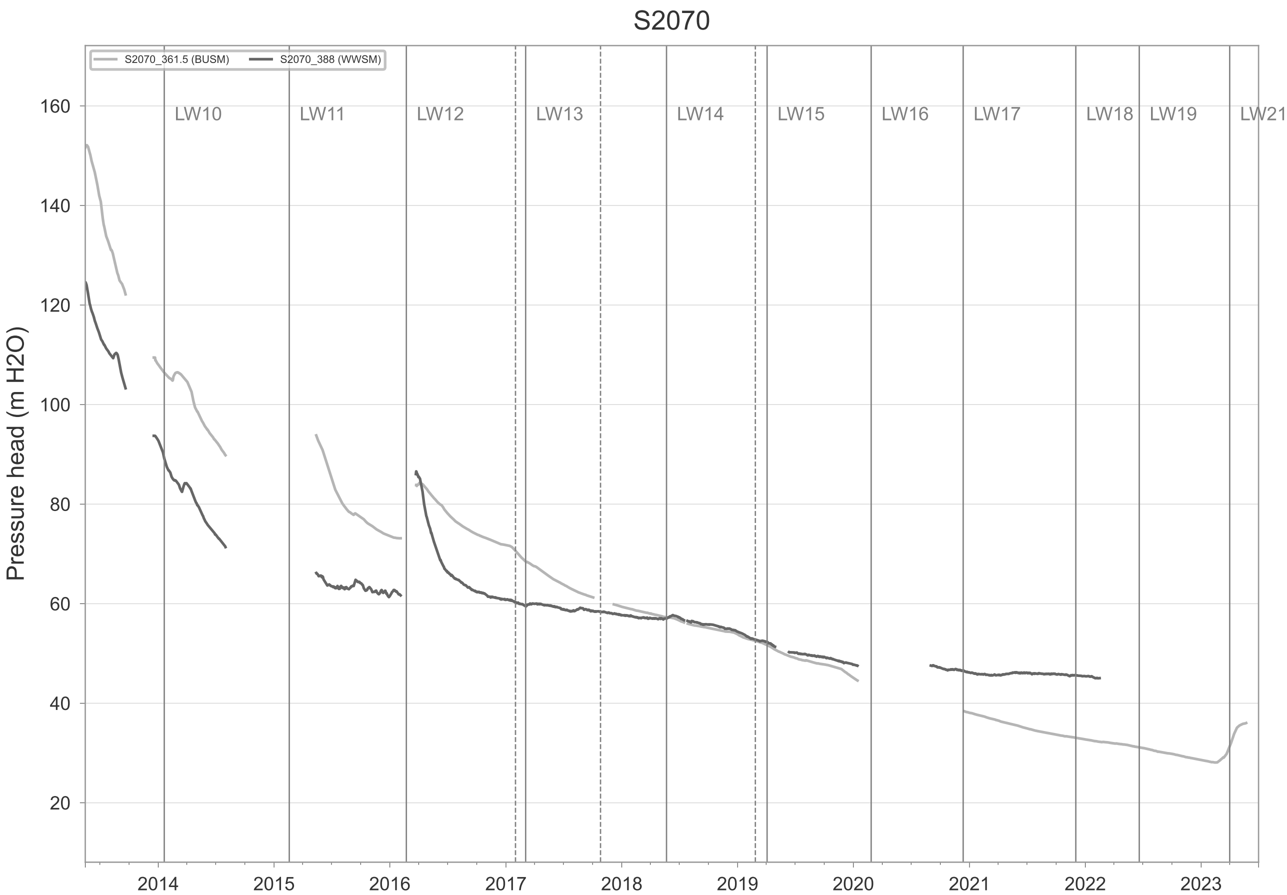

S2013
Piezometric head (m RL)
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
Ground RL
Wongawilli Creek bed
400
350
300
250
200
150
100
50
0
2010
2012
2014
2016
2018
2020
2022
S2013_299.5 (BUSM)
S2013_333.3 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam


S2013
Pressure head (m H2O)
S2013_299.5 (BUSM)
S2013_333.3 (WWSM)
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
100
80
60
40
20
0
−20
2010
2012
2014
2016
2018
2020
2022

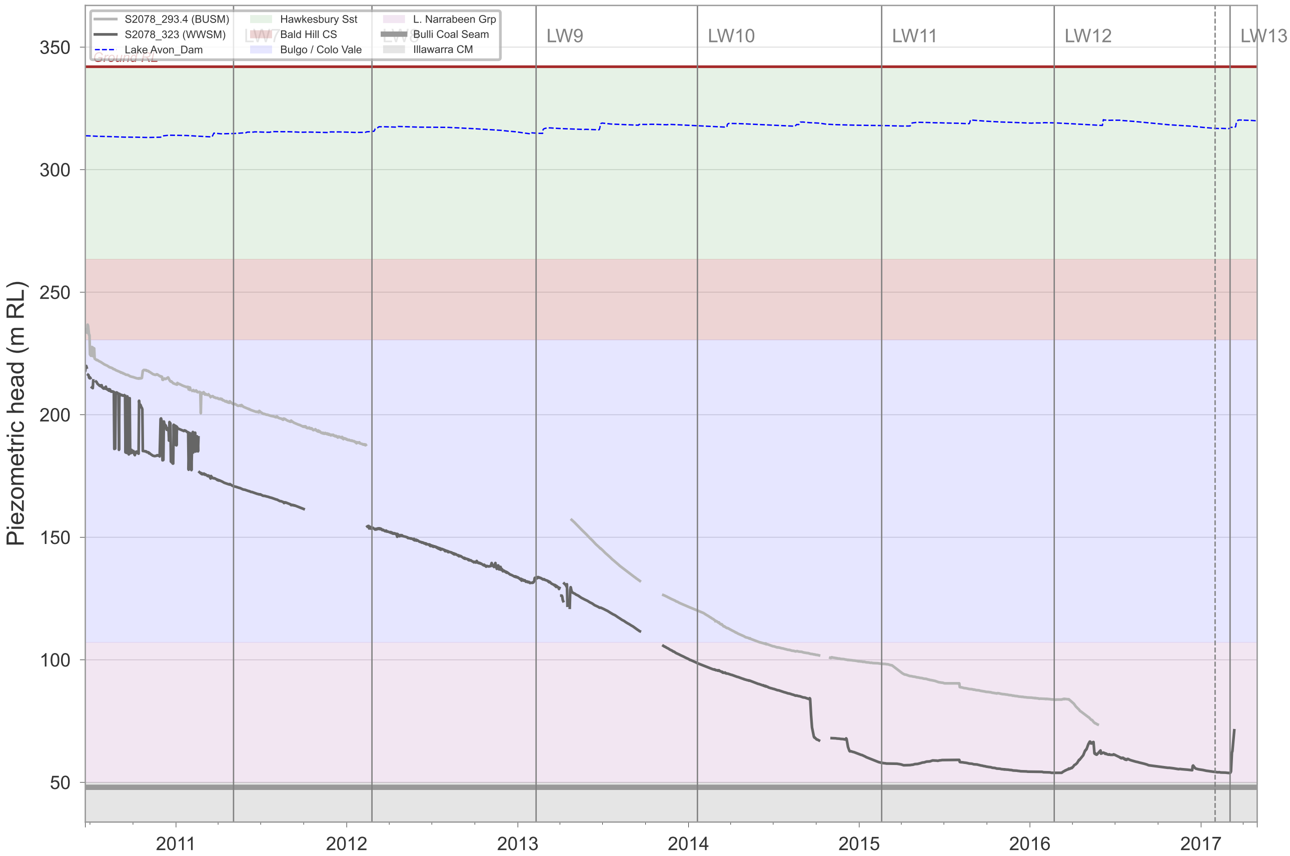

S2059
S2059_33 (HBSS)
S2059_61 (HBSS)
S2059_79 (HBSS)
S2059_113 (BGSS)
S2059_151.5 (BGSS)
S2059_195 (BGSS)
S2059_221 (SBSS)
S2059_242 (SBSS)
S2059_263 (SBSS)
S2059_311.7 (BUSM)
S2059_340.7 (WWSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Piezometric head (m RL)
400
350
300
250
200
150
2012
2014
2016
2018
2020
2022


S2059
S2059_33 (HBSS)
S2059_61 (HBSS)
S2059_79 (HBSS)
S2059_113 (BGSS)
S2059_151.5 (BGSS)
S2059_195 (BGSS)
S2059_221 (SBSS)
S2059_242 (SBSS)
S2059_263 (SBSS)
S2059_311.7 (BUSM)
S2059_340.7 (WWSM)
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Pressure head (m H2O)
175
150
125
100
75
50
25
0
2012
2014
2016
2018
2020
2022

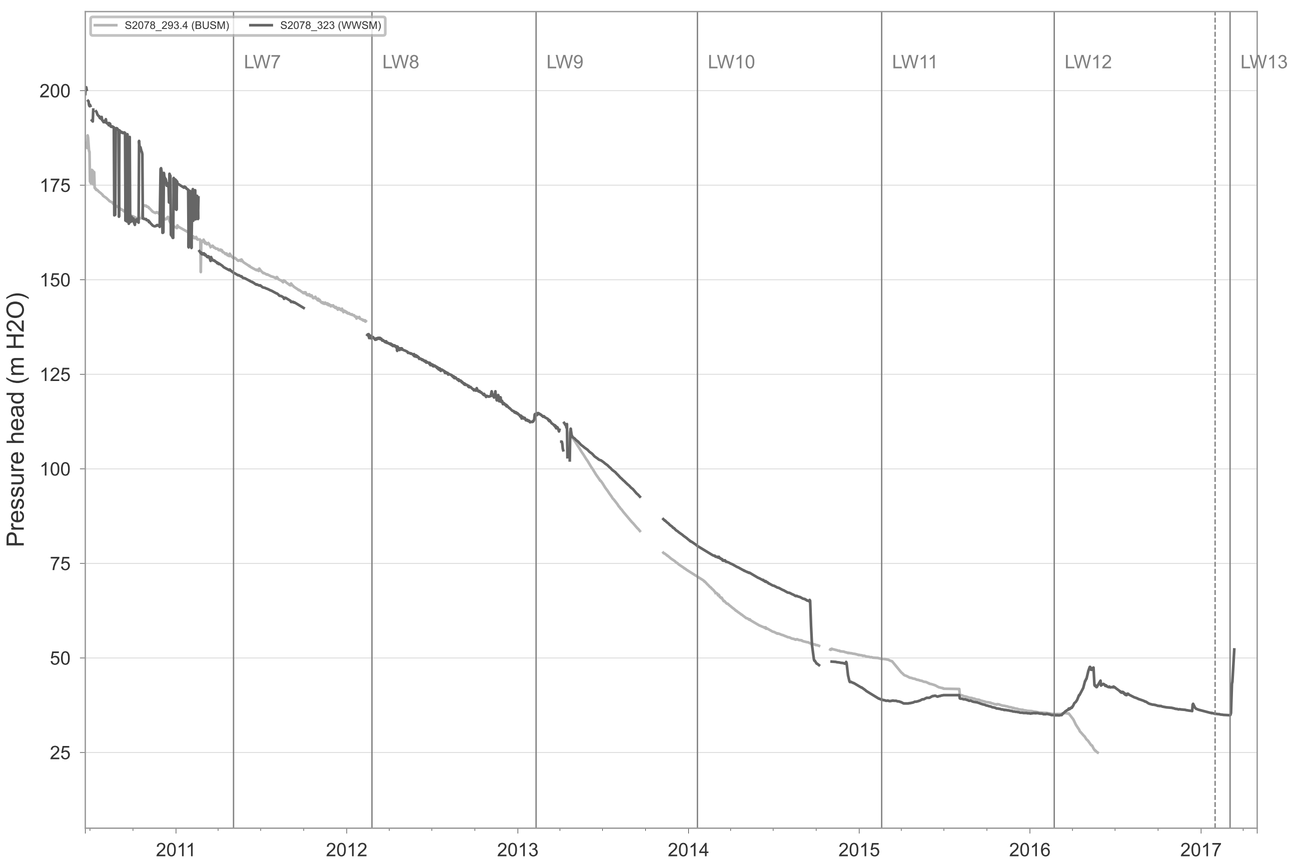

S2070
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Ground RL
Piezometric head (m RL)
400
350
300
250
200
150
100
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
S2070_361.5 (BUSM)
S2070_388 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM


S2070
S2070_361.5 (BUSM)
S2070_388 (WWSM)
LW10
LW11
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Pressure head (m H2O)
160
140
120
100
80
60
40
20
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

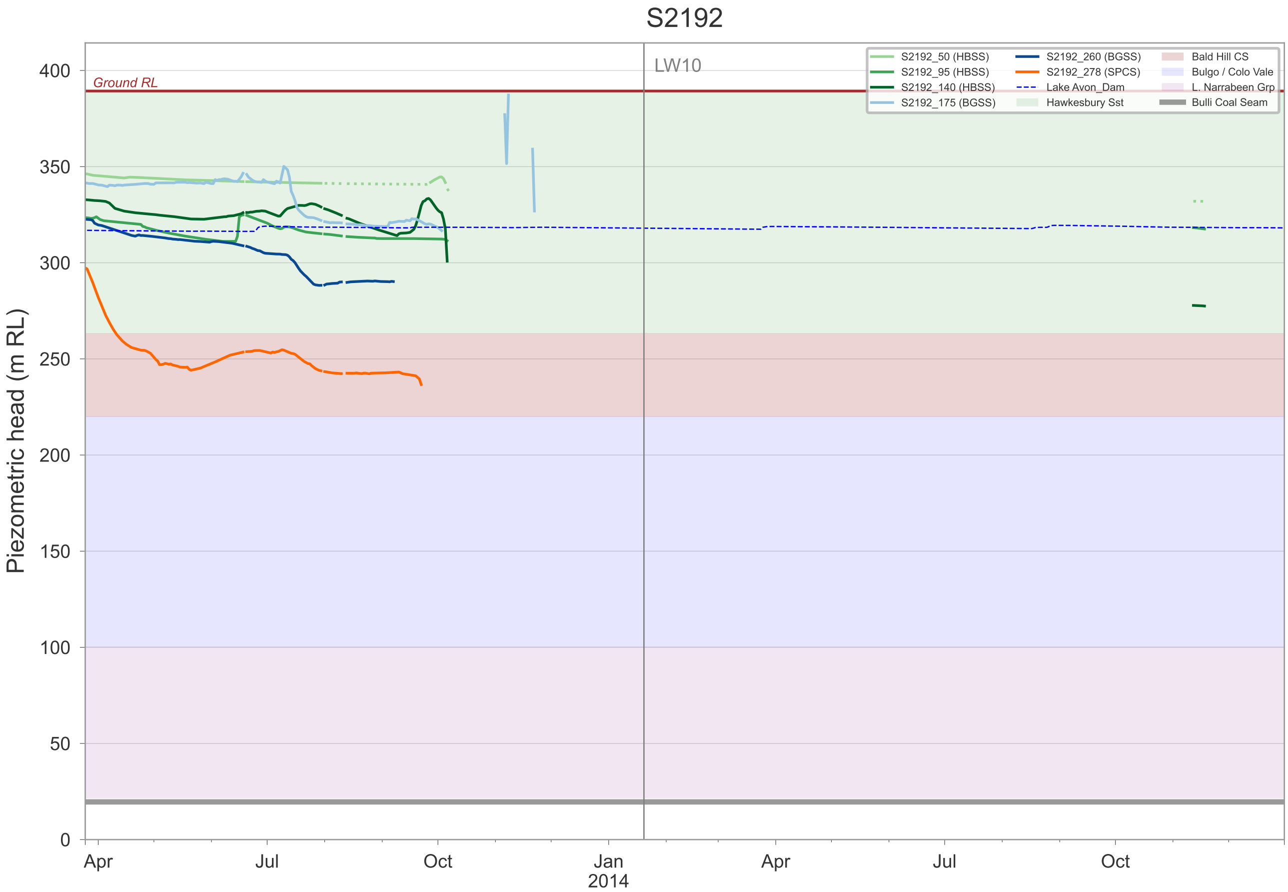
S2078

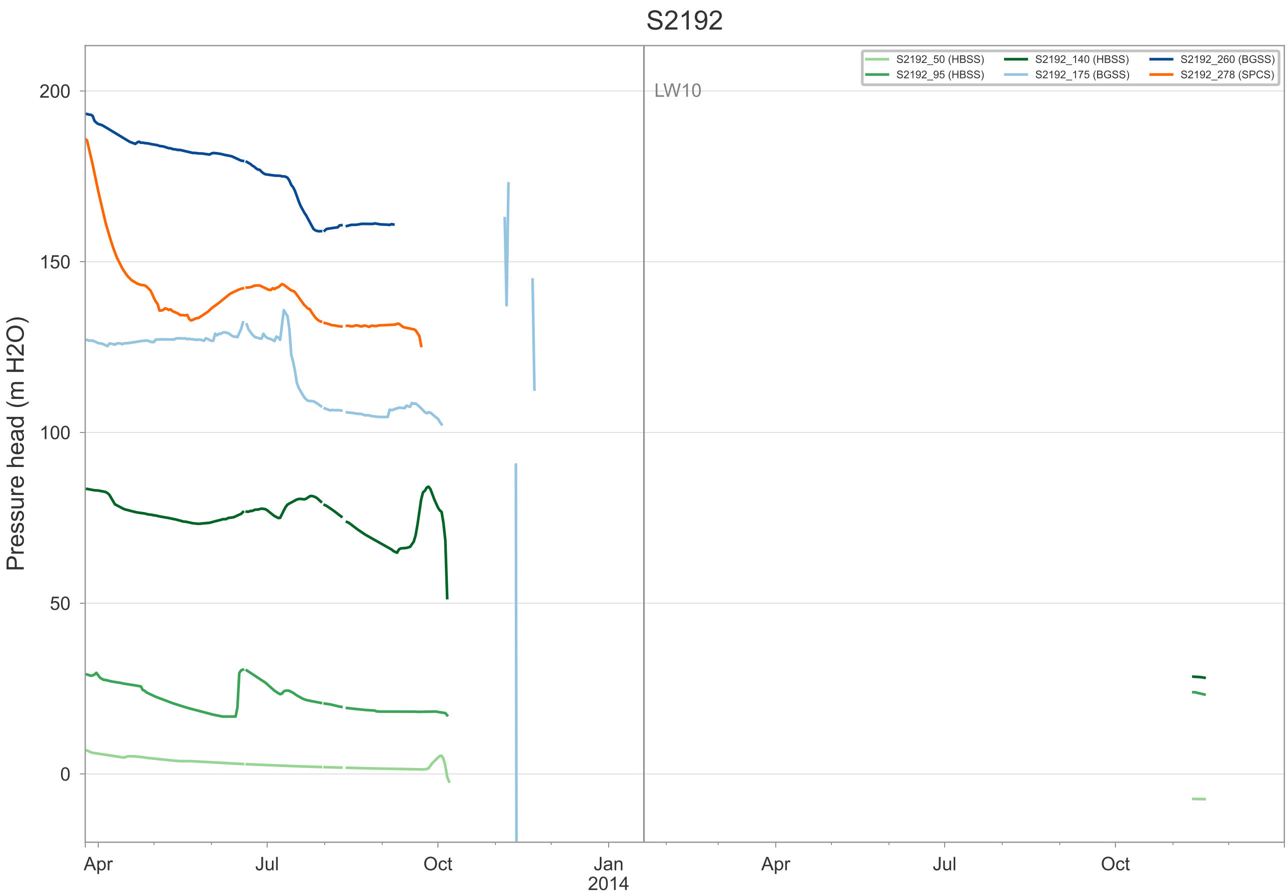

S2078_293.4 (BUSM)
S2078_323 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Ground RL
LW9
LW10
LW11
LW12
LW13
Piezometric head (m RL)
350
300
250
200
150
100
50
2011
2012
2013
2014
2015
2016
2017

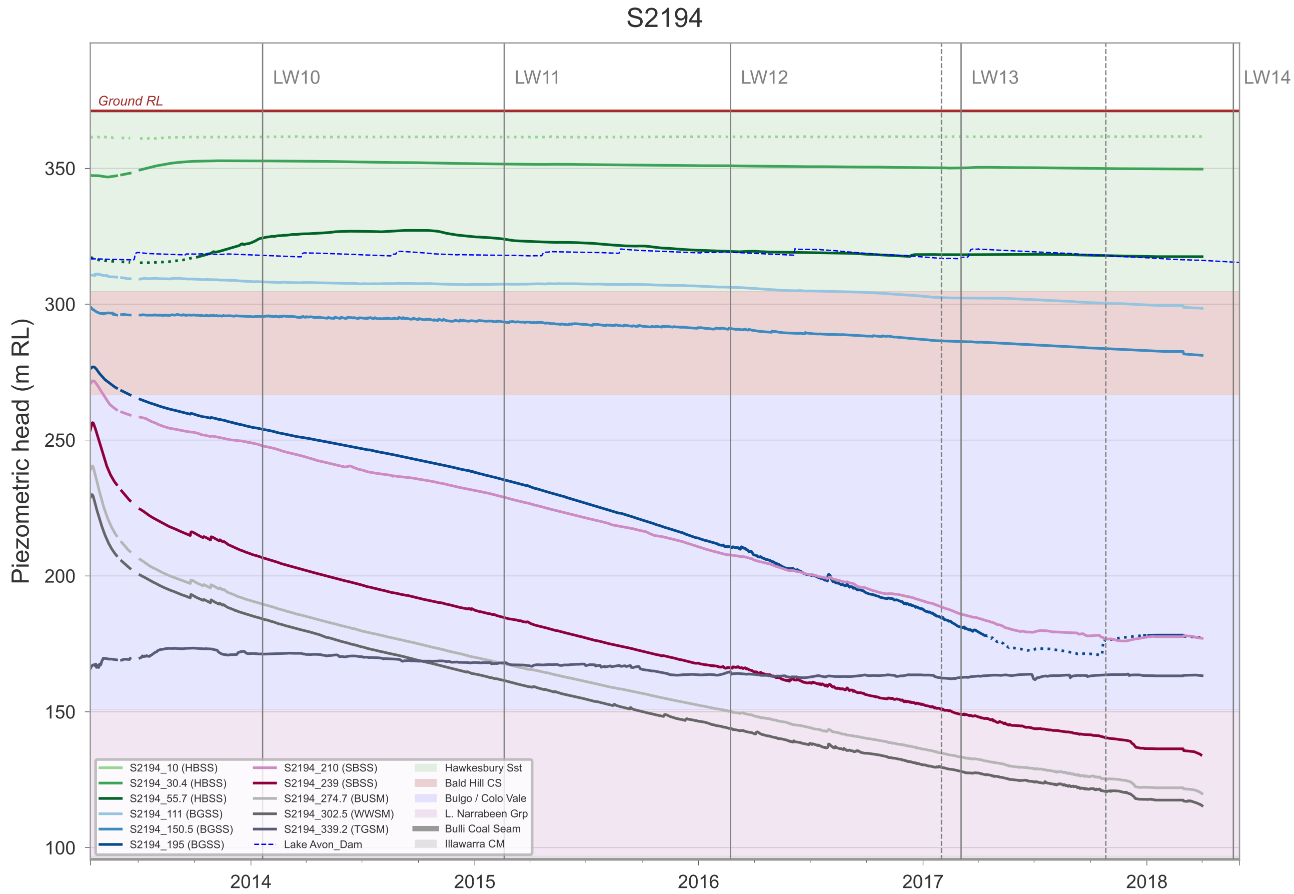
S2078

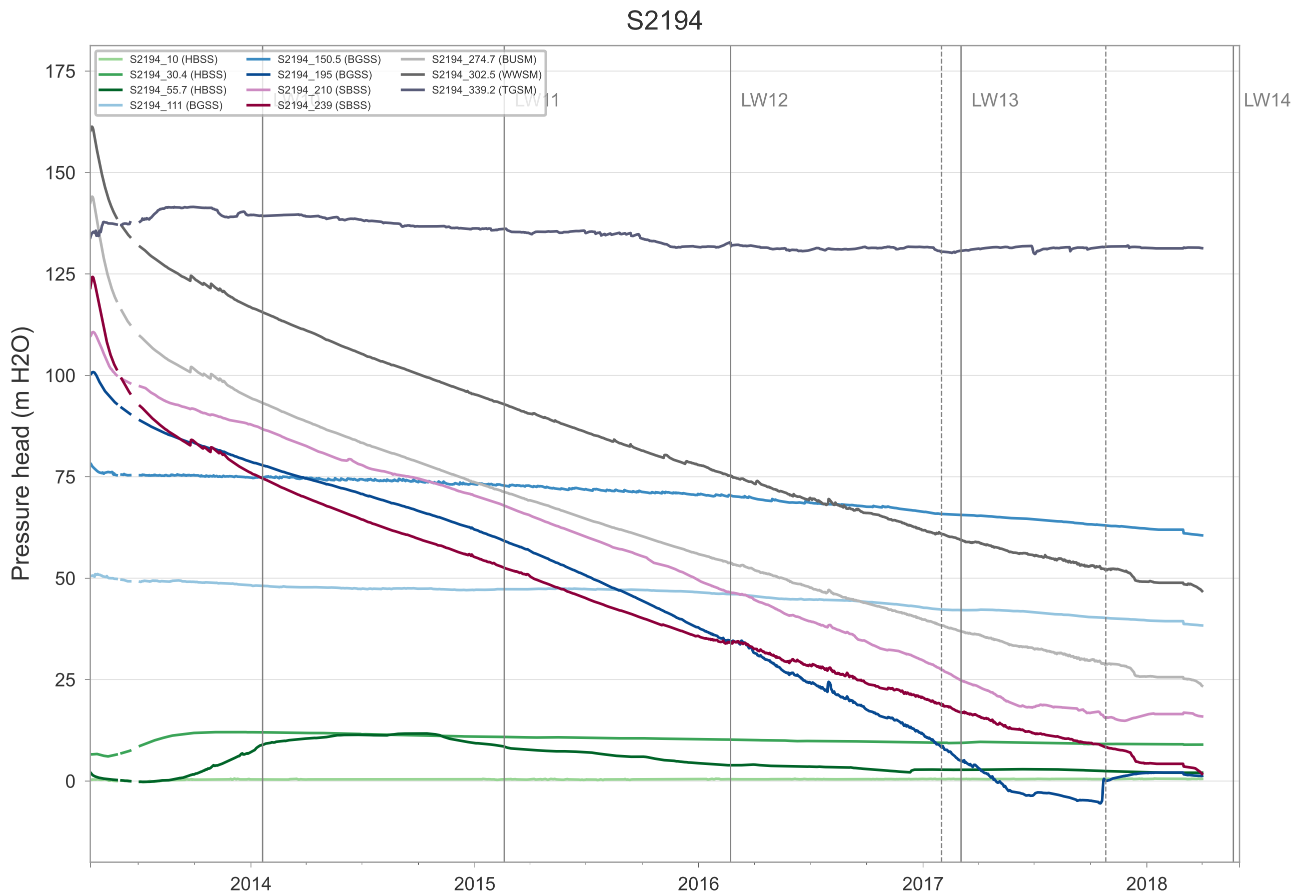

S2078_293.4 (BUSM)
S2078_323 (WWSM)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
Pressure head (m H2O)
200
175
150
125
100
75
50
25
2011
2012
2013
2014
2015
2016
2017

Groundwater hydrographs

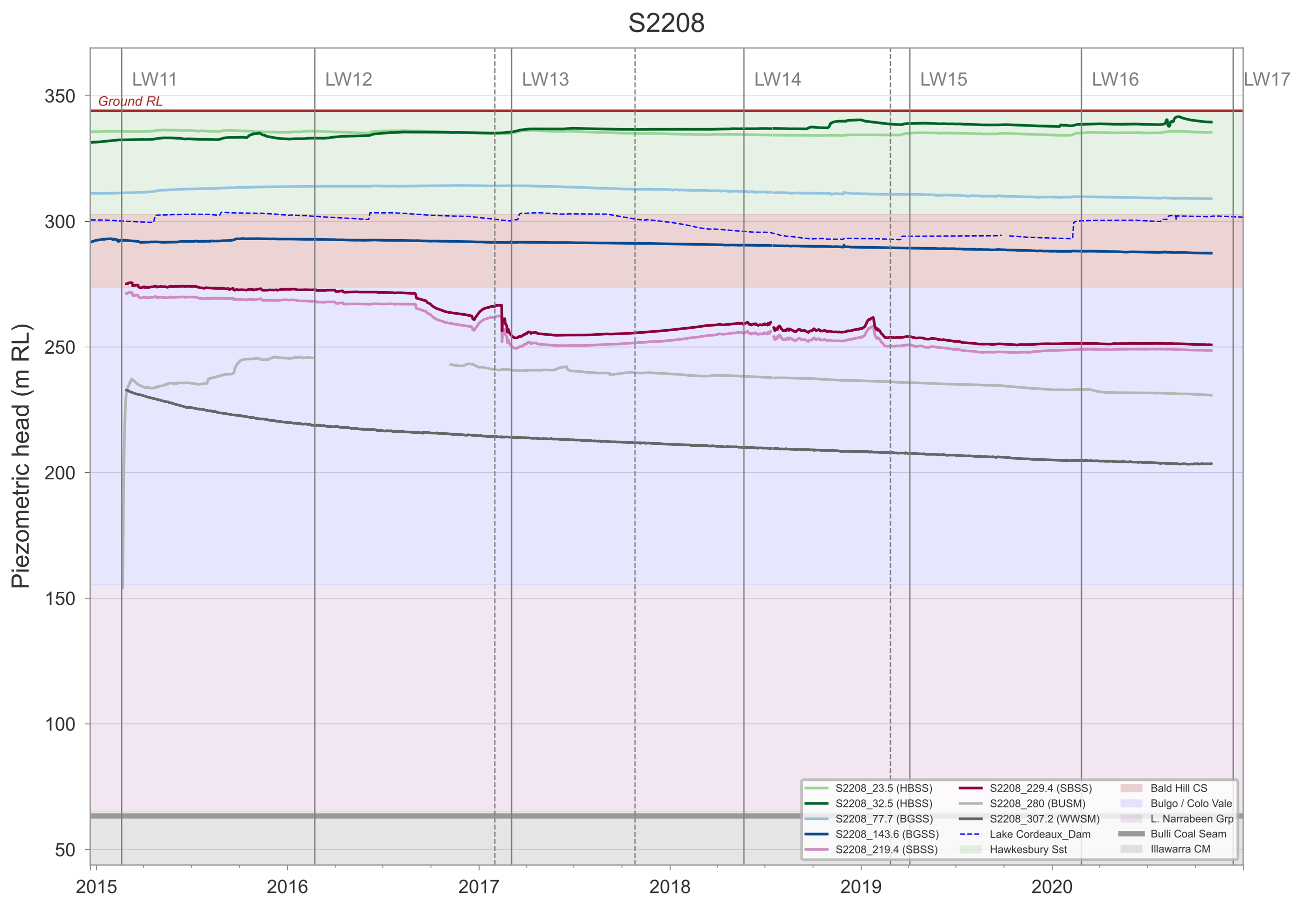


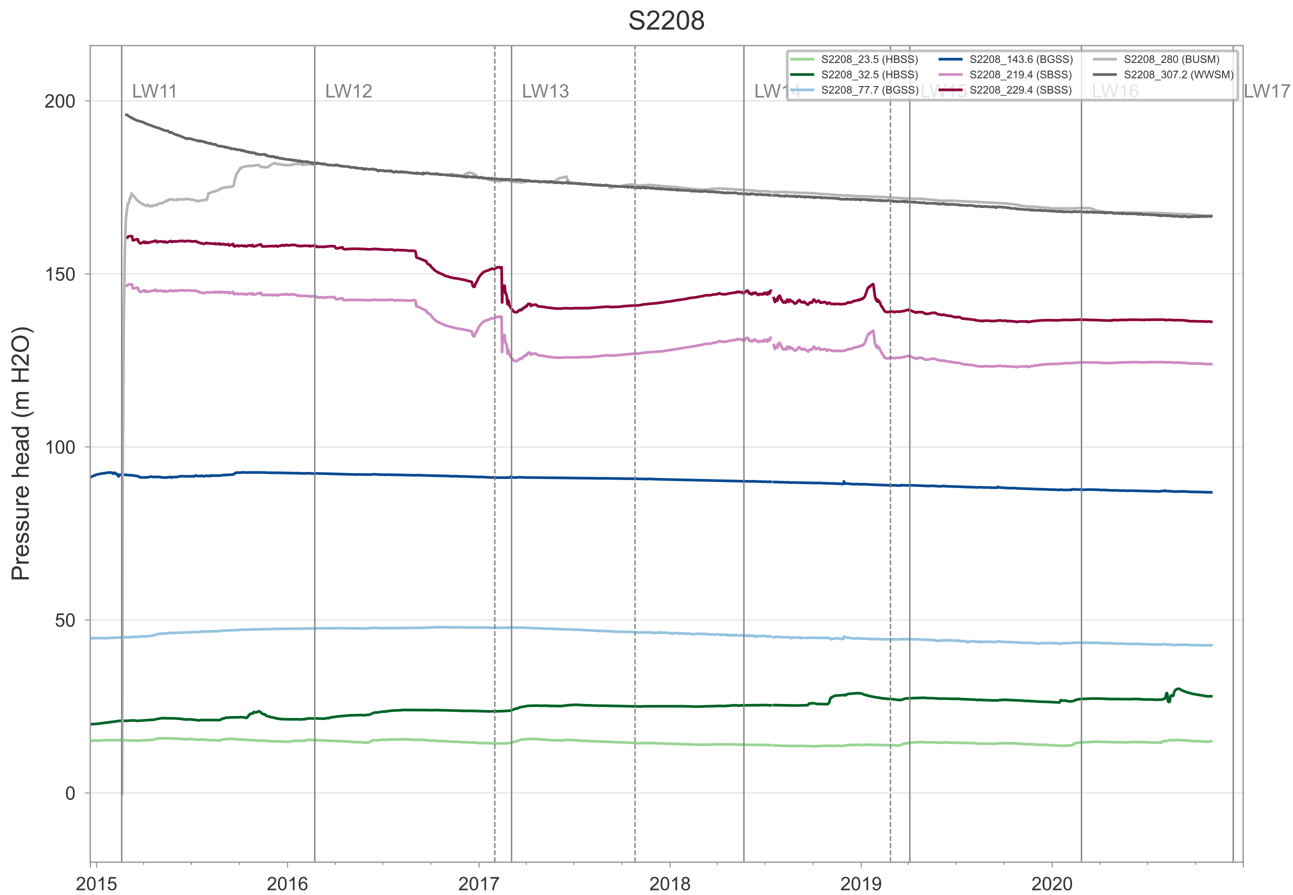



S2194
LW10
LW11
LW12
LW13
LW14
Ground RL
Piezometric head (m RL)
350
300
250
200
150
100
2014
2015
2016
2017
2018
S2194_10 (HBSS)
S2194_30.4 (HBSS)
S2194_55.7 (HBSS)
S2194_111 (BGSS)
S2194_150.5 (BGSS)
S2194_195 (BGSS)
S2194_210 (SBSS)
S2194_239 (SBSS)
S2194_274.7 (BUSM)
S2194_302.5 (WWSM)
S2194_339.2 (TGSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM

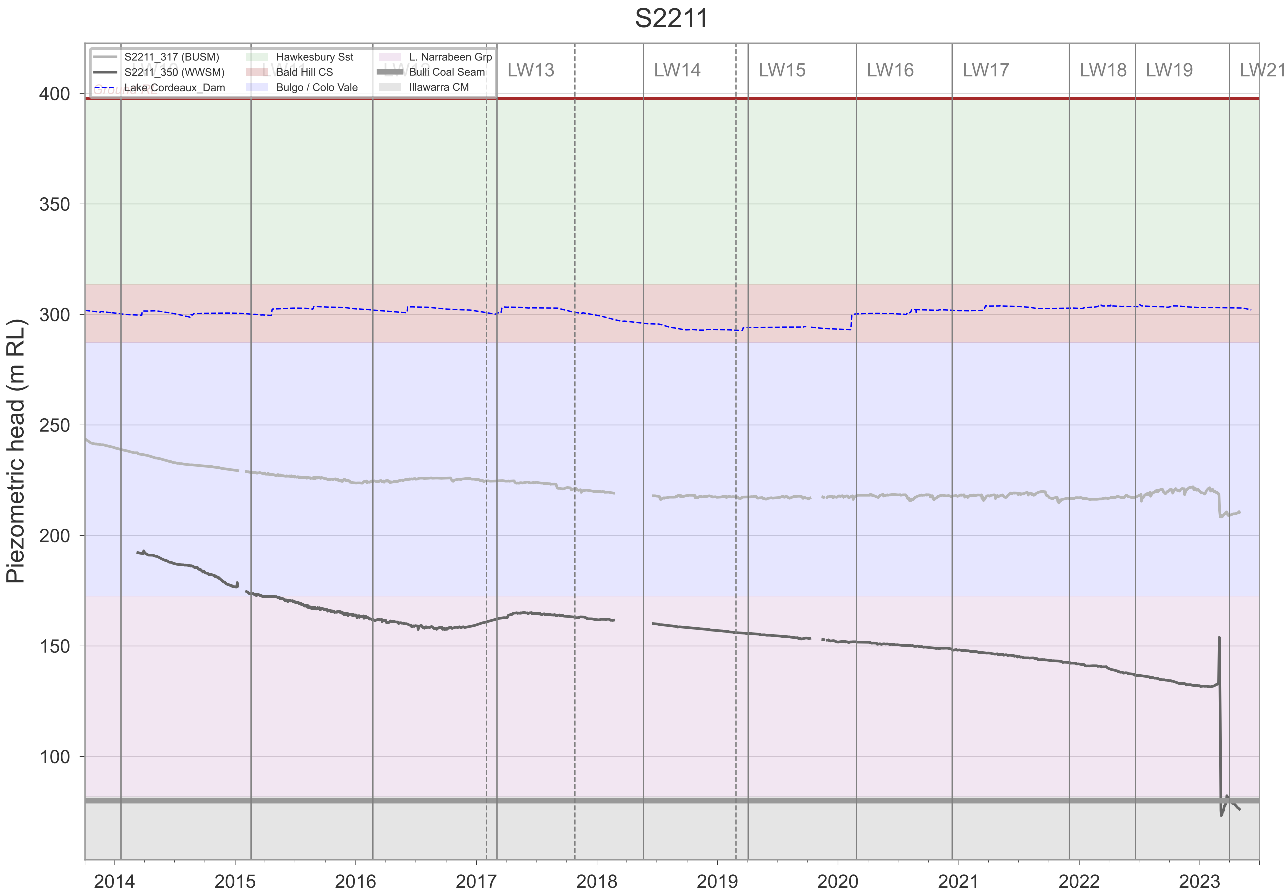

S2194
LW11
LW12
LW13
LW14
Pressure head (m H2O)
175
150
125
100
75
50
25
0
2014
2015
2016
2017
2018
S2194_10 (HBSS)
S2194_30.4 (HBSS)
S2194_55.7 (HBSS)
S2194_111 (BGSS)
S2194_150.5 (BGSS)
S2194_195 (BGSS)
S2194_210 (SBSS)
S2194_239 (SBSS)
S2194_274.7 (BUSM)
S2194_302.5 (WWSM)
S2194_339.2 (TGSM)

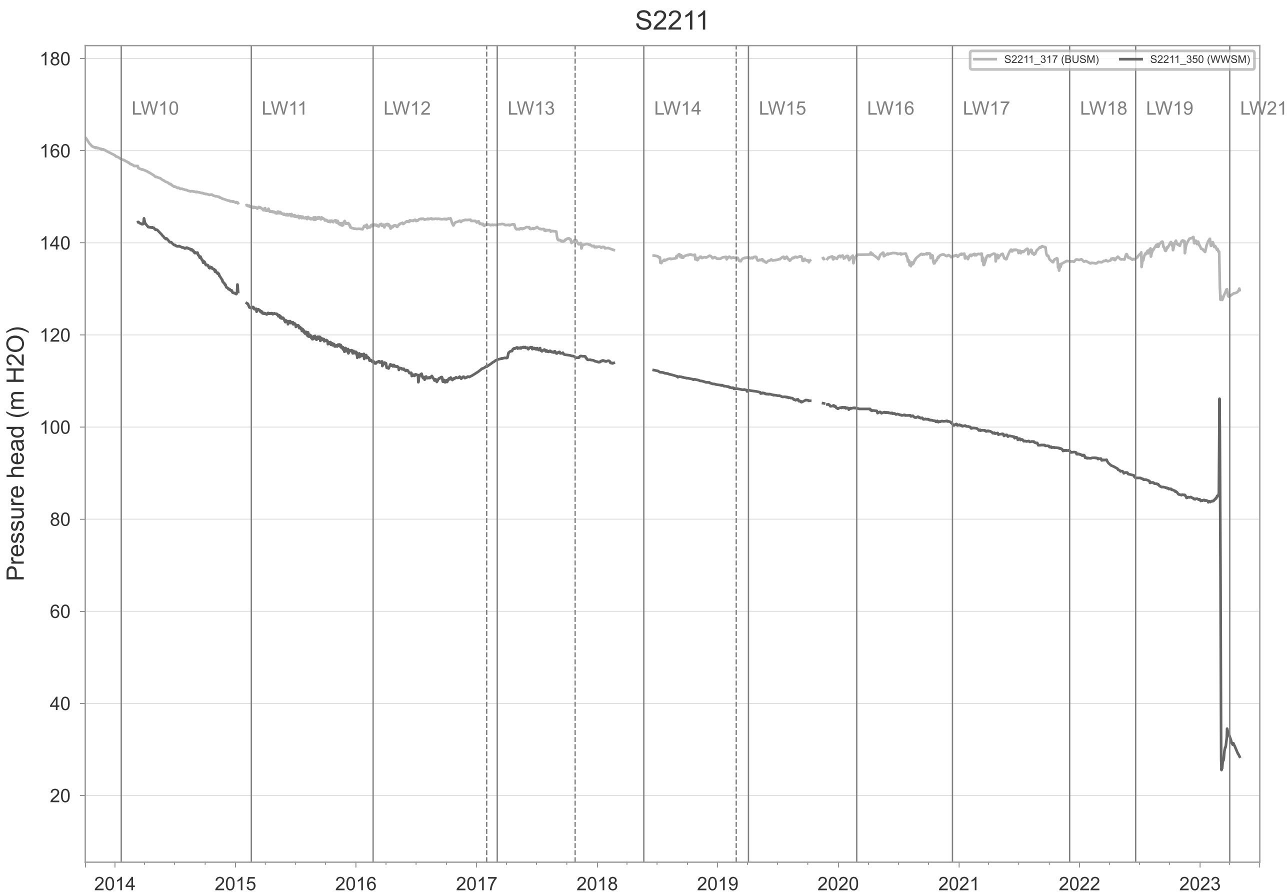
Groundwater hydrographs



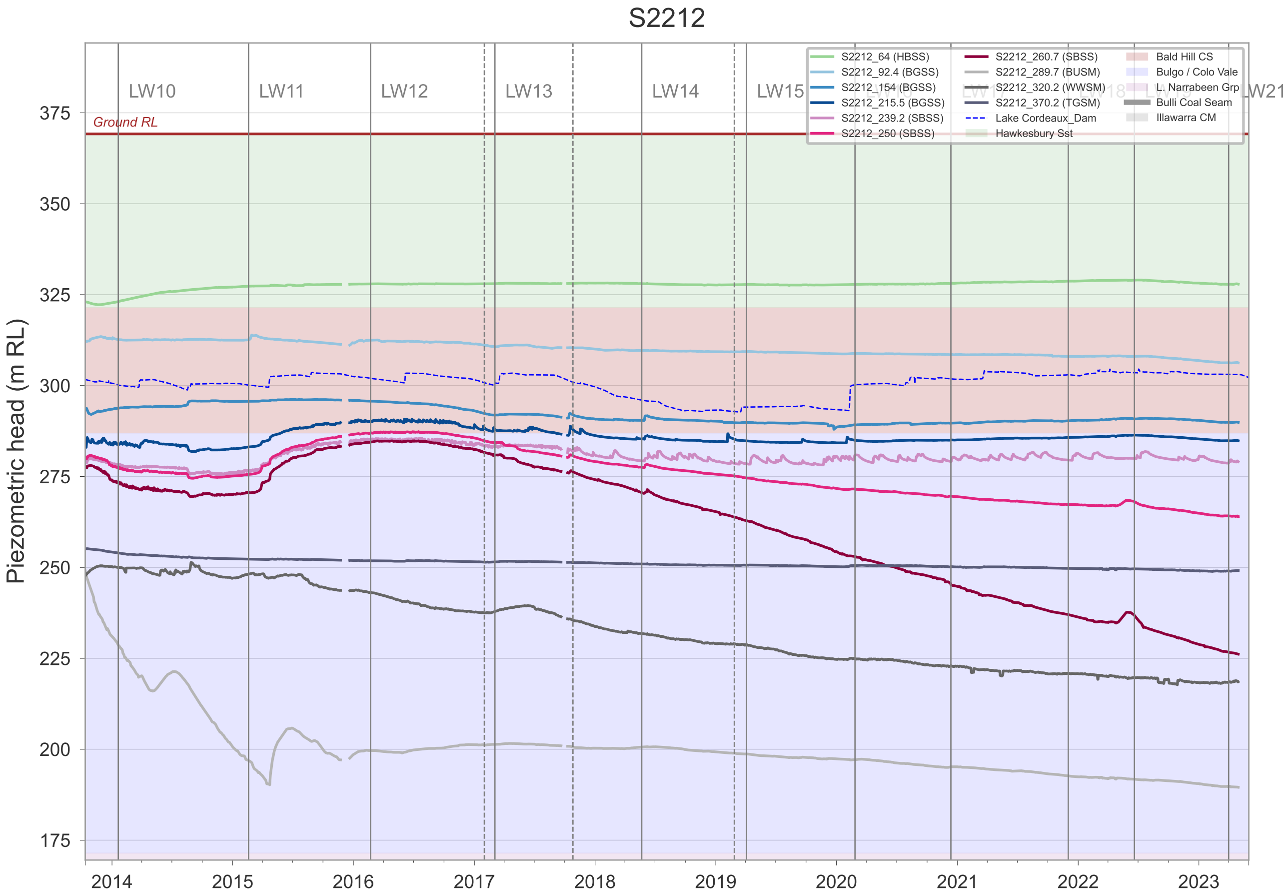


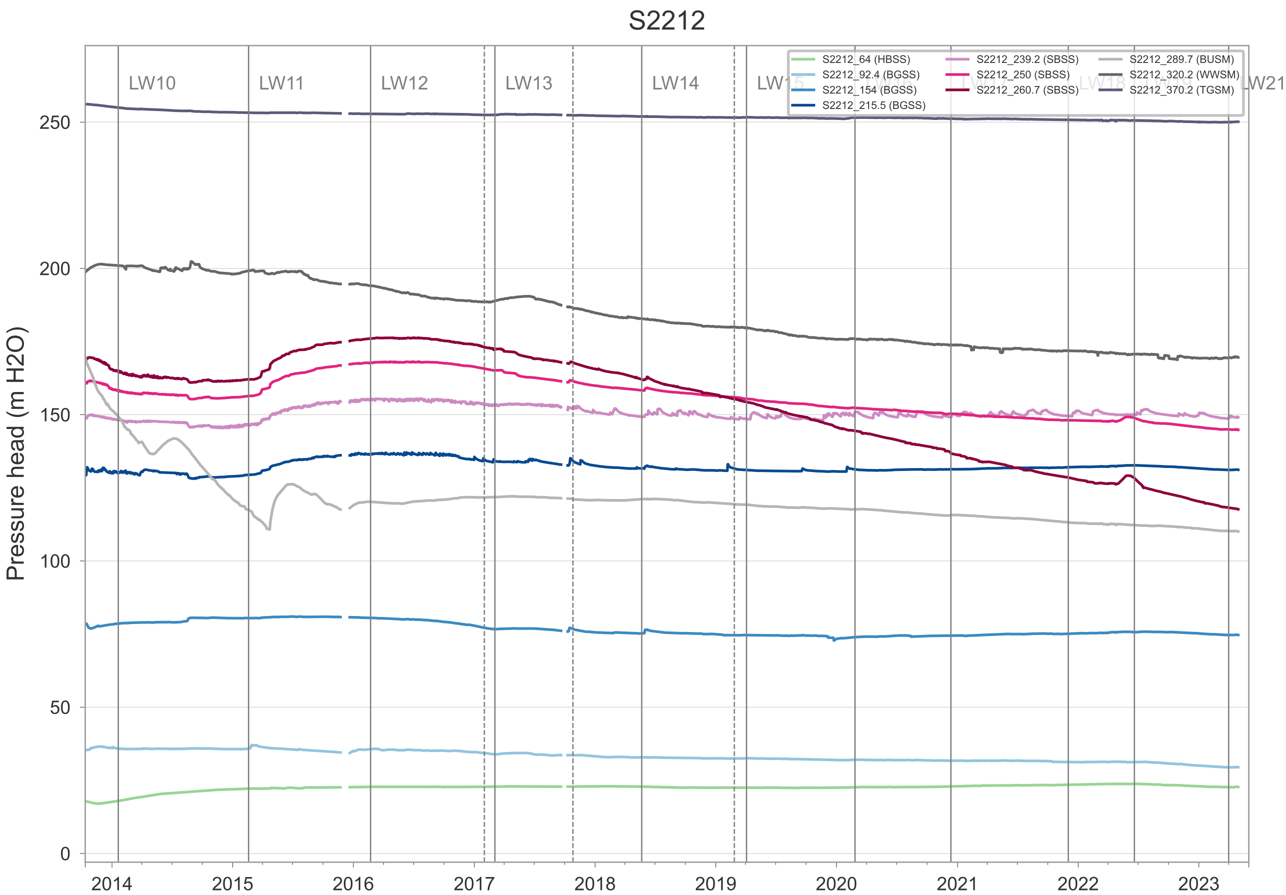
Groundwater hydrographs



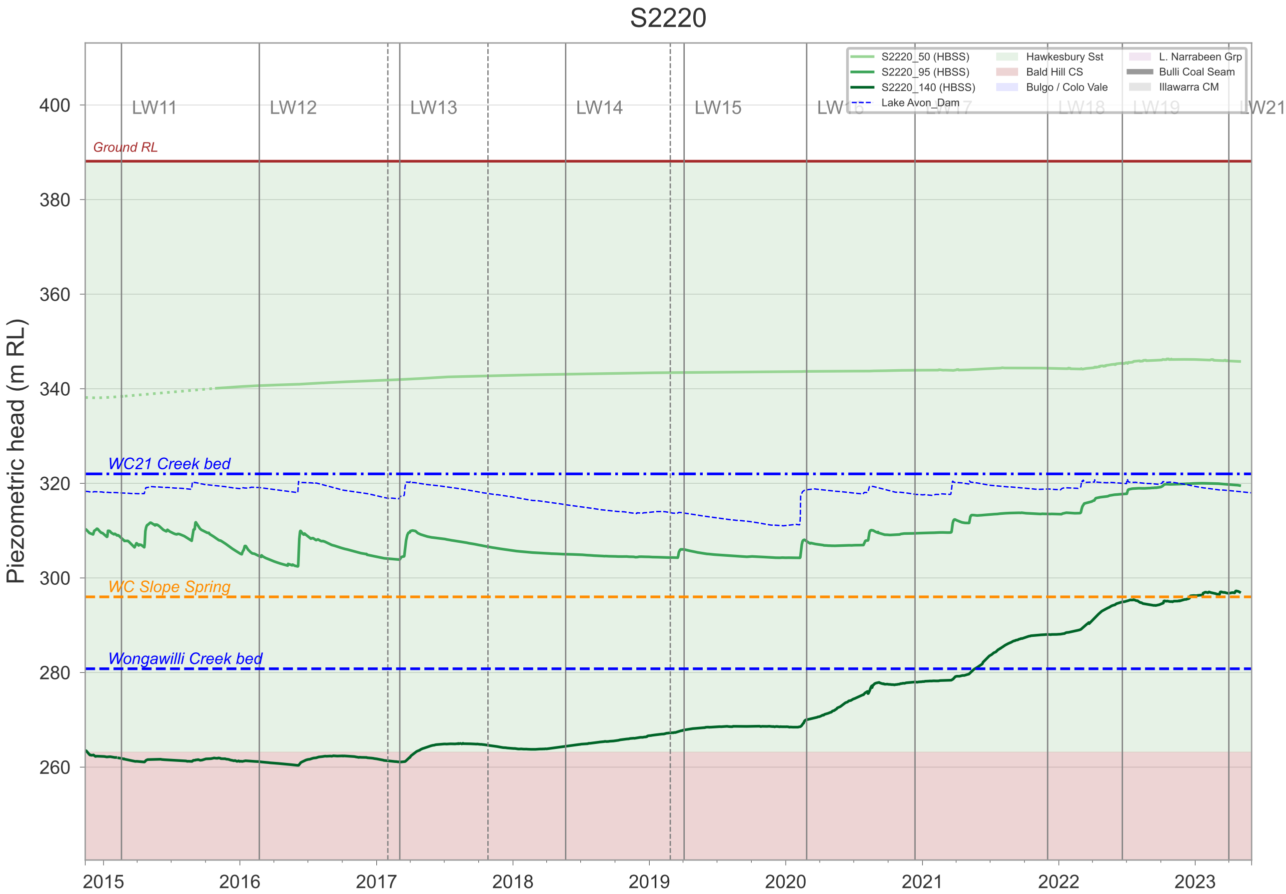


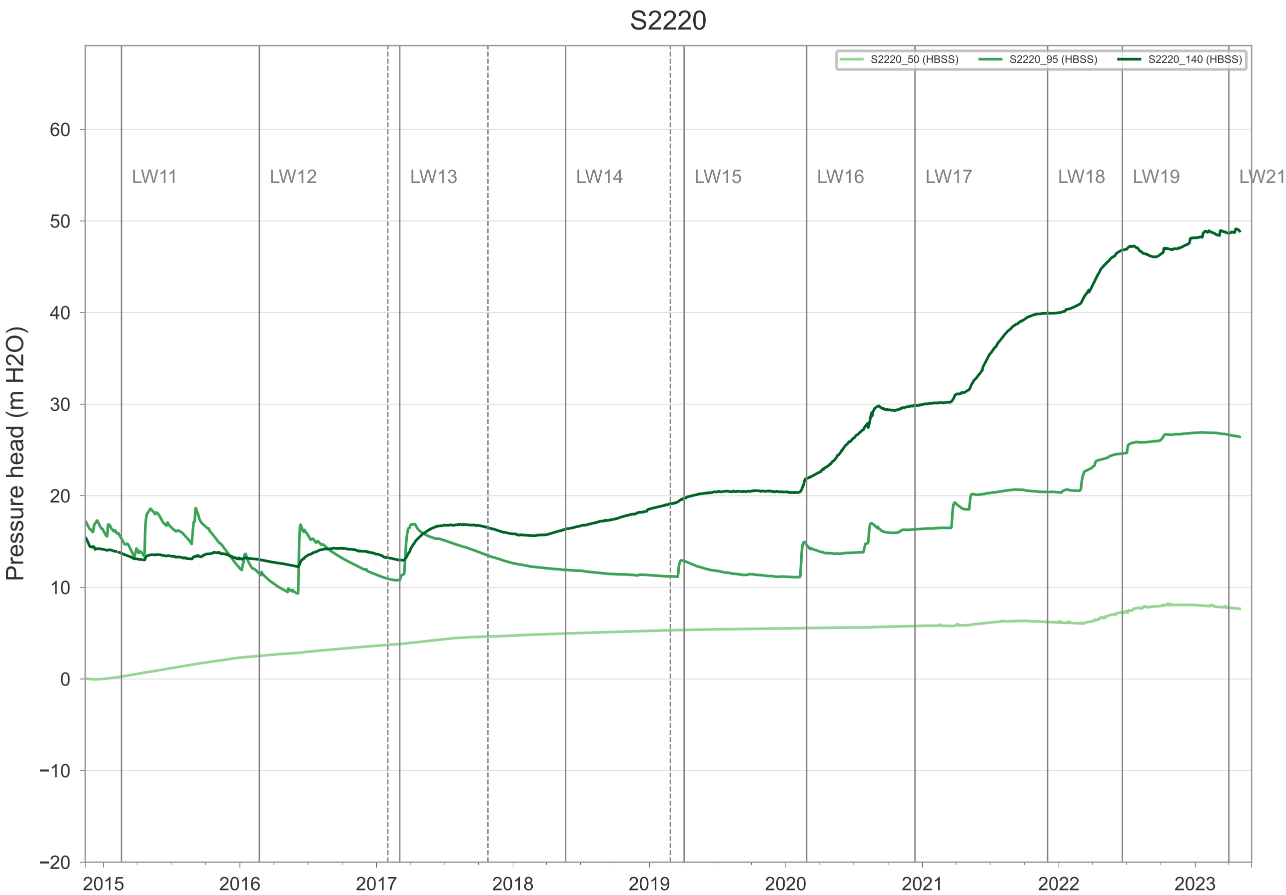
Groundwater hydrographs



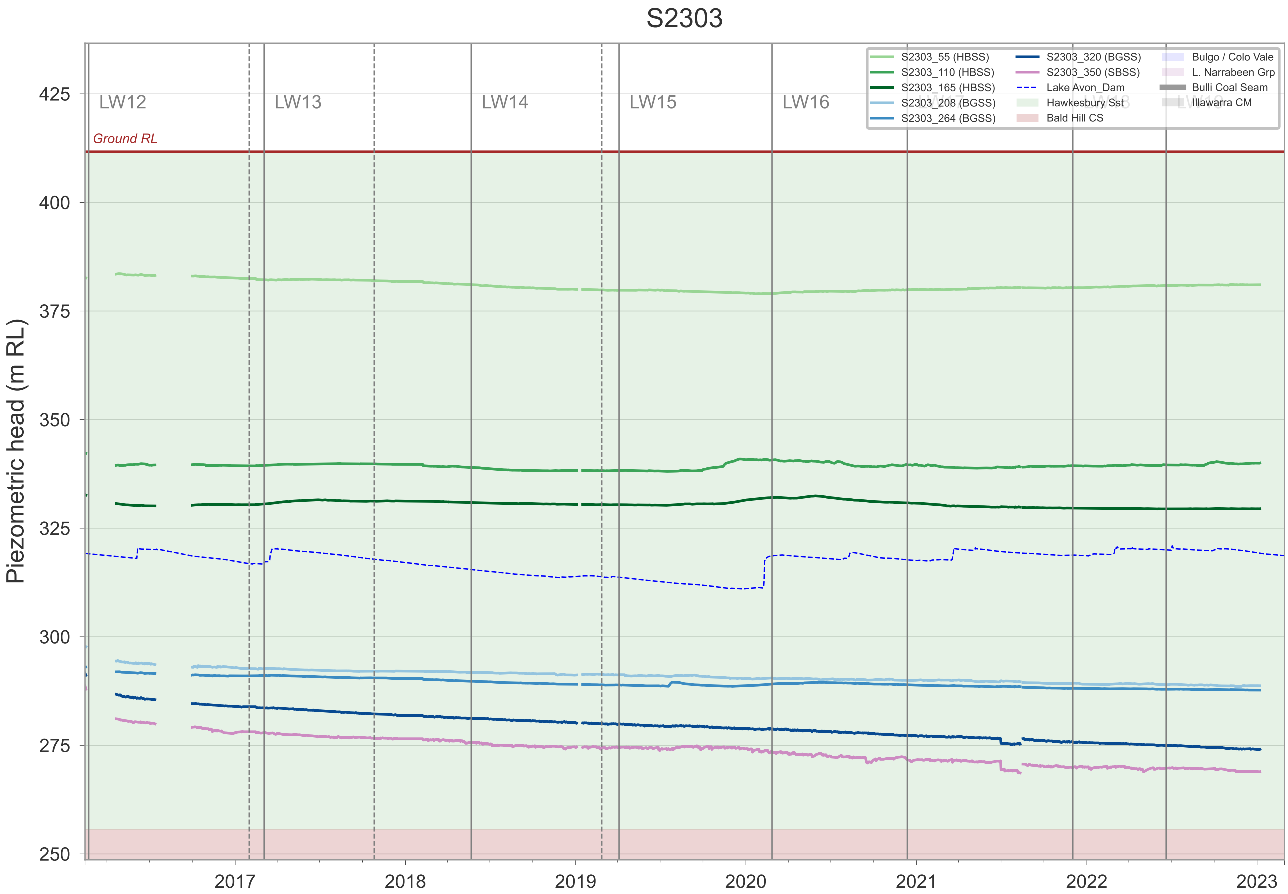


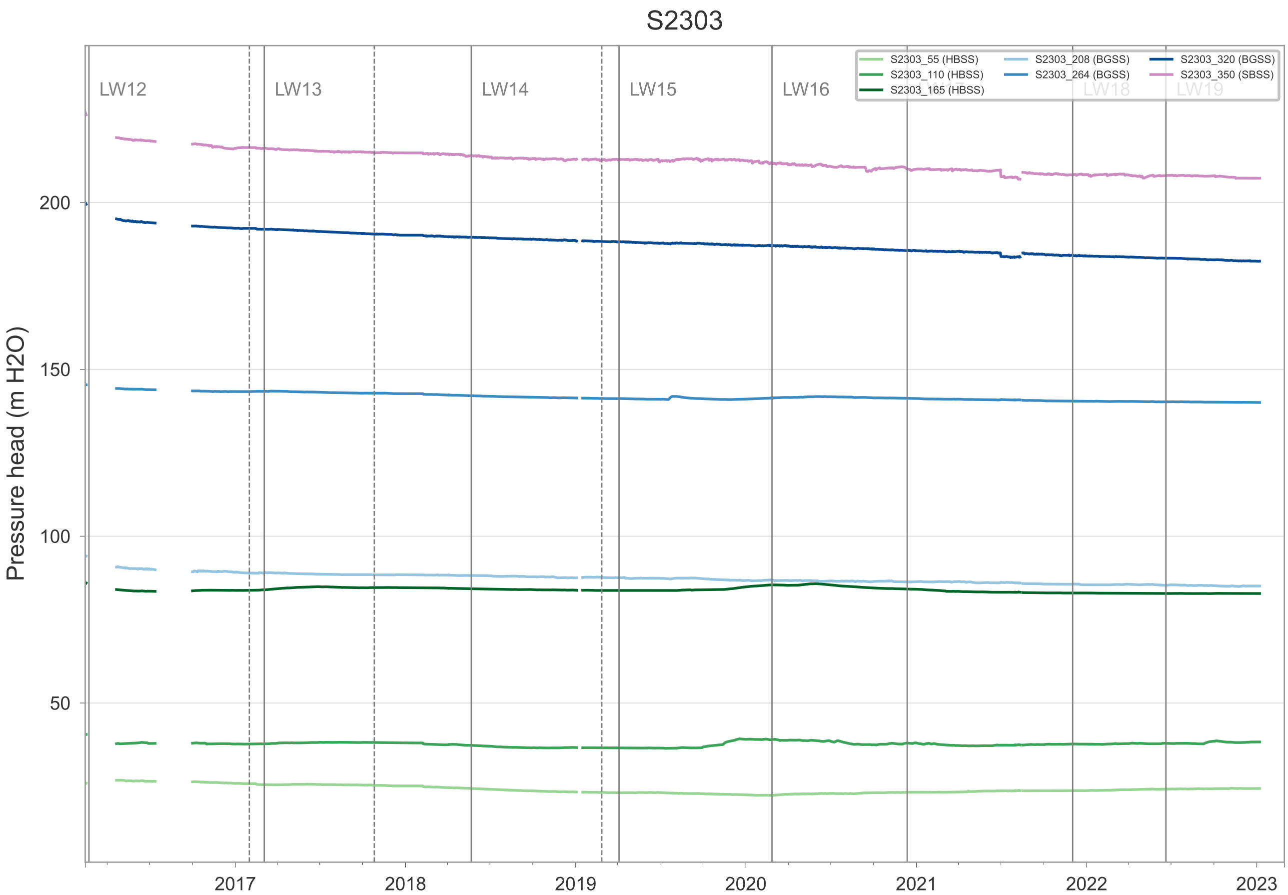
Groundwater hydrographs



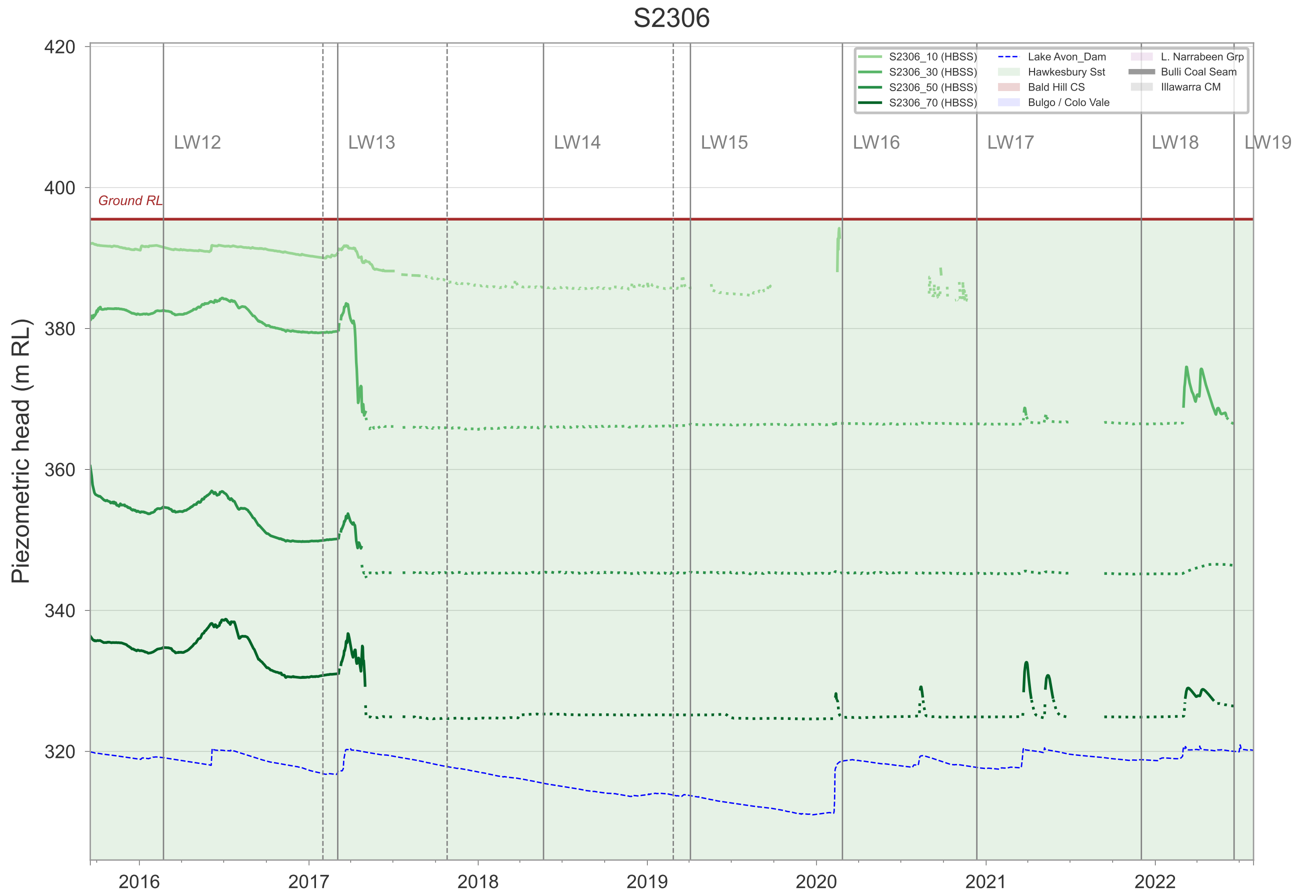


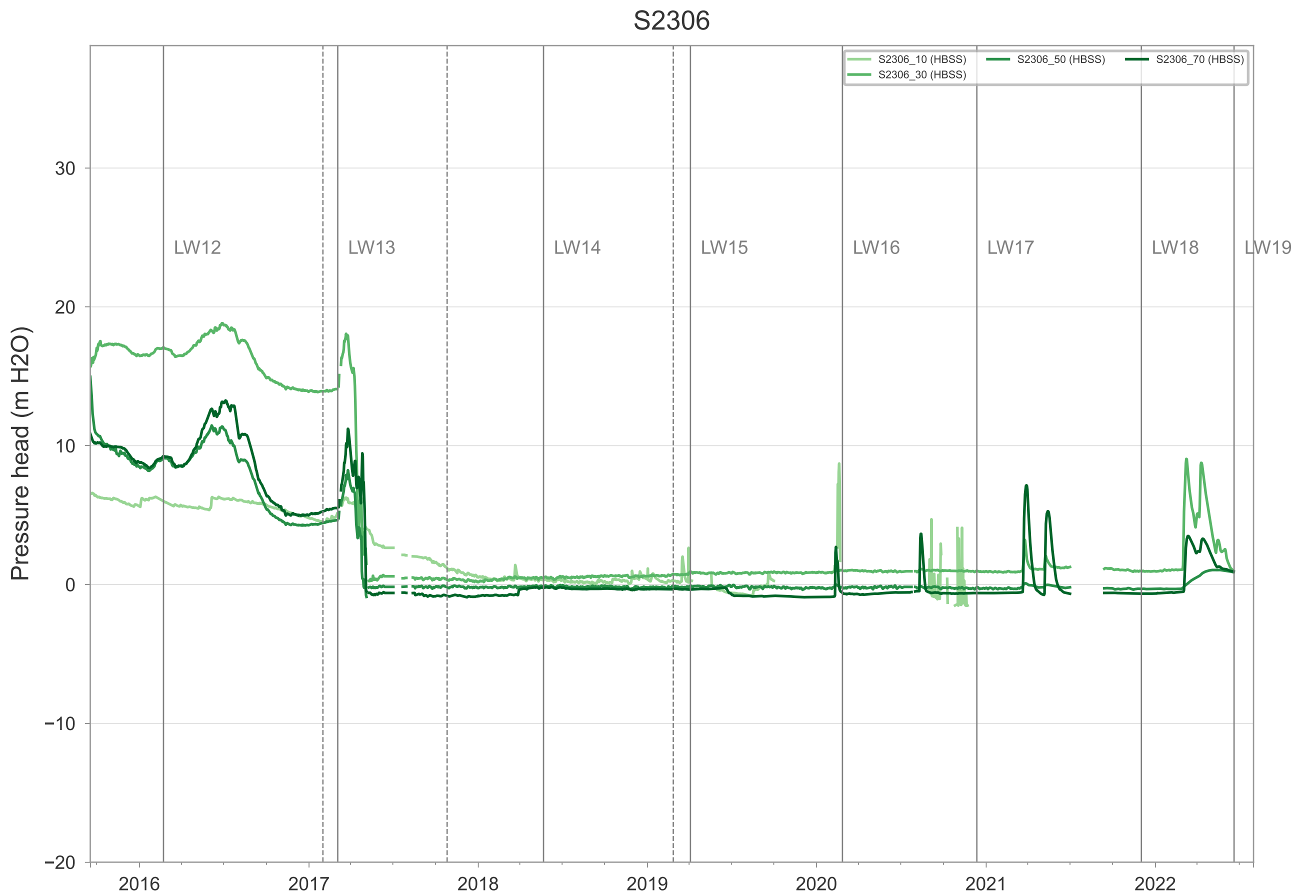
Groundwater hydrographs



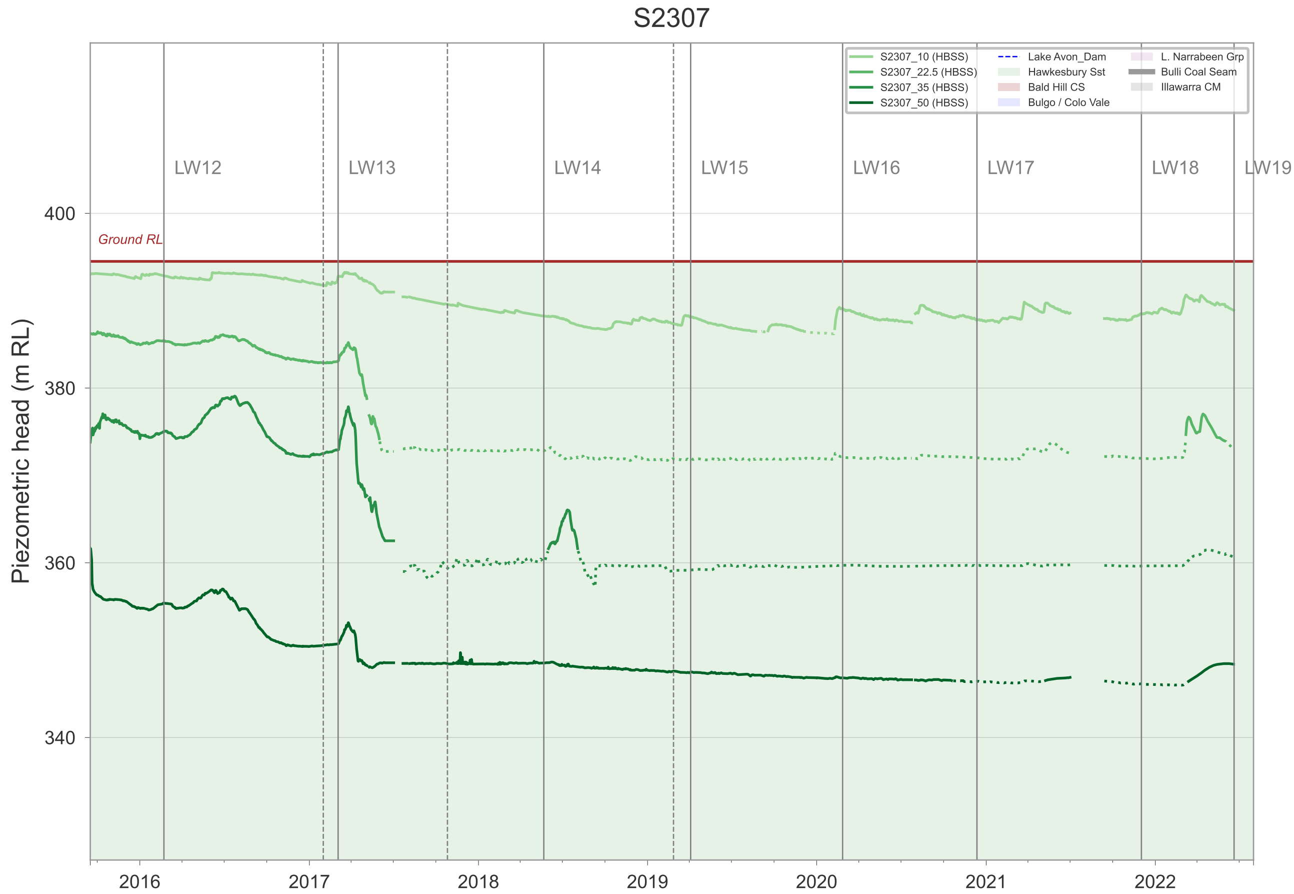


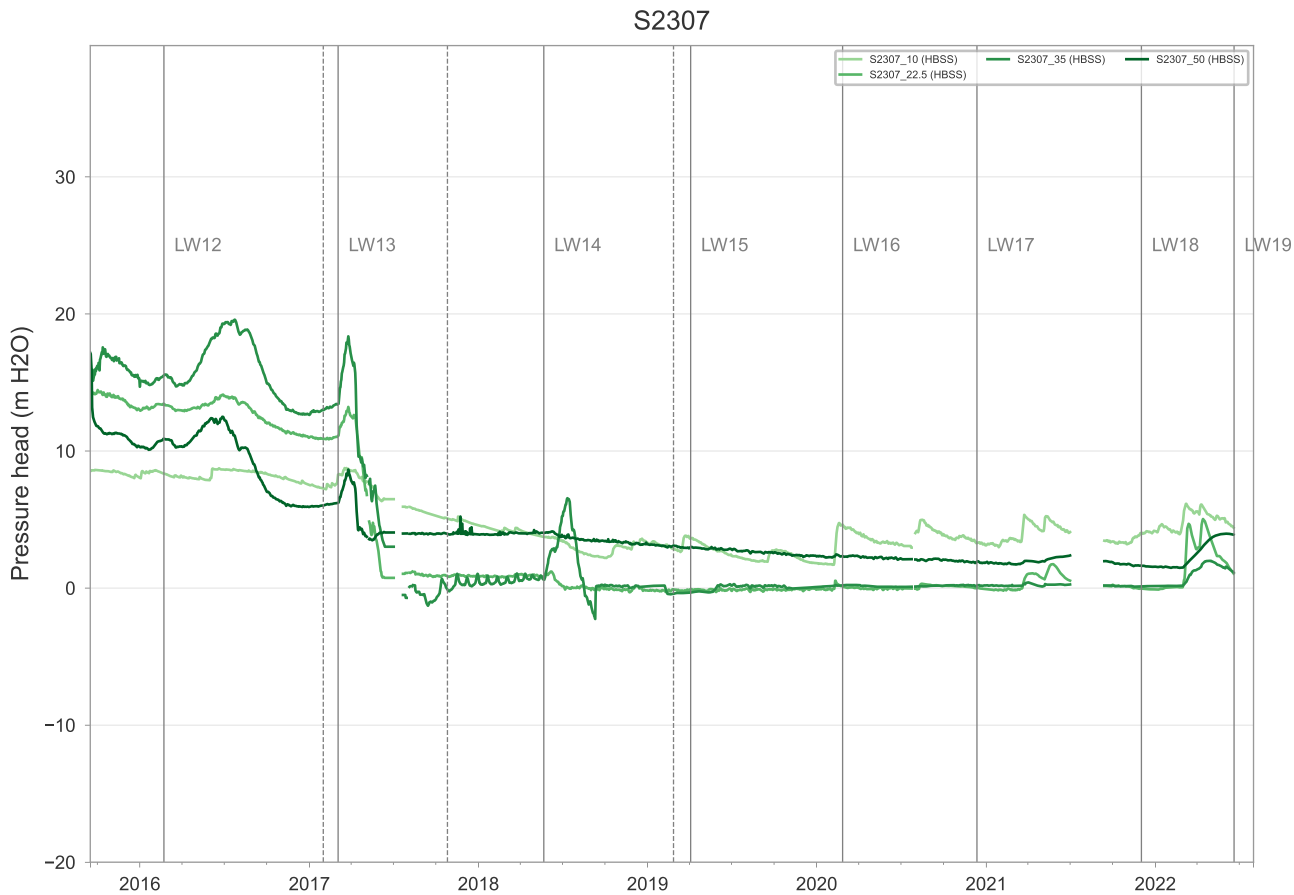
Groundwater hydrographs



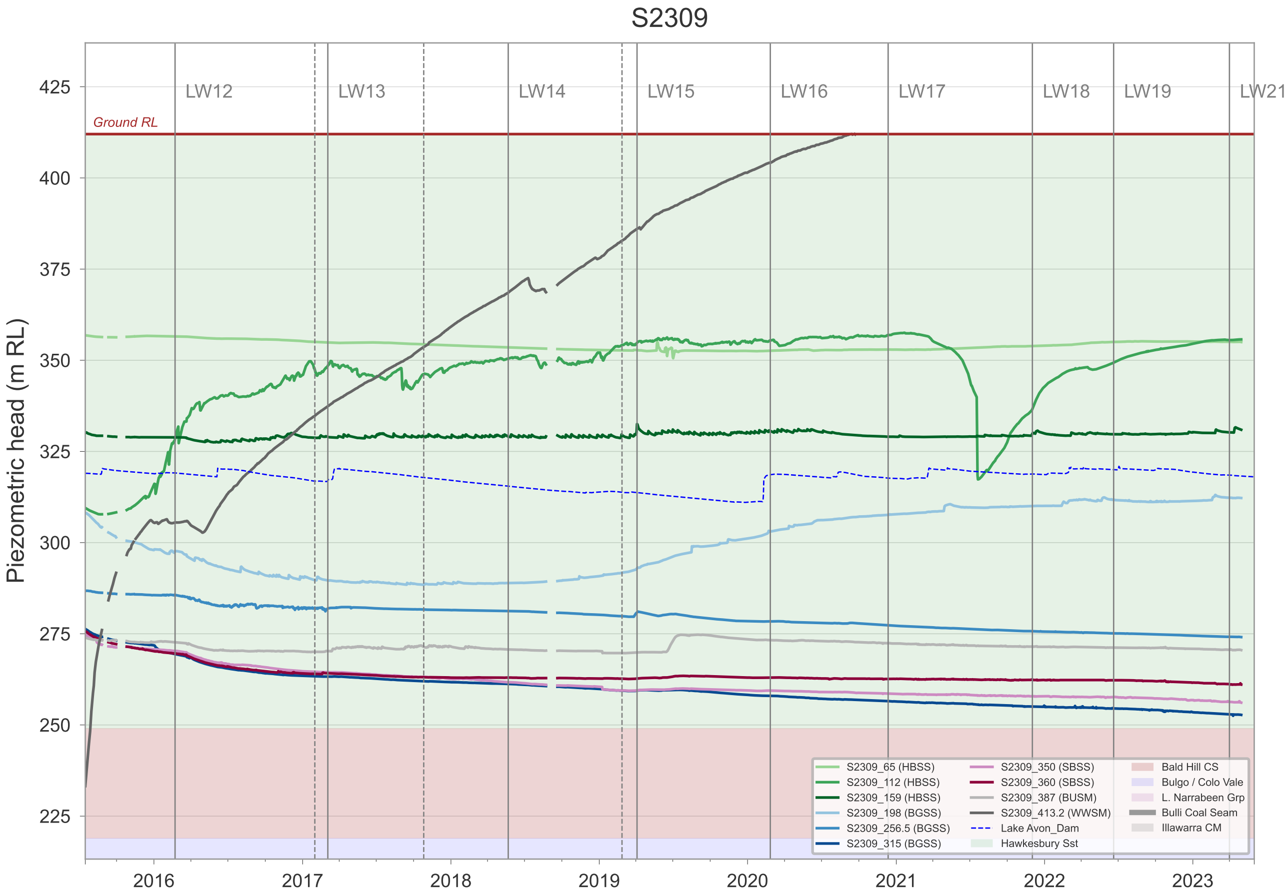


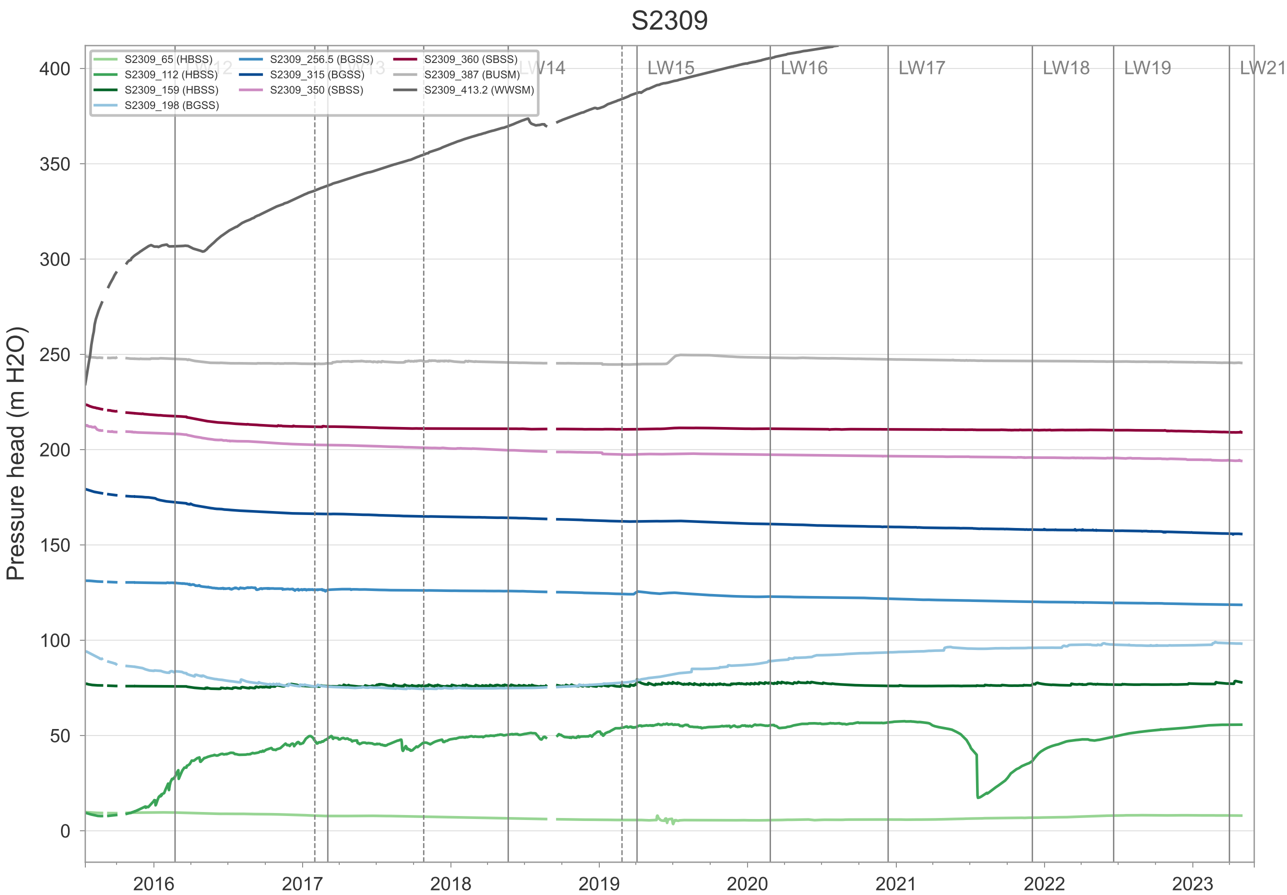
Groundwater hydrographs



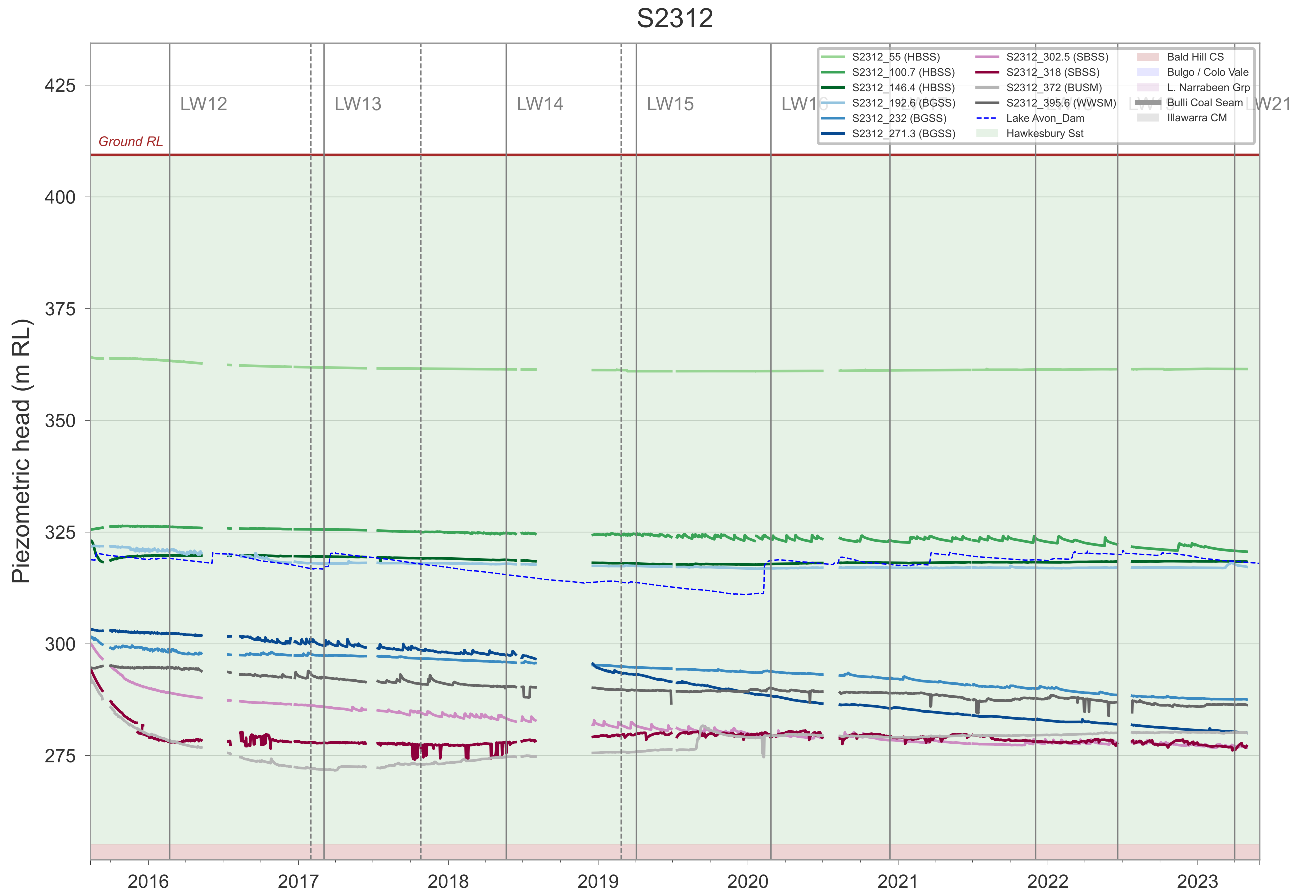


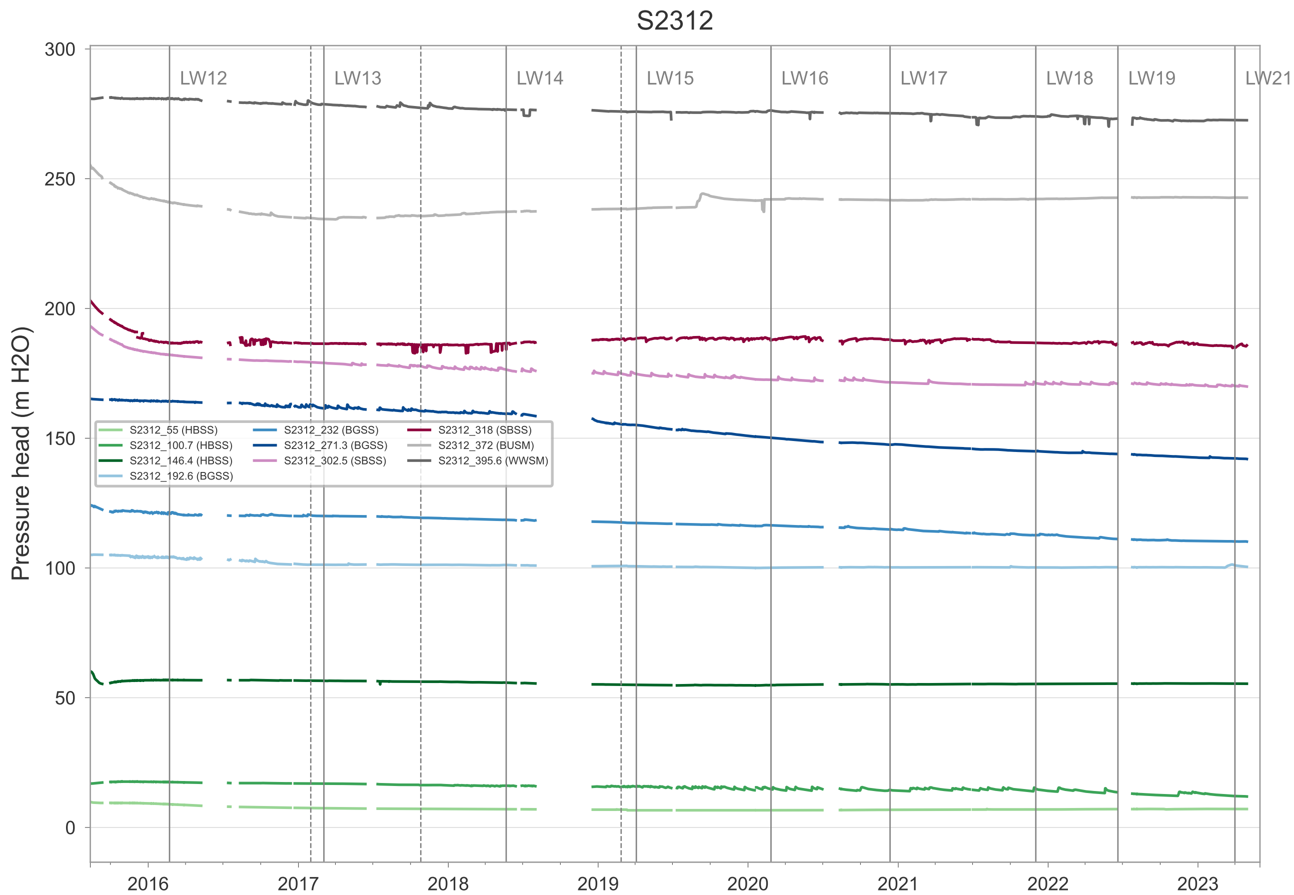
Groundwater hydrographs

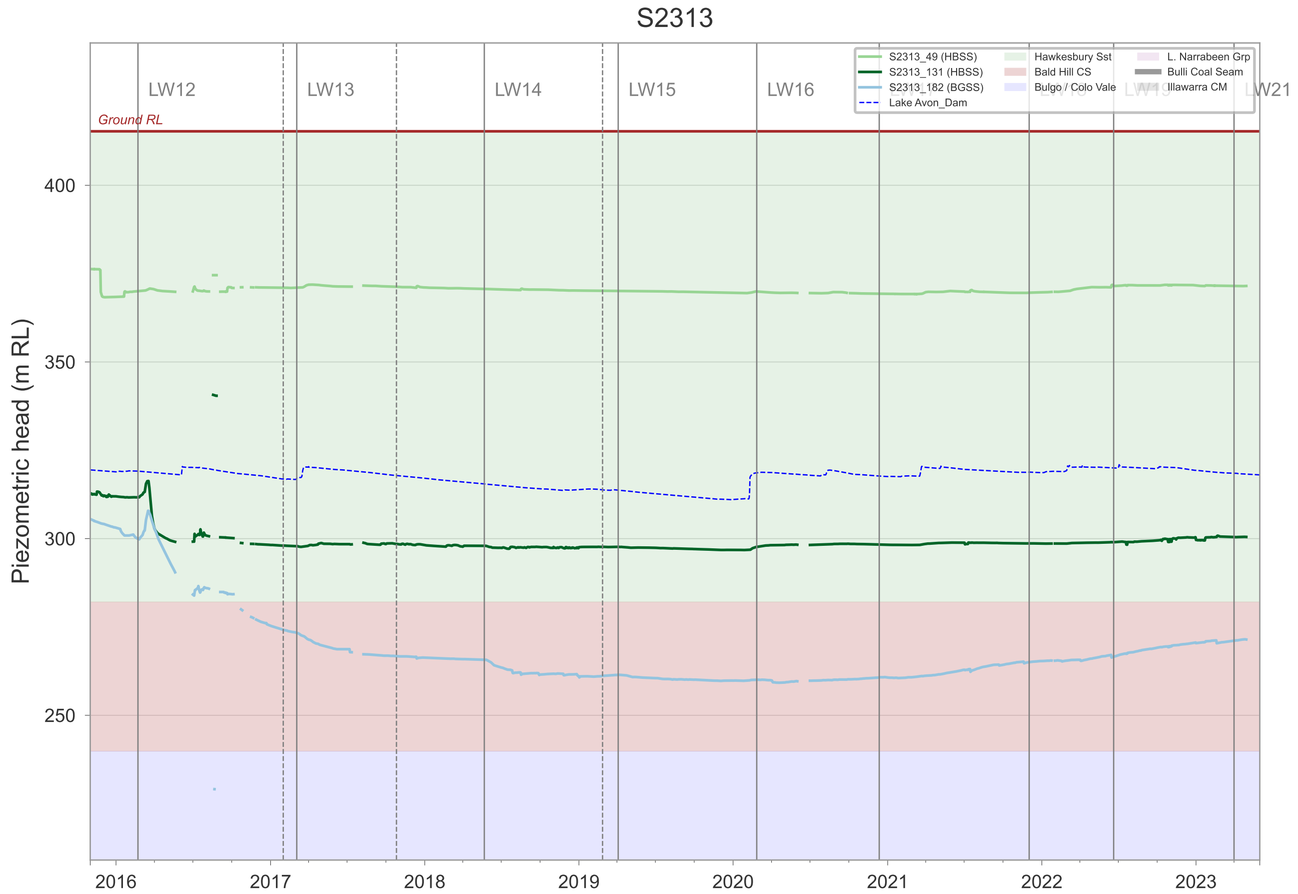


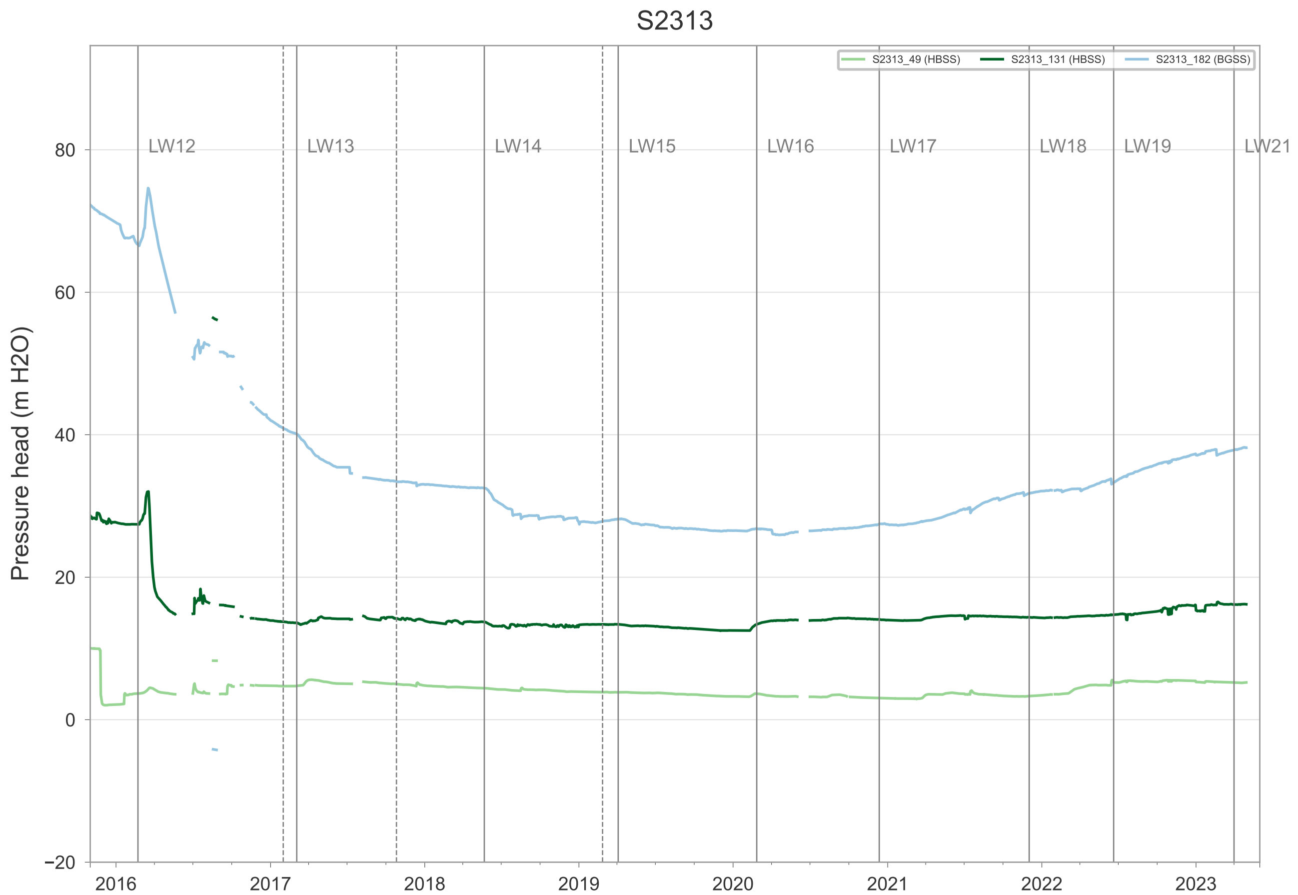


Groundwater hydrographs

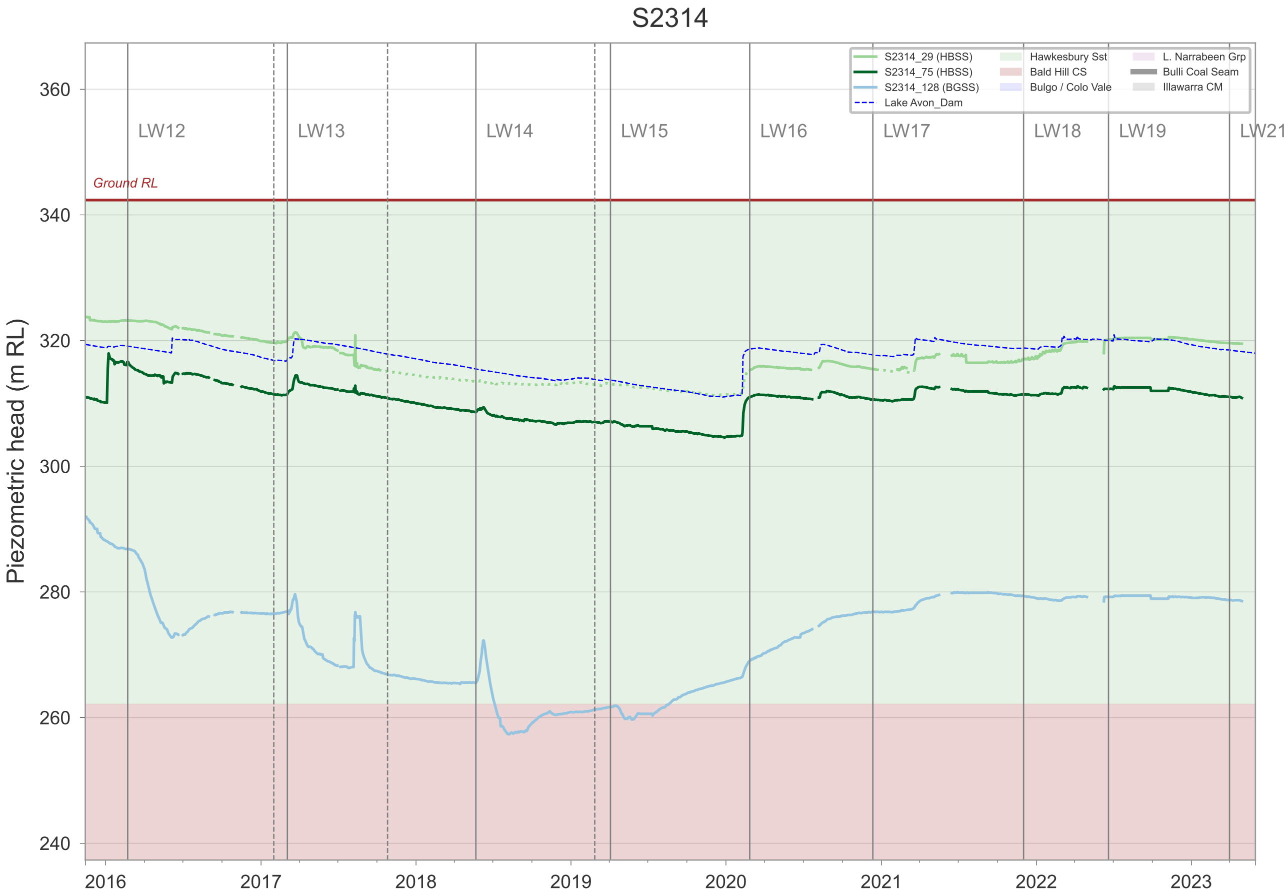


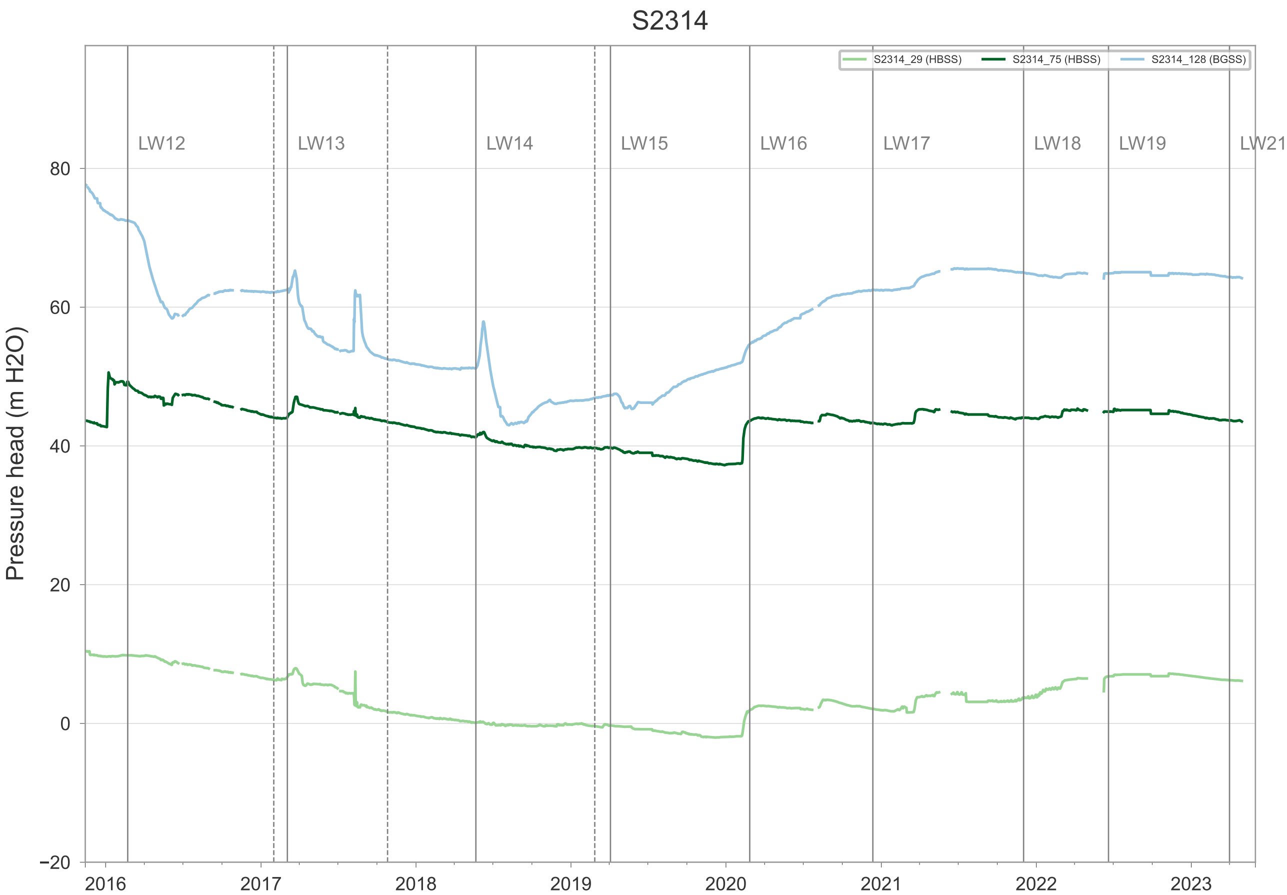



S2313
LW12
LW13
LW14
LW15
LW16
LW21
Ground RL
S2313_49 (HBSS)
S2313_131 (HBSS)
S2313_182 (BGSS)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Piezometric head (m RL)
400
350
300
250
2016
2017
2018
2019
2020
2021
2022
2023

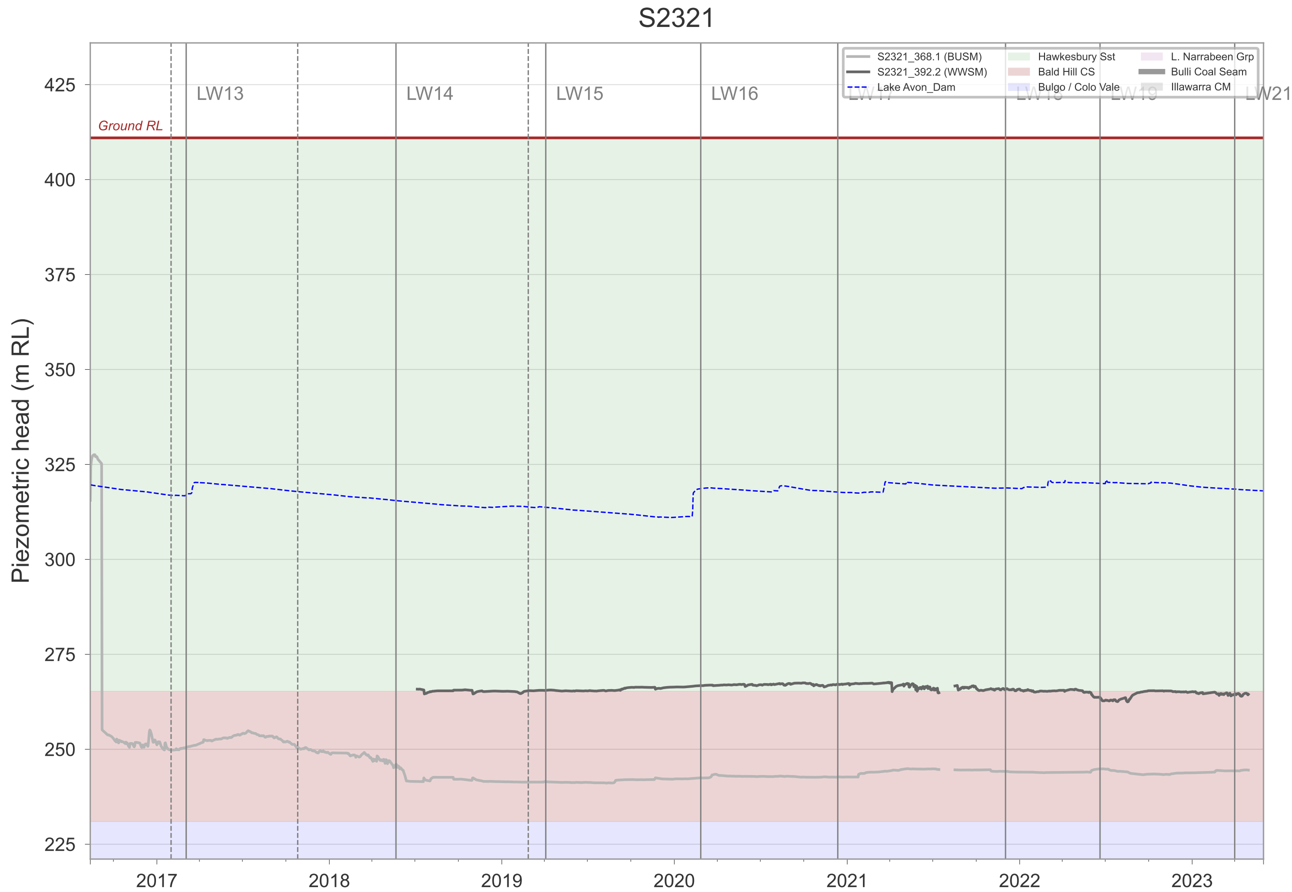

S2313
S2313_49 (HBSS)
S2313_131 (HBSS)
S2313_182 (BGSS)
LW12
LW13
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Pressure head (m H2O)
80
60
40
20
0
−20
2016
2017
2018
2019
2020
2021
2022
2023

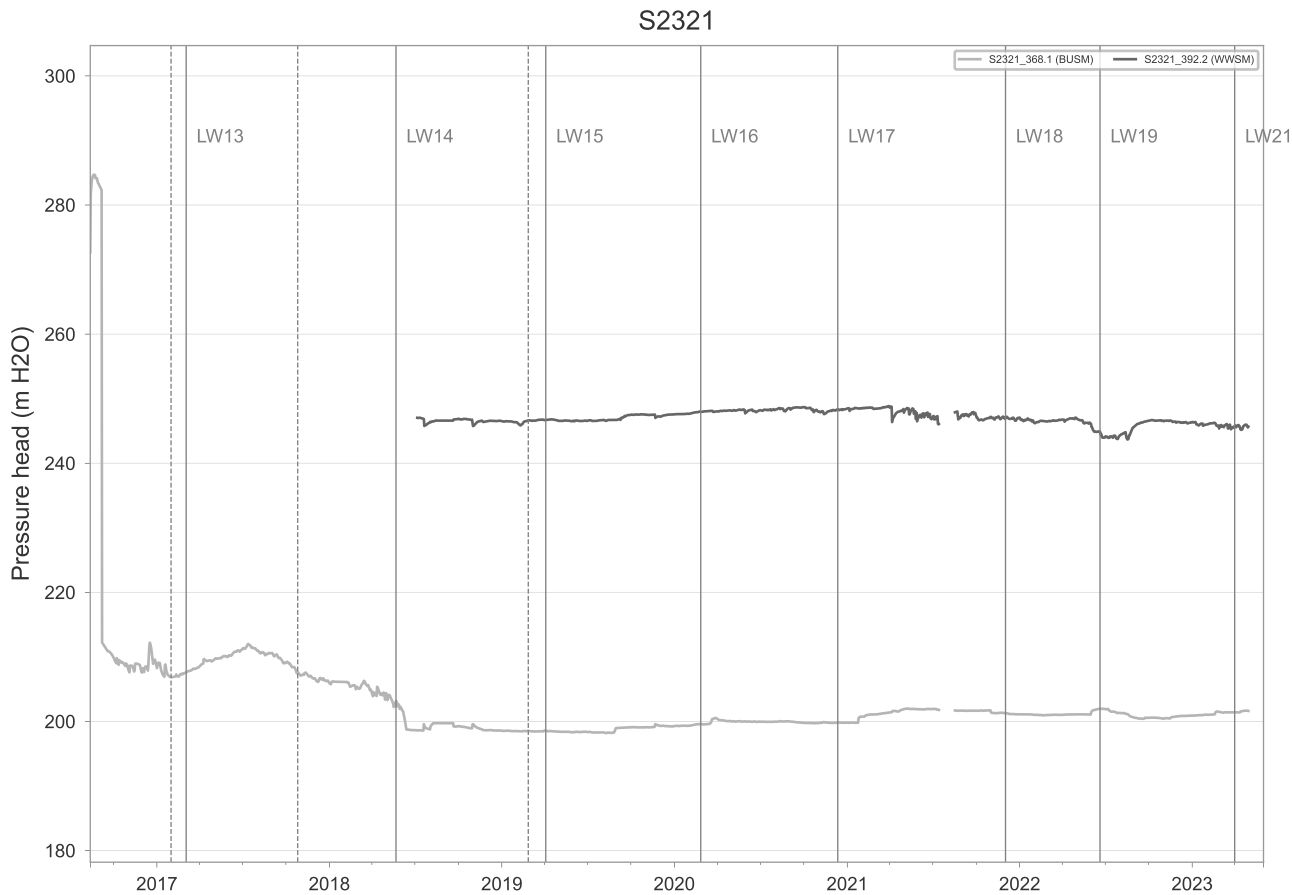
Groundwater hydrographs



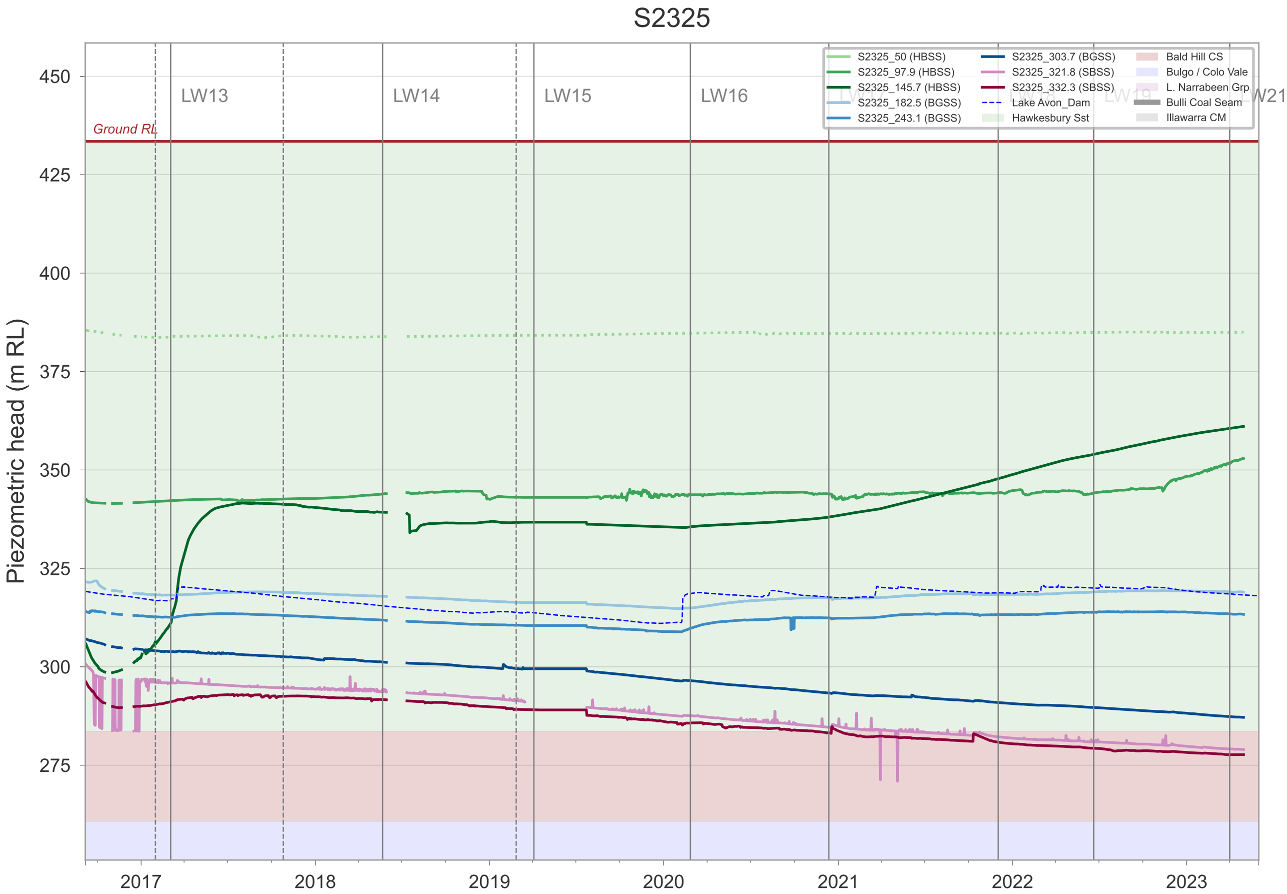


Groundwater hydrographs

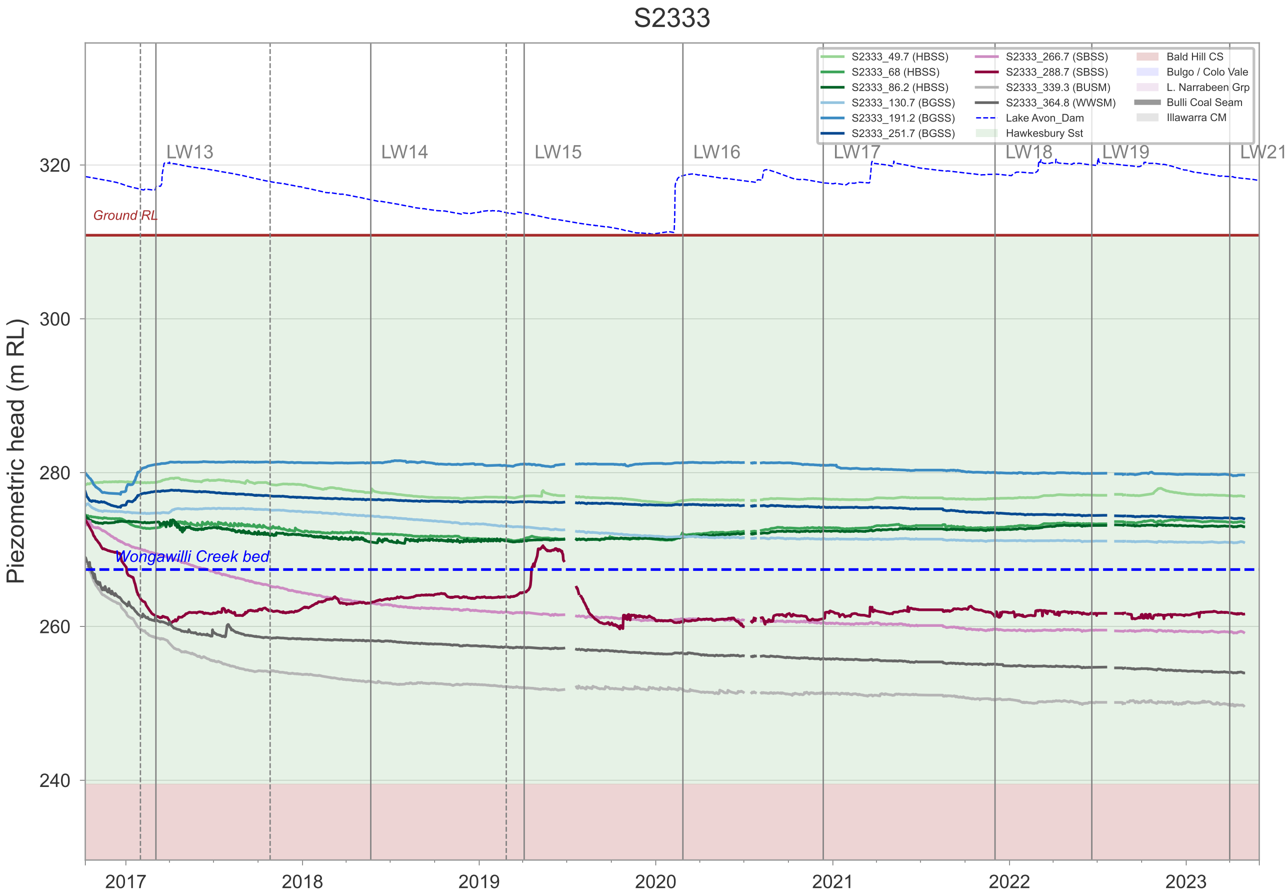


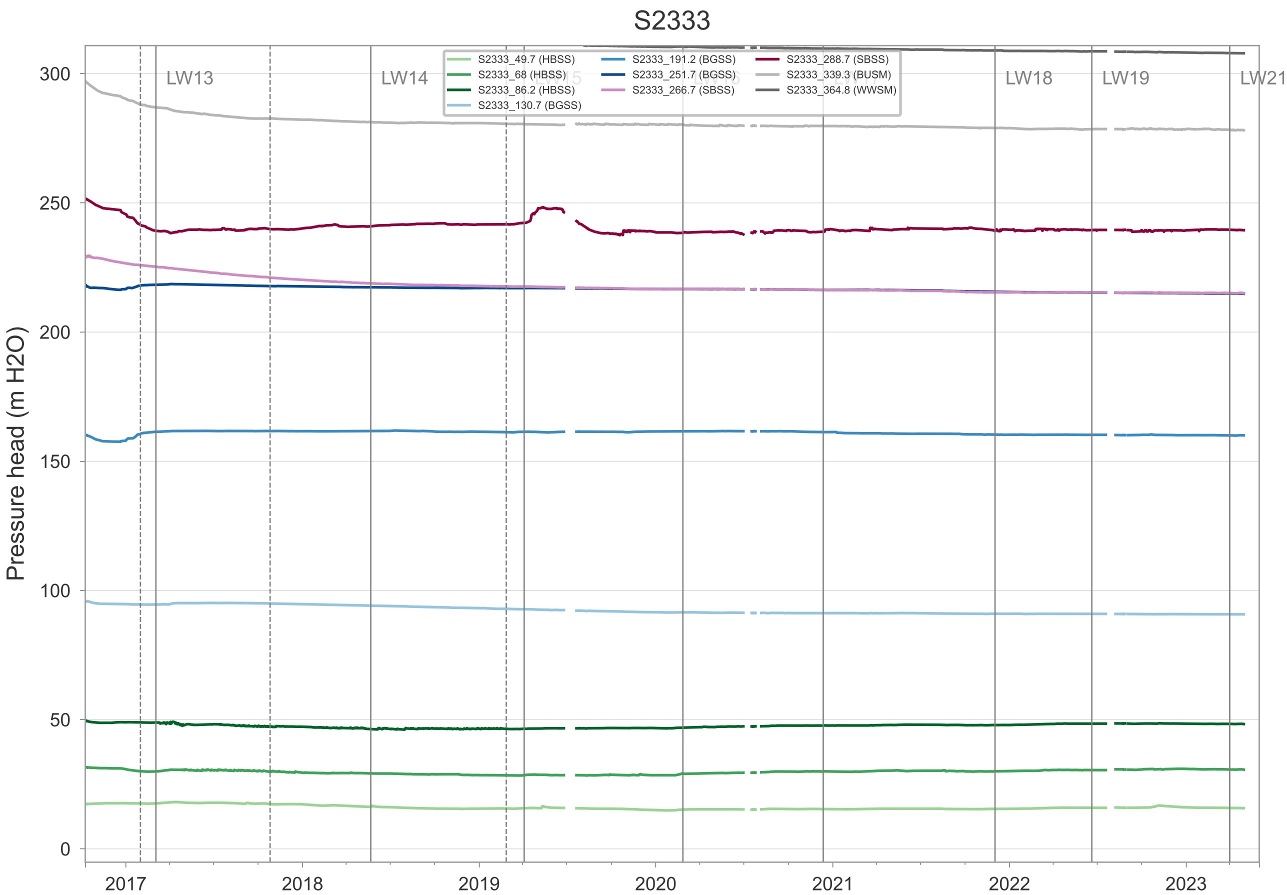


Groundwater hydrographs

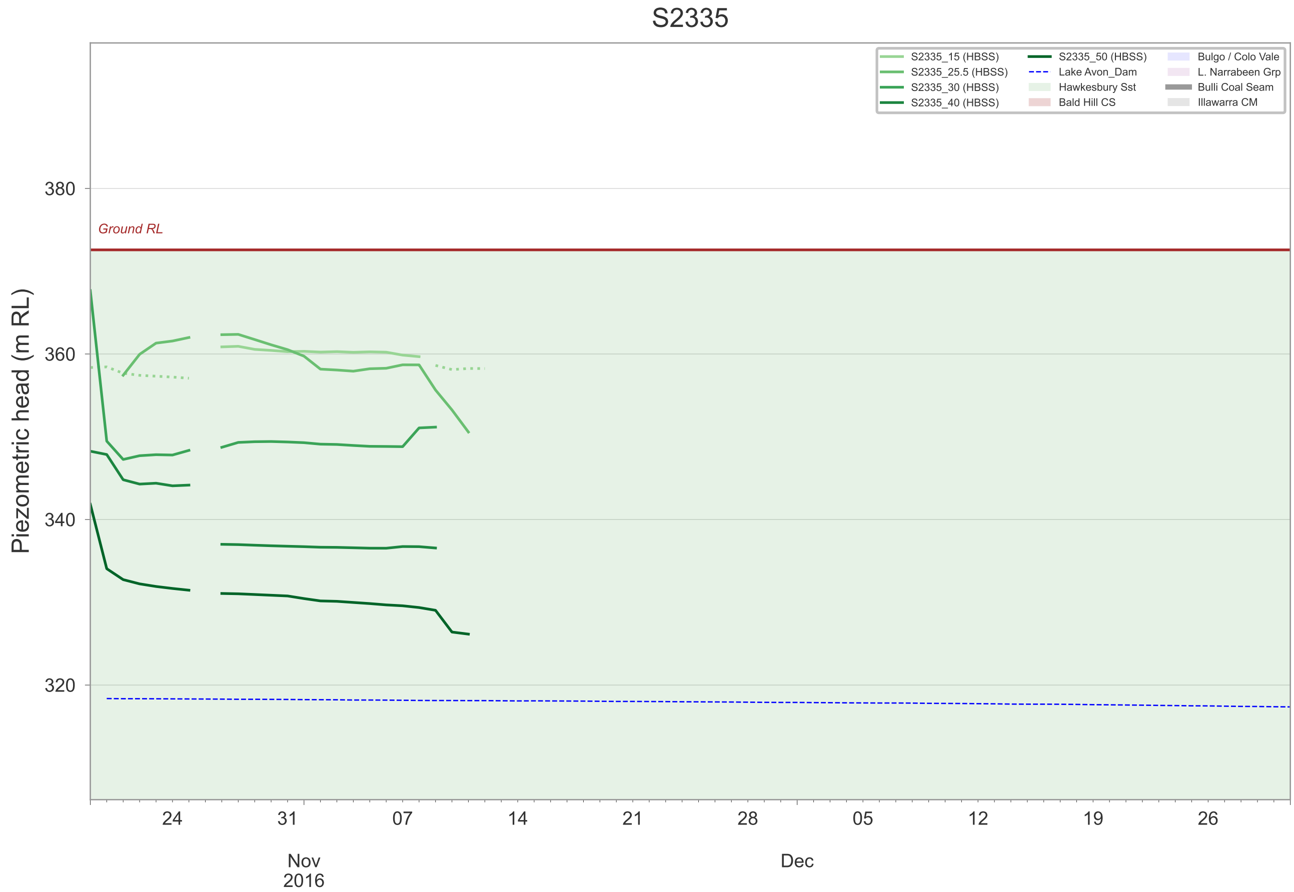


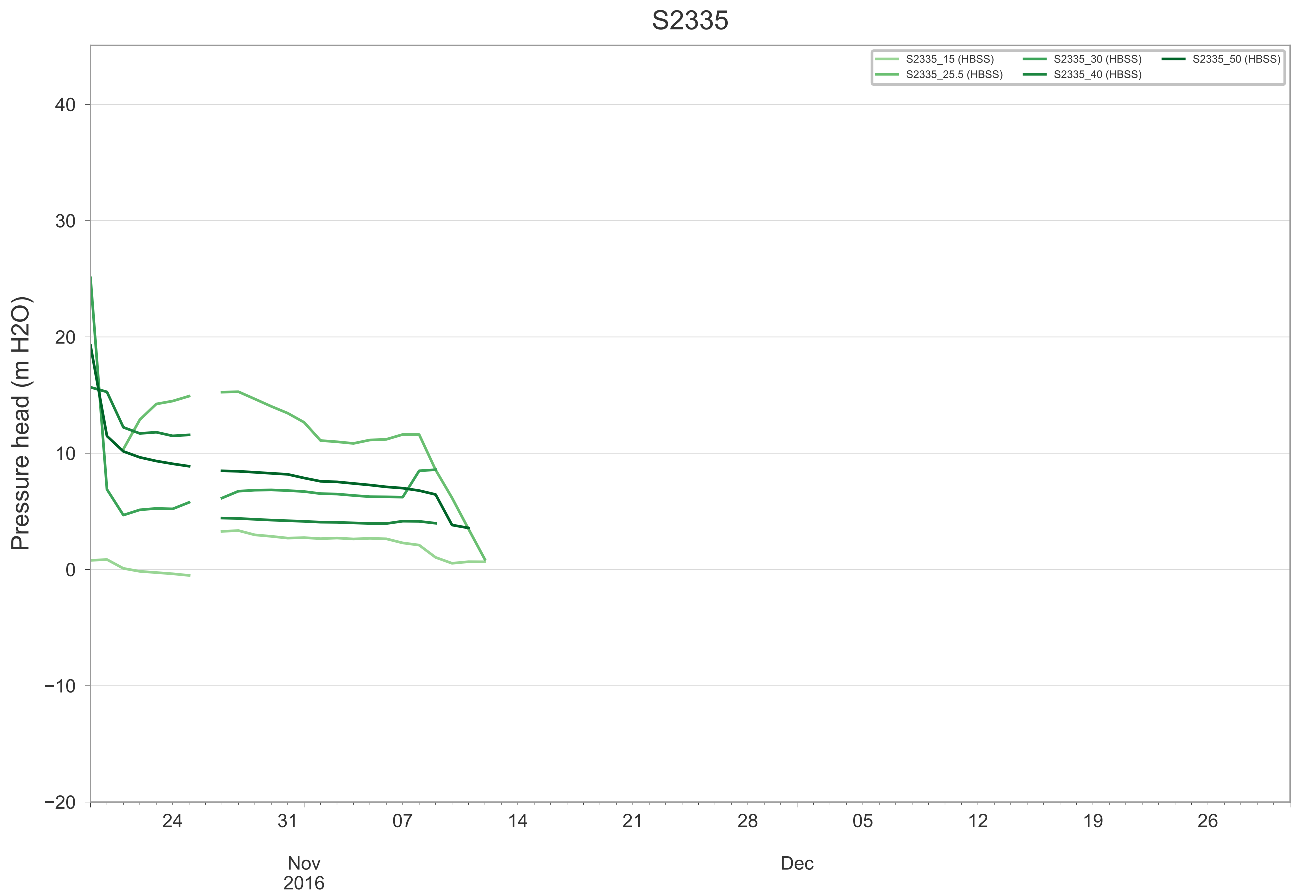
Groundwater hydrographs

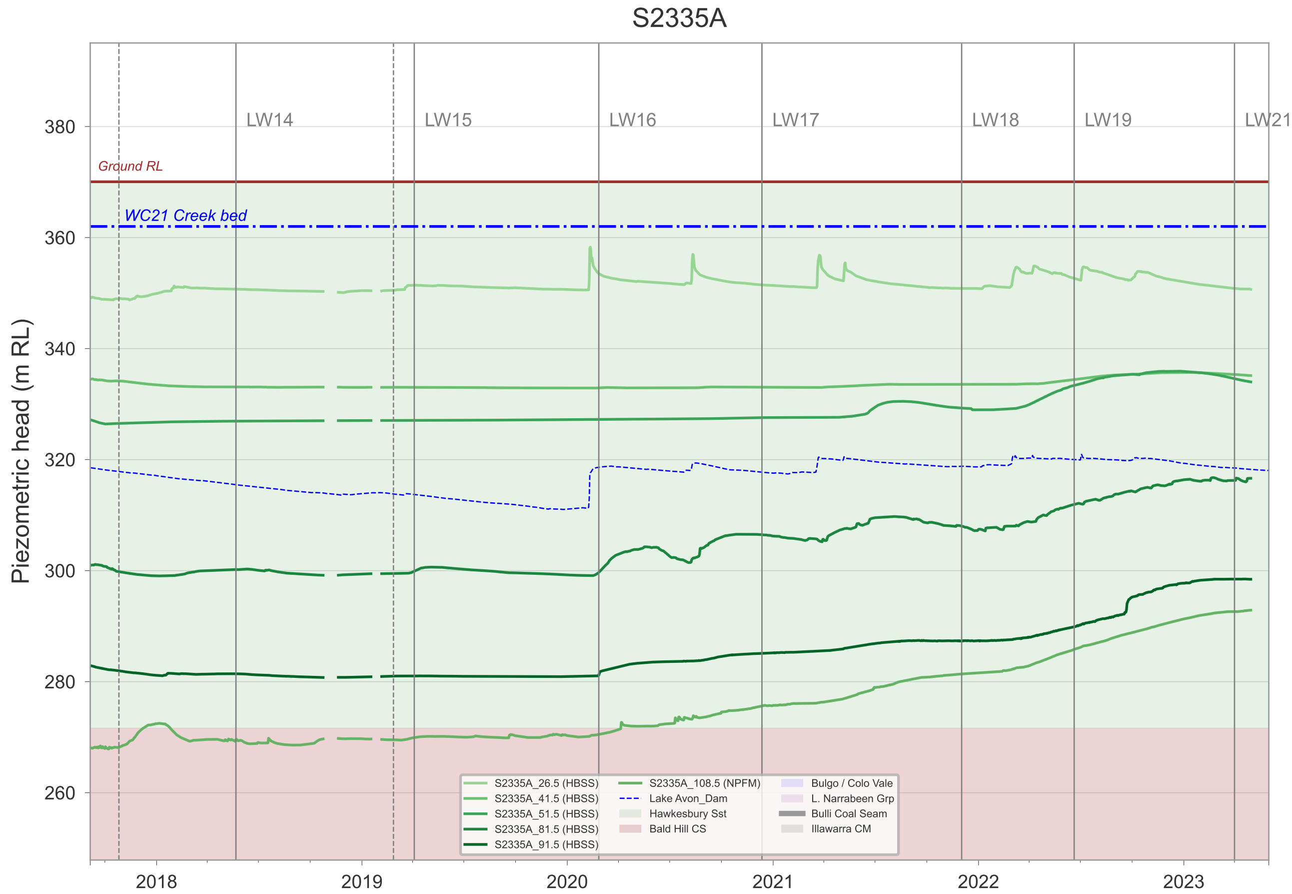


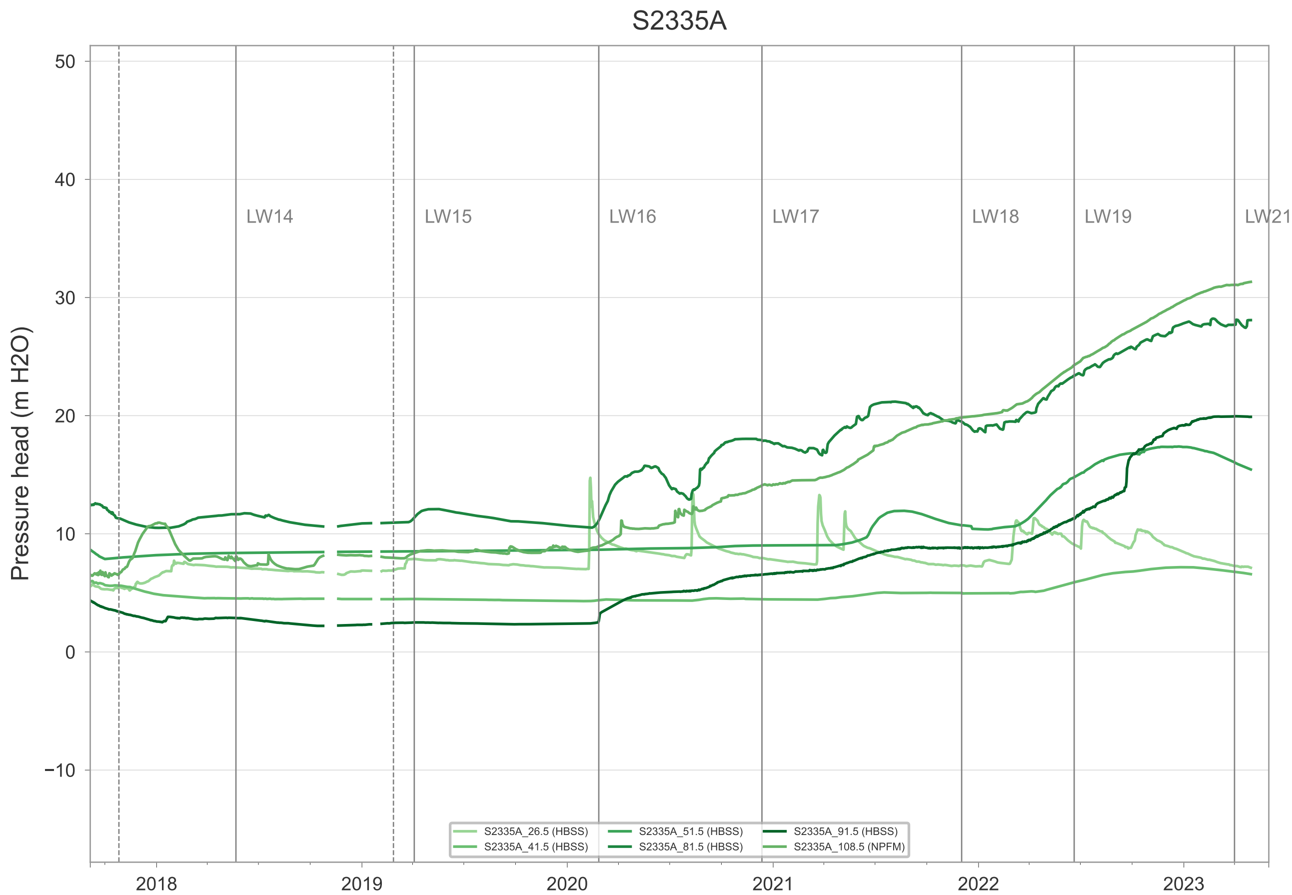


Groundwater hydrographs

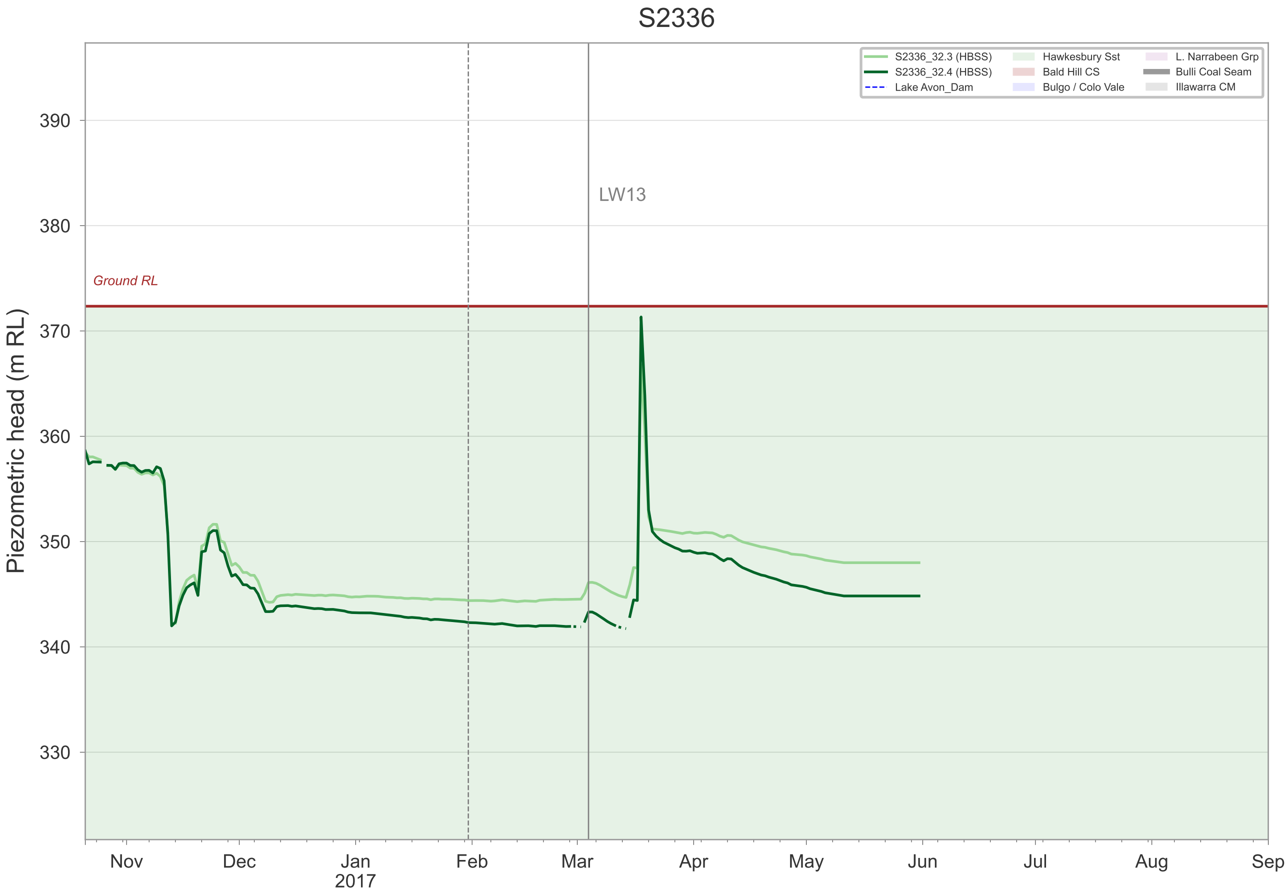


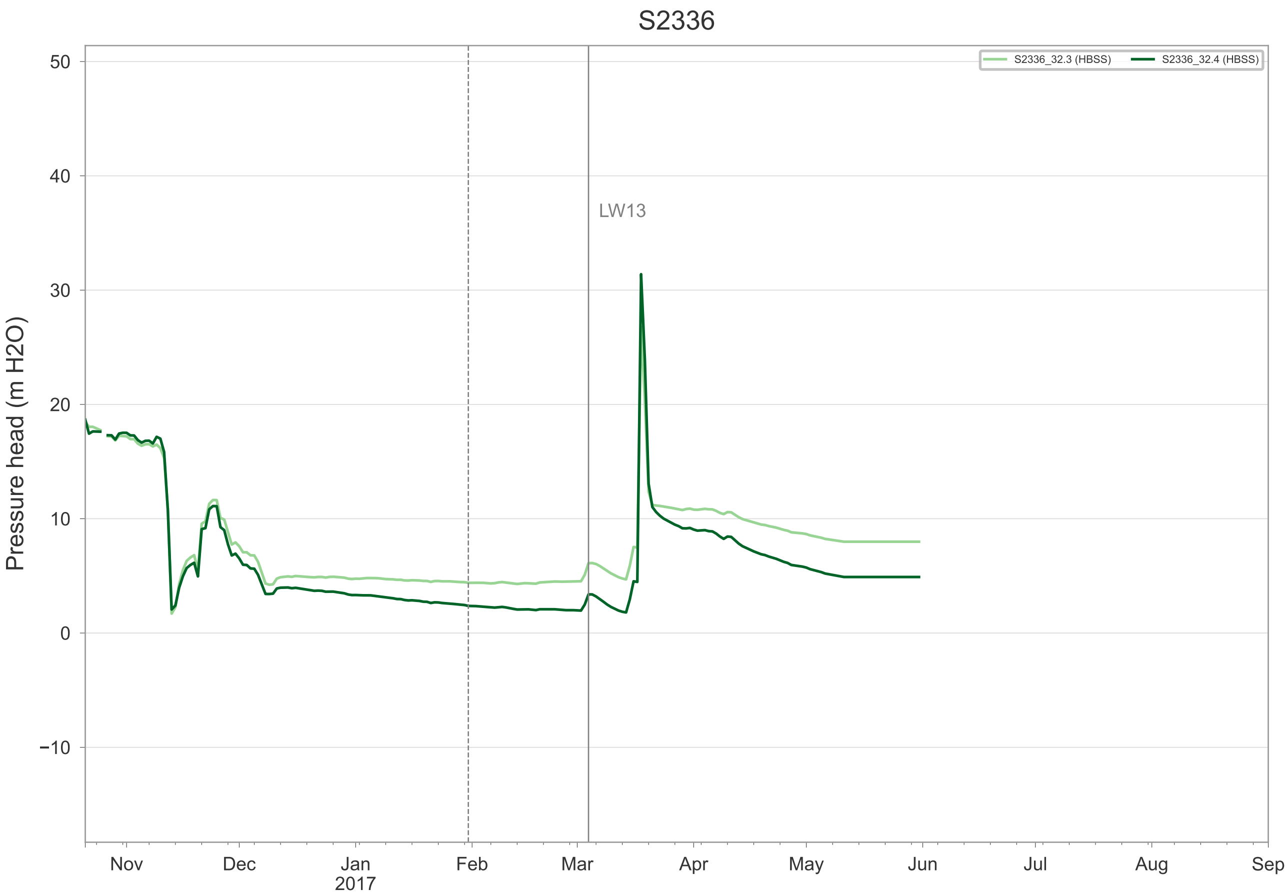



S2335A
Piezometric head (m RL)
Ground RL
WC21 Creek bed
LW14
LW15
LW16
LW17
LW18
LW19
LW21
S2335A_26.5 (HBSS)
S2335A_41.5 (HBSS)
S2335A_51.5 (HBSS)
S2335A_81.5 (HBSS)
S2335A_91.5 (HBSS)
S2335A_108.5 (NPFM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
2018
2019
2020
2021
2022
2023

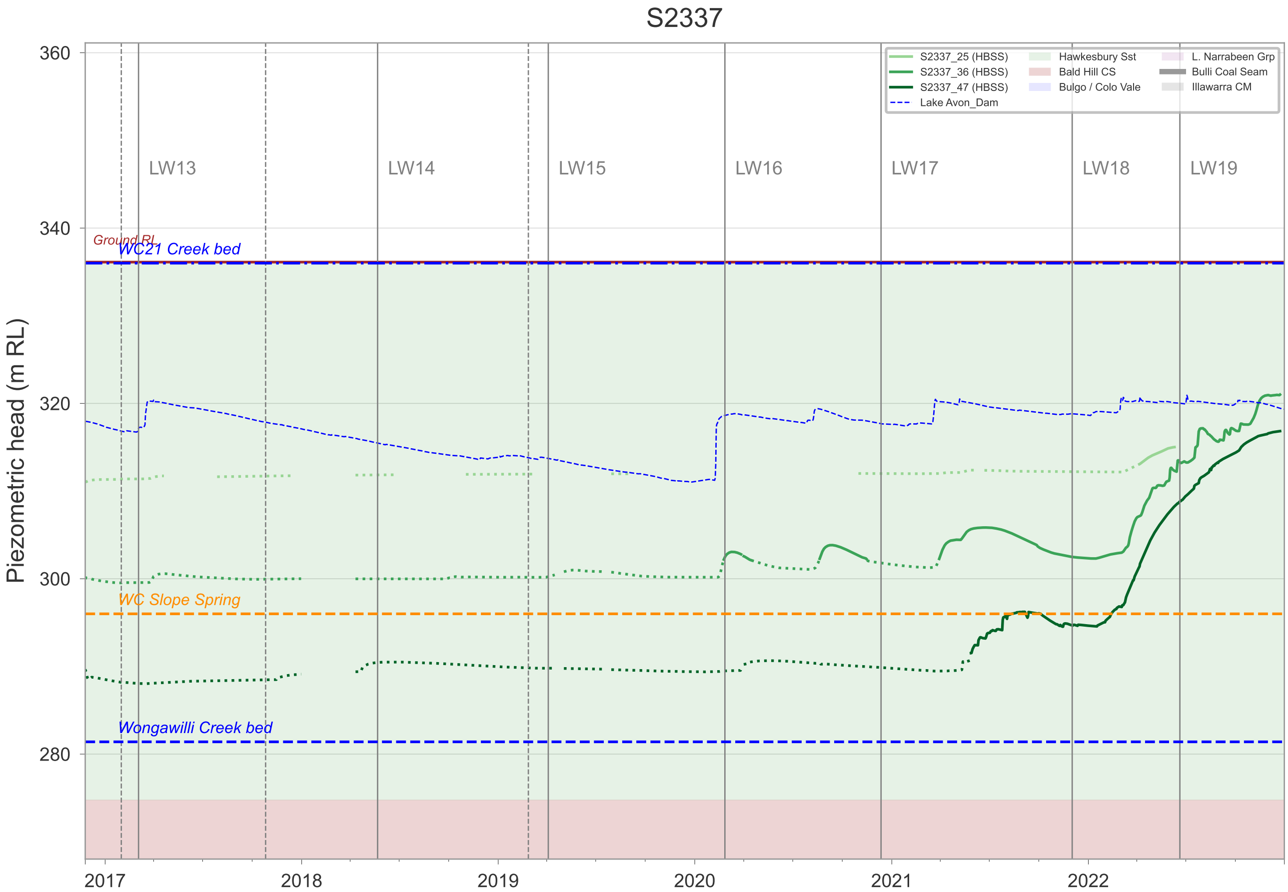

S2335A
Pressure head (m H2O)
LW14
LW15
LW16
LW17
LW18
LW19
LW21
S2335A_26.5 (HBSS)
S2335A_41.5 (HBSS)
S2335A_51.5 (HBSS)
S2335A_81.5 (HBSS)
S2335A_91.5 (HBSS)
S2335A_108.5 (NPFM)
2018
2019
2020
2021
2022
2023

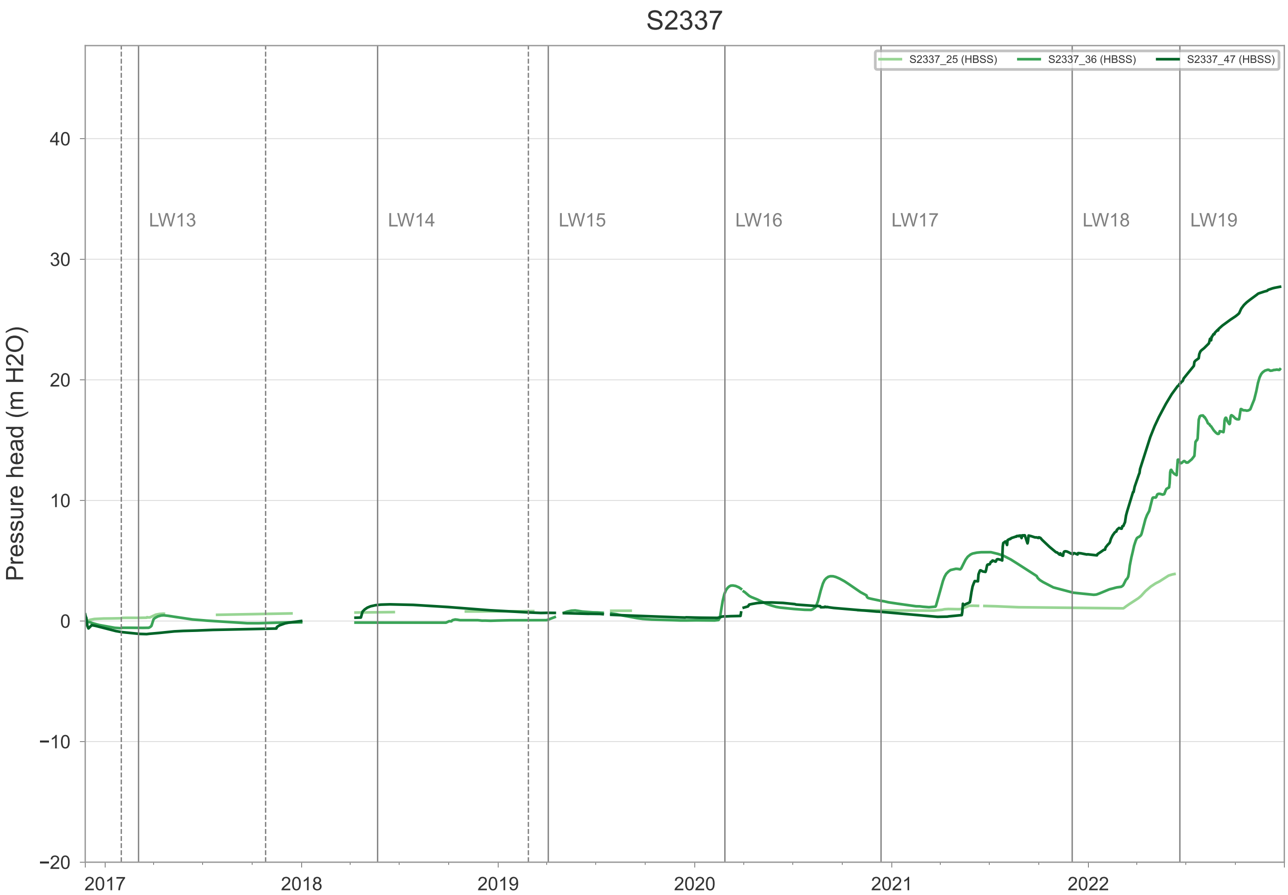
Groundwater hydrographs



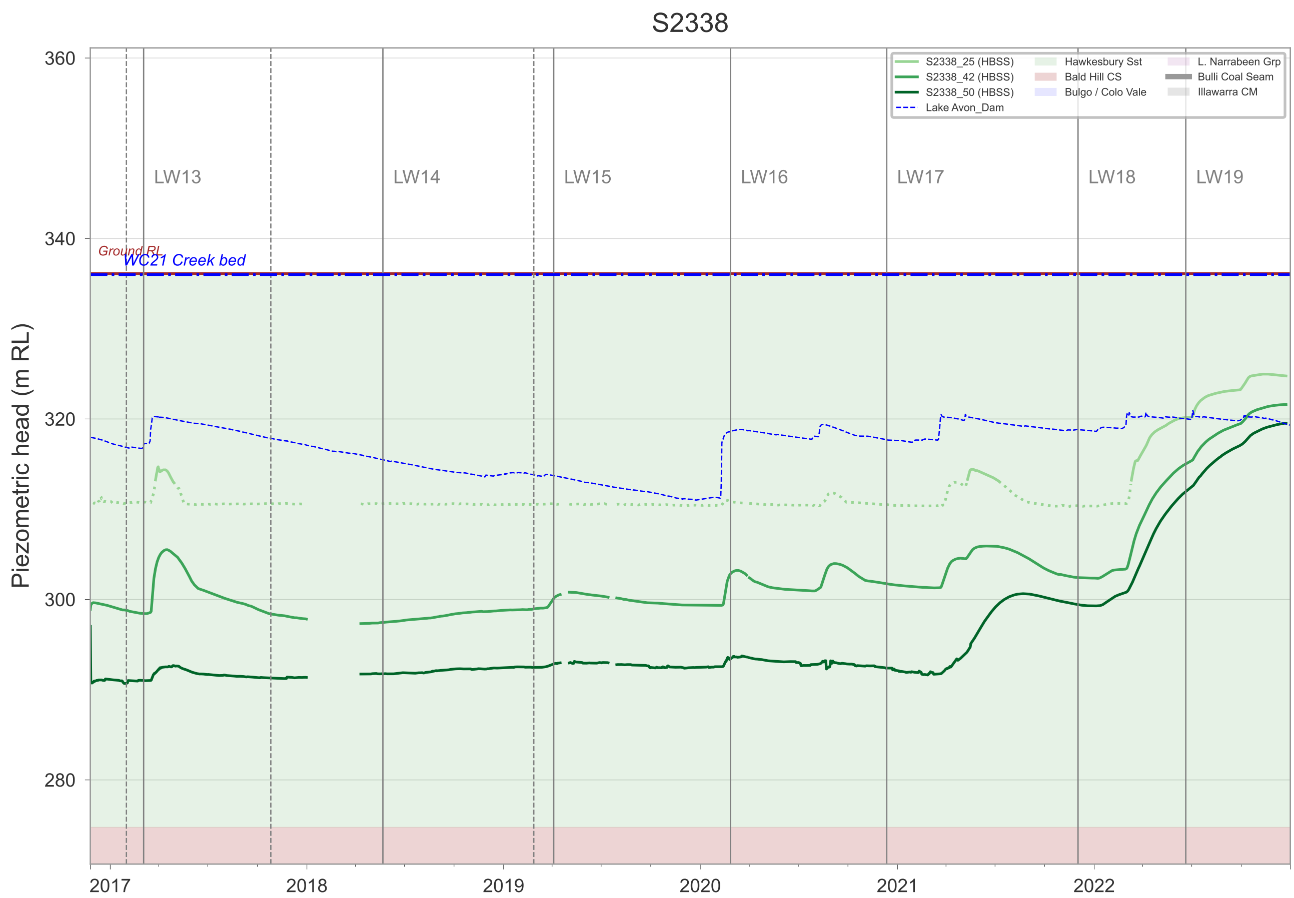


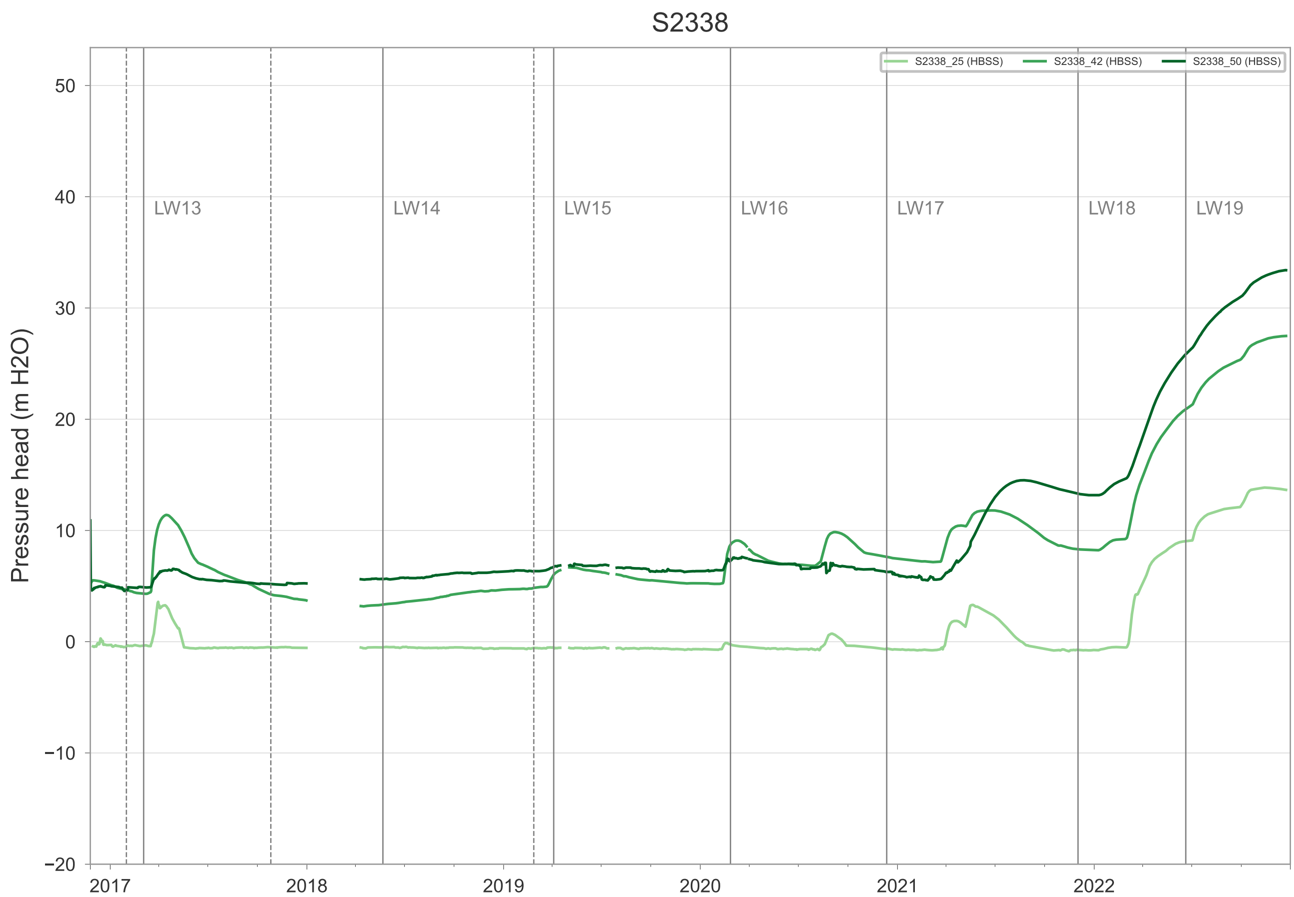
Groundwater hydrographs



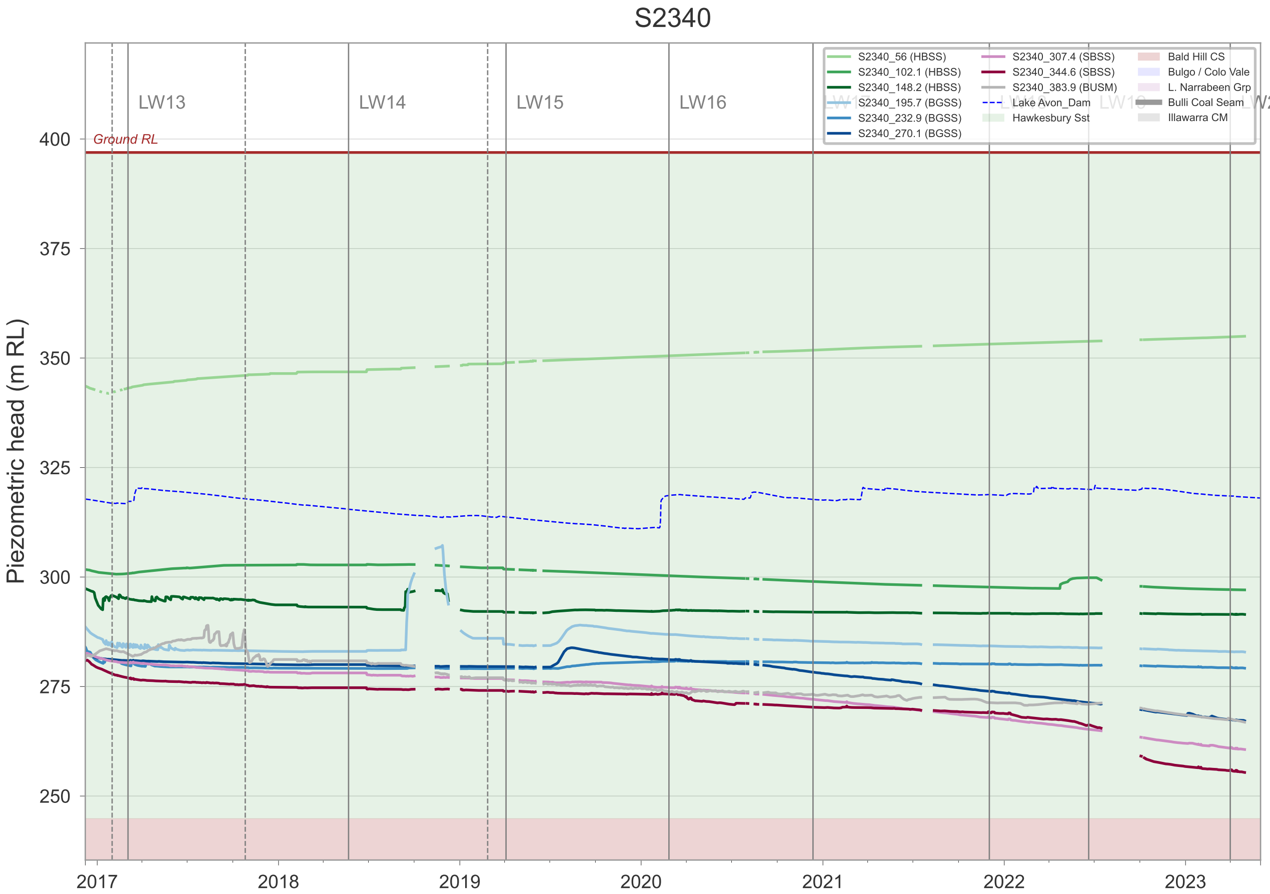


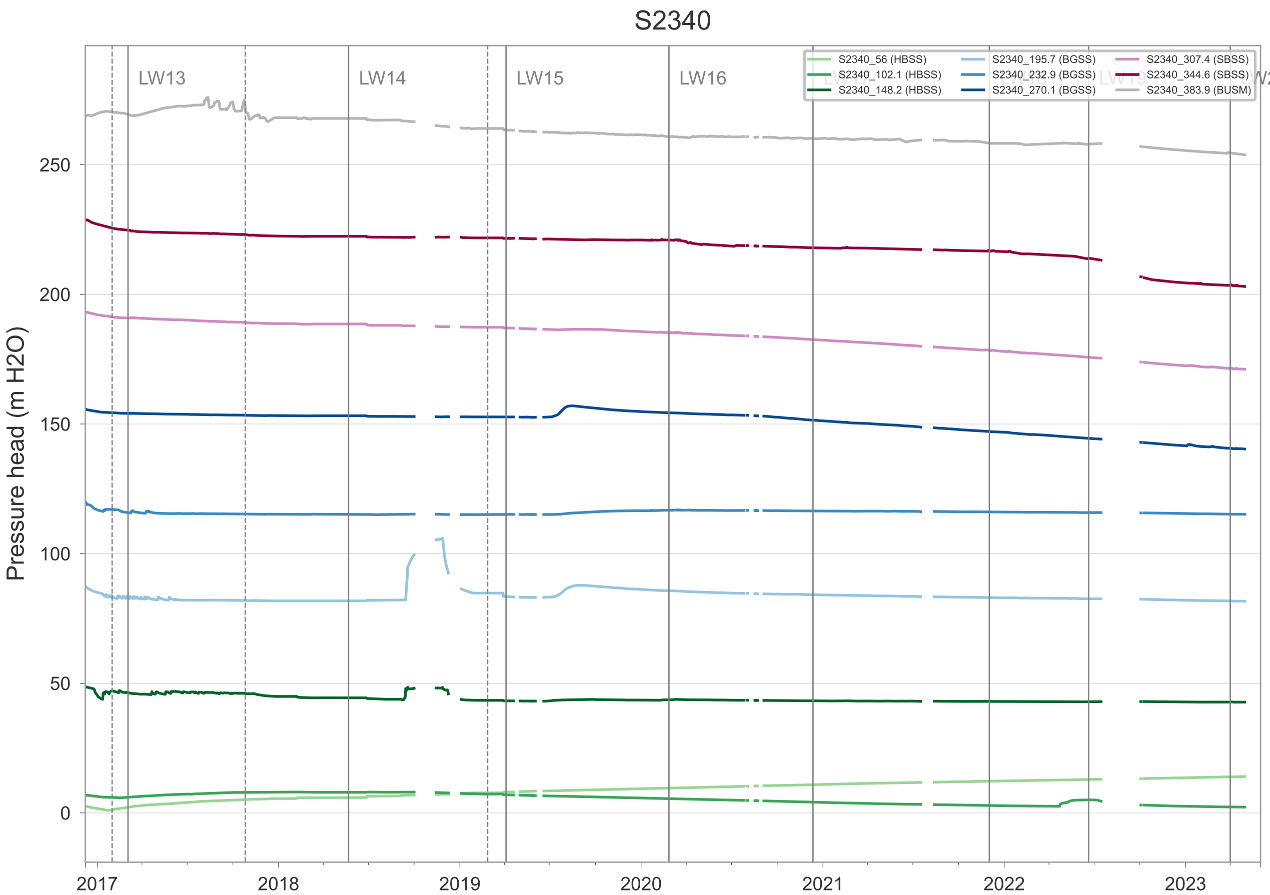
Groundwater hydrographs



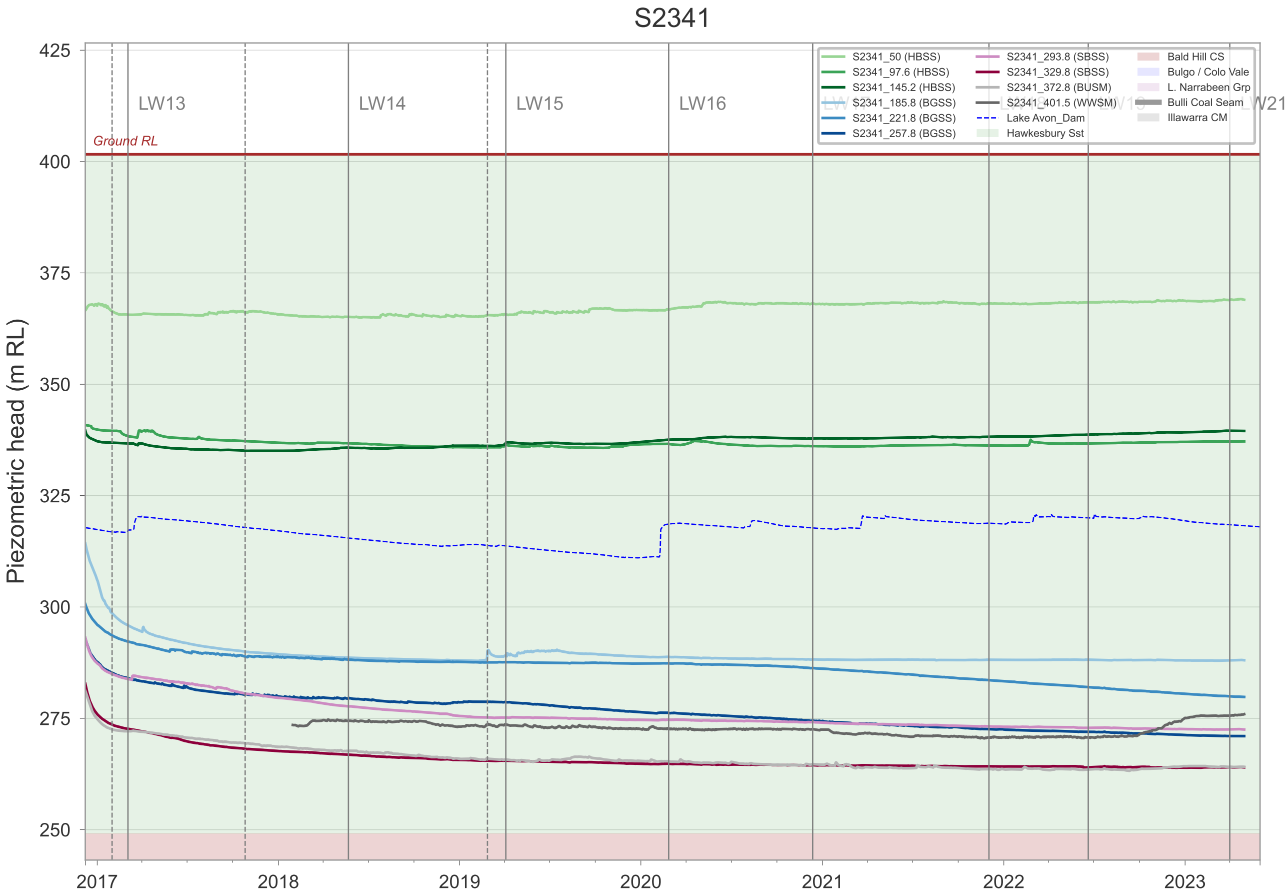


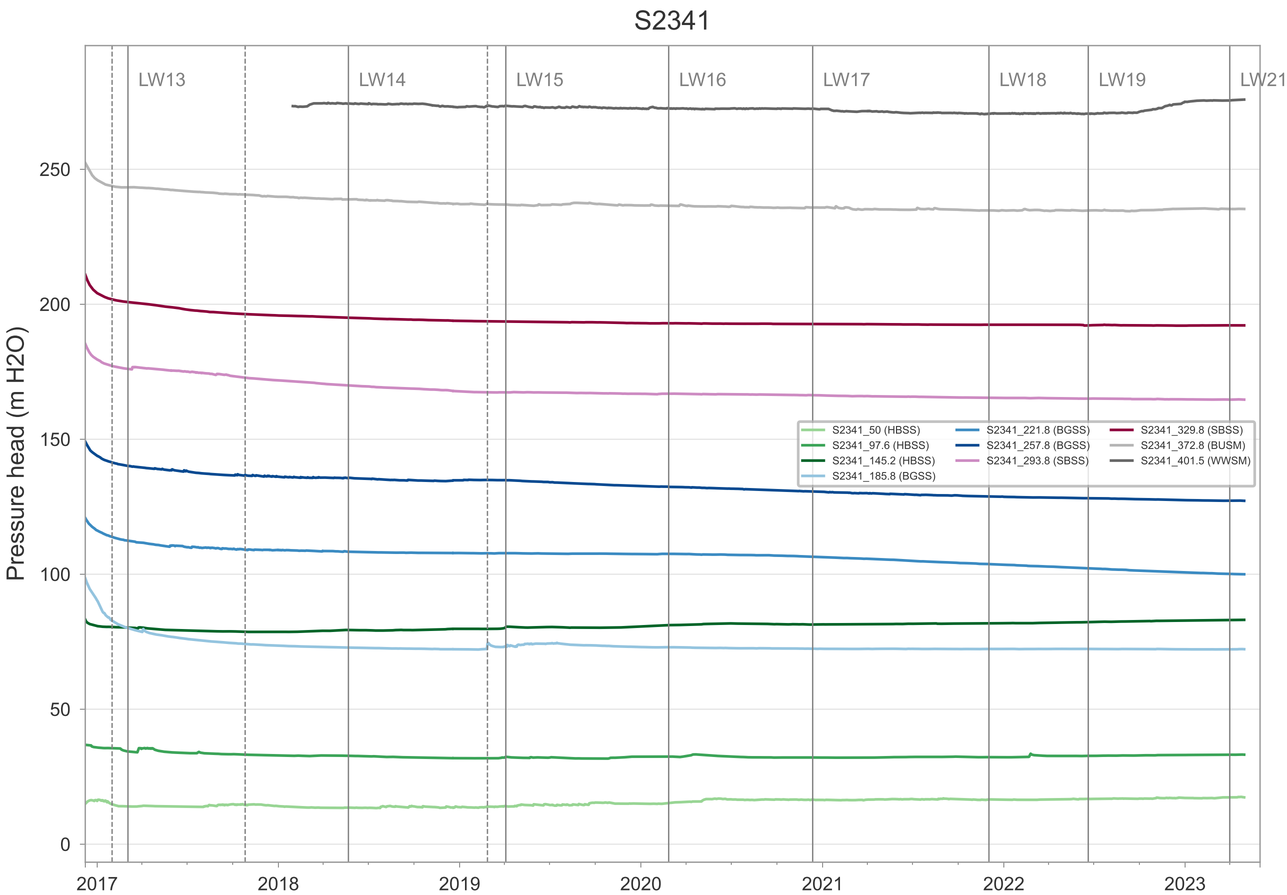
Groundwater hydrographs



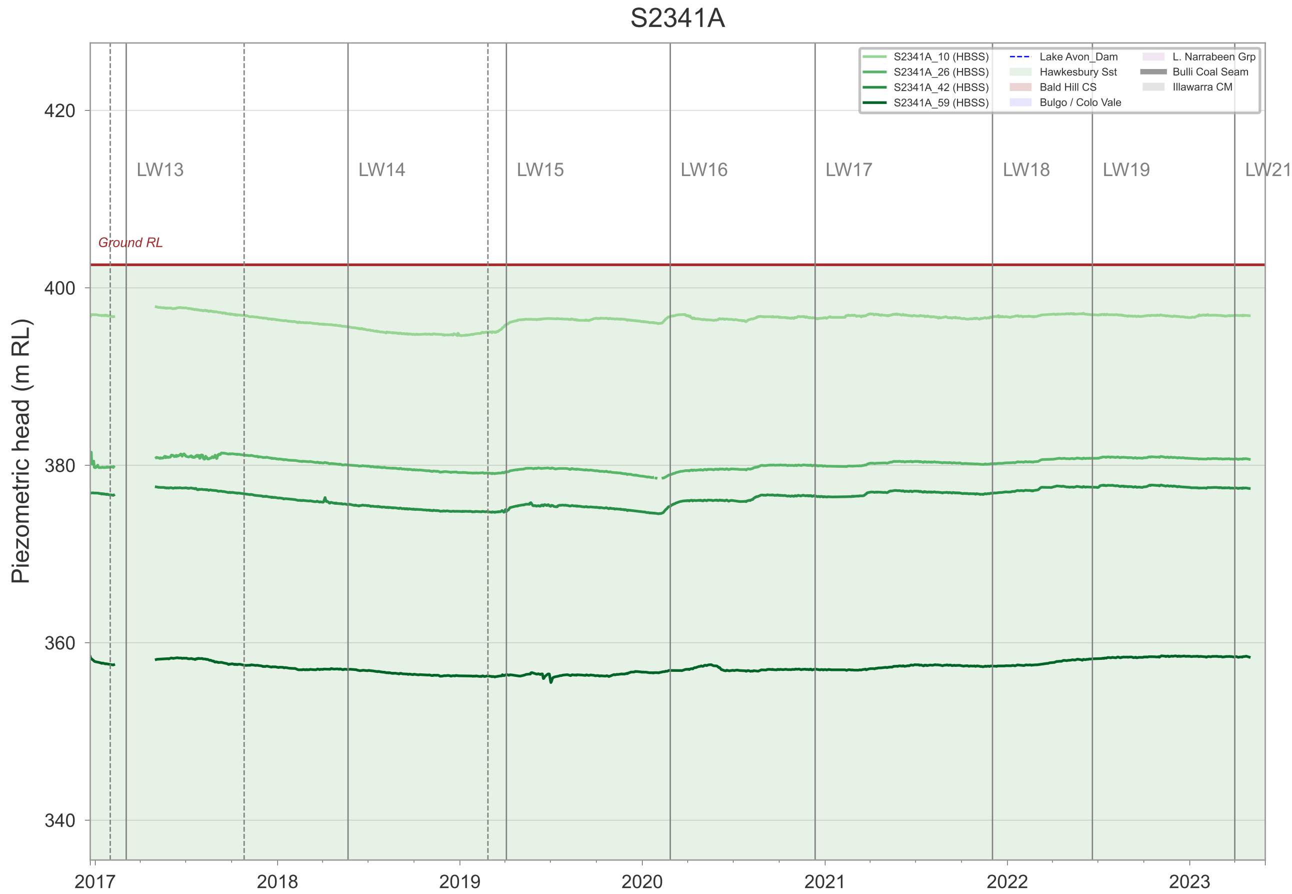


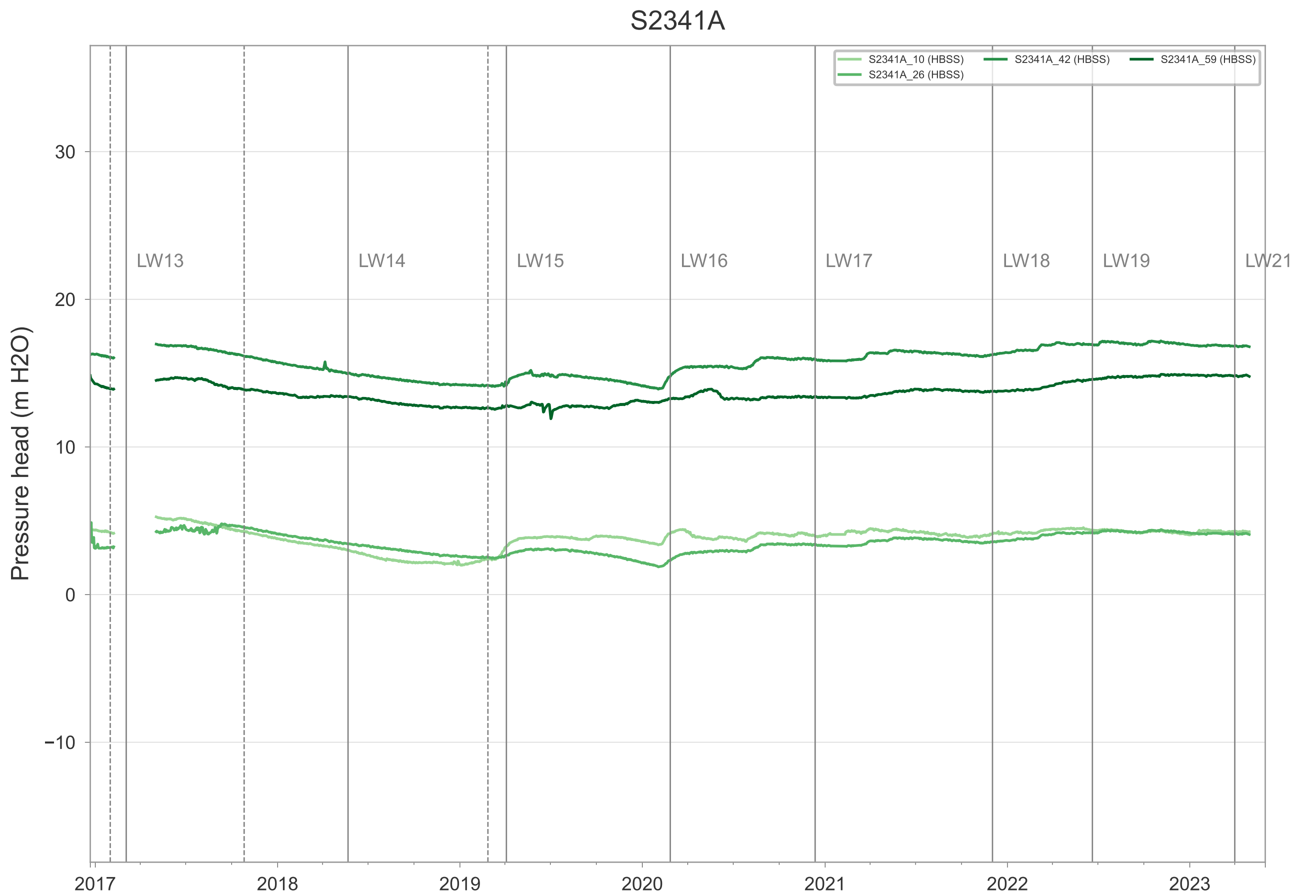
Groundwater hydrographs



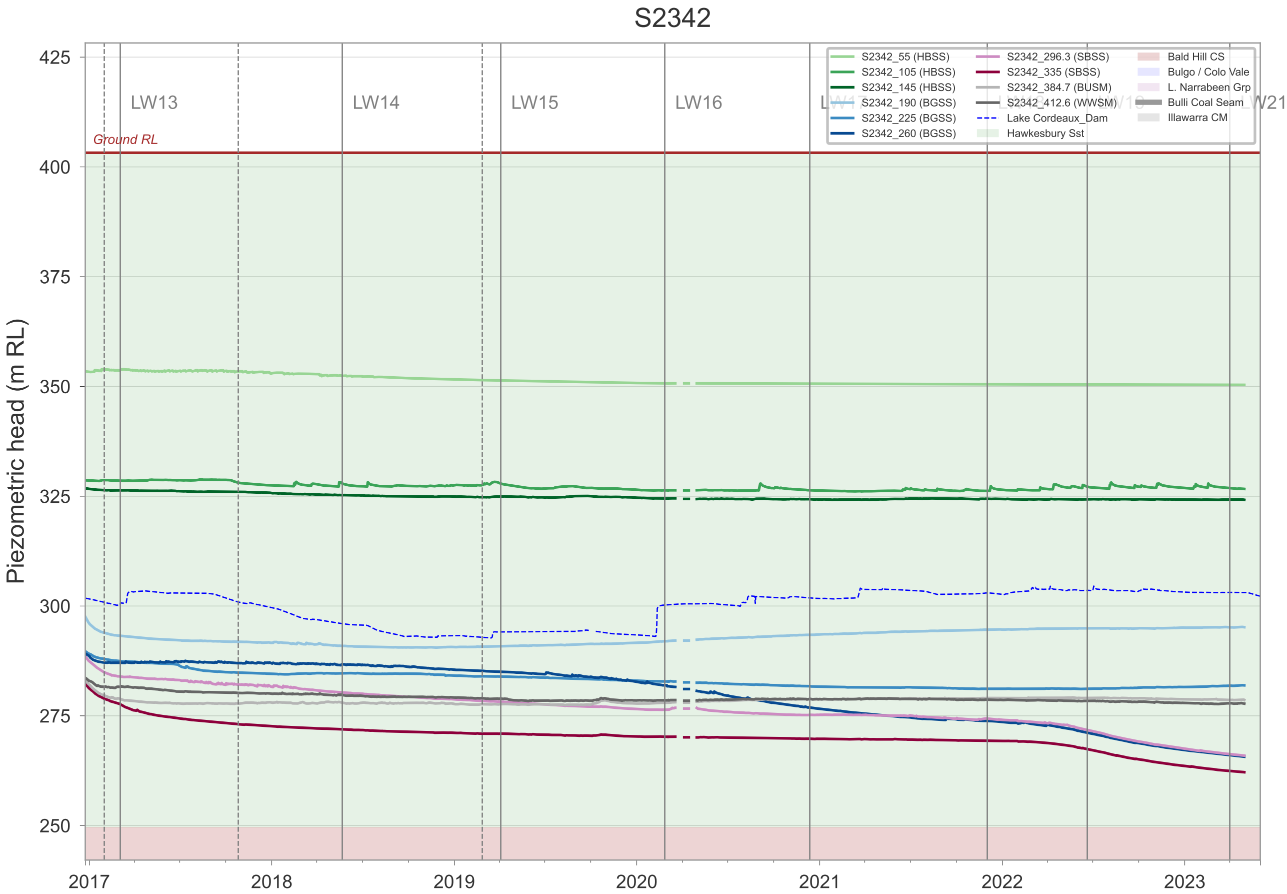


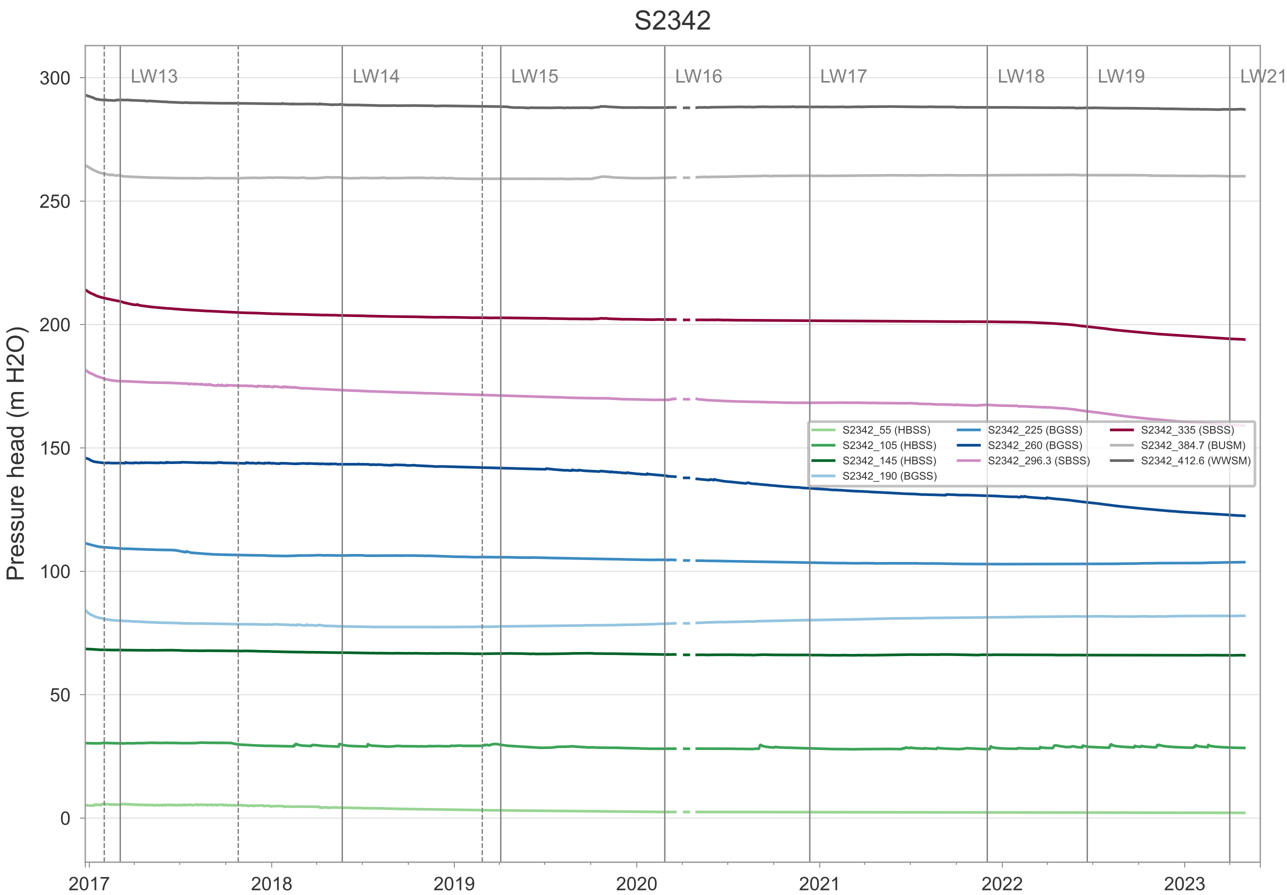
Groundwater hydrographs



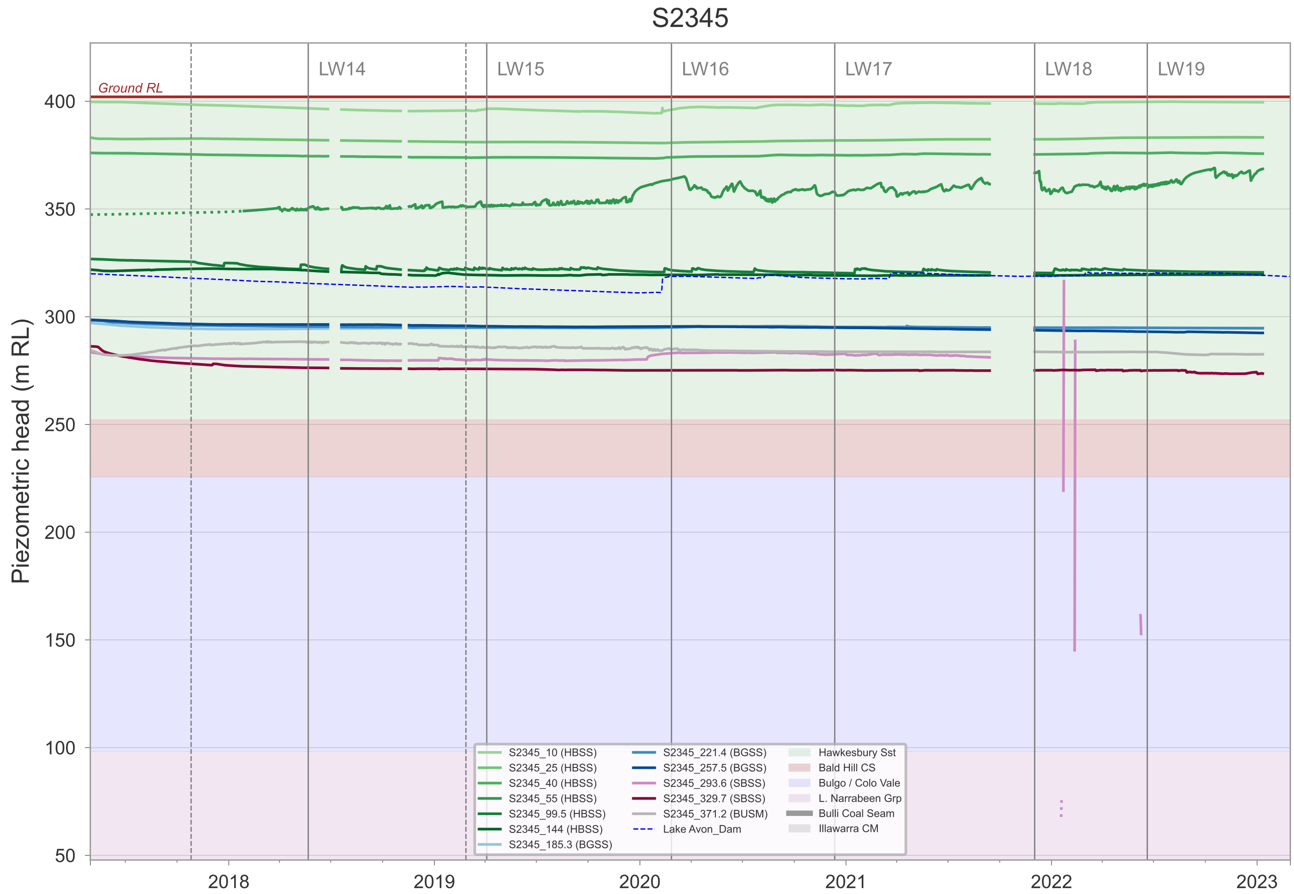


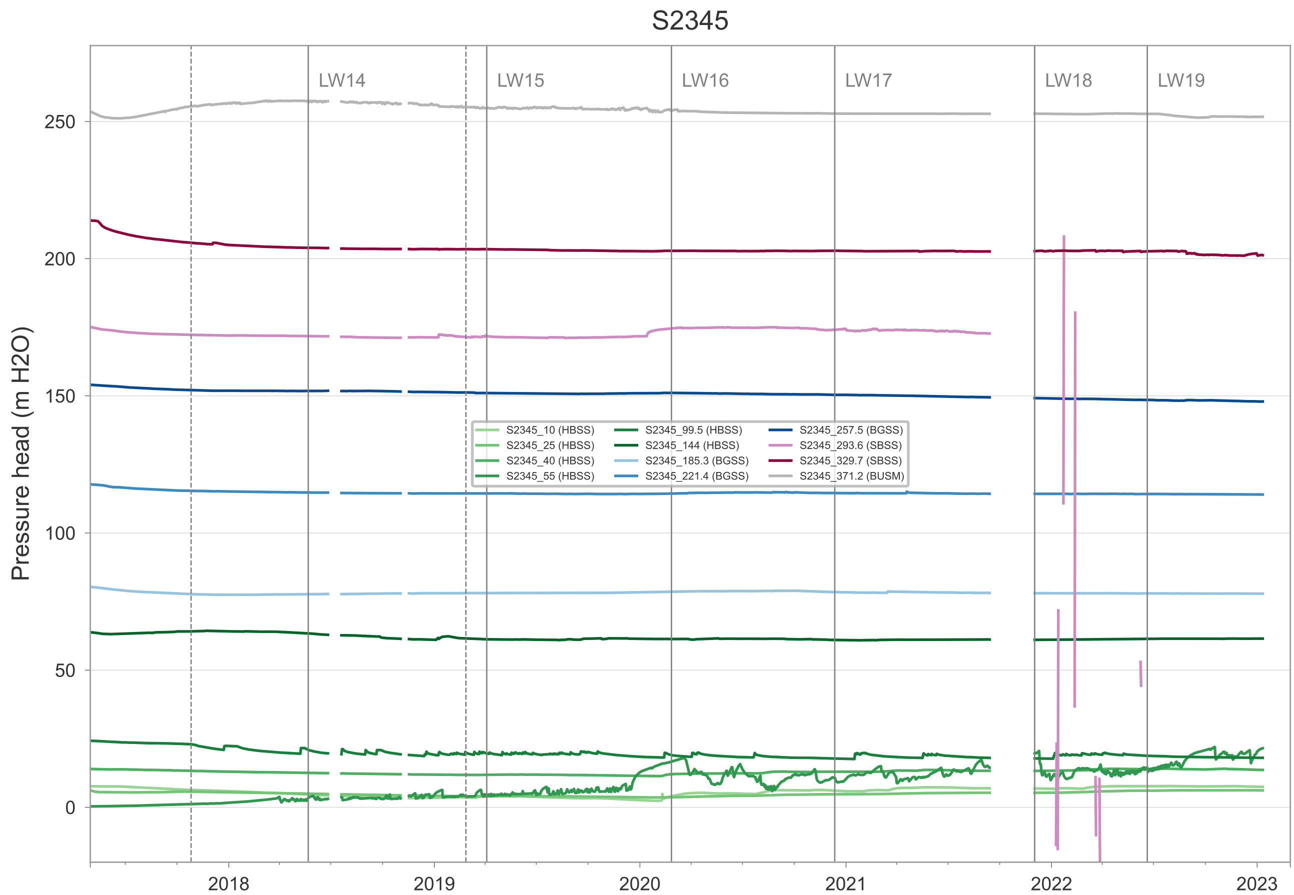
Groundwater hydrographs

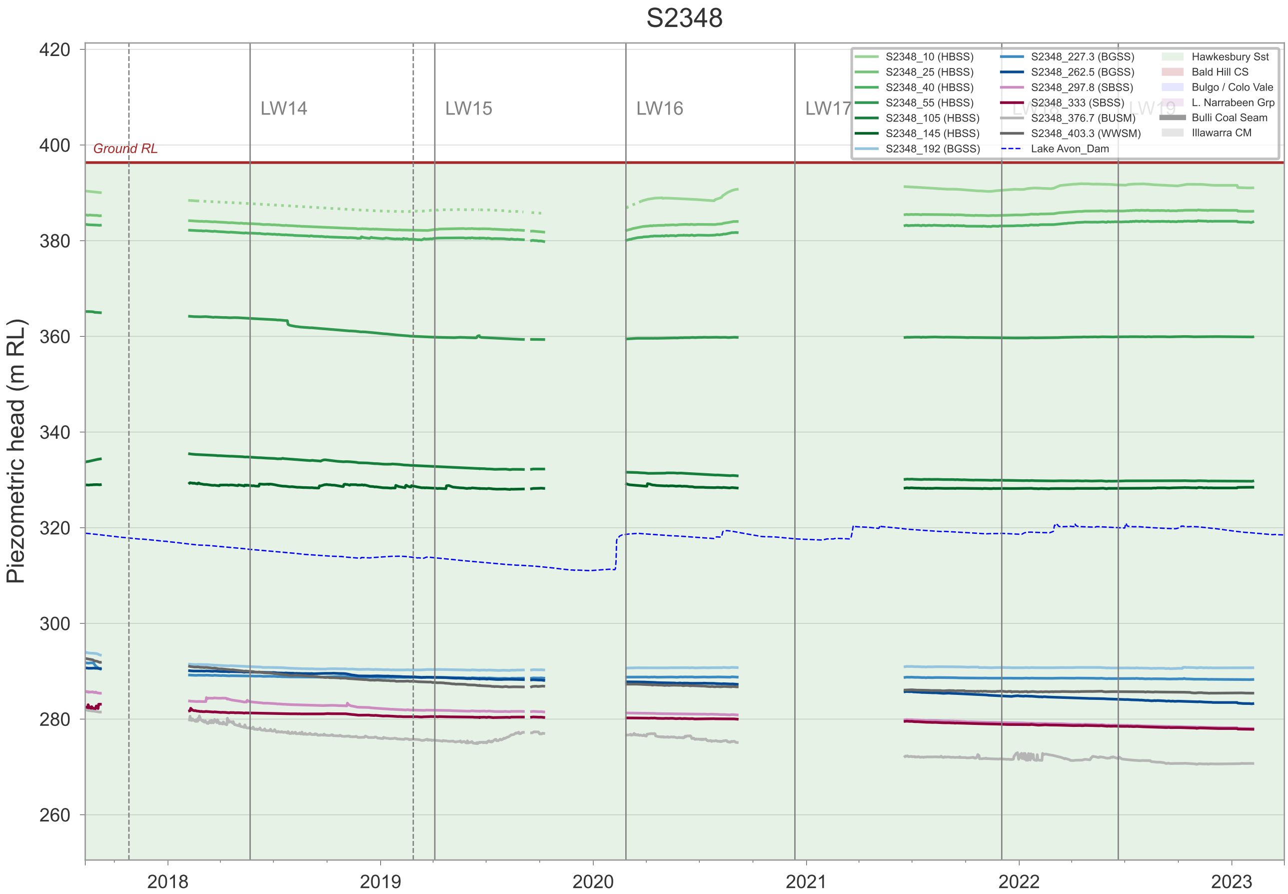


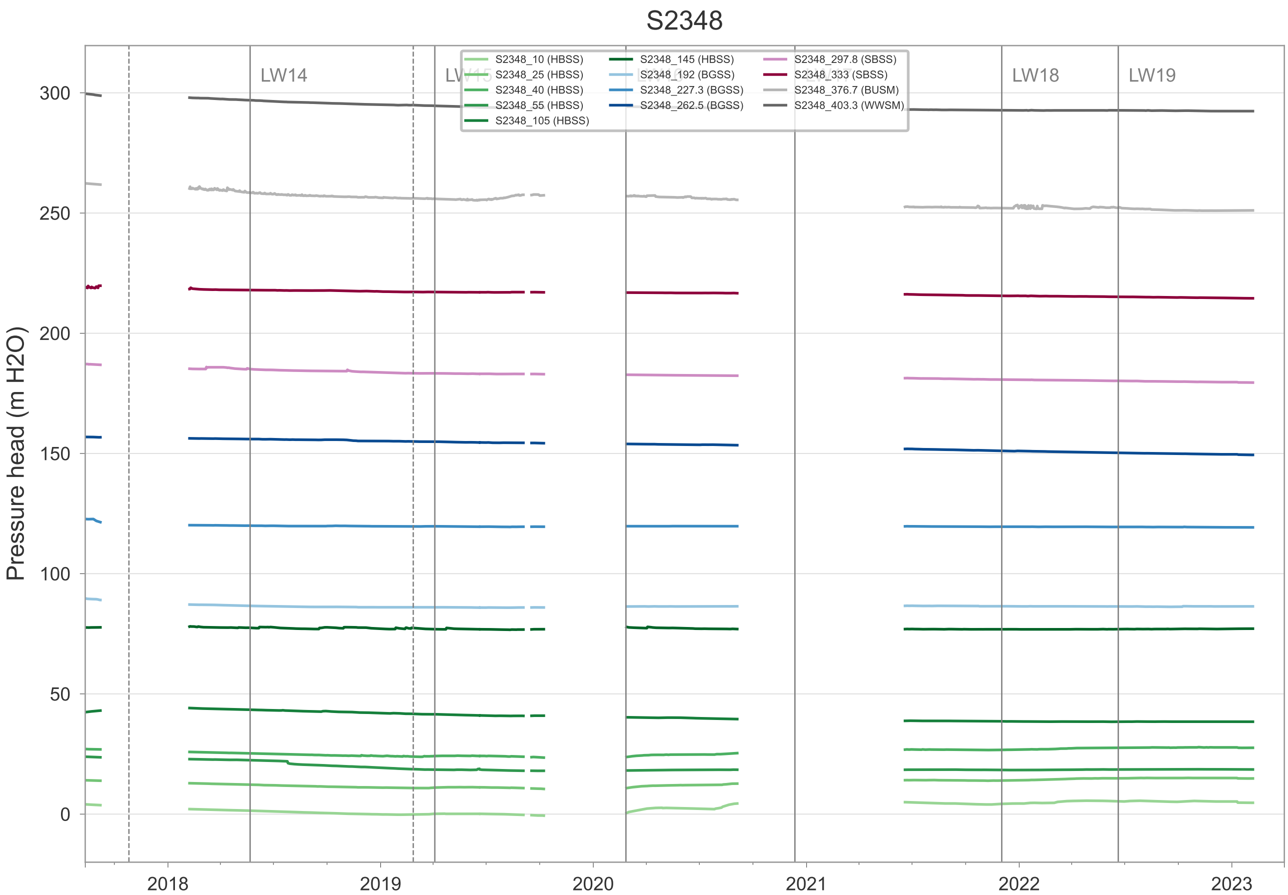


Groundwater hydrographs

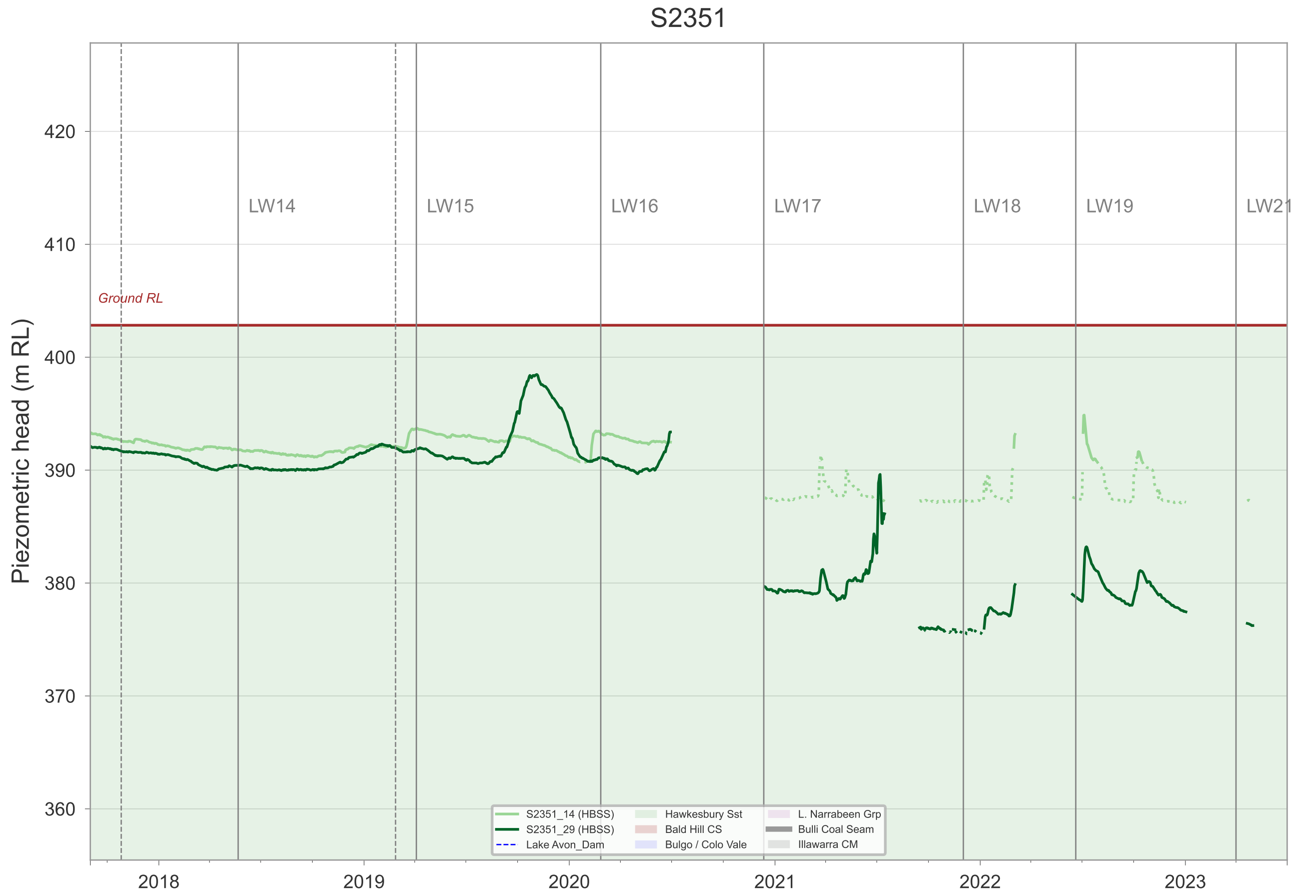


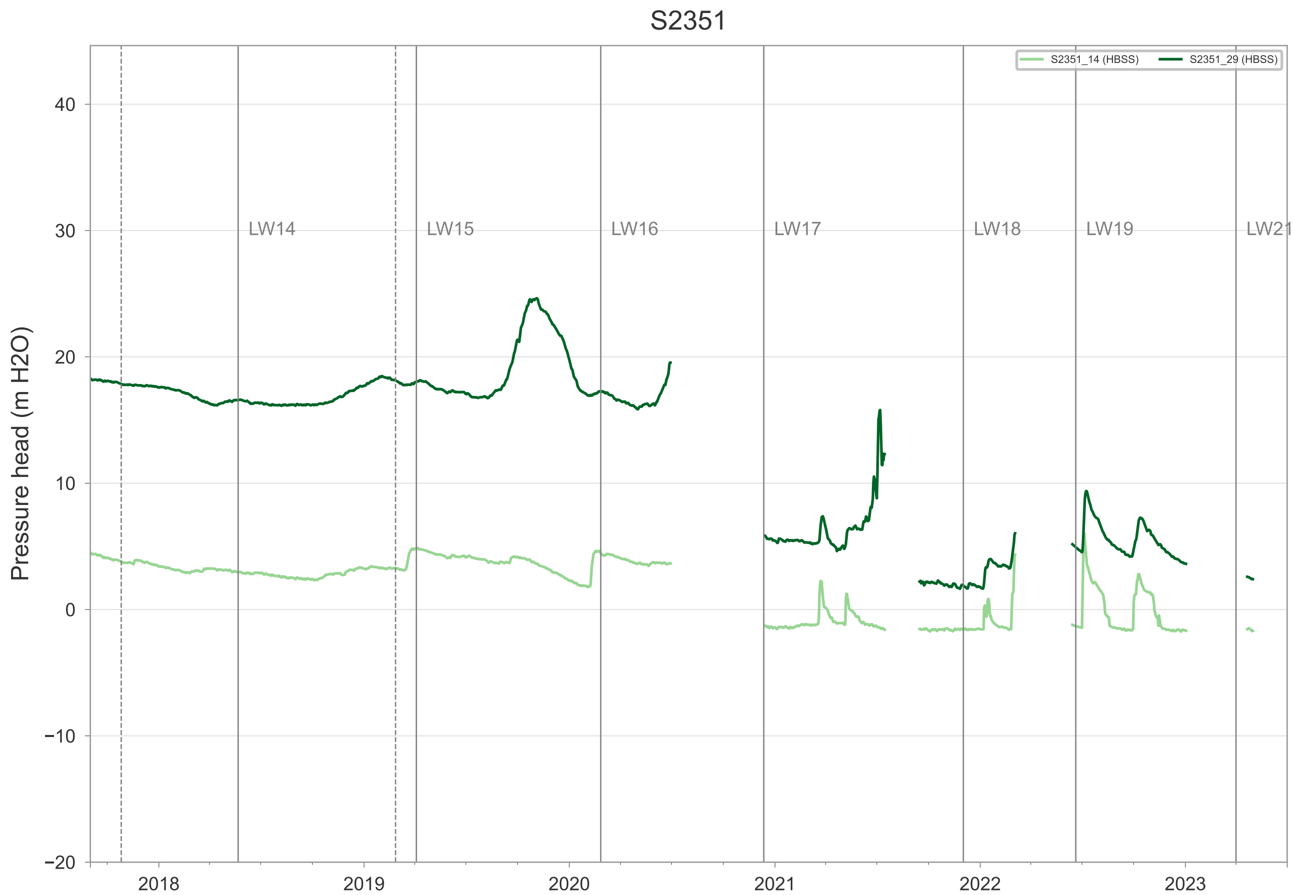



S2348
Piezometric head (m RL)
Ground RL
LW14
LW15
LW16
LW17
S2348_10 (HBSS)
S2348_25 (HBSS)
S2348_40 (HBSS)
S2348_55 (HBSS)
S2348_105 (HBSS)
S2348_145 (HBSS)
S2348_192 (BGSS)
S2348_227.3 (BGSS)
S2348_262.5 (BGSS)
S2348_297.8 (SBSS)
S2348_333 (SBSS)
S2348_376.7 (BUSM)
S2348_403.3 (WWSM)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM

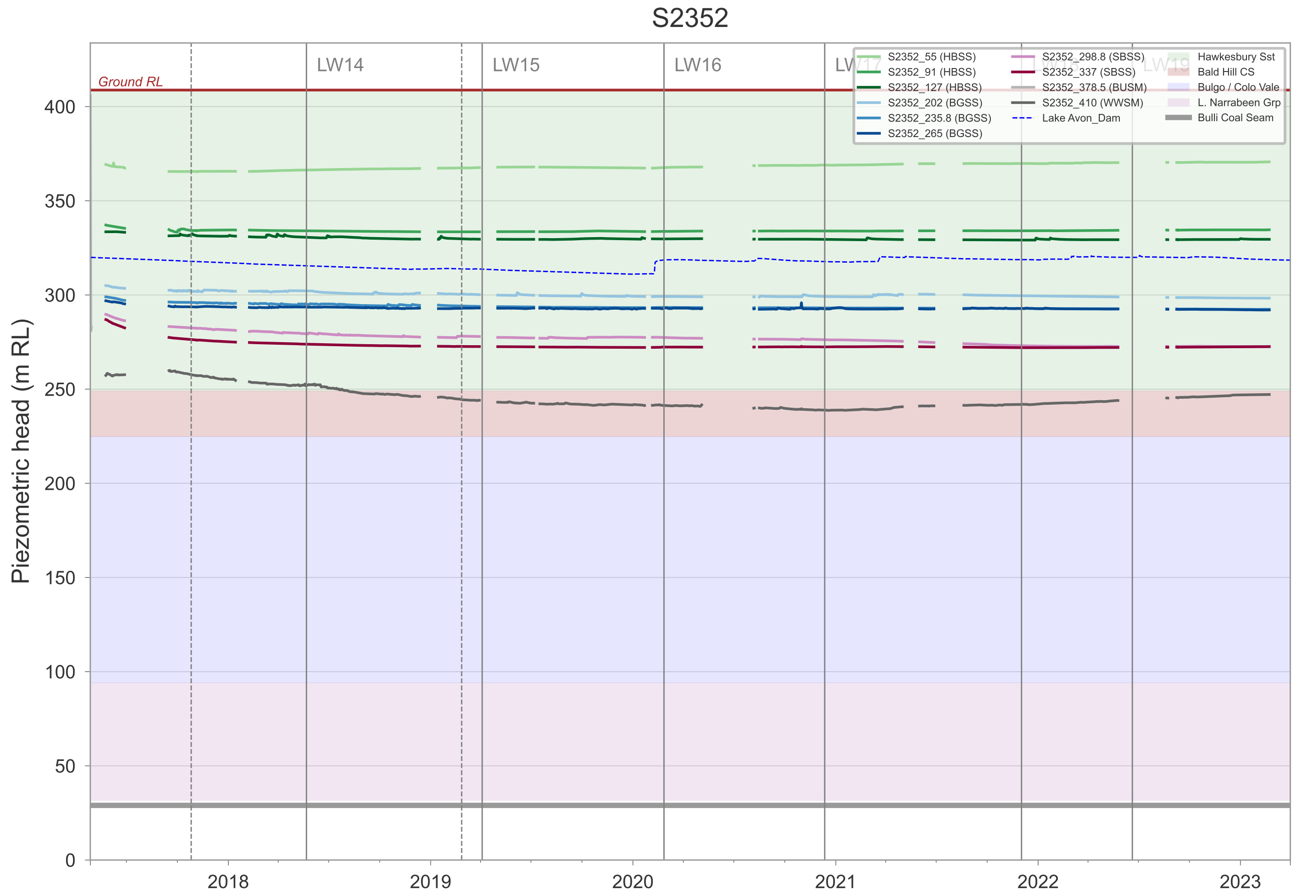

S2348
Pressure head (m H2O)
LW14
LW18
LW19
S2348_10 (HBSS)
S2348_25 (HBSS)
S2348_40 (HBSS)
S2348_55 (HBSS)
S2348_105 (HBSS)
S2348_145 (HBSS)
S2348_192 (BGSS)
S2348_227.3 (BGSS)
S2348_262.5 (BGSS)
S2348_297.8 (SBSS)
S2348_333 (SBSS)
S2348_376.7 (BUSM)
S2348_403.3 (WWSM)

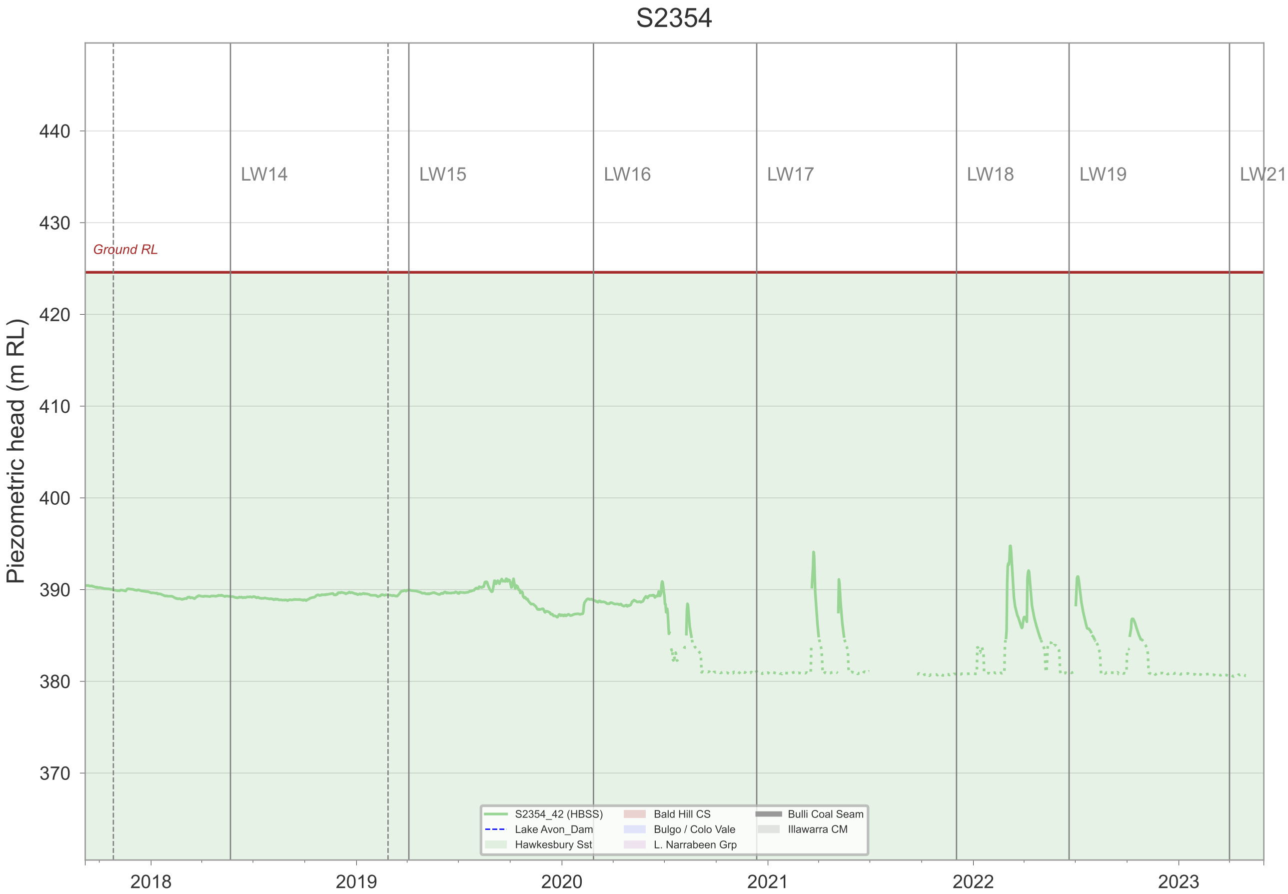
Groundwater hydrographs

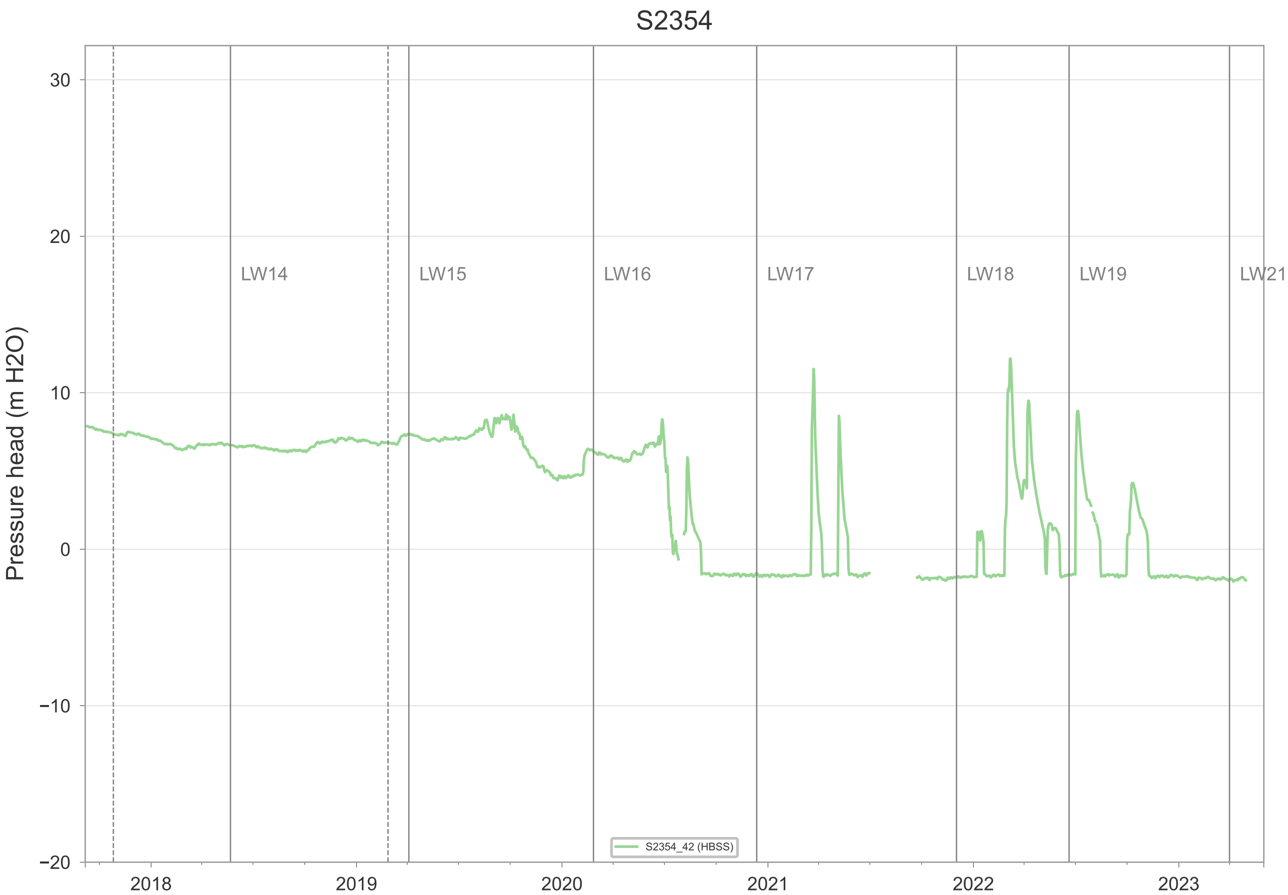


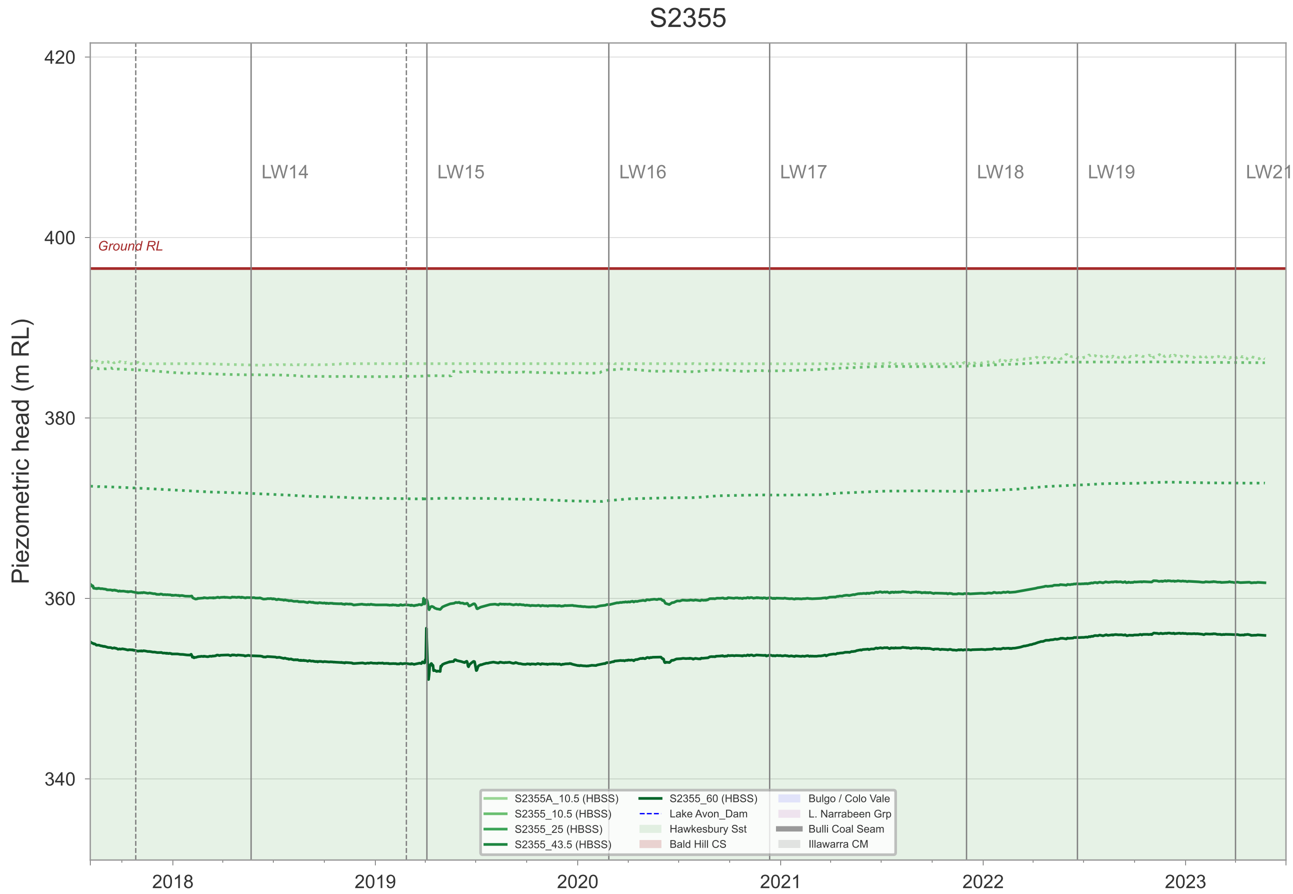


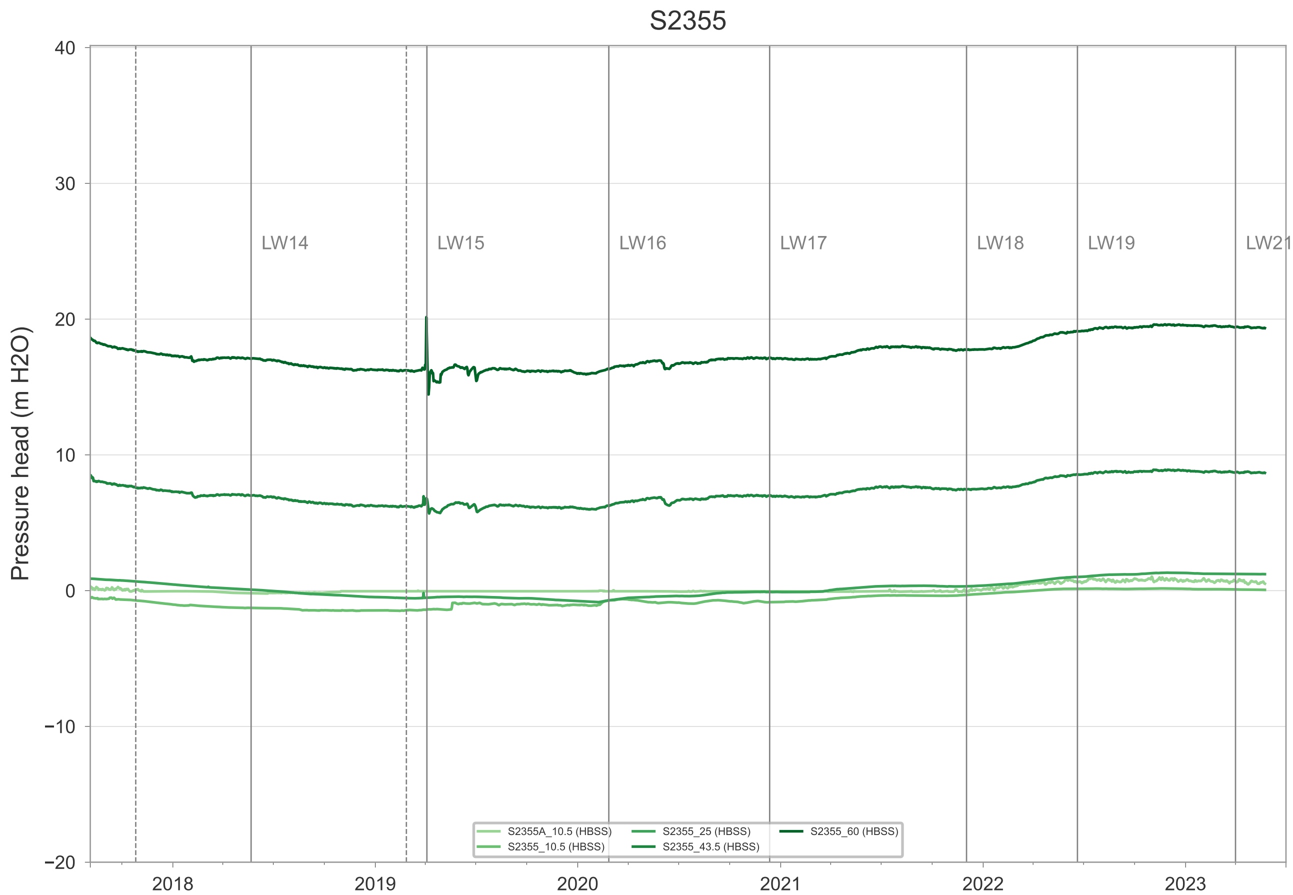
Groundwater hydrographs



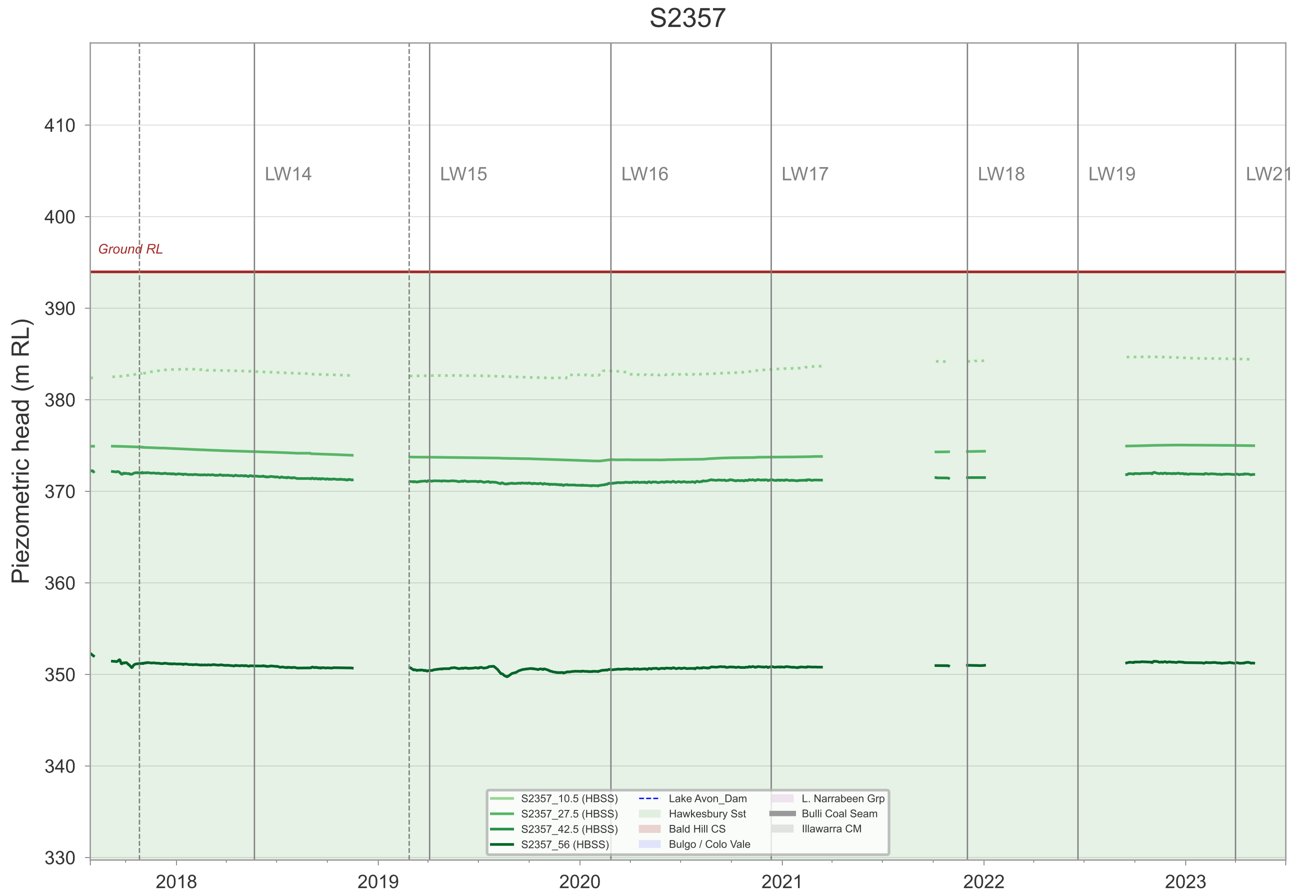

S2354
Piezometric head (m RL)
440
430
420
410
400
390
380
370
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Ground RL
S2354_42 (HBSS)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
2018
2019
2020
2021
2022
2023

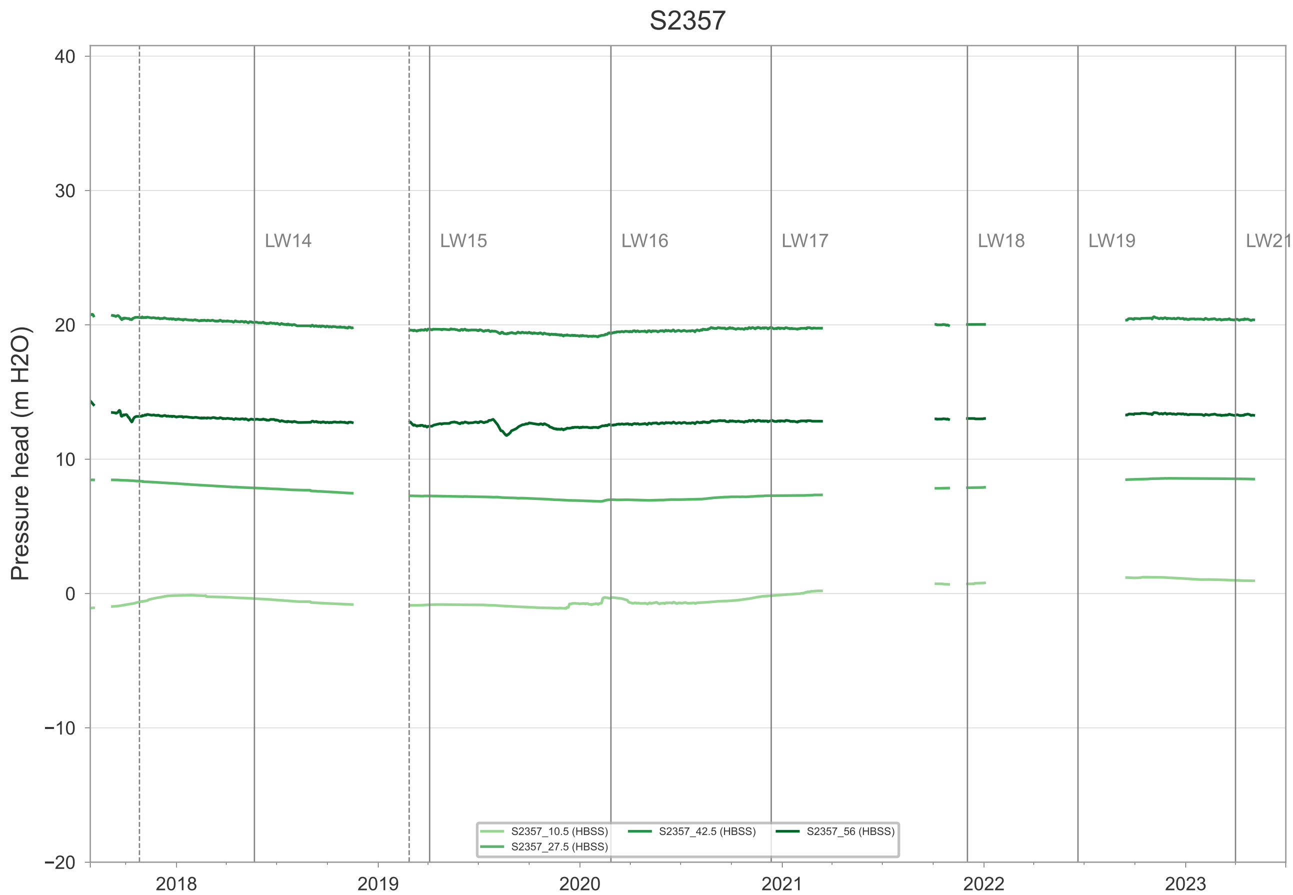

S2354
Pressure head (m H2O)
30
20
10
0
−10
−20
LW14
LW15
LW16
LW17
LW18
LW19
LW21
S2354_42 (HBSS)
2018
2019
2020
2021
2022
2023


S2355
Piezometric head (m RL)
420
400
380
360
340
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Ground RL
S2355A_10.5 (HBSS)
S2355_10.5 (HBSS)
S2355_25 (HBSS)
S2355_43.5 (HBSS)
S2355_60 (HBSS)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
2018
2019
2020
2021
2022
2023

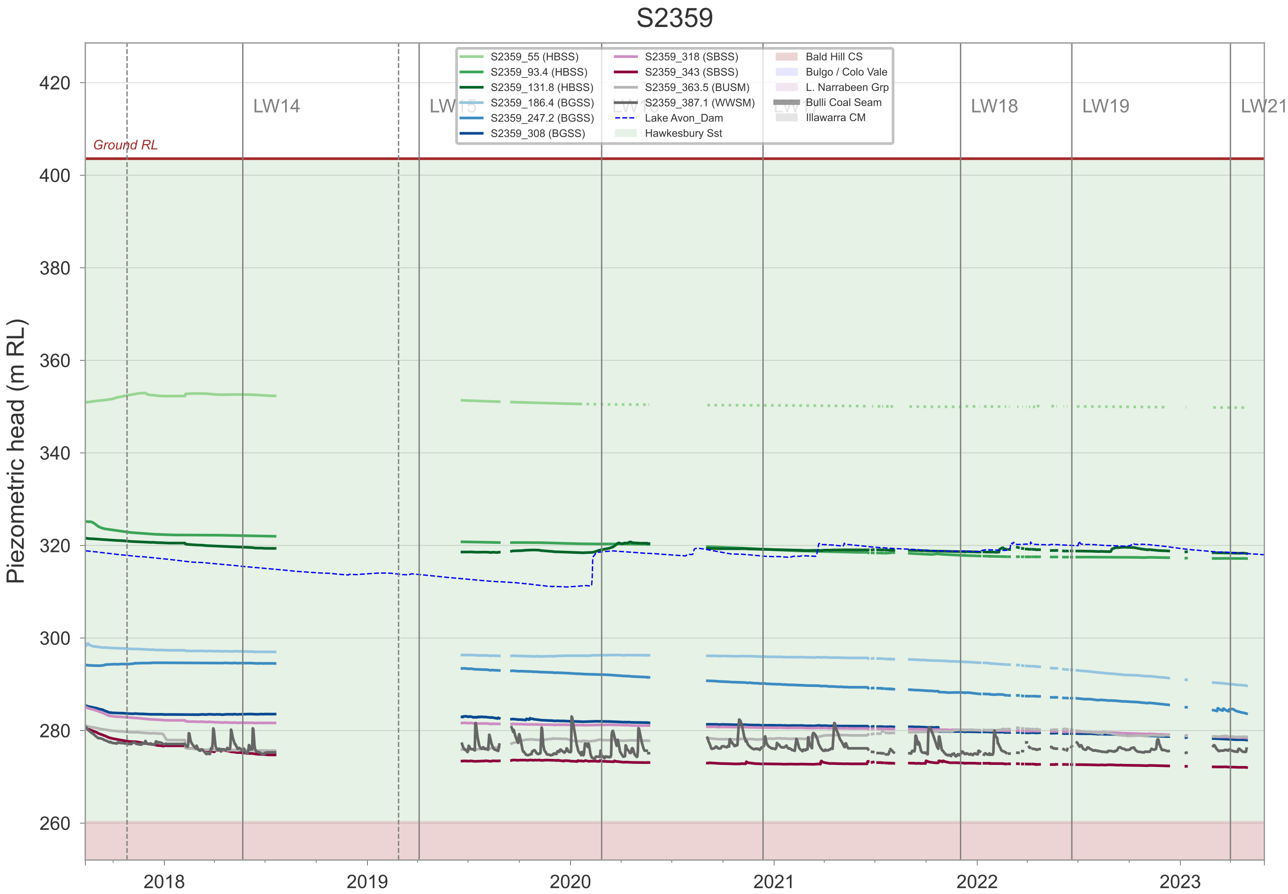

S2355
Pressure head (m H2O)
40
30
20
10
0
−10
−20
LW14
LW15
LW16
LW17
LW18
LW19
LW21
S2355A_10.5 (HBSS)
S2355_10.5 (HBSS)
S2355_25 (HBSS)
S2355_43.5 (HBSS)
S2355_60 (HBSS)
2018
2019
2020
2021
2022
2023

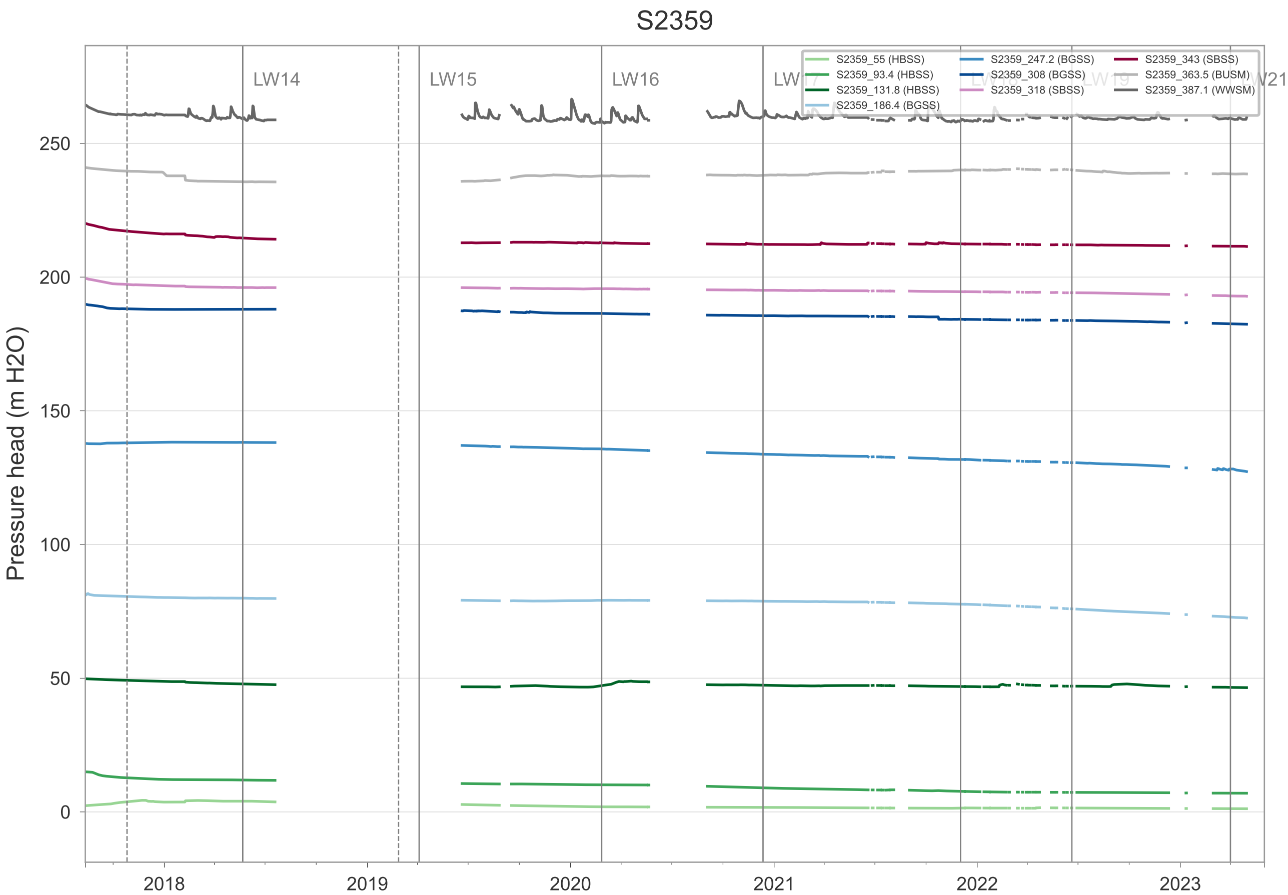
Groundwater hydrographs

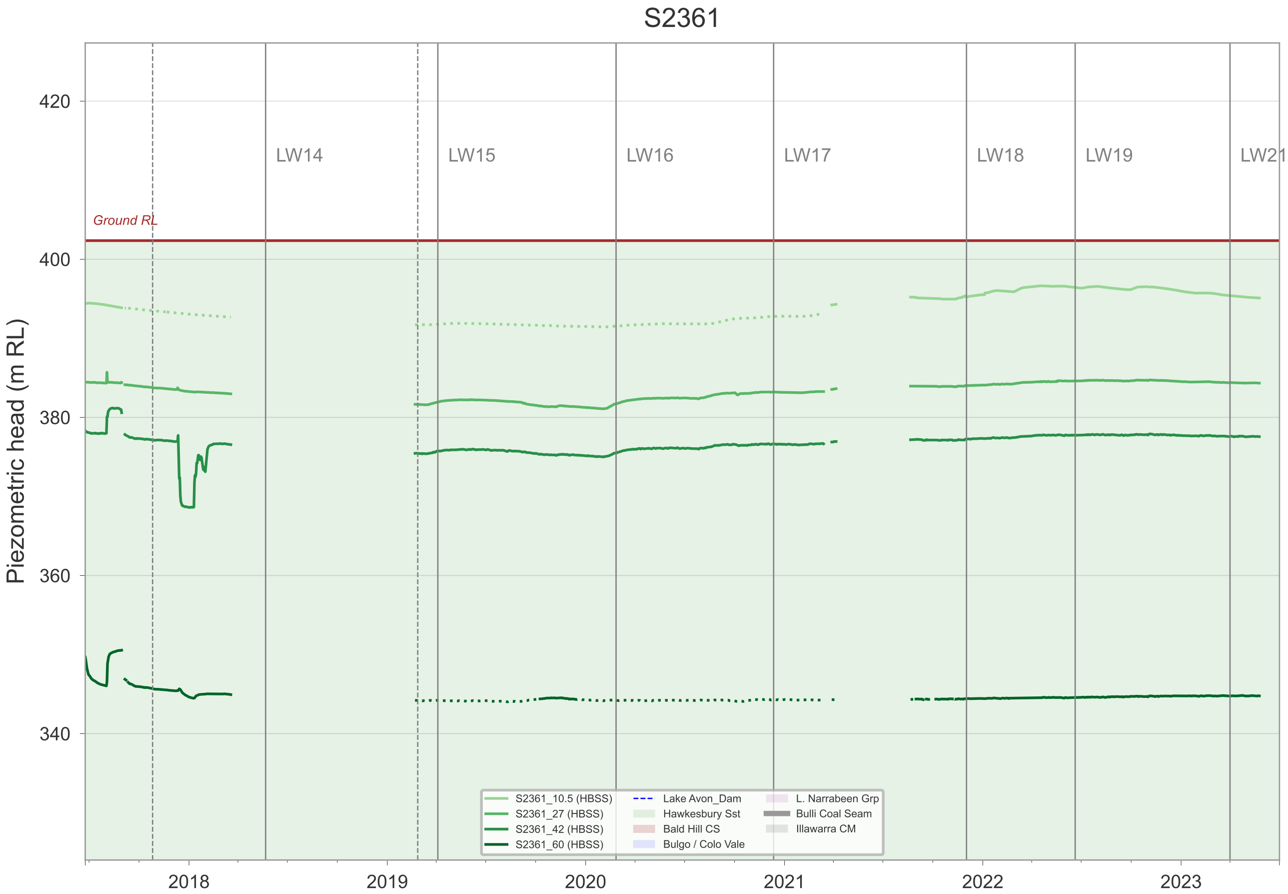


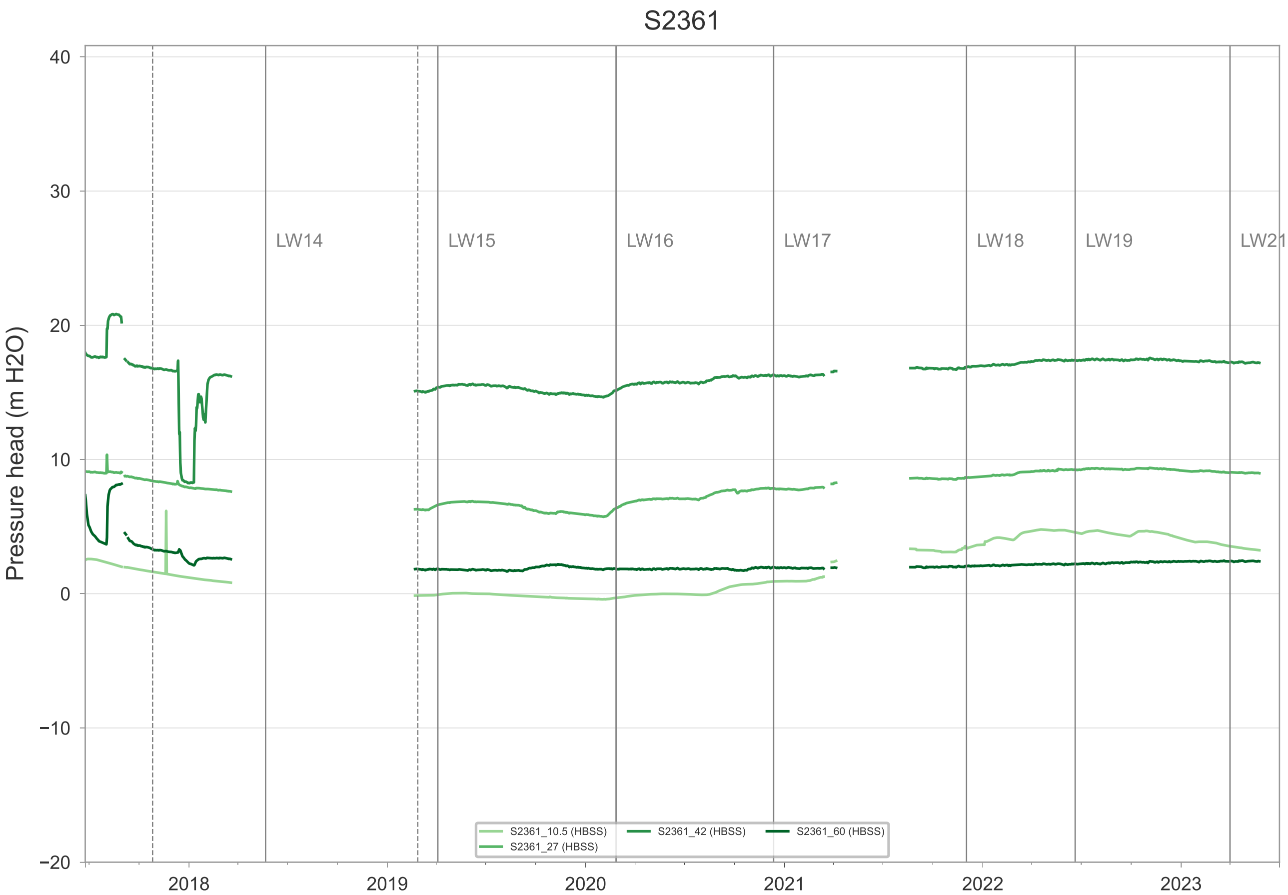


Groundwater hydrographs

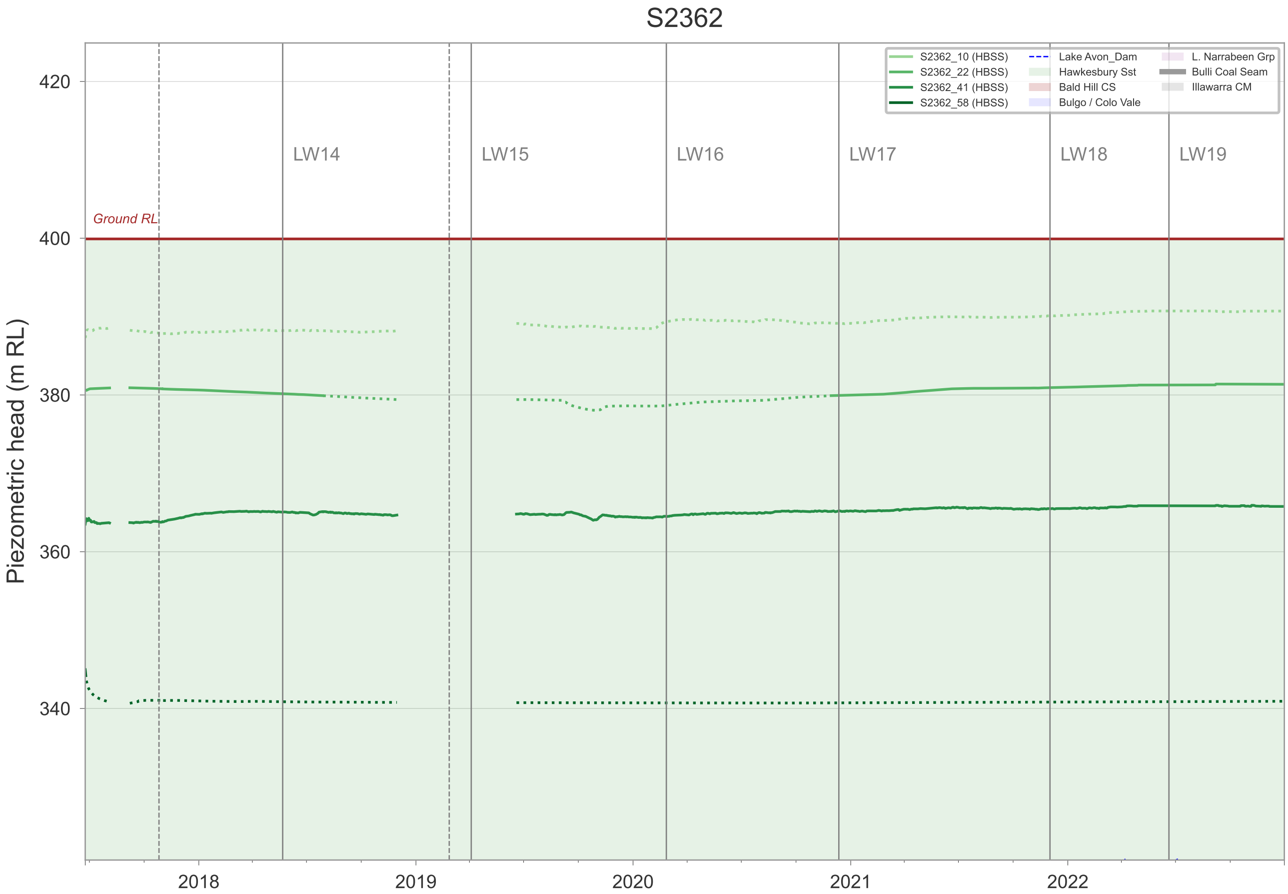


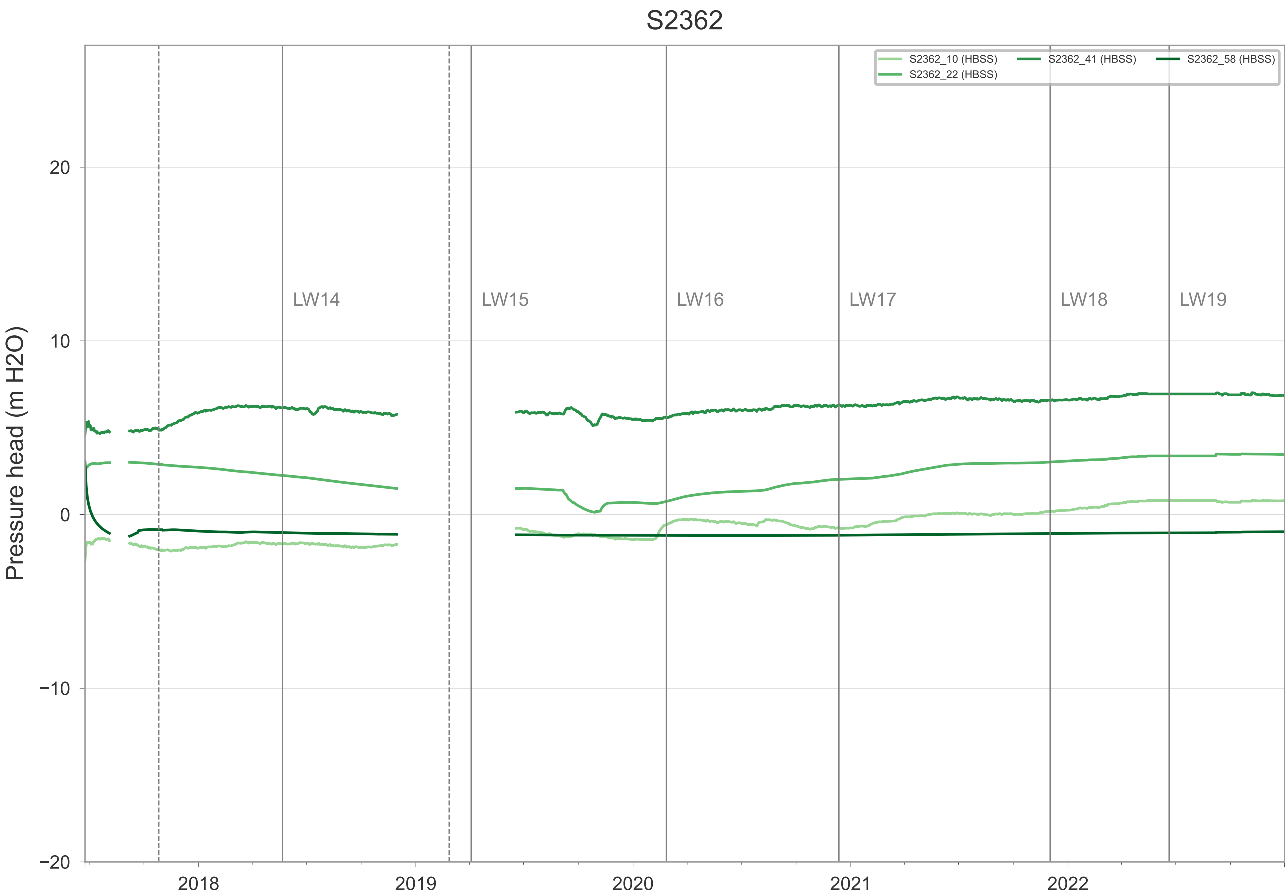



S2361
Piezometric head (m RL)
420
400
380
360
340
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Ground RL
2018
2019
2020
2021
2022
2023
S2361_10.5 (HBSS)
S2361_27 (HBSS)
S2361_42 (HBSS)
S2361_60 (HBSS)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM

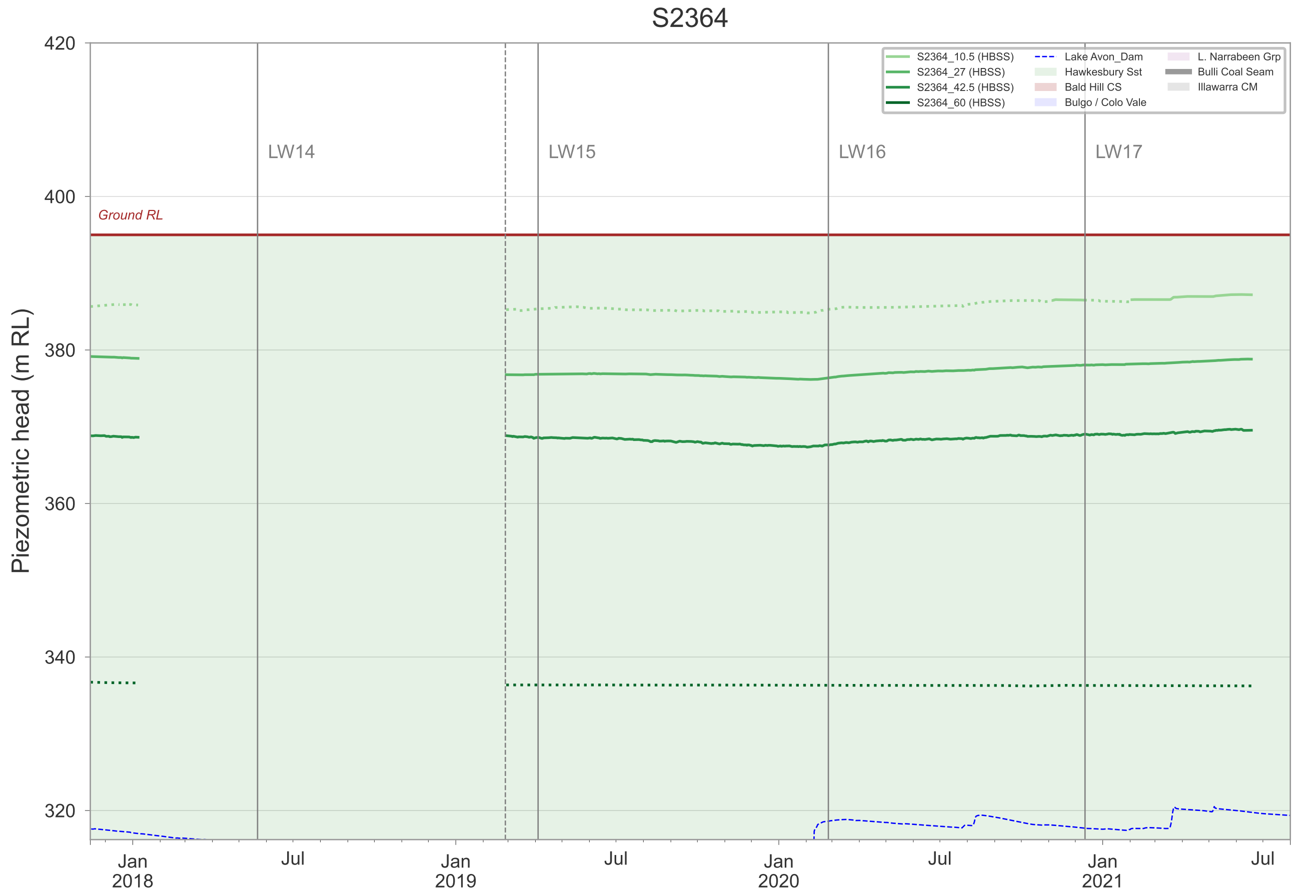

S2361
Pressure head (m H2O)
40
30
20
10
0
−10
−20
LW14
LW15
LW16
LW17
LW18
LW19
LW21
2018
2019
2020
2021
2022
2023
S2361_10.5 (HBSS)
S2361_27 (HBSS)
S2361_42 (HBSS)
S2361_60 (HBSS)

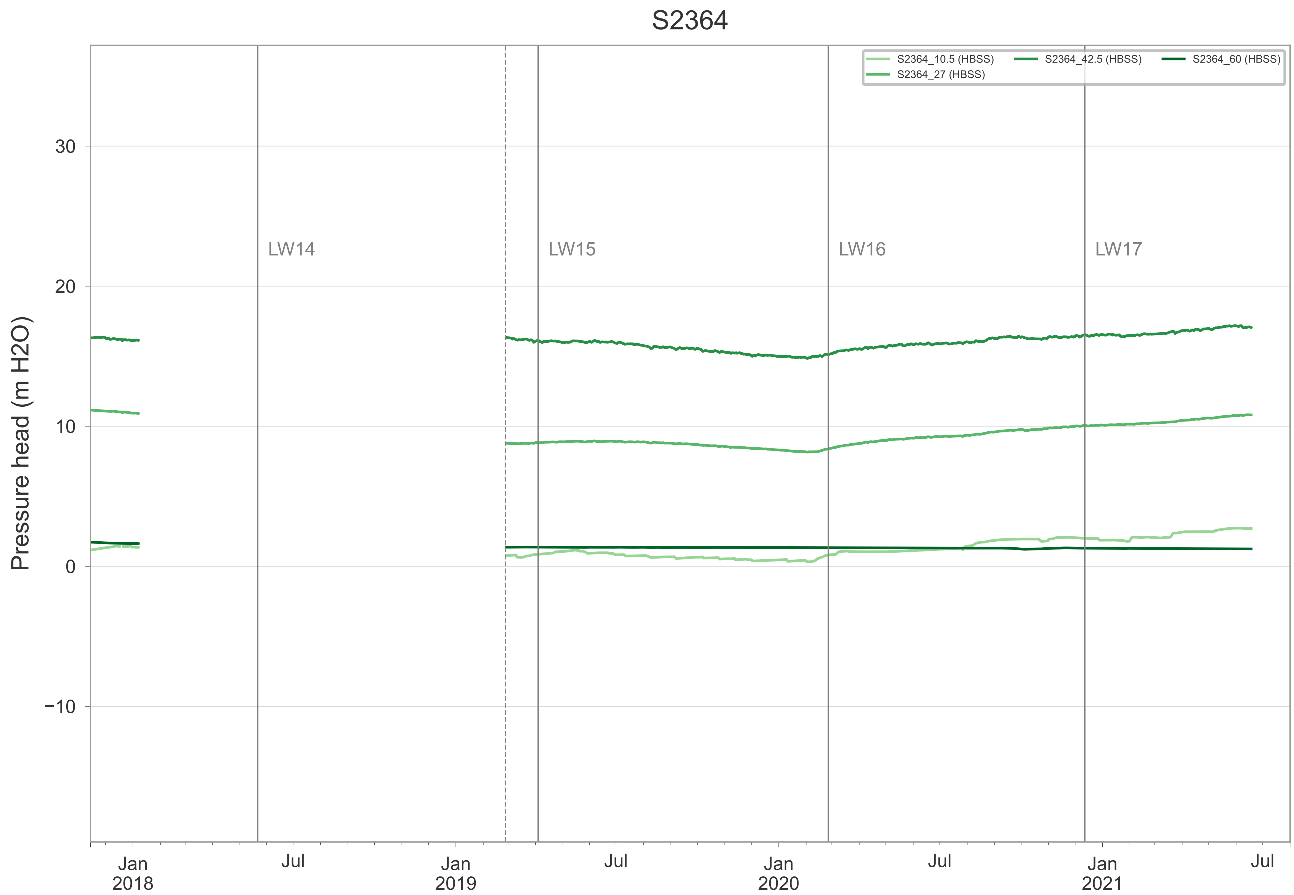
Groundwater hydrographs

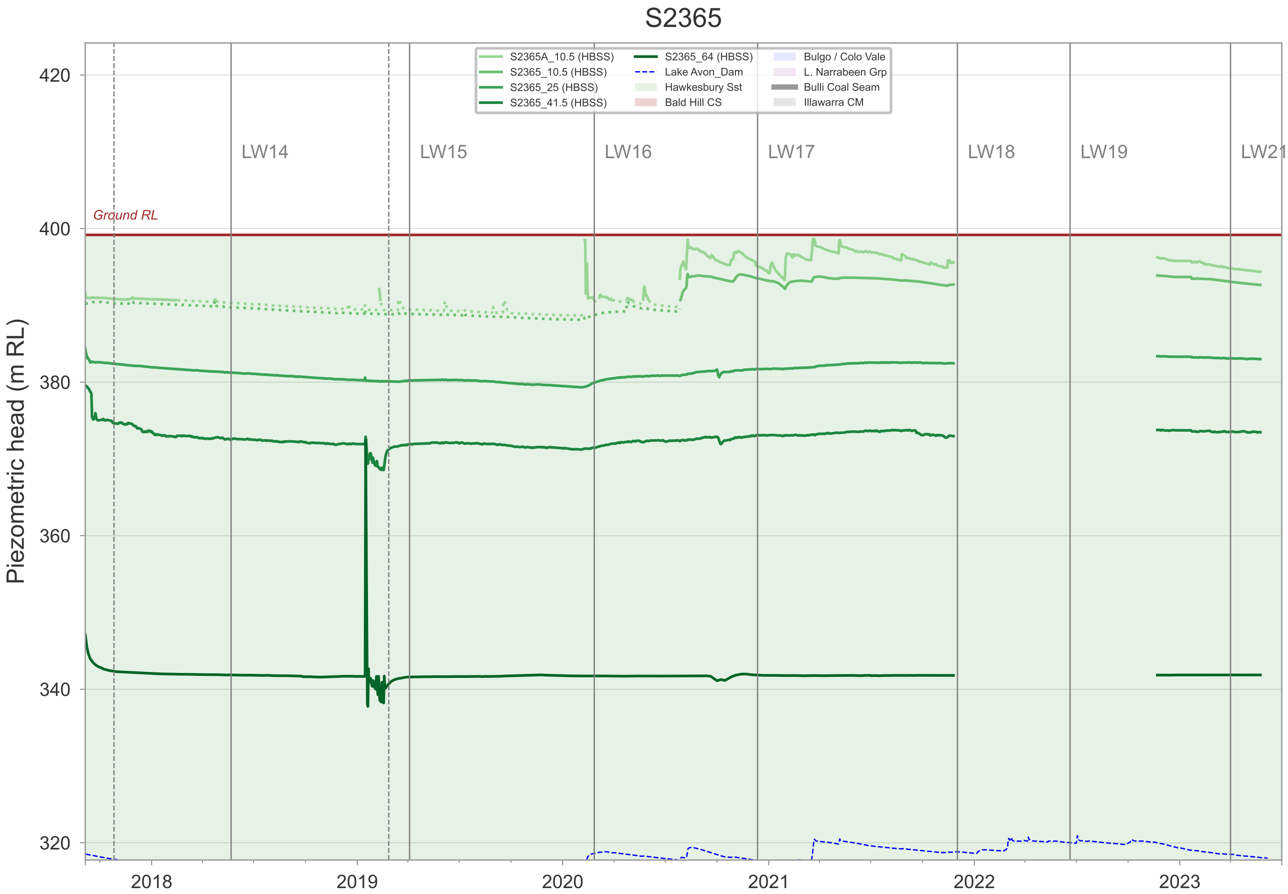


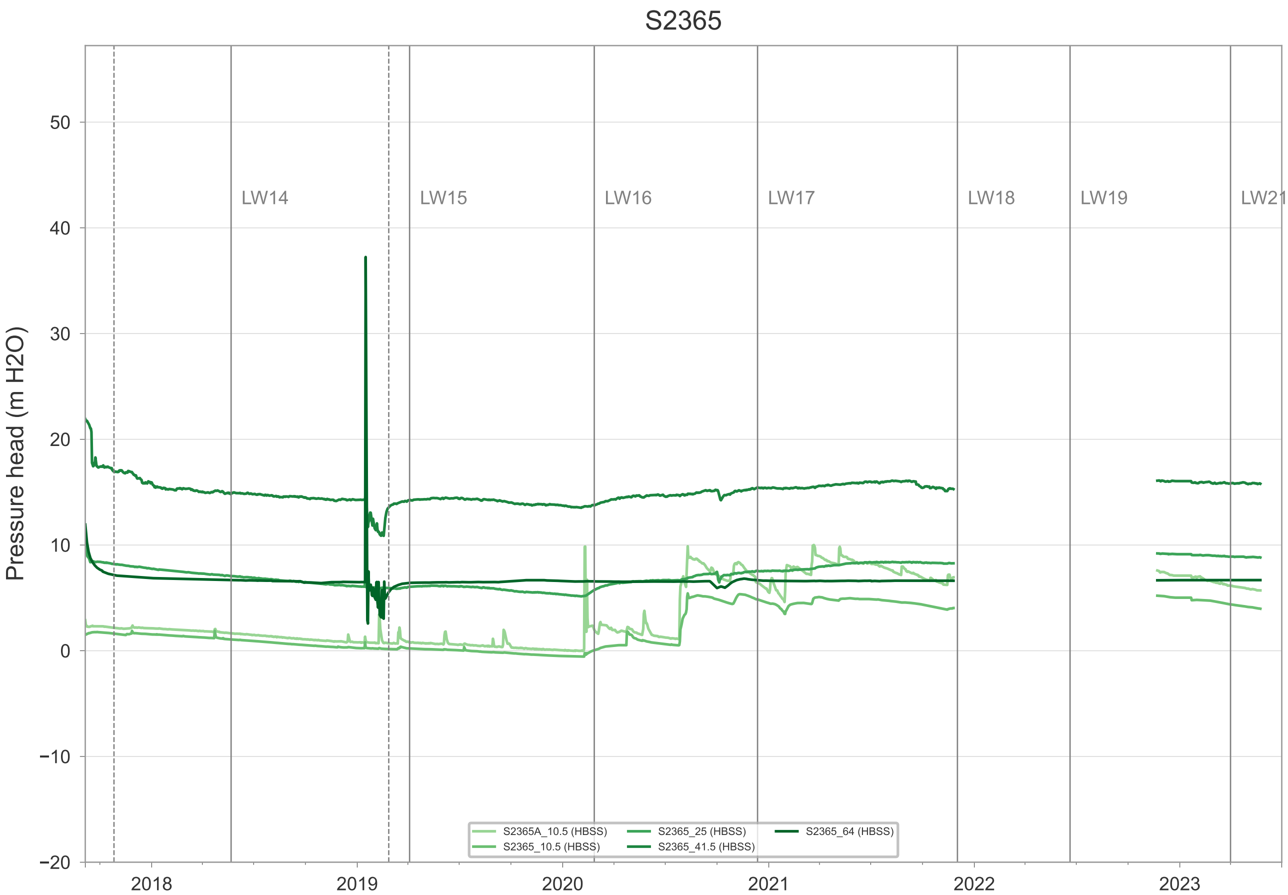


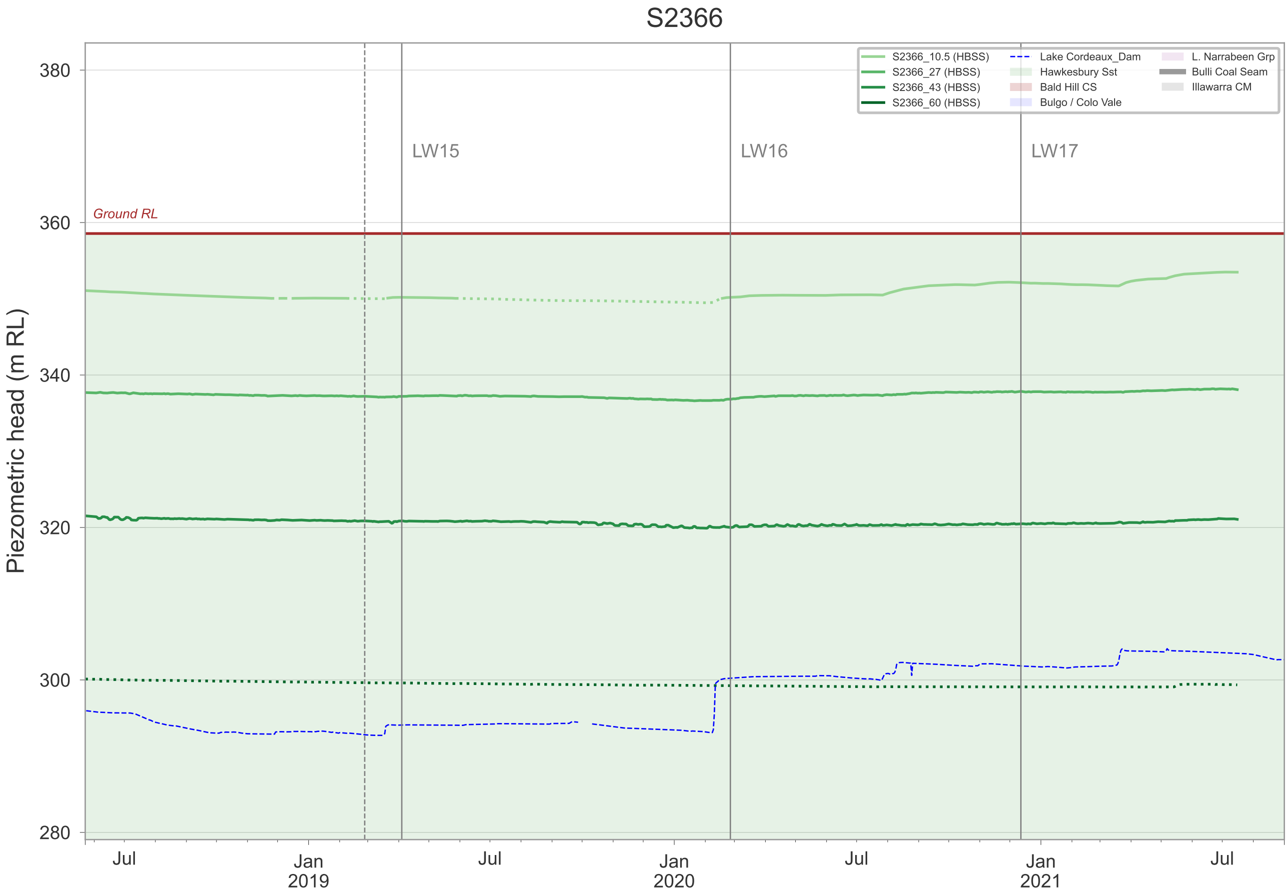
Groundwater hydrographs

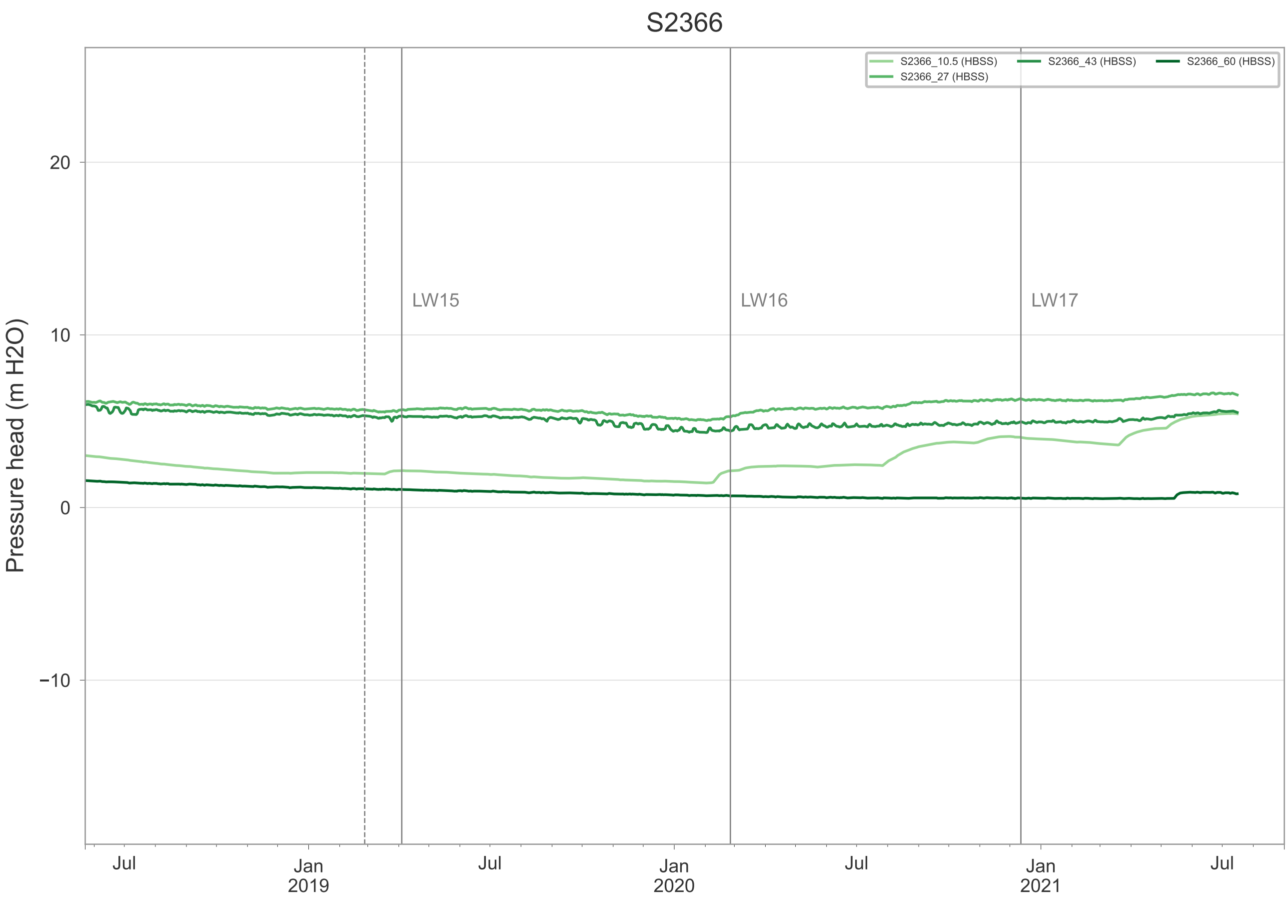


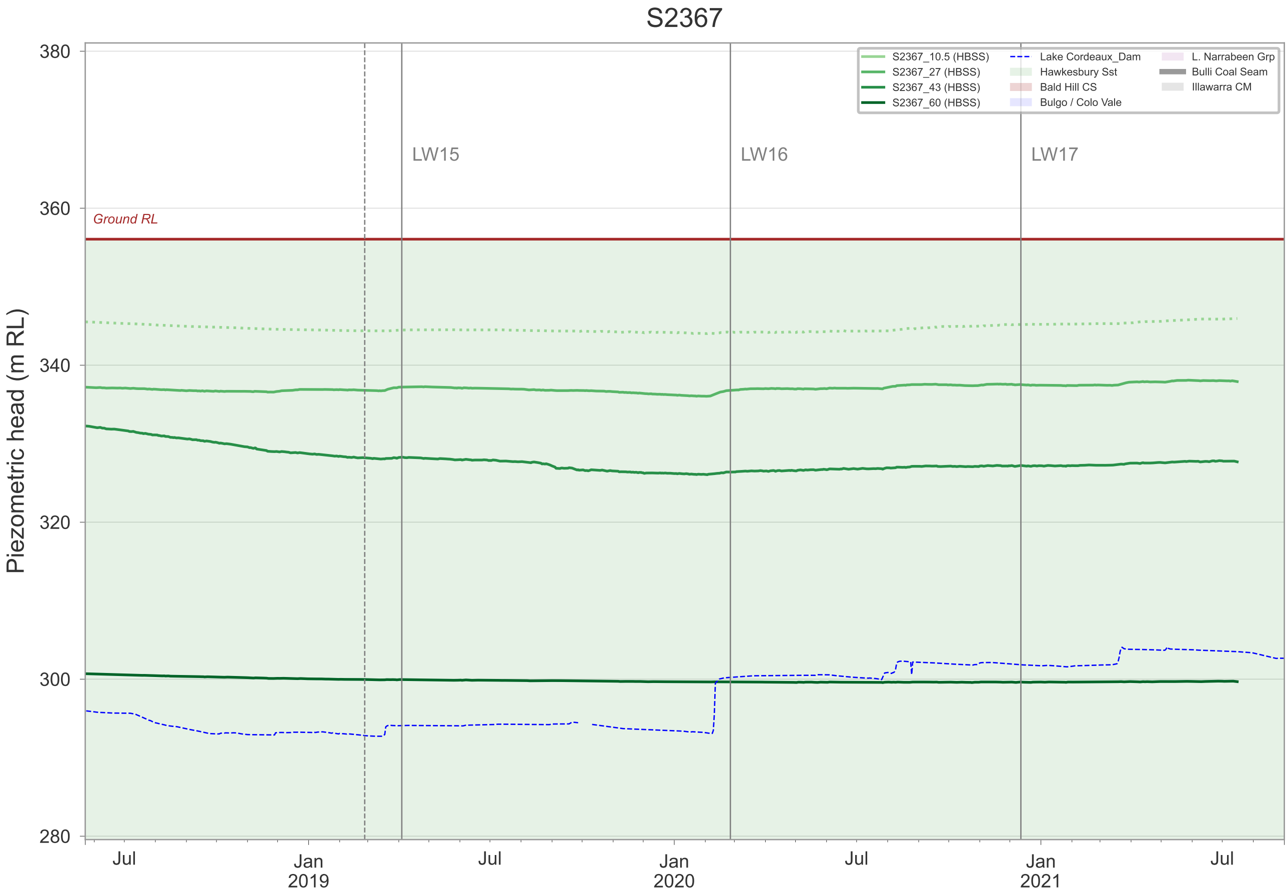


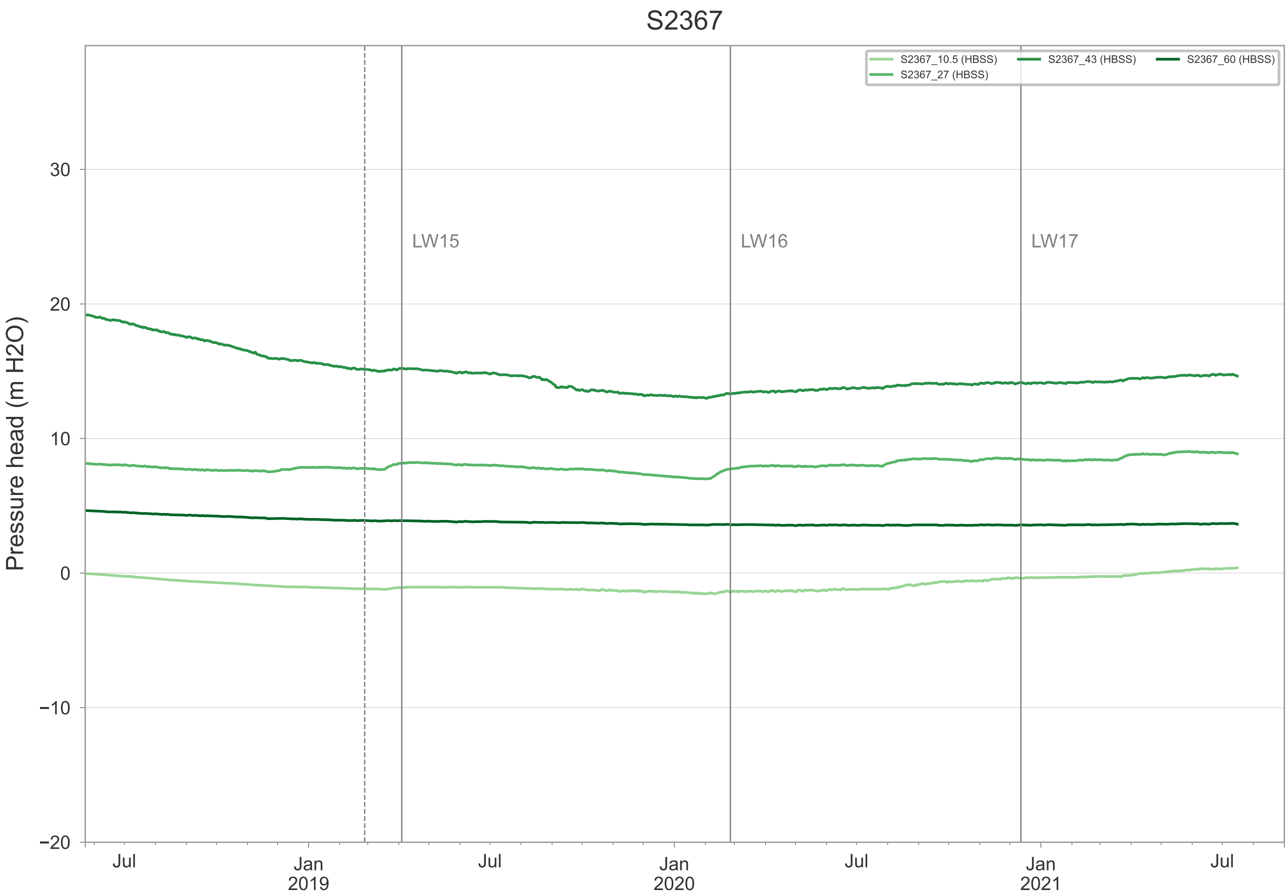

S2365
S2365A_10.5 (HBSS)
S2365_10.5 (HBSS)
S2365_25 (HBSS)
S2365_41.5 (HBSS)
S2365_64 (HBSS)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Ground RL
Piezometric head (m RL)
420
400
380
360
340
320
2018
2019
2020
2021
2022
2023


S2365
LW14
LW15
LW16
LW17
LW18
LW19
LW21
Pressure head (m H2O)
50
40
30
20
10
0
−10
−20
S2365A_10.5 (HBSS)
S2365_10.5 (HBSS)
S2365_25 (HBSS)
S2365_41.5 (HBSS)
S2365_64 (HBSS)
2018
2019
2020
2021
2022
2023

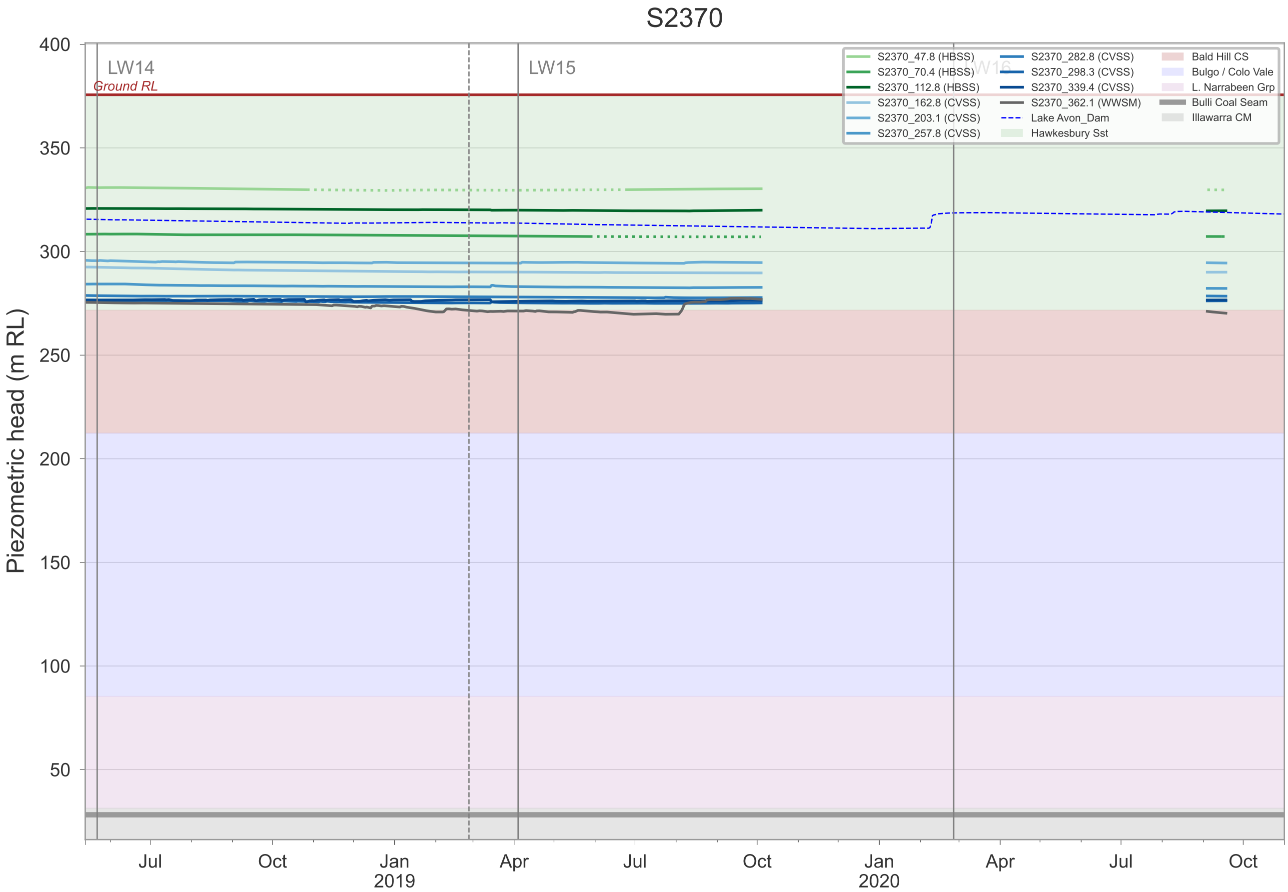

S2366
S2366_10.5 (HBSS)
S2366_27 (HBSS)
S2366_43 (HBSS)
S2366_60 (HBSS)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
LW15
LW16
LW17
Ground RL
Piezometric head (m RL)
380
360
340
320
300
280
Jul
Jan
2019
Jul
Jan
2020
Jul
Jan
2021
Jul

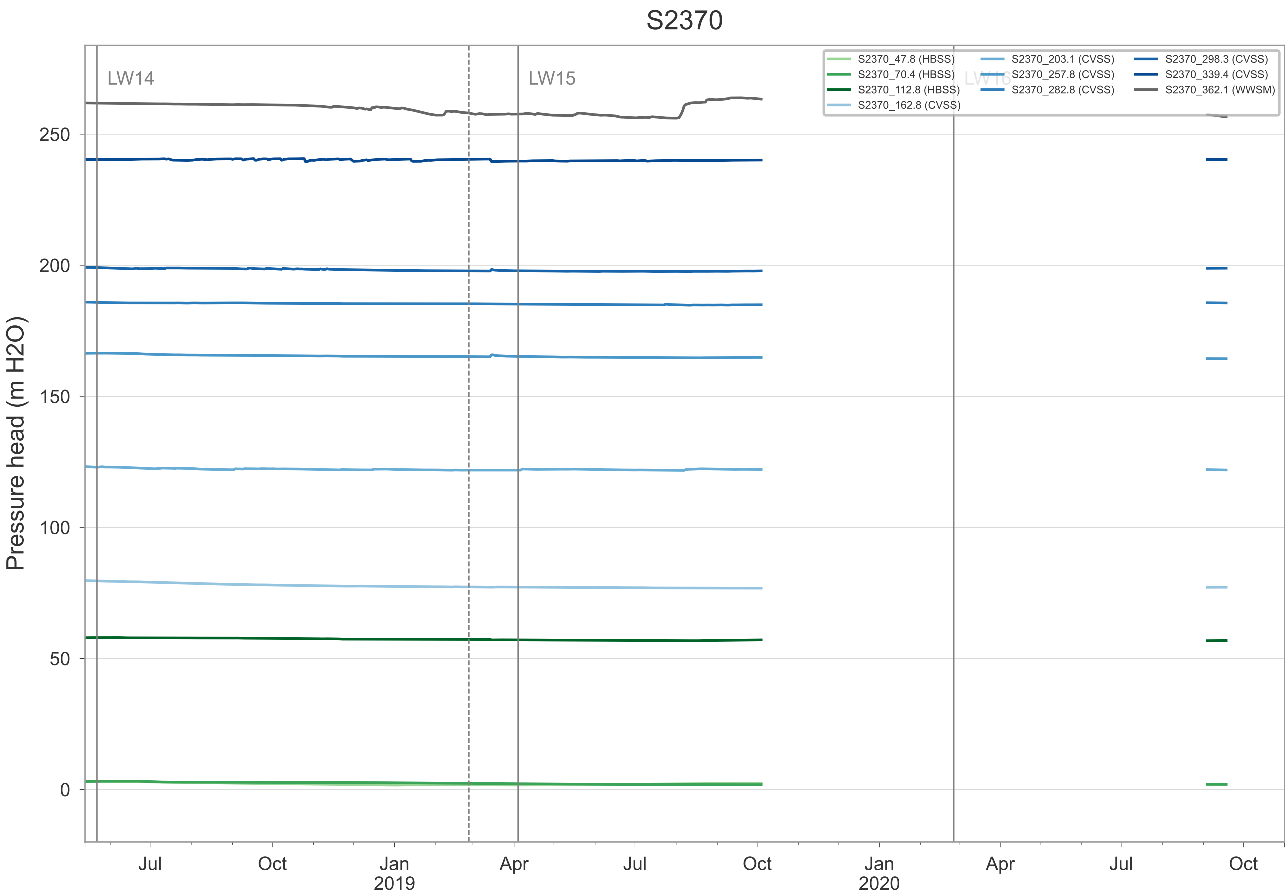

S2366
S2366_10.5 (HBSS)
S2366_27 (HBSS)
S2366_43 (HBSS)
S2366_60 (HBSS)
LW15
LW16
LW17
Pressure head (m H2O)
20
10
0
−10
Jul
Jan
2019
Jul
Jan
2020
Jul
Jan
2021
Jul


S2367
Piezometric head (m RL)
380
360
340
320
300
280
Ground RL
LW15
LW16
LW17
S2367_10.5 (HBSS)
S2367_27 (HBSS)
S2367_43 (HBSS)
S2367_60 (HBSS)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Jul
Jan 2019
Jul
Jan 2020
Jul
Jan 2021
Jul

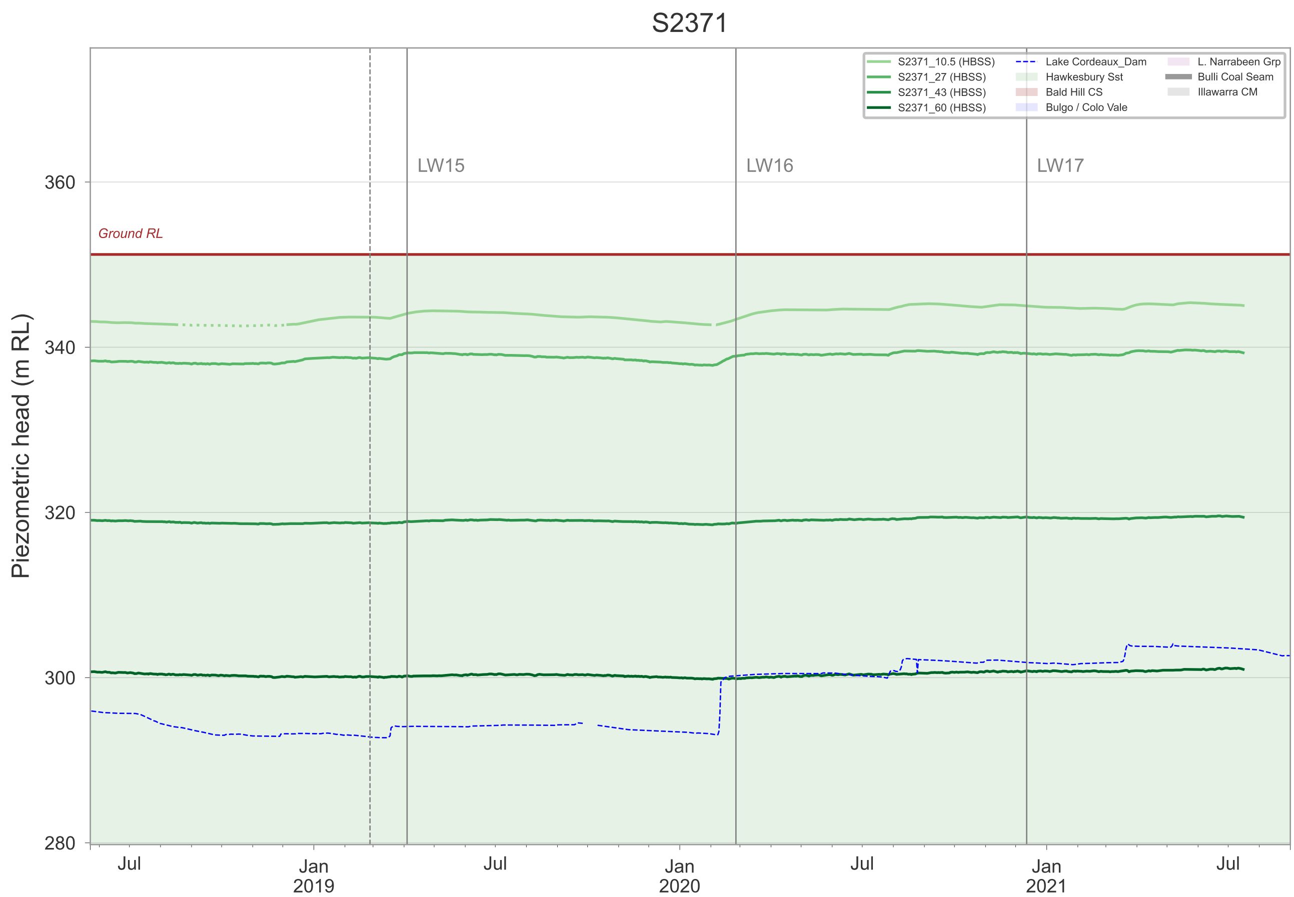

S2367
Pressure head (m H2O)
30
20
10
0
−10
−20
LW15
LW16
LW17
S2367_10.5 (HBSS)
S2367_27 (HBSS)
S2367_43 (HBSS)
S2367_60 (HBSS)
Jul
Jan 2019
Jul
Jan 2020
Jul
Jan 2021
Jul

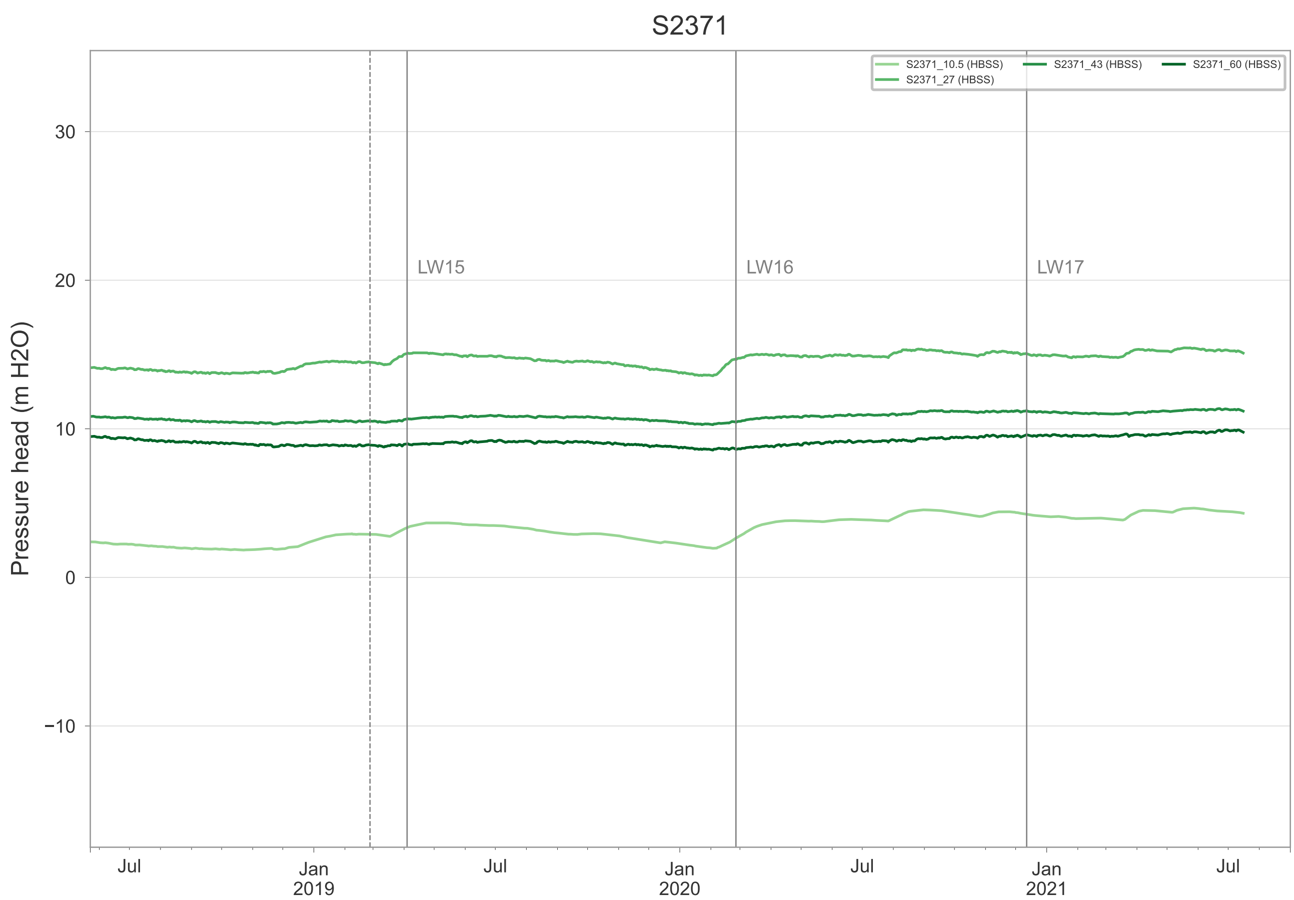
Groundwater hydrographs

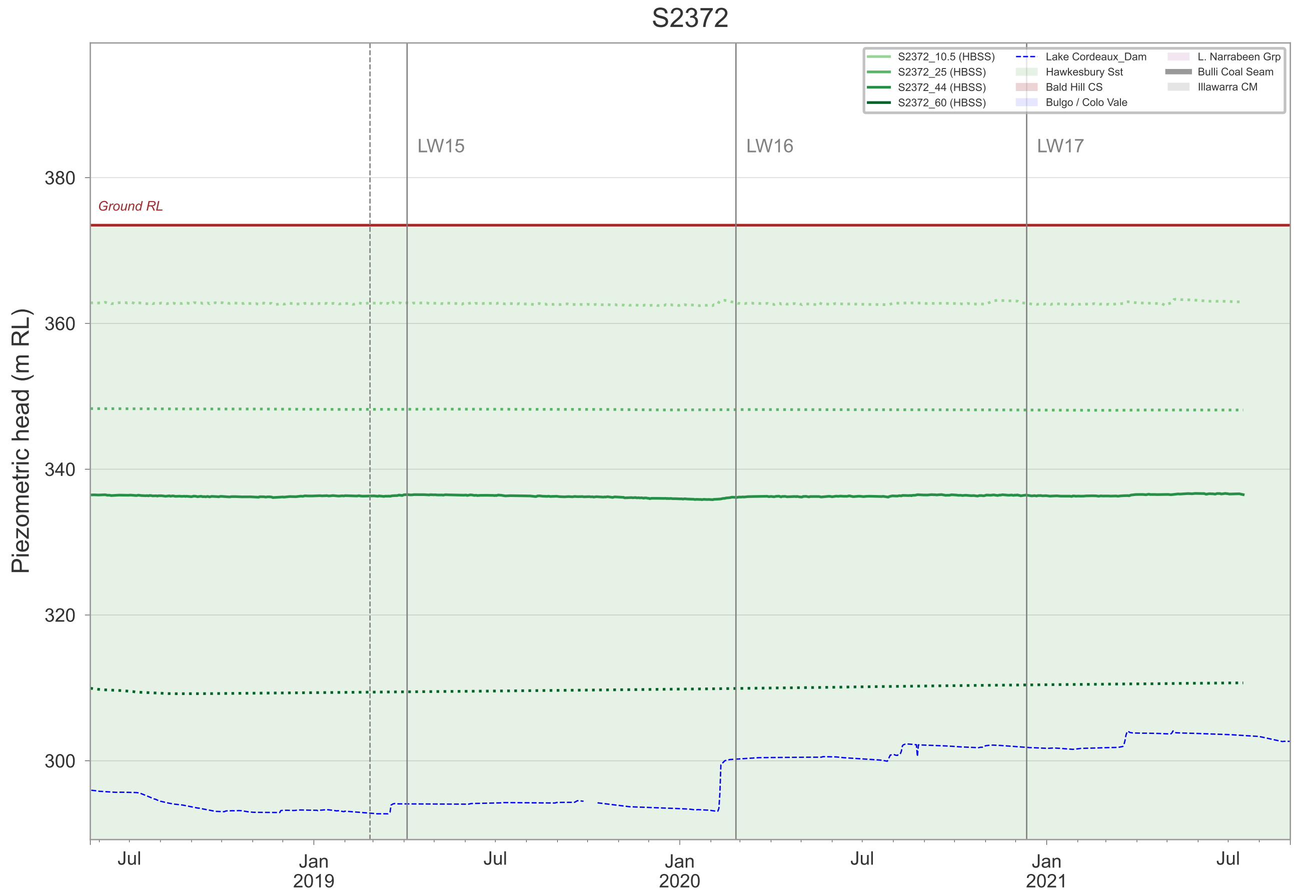


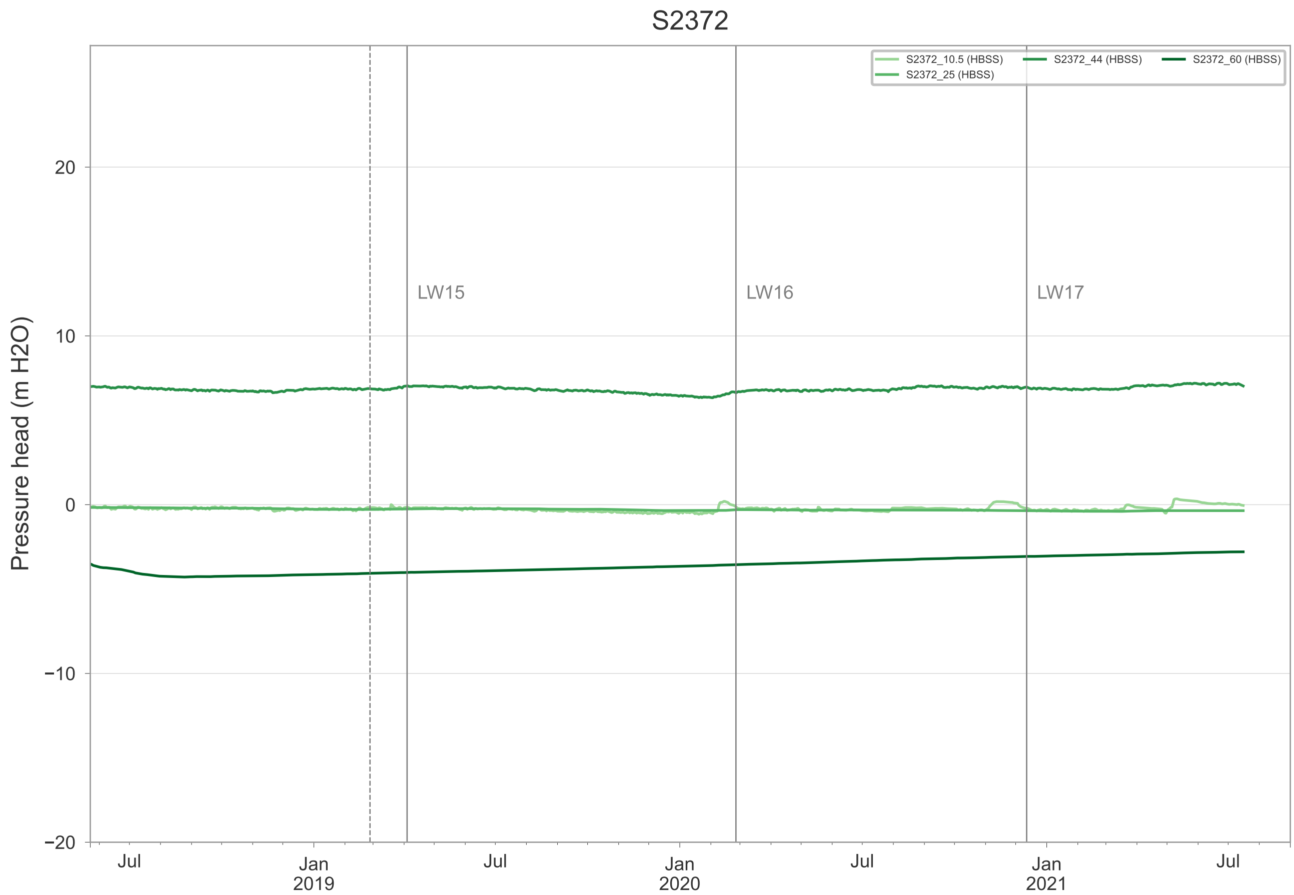


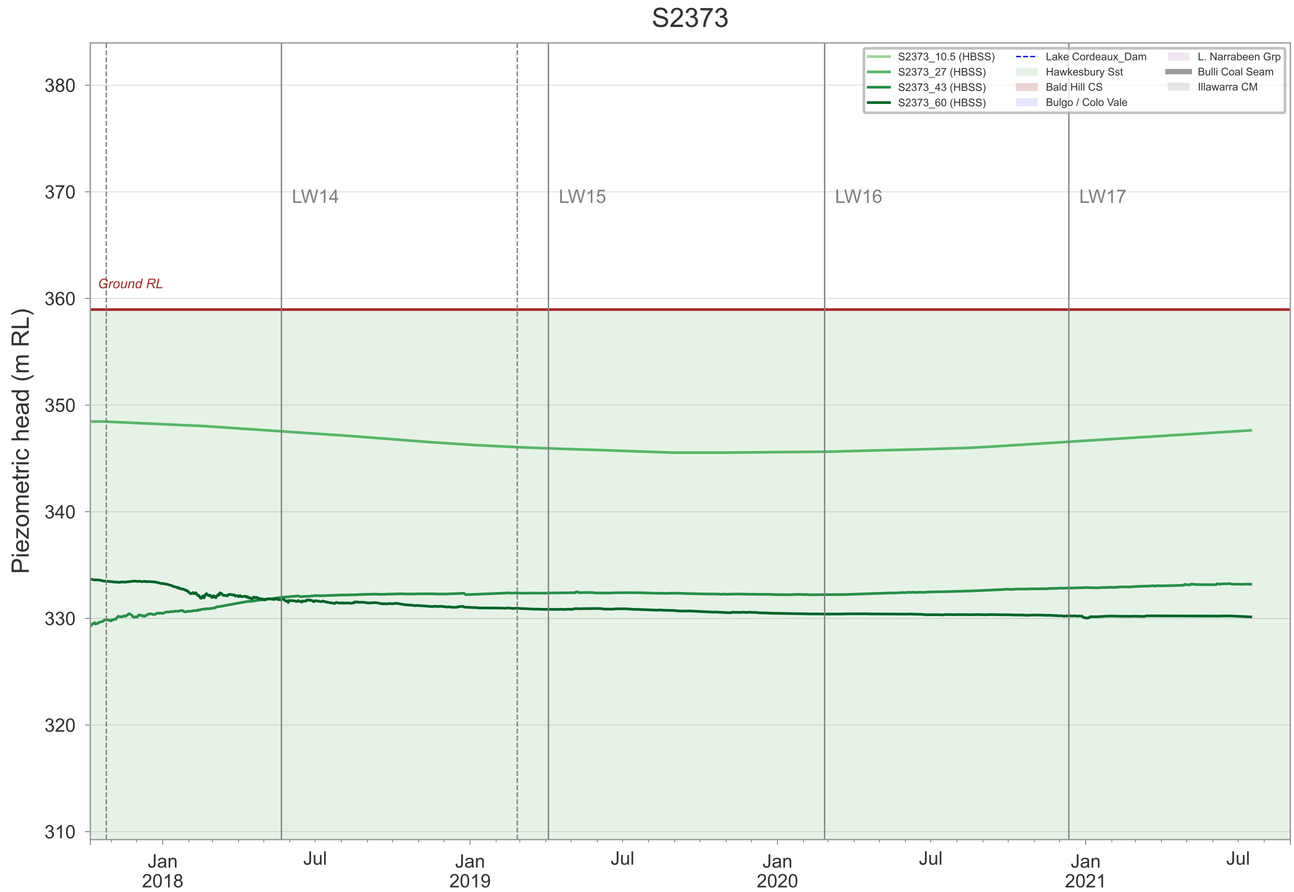
Groundwater hydrographs

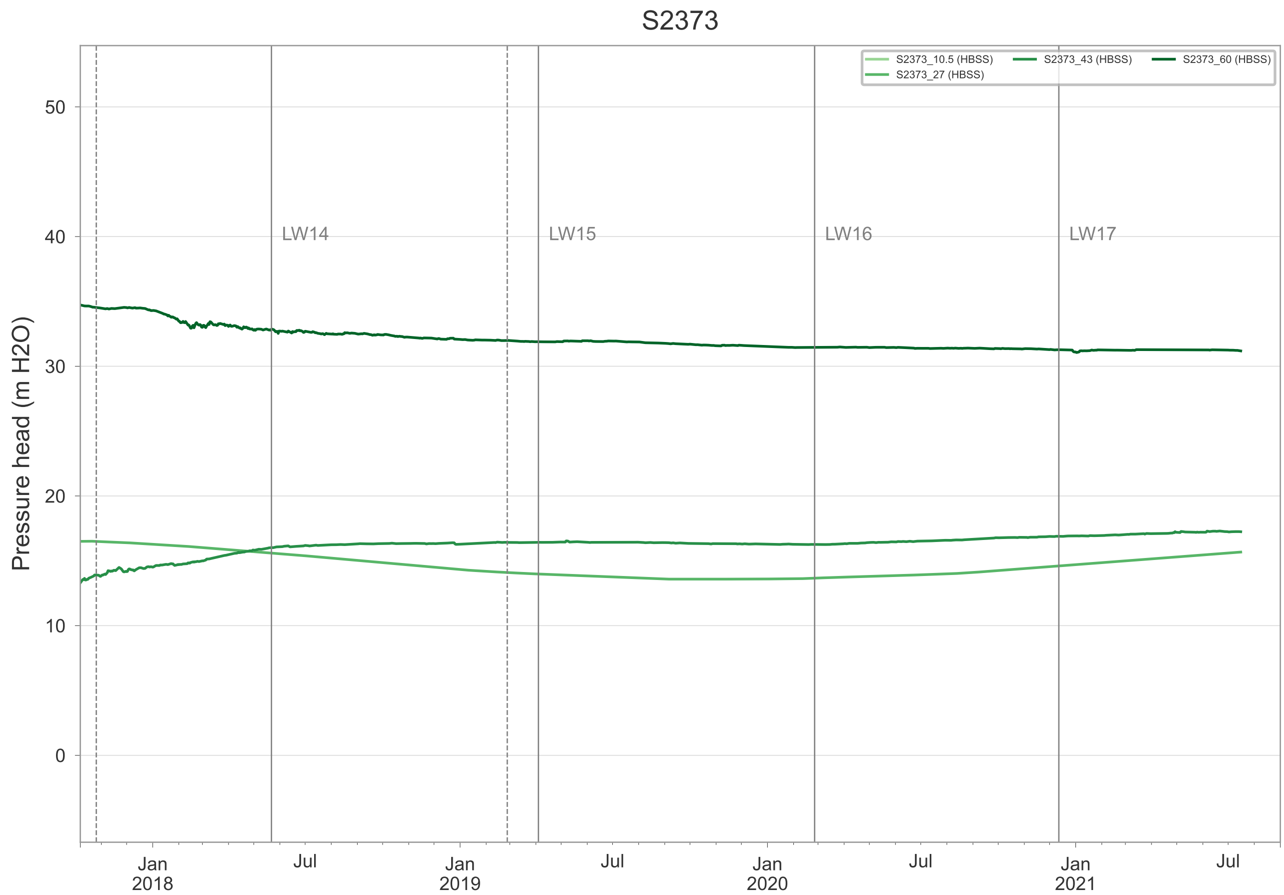




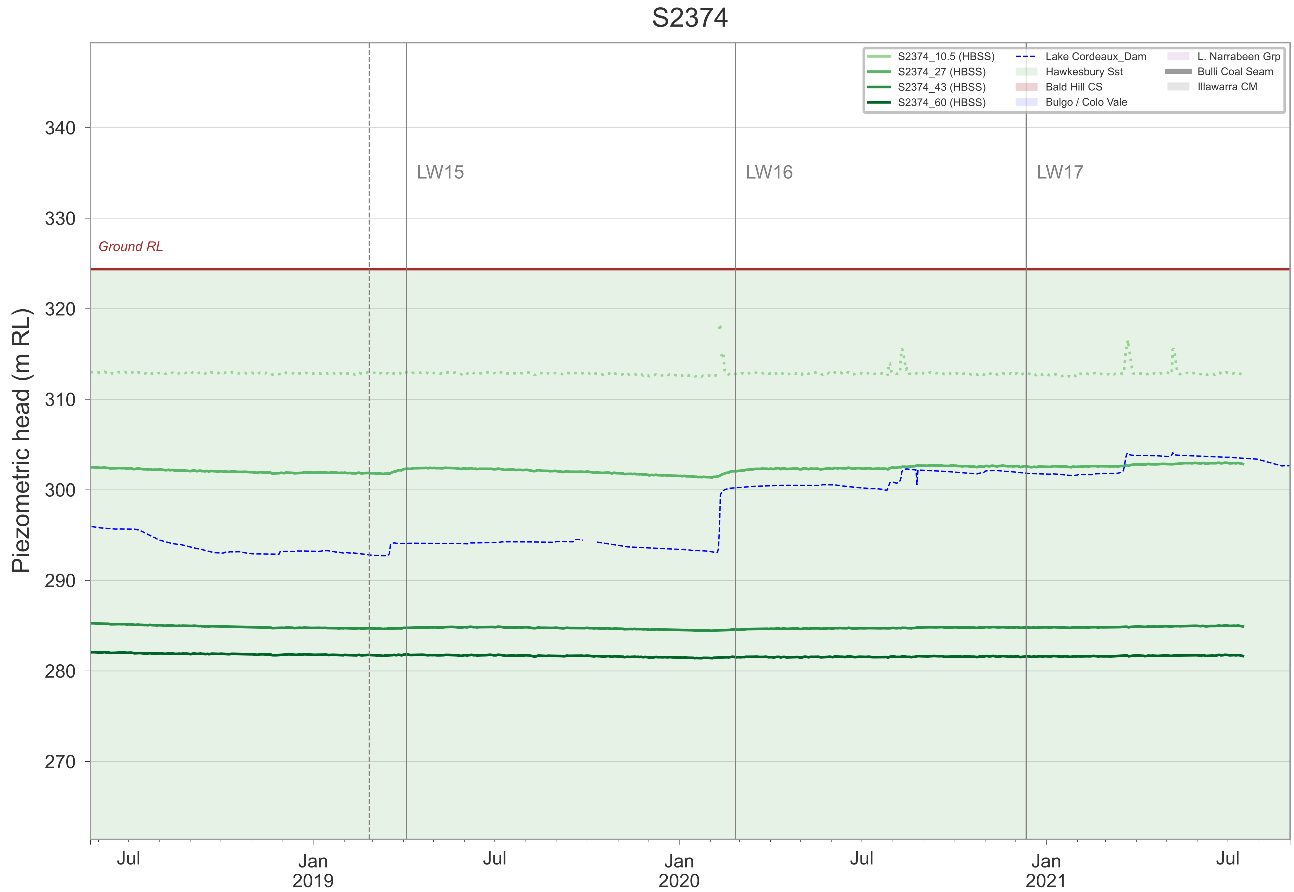

S2372
S2372_10.5 (HBSS)
S2372_25 (HBSS)
S2372_44 (HBSS)
S2372_60 (HBSS)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
LW15
LW16
LW17
Ground RL
Piezometric head (m RL)
380
360
340
320
300
Jul
Jan 2019
Jul
Jan 2020
Jul
Jan 2021
Jul

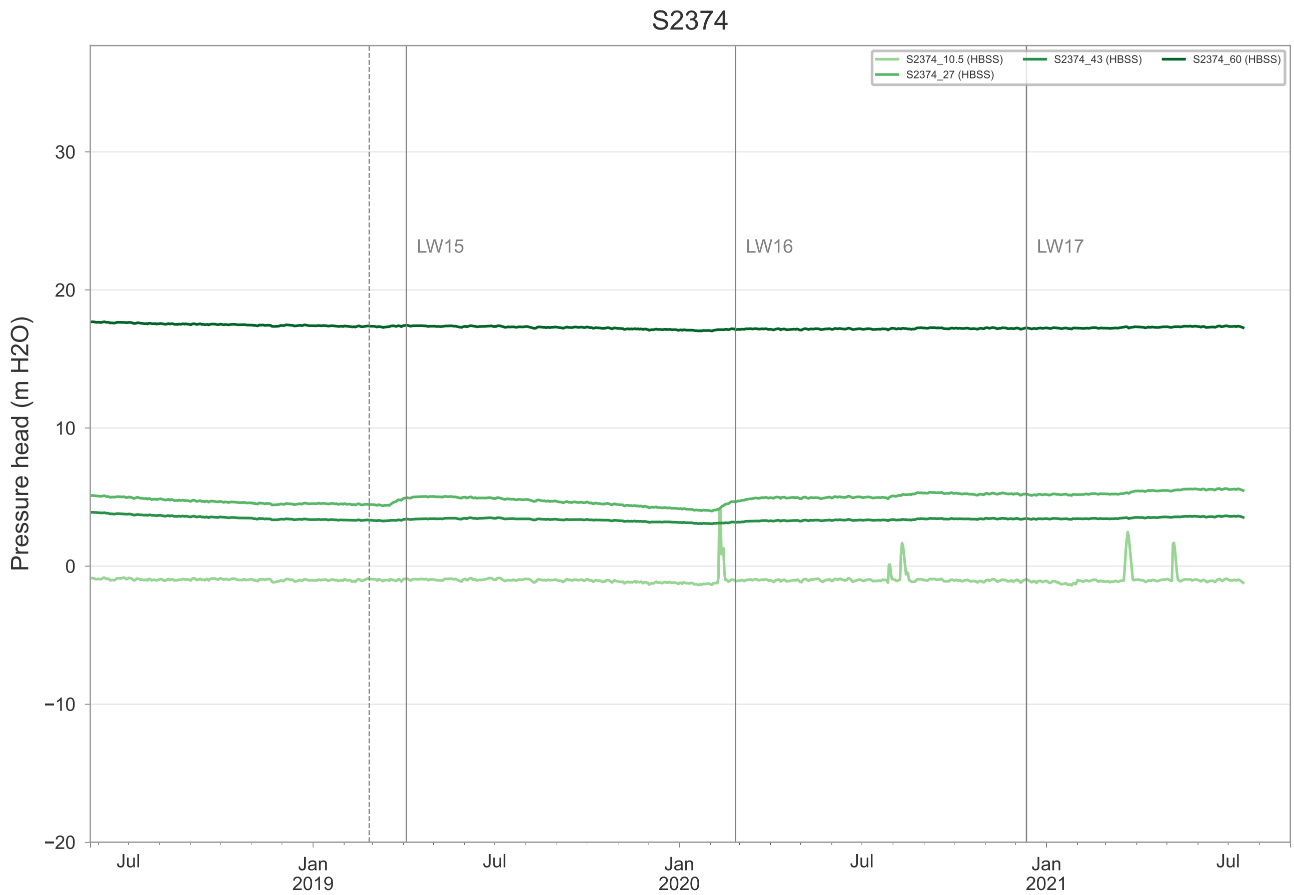

S2372
S2372_10.5 (HBSS)
S2372_25 (HBSS)
S2372_44 (HBSS)
S2372_60 (HBSS)
LW15
LW16
LW17
Pressure head (m H2O)
20
10
0
−10
−20
Jul
Jan 2019
Jul
Jan 2020
Jul
Jan 2021
Jul


S2373
S2373_10.5 (HBSS)
S2373_27 (HBSS)
S2373_43 (HBSS)
S2373_60 (HBSS)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
LW14
LW15
LW16
LW17
Ground RL
Piezometric head (m RL)
Jan 2018
Jul
Jan 2019
Jul
Jan 2020
Jul
Jan 2021
Jul

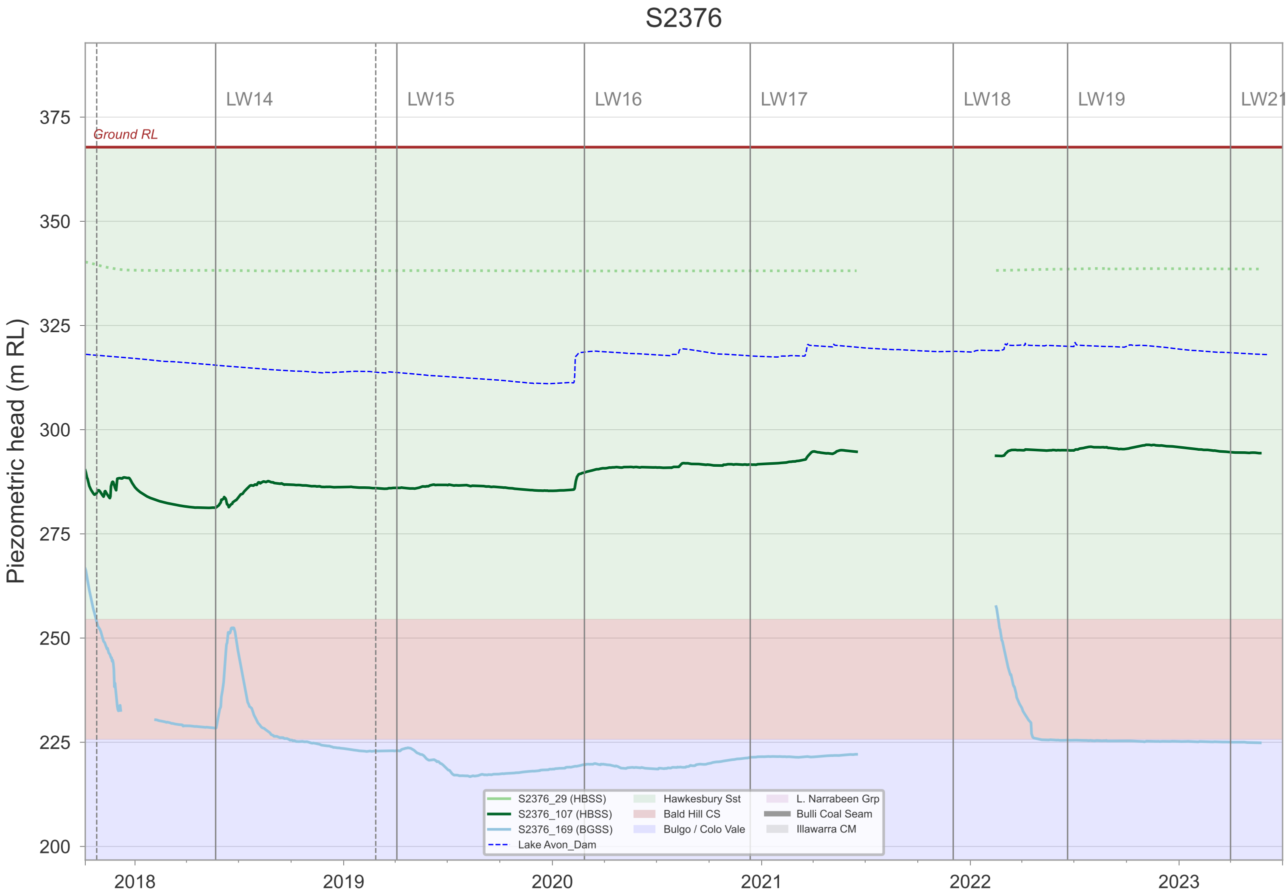

S2373
S2373_10.5 (HBSS)
S2373_27 (HBSS)
S2373_43 (HBSS)
S2373_60 (HBSS)
LW14
LW15
LW16
LW17
Pressure head (m H2O)
Jan 2018
Jul
Jan 2019
Jul
Jan 2020
Jul
Jan 2021
Jul

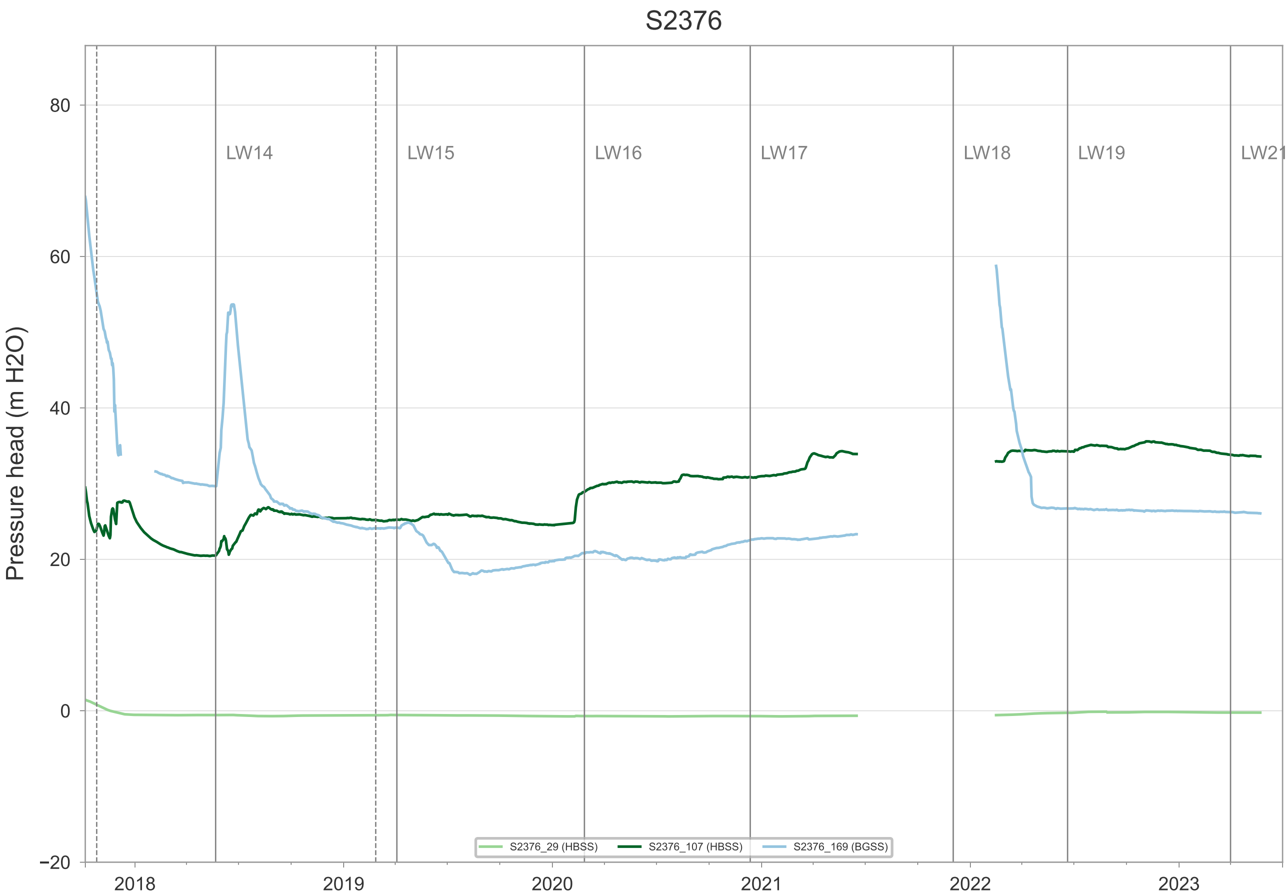
Groundwater hydrographs



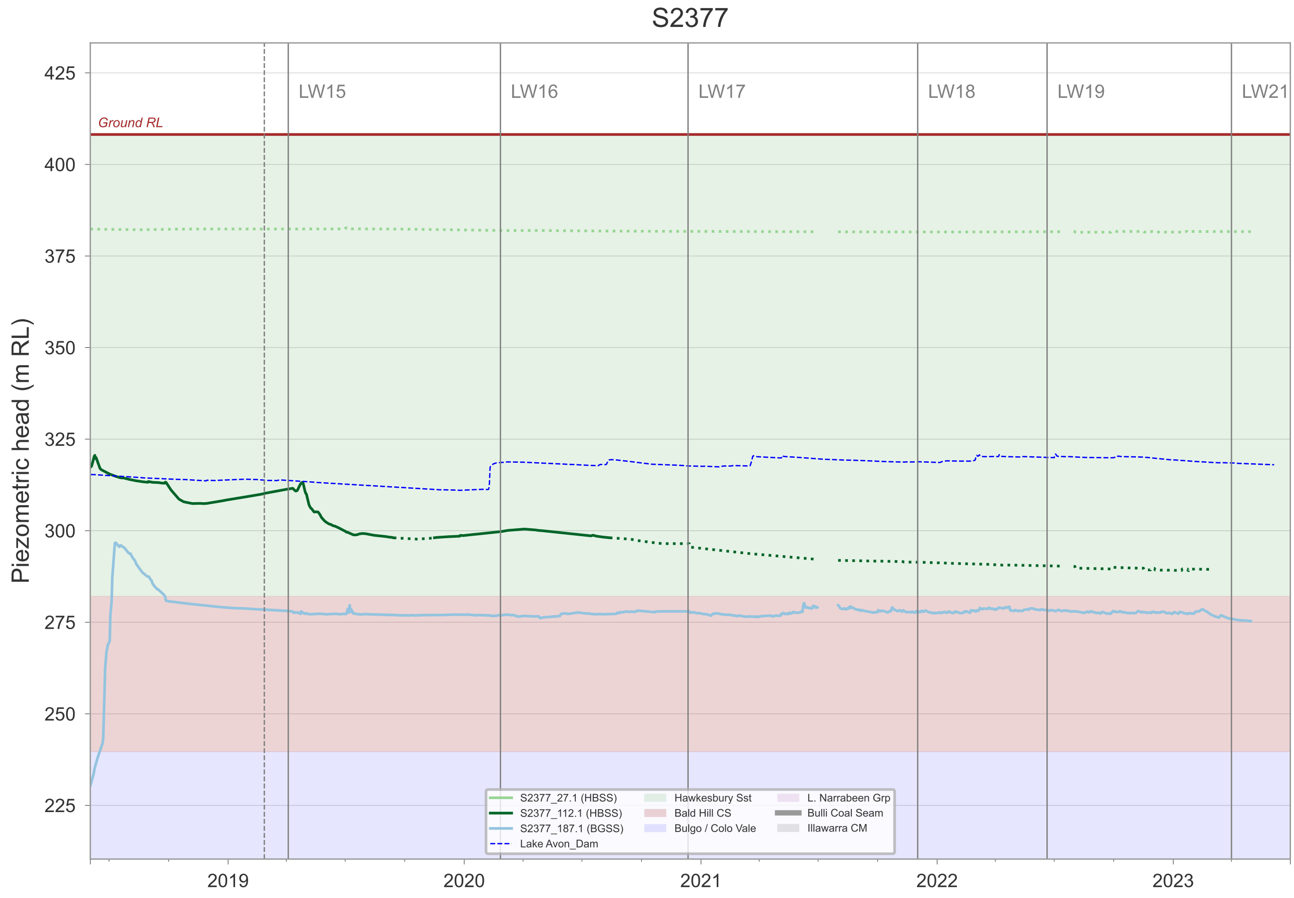


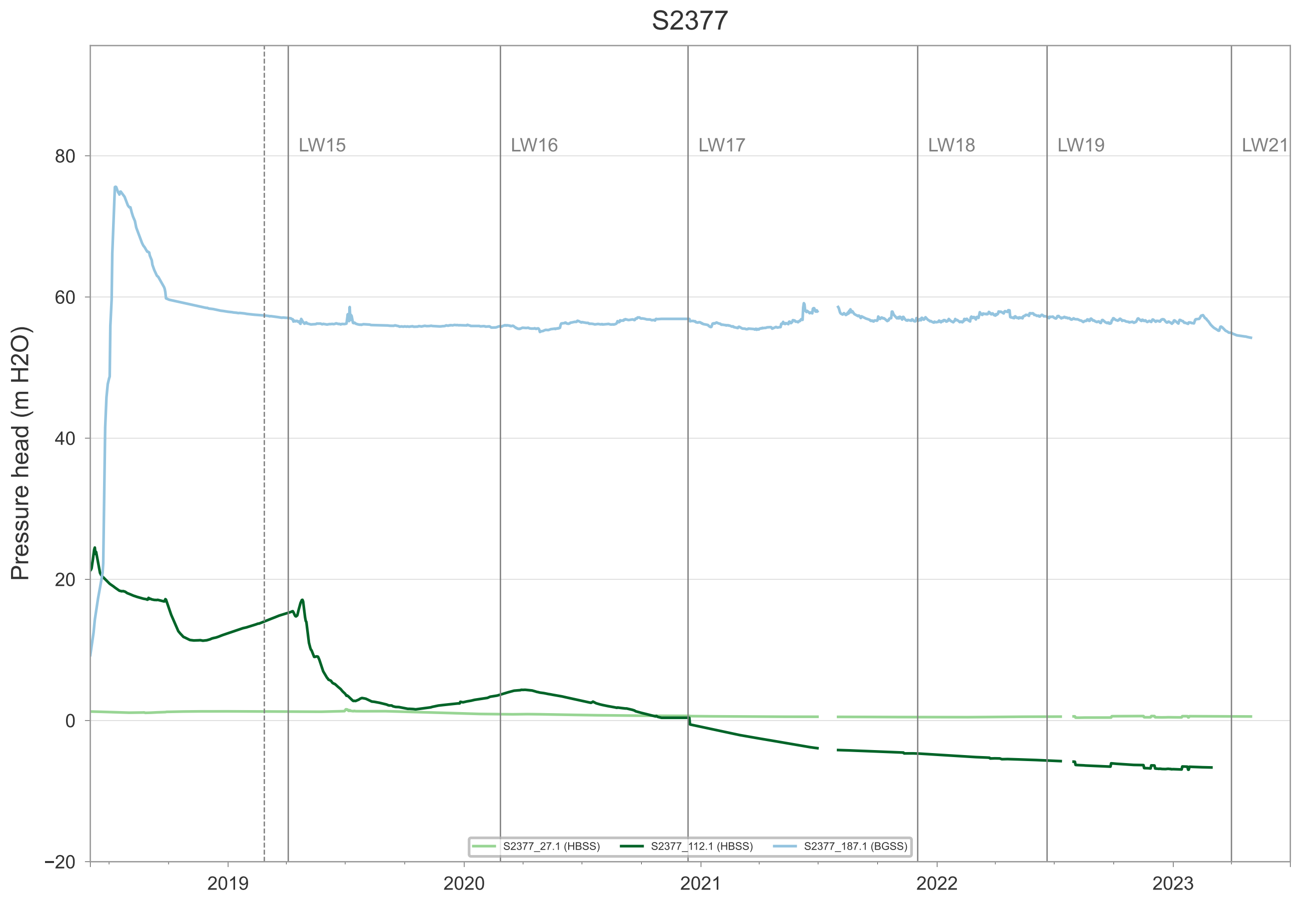
Groundwater hydrographs



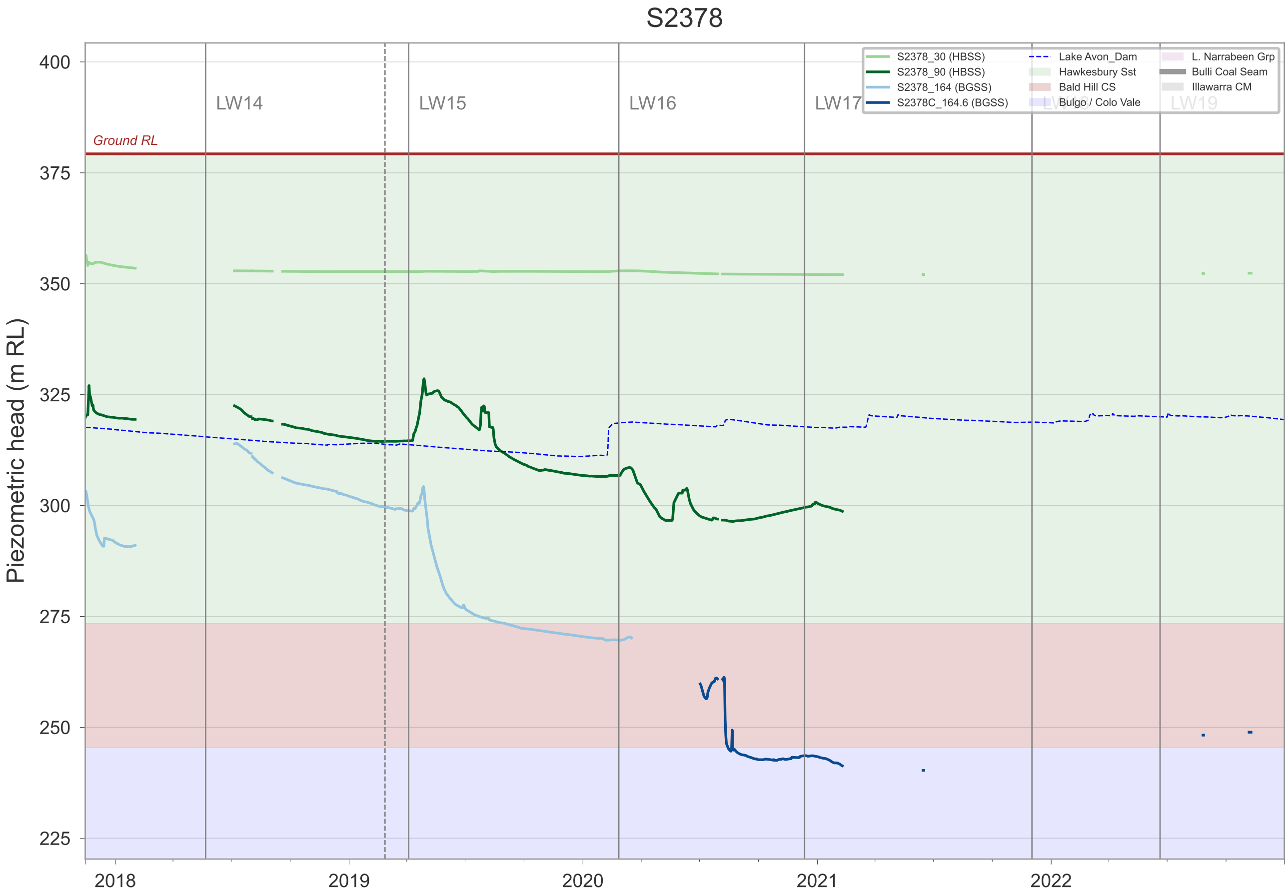


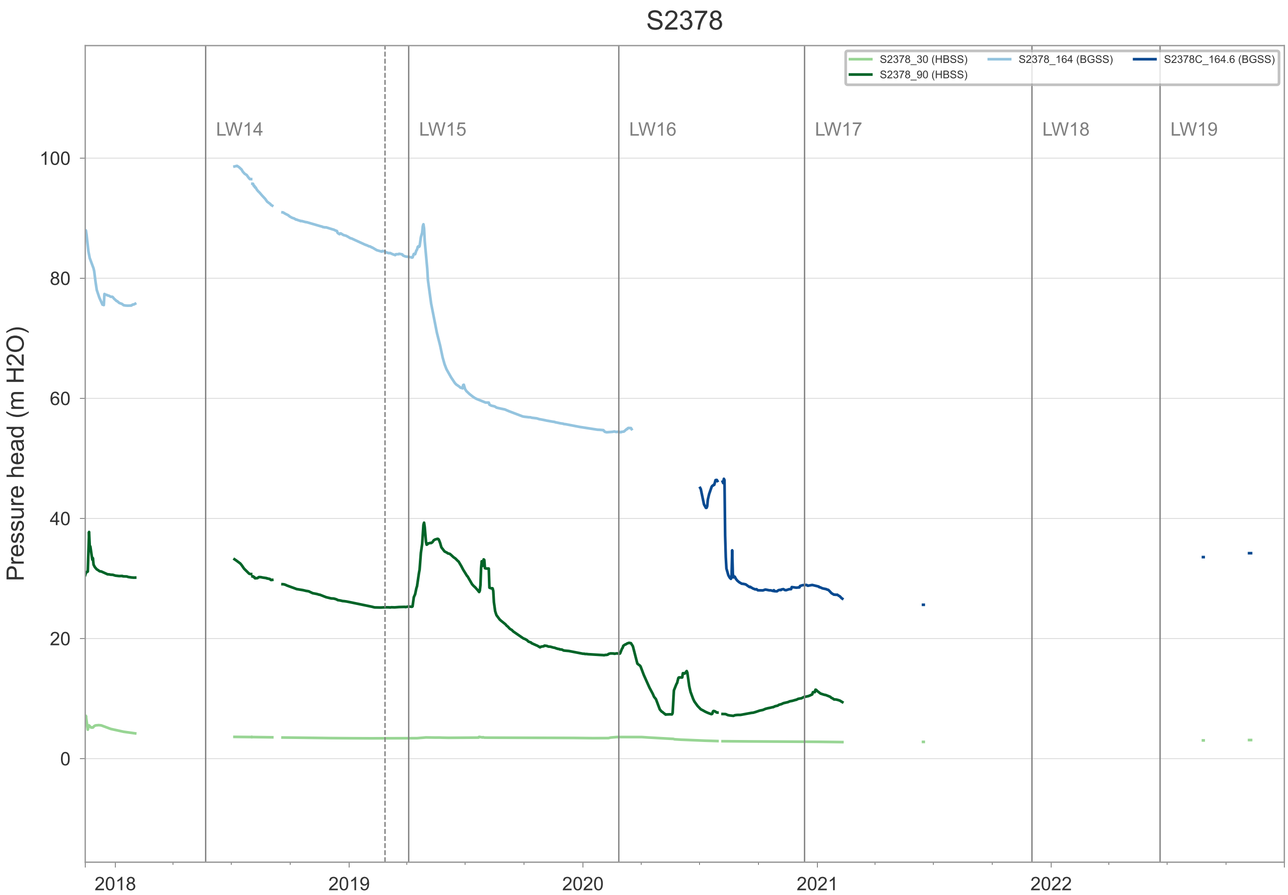
Groundwater hydrographs



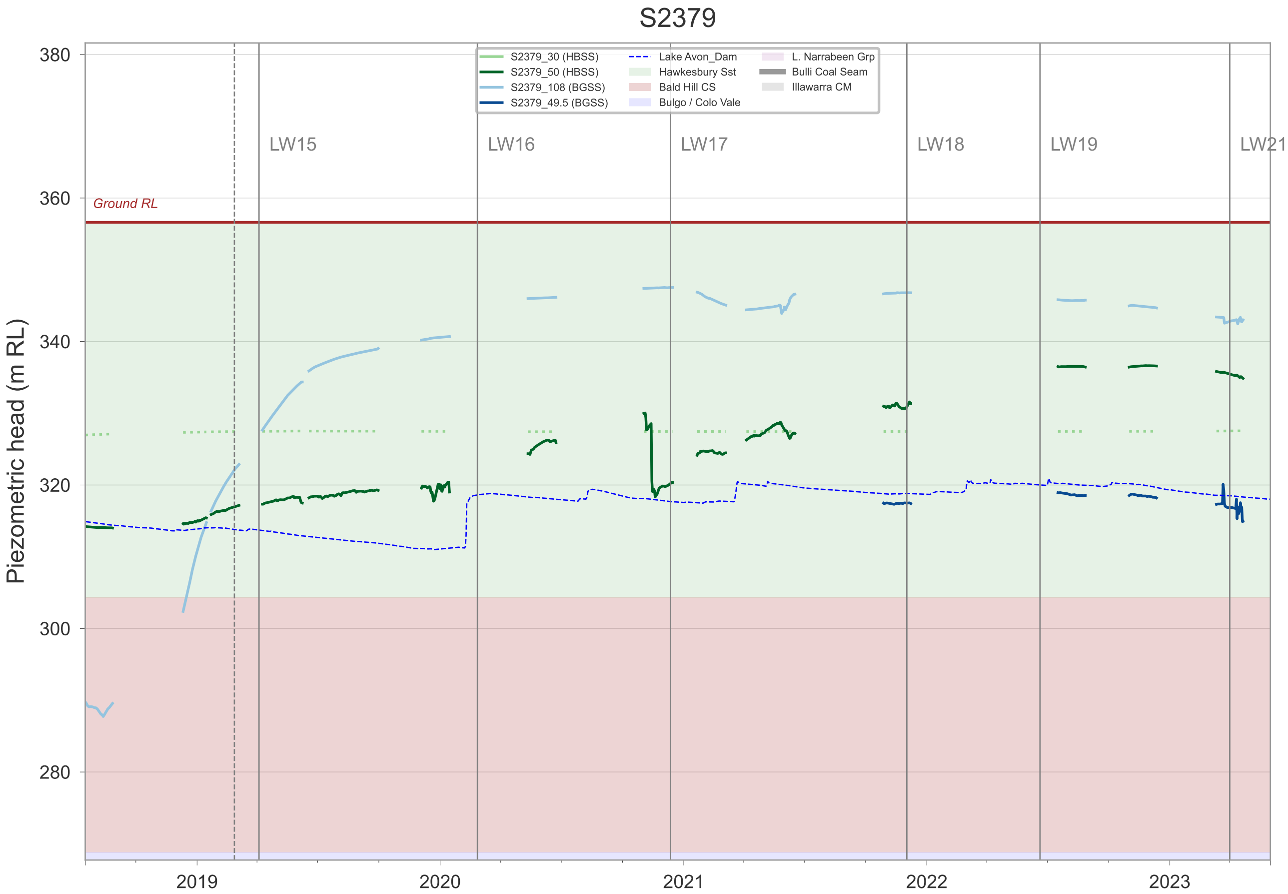


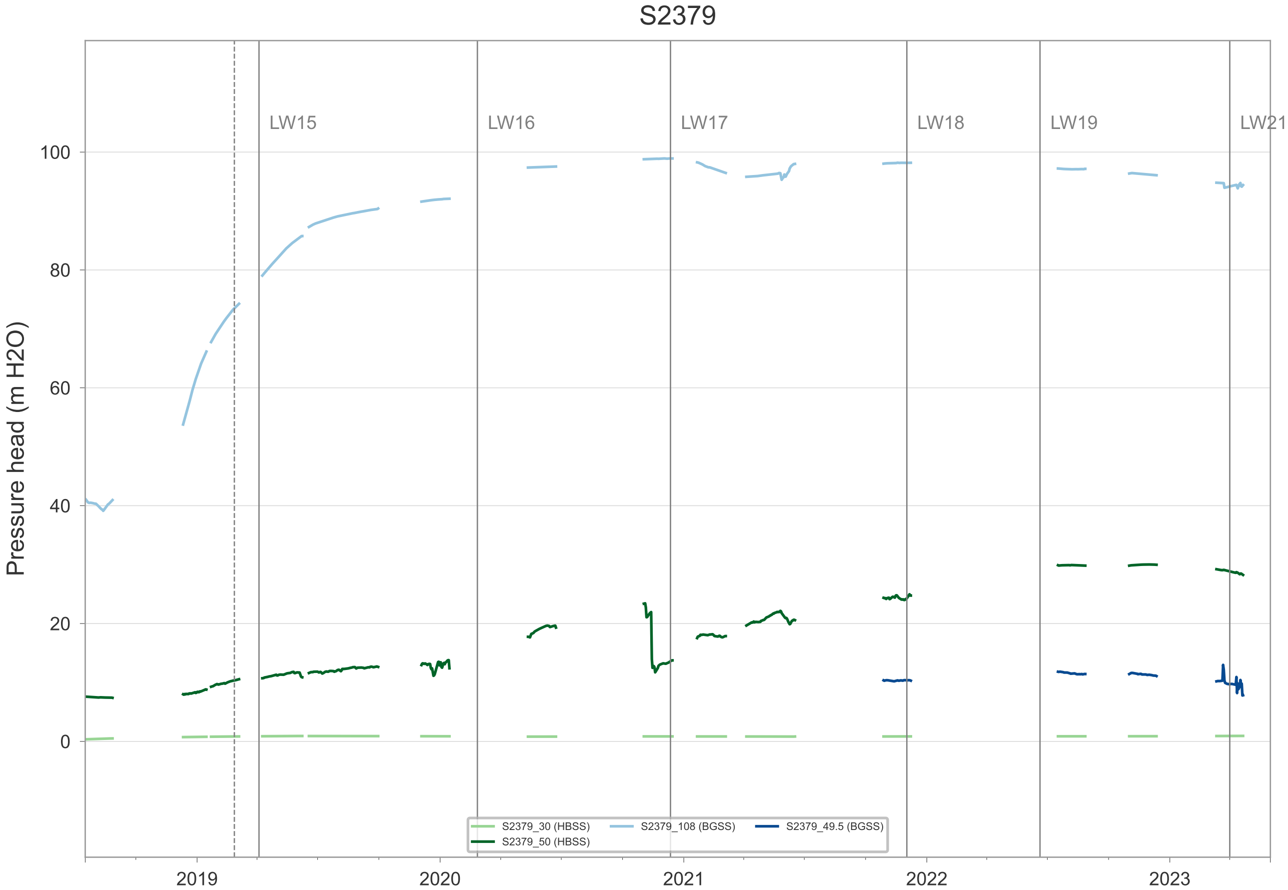
Groundwater hydrographs



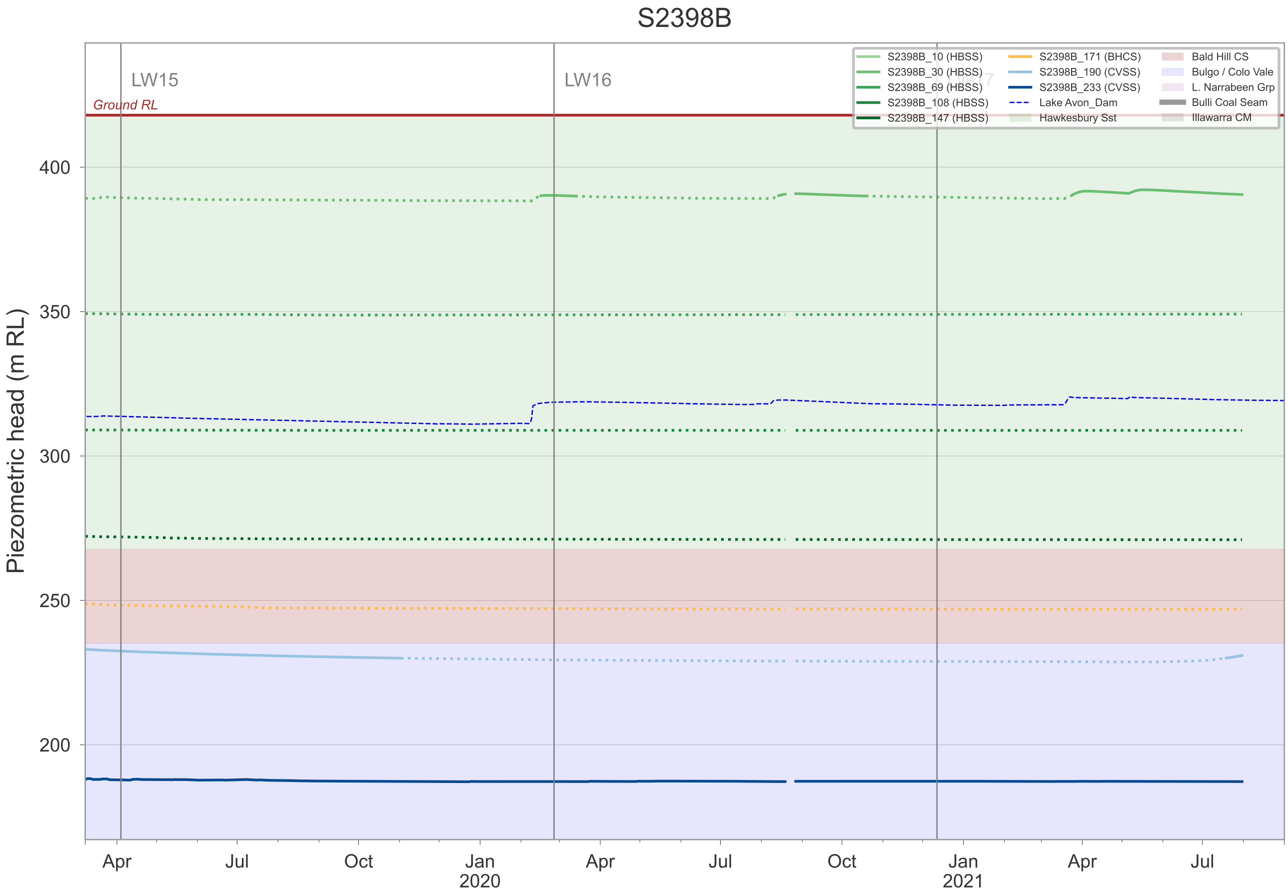


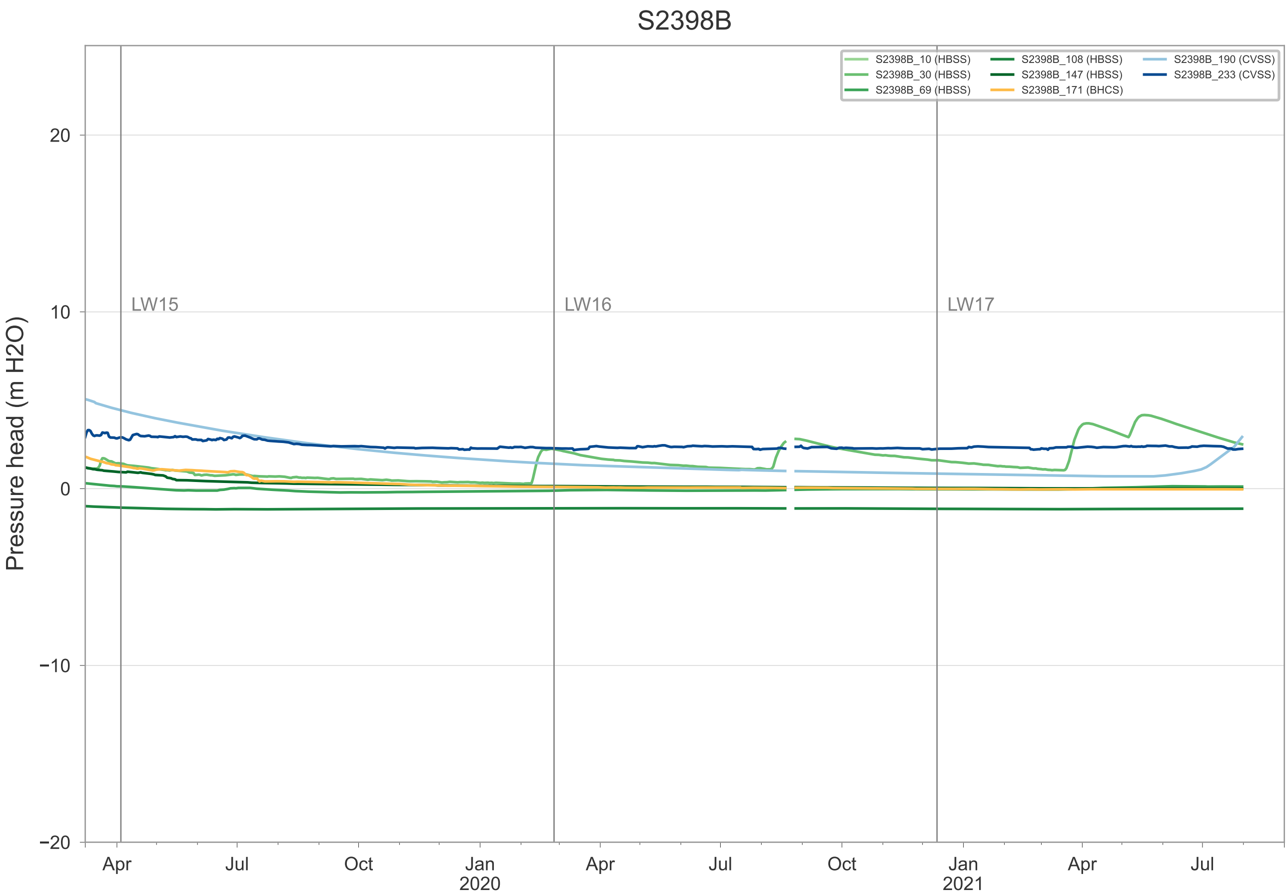
Groundwater hydrographs



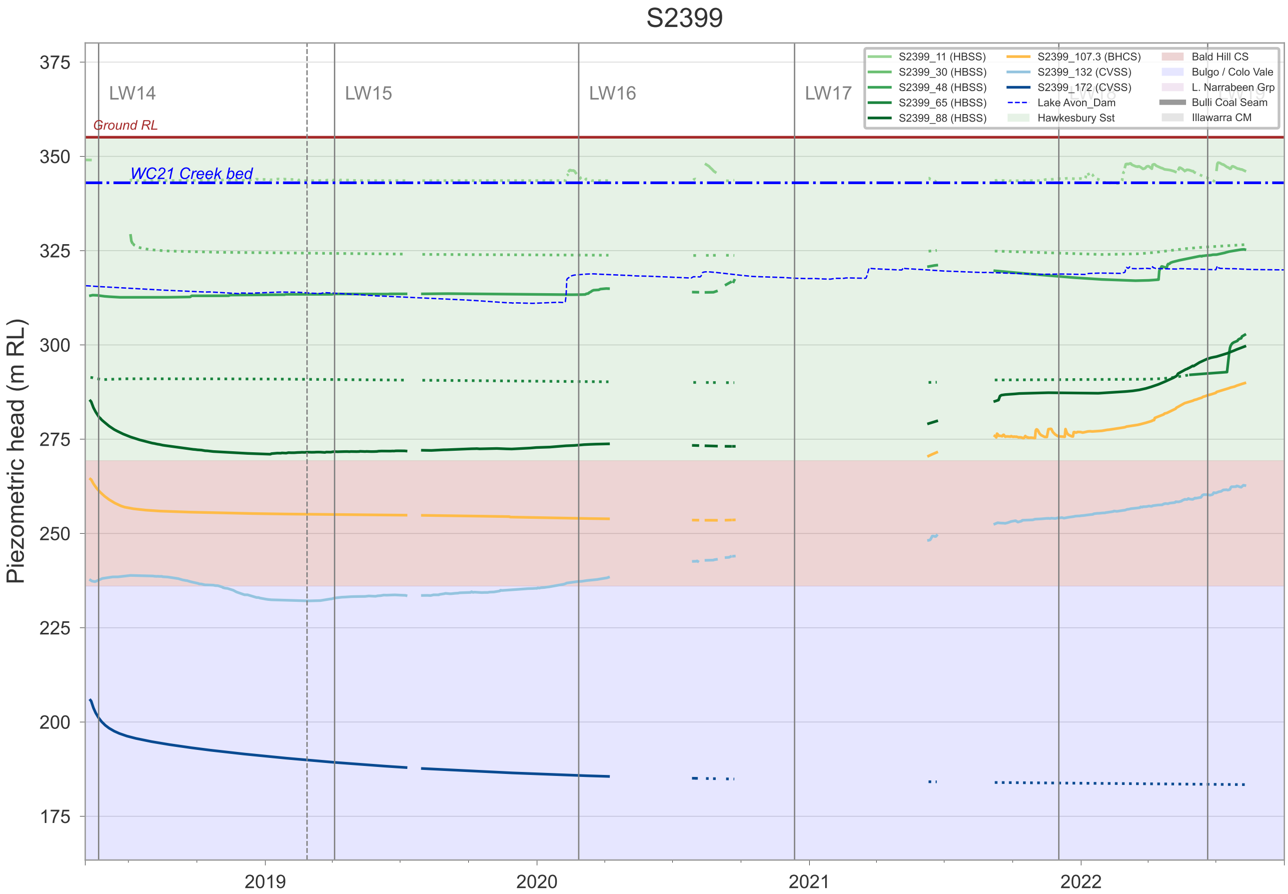


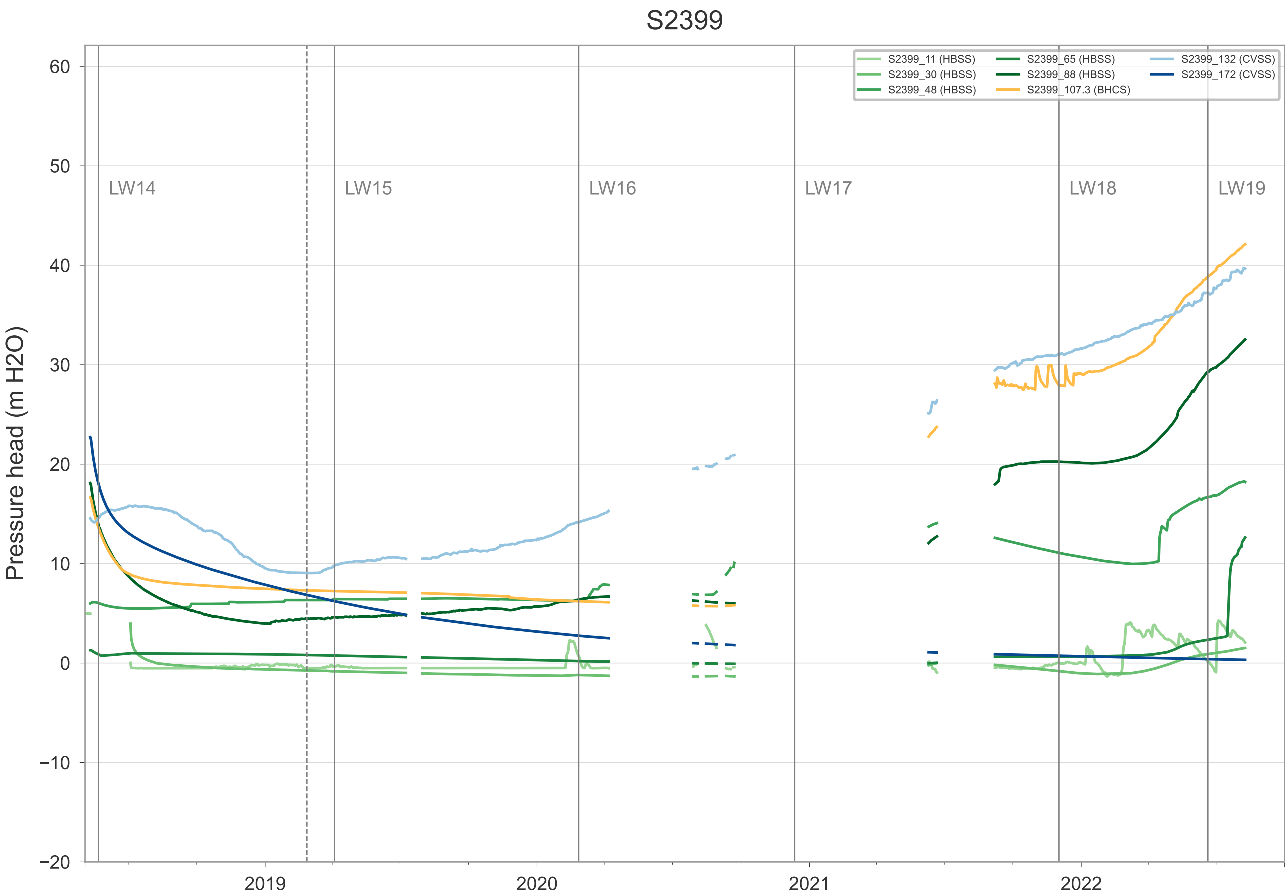
Groundwater hydrographs



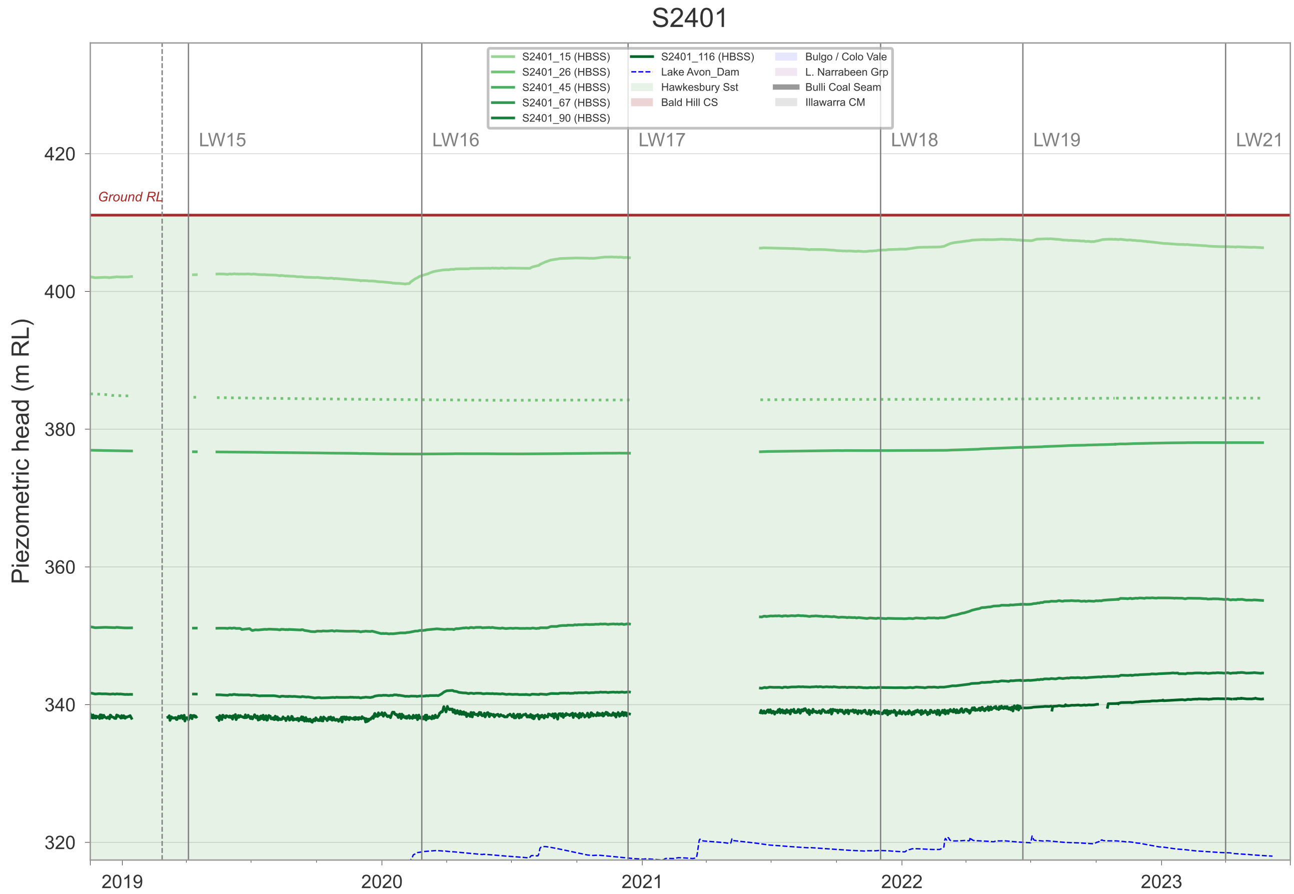


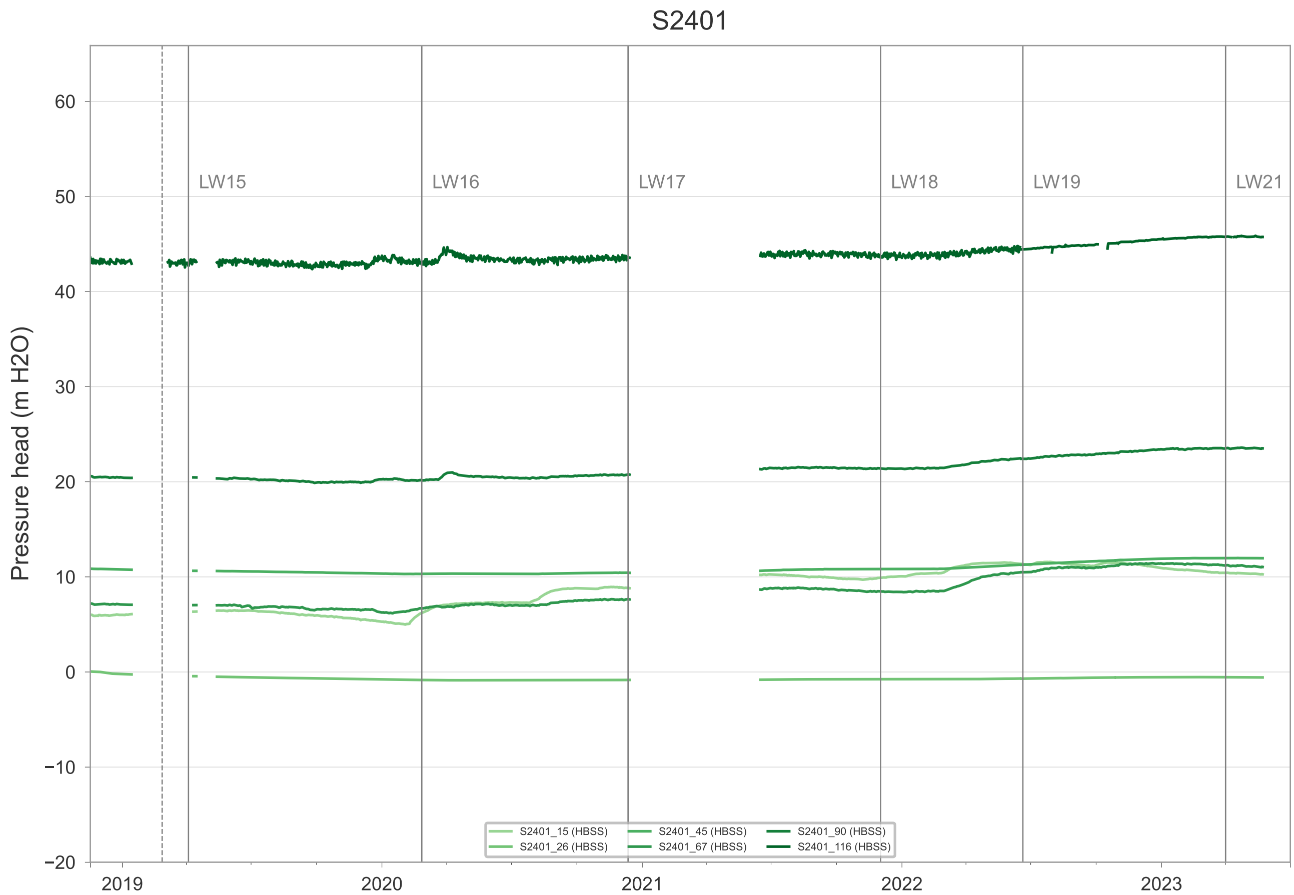
Groundwater hydrographs



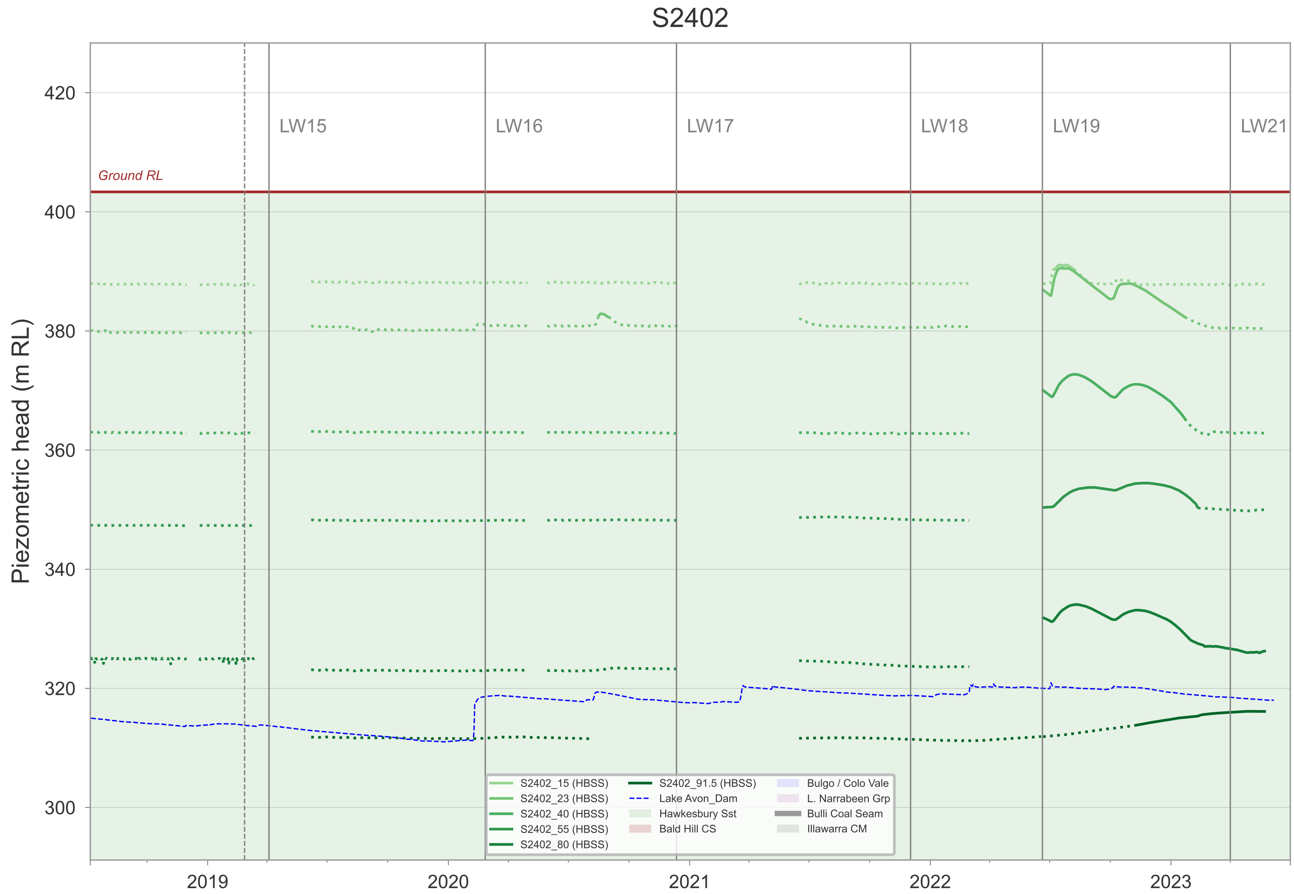


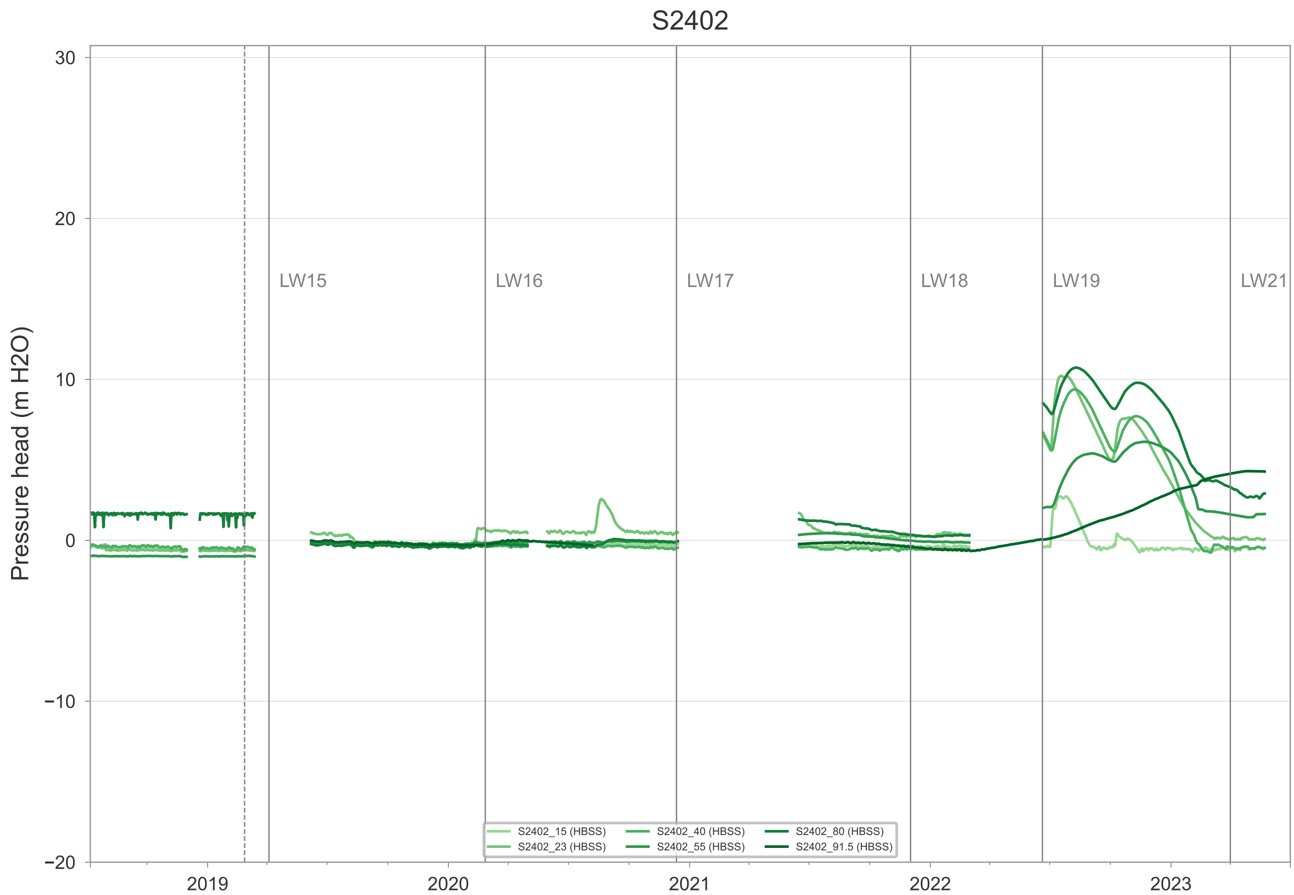
Groundwater hydrographs



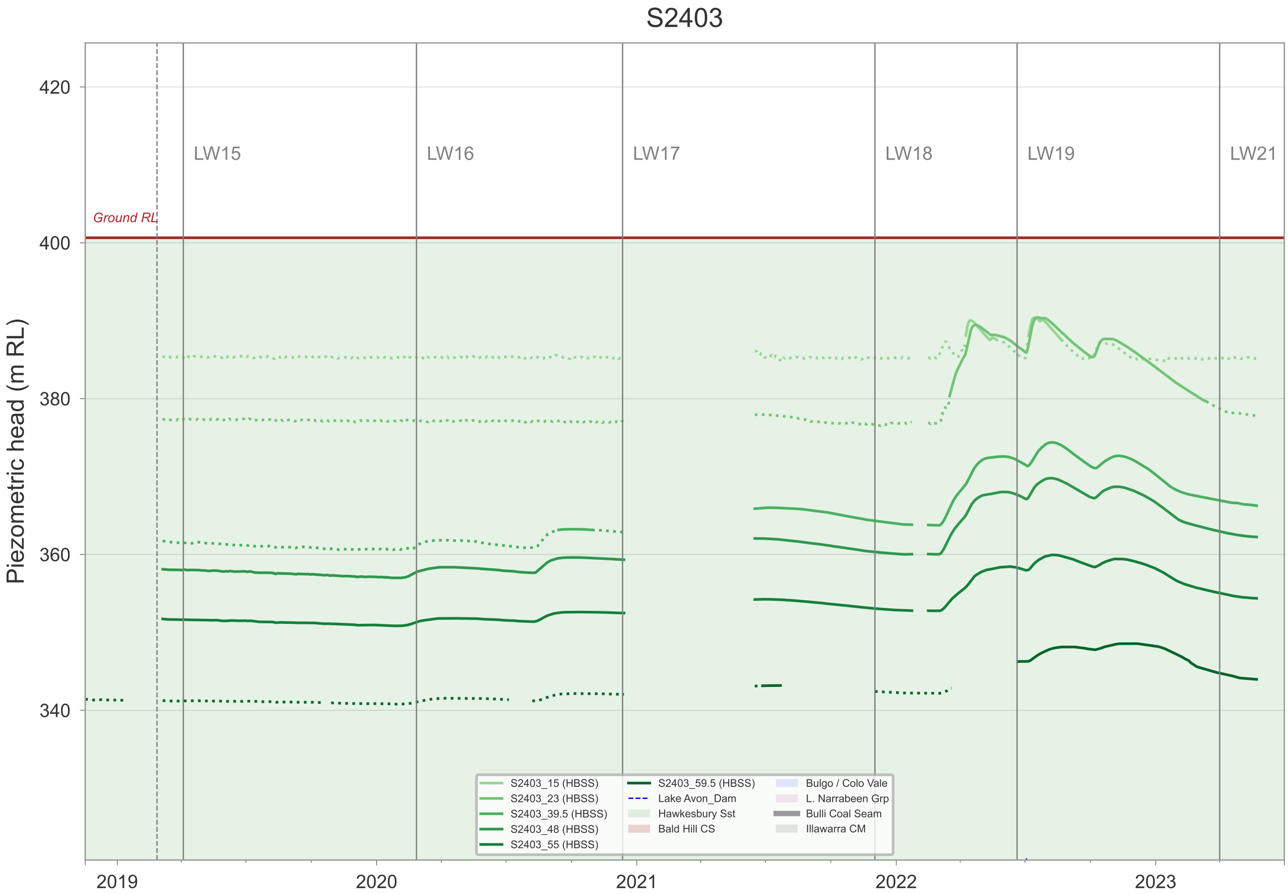


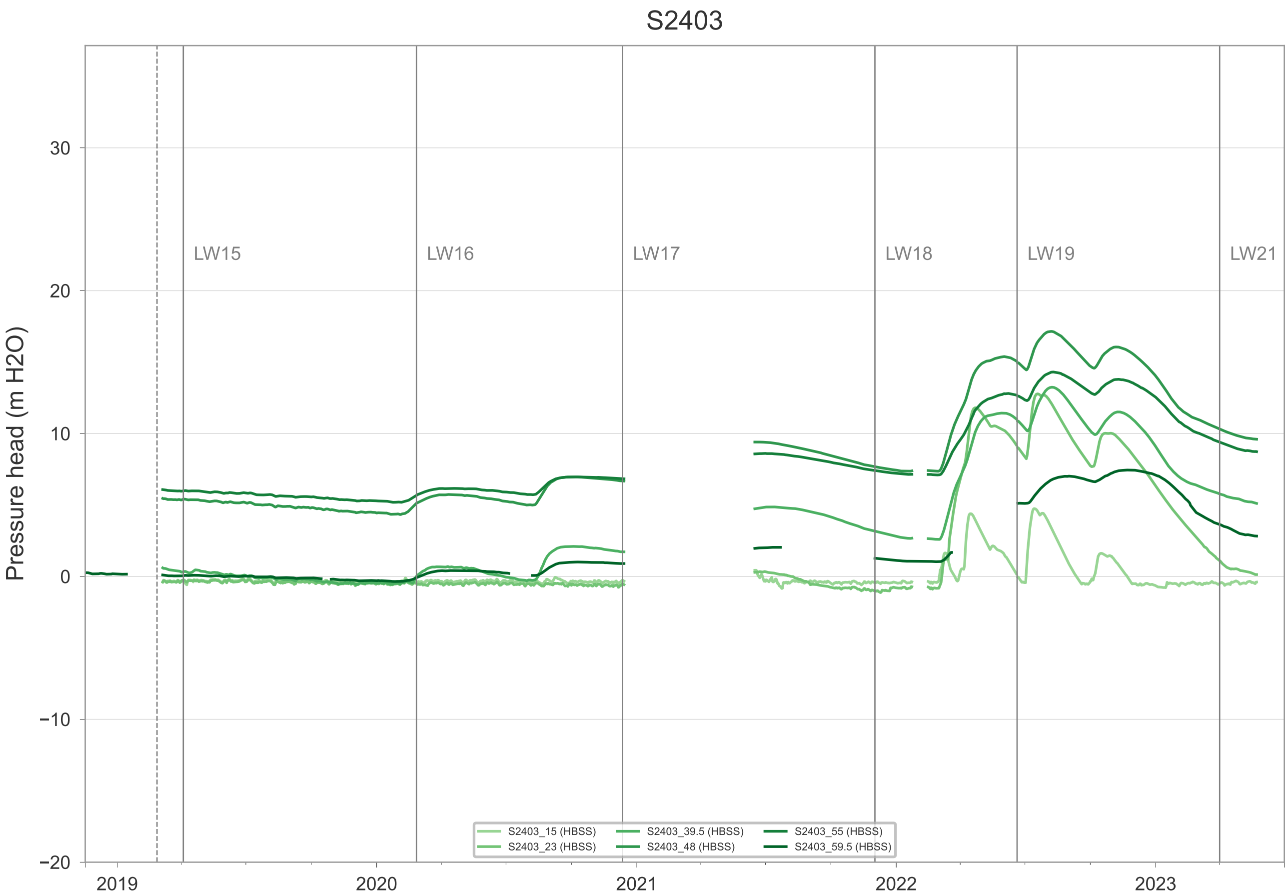
Groundwater hydrographs



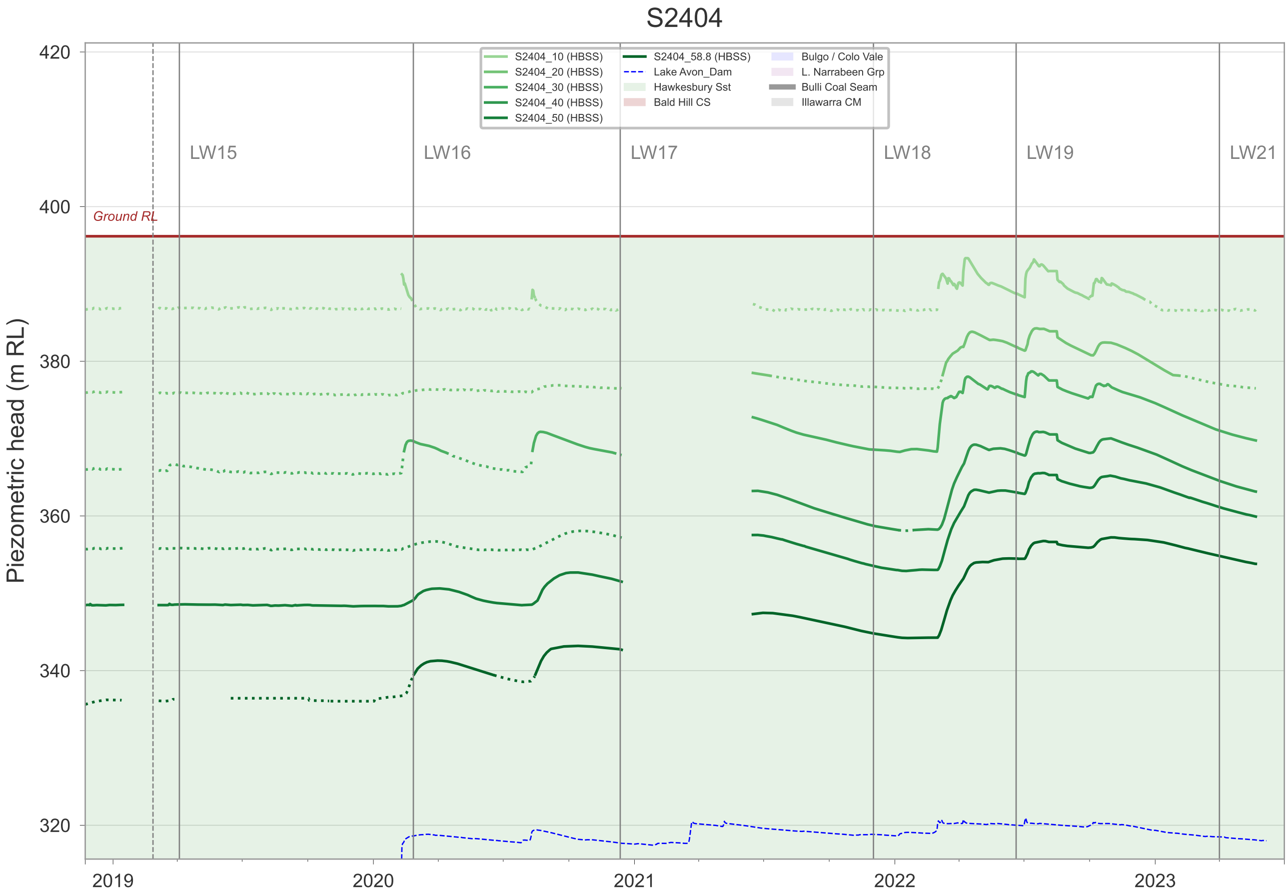


Groundwater hydrographs

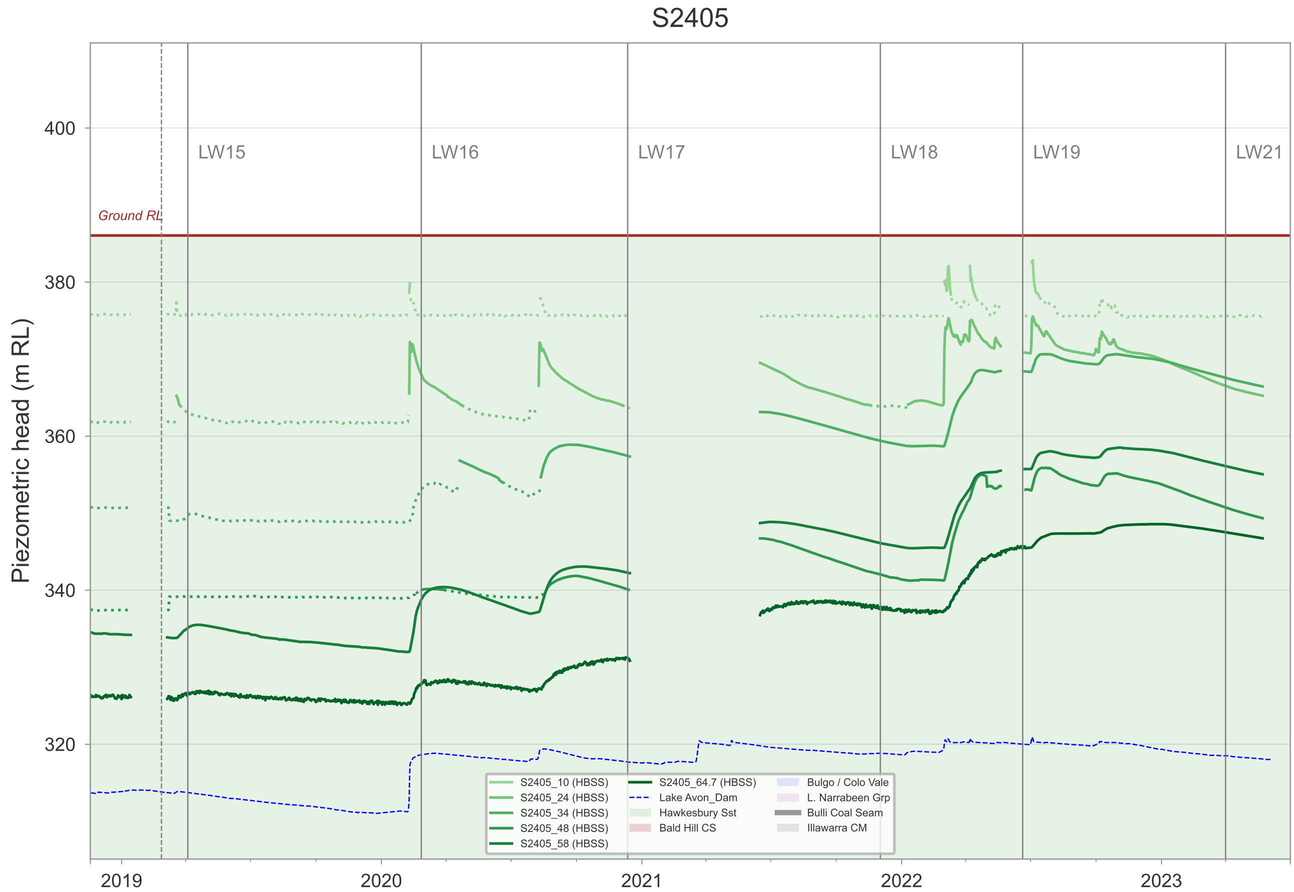


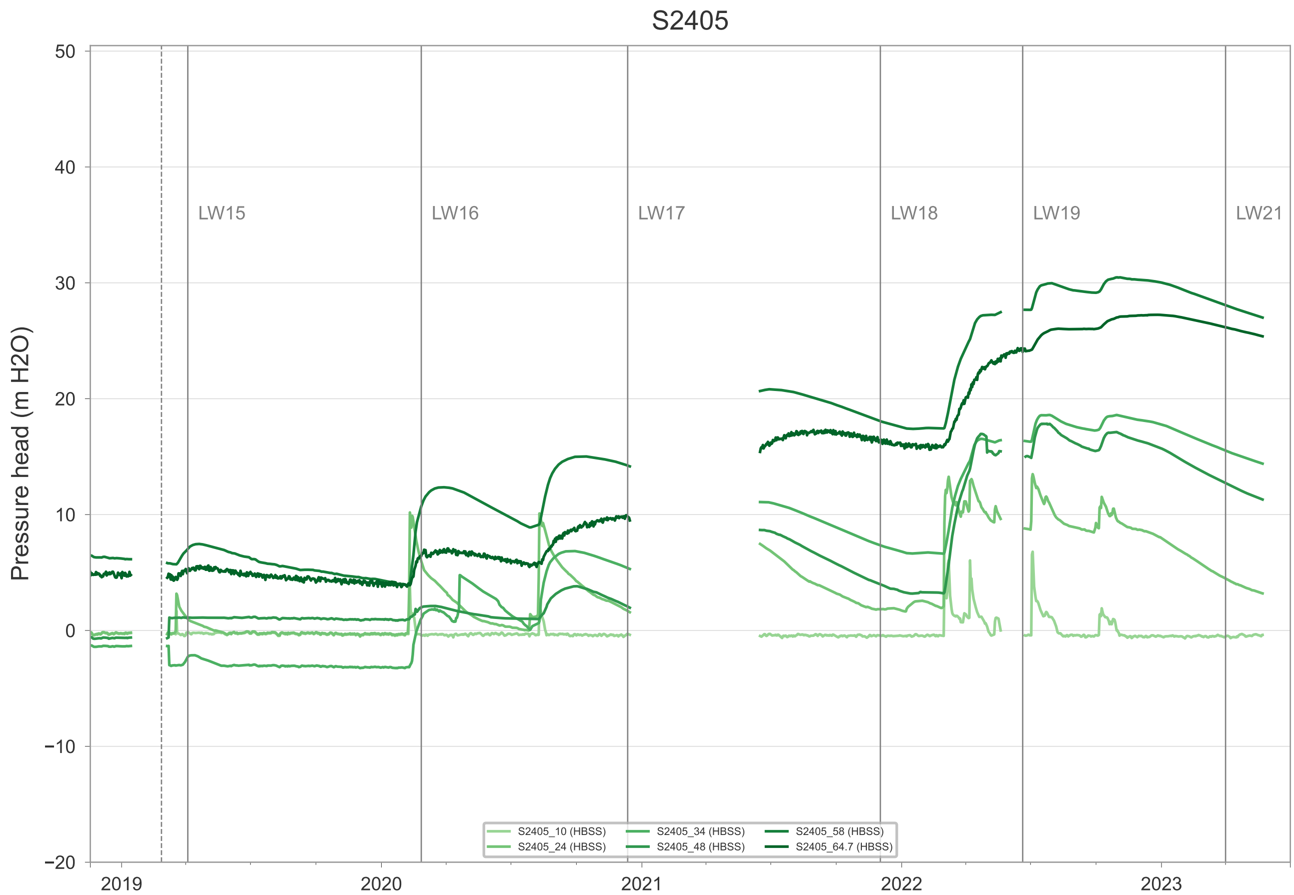


Groundwater hydrographs

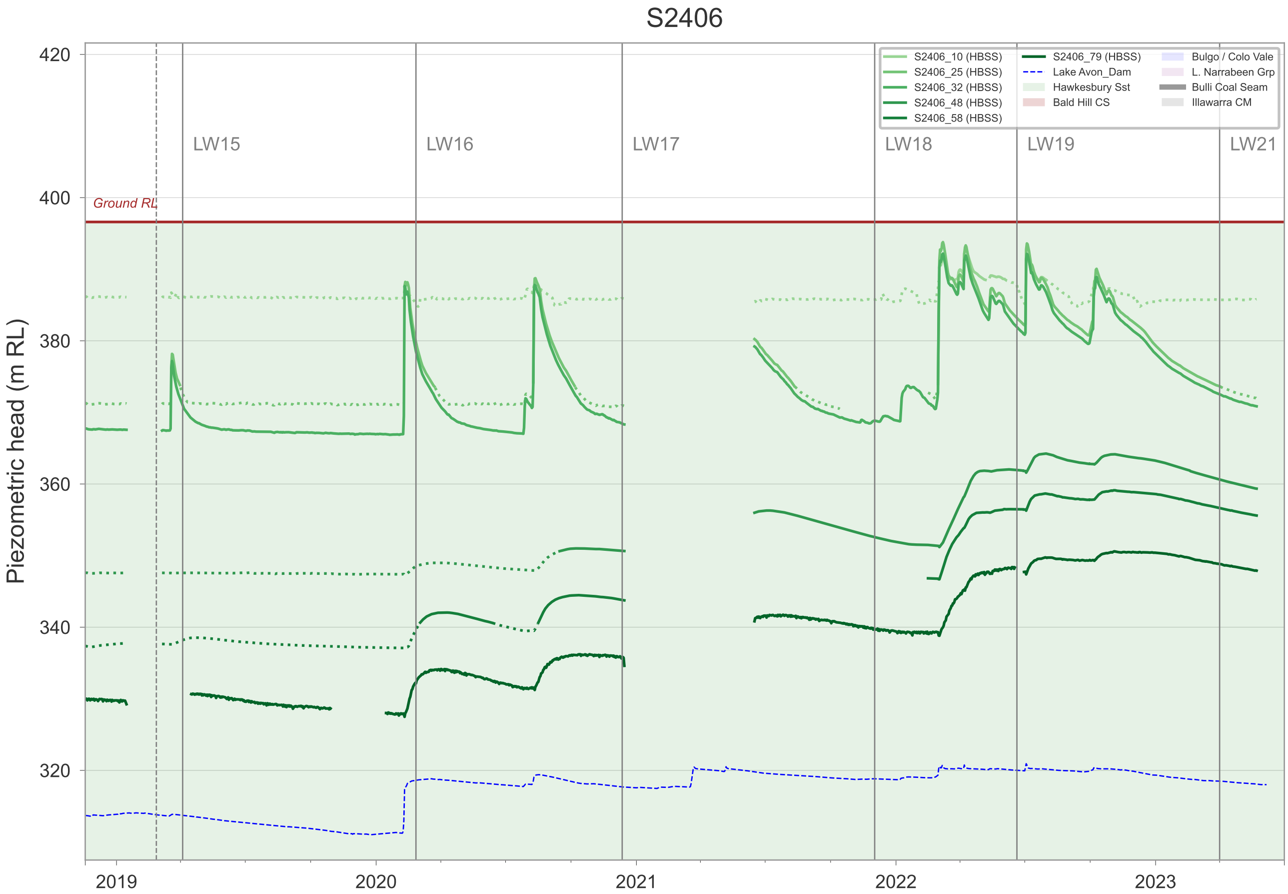


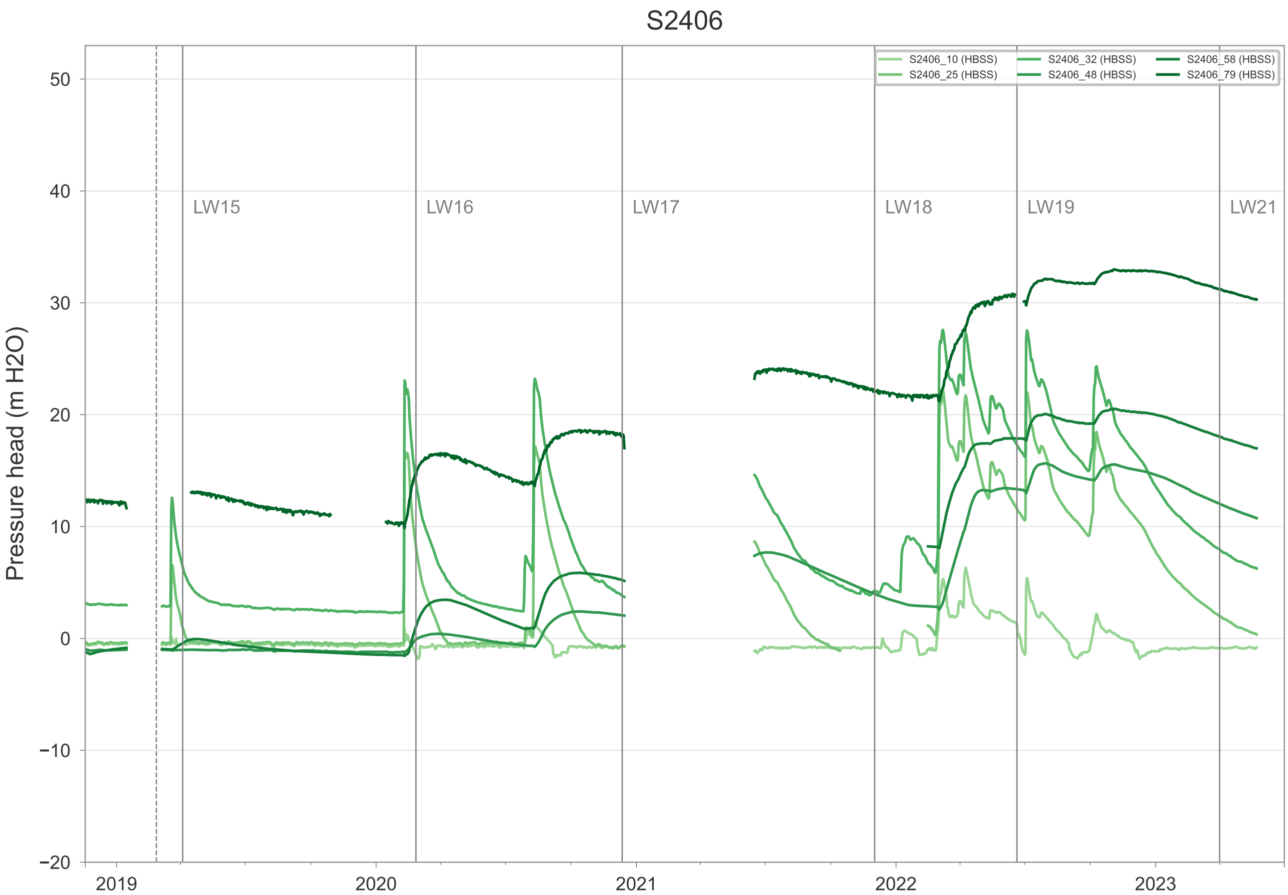
Groundwater hydrographs



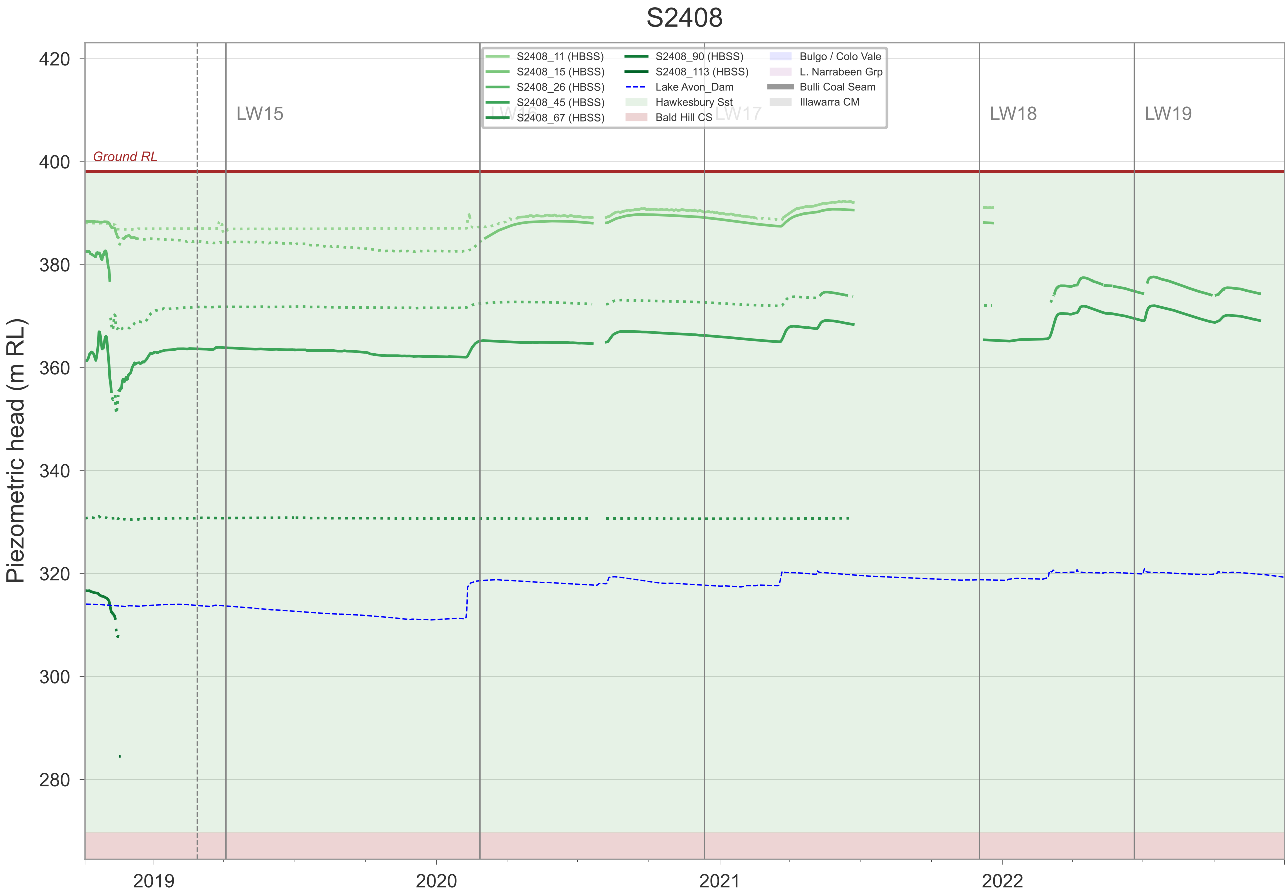


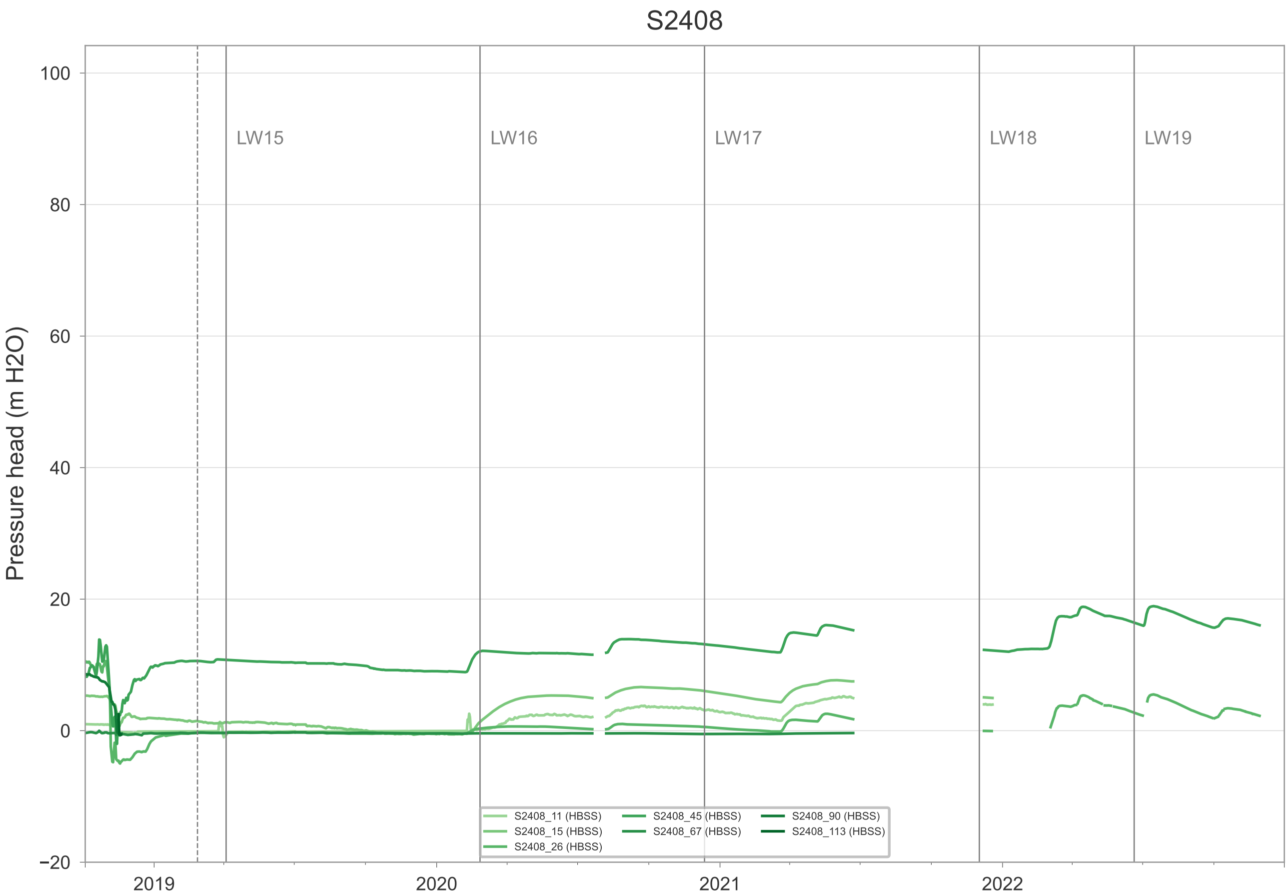
Groundwater hydrographs



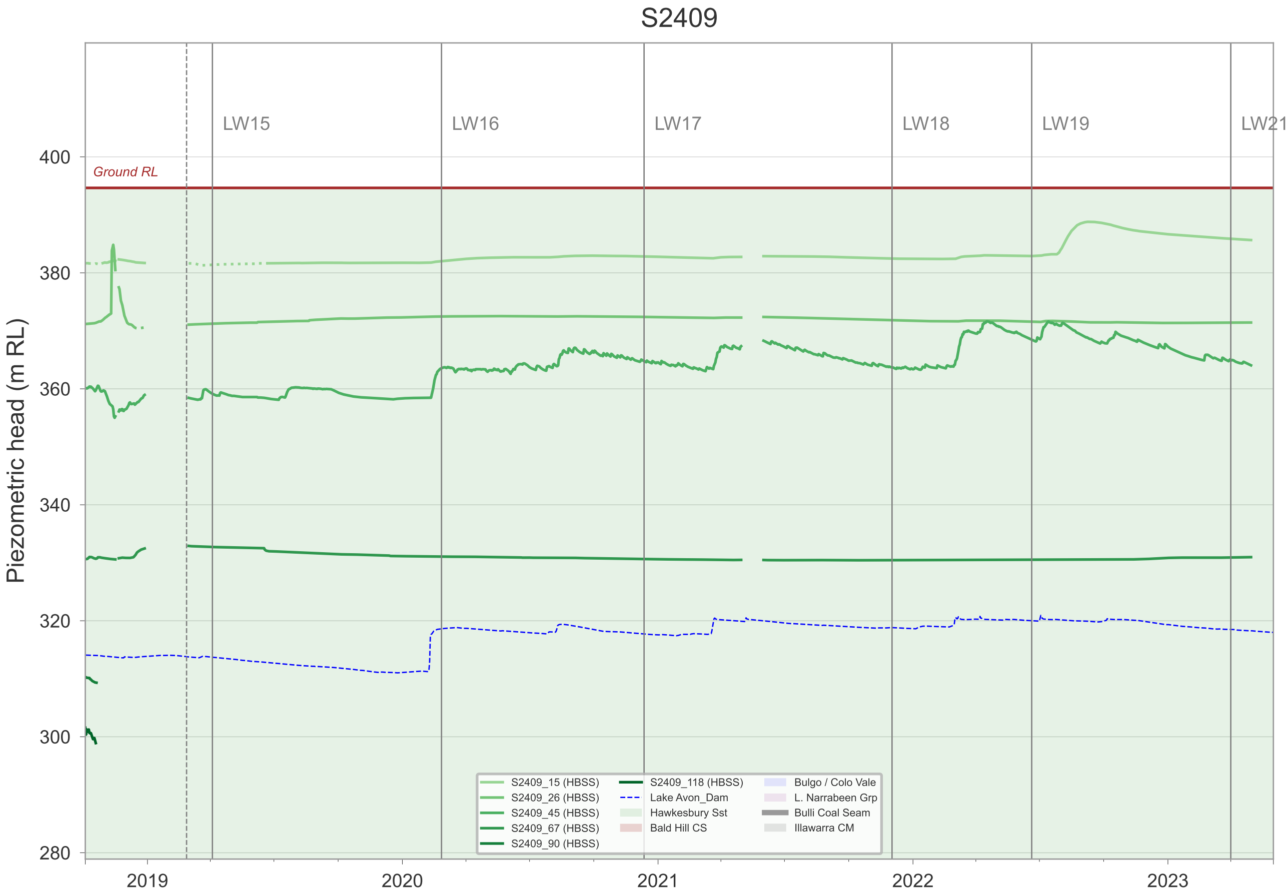


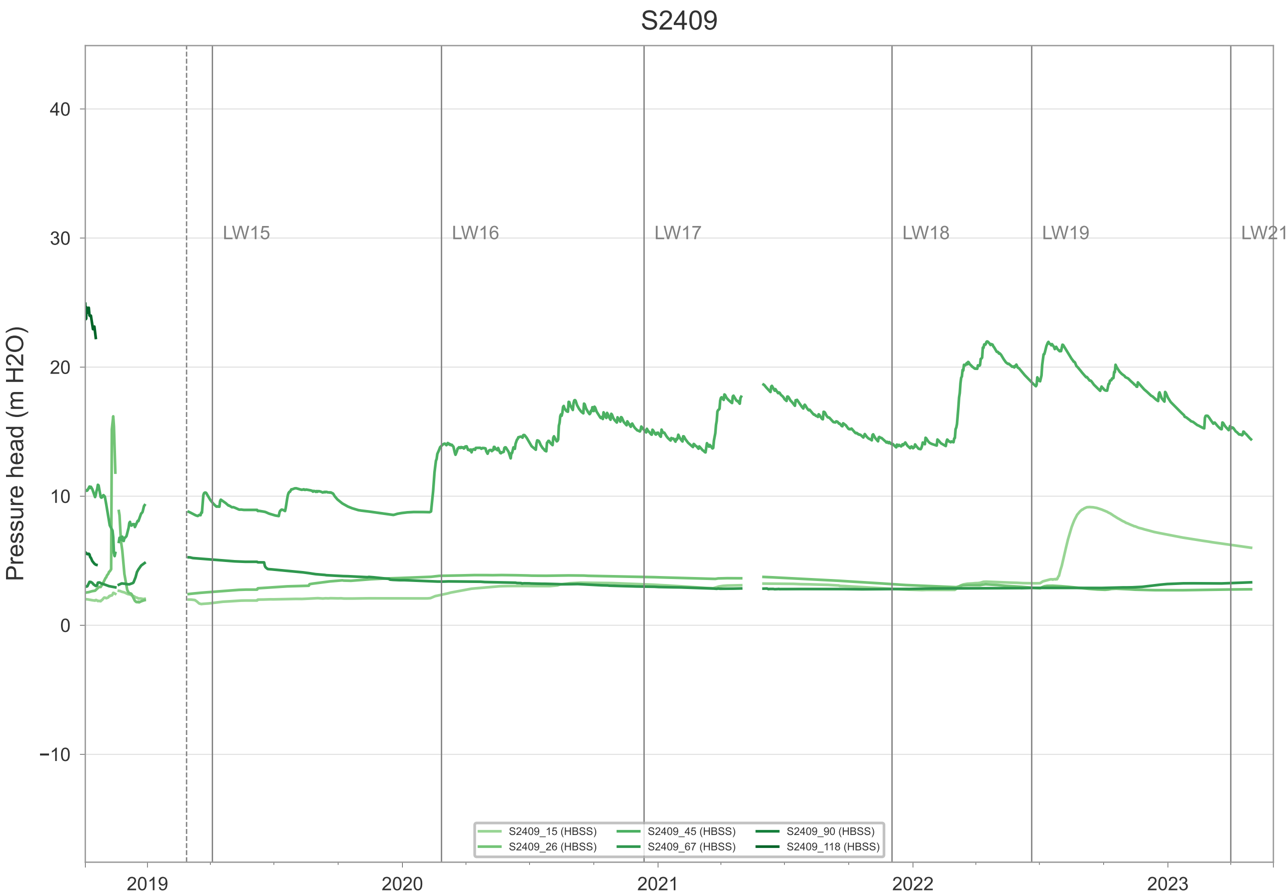
Groundwater hydrographs



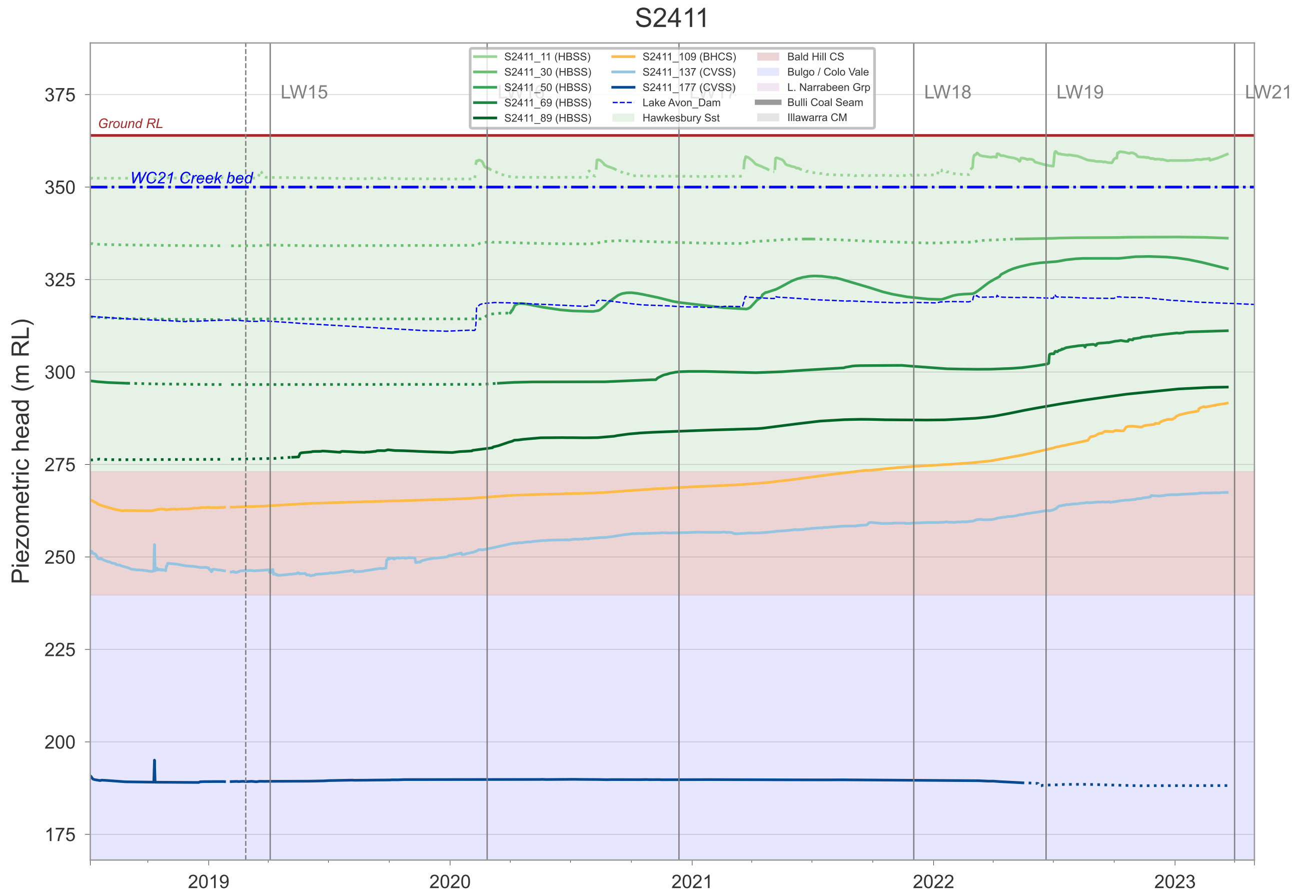


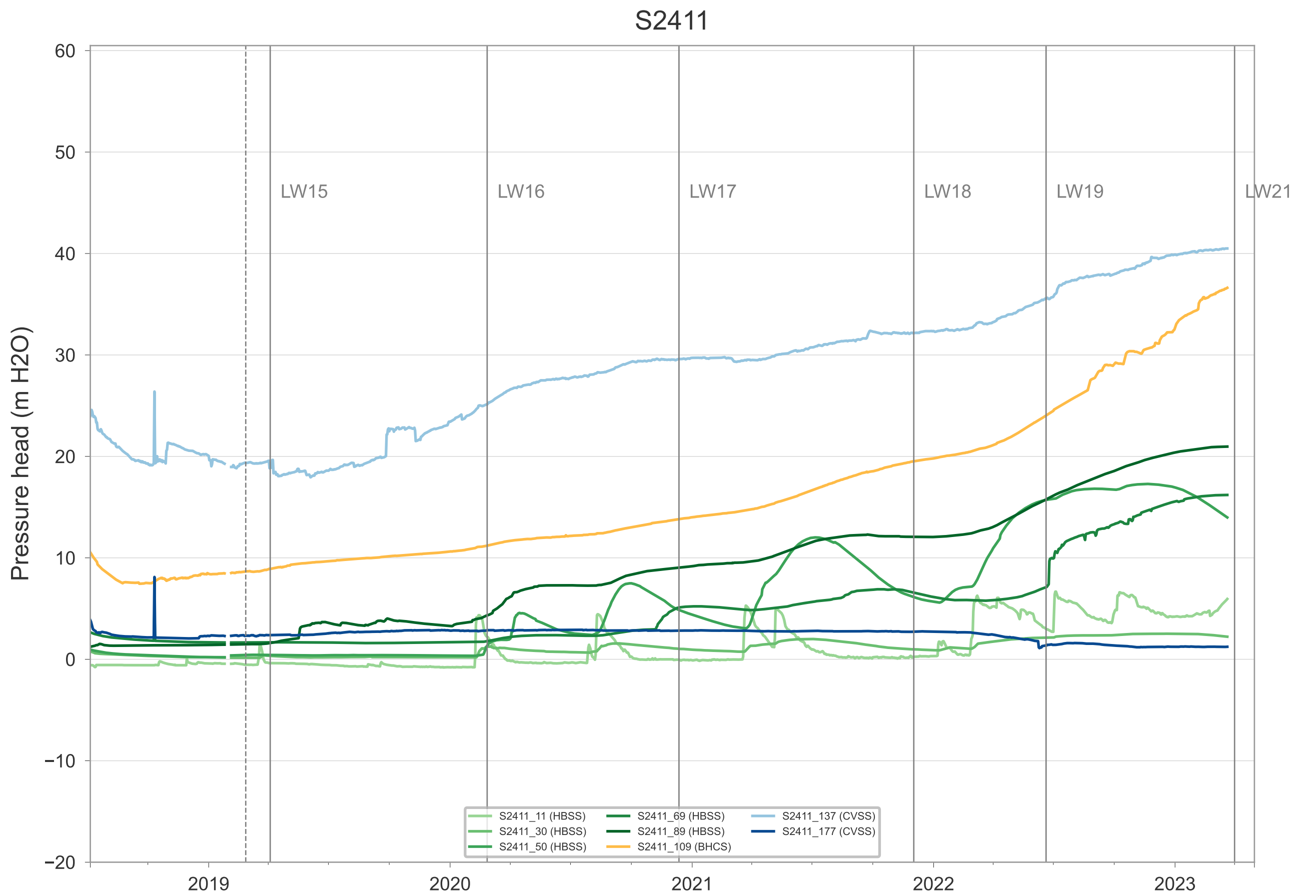
Groundwater hydrographs

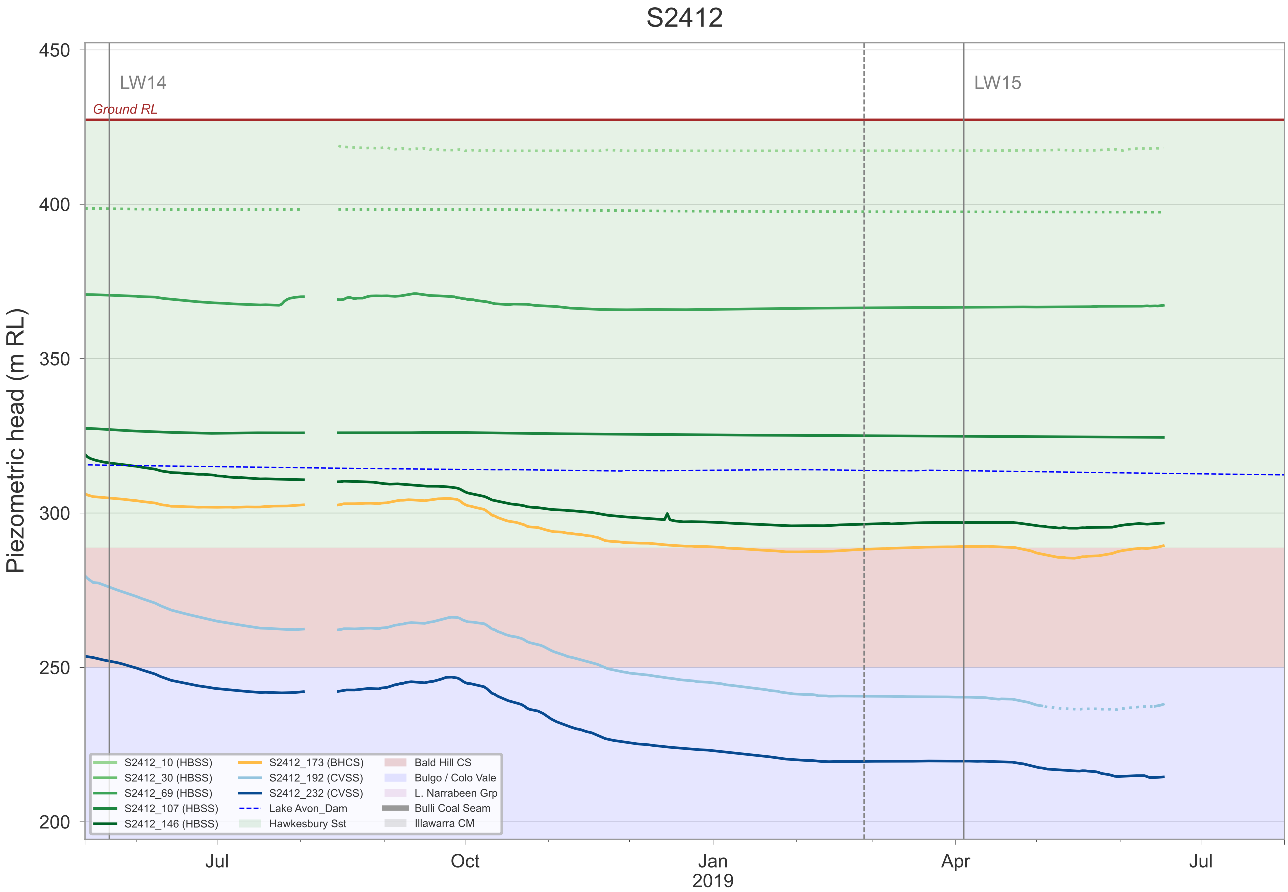


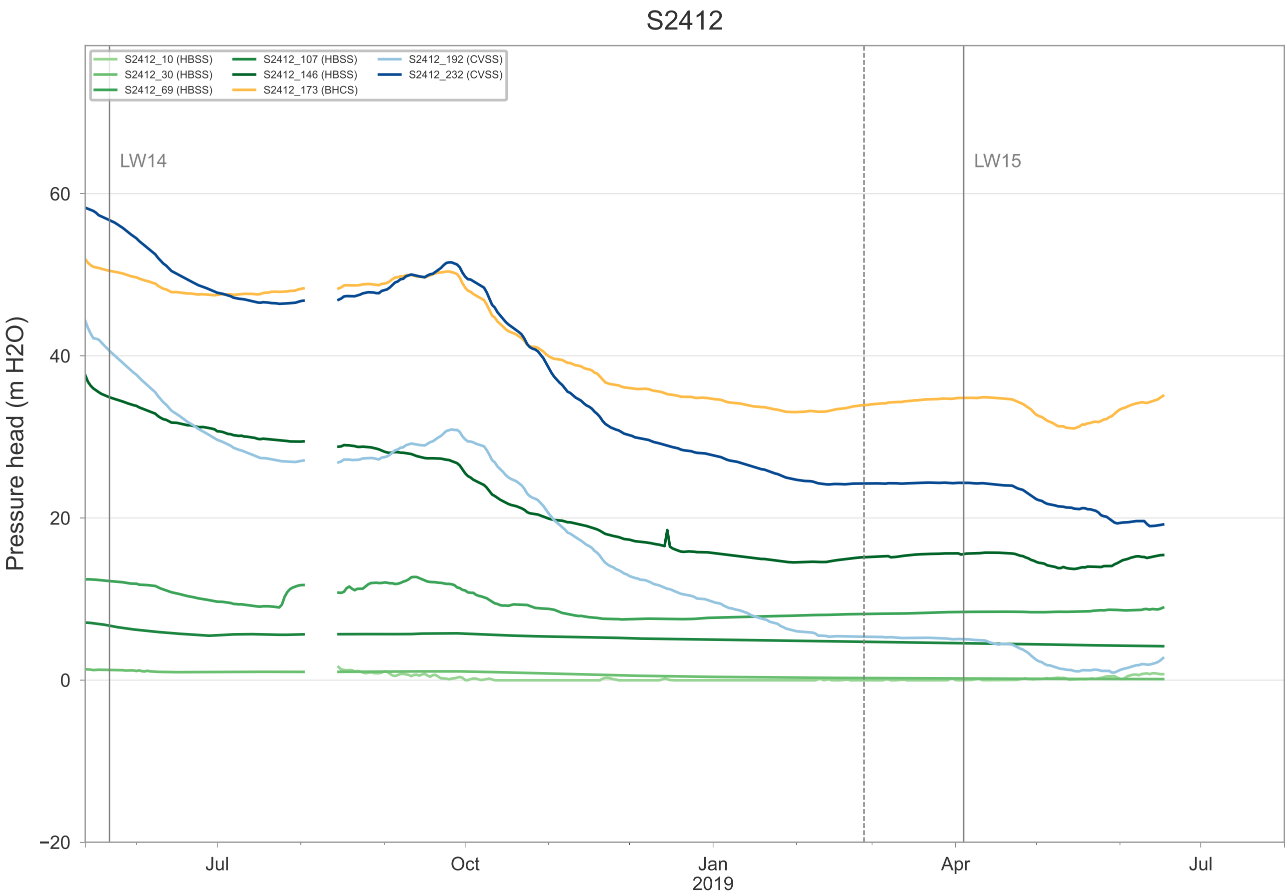


Groundwater hydrographs

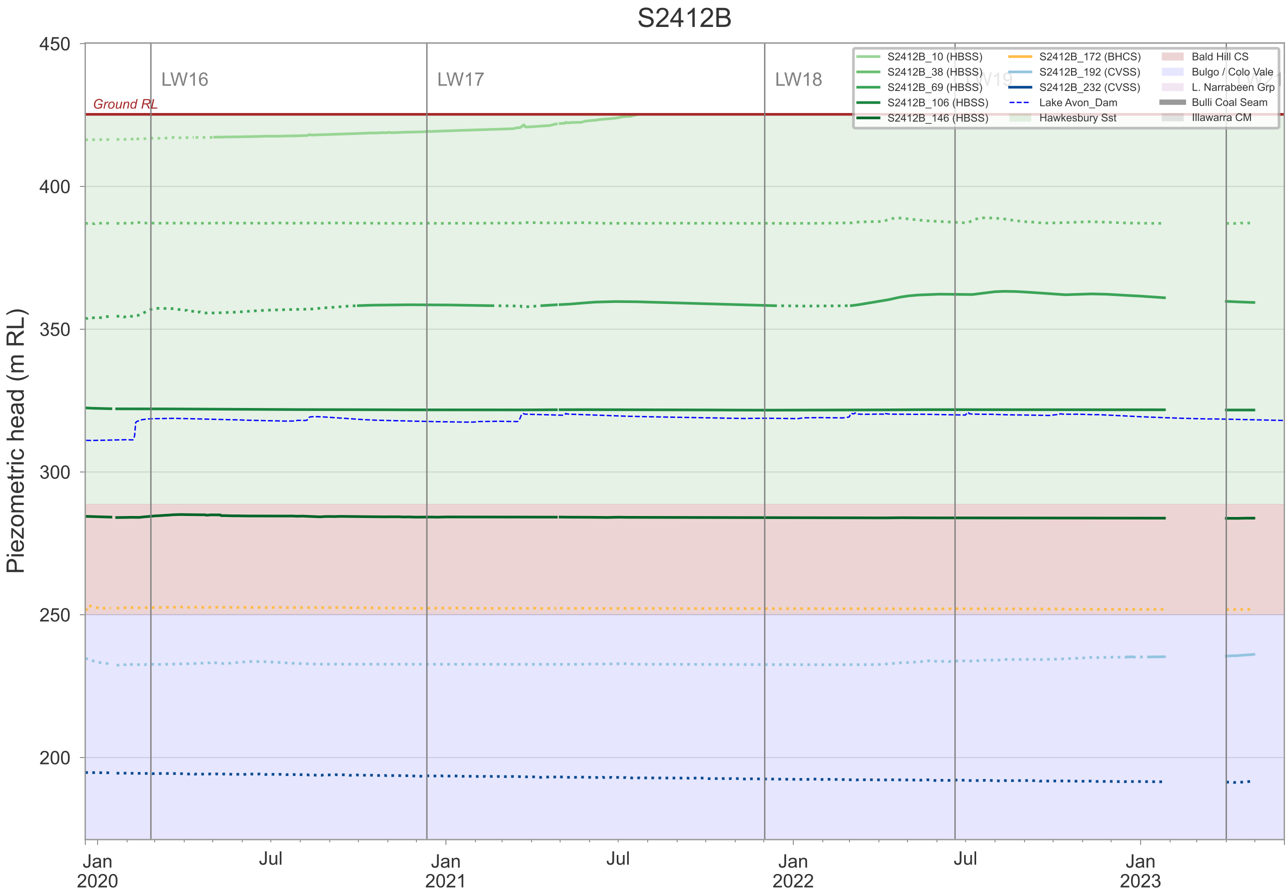


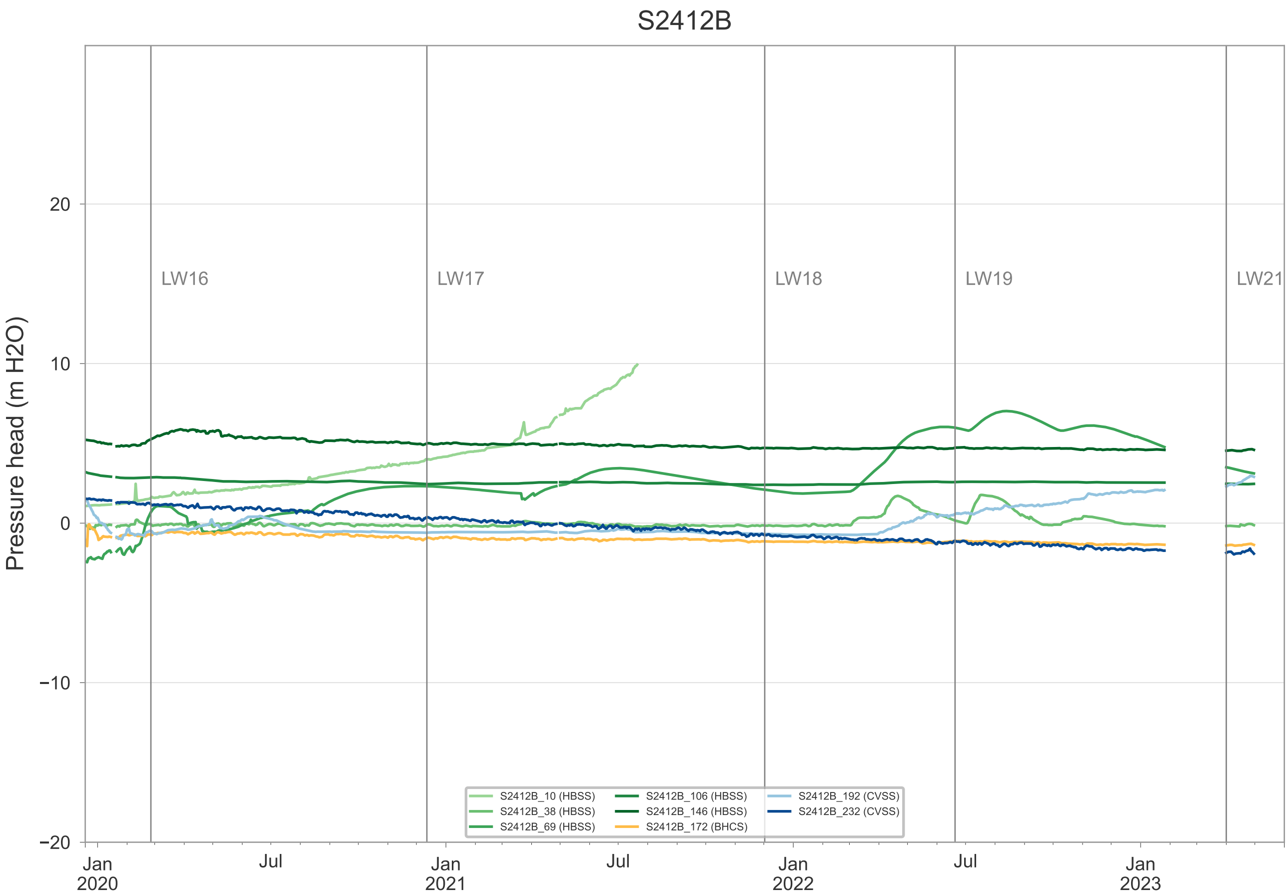



S2412
Piezometric head (m RL)
450
400
350
300
250
200
LW14
LW15
Ground RL
Jul
Oct
Jan
2019
Apr
Jul
S2412_10 (HBSS)
S2412_30 (HBSS)
S2412_69 (HBSS)
S2412_107 (HBSS)
S2412_146 (HBSS)
S2412_173 (BHCS)
S2412_192 (CVSS)
S2412_232 (CVSS)
Lake Avon_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM

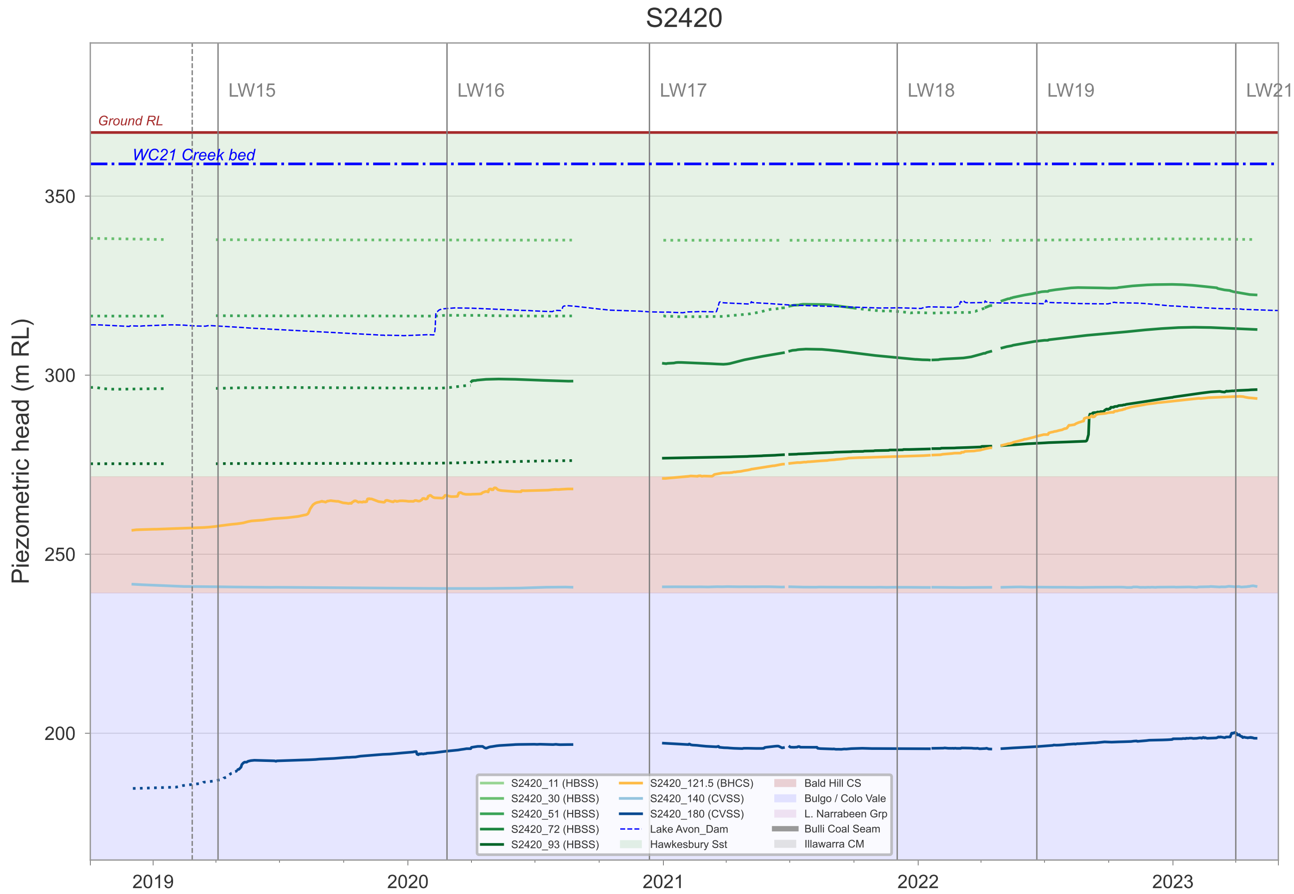

S2412
Pressure head (m H2O)
60
40
20
0
−20
LW14
LW15
Jul
Oct
Jan
2019
Apr
Jul
S2412_10 (HBSS)
S2412_30 (HBSS)
S2412_69 (HBSS)
S2412_107 (HBSS)
S2412_146 (HBSS)
S2412_173 (BHCS)
S2412_192 (CVSS)
S2412_232 (CVSS)

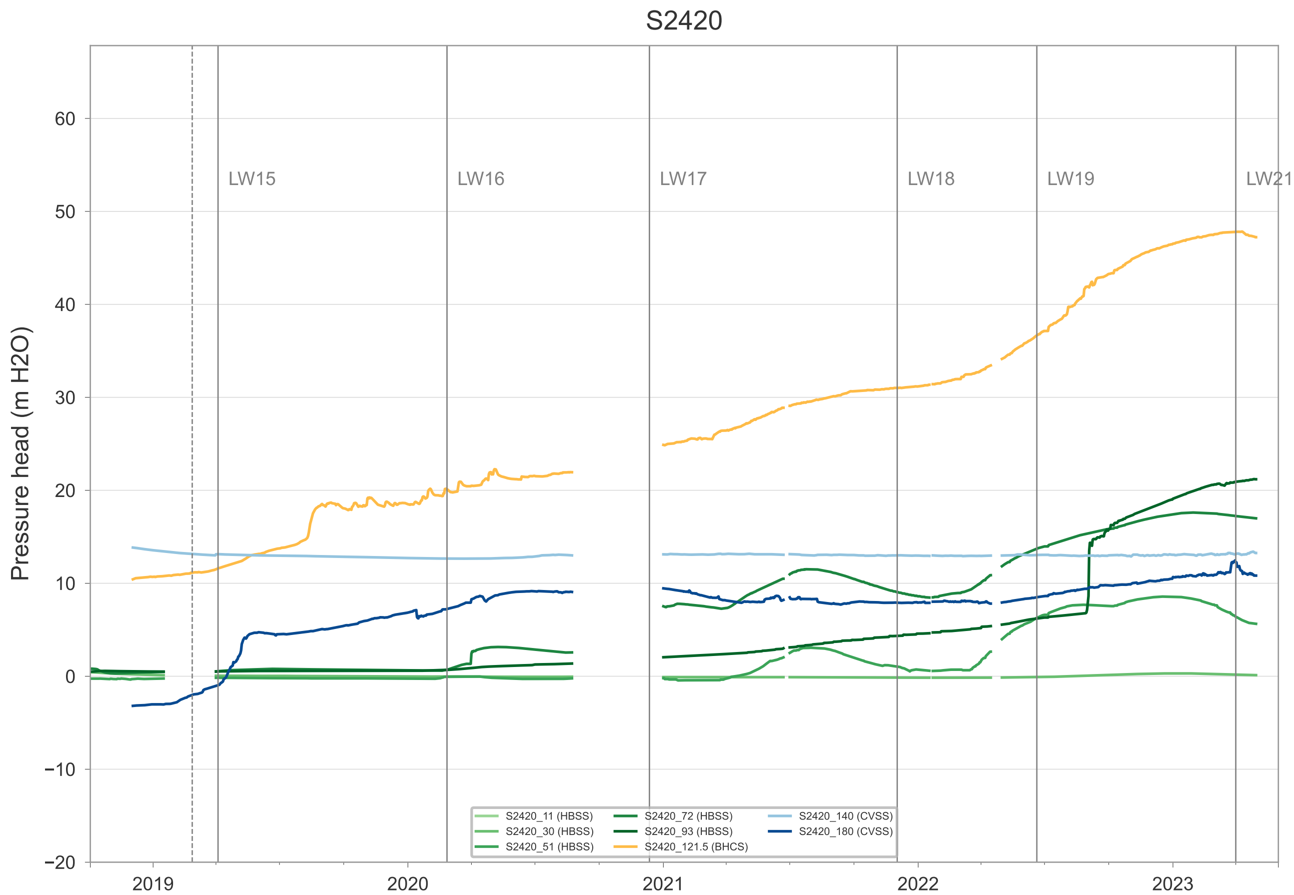
Groundwater hydrographs



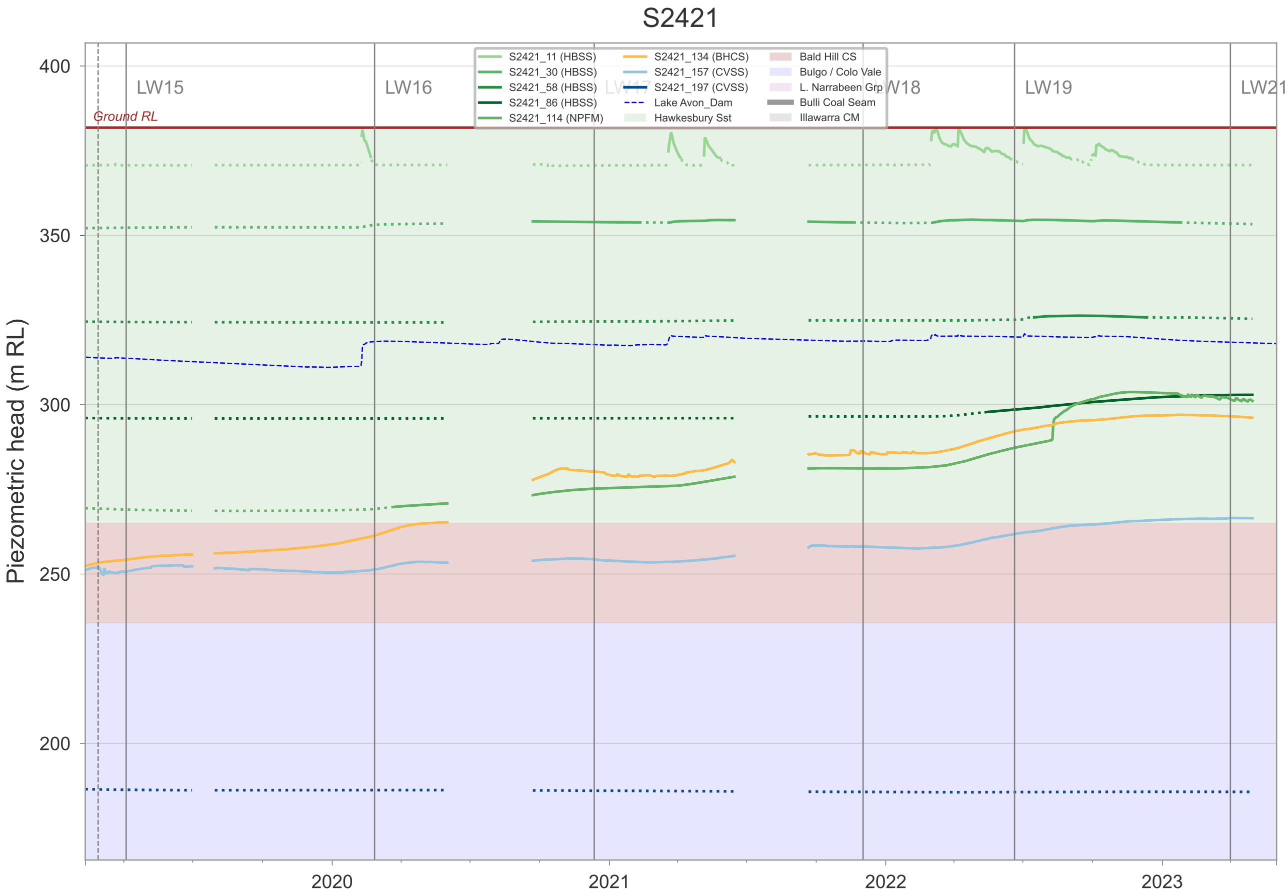


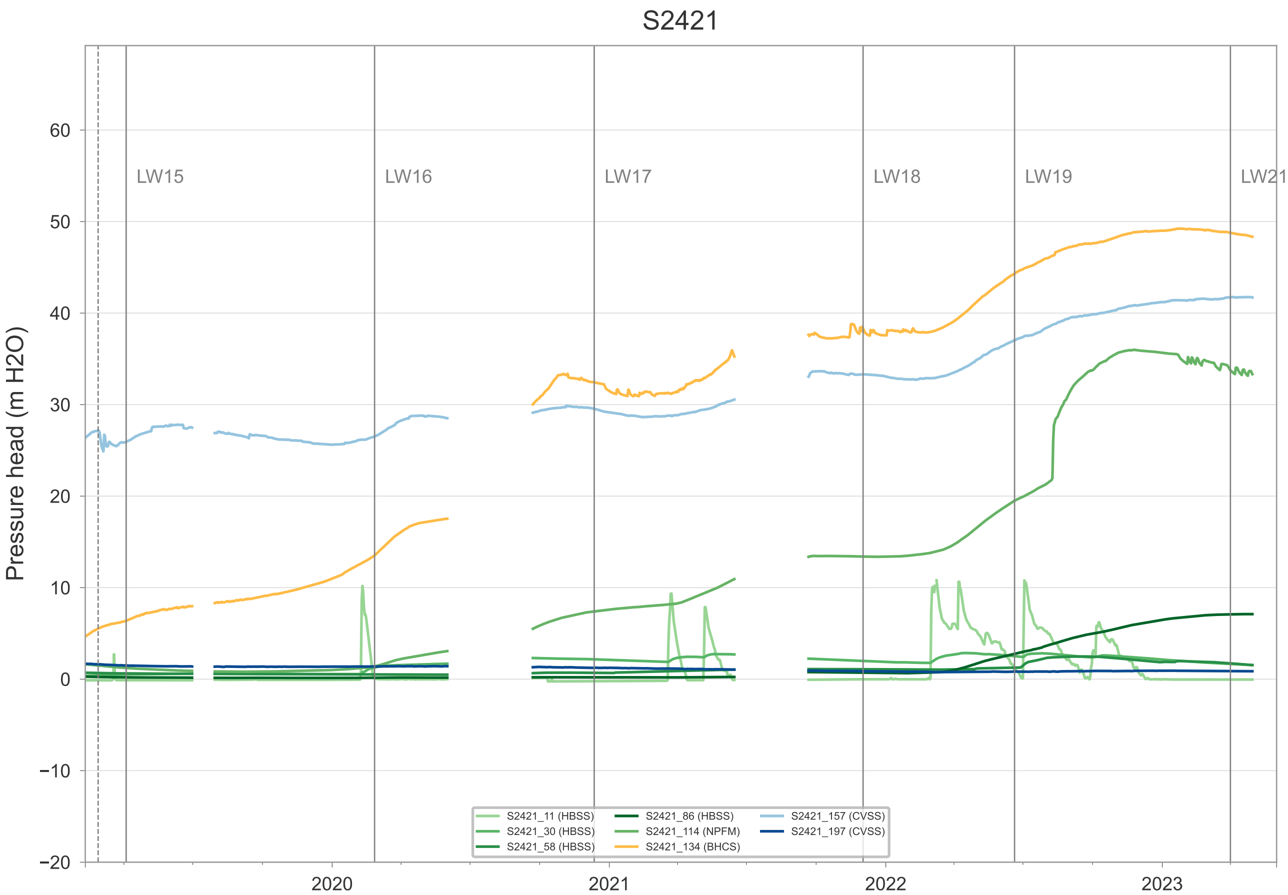
Groundwater hydrographs



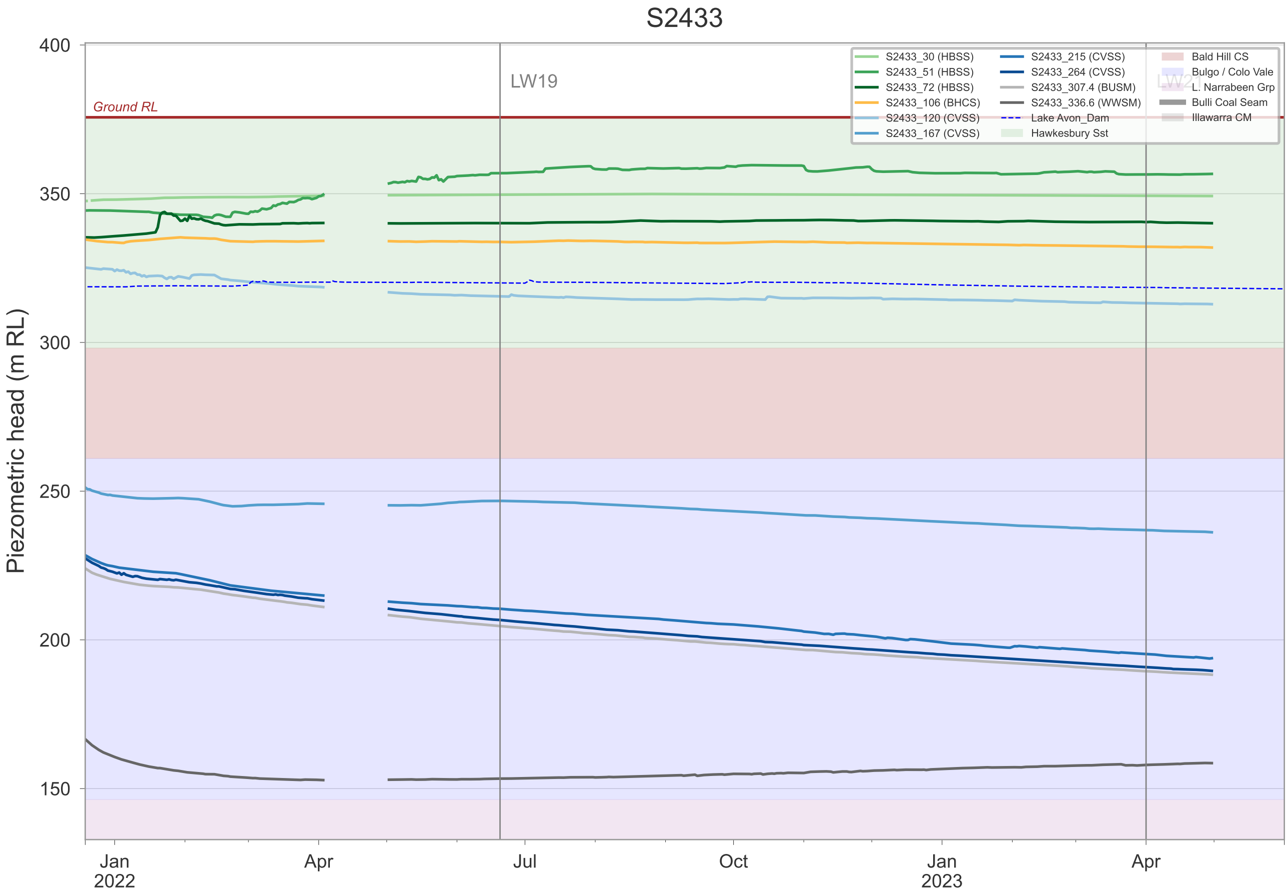


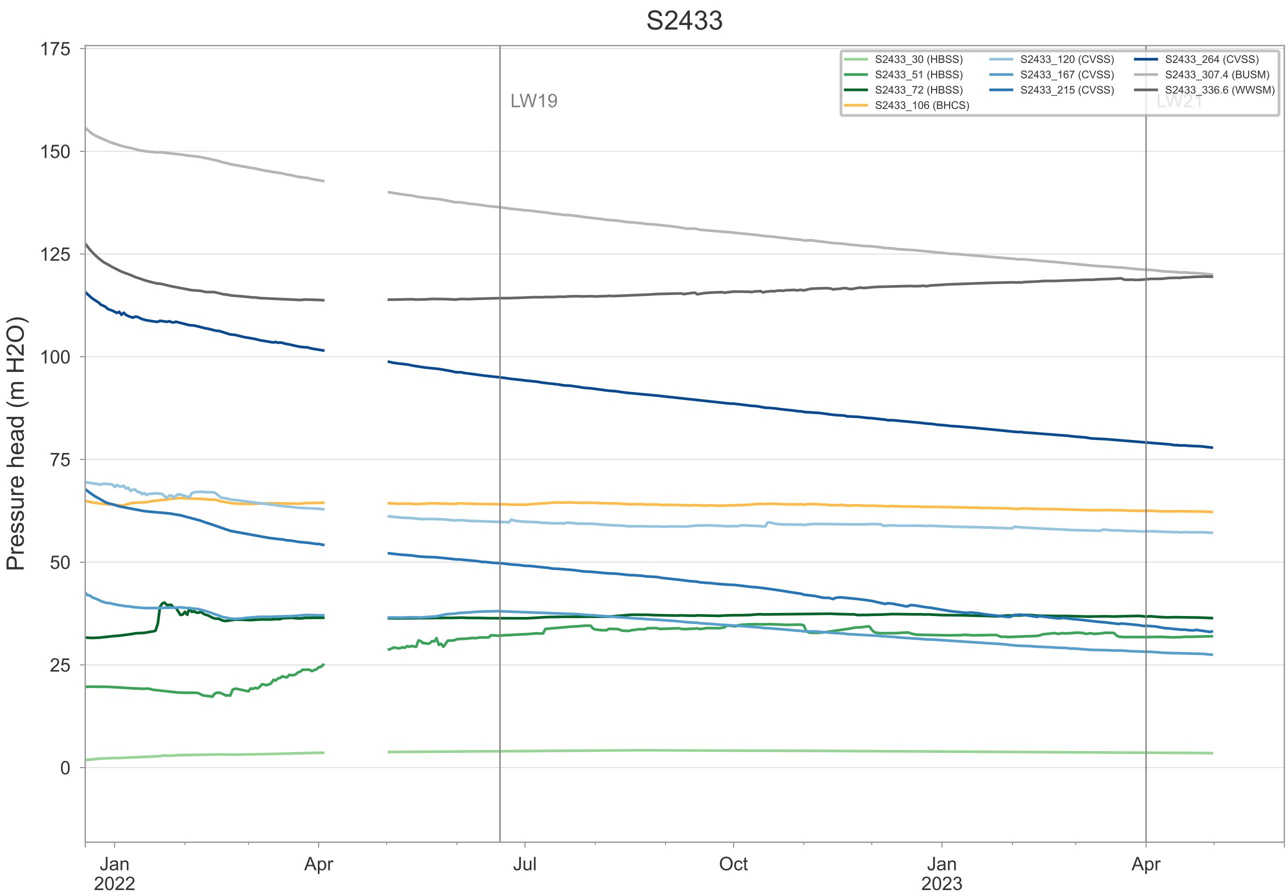
Groundwater hydrographs



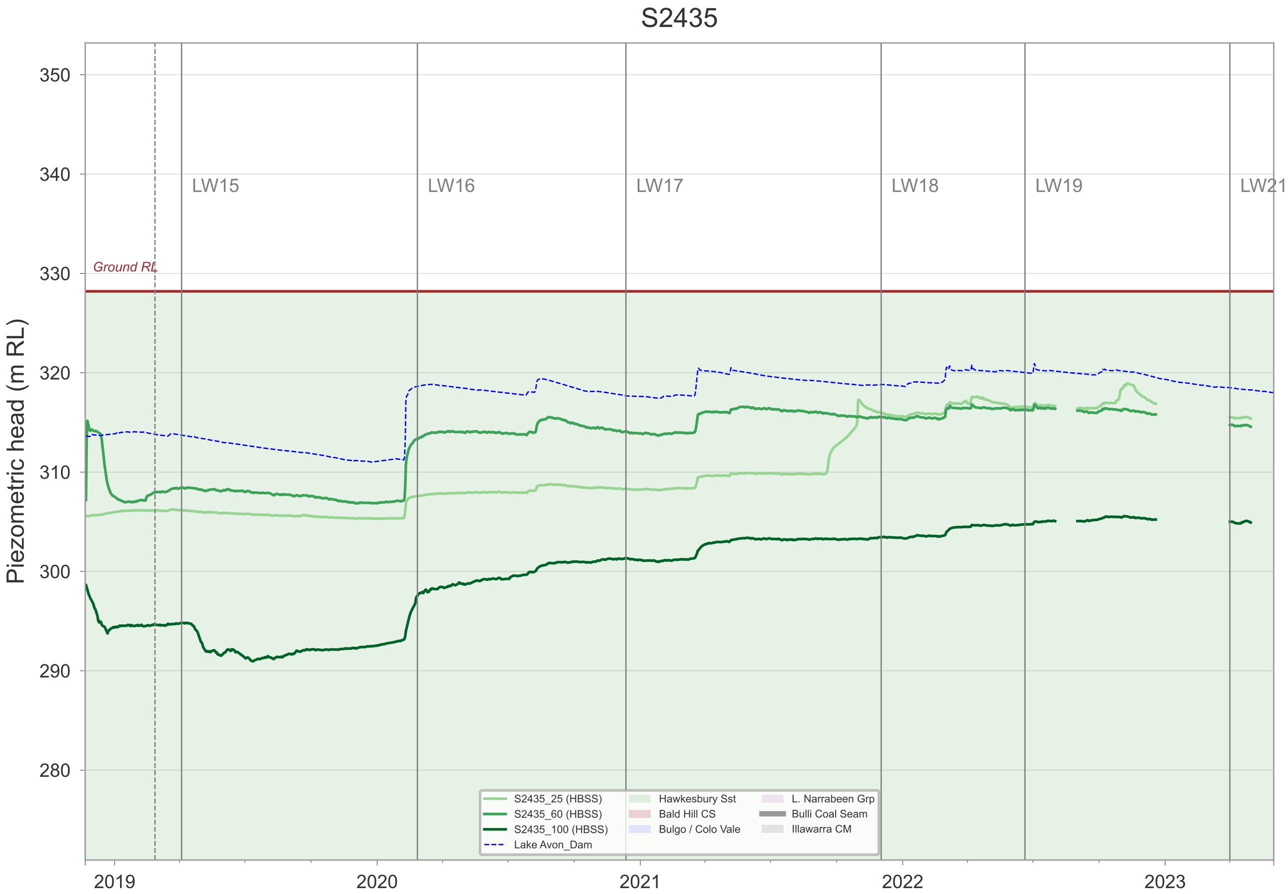


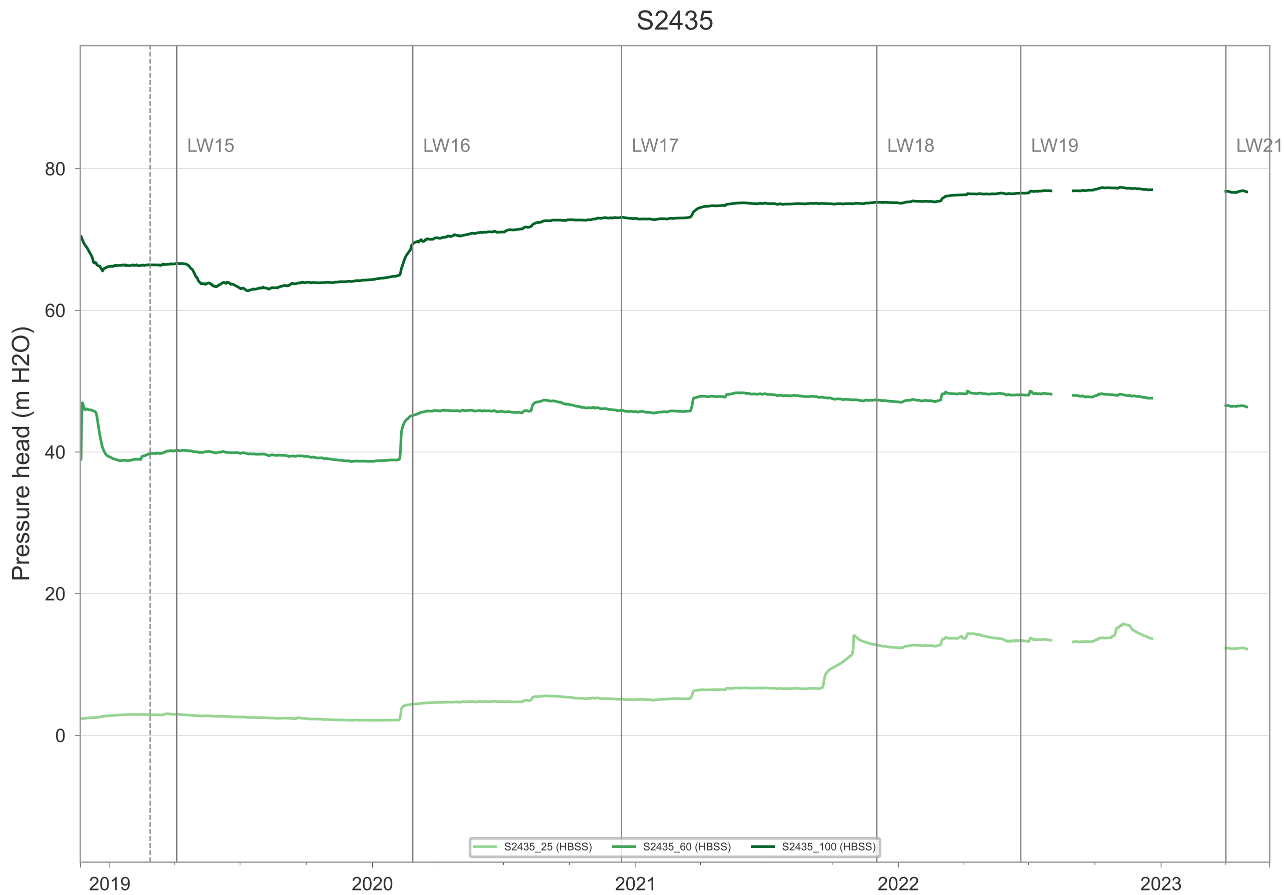
Groundwater hydrographs



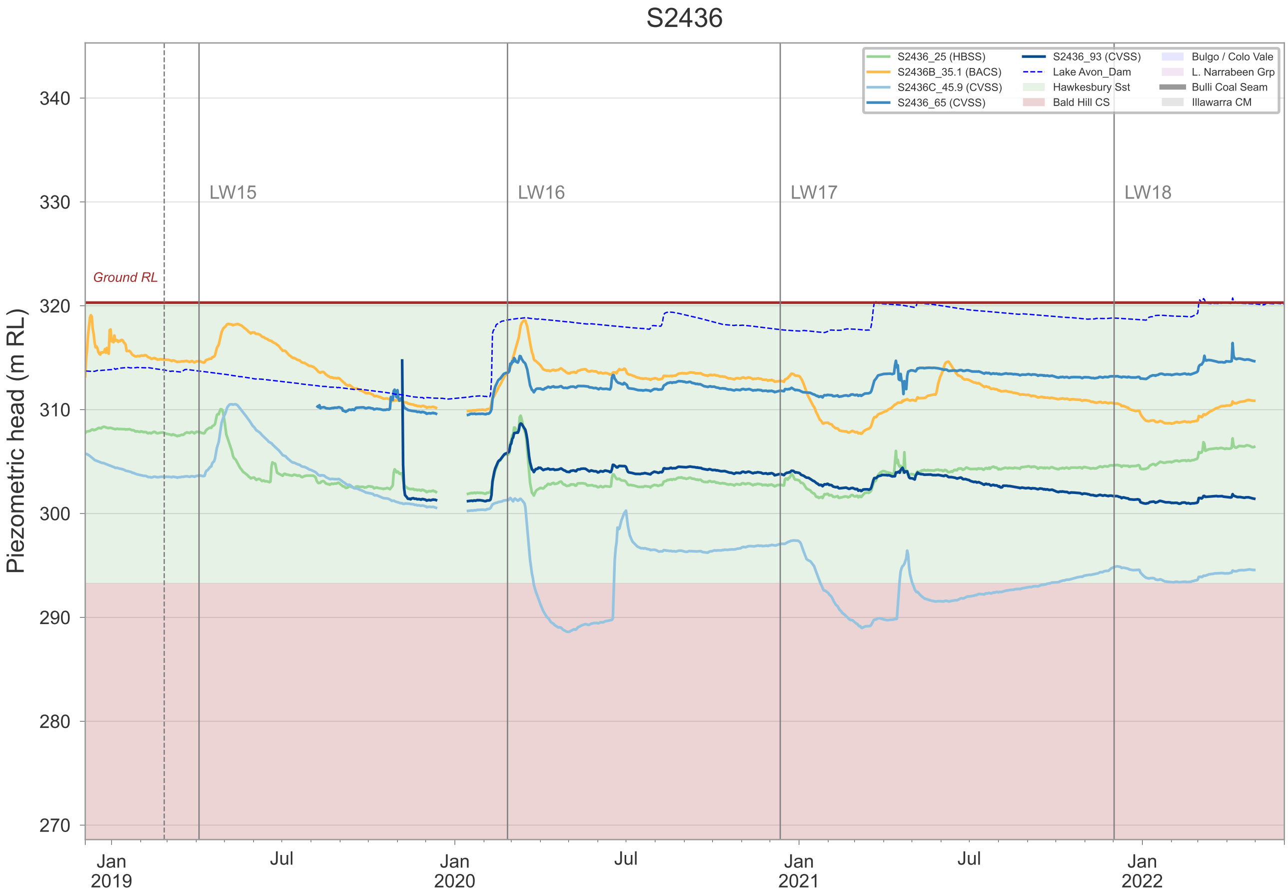


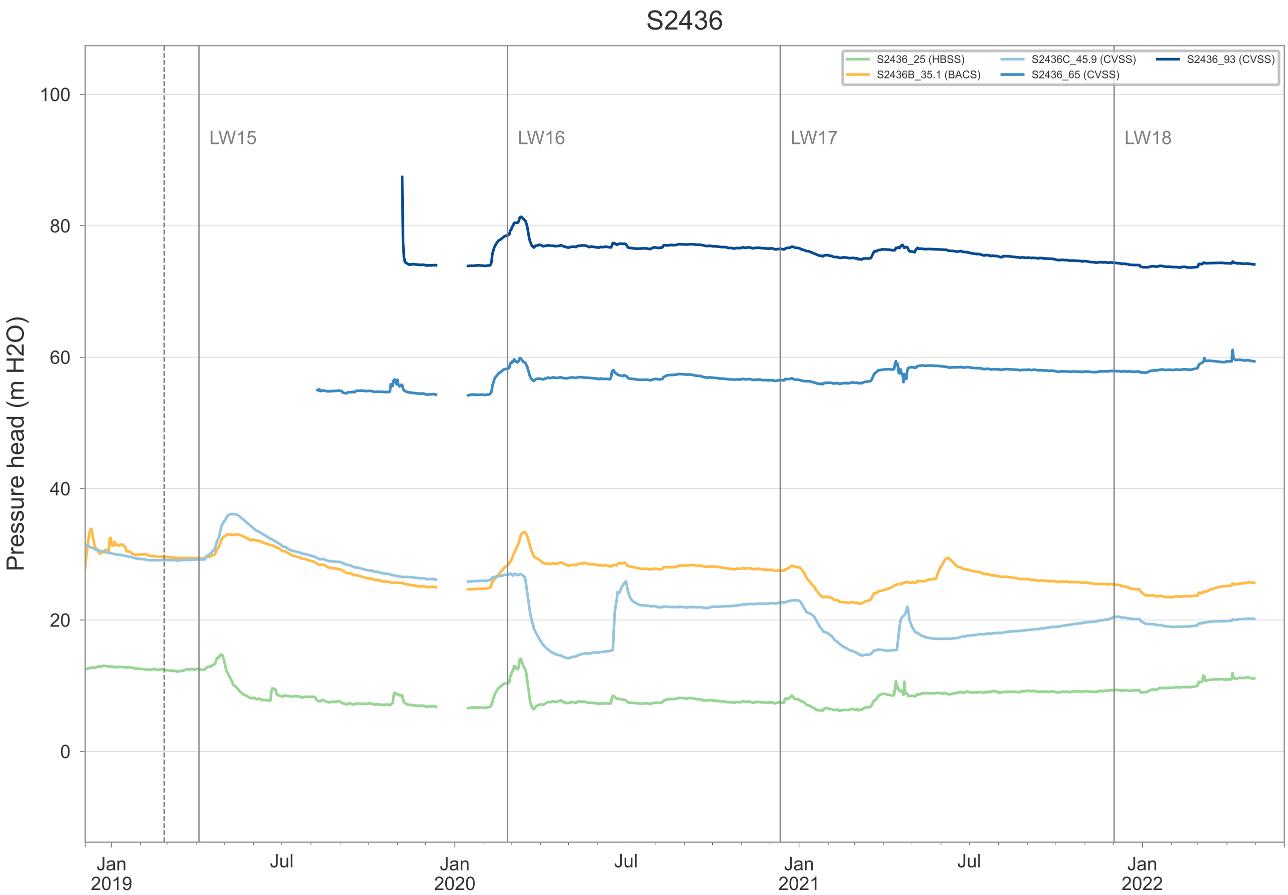
Groundwater hydrographs



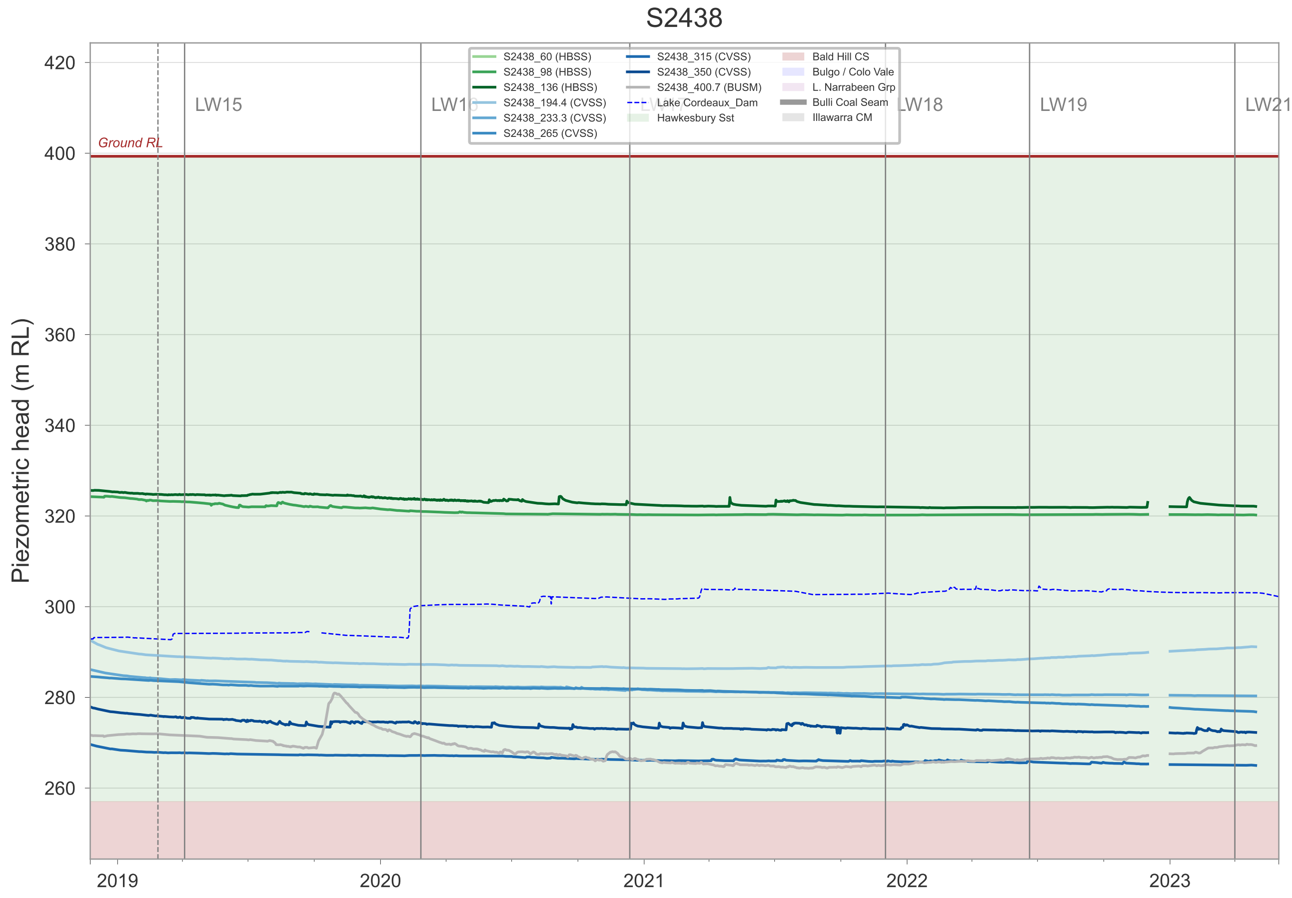


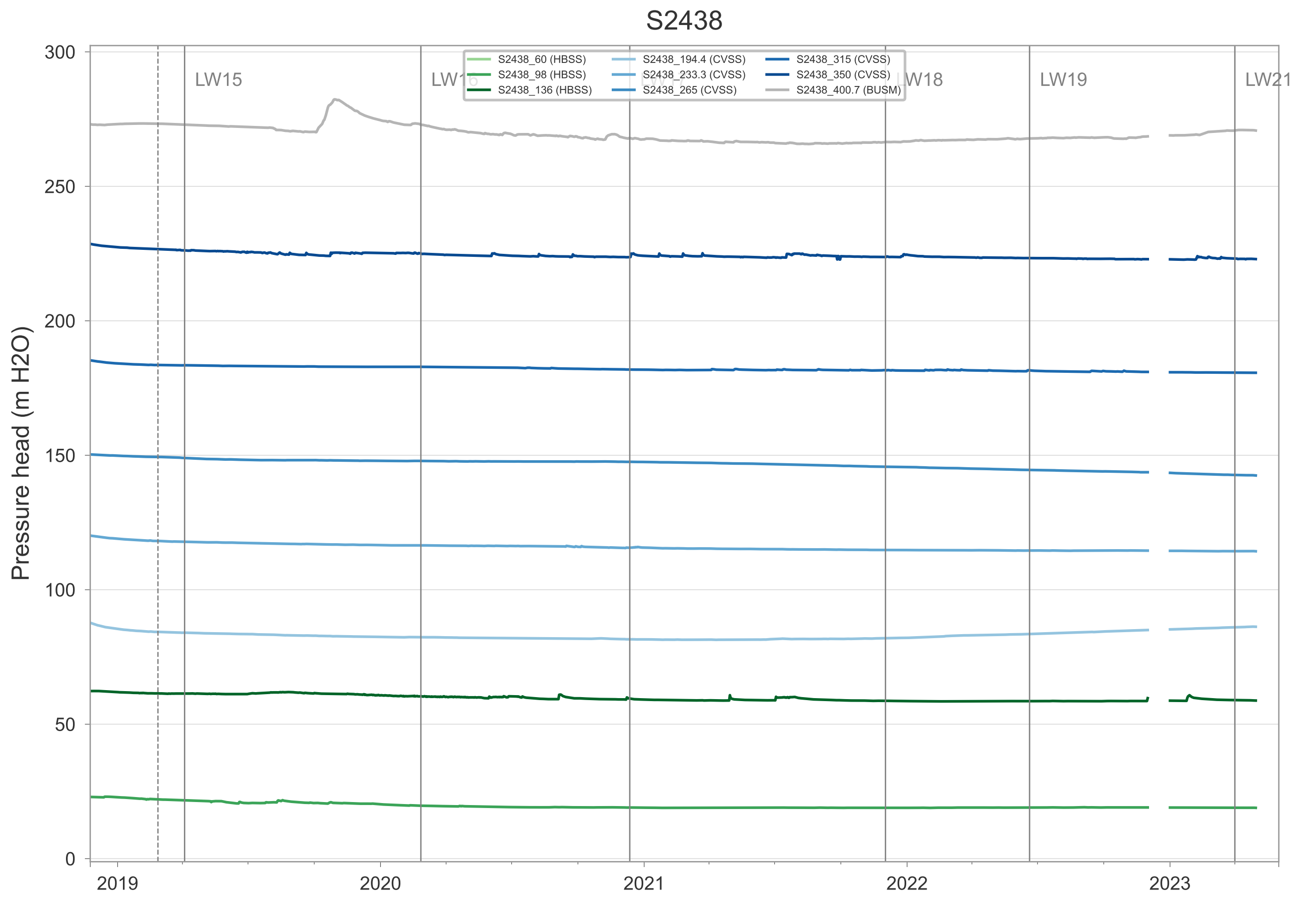
Groundwater hydrographs



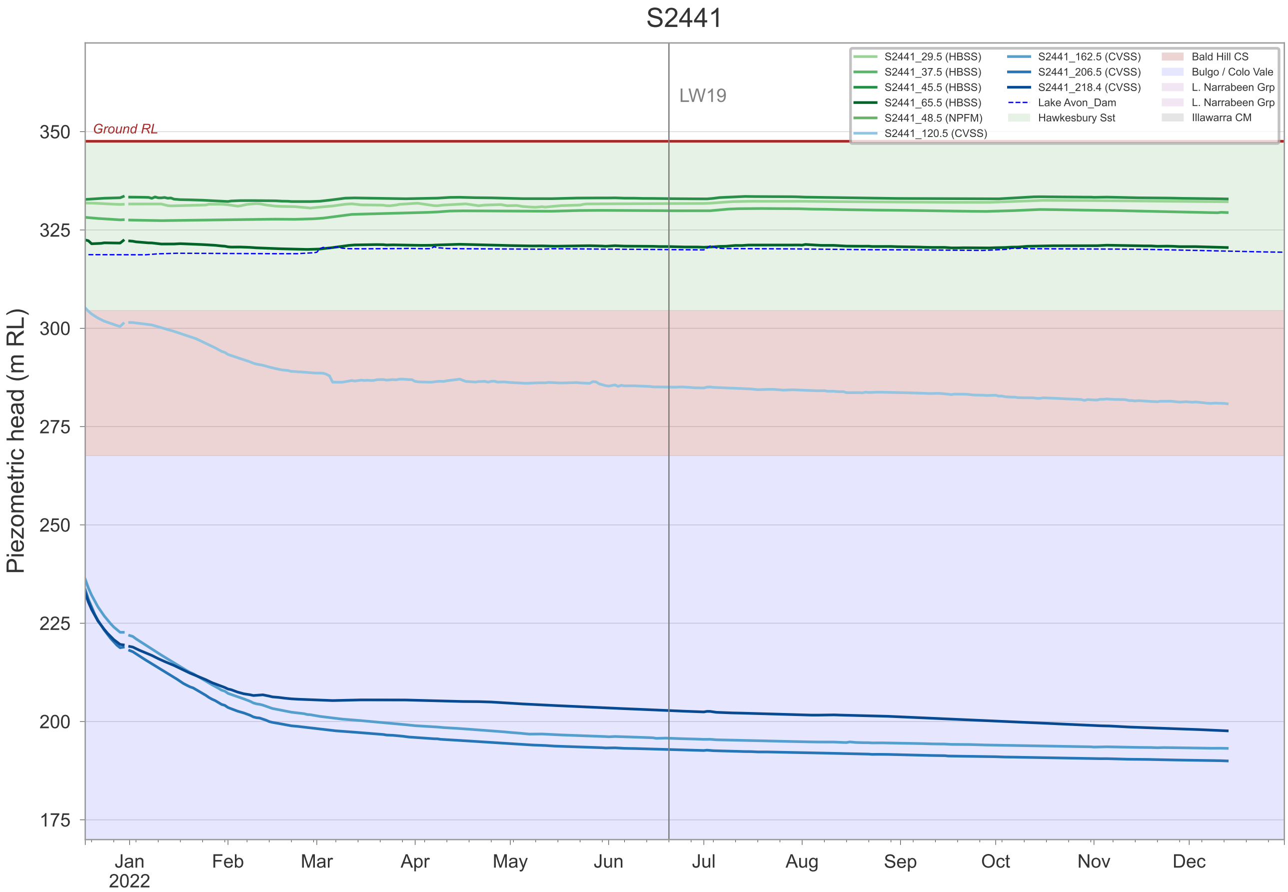


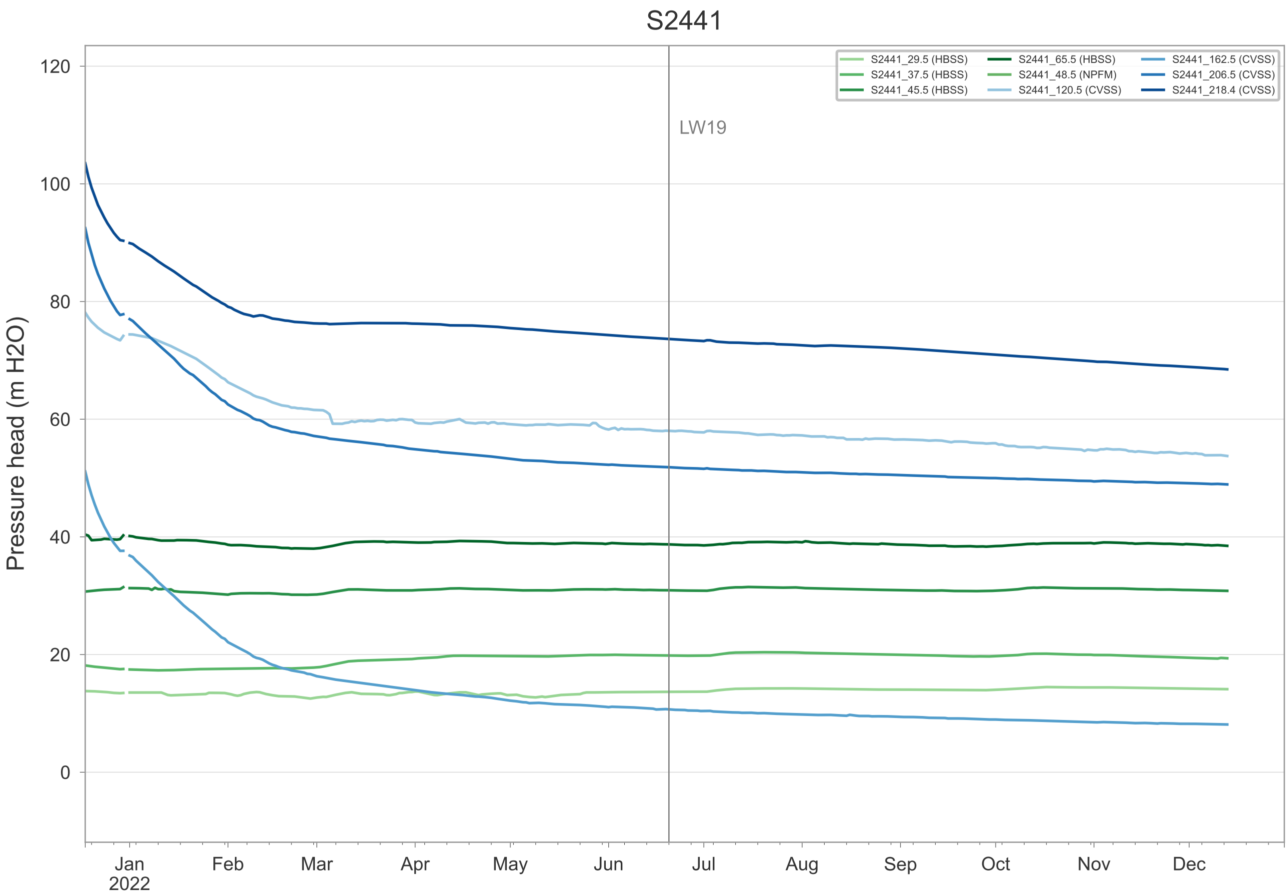
Groundwater hydrographs



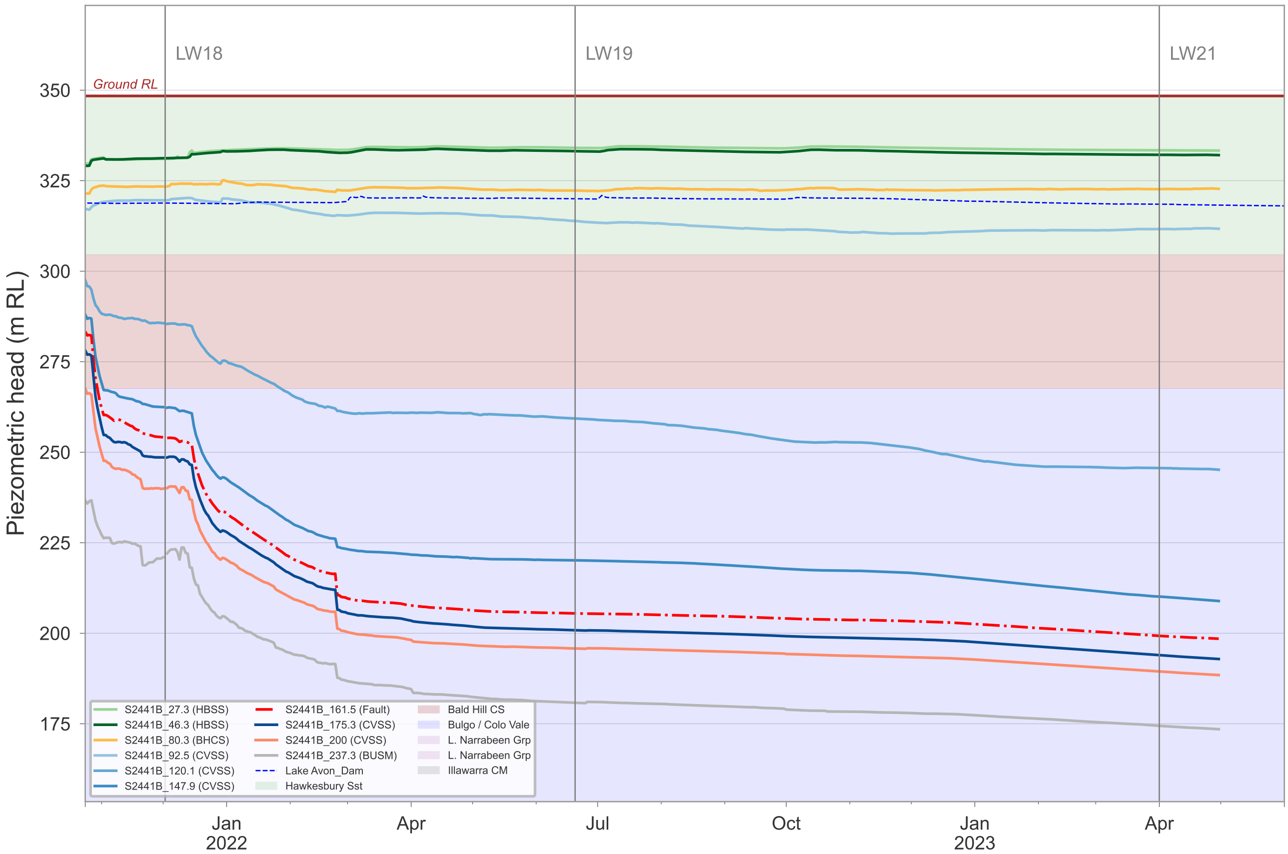


Groundwater hydrographs

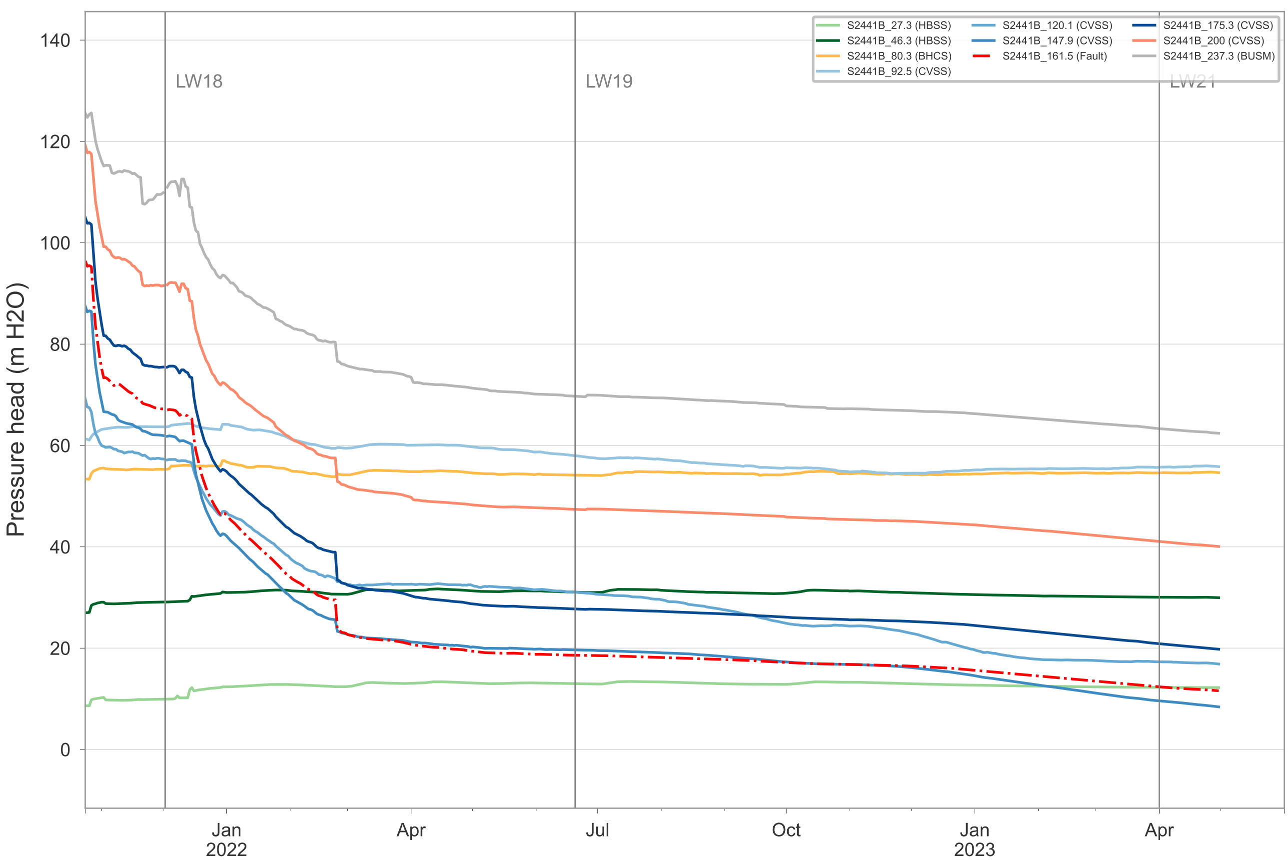


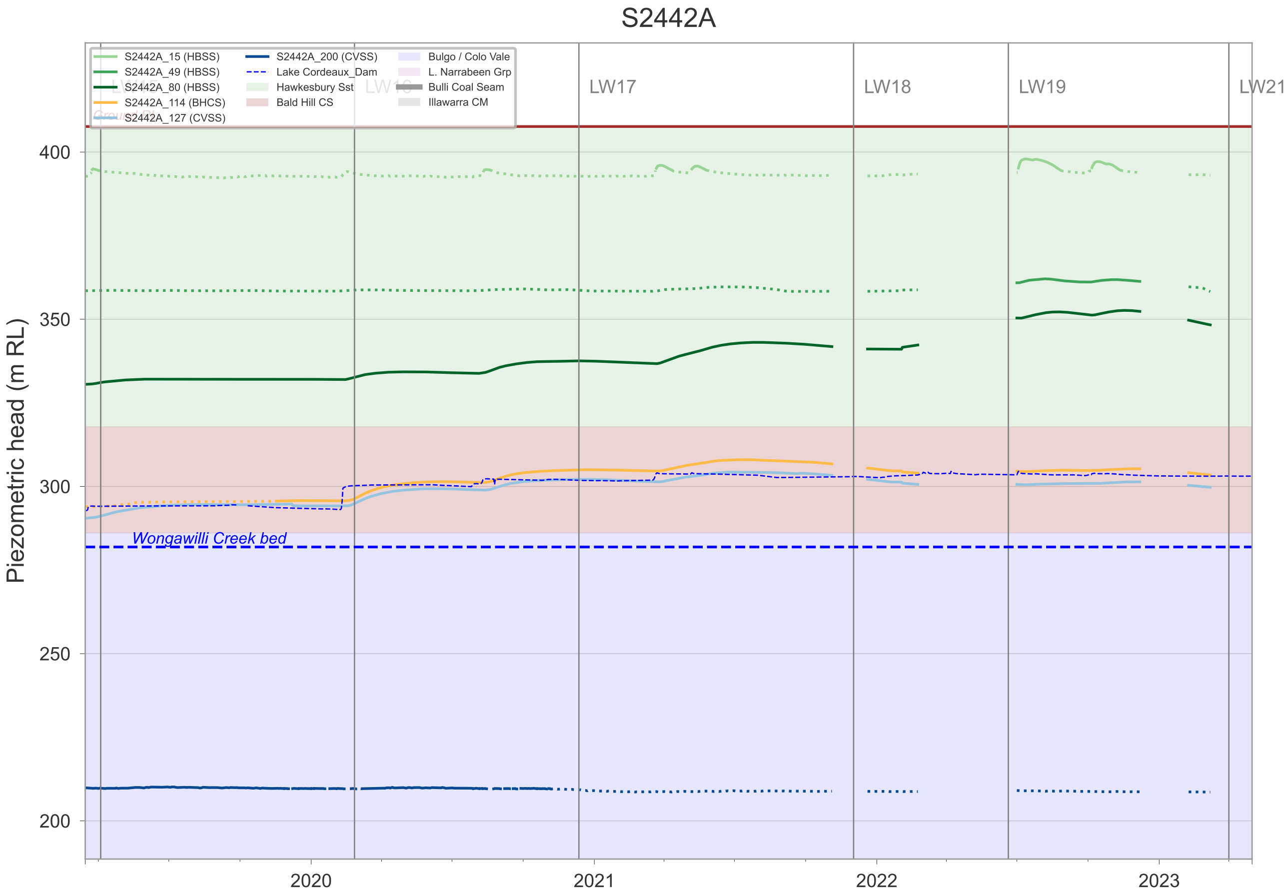


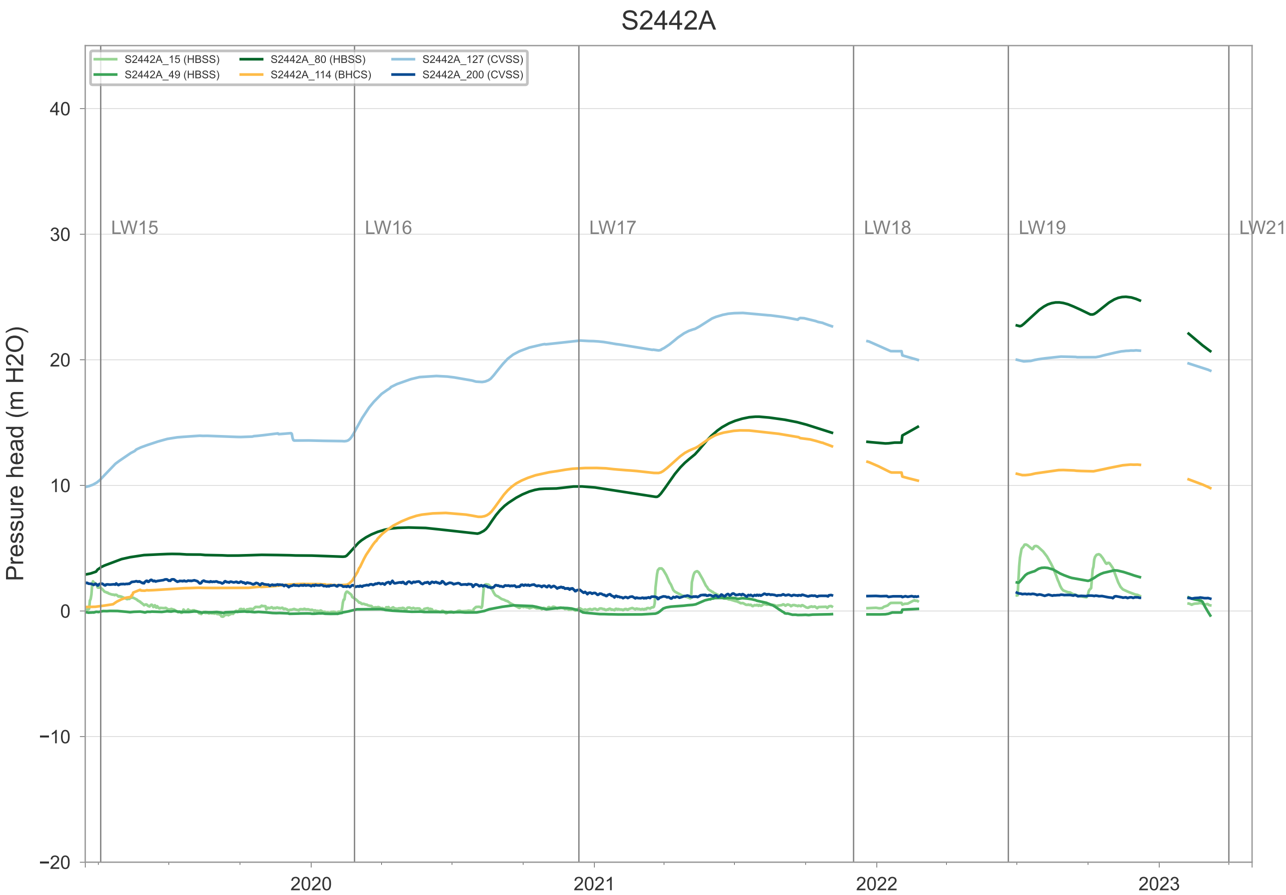
S2441B

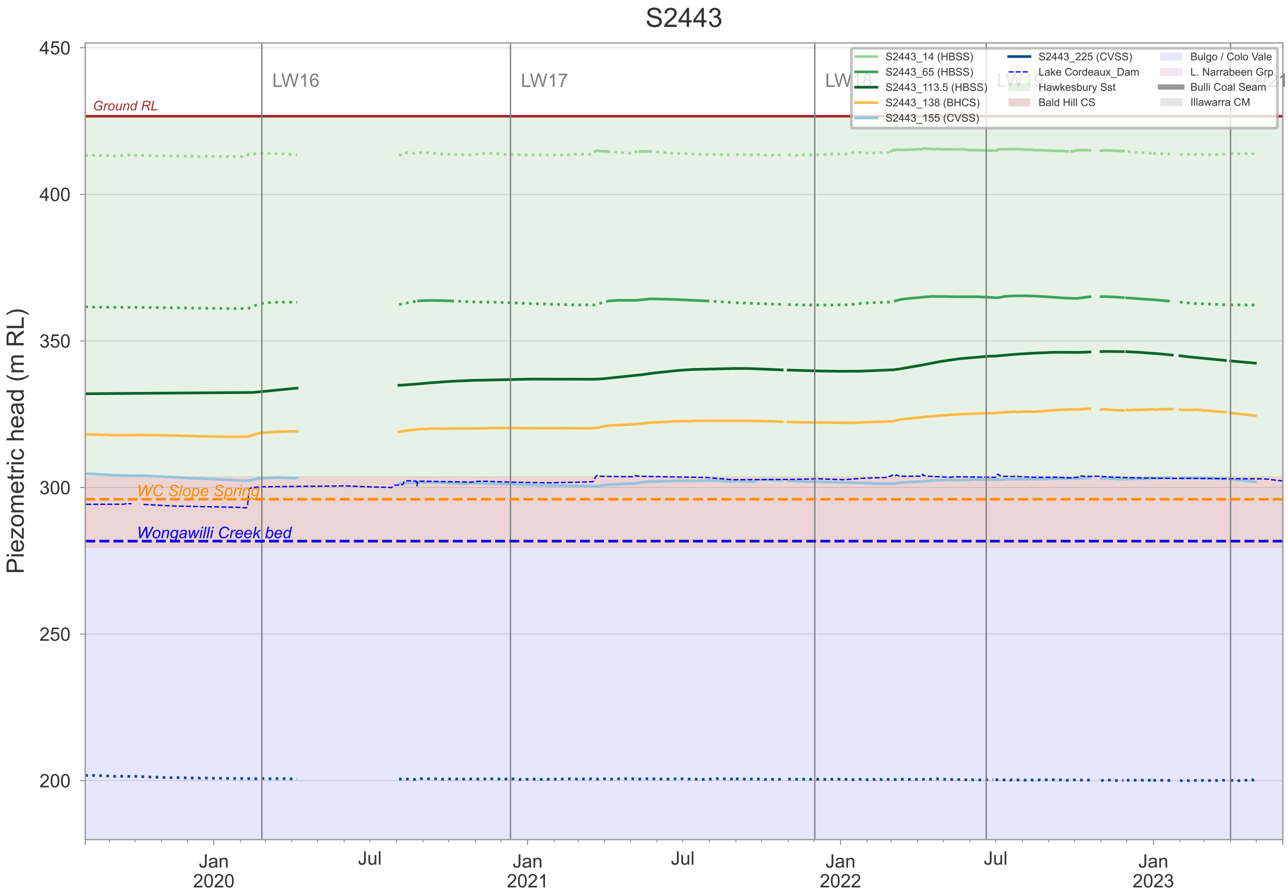


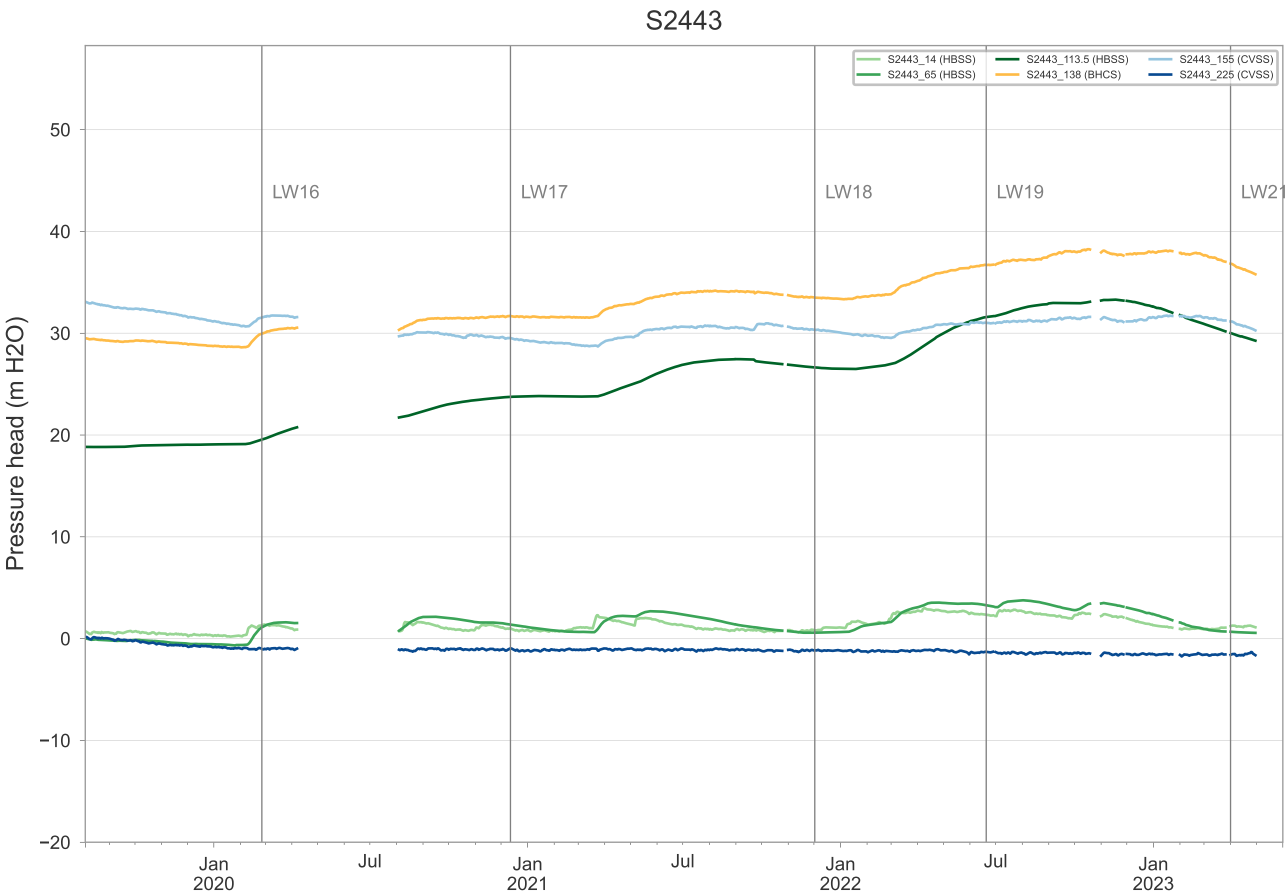
S2441B



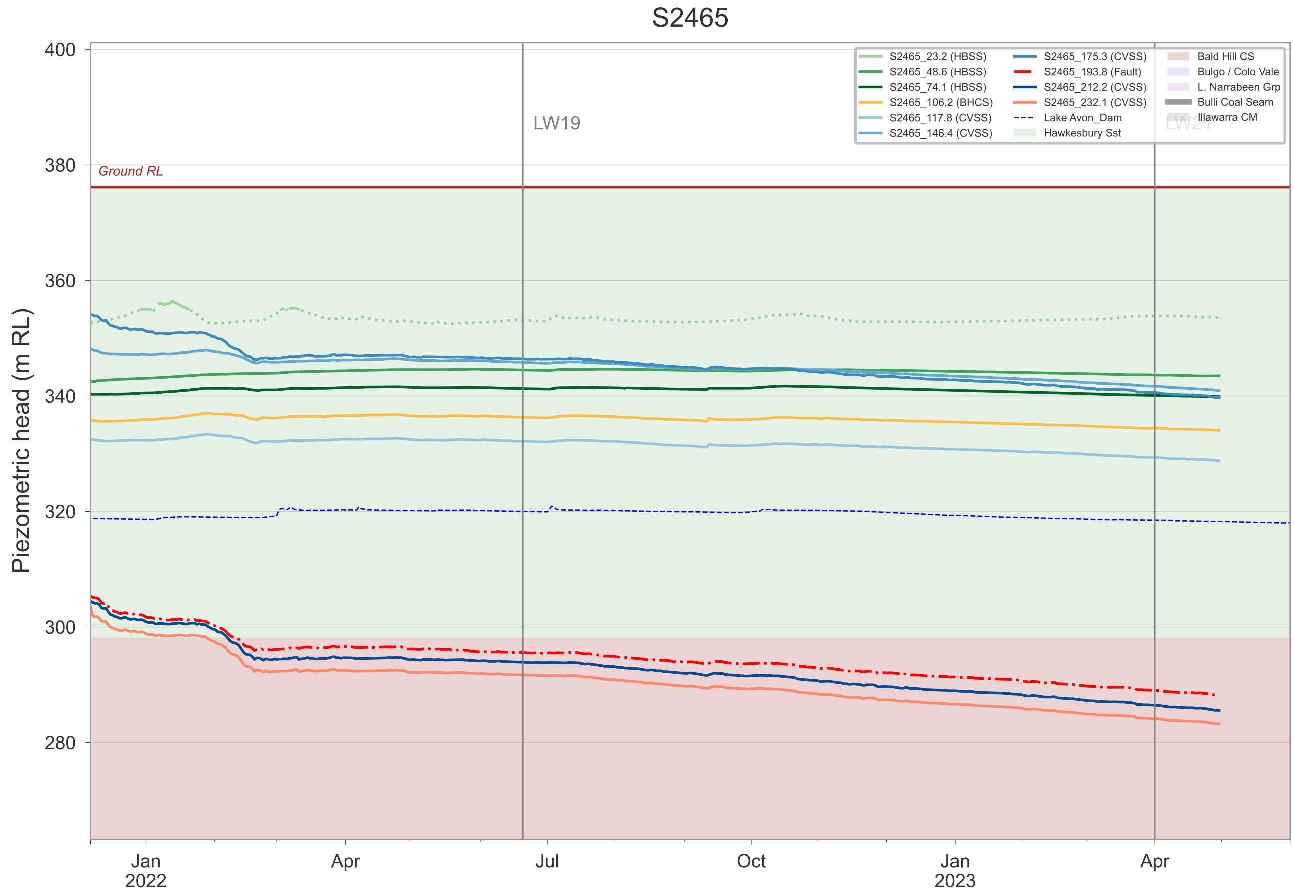

S2442A
S2442A_15 (HBSS)
S2442A_49 (HBSS)
S2442A_80 (HBSS)
S2442A_114 (BHCS)
S2442A_127 (CVSS)
S2442A_200 (CVSS)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
LW17
LW18
LW19
LW21
Wongawilli Creek bed
Piezometric head (m RL)
400
350
300
250
200
2020
2021
2022
2023

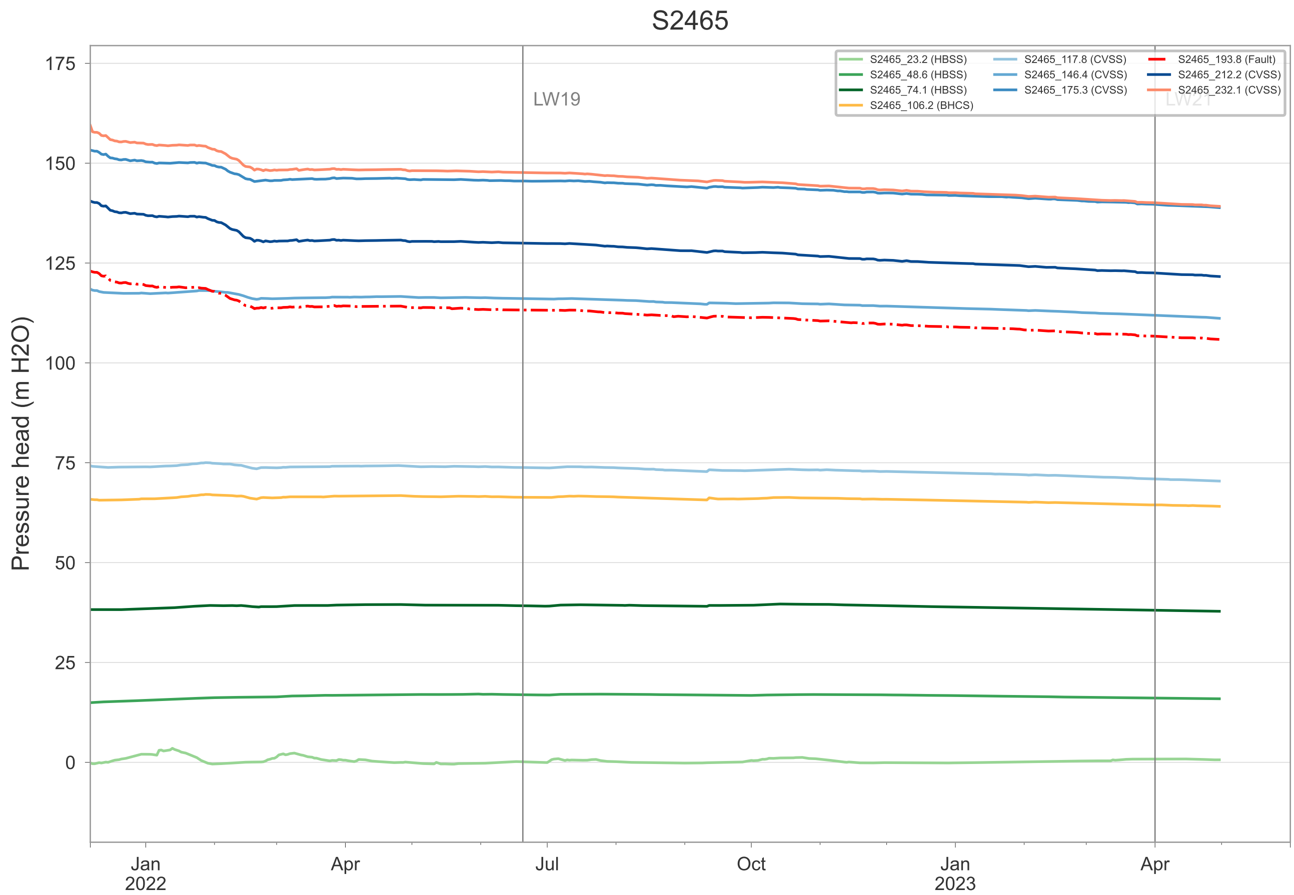

S2442A
S2442A_15 (HBSS)
S2442A_49 (HBSS)
S2442A_80 (HBSS)
S2442A_114 (BHCS)
S2442A_127 (CVSS)
S2442A_200 (CVSS)
LW15
LW16
LW17
LW18
LW19
LW21
Pressure head (m H2O)
40
30
20
10
0
−10
−20
2020
2021
2022
2023


S2443
Piezometric head (m RL)
LW16
LW17
LW18
LW19
LW21
Ground RL
WC Slope Spring
Wongawilli Creek bed
S2443_14 (HBSS)
S2443_65 (HBSS)
S2443_113.5 (HBSS)
S2443_138 (BHCS)
S2443_155 (CVSS)
S2443_225 (CVSS)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Jan 2020
Jul
Jan 2021
Jul
Jan 2022
Jul
Jan 2023

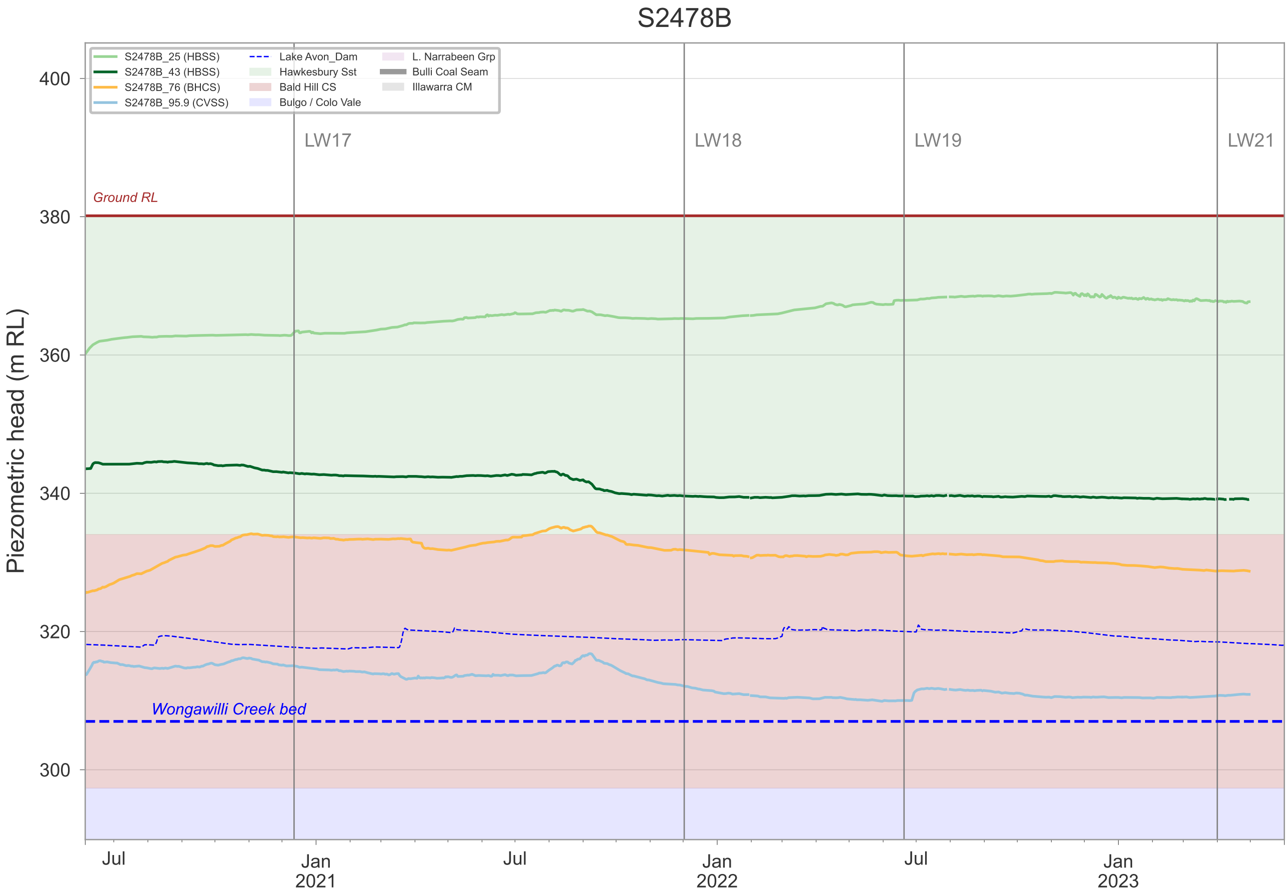

S2443
Pressure head (m H2O)
LW16
LW17
LW18
LW19
LW21
S2443_14 (HBSS)
S2443_65 (HBSS)
S2443_113.5 (HBSS)
S2443_138 (BHCS)
S2443_155 (CVSS)
S2443_225 (CVSS)
Jan 2020
Jul
Jan 2021
Jul
Jan 2022
Jul
Jan 2023

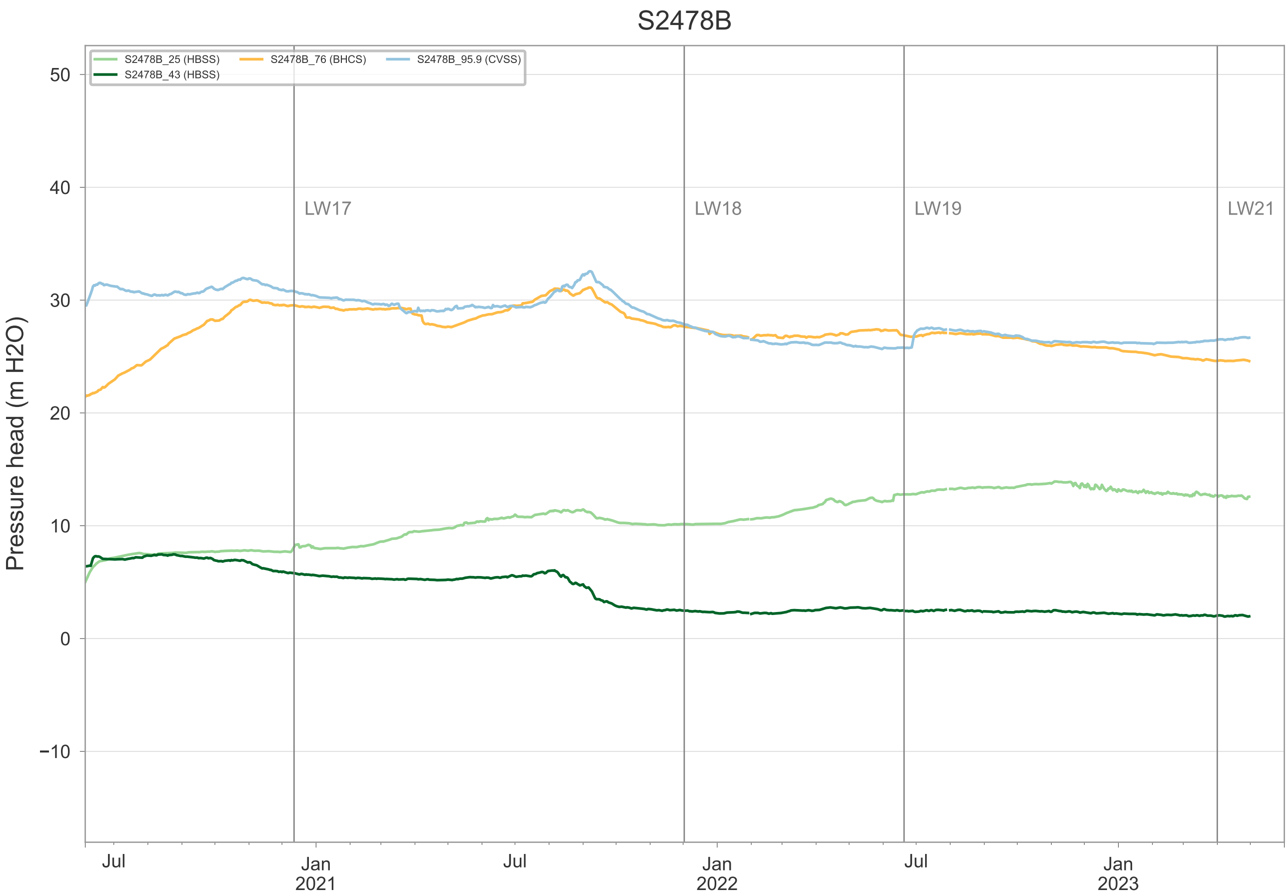
Groundwater hydrographs



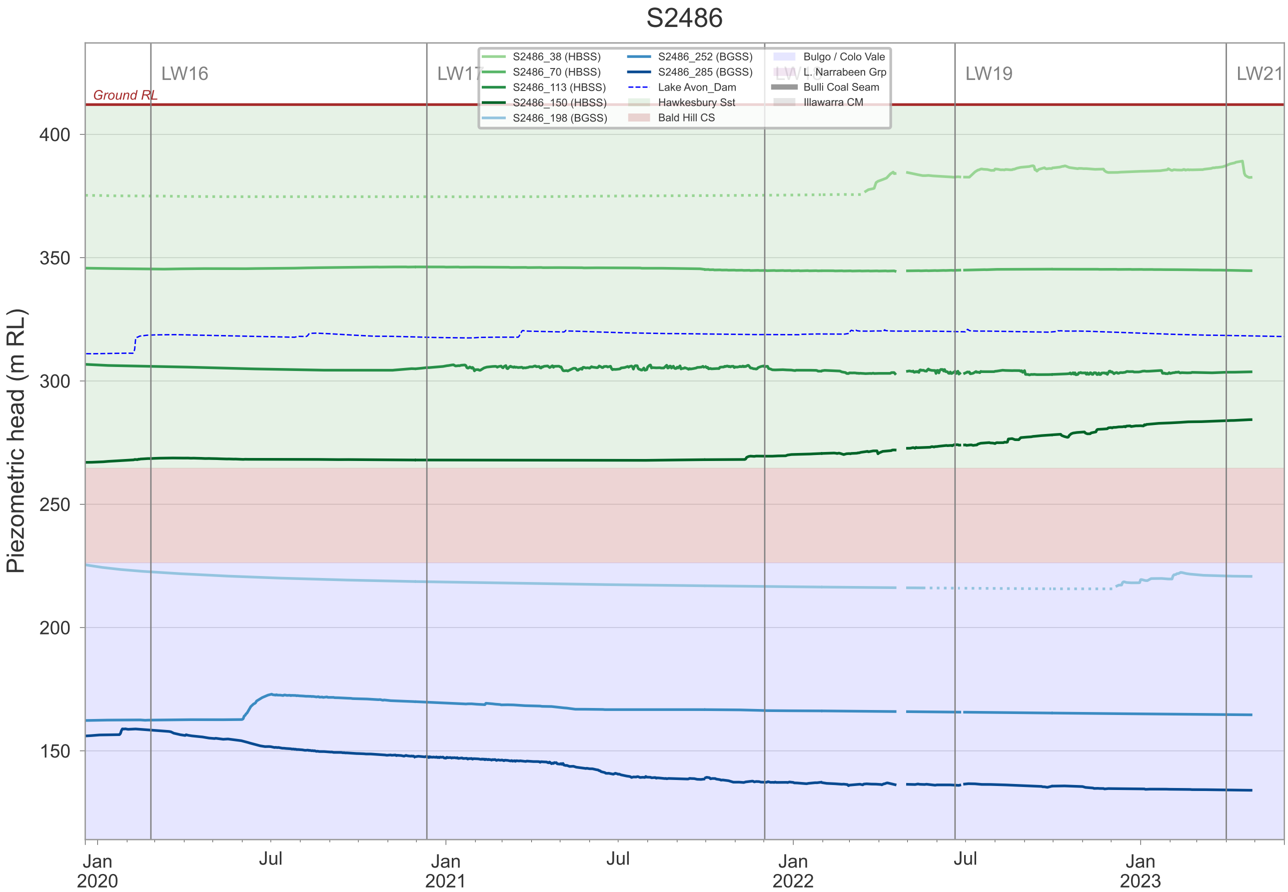


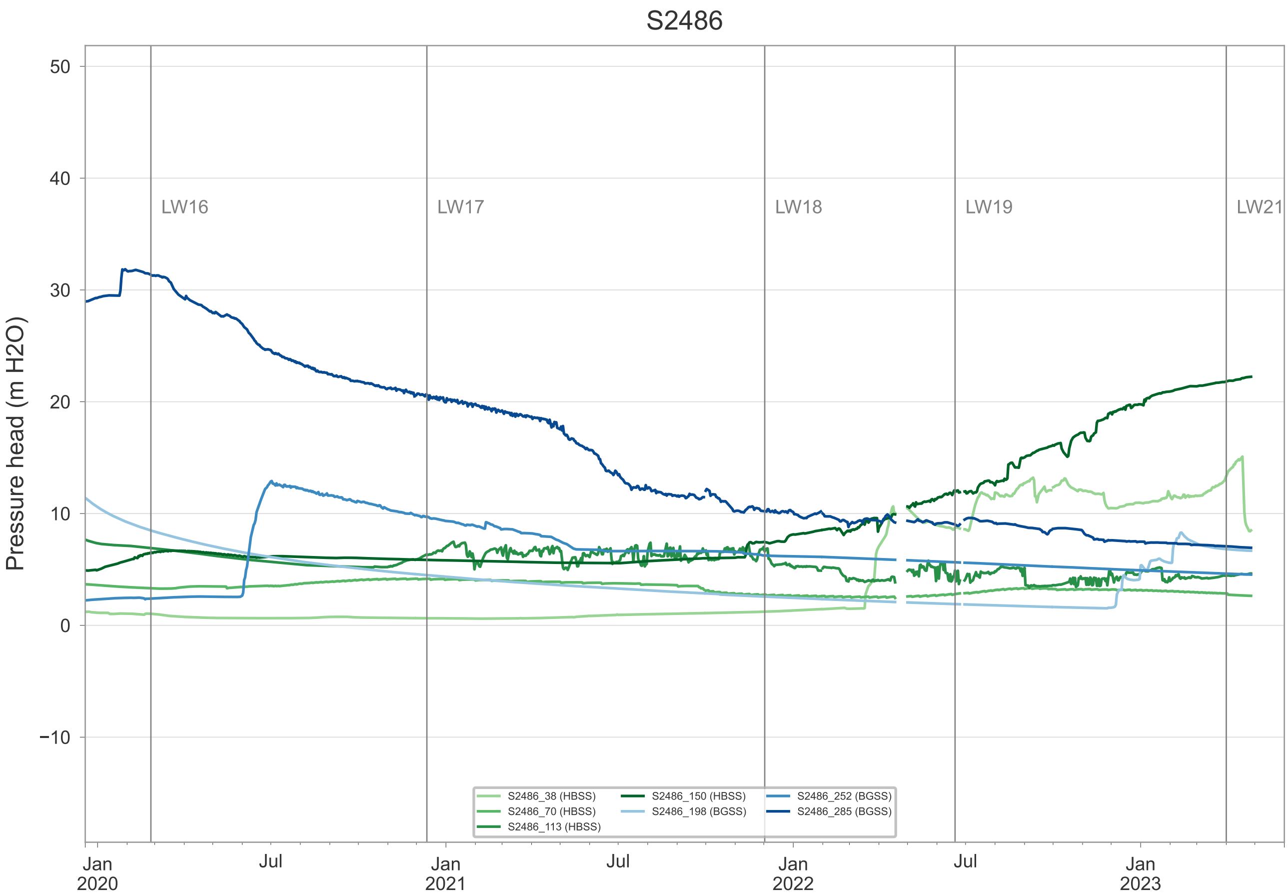
Groundwater hydrographs



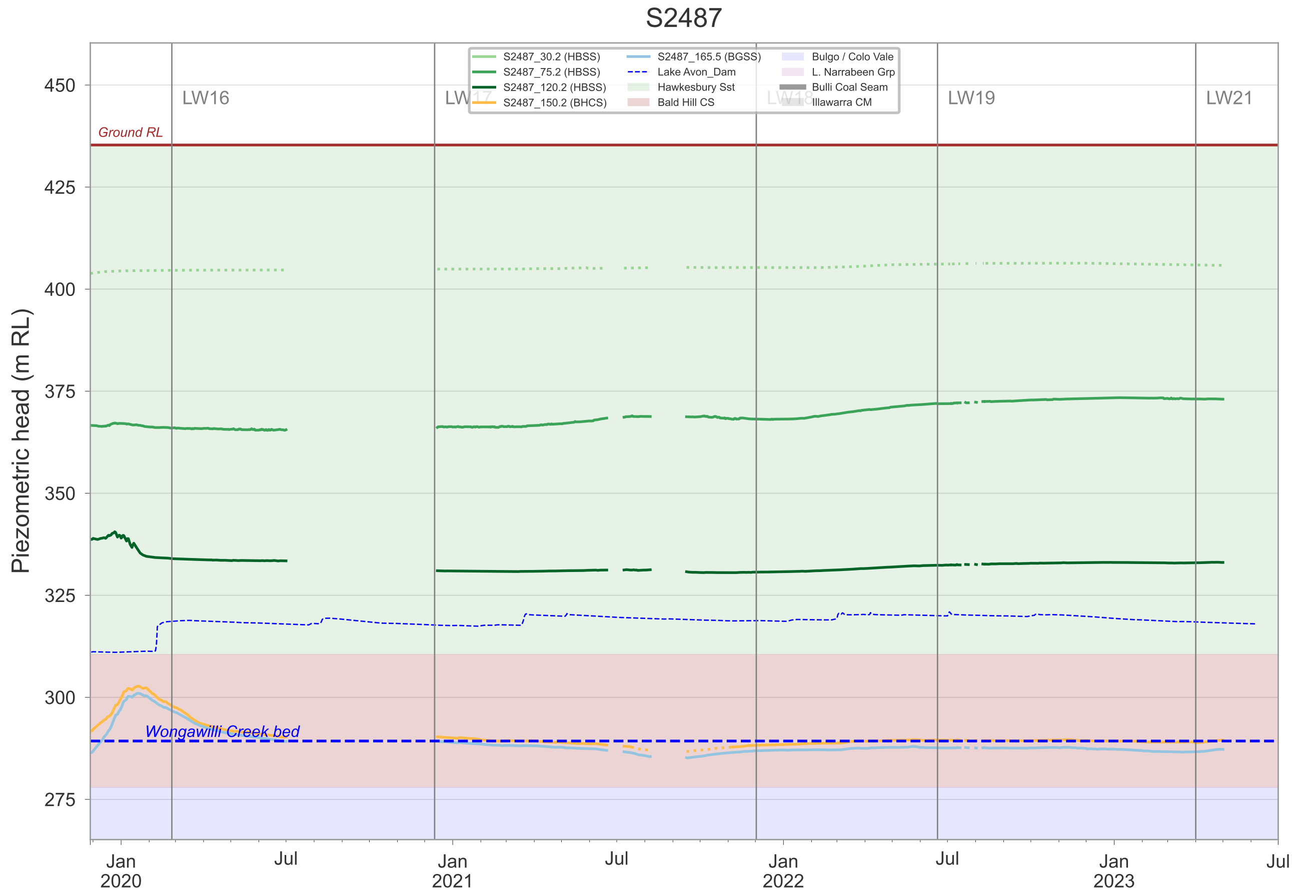


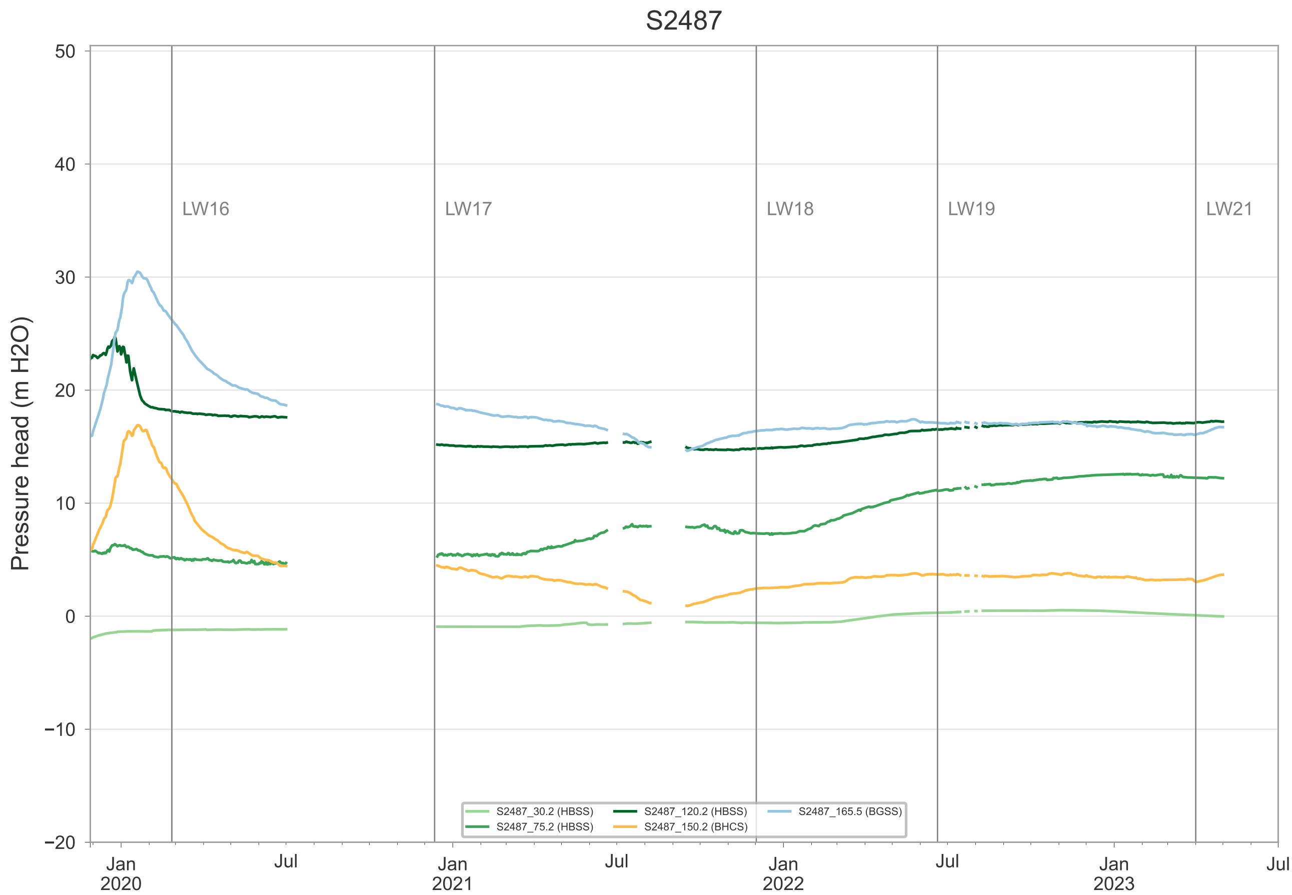
Groundwater hydrographs



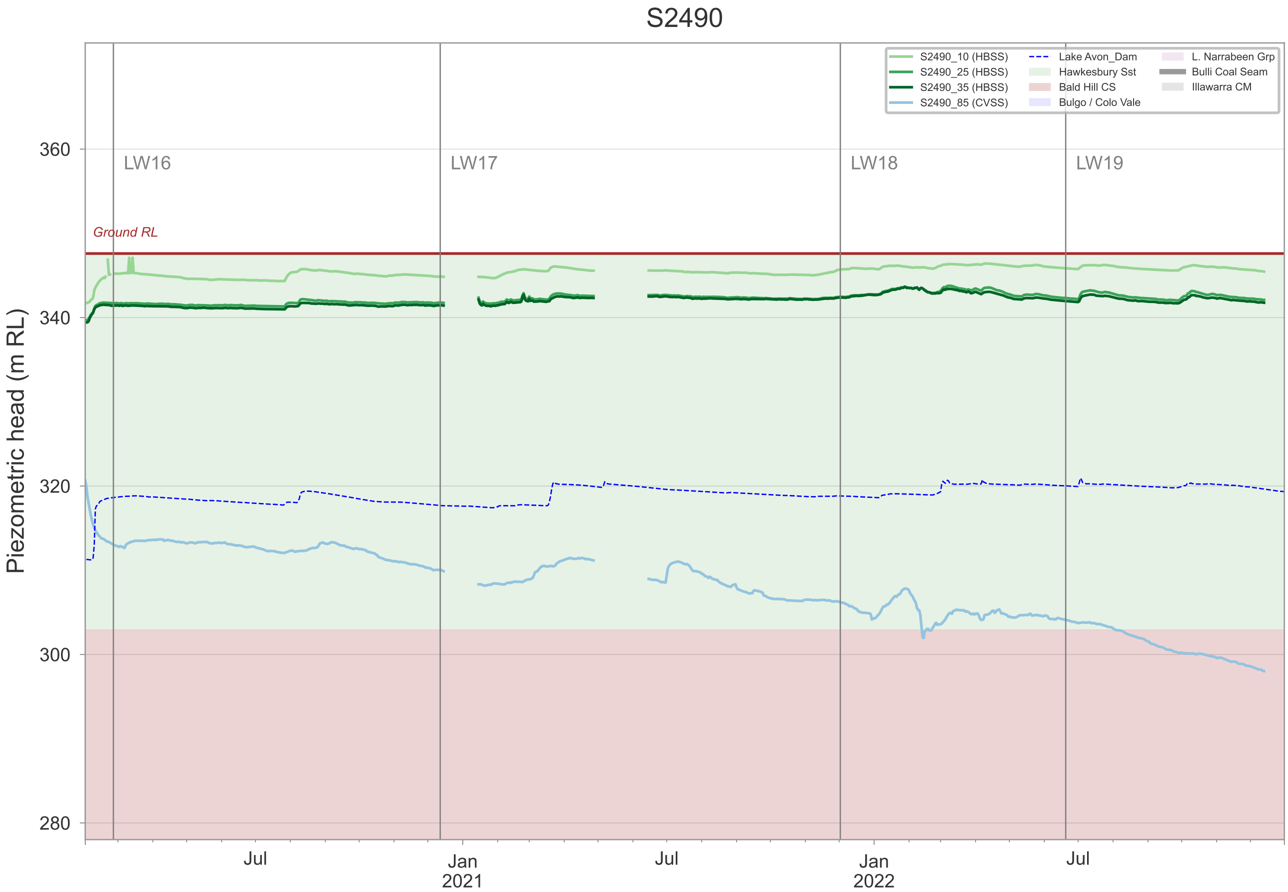


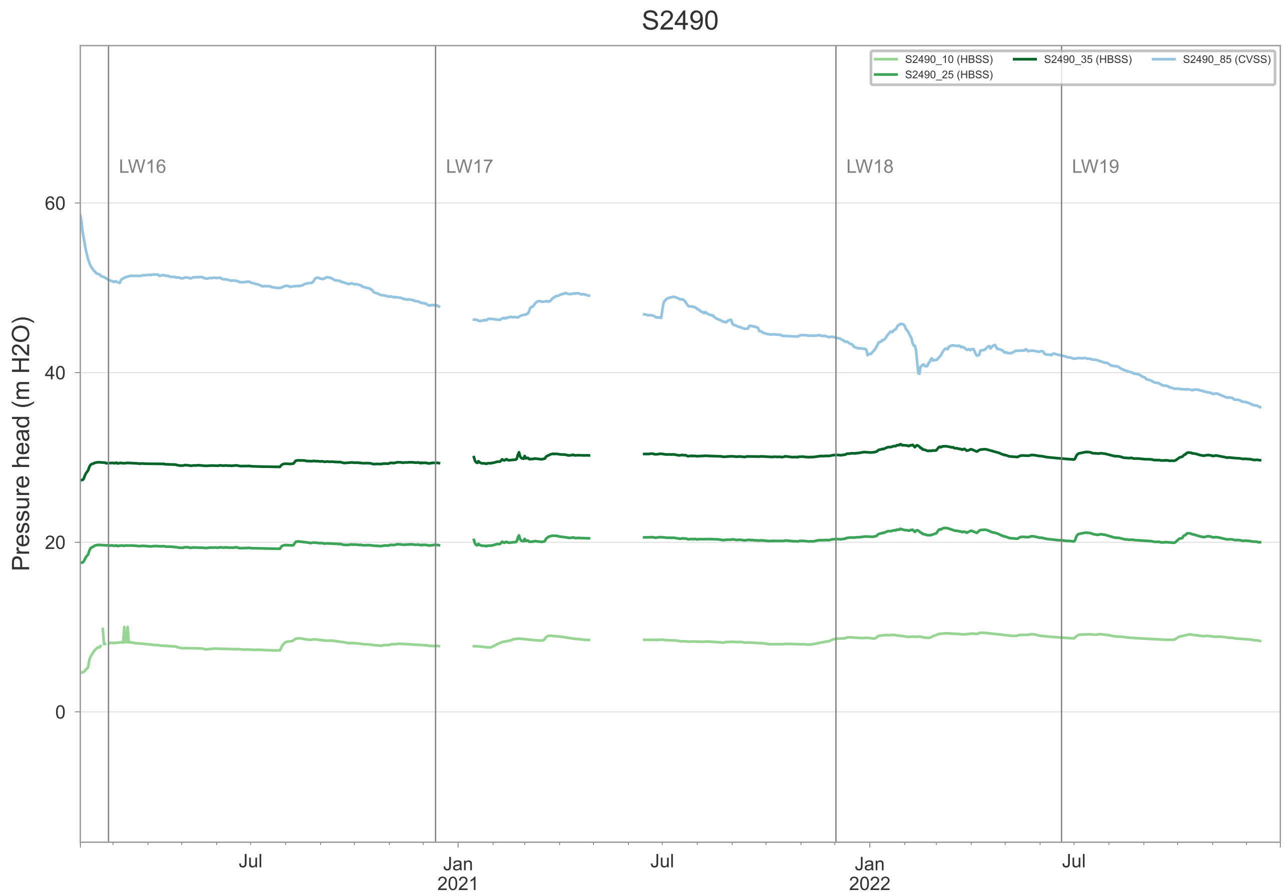
Groundwater hydrographs



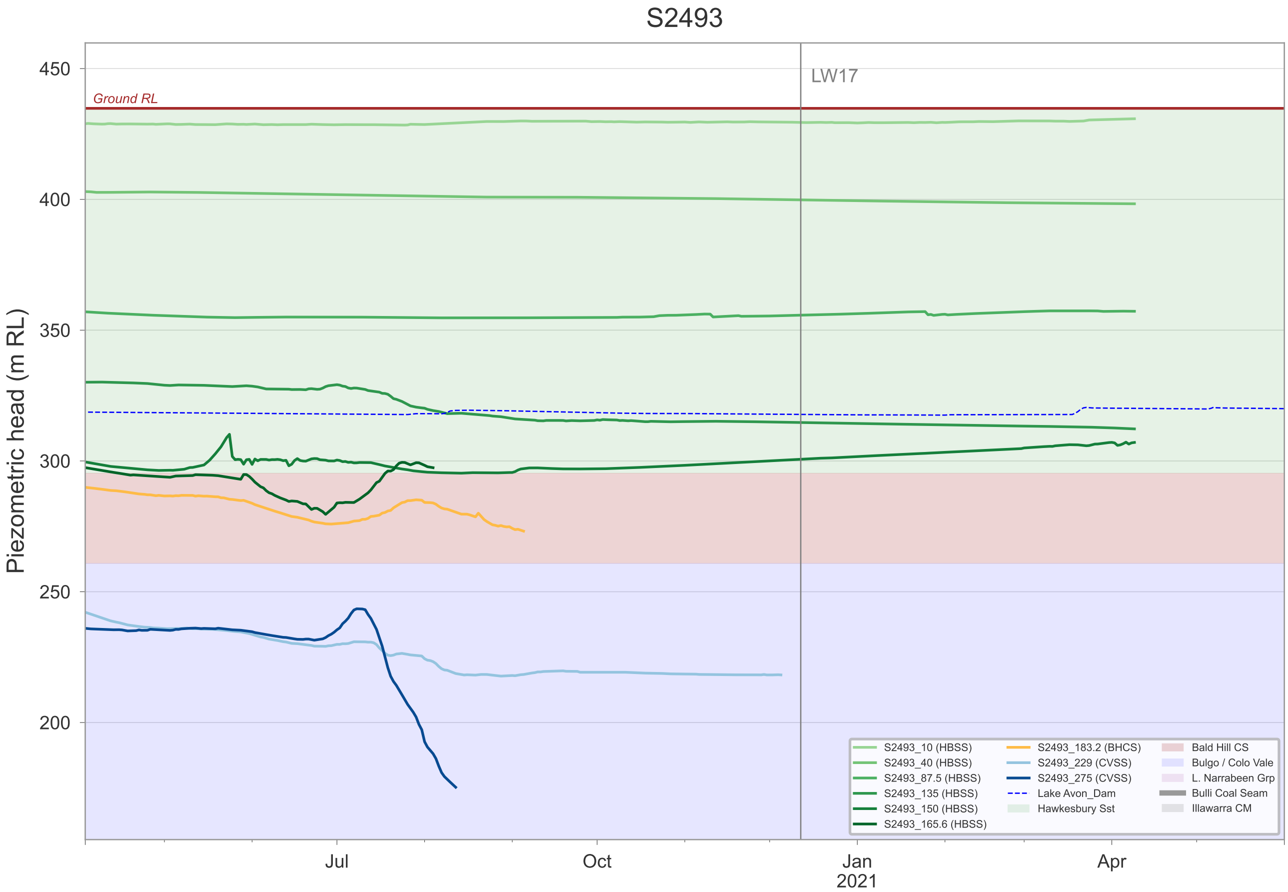


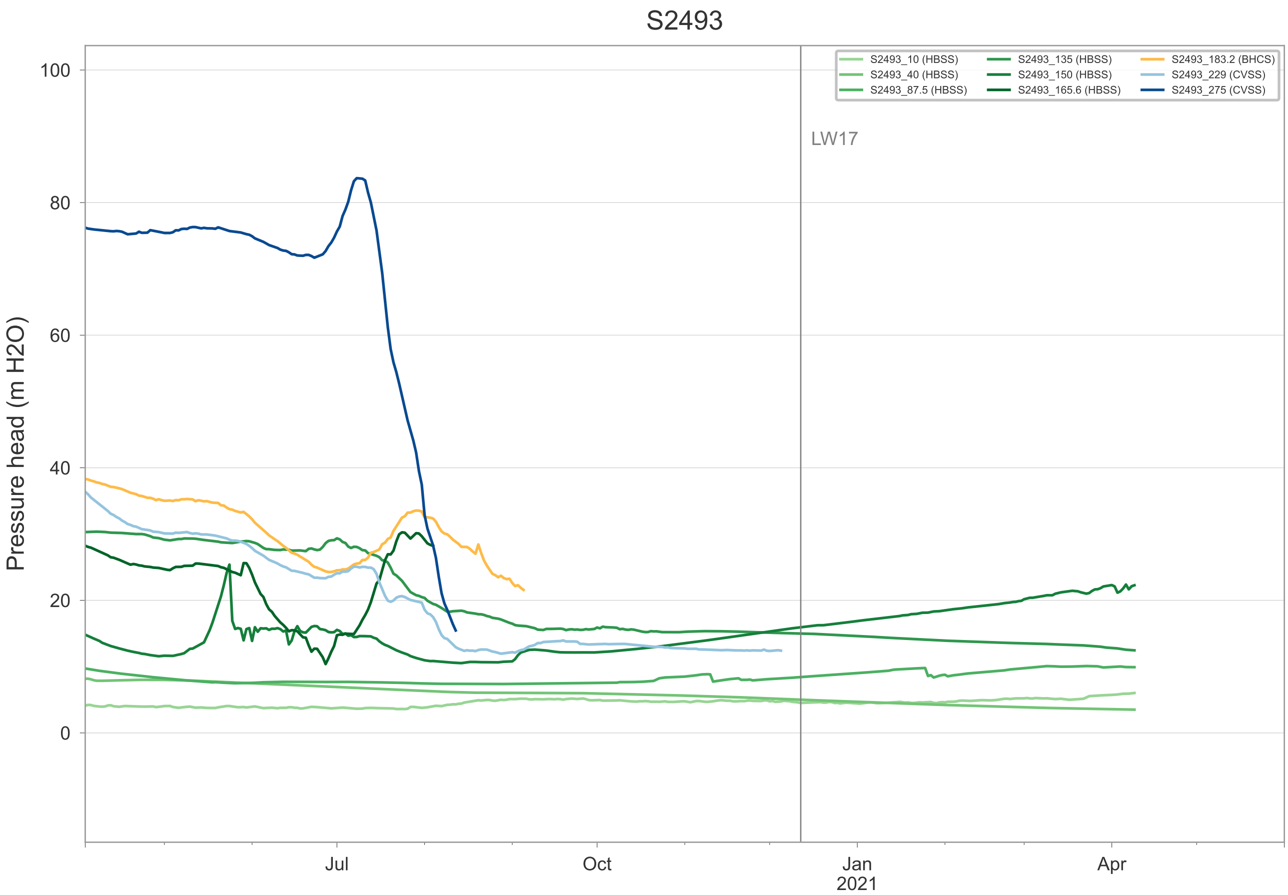
Groundwater hydrographs



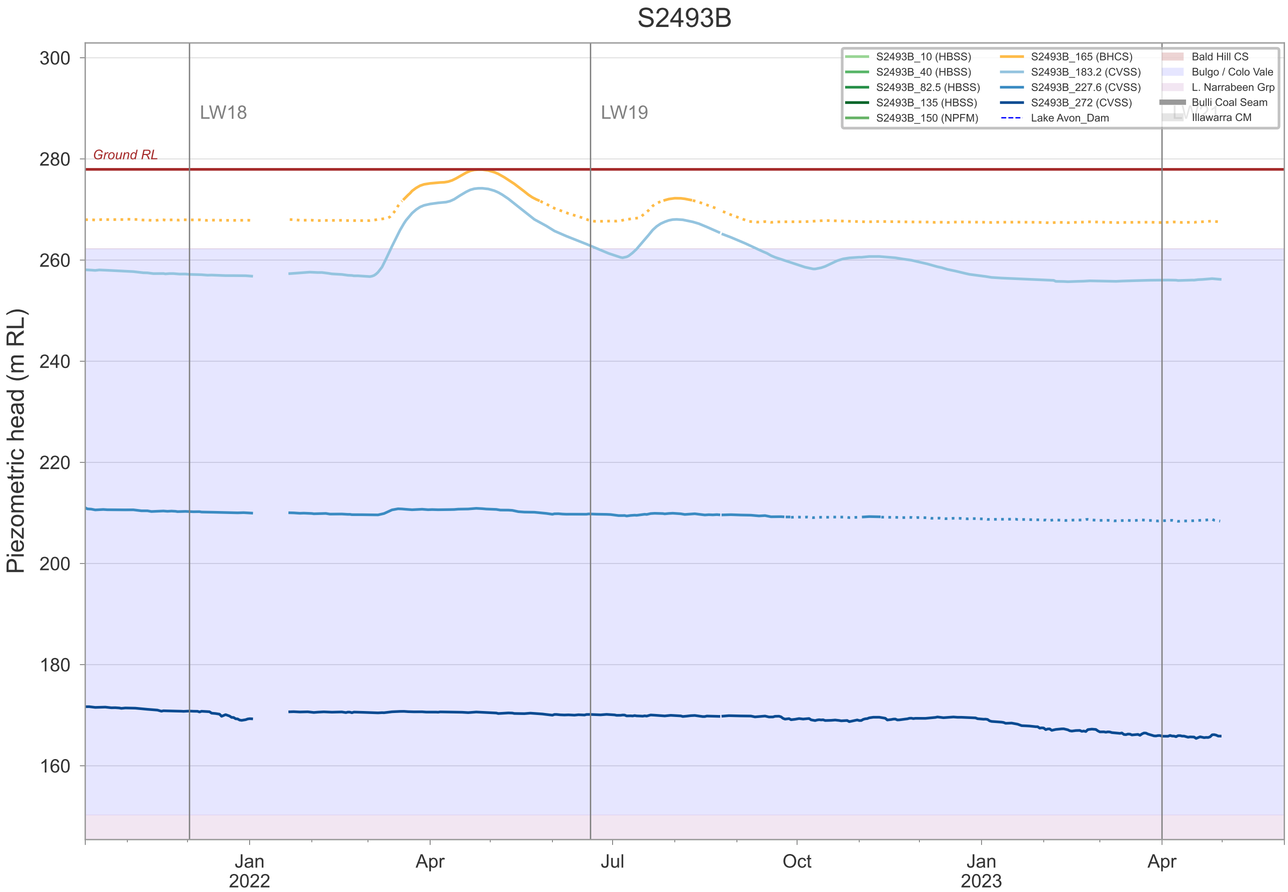


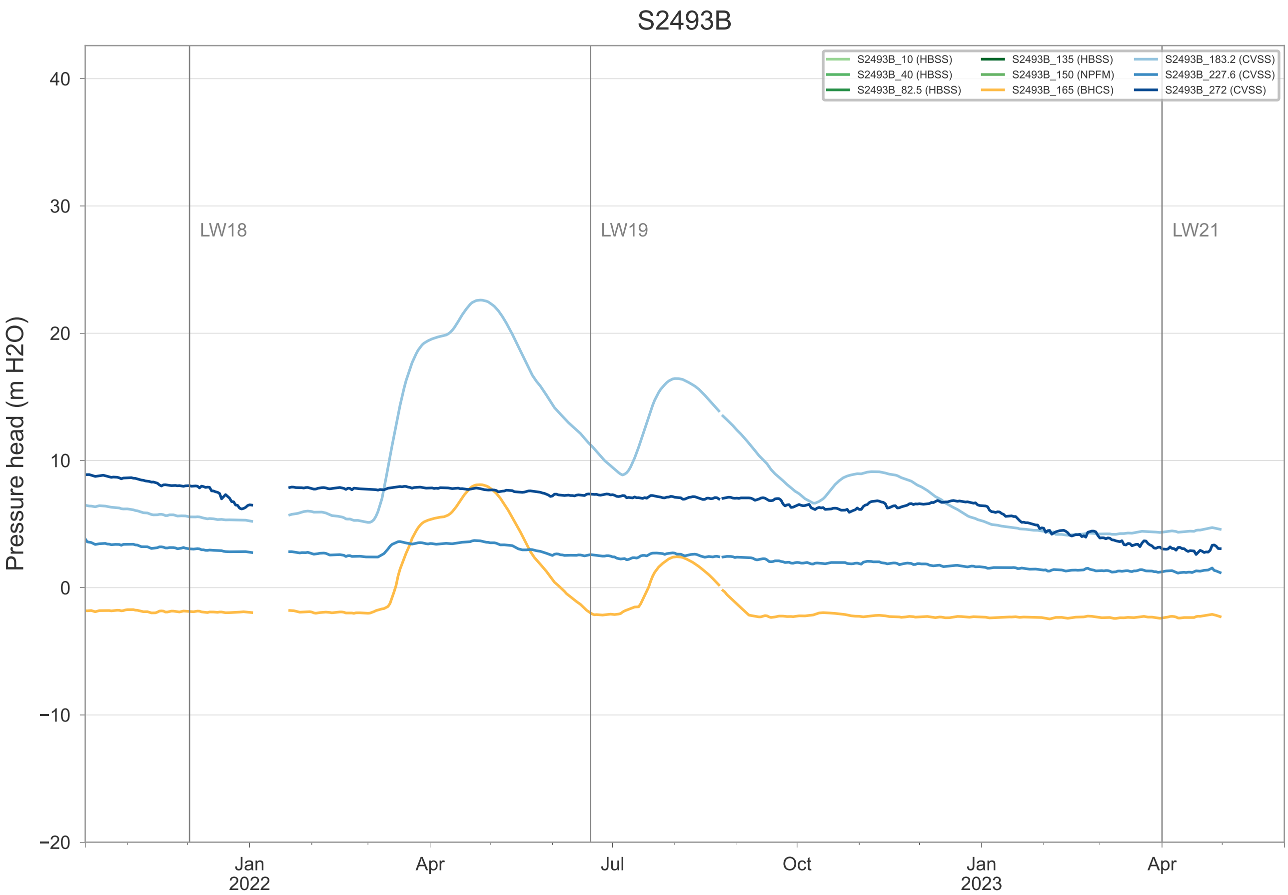
Groundwater hydrographs



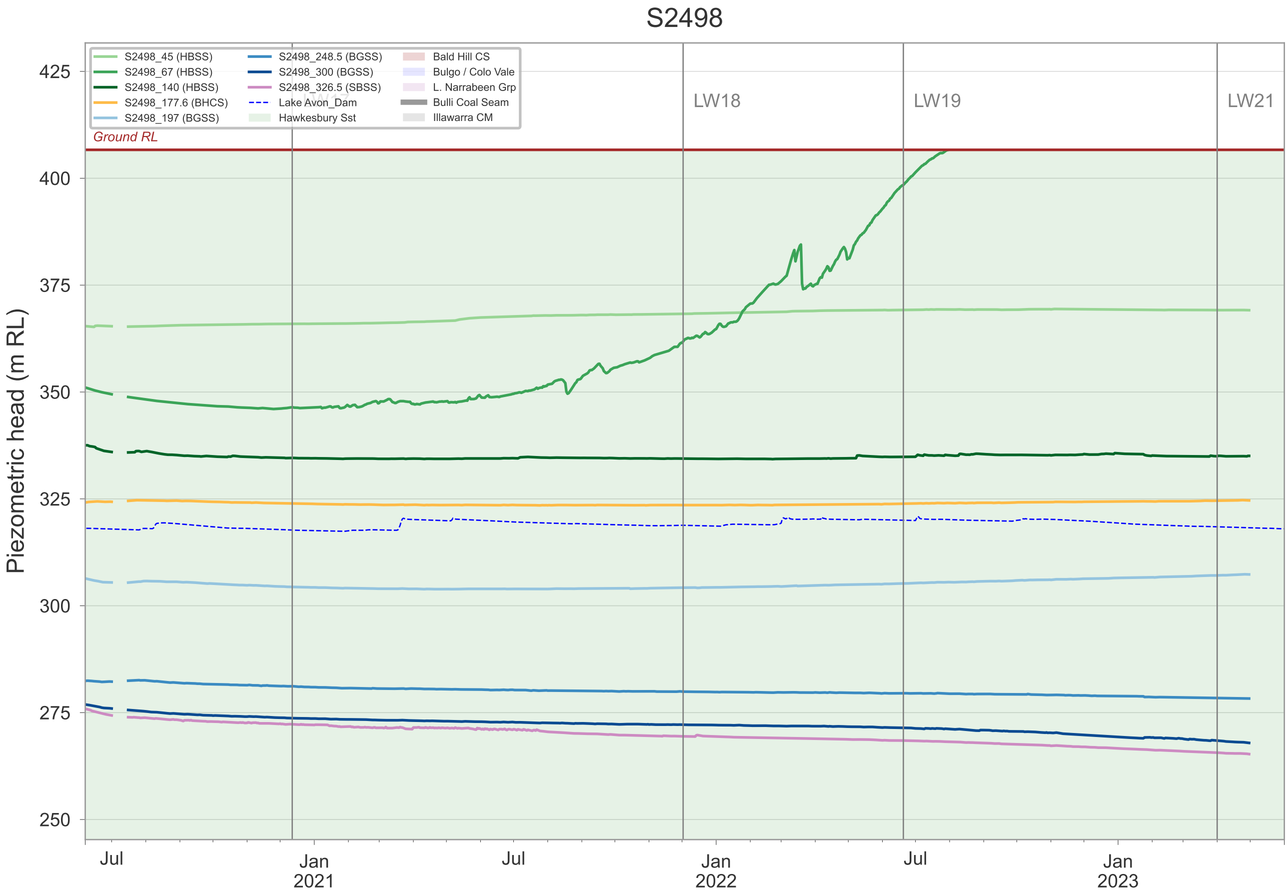


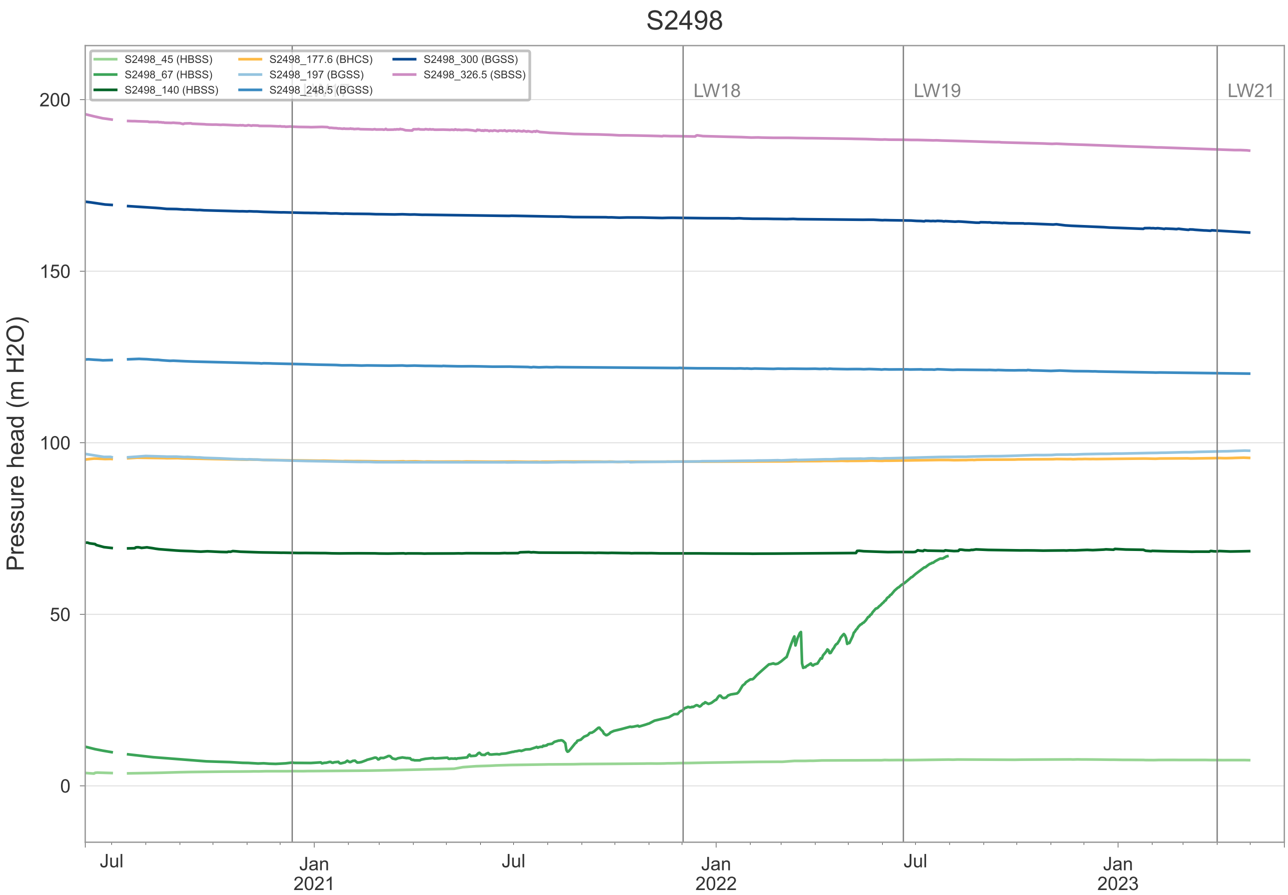
Groundwater hydrographs



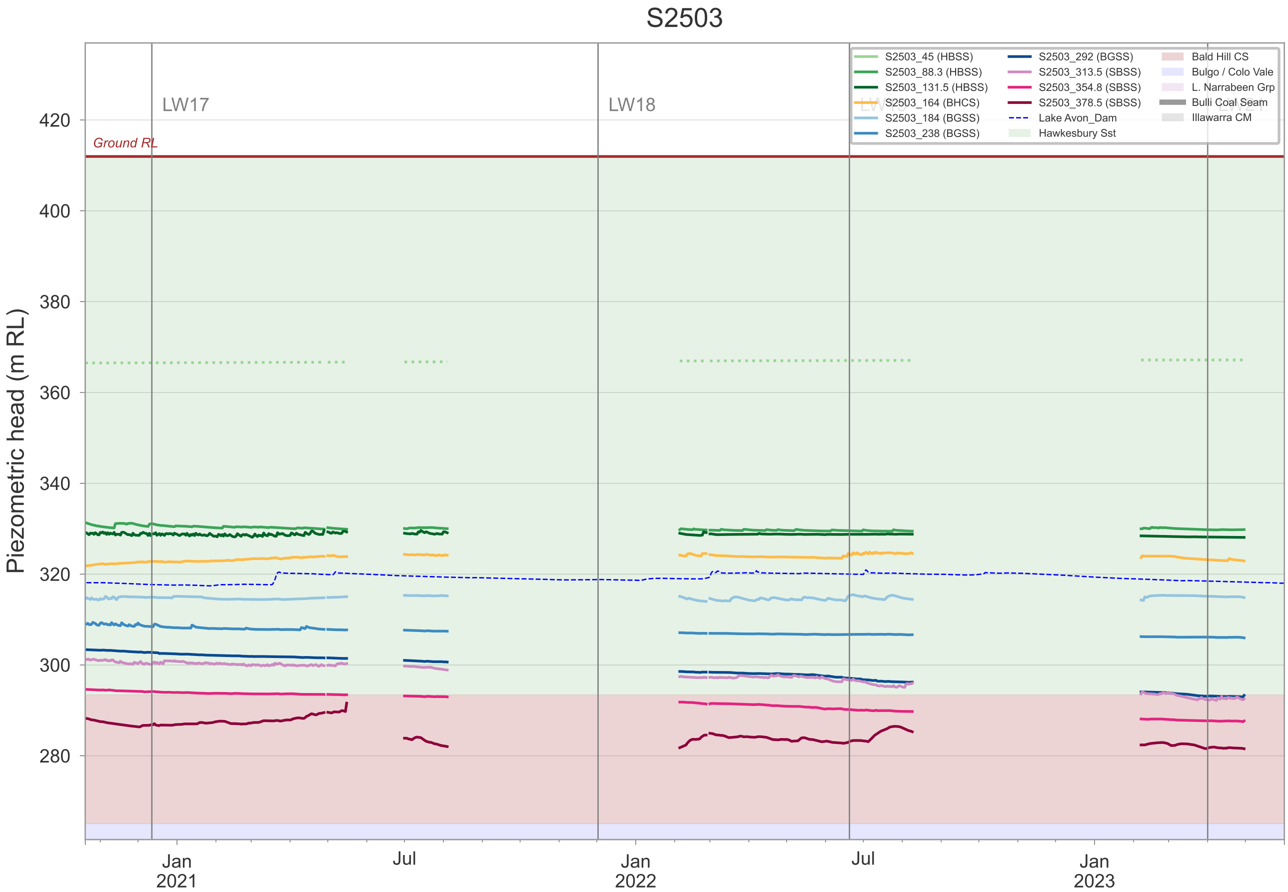


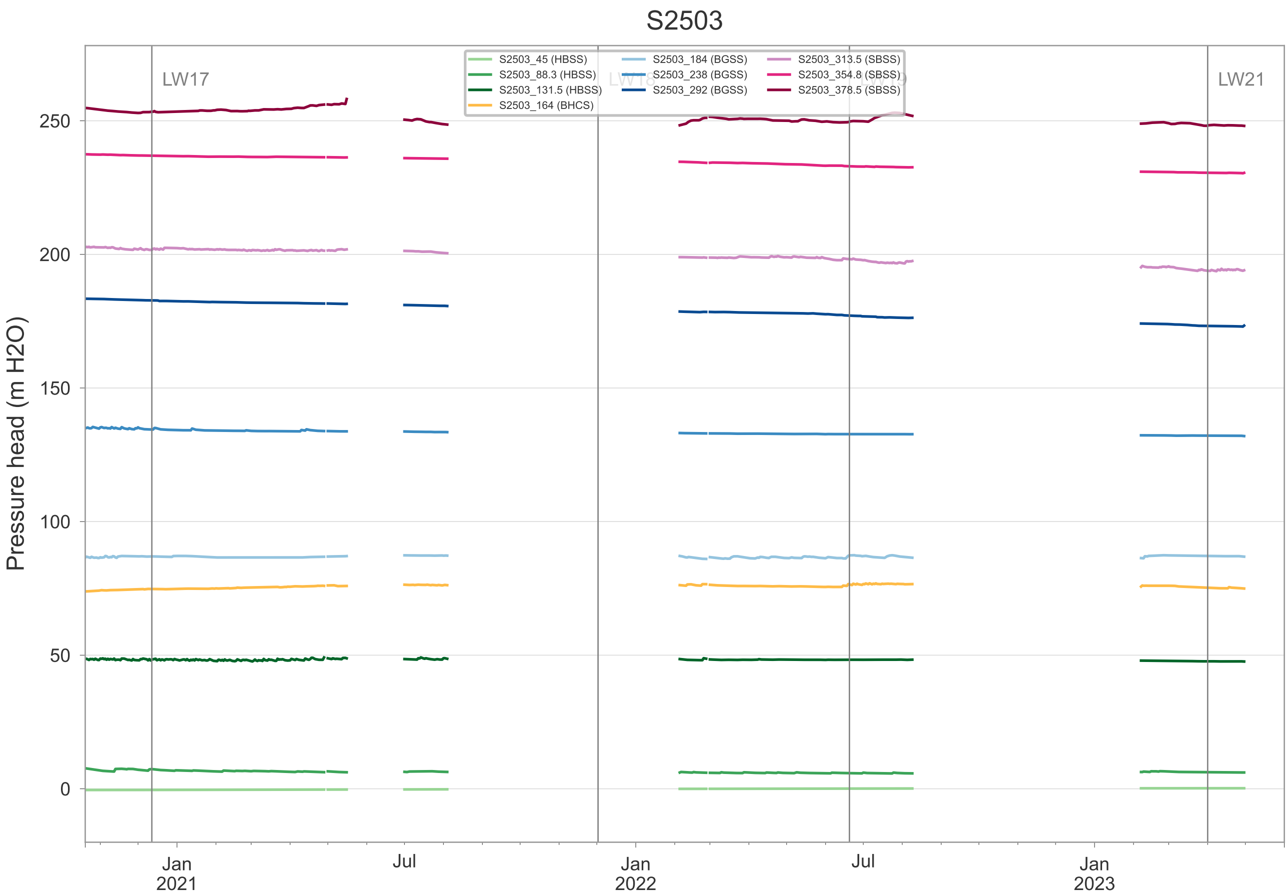
Groundwater hydrographs



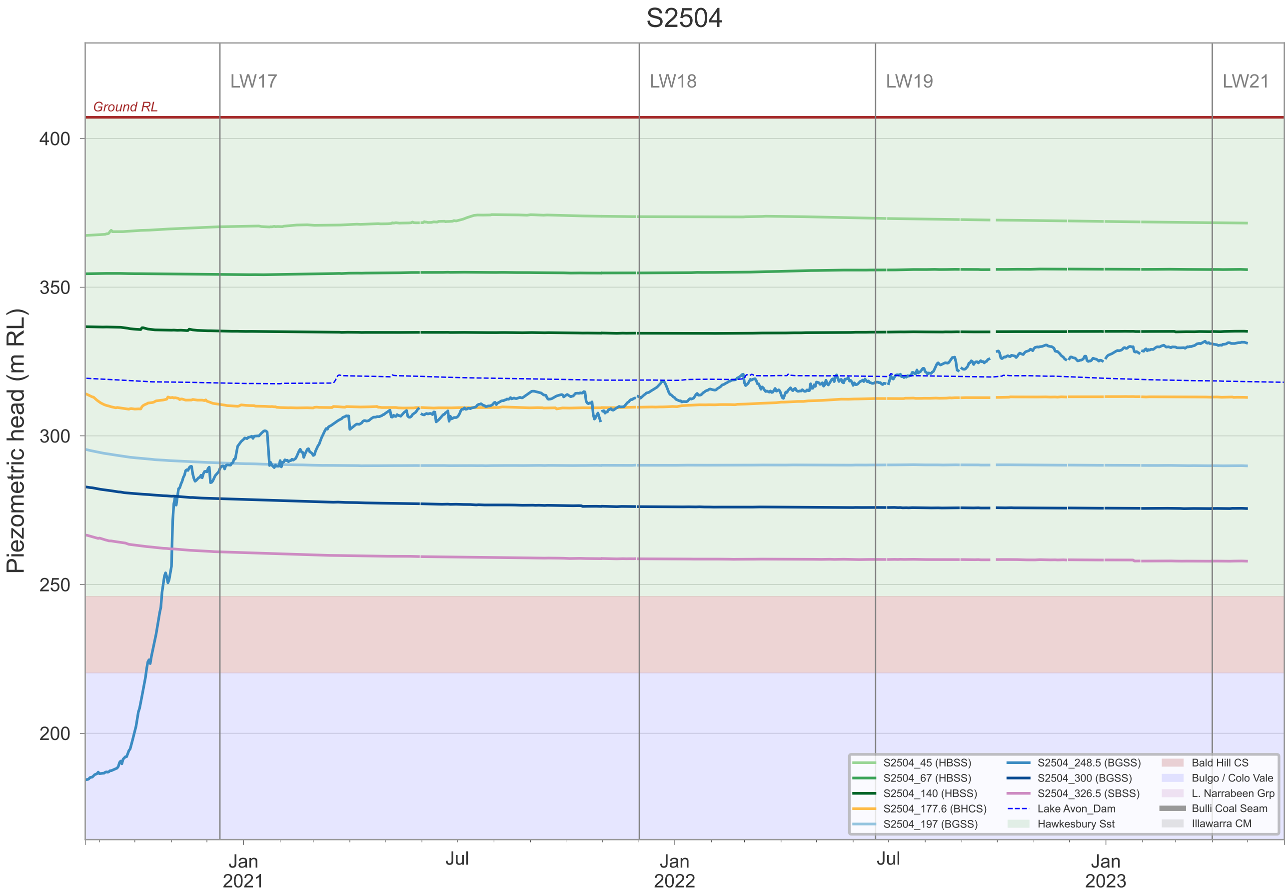


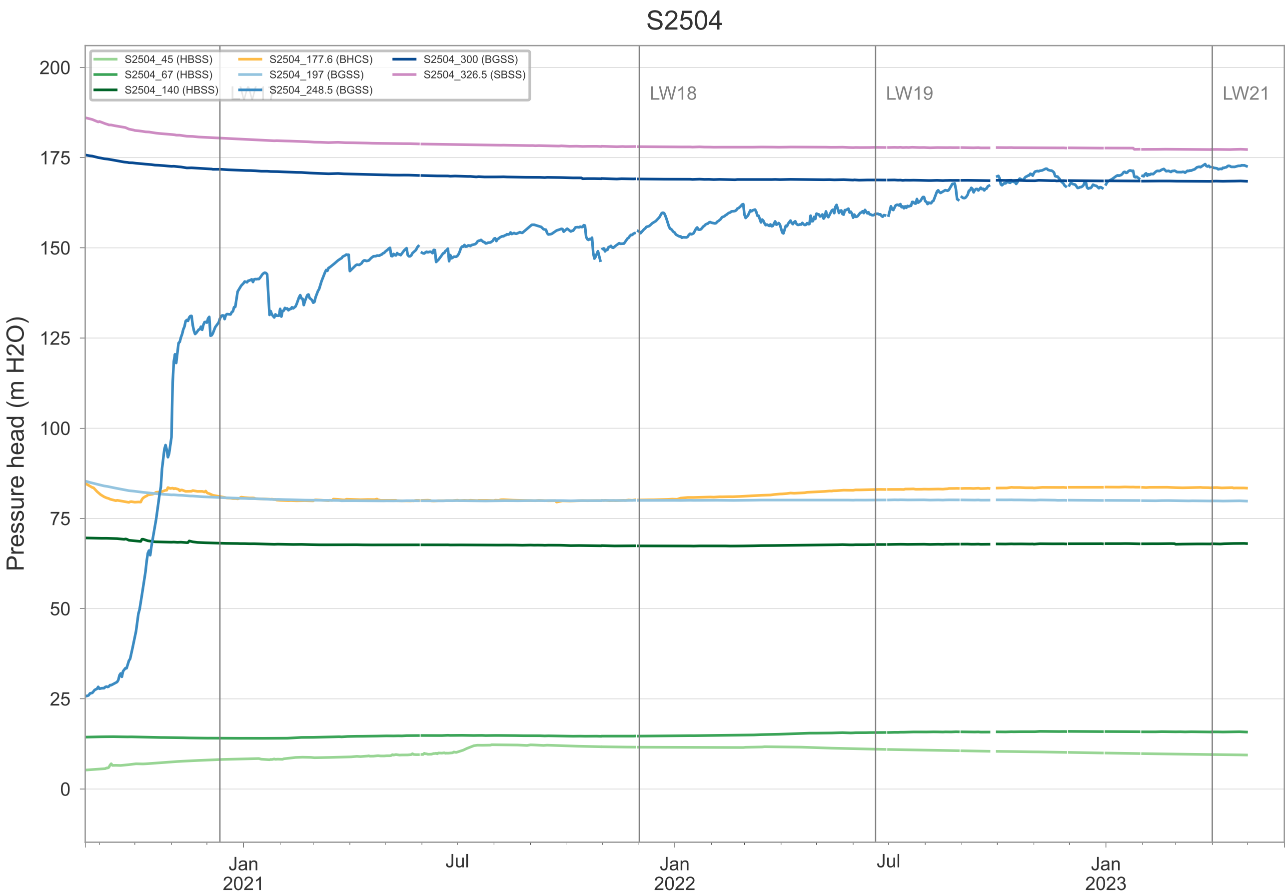
Groundwater hydrographs



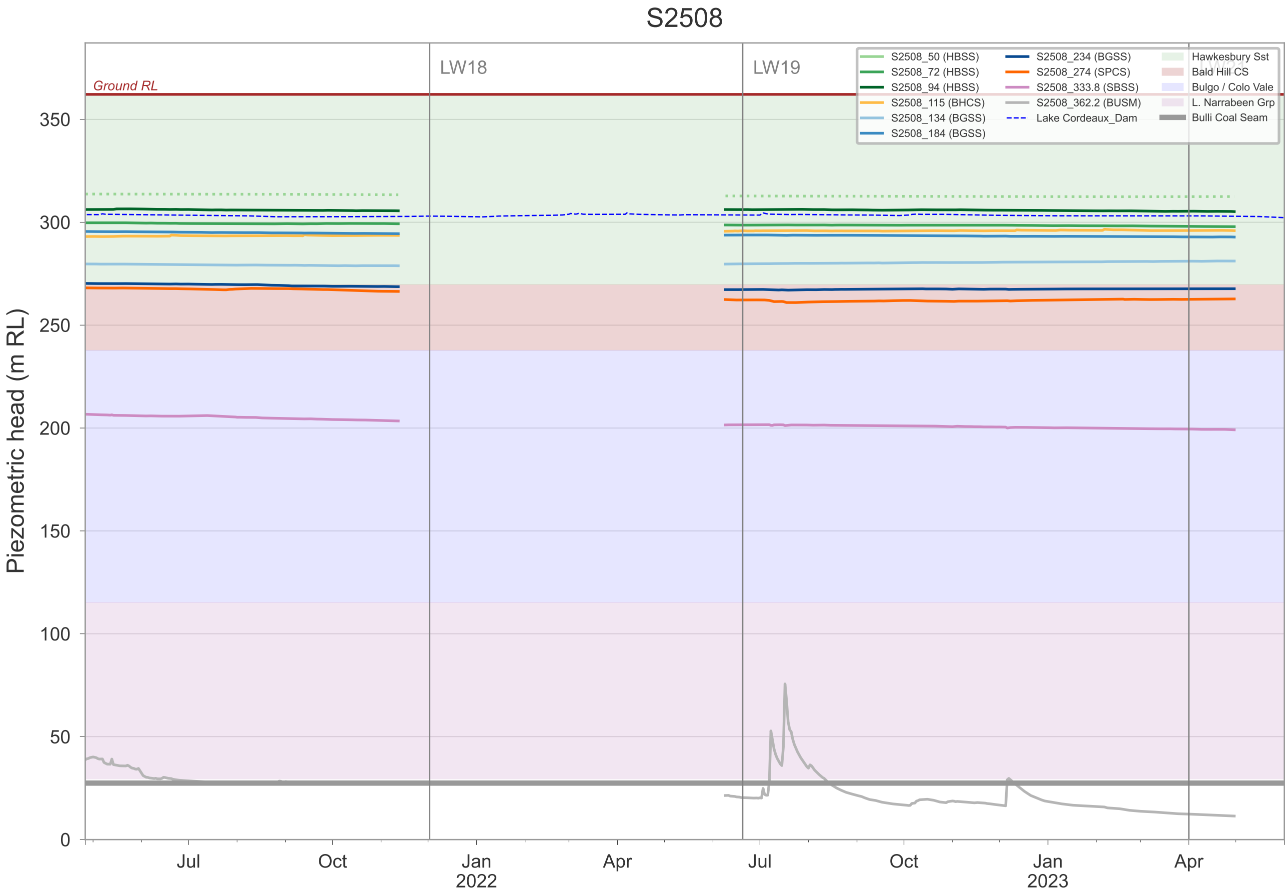


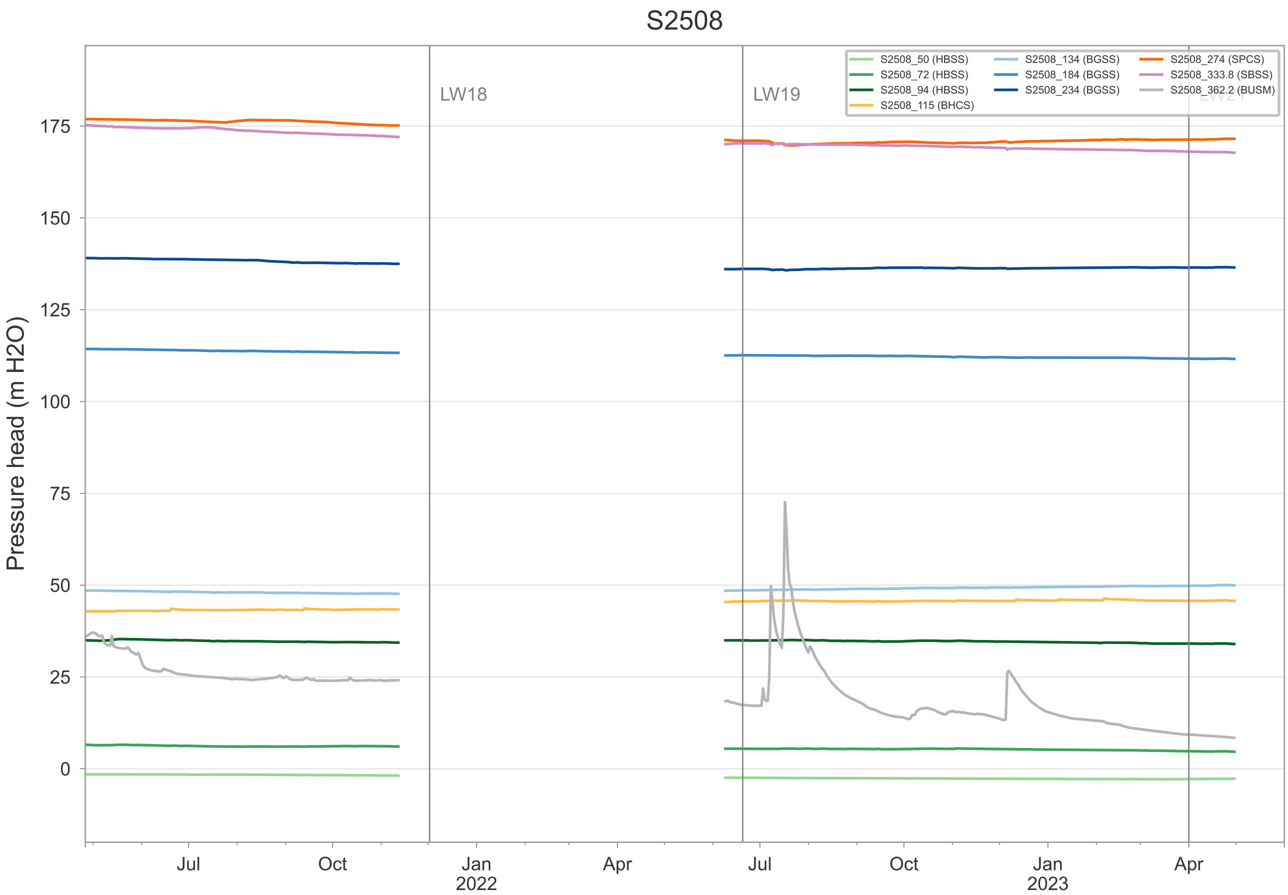
Groundwater hydrographs



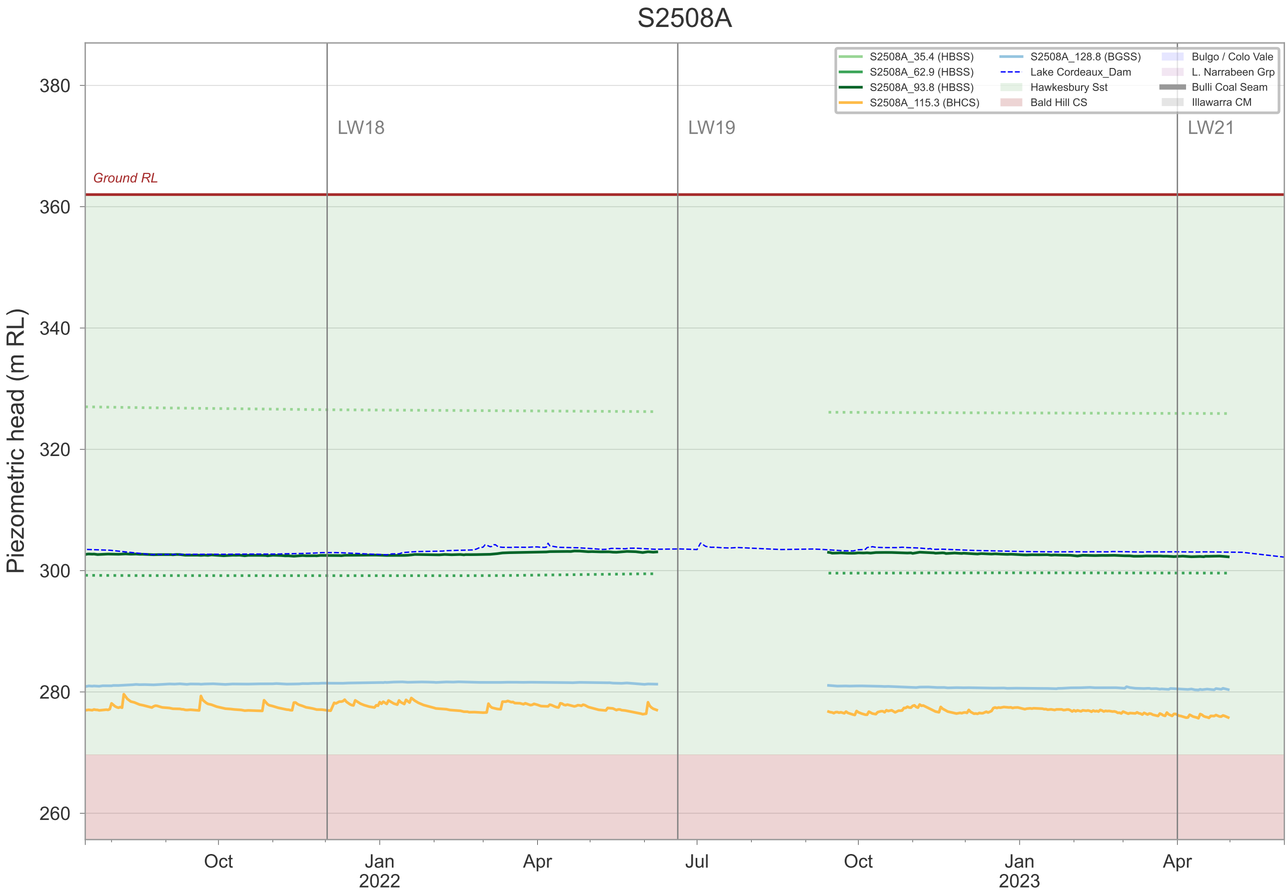


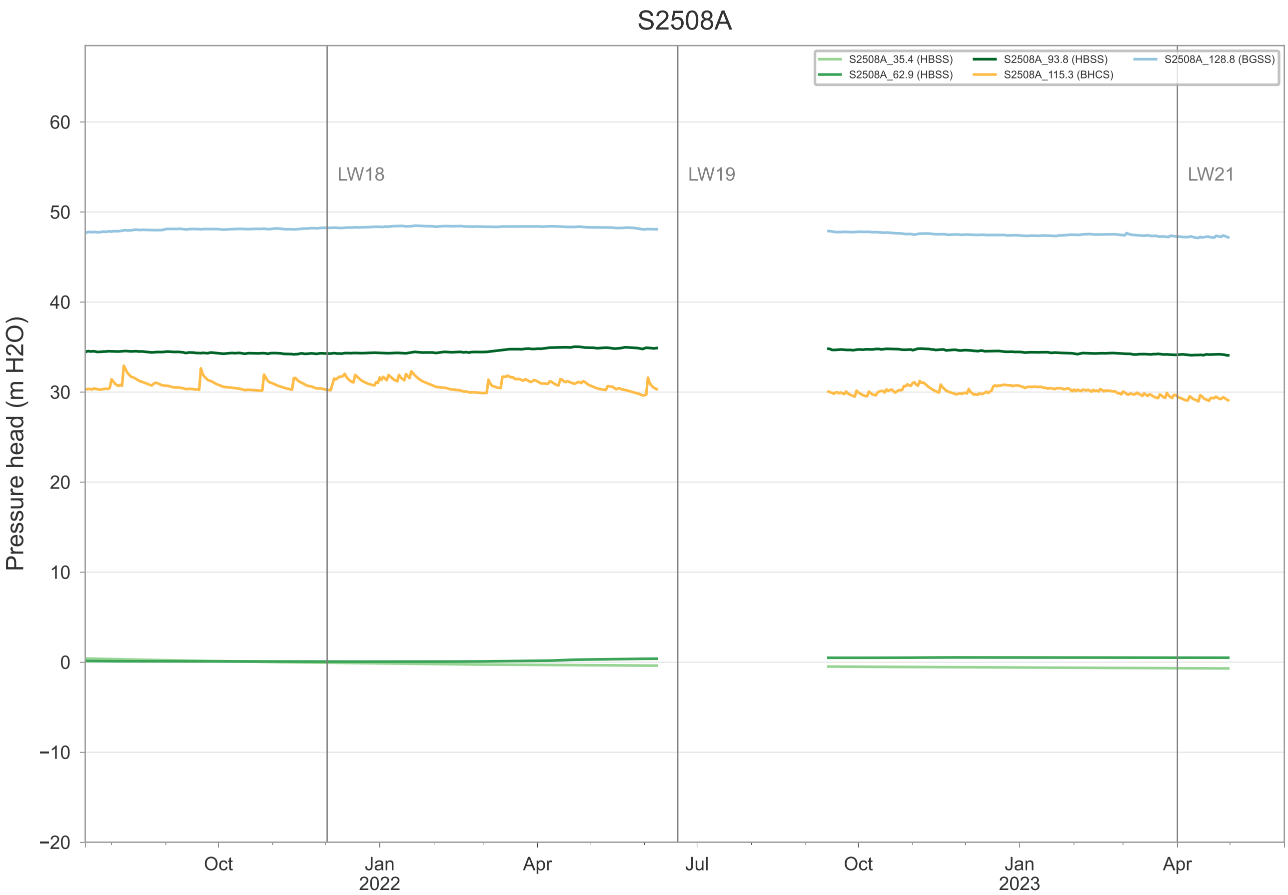
Groundwater hydrographs



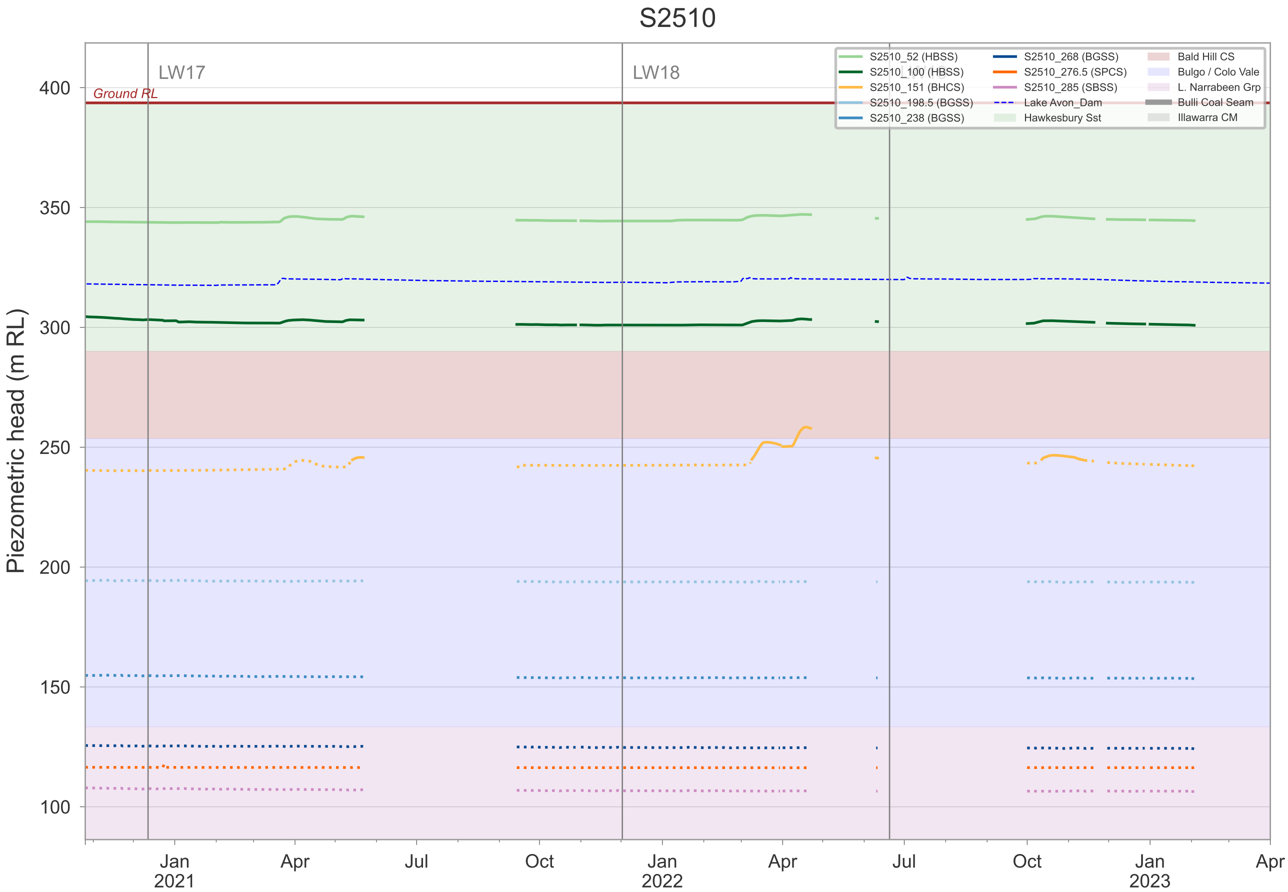


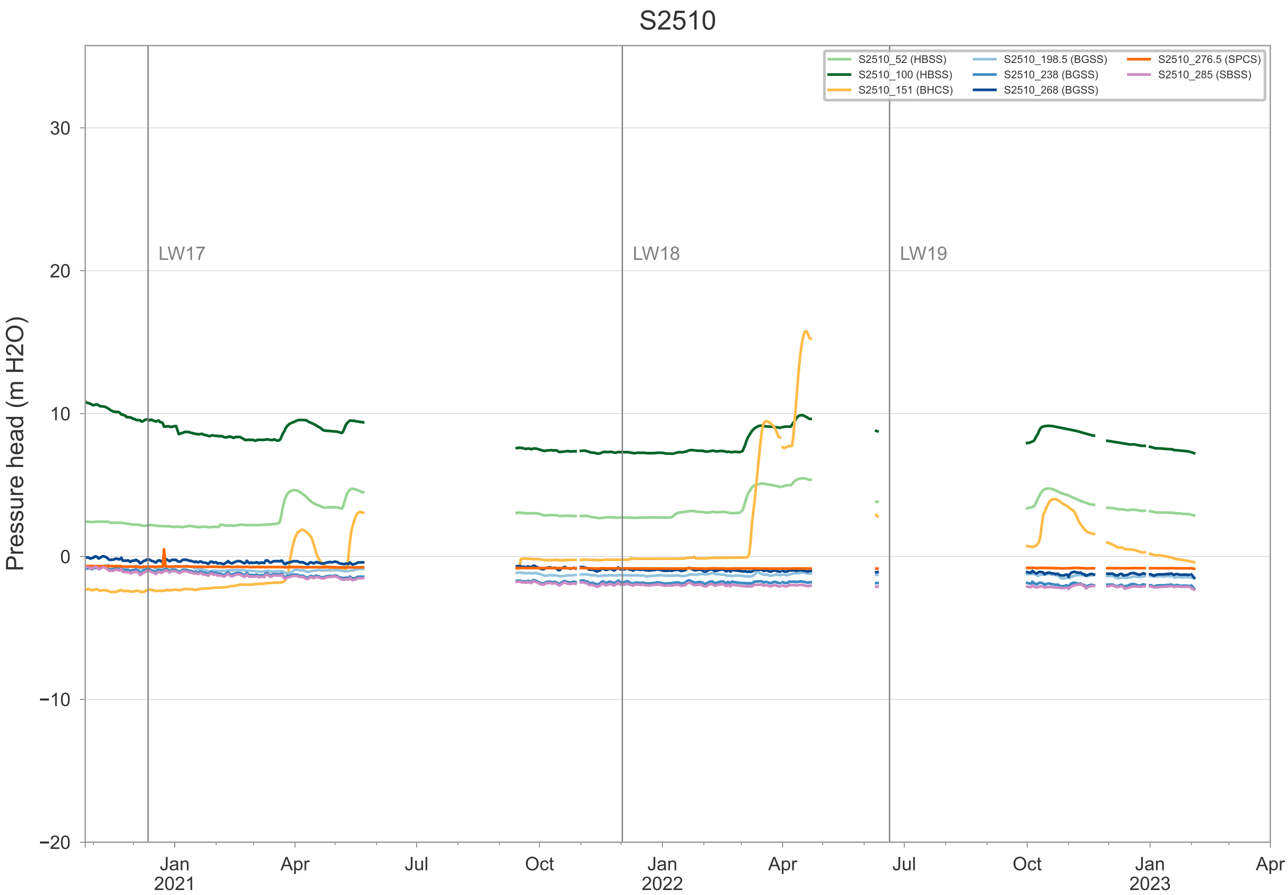
Groundwater hydrographs



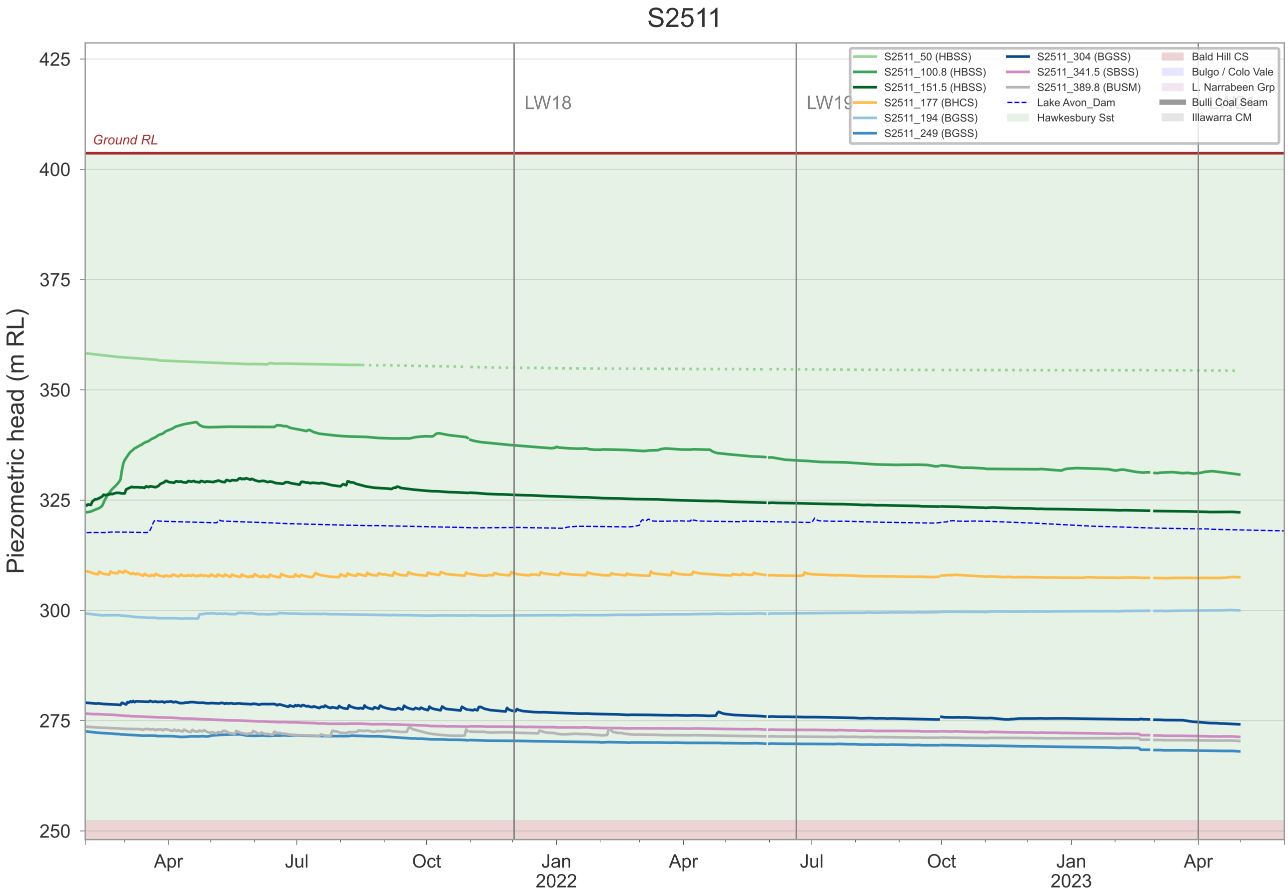


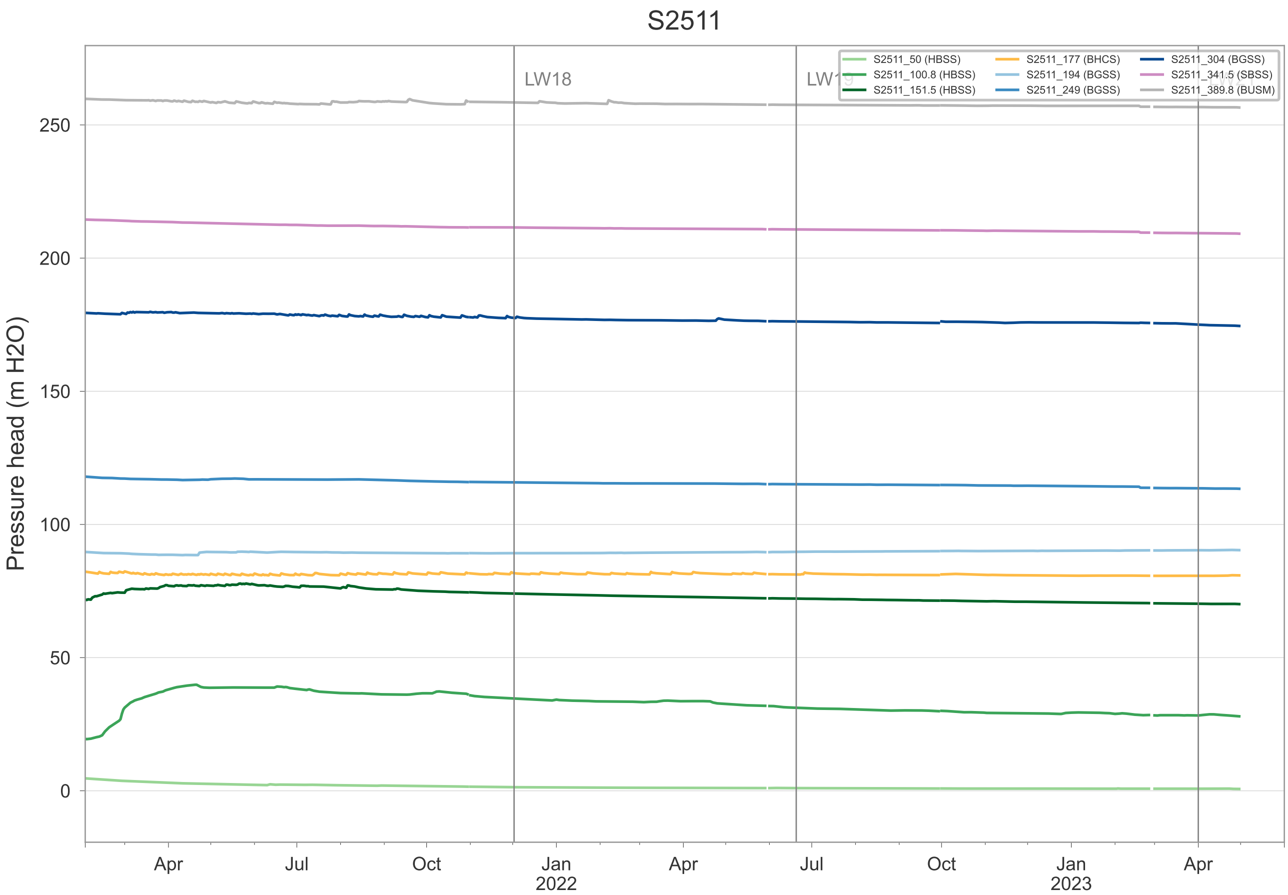
Groundwater hydrographs



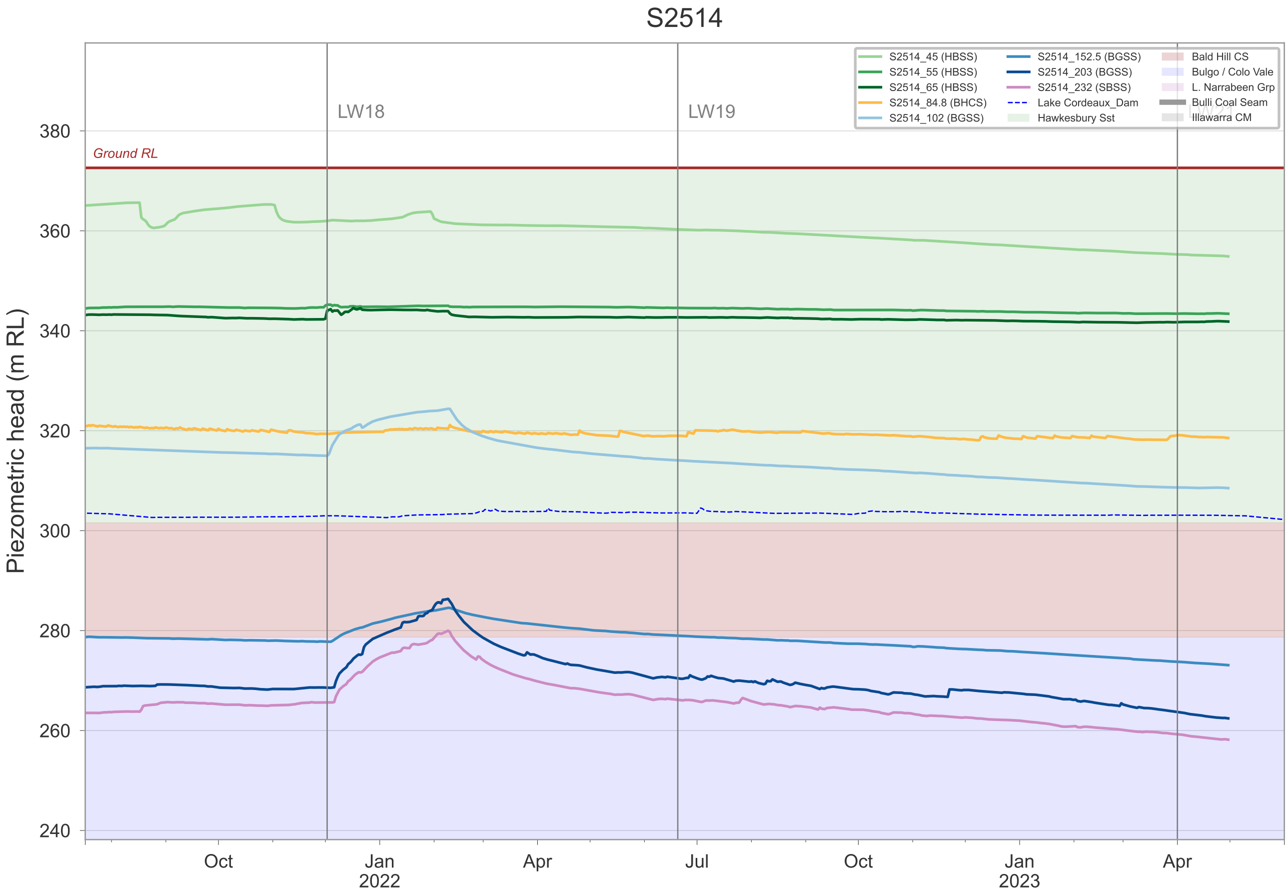


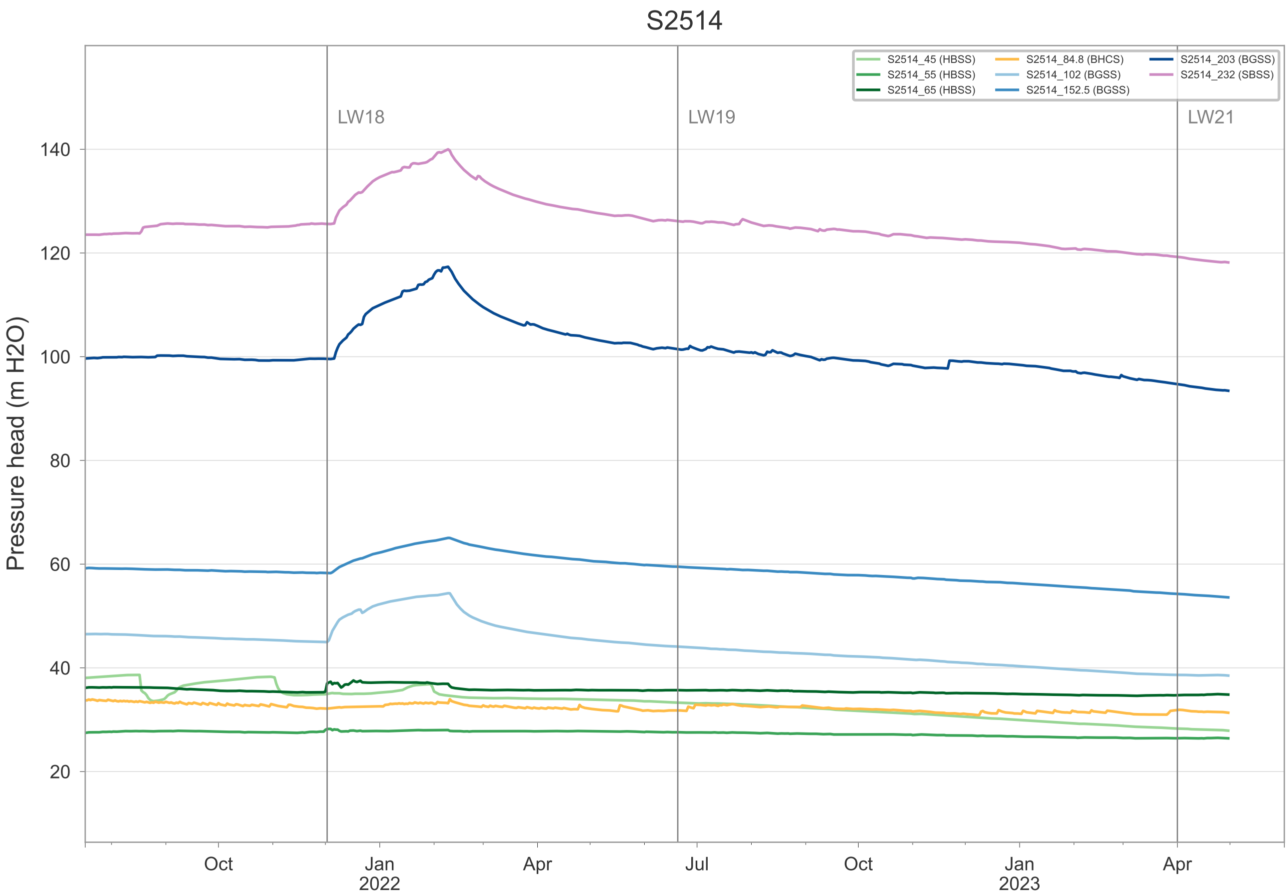
Groundwater hydrographs



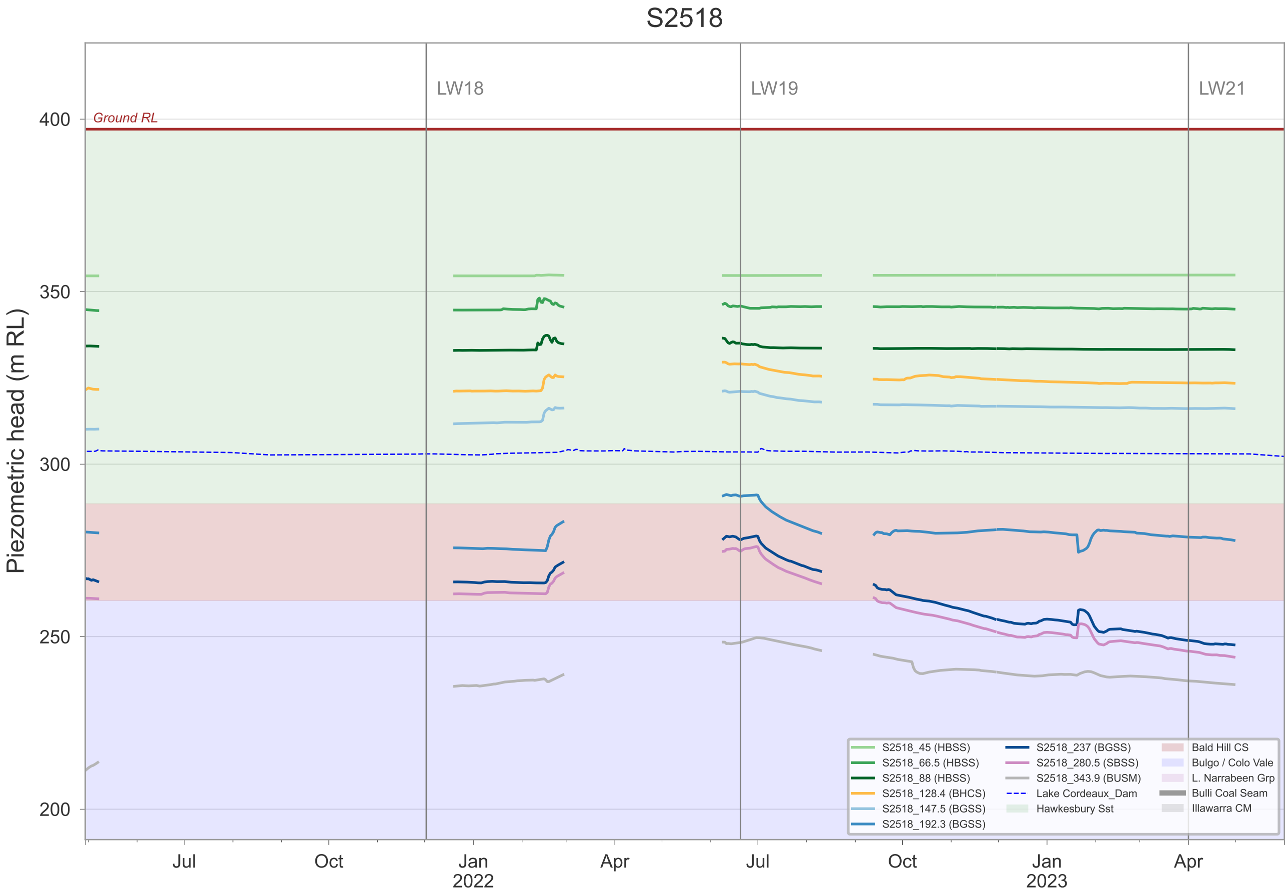


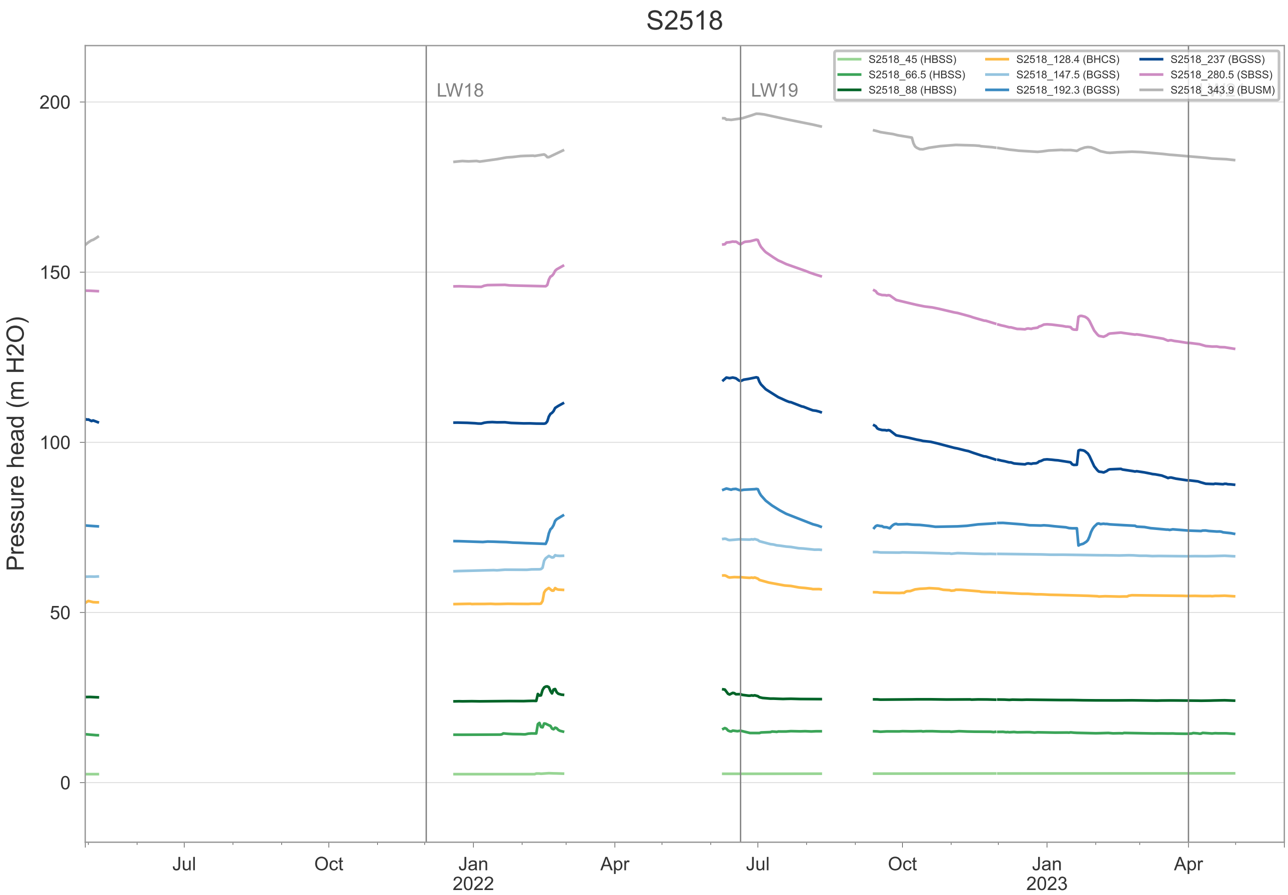
Groundwater hydrographs

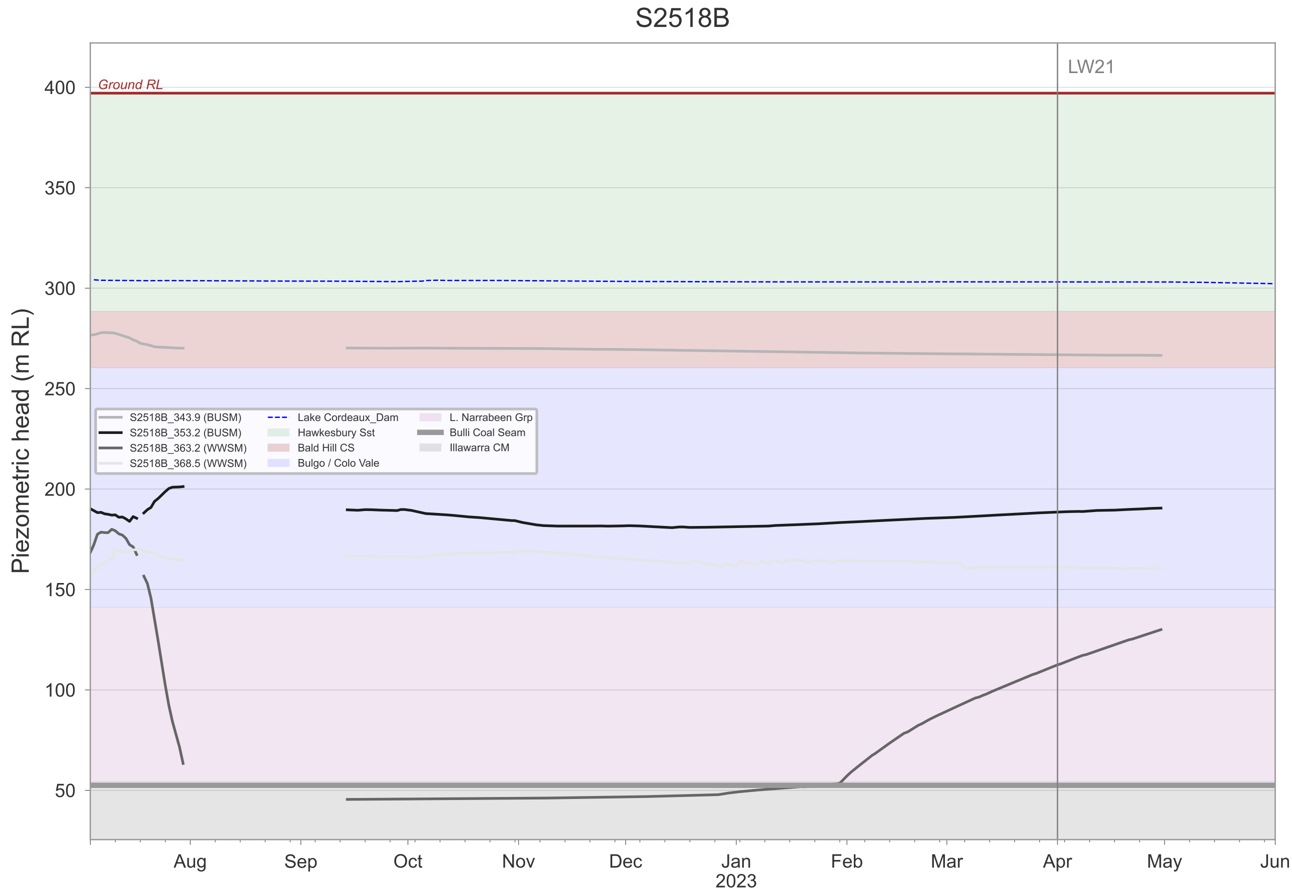


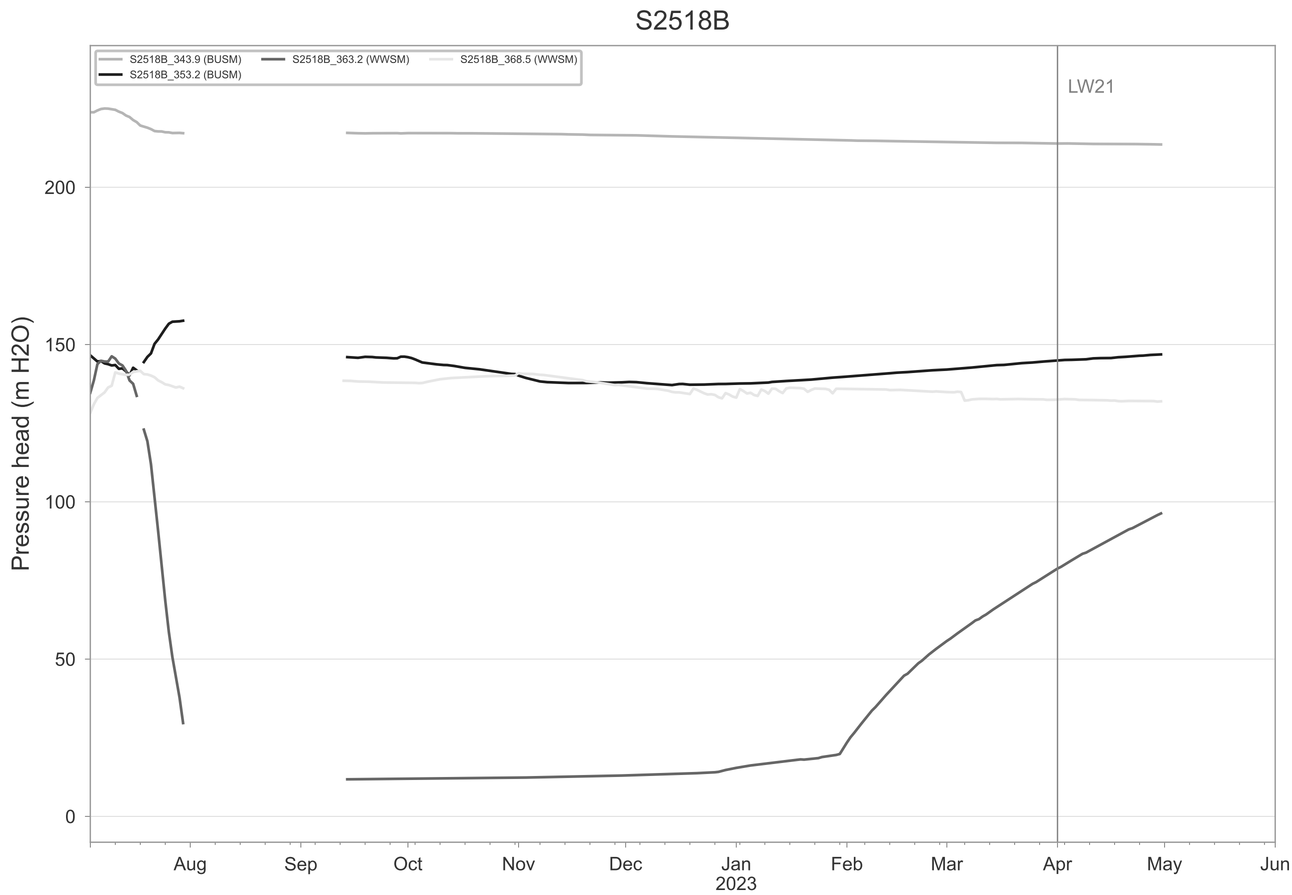


Groundwater hydrographs

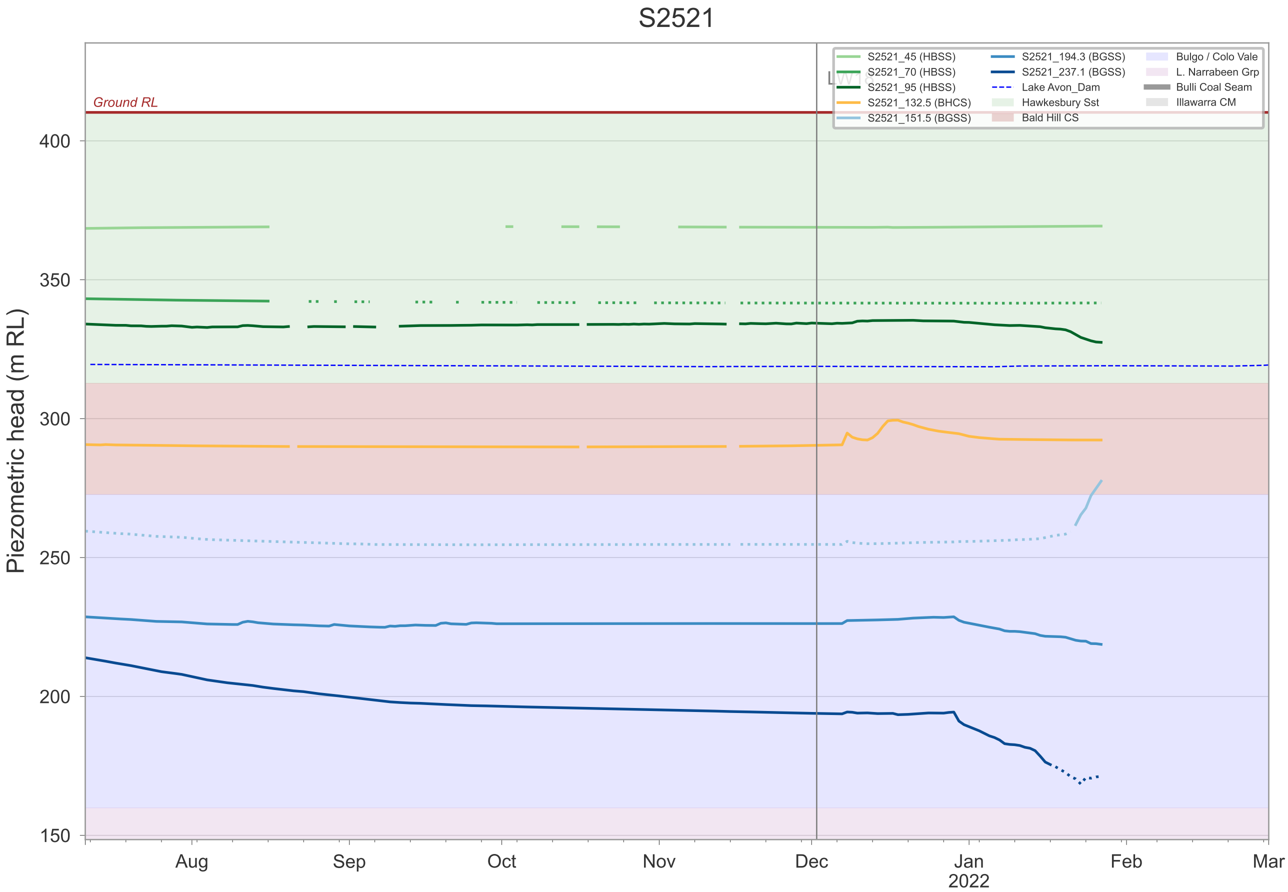


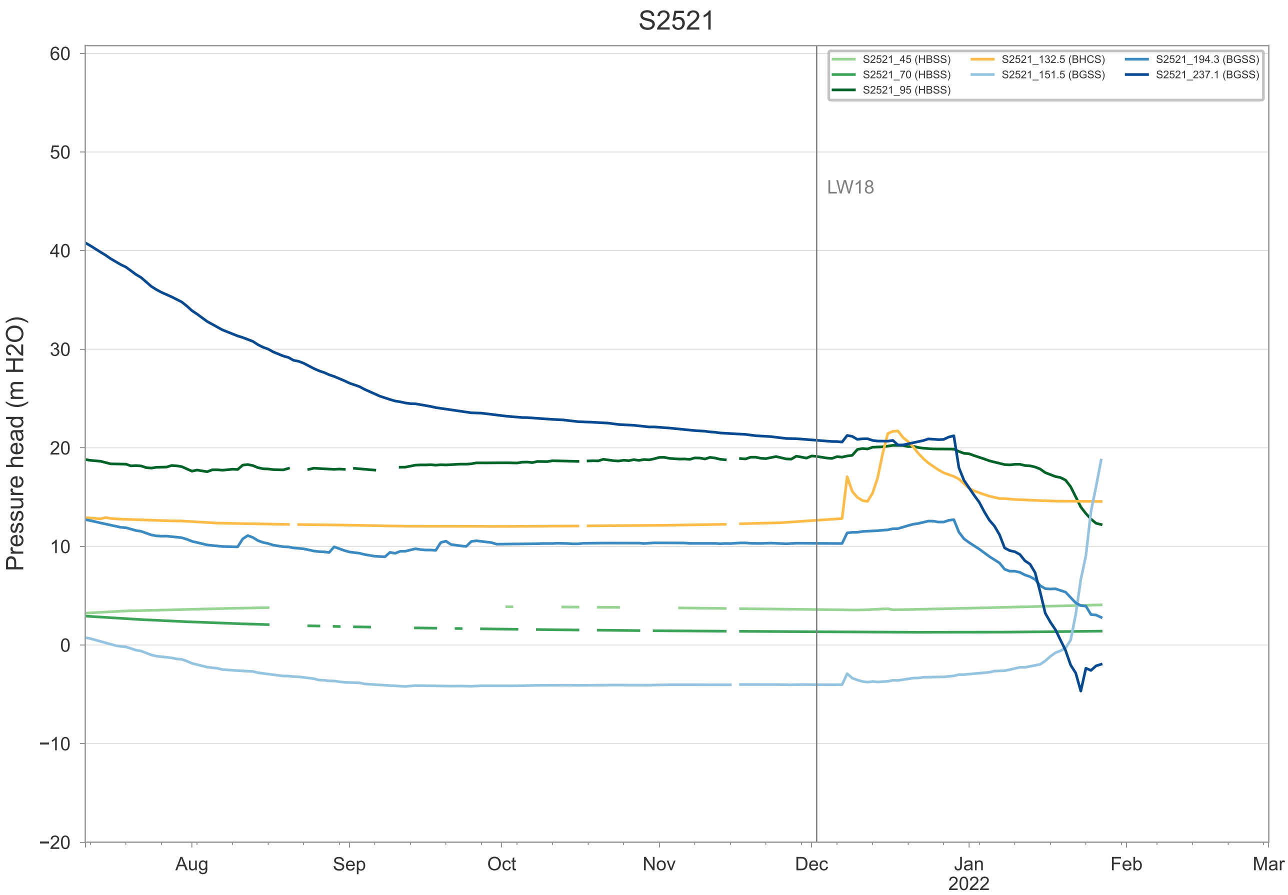



S2518B
LW21
Ground RL
Piezometric head (m RL)
400
350
300
250
200
150
100
50
S2518B_343.9 (BUSM)
S2518B_353.2 (BUSM)
S2518B_363.2 (WWSM)
S2518B_368.5 (WWSM)
Lake Cordeaux_Dam
Hawkesbury Sst
Bald Hill CS
Bulgo / Colo Vale
L. Narrabeen Grp
Bulli Coal Seam
Illawarra CM
Aug
Sep
Oct
Nov
Dec
Jan
2023
Feb
Mar
Apr
May
Jun

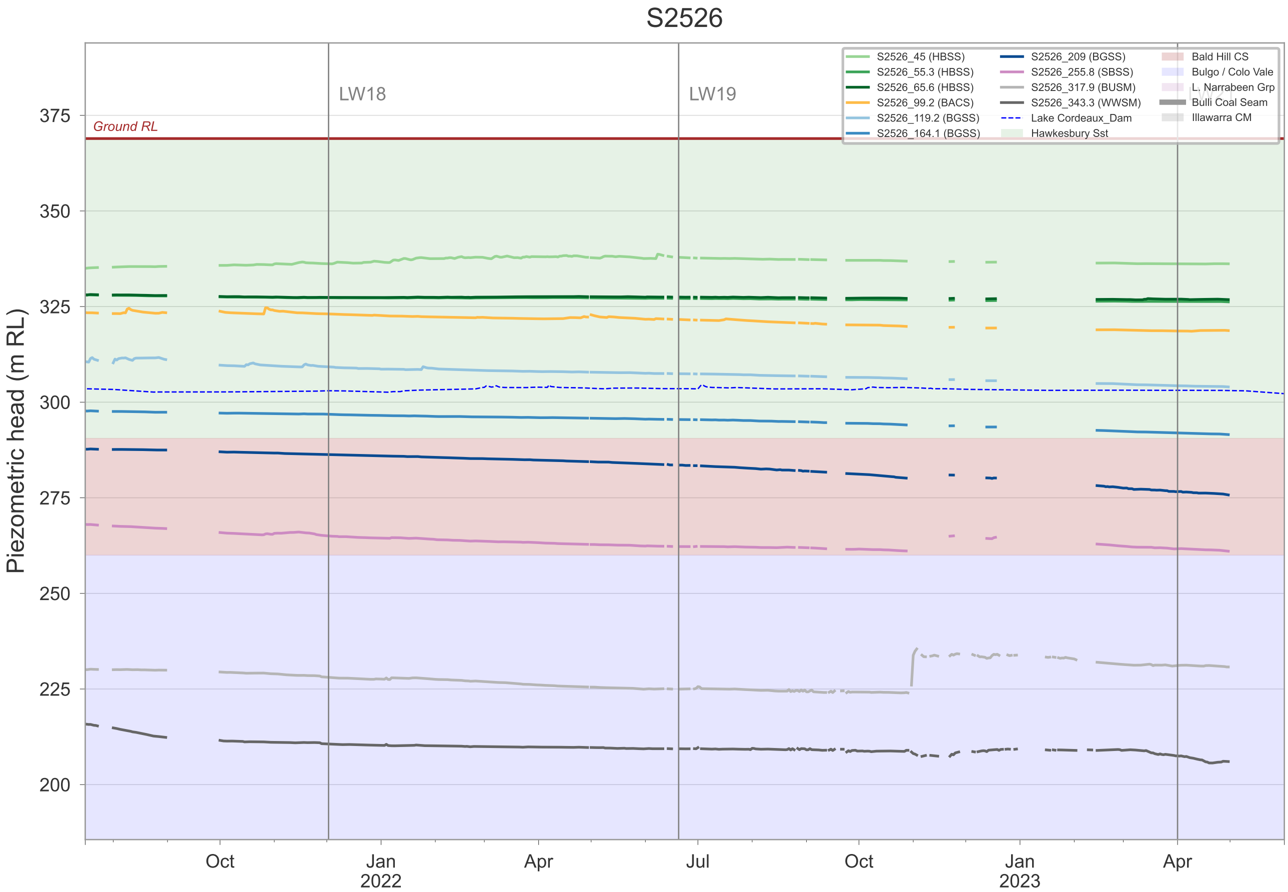

S2518B
S2518B_343.9 (BUSM)
S2518B_353.2 (BUSM)
S2518B_363.2 (WWSM)
S2518B_368.5 (WWSM)
LW21
Pressure head (m H2O)
200
150
100
50
0
Aug
Sep
Oct
Nov
Dec
Jan
2023
Feb
Mar
Apr
May
Jun

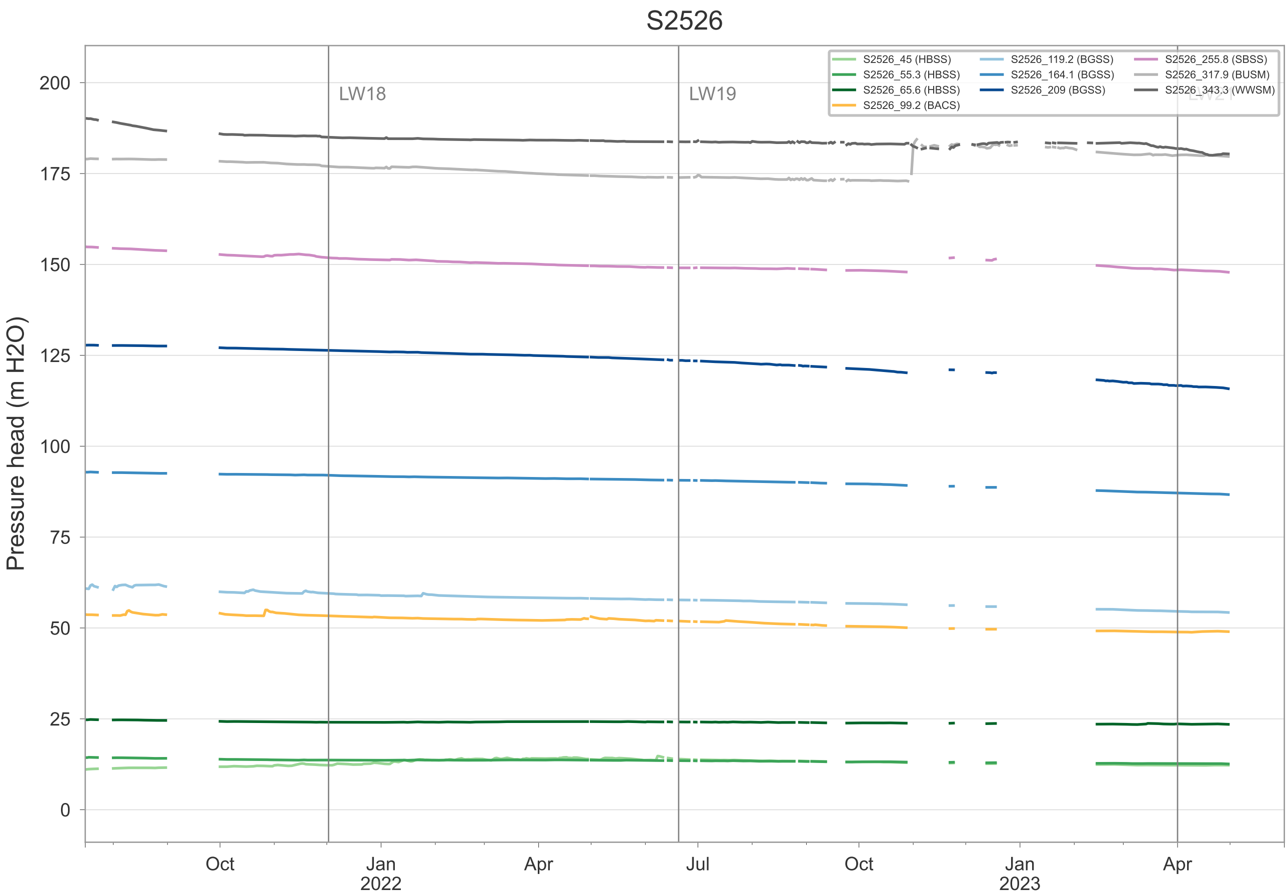
Groundwater hydrographs



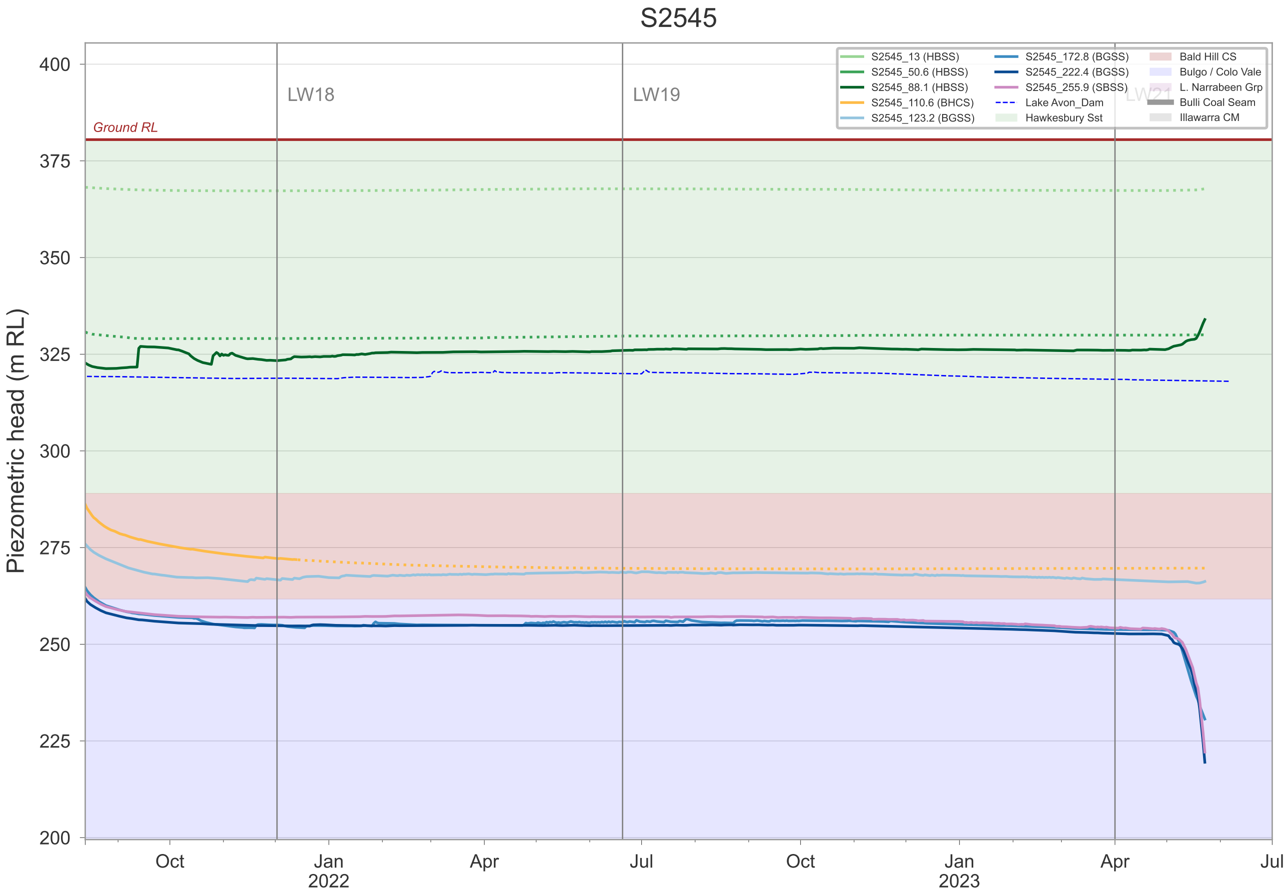


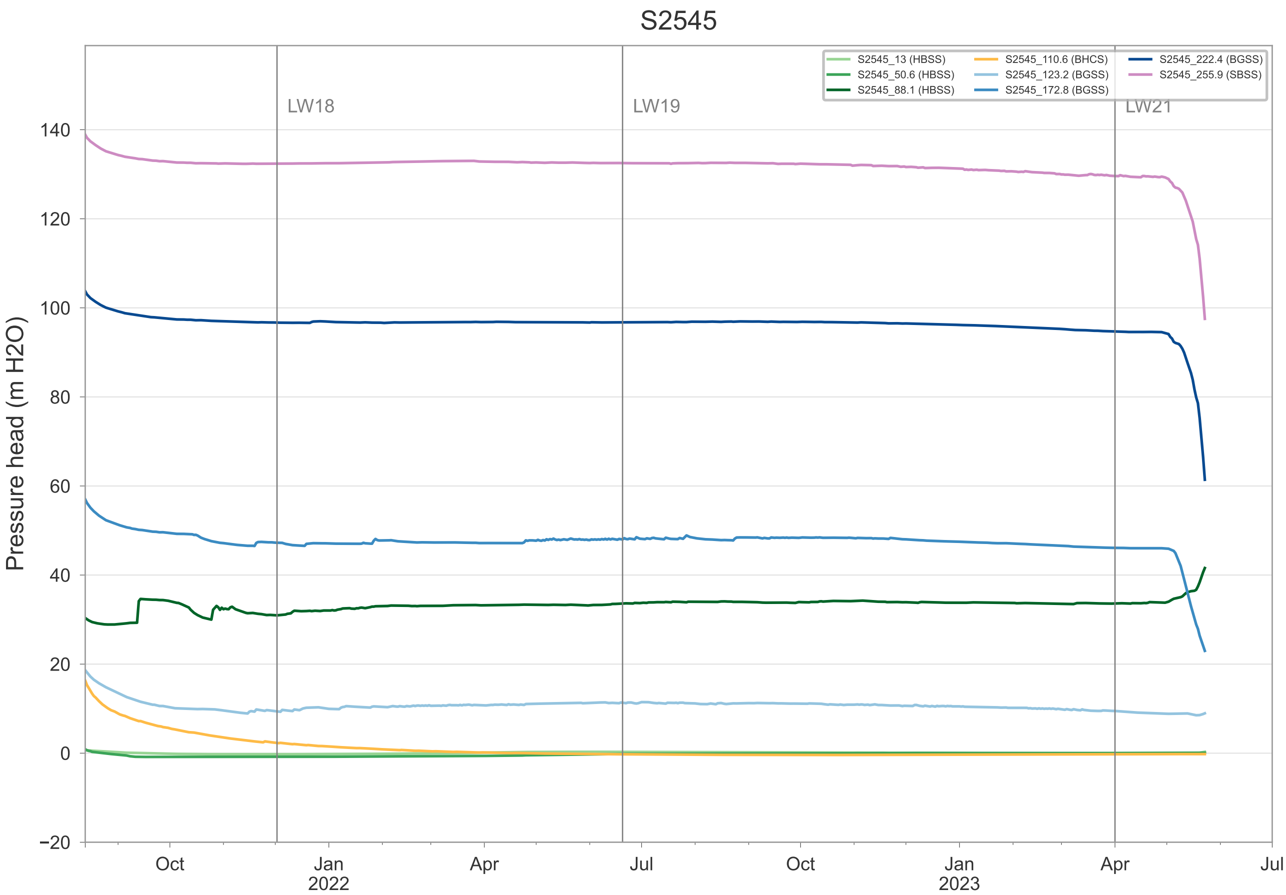
Groundwater hydrographs



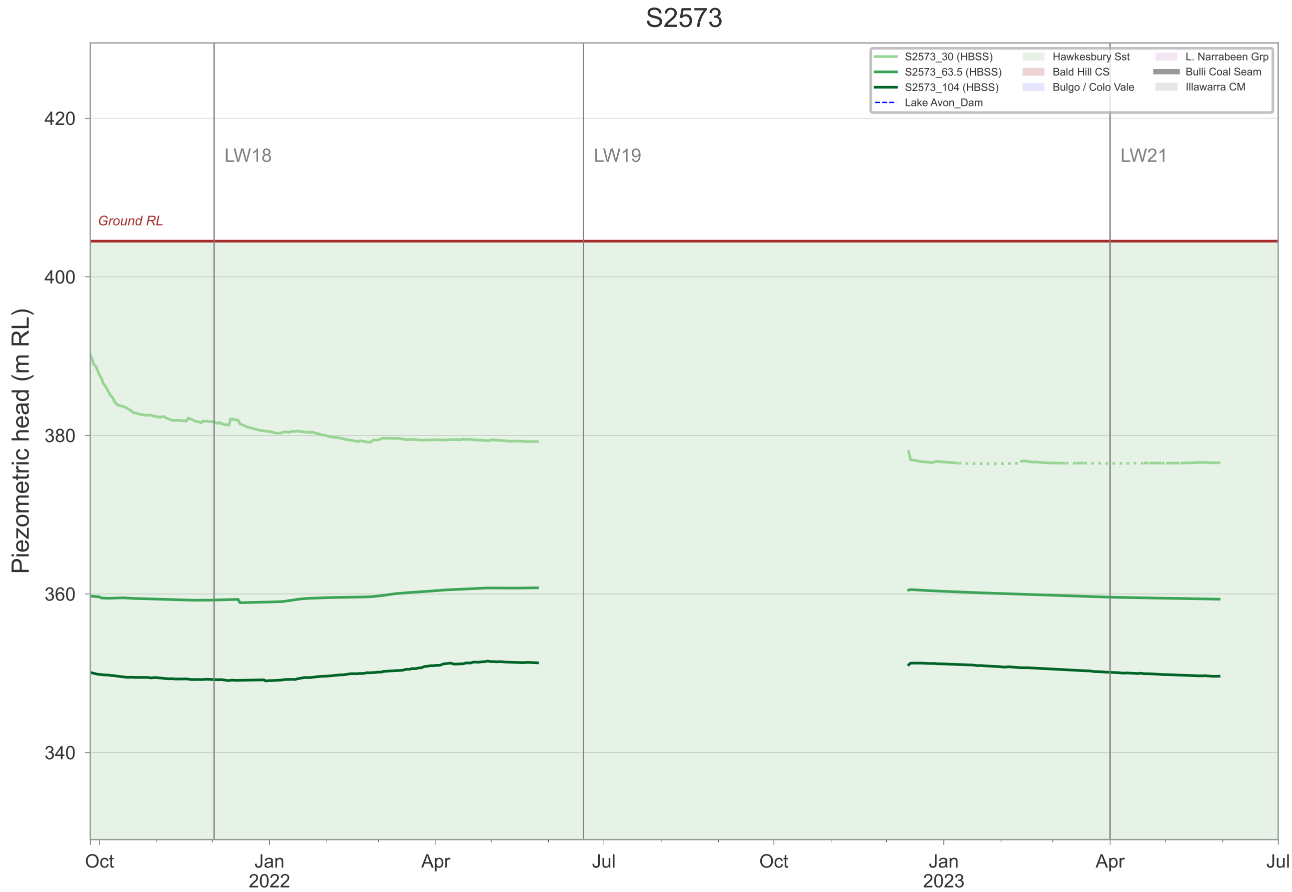


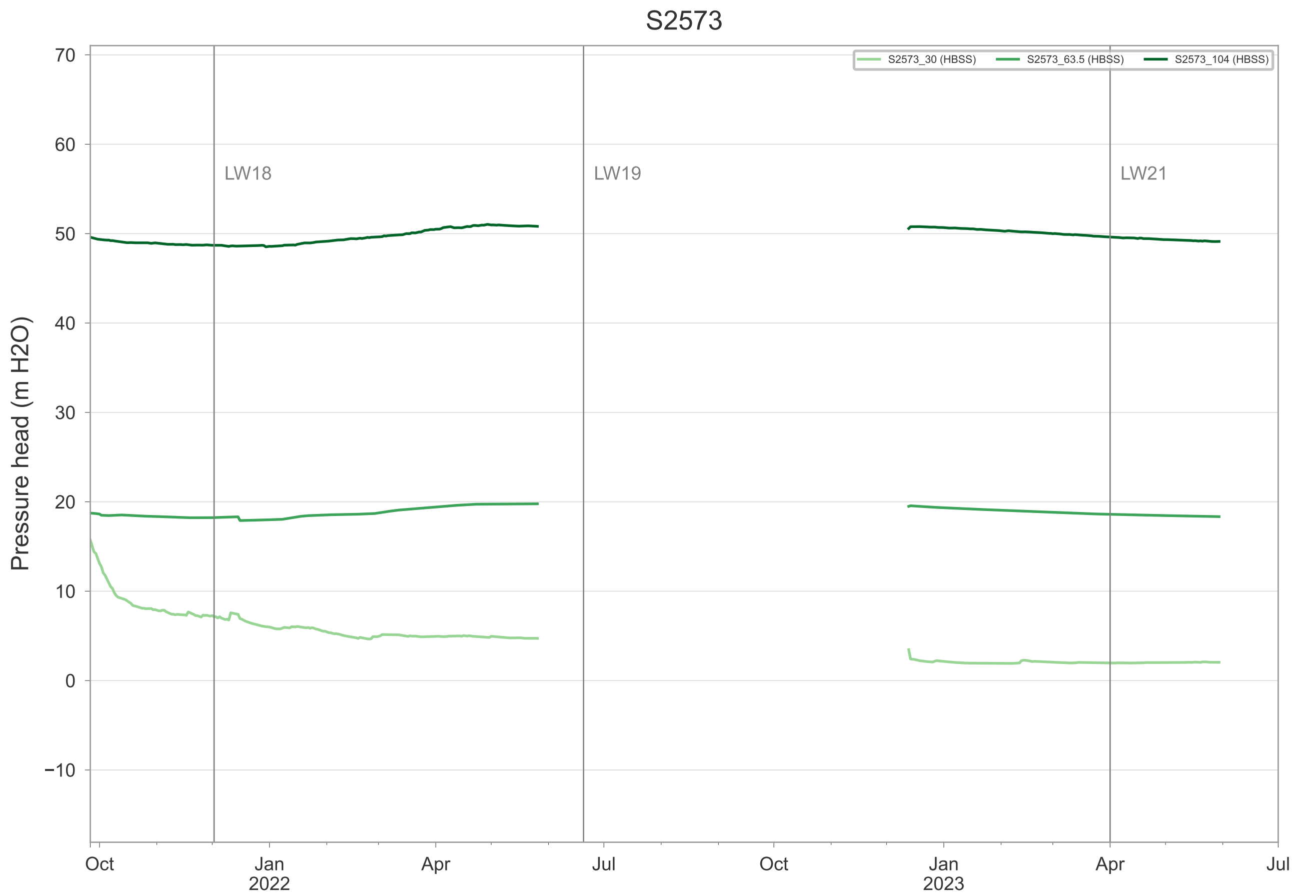
Groundwater hydrographs





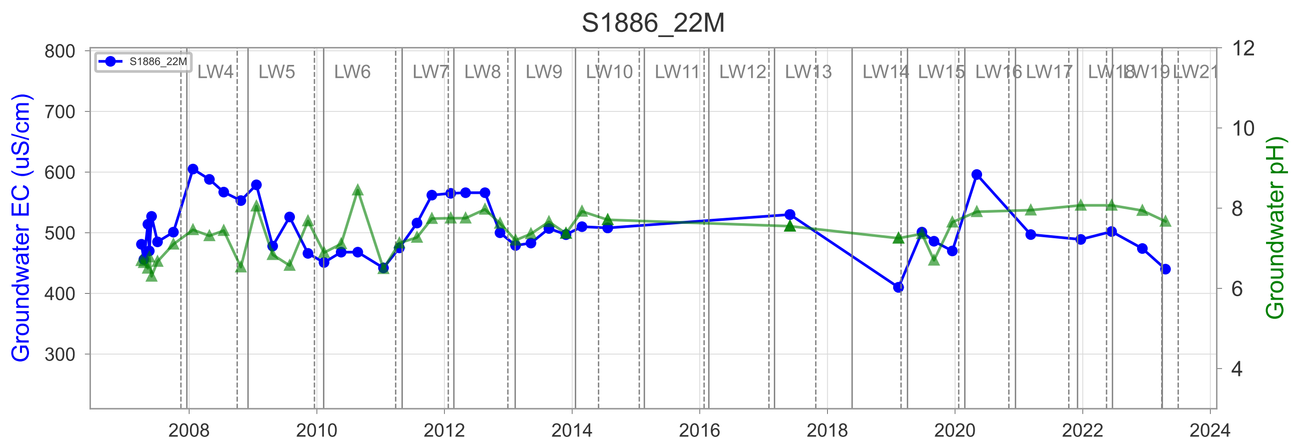
Groundwater hydrographs

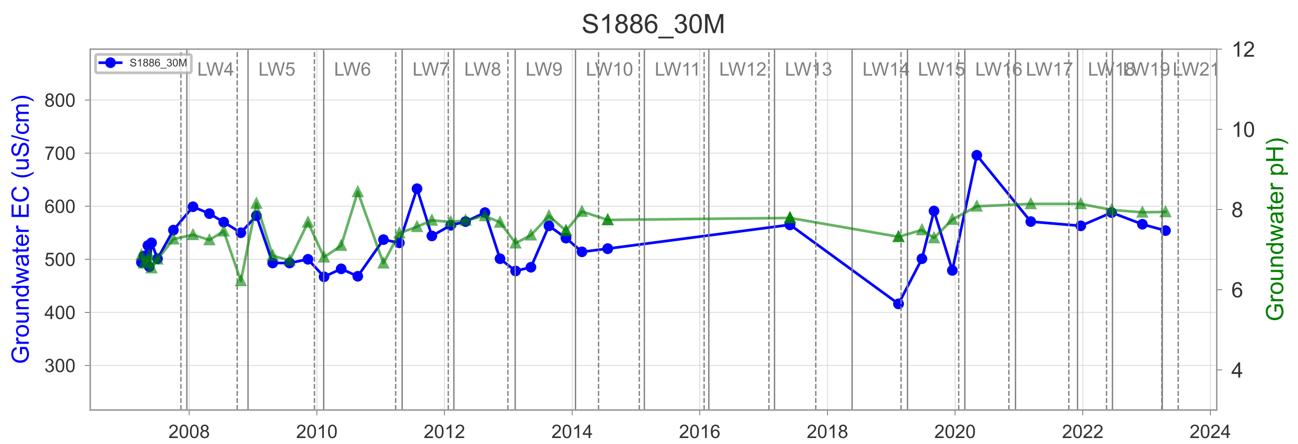


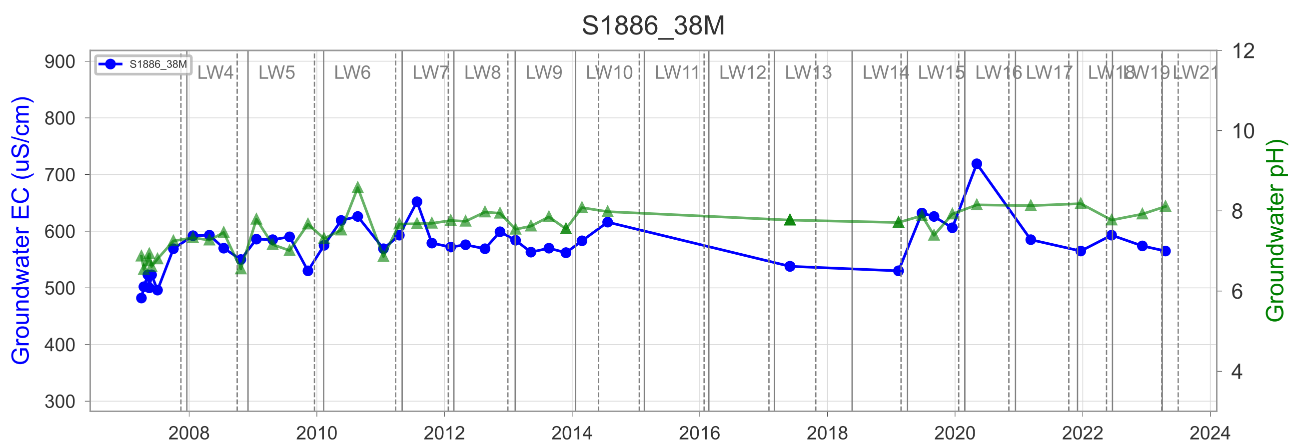


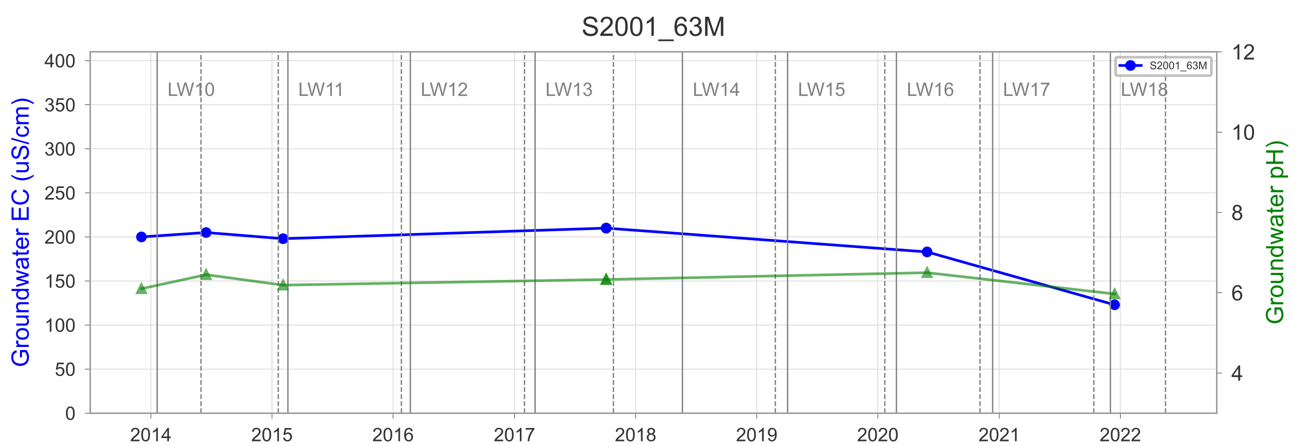
APPENDIX C: Groundwater quality timeseries

Groundwater EC timeseries



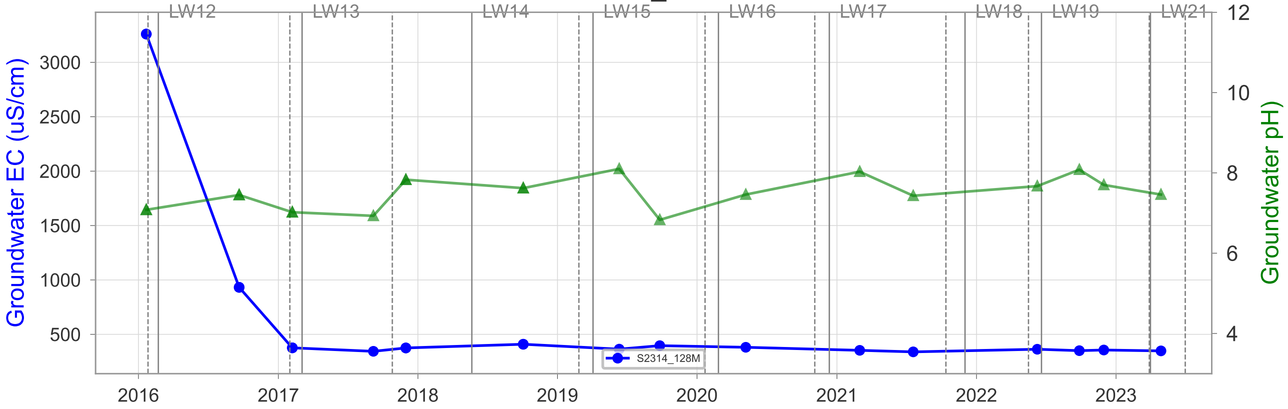




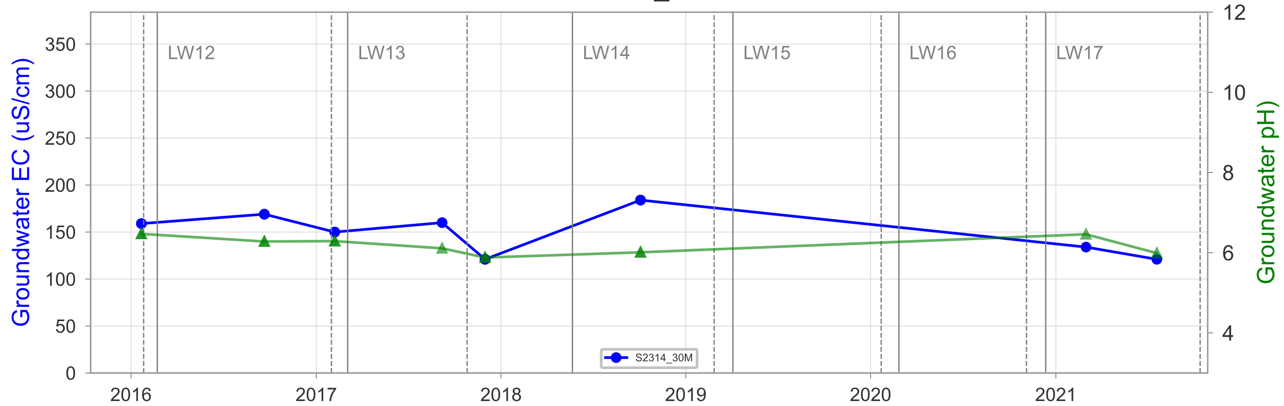


Groundwater EC timeseries

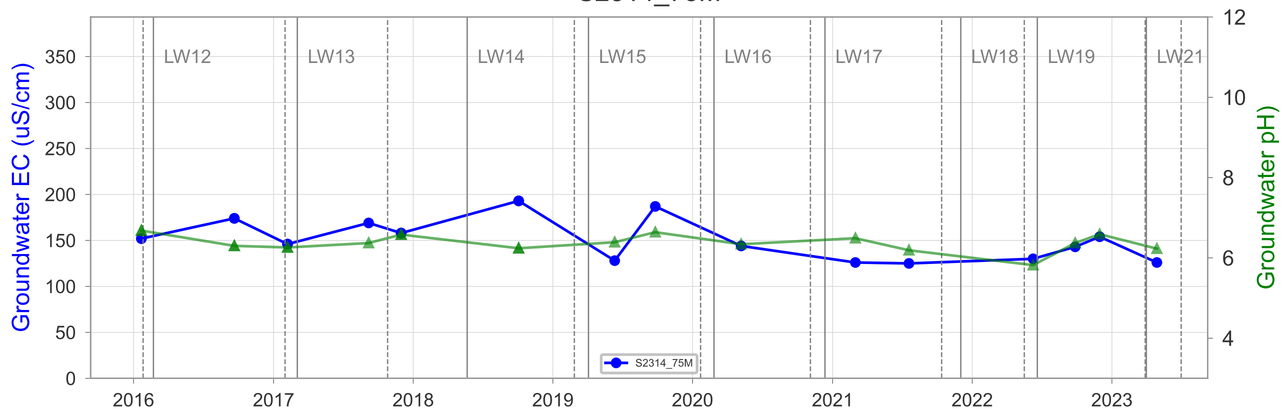
S2314_128M



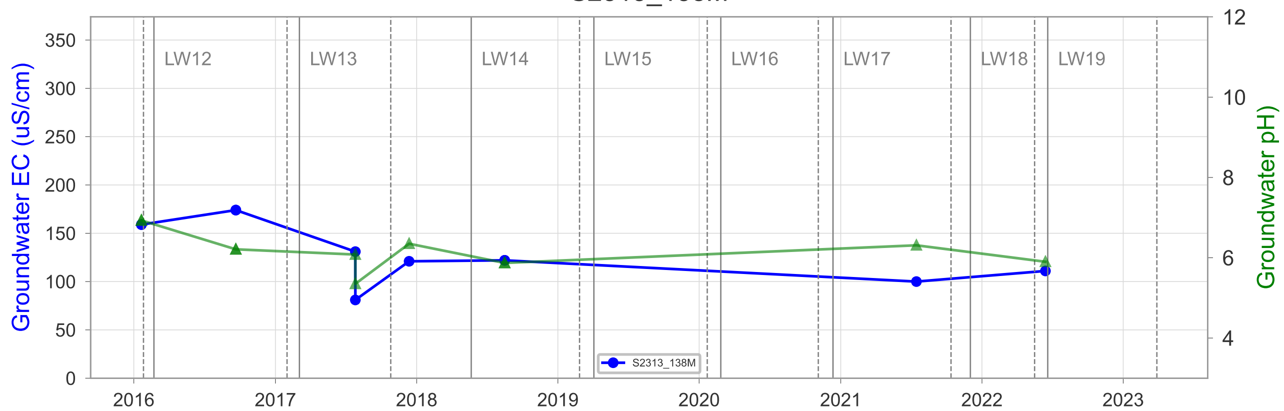
S2314_30M



S2314_75M

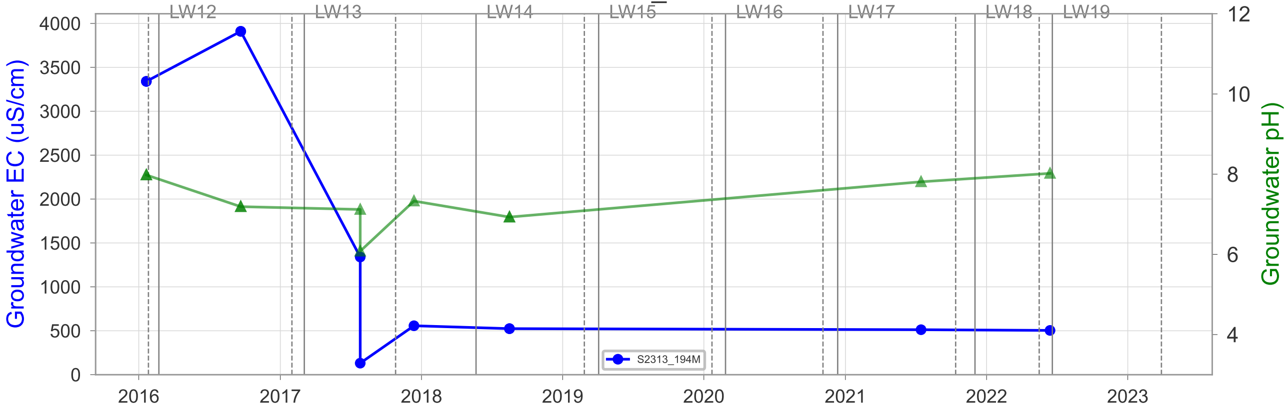


S2313_138M

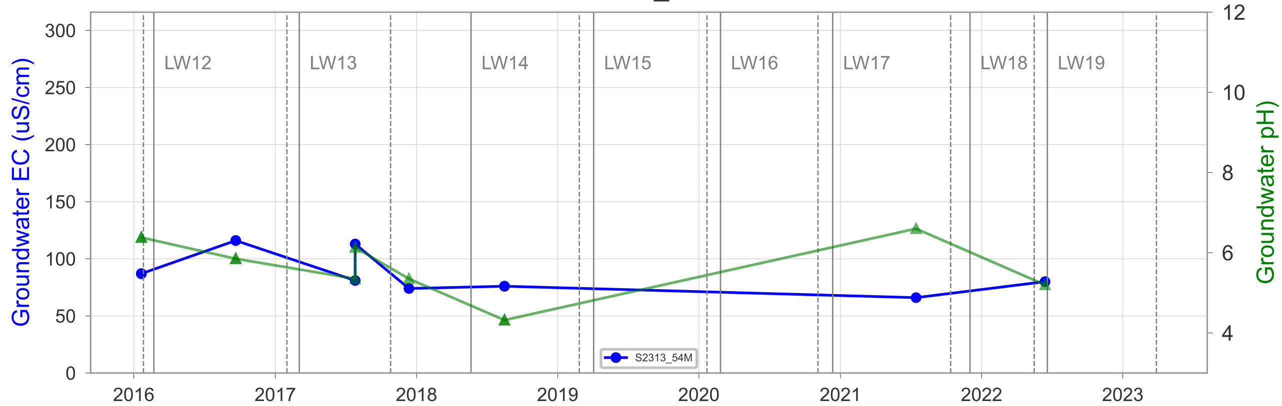


Groundwater EC timeseries

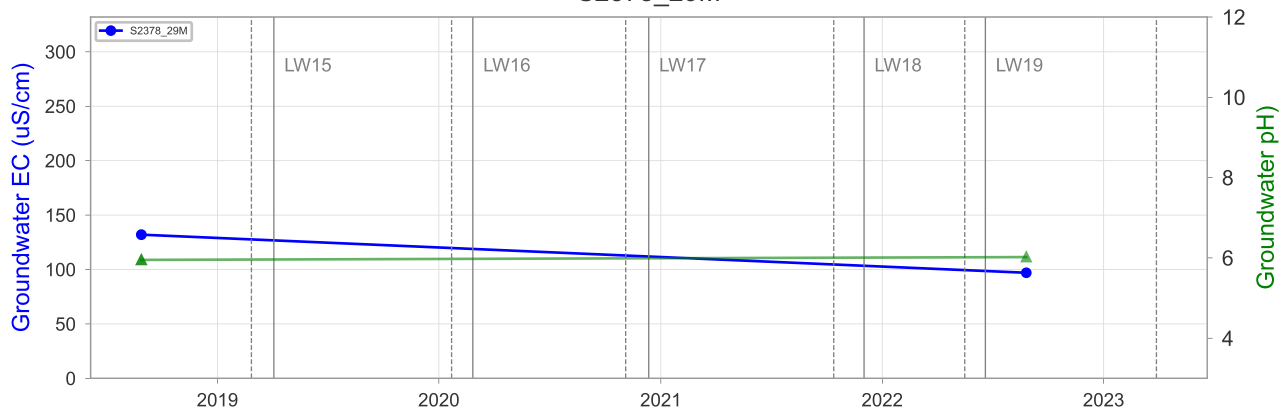
S2313_194M



S2313_54M



S2378_29M



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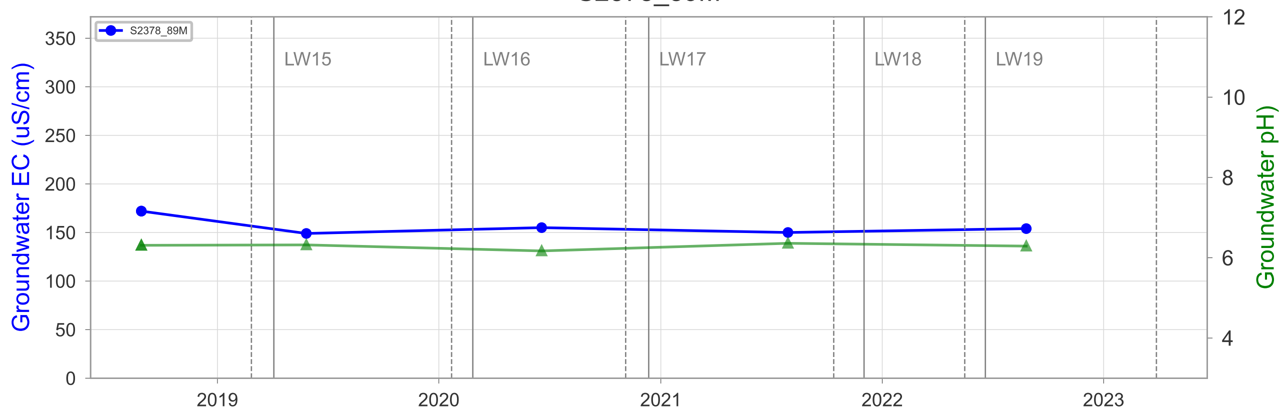
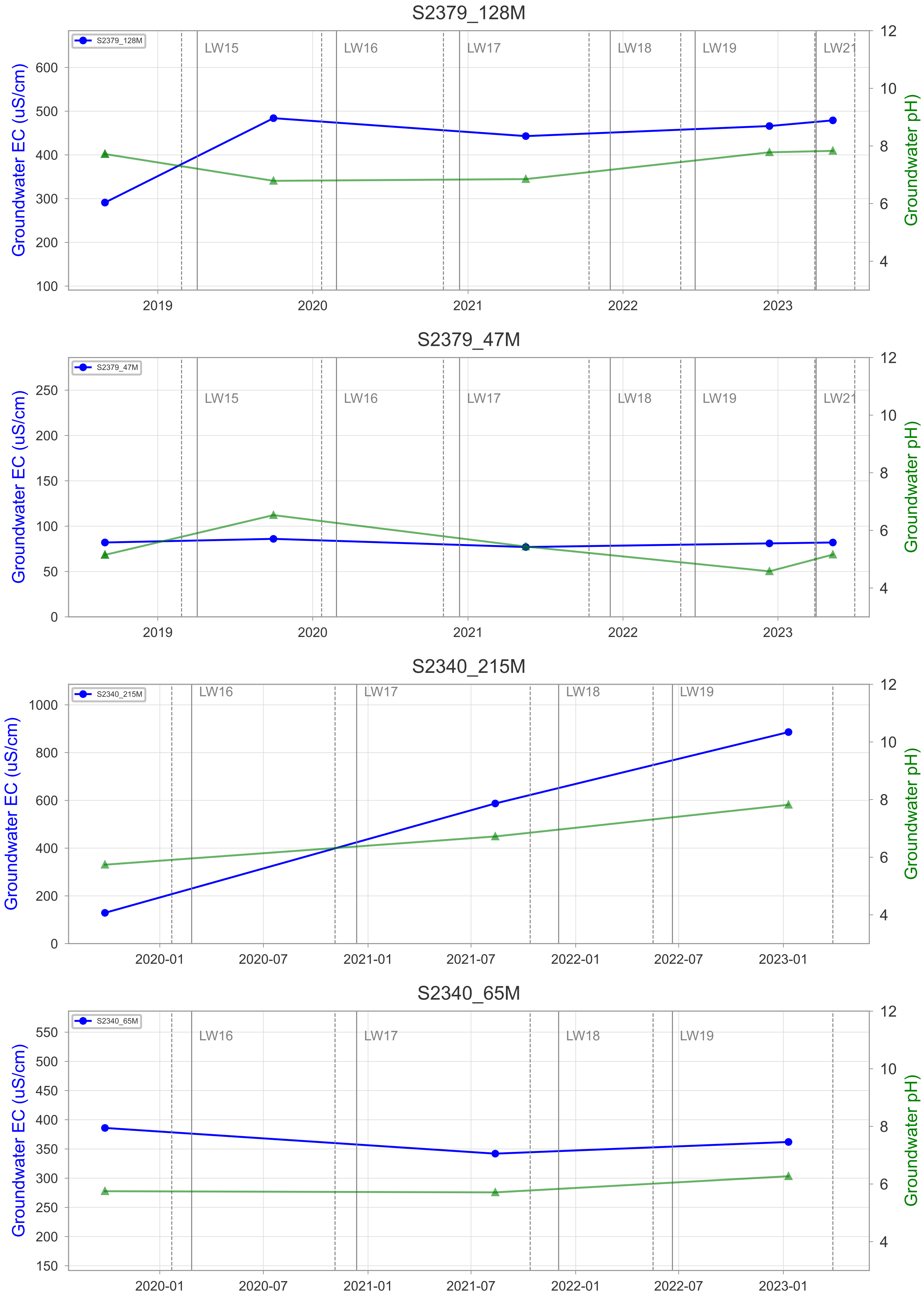
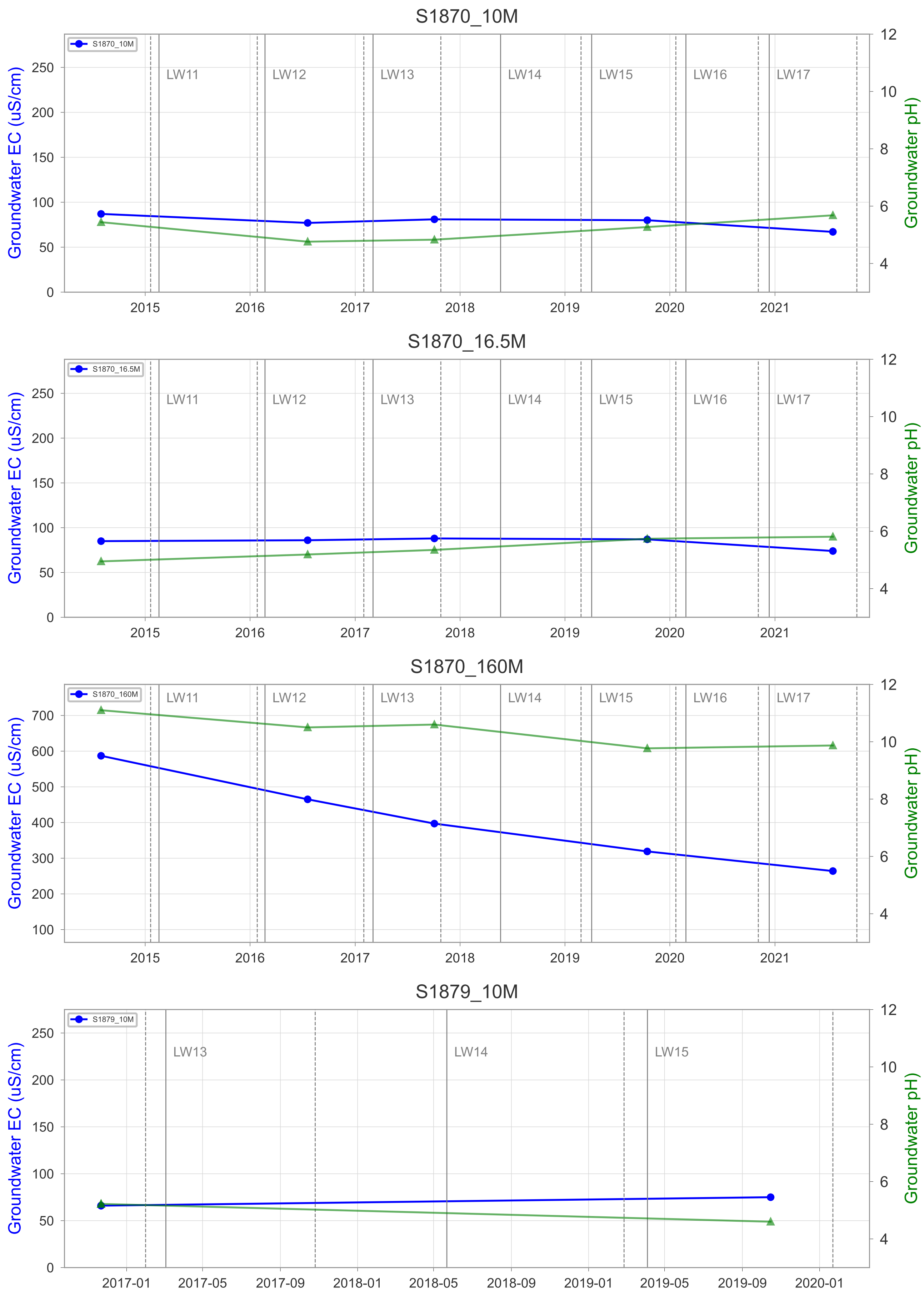


Groundwater EC timeseries

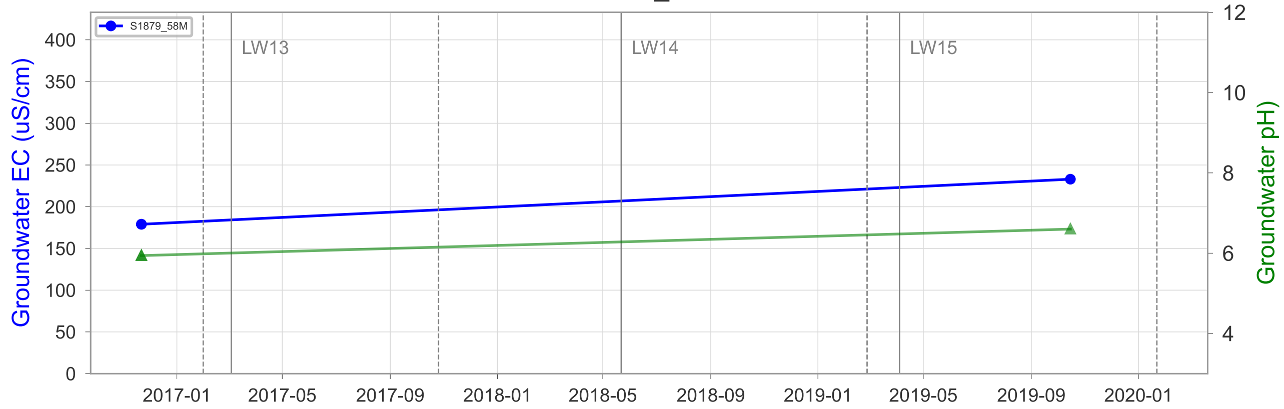


Groundwater EC timeseries

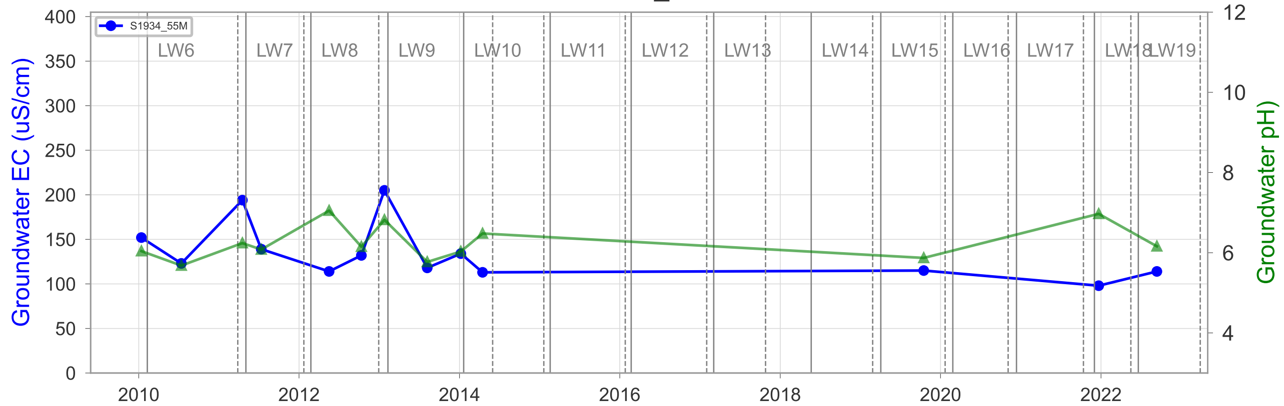


Groundwater EC timeseries

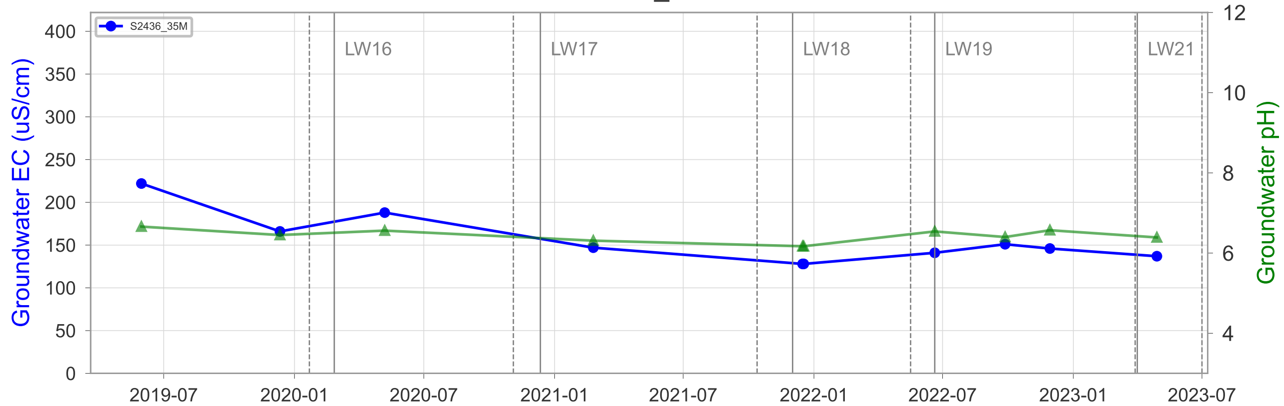
S1879_58M



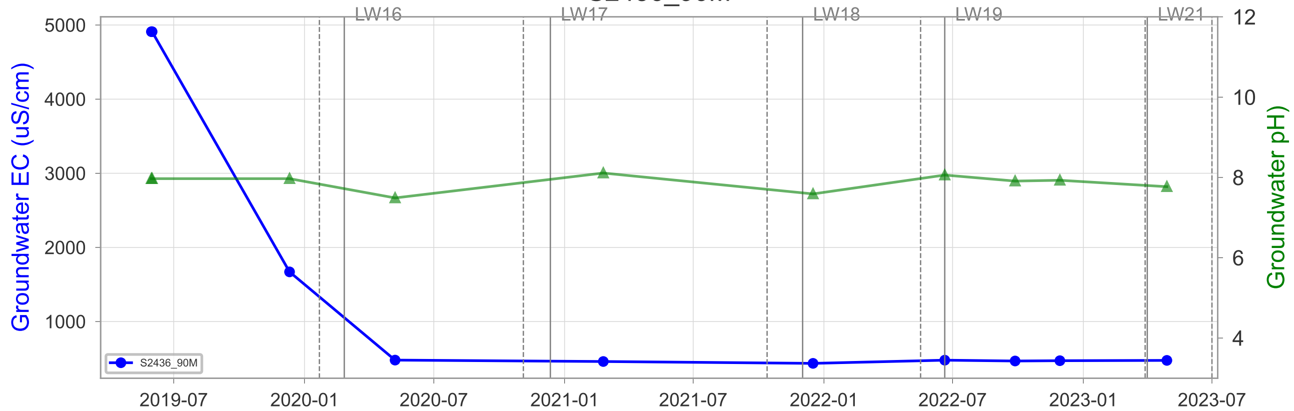
S1934_55M



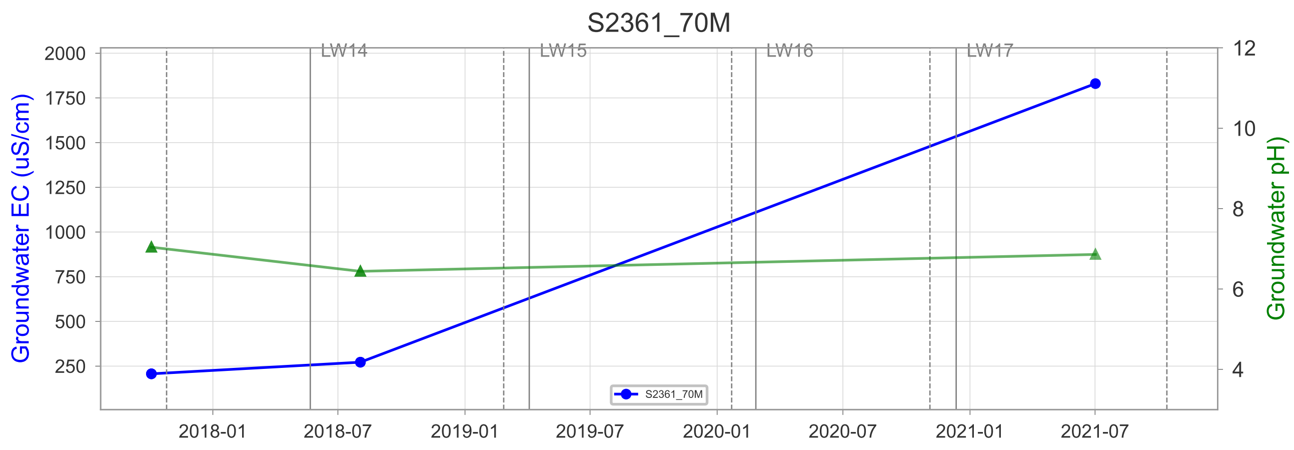
S2436_35M

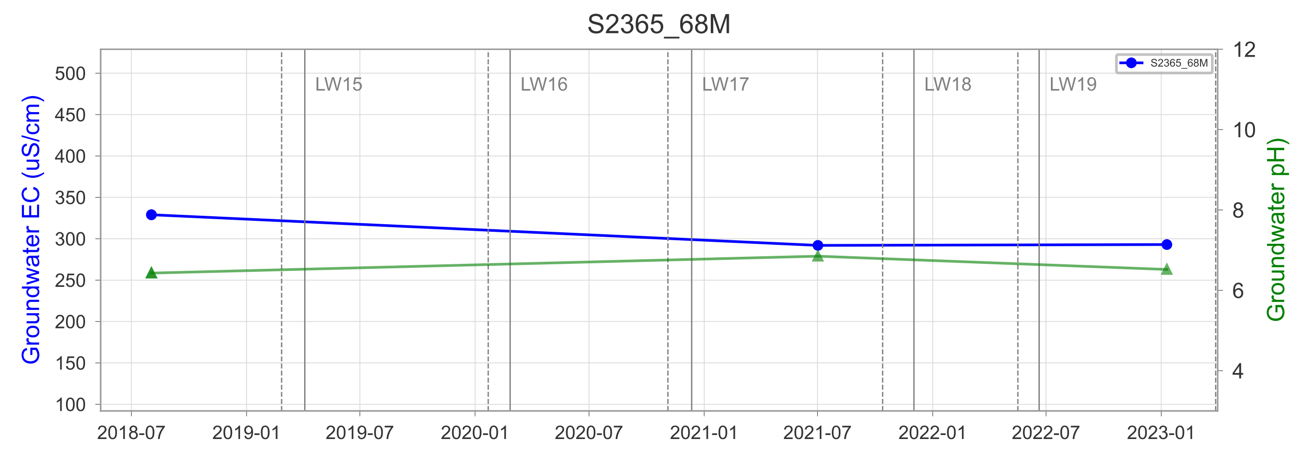


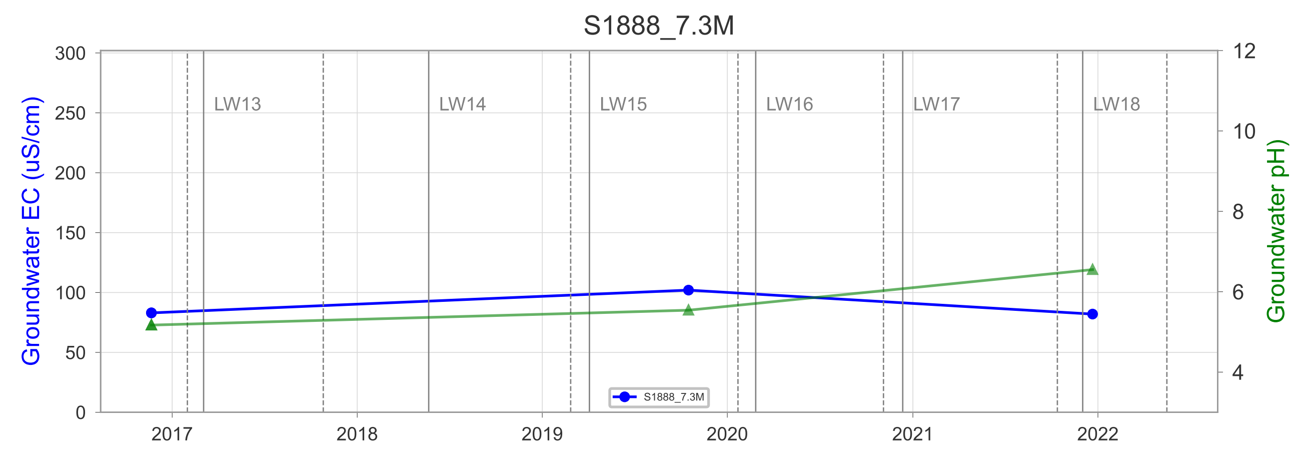
S2436_90M

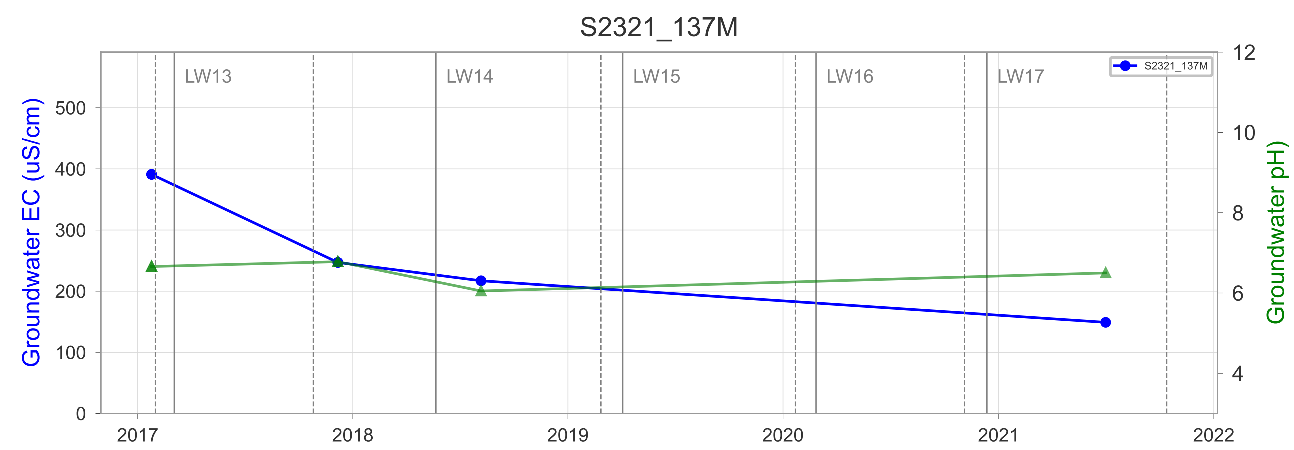


Groundwater EC timeseries

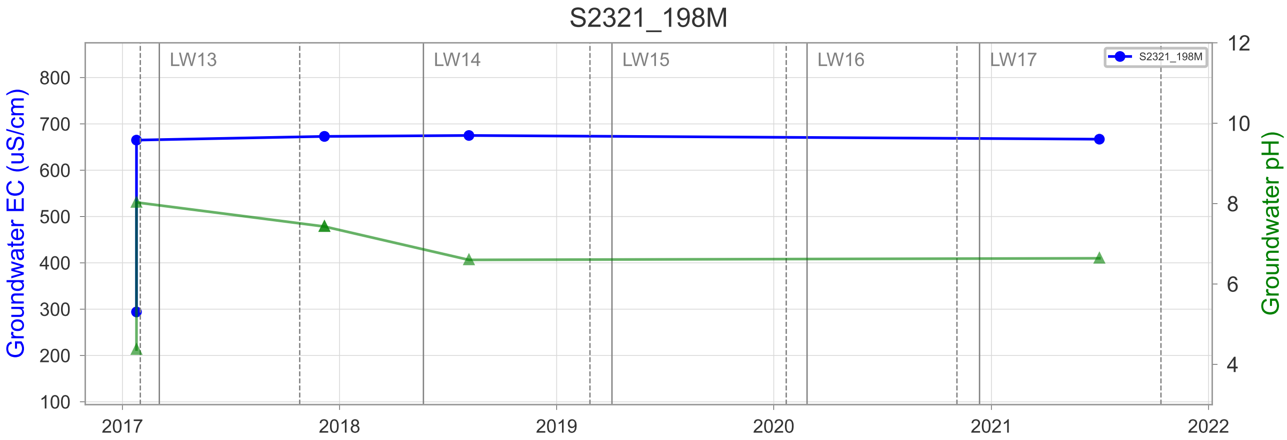


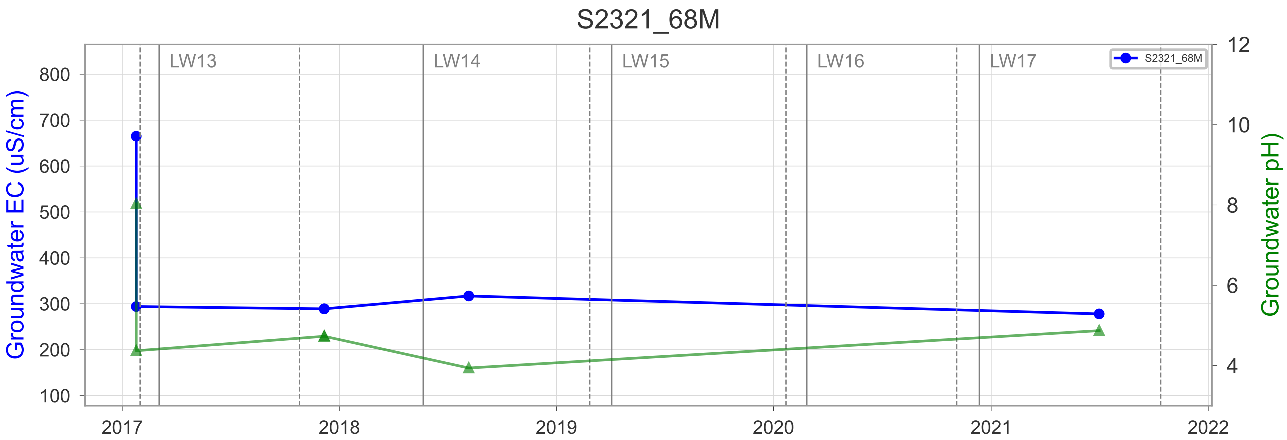


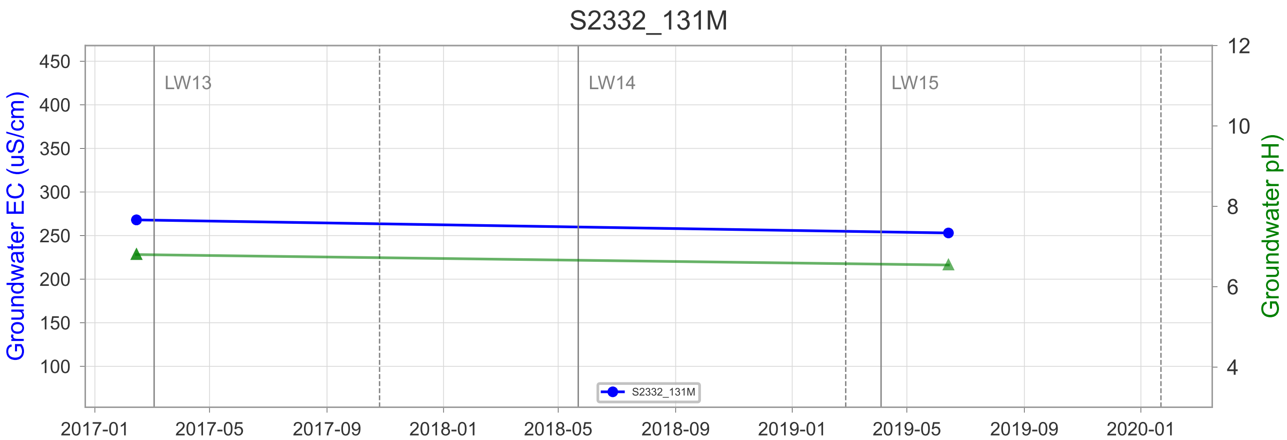


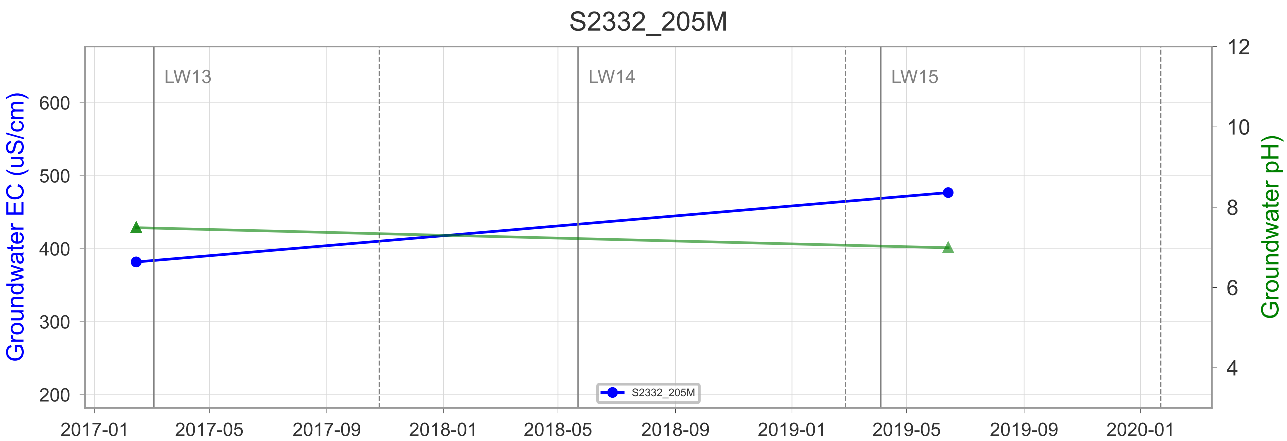


Groundwater EC timeseries

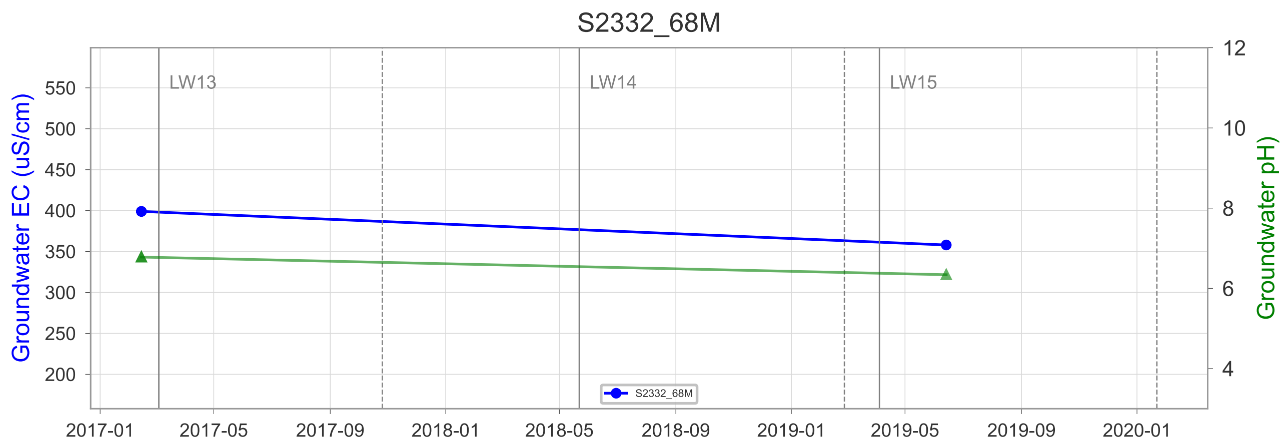


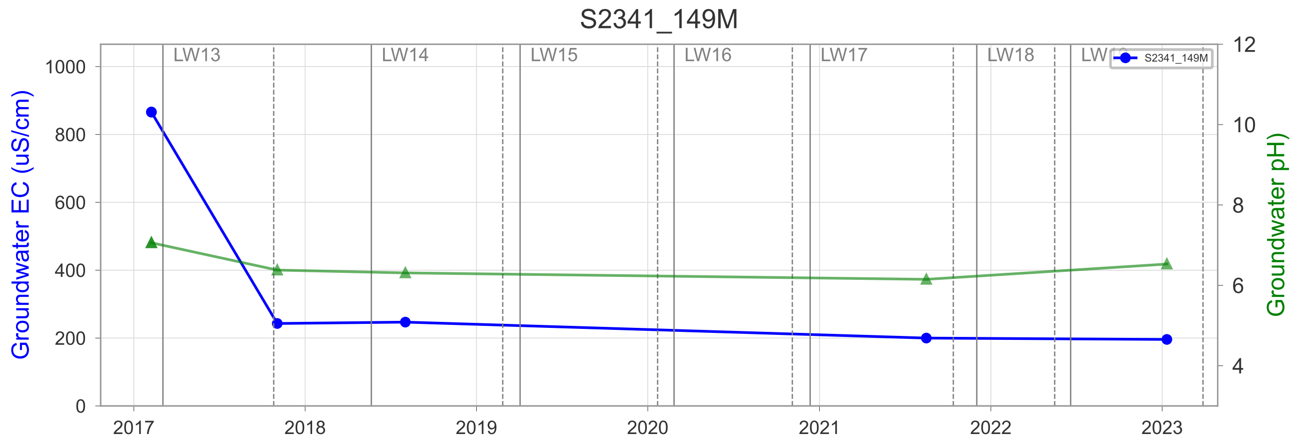


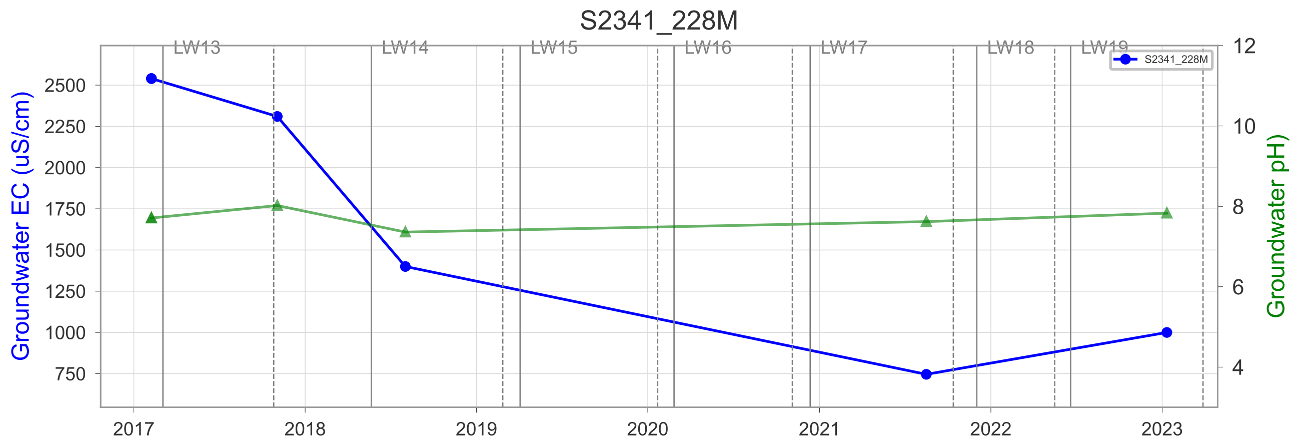


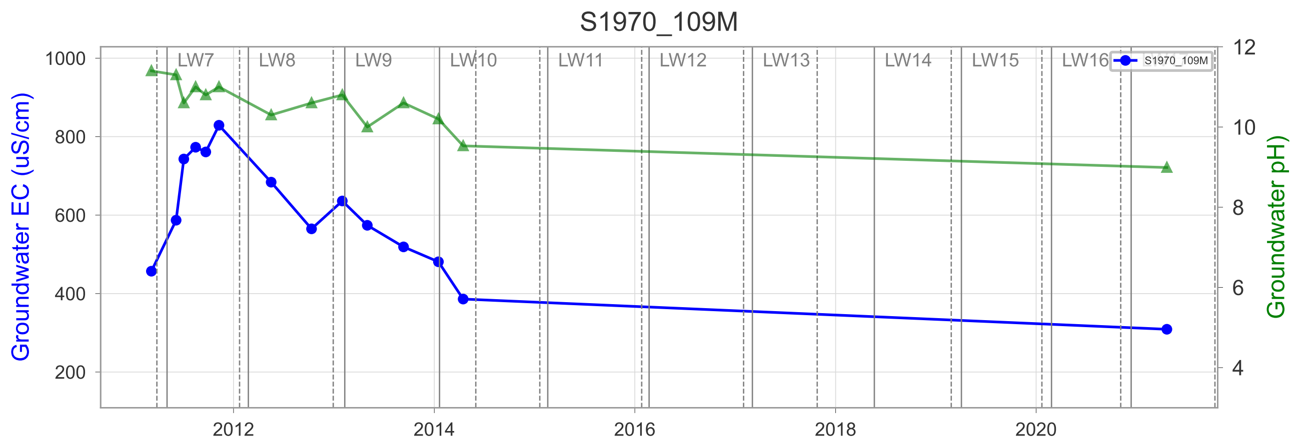


Groundwater EC timeseries









Groundwater EC timeseries