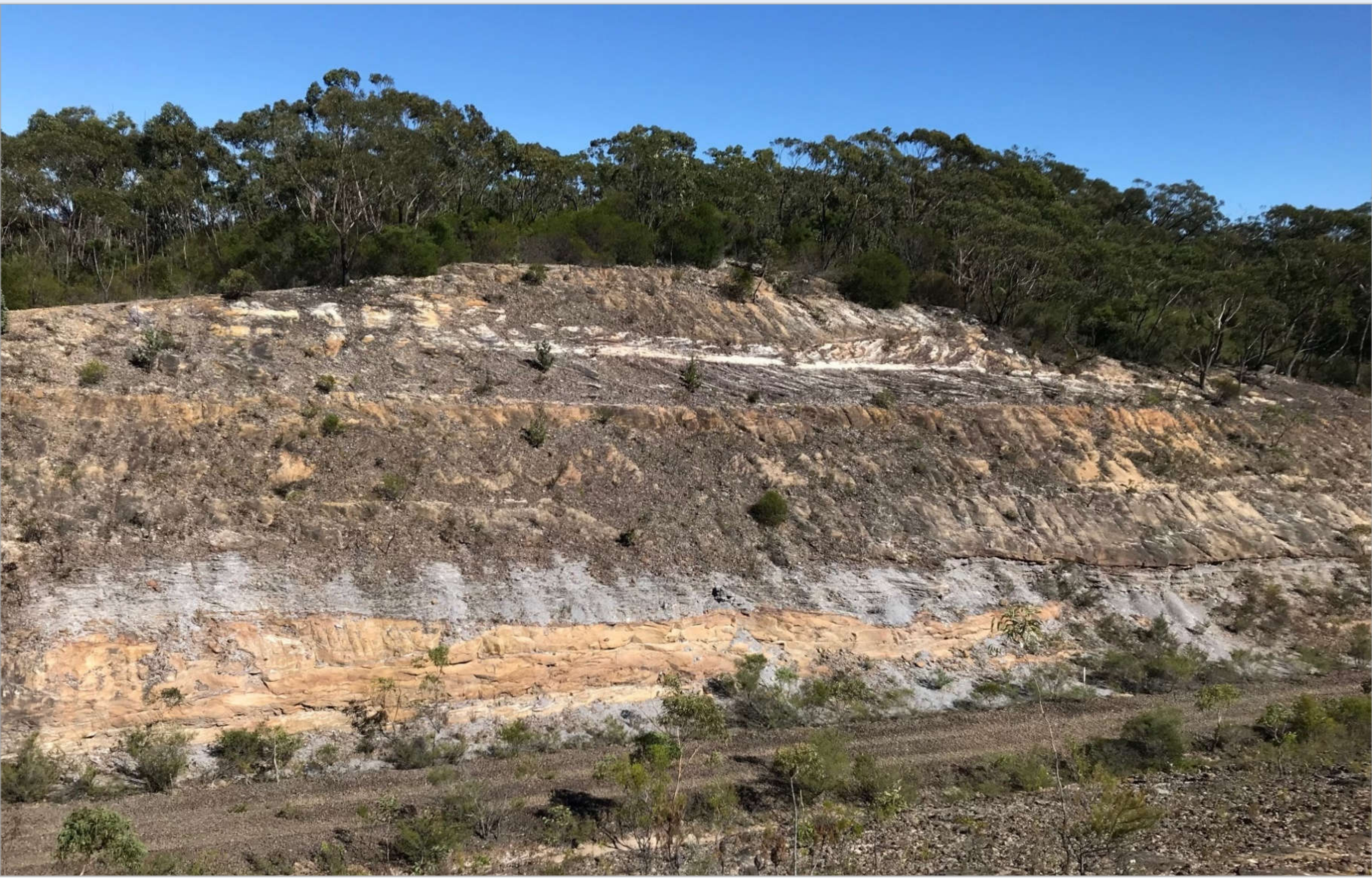
South32 - Illawarra Coal

DENDROBIUM MINE

End of Panel Groundwater Assessment for Longwall 14 (Area 3B)



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EXECUTIVE SUMMARY

This report provides an assessment of the hydrogeological effects of Longwall 14 (LW14) extraction in Area 3B at Dendrobium Mine, as required under the conditions of mining approval. Extraction of LW14 commenced on 22 May 2018 and was completed on 26 February 2019. LW14 is the sixth panel to be extracted in Area 3B, with an extracted length of 1969 m, a void width of 305 m (including first workings) and a cutting height of up to 3.9 m.

The average daily inflow to Area 3B during LW14 extraction was 4.21 ML/d which is approximately 10% lower than the previous longwall (4.68 ML/day; LW13). The decline is likely due to a combination of reduced rainfall during the extraction period and depressurisation of the surrounding strata from previous mining operations. From 2016 there is an apparent correlation between large rainfall events and peaks in mine inflow. The amplitude of the rainfall-related peaks accounts for approximately 11 - 15% of the total inflow. However, to date, the concentration of tritium (an isotopic indicator of modern water) in Area 3B mine inflow water is not statistically different from deep groundwater.

Groundwater salinity (as indicated by Electrical Conductivity – EC) shows a general increase with depth below the surface. During LW14, anomalous EC was noted in samples from strata groundwater monitoring site S1886 (DEN94). It is recommended that the bore is resampled as soon as practical.

Mining of LW14 resulted in continued depressurisation of the target coal seam and overlying strata. The observed changes in groundwater levels are in line with (or less than) numerical model predictions that support mining approvals. As expected, the greatest depressurisation is within the Wongawilli Coal Seam, and decreases with height above the seam. Incremental drawdown in the Scarborough and Bulgo Sandstones is apparent in the areas immediately to the south-west of LW14. Estimated groundwater drawdown in the Hawkesbury Sandstone since prior to the start of mining in Area 3A (November 2009) is greatest above and immediately adjacent to extracted longwalls, with maximum drawdown up to 52.8 m (at S1910, located 125 m north of LW9).

Observations at monitoring bores installed above mined longwalls indicate that the Hawkesbury Sandstone undergoes fracturing to the ground surface, accompanied by depressurisation of most shallow strata. There is evidence that drainage of the Hawkesbury Sandstone above goafs is not complete in all areas and some perched groundwater horizons remain.

Between 2015 and 2018, a series of monitoring bores were installed along the barrier zone between Lake Avon reservoir and Area 3B. Observations at those bores indicate depressurisation of the upper Colo Vale Sandstone in response to longwall extraction, and variable drawdown in the Hawkesbury Sandstone. A hydraulic gradient towards the lake is preserved in the Hawkesbury Sandstone at S2313, whereas at S2314 and S2376 the hydraulic gradient is locally reversed towards the mine, implying movement of groundwater from the lake to the mine. The Dendrobium Regional Groundwater Model (2016) estimates that seepage loss between Lake Avon and Longwalls 12 to 16 would be less than 0.28 ML/day (or 0.17 ML/day/km of shoreline adjacent to extracted longwalls). This estimate is consistent with numerical modelling predictions.

The numerical model developed by Hydrosimulations in 2014 and updated in 2016 was assessed to be accurate with respect to estimated groundwater levels within the Hawkesbury Sandstone at the end of LW14. The model overestimates drawdown in the Bulgo and Scarborough Sandstones and is therefore conservative.

Seepage losses from Lake Avon was also estimated using a specific local scale numerical model at approximately 0.44 ML/km per day following the extraction of LW14. The estimate is of a similar magnitude to those from regional numerical modelling and is within the tolerable loss limit of 1 ML/da prescribed by the NSW Dams Safety Committee (DSC).

1. INTRODUCTION

HGEO Pty Ltd (HGEO) was engaged by Illawarra Coal (IC) to prepare an assessment of hydrogeological effects of LW14 extraction in Area 3B at Dendrobium Mine, as required under the conditions of mining approval. Extraction of Longwall 14 (LW14) commenced on 22 May 2018 and was completed on 26 February 2019. LW14 is the sixth panel to be extracted in Area 3B, with an extracted length of 1969 m, a void width of 305 m (including first workings) and a cutting height of up to 3.9 m.

Dendrobium Mine is located approximately 12 km west of Wollongong (NSW) in the Southern Coalfield and within the Metropolitan Special Catchment Area managed by WaterNSW. The three designated areas of extraction are Area 1 (east of Lake Cordeaux), Area 2 (west of Lake Cordeaux), and Areas 3A and 3B (between Lake Cordeaux and Lake Avon) (Figure 1). Coal is extracted from the Wongawilli Seam by longwall mining. 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.

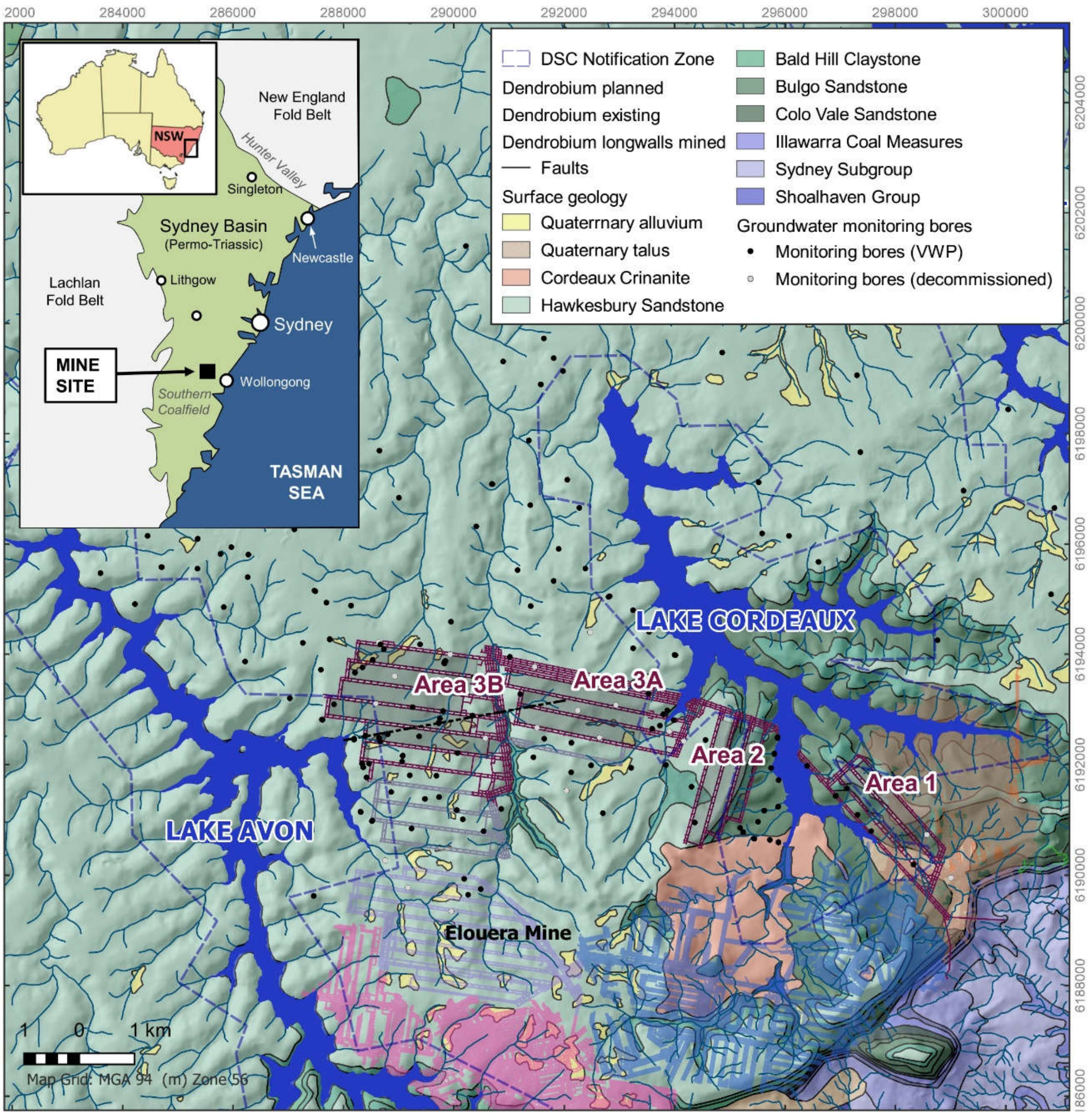

Figure 1. Location of Dendrobium Mine and surface geology

1.1 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. The Hawkesbury Sandstone is the dominant outcropping formation across the mine area, but lower stratigraphic units (Bald Hill Claystone, Narrabeen Group) are exposed in deeply incised parts of Wongawilli Creek and along the south-eastern shores of Lake Cordeaux.

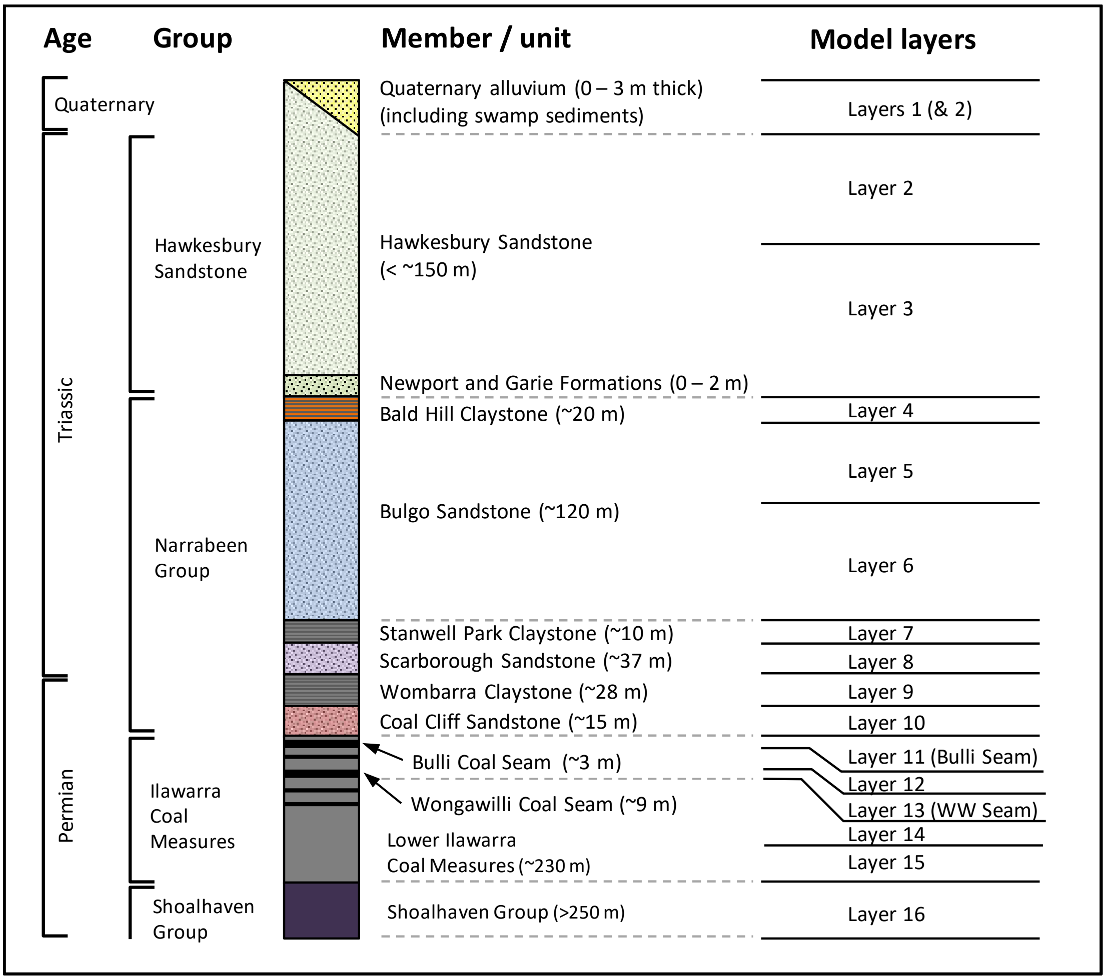

Figure 2. Stratigraphy of the Southern Coalfield

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 Hawkesbury Sandstone; 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 Hawkesbury Sandstone in the western half of the Dendrobium mine area and the Bulgo Sandstone 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.

1.2 Effects of mining

Extraction of coal using longwall methods commonly results in ground subsidence and associated deformation and fracturing of overlying strata (Peng & Chiang 1984; Whittaker & Reddish 1989). While authors differ in their terminology, there is general agreement on the overall fracture zonation patterns. 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 (McNally & Evans 2007; Advisian 2016). 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 (Forster 1995; Guo *et al.* 2007; Mills 2011; Tammetta 2013; e.g. Ditton & Merrick 2014). These methods have been used at numerous coal mines in NSW to provide guidance on the height of fracturing for the development of numerical groundwater impact models. At Dendrobium, the methods of Ditton and Merrick (2014) and Tammetta (2013) yield estimates that are significantly different from each other. A review of longwall subsidence fracturing at Dendrobium was commissioned by the NSW Department of Planning and Environment (DPE). The review by consultants PSM (2017) concluded that such empirical approaches carry significant uncertainty and limitations related to the data on which they were based, and that fracturing above the (305 m wide) panels in Area 3B likely extends to the surface (Galvin 2017; PSM 2017). The latter conclusion is consistent with the predictions of the Tammetta model at Dendrobium Area 3B, and observations presented here.

1.3 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 was revised and updated in 2014 (HydroSimulations 2014) to include calibration to shallow (swamp) groundwater data and surface water (creek) flows, and again in 2016 (HydroSimulations 2016). The 2016 model addressed the Area 3B SMP approval conditions and provides the basis for this groundwater impact assessment.

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

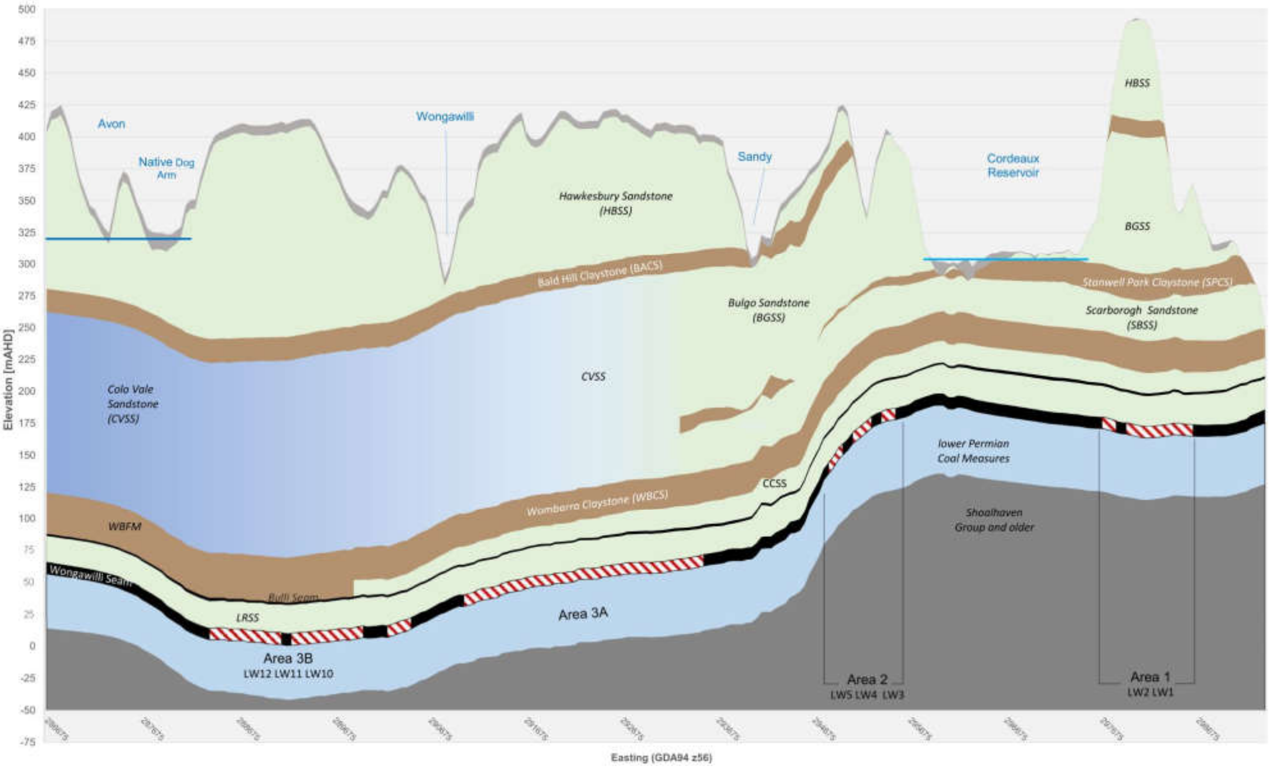

Figure 3. Geological cross-section (east-west) through Dendrobium Mine

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 3B Subsidence Management Plan (South32 2018a).

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 3B are shown in Figure 4. A list of all piezometers installed in Areas 2 and 3 are listed in Appendix A.

There are approximately 176 monitoring bores located across the Dendrobium mine lease, containing 810 piezometers, excluding those that are decommissioned or no longer monitored. Within the area covered by Figure 4 alone, there are approximately 100 active monitoring bores with more than 450 sensors.

In recent years, new monitoring bores have been installed above mined and planned longwalls, and between Lake Avon Reservoir and Area 3B. These new sites provide important information on groundwater responses to mining, and groundwater conditions within the barrier between the lake and the mine. New sites include:

- Swamp 11 monitoring bores (S2306 and S2307), above and at the margin of LW13;
- Avon Dam holes (S2313, S2314, S2376, S2377, S2378, S2379, S2435 and S2436), between Lake Avon and Mine Area 3B;
- Swamp 14 holes (S2354 and S2351), above and at the edge of LW16;
- Above longwall holes: LW12 (S2399), LW14 (S2398), LW15 (S2412) and LW16 (S2354);
- Swamp 1b rehabilitation study (S2401 – S2406), above Longwalls 9 and 10.

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 (Mikkelson & Green 2003; Contreras *et al.* 2008).

Standpipe piezometers, consisting of a slotted open casing, are used in a small number of locations and are best suited to monitoring of relatively shallow groundwater systems within moderate to high permeability strata (e.g. swamp sediments and shallow Hawkesbury Sandstone). 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.

Hydrographs are plotted in terms of ***potentiometric head*** (mAHD). Potentiometric 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 desaturation at the location of the sensor. 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 previous assessments, estimates of groundwater drawdown were calculated for each geological unit (e.g. Hawkesbury Sandstone) for the reporting period. The approach followed earlier assessments and was intended to allow comparison with numerical model predictions. The calculation involved averaging of data where there is more than one sensor in a geological unit and extrapolation when sensors became inoperable.

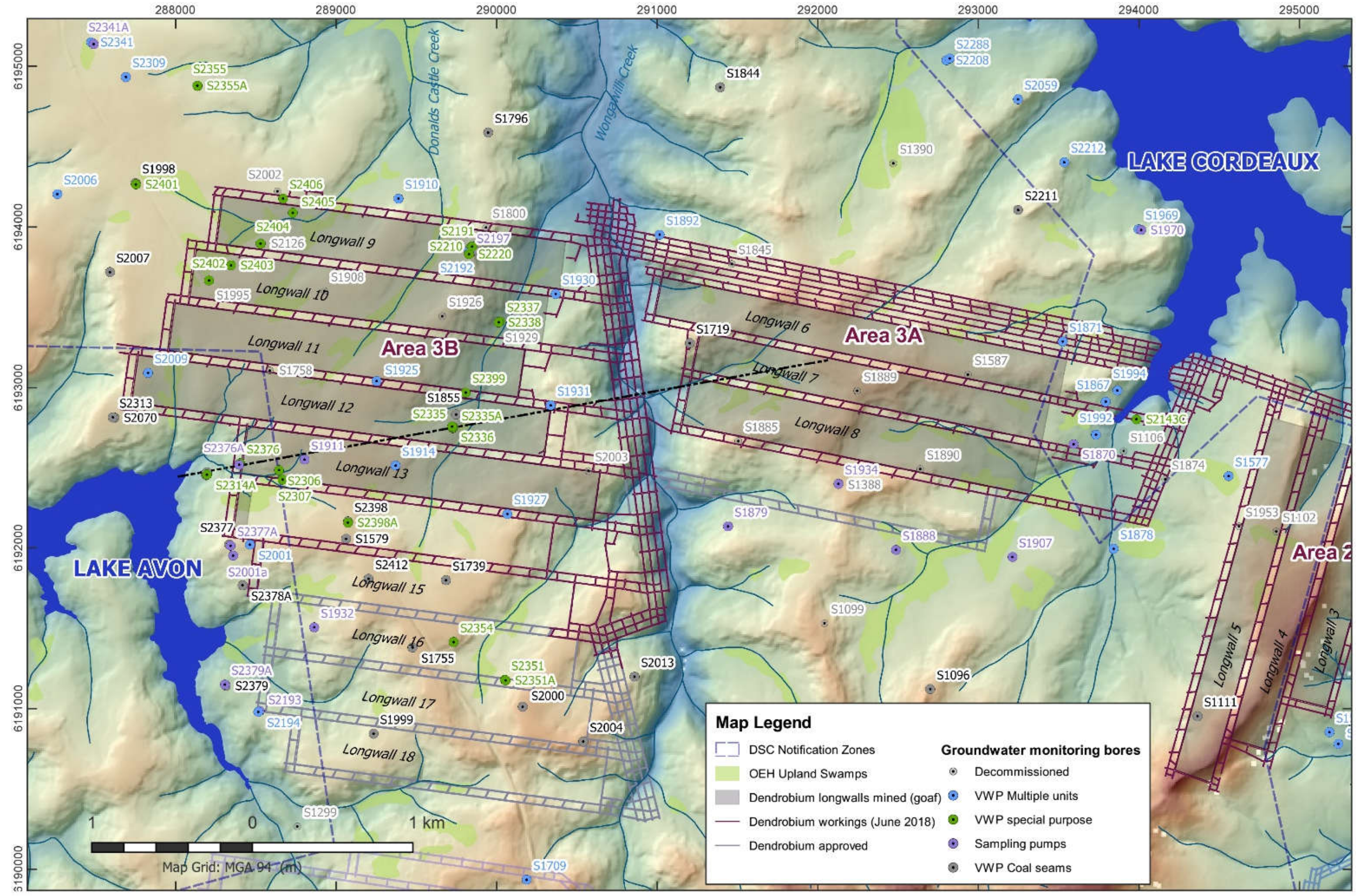

Figure 4. Deep groundwater monitoring network around Areas 2, 3A and 3B

In response to feedback from WaterNSW (2019) and to better represent groundwater conditions in the Hawkesbury Sandstone, the calculation of drawdown and presentation of data has changed in this assessment. In this assessment the 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 LW5 (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 Hawkesbury Sandstone, lower Hawkesbury Sandstone, upper Bulgo Sandstone, lower Bulgo Sandstone and Scarborough Sandstone (note not the whole geological unit as was previously done). This allows piezometric heads 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 (HydroSimulations 2016), 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 LW5 (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 is 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 the DSC fortnightly.

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, and listed in Table 1. Currently there are seven sampling bores in Area 3B containing 13 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 shores of Lake Avon. Two sites (S2197, S1929) monitor water quality adjacent to the WC21 tributary to Wongawilli Creek. A total of eight sampling bores with 15 individual pumps are located in Area 3A. The Scarborough Sandstone is monitored at two locations: S1904 (Area 2) and S1970 (Area 3C).

Table 1. Groundwater chemistry monitoring bores for Areas 2 to 3B

Bore ID	Alt. ID	Mine Area	Number of sampling pumps			Last Sampled
			Hawkesbury Sandstone	Bulgo Sandstone	Scarborough Sandstone	
S1886	DEN94	2			3	11/02/2019
S1870	DEN85	3A	2	1		03/10/2017
S1879	DEN92	3A	2	1		21/11/2016
S1885	DEN93	3A	2	1		19/06/2012
S1888	DEN96	3A	2	1		21/11/2016
S1889	DEN97	3A	2	1		13/07/2011
S1890	DEN98	3A	1	1		19/06/2012
S1907	DEN103	3A	2	1		19/12/2013
S1934	DEN115	3A	2			16/04/2014
S1911	DEN106	3B	2	1		26/11/2015
S1929	DEN111	3B	2	1		28/07/2014
S1932	DEN114	3B	3			01/02/2018
S1970	DEN118A	3C	1	1	1	16/04/2014
S2001a	DEN125A	3B	2	1		04/10/2017
S2197		3B	1	1		04/10/2017
S2313	AD1	3B	2	1		16/08/2018
S2314	AD2	3B	2	1		03/10/2018
S2376A	AD6	3B	2	1		Scheduled*
S2377A	AD3	3B	2	1		Scheduled
S2378A	AD4	3B	2	1		28/08/2018
S2379A	AD5	3B	2	1		29/08/2018
S2436A	AD8	3B	1	2		Scheduled

Note: *Results for Avon Dam series bores not yet available

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), algae and isotopes of carbon, hydrogen and nitrogen. Weekly water samples are taken from the current longwall panel (roof and face) and from water pumped from the goaf. 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 the DSC. More than 3,280 water samples have been collected and analysed at Dendrobium Mine since 2004 (including > 1000 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 Hawkesbury Sandstone (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 3.4.

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 show chemical evidence of influence by grout or bentonite are excluded from assessment.

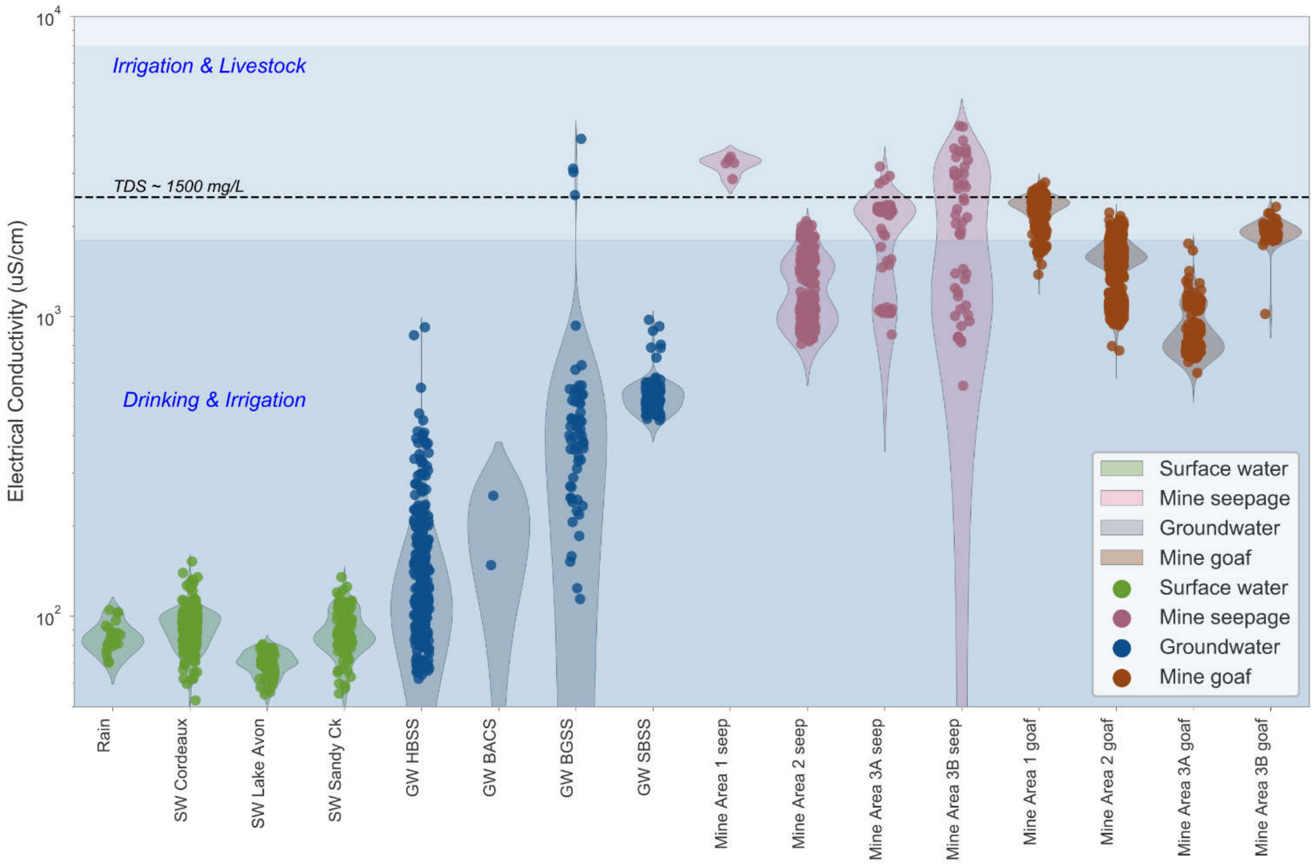

Figure 5. Violin plot showing the range in EC of surface water, groundwater and mine inflow

3. ASSESSMENT OF GROUNDWATER RESPONSE TO MINING

3.1 Mine water balance

Table 2 presents mine inflow statistics (as indicated by pump-out data) for each Area for the period over which LW14 was extracted (22 May 2018 to 26 February 2019). The average daily inflow to Area 3B during LW14 extraction was 4.21 ML/day which represents approximately 72% of total mine inflow for the period. The average water balance for Area 3B during LW14 is approximately 10% lower than the previous longwall (4.68 ML/day; LW13). As discussed below, this is likely due to a combination of the low rainfall conditions throughout longwall extraction and the continuing depressurisation of the surrounding strata from previous mining operations.

Table 2. Dendrobium Mine Inflow during the Extraction of Longwall 14 (in ML/day)

STATISTIC	AREA 1	AREA 2	AREA 3A	AREA 3B	TOTAL
MEAN	0.33	0.28	1.03	4.21	5.84
STANDARD DEVIATION	0.00	0.61	0.77	0.97	1.06
MINIMUM	0.33	0	0	0.27	1.51
MAXIMUM	0.33	3.90	6.27	7.15	8.90
MEAN (LW14)	*0.33*	*1.08*	*1.45*	*4.68*	*7.53*

Time-series plot of total groundwater inflow to Dendrobium Mine (all mine areas) as determined from the mine water balance is shown in Figure 6 as daily volumes in kilolitres (kL/d) and as a 30-day moving median. The total mine water balance has increased steadily from 2010 as mining progressed with peak mine inflows correlating closely with periods of high rainfall.

The mine water balances for Areas 3A and 3B are shown in Figure 7. Groundwater ingress to Area 3B has increased steadily since the start of mining (2013), initially correlating with the total area mined. However, the rate of increase has declined (flattened) during the mining of Longwalls 12 and 13 and the water balance decreased during the extraction of LW14. This overall trend reflects a declining groundwater inflow per unit area mined due to progressive depressurisation of the surrounding strata by previous mining (a decline in driving head). As of LW12 peaks in inflow to Area 3B appear to correlate with periods of high rainfall with a lag time of between two and three months. Prior to LW12, the influence of rainfall on the water balance was less distinct. The decline in groundwater inflow to Area 3B during LW14 is likely to be due partly to the unusually dry conditions during extraction.

Groundwater ingress to Area 3A has declined by more than 50% as mining has progressed in Area 3B. The correlation of inflow peaks to major rainfall events in Area 3A has become less distinct since the end of LW12.

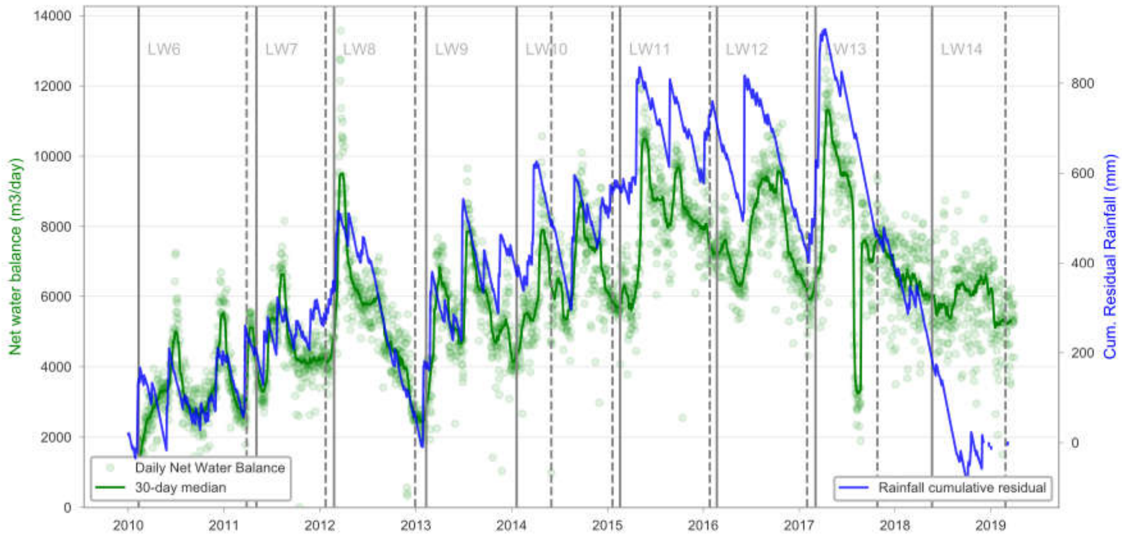

Figure 6. Groundwater inflow from water balance for all mine areas (kL/day)

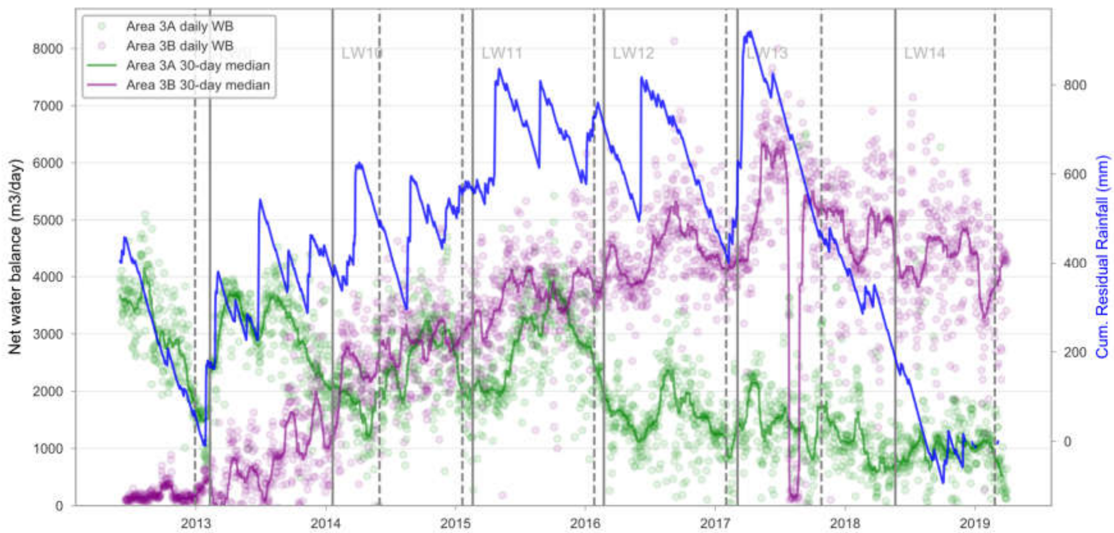

Figure 7. Groundwater inflow to the mine for Areas 3A and 3B (kL/d)

3.1.1 Estimates of the surface water component of mine inflow

The correlation of inflow peaks with periods of high rainfall at Area 3B 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 at Area 3B 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 borrowed from stream flow analysis whereby the baseflow represents the component of stream flow due to groundwater discharge, as opposed to the 'quick flow' component of rainfall runoff represented by the hydrograph peaks.

2. Isotopic tracer approach, whereby a tracer of modern water (in this case, tritium) is 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. In fact, the difference in the estimates provides important information about groundwater pathways of mine inflow. 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 or entirely derived from the release of (old) groundwater storage[1] unless there are direct and rapid pathways between the surface and the goaf. This appears to be the case for Area 3B inflows and contrasts with observations at Area 2, as evidenced below.

A base-flow separation analysis of Area 3B water balance data is shown in Figure 8. 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 blue line). The moving average clearly defines peaks in net mine inflow following the large rainfall events in 2015, 2016 and 2017. Applying digital stream baseflow separation filters to the water balance data is problematic due to the high variability of the data. Therefore, the baseflow component has been estimated using a LOWES trend line (LOcally WEighted regression Smoothing; Cleveland 1979), translated to correspond with most of the troughs in the moving average. The potential rainfall-induced inflow component is defined by the difference between the two curves (blue shading). Using this method, the rainfall-induced component of inflow during LW14 was 11%, compared with 15% during LW13 and 12% during LW12.

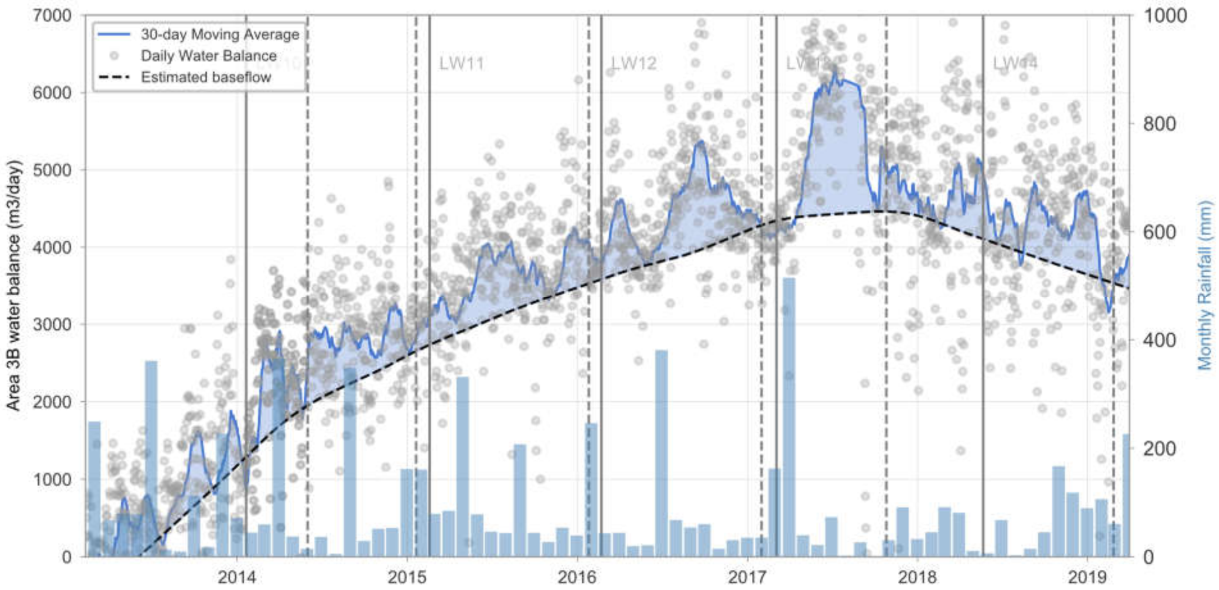

Figure 8. Estimate of potential surface water component to Area 3B water balance

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 the DSC. 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

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[1] 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 in Area 3B). 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.

(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 recent 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 Area 3B goaf (at the outflow point) is shown in Figure 9. As of the last sample analysis (27/9/2018) tritium in samples collected from the Area 3B goaf is not statistically different from deep groundwater baseline data (represented by the shaded area below 0.2 TU in Figure 9, from HGEO 2019). The most recent goaf outflow samples are collected from the main dam at Tailgate 9 from which all goaf drainage from Area 3B is pumped (DWS203; green circles). Therefore, as of September 2018, there is no detectable component of modern water in Area 3B inflow. The laboratory processing time for high precision tritium analysis can be more than 6 months and therefore results for some samples collected in the latter part of LW14 are pending.

From July 2017, the north-western part of Area 3B has been used as mine water storage (incorporating most of LW9 goaf and part of LW10 goaf). The volume of storage is estimated at ~71 ML. At an average pumping rate of 4.2 ML/day, the mean residence time for mine water within the storage is ~17 days, approximately half of the monthly sampling frequency.

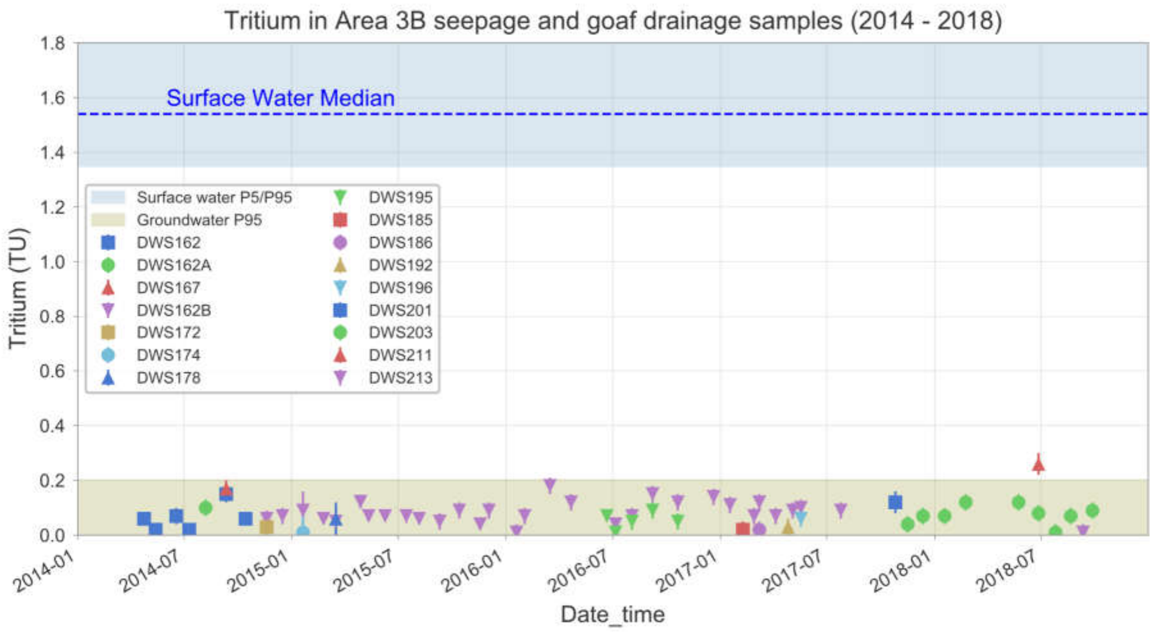

Figure 9. Tritium concentration in water samples from Area 3B (from HGEO, 2019)

3.2 Deep groundwater levels – time-series hydrographs

Representative hydrographs from VWP arrays are presented and discussed below. Hydrograph plots are presented in Appendix B (Piezometric head and pressure head hydrographs).

3.2.1 Area 3B: 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). The most useful locations for this purpose are S1910, S1911, S1914, S1925, S1929, and S2192; and

2. Monitoring established over the goaf following the passage of the longwall. Currently operational locations include: S2220, S2306, S2337/S2338 and S2335A; piezometers installed over Longwalls 9, 10 (Swamp 1b) and over Longwalls 12, 14 and 15.

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 (Table 3; 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 last observations prior to shearing at S1911 and S1914 (for example) show strong depressurisation throughout the strata, with some horizons in the Colo Vale Sandstone at, or close to, zero pressure head. However, some sensors continue to record positive pressure heads indicating incomplete drainage of some strata or fractured rock domains above the goaf.

After being mined beneath:

Observations during installation of S2220, S2306, S2335A and S2338, indicate that the Hawkesbury Sandstone undergoes fracturing to the surface, accompanied by depressurisation of most strata (Table 3; Appendix B). Pressure head in all piezometers at S2306 declined to near-zero, whereas positive pressure head is observed in sensors at S2220 and S2338. Pressure head has increased at two sensors in S2220 (S2220_50, S2220_95) and S2338 (S2338_42 and S2338_50) during LW14 despite the unusually low rainfall conditions in 2018.

Four of the six monitoring bores installed near Swamp 1b overlie the goaf footprints of LW9 and LW10 (S2402, S2403, S2404 and S2405). Boreholes located above the goaf areas show evidence of enhanced strata permeability compared with pre-mining conditions due to mine subsidence (HGEO 2019b). Groundwater levels have declined at all four bores overlying the extracted longwalls and desaturated conditions are apparent in all monitored strata within the Hawkesbury Sandstone in three of the four bores. There is no evidence for a significant decline in groundwater levels at S2401, located 540 m from the goaf footprint, compared with pre-mining groundwater levels.

During LW14, additional holes were drilled above previously extracted longwalls to assess above-goaf conditions in fulfilment of SMP approval conditions. Holes were drilled above LW6 (S2442), LW12 (S2411, S2420), LW13 (S2421), and LW14 (S2398, S2408). At the time of review, data are available only for S2411 (Table 3), located above LW12 and 90 m from S2335. Observations at S2411 are consistent with those at S2335-S2337 and show zero or near-zero pressures at all sensors within the Hawkesbury Sandstone.

These results indicate that fracture networks propagate to shallow depths causing depressurisation of adjacent strata above mined longwalls over much of Area 3B. However, there is evidence that drainage of the Hawkesbury Sandstone above goafs is not complete in all areas and some perched groundwater horizons remain in shallow sandstone strata. In the case of S2220, perched horizons appear to respond to groundwater recharge events. Although there is evidence of perching at S2338, it is noted that piezometers at a similar depth in the immediately adjacent S2337 record near-zero pressure head suggesting full depressurisation of monitored strata (Hawkesbury Sandstone).

Table 3. Observations at piezometers above longwall panels

Bore ID	Location	Date installed	Status	Observations
S2192	LW9	25/3/2013	Inactive from 18/11/2014	Only seven months of data were recorded prior to cable shearing when mined under by LW9. Evidence for depressurisation of Bulgo Sandstone and Stanwell Park Claystone prior to shearing.
S2220	LW9 (post-mining)	10/10/2014	Operational	Installed over LW9 goaf post-mining at LW9 investigation site; records strong downward gradient, but with positive pressure heads, and distinct trends in the three sensors (likely perching); gradual recovery of pore pressures since LW10.
S1908	LW10	16/5/2008	Inactive from 1/5/2014	Gradual depressurisation of deeper sandstone strata (lower BGSS and SBSS) during Area 3A mining; rapid depressurisation in all strata as LW9 passed; cable sheared as LW10 mined under the bore.
S1926	LW10	27/8/2008	Inactive from 8/8/2014	Gradual depressurisation of deeper sandstone strata (lower BGSS and SBSS) but pressure increase in HBSS during Area 3A mining; transient compression effect as LW9 passed, then rapid depressurisation and cable sheared as LW10 mined under the bore.
S1929	LW10	27/8/2008	Inactive from 8/8/2014	Gradual depressurisation in all units since the start of LW6. Transient compression effects towards the end of LW9. Cables sheared on 8/8/2014 as LW10 approached at a distance of 660m. Mined under by LW10 on 5/11/2014.
S2009	LW12	10/8/2009	Inactive from 24/3/2016	Large gap in data between 2010 and late-2014. Moderate depressurisation in all units during LW11, before shearing as LW12 mined under the location.
S1911	LW13	22/1/2008	Inactive from 5/5/2017	Partial depressurisation in all units when LW12 passed on 9/7/2016. Mined under by LW13 on 12/5/2017 causing depressurisation in all units and cable shear.

Bore ID	Location	Date installed	Status	Observations
S1914	LW13	28/4/2008	Inactive from 10/8/2017	Partial depressurisation in all units when LW12 passed on 24/9/2016. Mined under by LW13 on 18/8/2017 causing depressurisation in all units and cable shear.
S2306	LW13 (Swamp 11) (post-mining)	9/9/2015	Operational	Pressure increase as LW12 passed in July 2016; sharp depressurisation at all levels in HBSS when undermined by LW13 on 14/4/2017. All sensors record zero pressure head since LW13 (desaturated).
S2335 / S2336	LW12 (WC21)	19/10/2016	Operational as of 20/7/2017	Depressurisation of HBSS when mined under by LW12; piezometers record near-zero pressure head, but responsive to flood events in adjacent WC21.
S2337 / S2338	LW10 (post-mining)	25/11/2016	Operational	Piezometers in S2337 show close to zero pressure head (fully depressurised) whereas sensors in S2338 record possible perching, responses to rainfall and creek flooding and gradual increases in pressure head despite dry conditions in 2018.
S2411	LW12 (post-mining)	18/6/2018	Operational	All piezometers within HBSS are at or near zero pressure head. Water table therefore is between 275 m and 263.4 m AHD (head in the BHCS); below the creek beds of WC21 and Wongawilli Creek (~283 m).

3.2.2 Area 3B: Strata outside mined longwalls

In this section, data from piezometers located outside the mined longwall footprint of Area 3B are presented and discussed (excluding the Avon monitoring bores discussed below). These include bores S2006 (to the west of LW9), S2001, S1910, S1932 and S2194 (see Table 4).

Piezometers located to the north and west of the longwall footprint (S1910 and S2006) 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.

Piezometers located to the south of the active longwalls in Area 3B (in bores S1932, S2001, S2194) show more pronounced depressurisation in the mid- to deep stratigraphic levels with some strata pressures dropping to zero well in advance of the longwall. It is likely that those piezometers are affected by depressurisation from the Elouera Mine to the south, as well as drawdown from Dendrobium Mine, an effect that is predicted from numerical groundwater modelling. Sensors in S2001 and S1932 bores showed accelerated declines in pressure during LW14 extraction, particularly in S2001 which is located 86 m from the edge of the LW14 goaf. The datalogger at S2194 appears to have suffered a malfunction towards the end of LW14, possibly during to lightning strike and is scheduled for replacement.

Two monitoring bores located south of active mining (S1932 and S2001) show an unusual response of increasing hydraulic pressure in the Scarborough Sandstone (SBSS) following an initial decline. The apparent recovery in pressures affects only three sensors in each bore and occurs at different times in each bore (S2001: LW10; S1932: LW7-8). Given that the bores are only 650 m apart and at broadly similar distances from LW7 to LW10, it is difficult to reconcile the responses to a longwall event or strata compression effect, and it is possible that they reflect sensor malfunction.

Table 4. Observations at piezometers outside longwall panels

Bore ID	Location	Date installed	Status	Observations
S2006	1020 m west of LW9		Operational; no data since early 2017.	Gradual decline in Narrabeen Group sandstones and Coal Measures since 2010, starting to plateau. Minor drawdown in lower HBSS, GW levels in mid-HBSS continue to increase since 2010.
S1910	130 m north of LW9		Two sensors operational	Gradual decline in groundwater pressures in most strata prior to LW9 (~1.5 m/y in BGSS); sharp depressurisation and cables sheared when LW9 passed by in 2013. Upper two HBSS sensors remain active indicating groundwater recovery at 125 m depth since 2015.
S2001	LW15 (435 m south of LW13)		Operational	Unusual response: Initial depressurisation in SBSS and BGSS during LW6 and LW7 (Area 3A), but then apparent recovery in SBSS during mining of LW10. Increasing decline in pressures in lower HBSS, upper-BGSS and lower-SBSS; sharp depressurisation as LW14 passed within 90 m in early June 2018..
S1932	LW16 (890 m south of LW13)	31/8/2008	Operational	Unusual response: Initial depressurisation in SBSS and CCSS during LW6 and LW7 (Area 3A), but then apparent recovery in SBSS during mining LW8-LW10. Depressurisation started in most strata from LW11 and increased during LW13 and LW14. Slight drawdown in lower HBSS.
S2194	LW17 (1460 m south of LW13)		Operational	Steady depressurisation of lower BGSS and SBSS strata since installation in 2013 (55 – 67 m; or 10m/y), and to a lesser extent in upper BGSS (~6.5 m; or 1.5 m/y). Lower BGSS and SBSS now at or approaching zero head, likely due to combined Elouera Mine and Dendrobium effects. Datalogger producing anomalous data since early 2019 and scheduled for maintenance.

3.2.3 Avon reservoir bores

Between 2015 and 2018, a series of monitoring bores were installed along the barrier zone between Lake Avon reservoir and Area 3B. The objectives of the bores are to characterise the strata permeability before and/or after mining of adjacent longwall panels and to provide ongoing groundwater monitoring. Those observations provide critical information to allow more accurate calculation and modelling of potential seepage losses from the reservoir(s) to the mine. Monitoring bores that are installed and operational at the end of LW14 are listed in Table 5 with a summary of observations. Initial results of the investigations following the start of LW14 extraction were presented in a report by HGEO (2018a), the main conclusions from which are summarised below.

Strata permeability was assessed at each of the Avon Dam investigation sites using packer tests (Figure 10). Testing at sites AD2, AD3 and AD7 indicates an increase in strata permeability due to mine subsidence of at least an order of magnitude (10 times) in the depth interval between the lakebed and the lake full service level (FSL). At site AD6, just 10 m from LW13 goaf, there is no significant change in strata permeability. At AD1, adjacent to LW12, average permeability in the post-mining hole (S2331) is approximately 0.2 log units higher than the pre-mining hole (S2313), but the difference is not statistically significant. There is no simple correlation between permeability increase and proximity to goaf, implying that strata fracturing (including bedding plane shear) and strata stress changes is influenced by other factors such as topography and associated phenomena (valley closure) as was suggested by SCT (2015a).

Table 5. Observations at piezometers between Lake Avon and Area 3B

Bore ID	Location	Date installed	Status	Observations
S2313 (AD1)	140m from the western corner of LW12	31/10/2015	Operational	Pre- and post-mining holes reported in SCT (2015b, 2016) and in HGEO (2018a). Depressurisation in the lower HBSS and upper BGSS (Colo Vale SS at this location) in the months following the start of LW12. Slight additional drawdown after LW14. Upper HBSS shows no drawdown and head (371 m AHD) remains above the Lake Avon FSL (320.18 m AHD). Head in lower HBSS is below the Lake Avon FSL.
S2314 (AD2)	210 m from the western end of LW13	13/11/2015	Operational	Pre- and post-mining holes reported in HGEO (2017). Piezometers show depressurisation in HBSS and BGSS, with all showing heads below the Lake Avon FSL. Additional drawdown following LW14 start and shallowest HBSS sensor now desaturated.
S2377 (AD3)	100 m from LW14 and 200 m from LW15	25/1/2018	Operational	Sensor data stabilised after Nov 2018. Piezometric heads relatively stable during LW14 with gently declining head in upper BGSS. Shallowest HBSS sensor shows head above Lake Avon FSL; Pressure head ~1.2 m but subtle fluctuations indicate saturated conditions.
S2378 (AD4)	95 m from the western end of LW15	14/11/2017	Operational	Piezometric heads in lower HBSS and upper BGSS decline during LW14. Shallowest HBSS sensor shows head above Lake Avon FSL; Pressure head ~3.5 m.
S2379 (AD5)	265 m from the western end of LW17	22/2/2018	Operational	Piezometric heads in lower HBSS and upper BGSS increase during LW14. Shallowest HBSS sensor shows zero pressure head (desaturated), sensor in lower HBSS records head below Avon FSL but above current Lake level..
S2376 (AD6)	10 m from the western end of LW13	6/10/2017	Operational	Post-mining hole only, reported in HGEO (2018a). Piezometers record depressurisation in the upper BGSS (Colo Vale SS) during late 2018; Levels in the lower HBSS stable at ~283 m AHD, below Lake Avon FSL (320.18 m AHD); upper HBSS sensor recording zero head. Compression effects at start of LW14.
S2435 (AD7)	37 m from Lake Avon; 310 m west of LW14	12/11/2018	Operational	All sensors, including the shallowest HBSS sensor record piezometric head below current Lake Avon level. S2435_25 recorded 306.1 m at the end of LW14.
S2436 (AD8)	~10 from Lake Avon FSL; 310 m west of LW16	19/11/2018	Operational	The shallowest HBSS sensor recorded a piezometric head below current Lake Avon level at the end of LW14. A sensor in the upper CVSS records head above the current lake level but below the FSL.

Groundwater levels have declined at most piezometers located adjacent to extracted longwalls, with piezometric heads in the lower Hawkesbury Sandstone and upper Colo Vale Sandstone generally below the Lake Avon FSL (Table 5). Piezometric levels in the upper Hawkesbury Sandstone have declined to below the Lake Avon FSL at S2314, S2435 and S2436 but remain well above the lake level at S2313 and S2377. These observations indicate an average hydraulic gradient of 0.065

towards the mine in the barrier zone adjacent to LW12 to LW14. As discussed further below, the observed piezometric heads imply seepage loss from the lake towards the mine; however, the observed heads are broadly in line with estimates from the numerical groundwater model of HydroSimulations (2016).

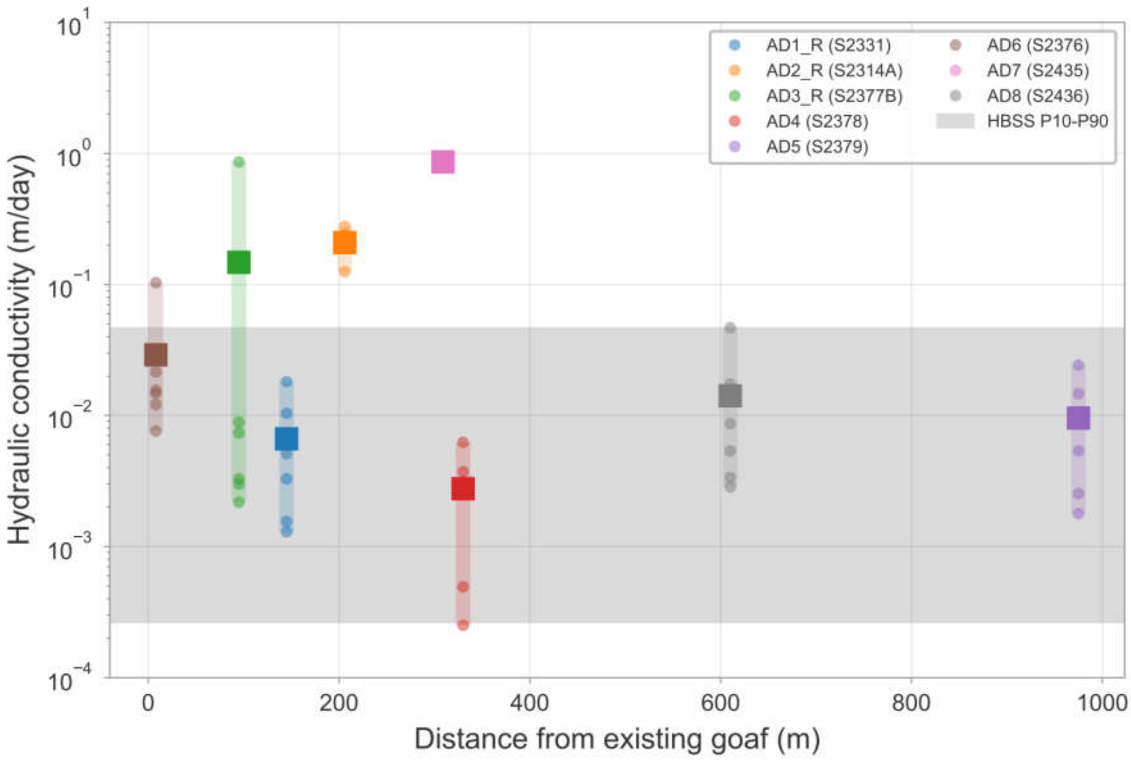

Figure 10. Permeability tests in Avon Dam bores.

The rate of seepage loss from the reservoir depends on both the hydraulic gradient and the permeability of the strata in the barrier zone. Estimates of seepage loss have been calculated using several approaches, including regional and local scale numerical models (see Section 3.5.3, below).

3.2.4 East of Area 3B

LW19 is located to the south of LW8 and on the southern edge of Area 3A. It is planned for extraction after completion of Area 3B.

S1879 is located near the south-western end of Area 3A, and about 600 m southeast of the current southern-most extent of Area 3B roadways and headings. Decline in potentiometric head began in early 2009, associated with Area 2 LW5 extraction, at much the same rate in all formations from the Wongawilli Seam to the upper Scarborough. During the second half of LW6 extraction, pressures also began to decline in the upper and lower Bulgo Sandstone, followed by a slight decline in pressure in the lower Hawkesbury Sandstone during LW8. Piezometric levels have remained stable in all strata since the end of LW10 (early 2015). Most sensors in the Scarborough and Wombara Sandstones record zero pressure head. A slight decline in head was observed in Bulgo Sandstone sensors during LW14.

S1907 which is located to the south of Area 3A shows early drawdown responses in the Bulli and Wongawilli coal seams, prior to mining in Area 3A.Drawdown in the Narrabeen Group Sandstones increases after the start of mining at Area 3A and gradual drawdown in the Scarborough and lower Bulgo Sandstone has continued to the current period. All sensors, including those in the middle to lower Hawkesbury Sandstone appear to record saturated conditions.

S1934 has sensors only within the Hawkesbury Sandstone and only two of those sensors have been operational since late 2013 (at 38 m and 65 m depth). Following a period of stepped drawdown in the 65 m sensor during mining at Area 3A, piezometric head has been relatively stable during mining in Area 3B. The shallowest sensor (38 m) shows increasing groundwater level in the Hawkesbury Sandstone since LW11.

3.2.5 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). Such factors can lead to a range of possible permeability structures, including a barrier to flow; a conduit to flow; or a complex conduit-barrier system whereby a fine-grained core may impede transverse flow and the damaged (outer) zone may promote enhanced flow along the fault. Complex barrier-window scenarios can arise where strata of varying permeability and thickness are variably off-set along the fault and fine-grained material from claystone units may be smeared along the core zone (Yielding *et al.* 1997).

A geological assessment, including mapped and potential structures was carried out prior to mining in Area 3B (BHPBilliton 2013). The geology between Avon Reservoir and Area 3B mine workings was further assessed by South32 (2018b). A combination of exploration techniques including; surface exploration boreholes, aeromagnetic and seismic surveys, surface mapping, underground in-seam drilling and underground mapping have been used to build the geological model in the area.

Doyle (2007) and Tonkin and Timms (2015) concluded that virtually all faults encountered in first workings near supply reservoirs in the Southern Coalfield produce no, or very minor inflows. The low transmissivity of faults is attributed to the discontinuous nature of most faults, infill by impermeable clay minerals, and high regional horizontal stress. Historical high inflow events (e.g. the Blue Panel, Wongawilli Colliery) have been associated with mining cover depths of less than 100 m leading to insufficient lateral offset from the reservoir because this offset was based on angle of draw and not a minimum offset distance. Nevertheless, the potential for reactivation of fault zones during mine subsidence and subsequent connection with surface water bodies needs to be considered.

Two faults or lineaments are of particular interest in respect of planned longwall extractions in Area 3B: 1) The Elouera Fault, located south of Area 3B and defining the northern extent of the Elouera Mine; and 2) Lineaments defined by the LA3 tributary.

Elouera Fault (Native Dog Creek)

The northern tributary to Native Dog Creek (NDT1) runs broadly parallel to, and north of, the mapped trace of the Elouera Fault (at seam level). 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 at the southern slopes of the Native Dog Creek valley. Recent drilling has identified the fault within the Colo Vale Sandstone; however, it has not been identified in surface mapping (Hawkesbury Sandstone).

Investigations are currently underway to assess the structural and hydrogeological characteristics of the Elouera Fault zone, and its potential to provide a connection between Lake Avon and the proposed longwalls. As of June 2019, six inclined cored holes have been drilled at two sites along the fault, four of which have intersected the fault plane. Further holes are planned so that interference and tracer testing can be carried out between holes to assess the permeability and continuity of the fault plane. Water samples will be collected from the fault zone to assess isotopic characteristics and modern water content. The holes will be equipped with piezometer arrays and TDR cables to assess progressive depressurisation across the fault and to detect reactivation due to mining in Area 3B.

LA3 Creek

Structural mapping at Area 3B by South32 identifies two lineaments running approximately parallel to tributary LA3 . The shallowest piezometer in hole AD8 (S2436_25m; Hawkesbury Sandstone), located within metres of the lake shoreline and near LA3, recorded a groundwater level some 6 metres below the current lake level (307.6 m AHD versus Lake Avon at 313.7 m AHD in May 2019). The piezometer at 65 m depth has a water level that is ~1 m above the current lake level (314.7 m AHD). In-seam drilling assessed by South32 (2018b) did not identify offset at the seam level associated with the surface lineament.

The low groundwater level in the shallow piezometer relative to the lake implies that the surrounding strata are connected to a depressurised zone. However, it is not clear if the depressurisation is related to current mining in Area 3B, or previous mining (Elouera Mine), or whether the depressurisation is controlled by a geological structure. Given the proximity of the monitoring hole to Lake Avon and LW15, it is important to understand the extent and cause of the depressurisation at S2436. Illawarra Coal has scheduled additional shallow piezometers near the site and along the access track to AD8 to investigate possible lineaments at LA3.

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 Hawkesbury Sandstone that record near-zero pressure head (assumed to be desaturated; Figure 11);
2. The change (drawdown) in average piezometric head between the end of LW5 (November 2009) and the end of LW14 (Figure 12 to Figure 16); and
3. The piezometric head in the lower Hawkesbury Sandstone relative to the Lake Avon FSL and recent lake levels (Figure 13).

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.

3.3.1 Spatial distribution in groundwater drawdown

Maps of observed and estimated drawdown are shown for subunits within the Hawkesbury Sandstone, Bulgo Sandstone (and stratigraphic equivalent within the Colo Vale Sandstone, and the Scarborough Sandstone). 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 coalesces with residual drawdown from neighbouring historic mines.

Analysis of drawdown in the Hawkesbury Sandstone focusses on the lower 70 m of the formation (lower Hawkesbury Sandstone). 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 (< 1 m H_2O pressure head) is shown in Figure 11. It is common for bores located above extracted longwalls to show desaturated 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.

The lower Hawkesbury Sandstone (Figure 12) is defined as sensors less than 70 m above the top of the Bald Hill Claystone. Maximum drawdown in the order of 40 to 50 m is observed in piezometer arrays above and immediately surrounding extracted longwalls. The highest estimated drawdown in the lower Hawkesbury Sandstone is 52.8 m in S1910 located 125 m north of LW9. Drawdown in the bores adjacent to WC21 represent minimum drawdown due to the number of dry sensors in those arrays.

Piezometric head in the lower Hawkesbury Sandstone compared with the water level in Lake Avon is shown in Figure 13. Several bores within the barrier zone between the lake and Area 3B show 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.

Observations of piezometric head in the Bulgo Sandstone are mainly restricted to near the extracted and planned longwalls (Figure 14 and Figure 15). Drawdown exceeding 70 m and up to 140 m is estimated at several bores (e.g. S2001). Drawdown decreases away from the mined areas such that less than 20 m of drawdown is estimated at distances of 1.2 km or more north of Area 3B (S2341, S2059). Significant depressurisation is expected in the Bulgo Sandstone (and units below) due to subsidence-related fracturing extending upwards from the goaf into these units.

The Scarborough Sandstone (Figure 16) is depressurised in the vicinity of the mined areas and to the south of LW14. As with the Bulgo Sandstone, estimated drawdown decreases to the northwest with distance from Area 3B; however, depressurisation exceeding 70 m is observed to the northeast (S2059) and south (S2194) due to residual drawdown from neighbouring mines.

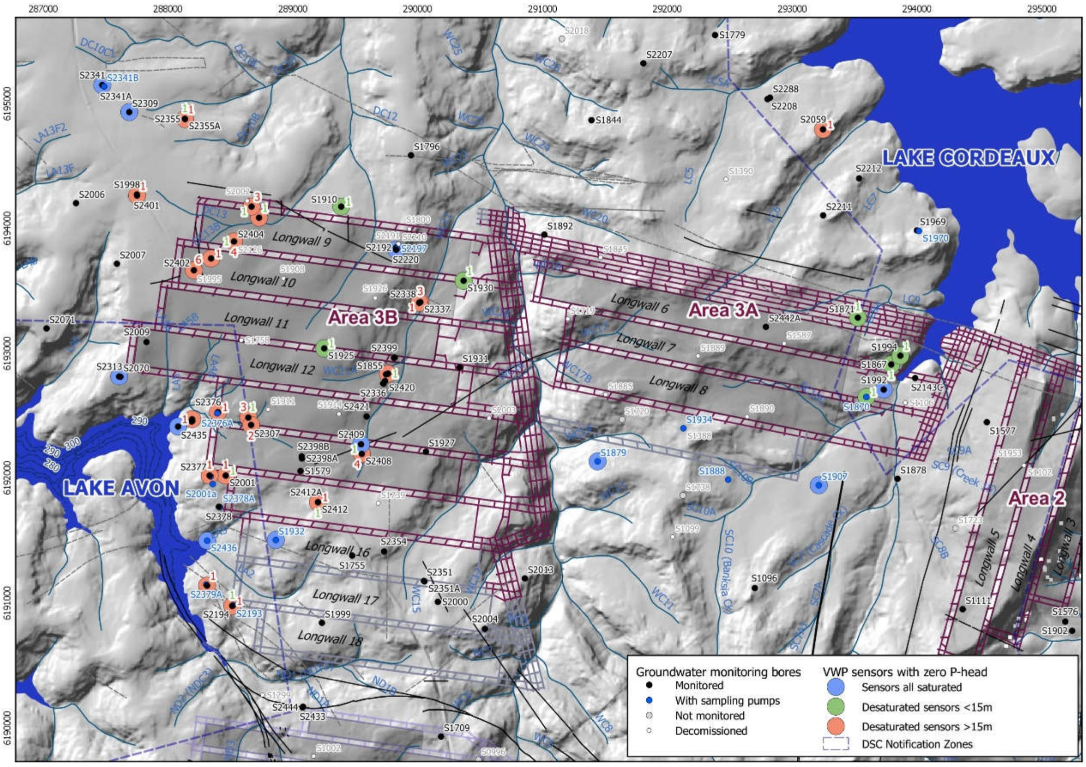

Figure 11. Sensors recording desaturated conditions in the Hawkesbury Sandstone (2019)

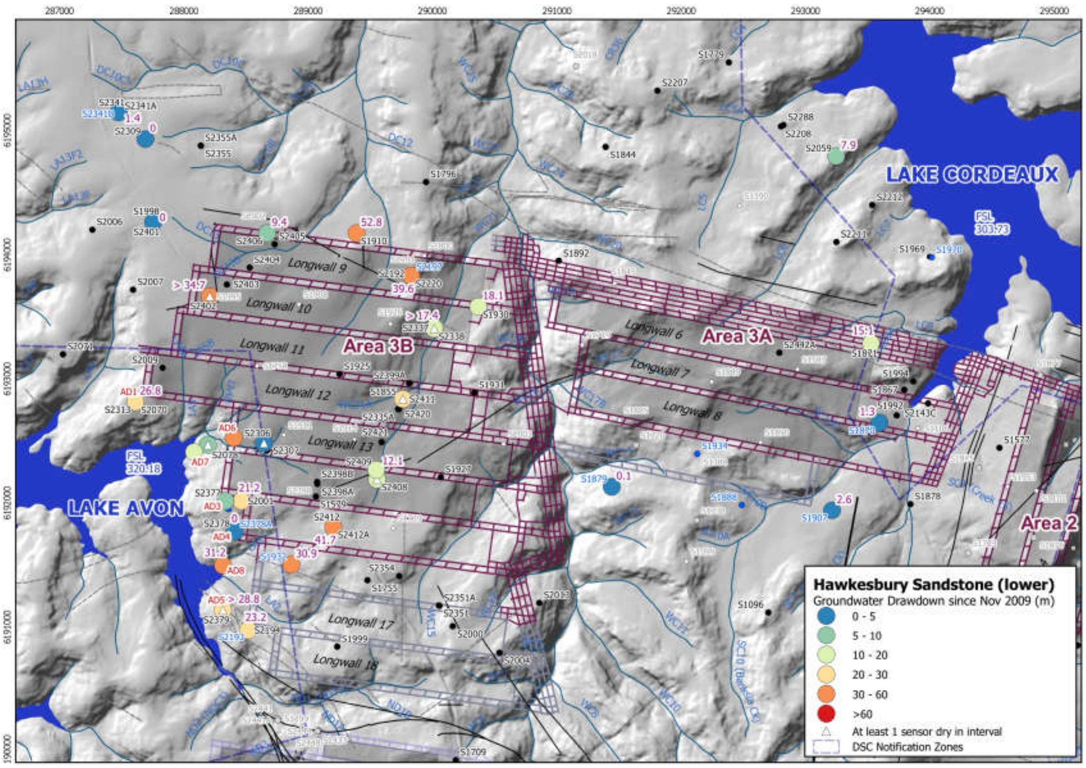

Figure 12. Drawdown in piezometric head in the lower Hawkesbury Sandstone (2009-2019)

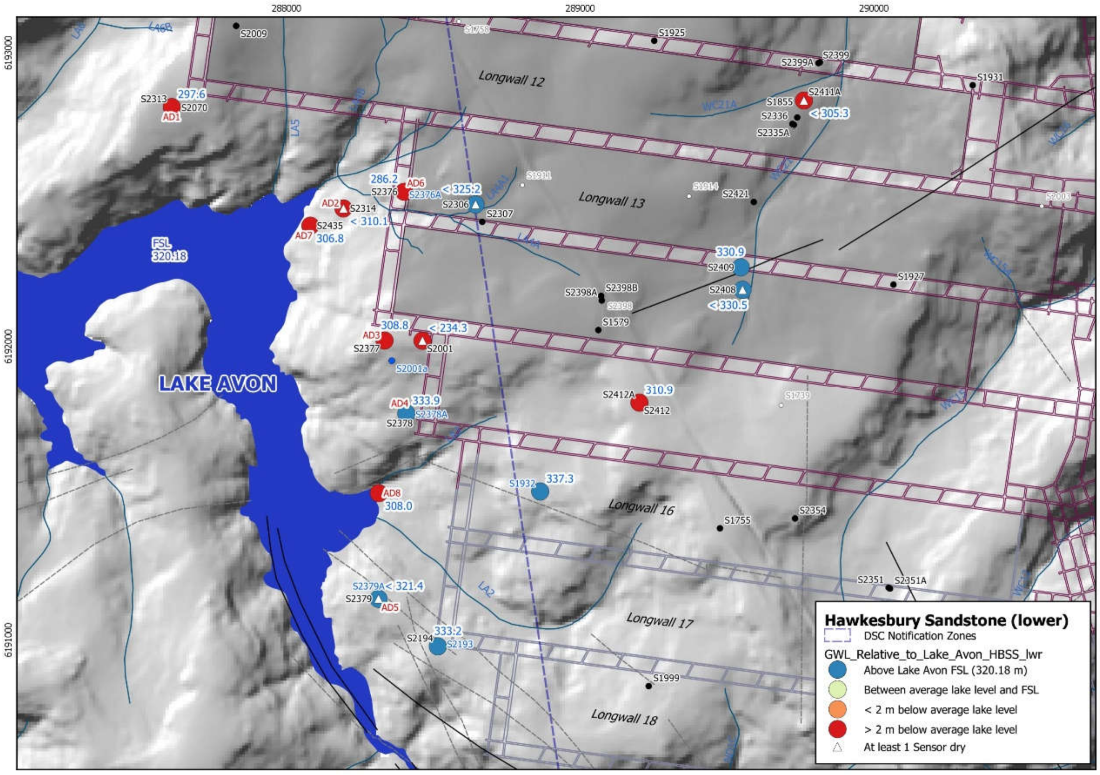

Figure 13. Piezometric head in the lower Hawkesbury Sandstone relative to Lake Avon

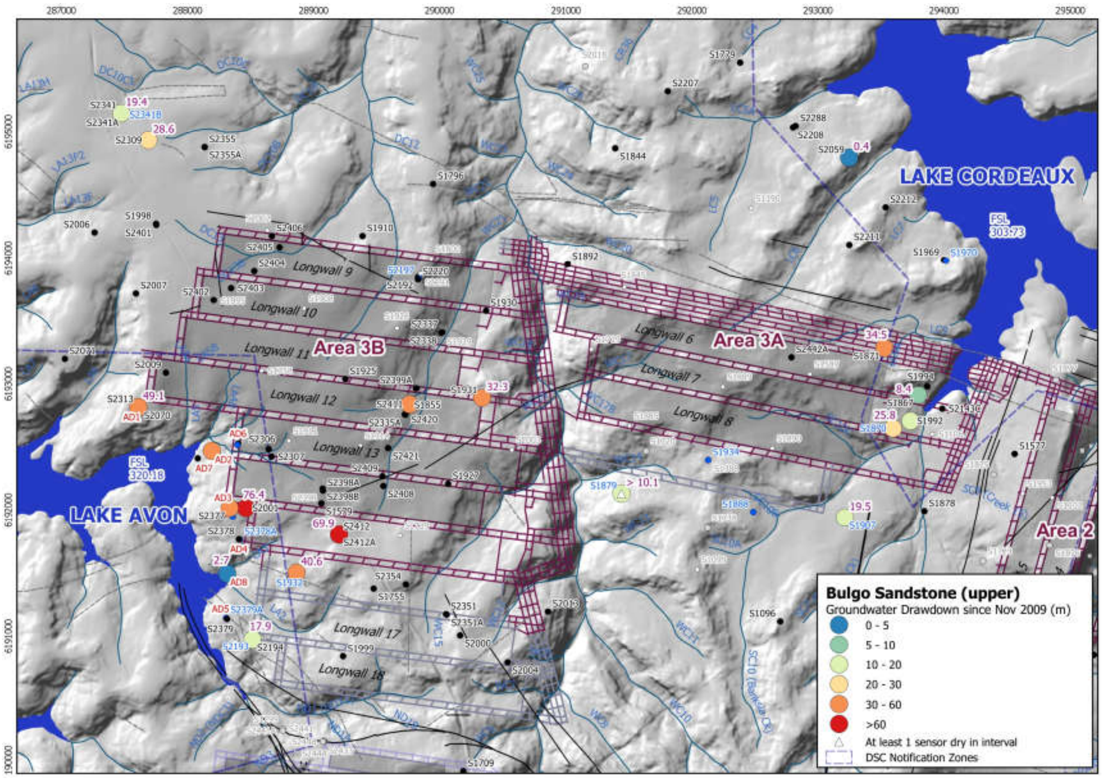

Figure 14. Drawdown in piezometric head in the upper Bulgo Sandstone (2009-2019)

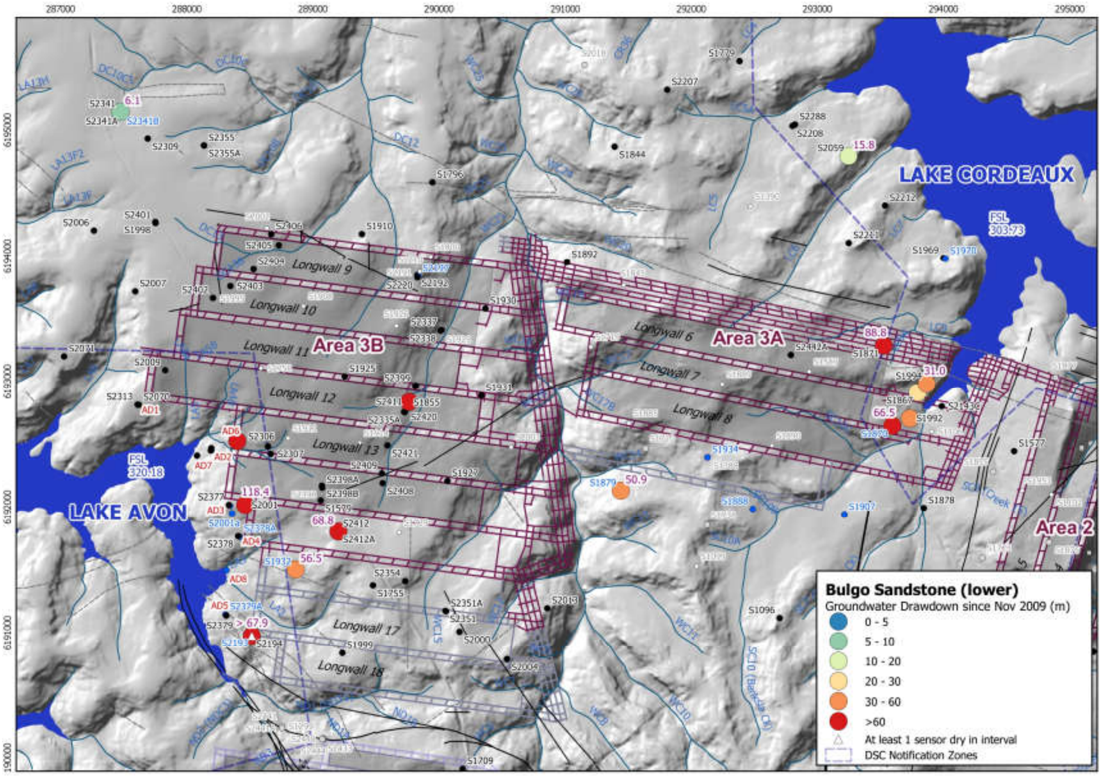

Figure 15. Drawdown in piezometric head in the lower Bulgo Sandstone (2009-2019)

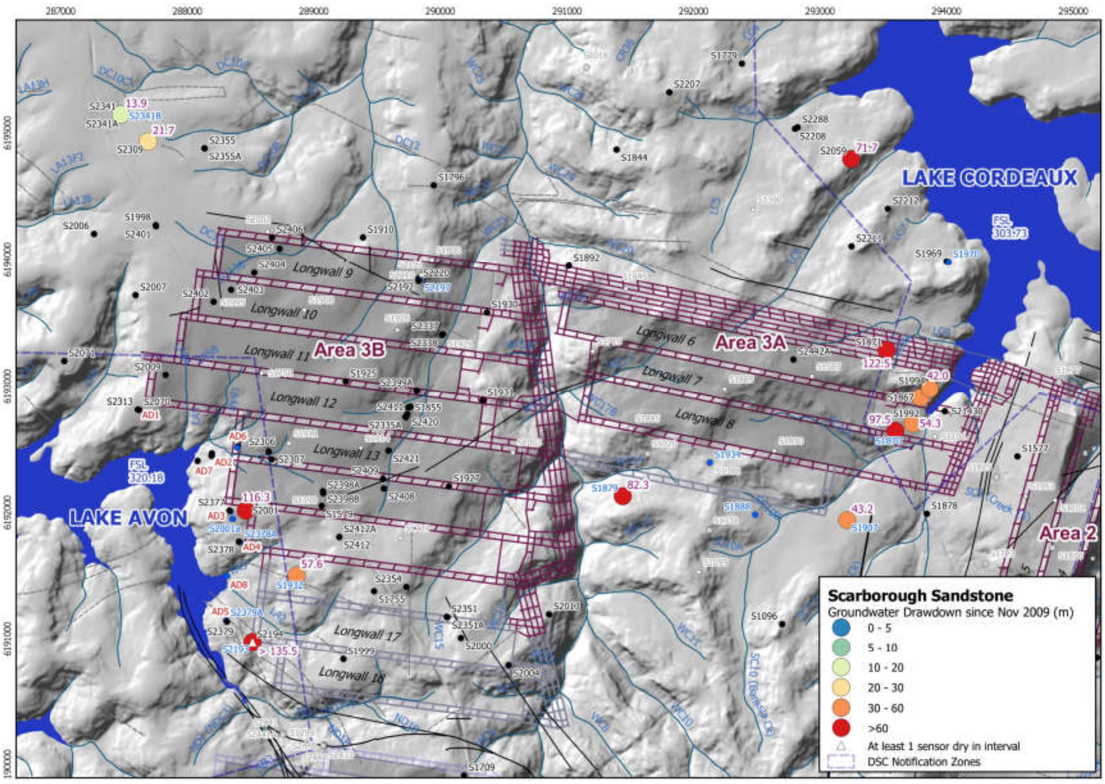

Figure 16. Drawdown in piezometric head in the Scarborough Sandstone (2009-2019)

3.4 Groundwater chemistry

Previous reviews have shown that there is no clear spatial pattern in the distribution of groundwater quality in Hawkesbury Sandstone and Bulgo Sandstone bores. Groundwater salinity- measured using electrical conductivity (EC) for all samples collected from monitoring bores in Areas 3A and 3B are summarised in Table 6. As with previous reviews, the groundwater salinity tends to increase with depth.

A notable change is seen in the most recent sampling round from S1886 (DEN94) where samples from all three depths (at 22 m, 30 m, and 38 m) show EC field measurements that are up to 200µS/cm higher than the last sampling round (highlighted in Table 6). Laboratory measured EC for all three samples are within the historical range suggesting that the field EC measurements are in error.

The average EC for all samples collected are: 168 µS/cm for the Hawkesbury Sandstone (n = 314), 559 µS/cm for the Bulgo Sandstone (n = 82) and 556 µS/cm for the Scarborough Sandstone (n = 115). It should be noted that Scarborough Sandstone outcrops at monitoring bore S1886 and therefore represents shallow groundwater.

Instances where the average EC is > 20% lower during the recently completed longwall compared with the previous longwall are highlighted in light red. The apparent low result for S2313_54 is probably not significant since a similar value was observed in a sample collected on 20/1/2016 (75 µS/cm). The apparent low EC values in samples collected from the upper two pumps at S1886 (DEN94) are the lowest recorded. Given the proximity of this bore to Lake Cordeaux, it is recommended that all three pumps at S1886 are resampled as soon as practical.

Further, it is recommended that South32 consider increasing the sampling frequency to quarterly for all pump-equipped bores that are located adjacent to Lake Avon and Lake Cordeaux. The samples should be submitted for the regular chemical suite, including tritium with the addition of carbon-14.

Table 6. Summary of EC measurements at monitoring bores

Bore ID	Alt ID	Depth (m)	Unit	Samples		Mean EC (µS/cm)	
				LW13	LW14	LW13	LW14
S1870	DEN85A	10	Hawkesbury Sandstone	1		91	
S1870	DEN85A	16.5		1		105	
S1879	DEN92	10					
S1879	DEN92	58					
S1888	DEN96	7.3					
S1932	DEN114	10		2		124	
S1932	DEN114	98		2		210	
S1934	DEN115	55					
S2001	DEN125A	106		1		289	
S2001	DEN125A	63		1		226	
S2313	S2313	138		2	1	138	122
S2313	S2313	54		2	1	115	76
S2314	S2314	30		2	1	215	184
S2314	S2314	75		2	1	191	193
S2378	S2378	164			1		153
S2378	S2378	29			1		132
S2378	S2378	89			1		172
S2379	S2379	128			1		291
S2379	S2379	47			1		82
S1888	DEN96	200	Bulgo / Colo Vale Sandstone				
S2313	S2313	194		2	1	375	524
S2314	S2314	128		2	1	445	409
S1886	DEN94	22	Scarborough Sandstone	1	1	530	410
S1886	DEN94	30		1	1	565	416
S1886	DEN94	38		1	1	538	530

Note: * Results affected by bentonite pack near pump intake and not reported

3.5 Comparison with model predictions

3.5.1 Deep groundwater levels

In this section observed deep groundwater levels are compared with those predicted in the groundwater impact model (HydroSimulations 2016). The comparison was carried out by extracting the predicted heads at representative sensors as of the end of LW14 from the original model output files (provided to HGEO by HydroSimulations), and plotting those heads against the observed heads at sensors within the same sub-units (as presented in Section 3.3). It is therefore an independent assessment of the ongoing accuracy of the 2016 model predictions.

Twenty-five piezometers were selected for comparison on the basis of their distribution across the site and their likelihood of providing ongoing monitoring data for future assessments. Importantly, piezometers adjacent to Lake Avon (The “Avon Dam” holes, S2313, S2314, S2376, S2377, S2378, S2379, S2435, S2436, and holes S2001, S2194) were included to allow assessment of the strata separating the mine from the stored waters of Lake Avon.

Figure 17 is a plot of the modelled and observed heads as of the end of LW14. The data are coloured according to the formation, and bores that are located adjacent to Lake Avon are highlighted. Data for 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.

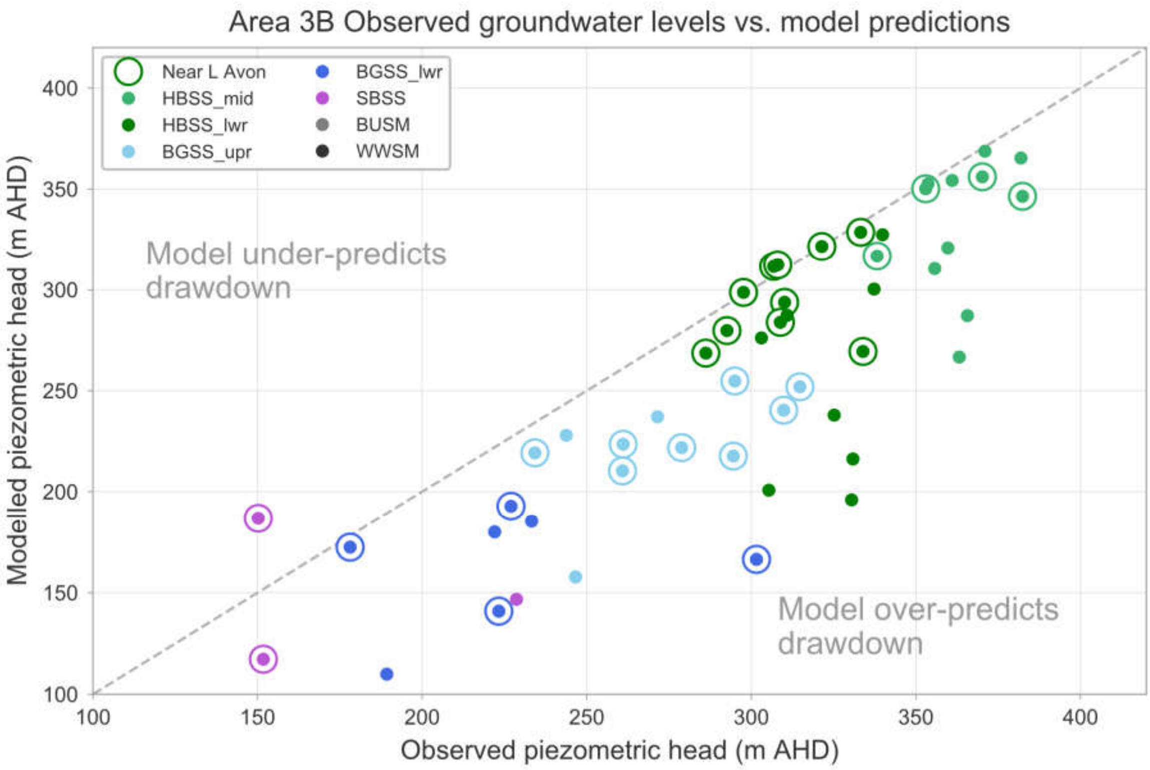

Figure 17. Observed versus model predicted heads at the end of Longwall 14

The following are concluded from the comparison in Figure 17:

- 90% 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.

- The model tends to overpredict drawdown in the Bulgo Sandstone and parts of the Scarborough and Hawkesbury Sandstones, but matches reasonably well for piezometers in the Hawkesbury Sandstone.

- Model and observed heads for piezometers within the Hawkesbury Sandstone adjacent to Lake Avon plot very close to the 1:1 line. Observed heads within this barrier zone are therefore in line with model predictions. The reader is also referred to hydrographs of modelled piezometric heads in the Lake Avon barrier zone in Figure 6.6 of HydroSimulations (2016), which show a close match with observations at the end of LW14.

3.5.2 Mine water balance

Figure 18 is a plot of the modelled and observed groundwater inflow to Area 3B during the extraction of LW14. The numerical model is set up with stress periods corresponding to the originally planned longwall start and end dates (approximately yearly). The plot shows that the model tends to over-predict inflow to Area 3B by approximately 50%, which is conservative with respect to impact assessment.

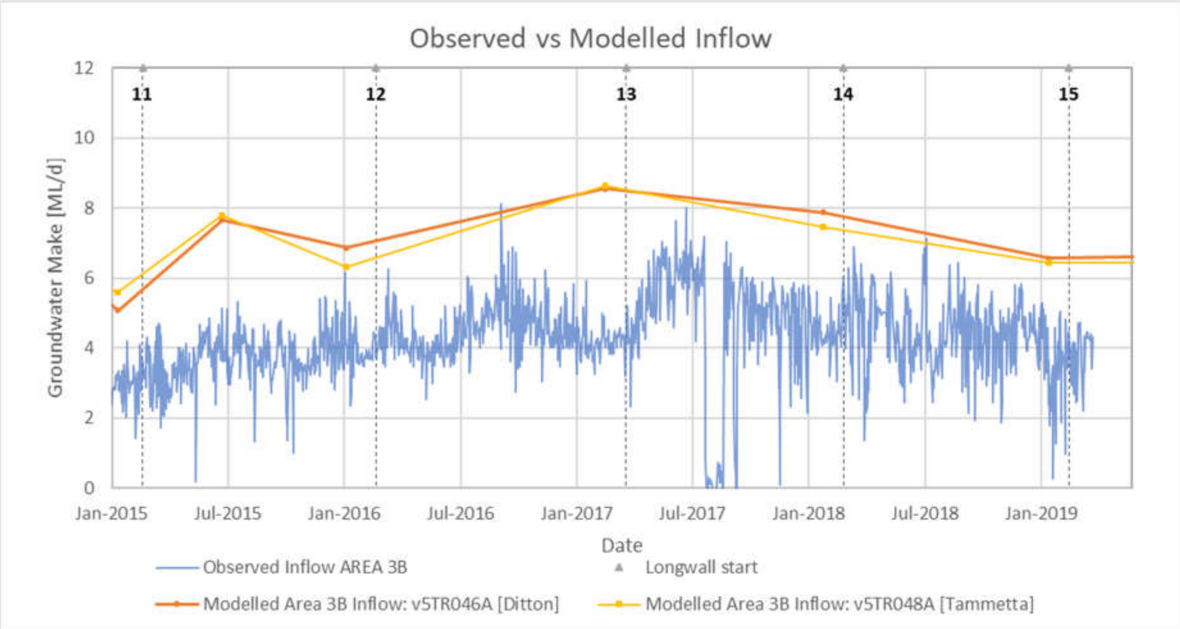

Figure 18. Observed versus model predicted mine groundwater inflow to mine Area 3B

3.5.3 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.

Estimates of the net loss (seepage) from Lake Avon as of the end of LW18, based on the regional groundwater model range between 0.39 and 0.47 ML/day (HydroSimulations 2016). 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 the DSC (DSC 2014).

The regional groundwater model of HydroSimulations (2016) contains estimates of permeability for geological strata that are based on numerous packer tests across the model domain. The permeability parameters were then refined where necessary during the history-matching ("model calibration") process to match predicted piezometric heads with observed heads. As seen in the previous section, the model continues to perform well in terms of providing conservative estimates of drawdown at the regional and catchment scales.

Since the development of the regional groundwater model detailed hydrogeological investigations have been carried out within the barrier zone between Lake Avon and Dendrobium Area 3B. These investigations included testing of permeability both prior to, and following, extraction of the adjacent longwall panels (LW12 – LW14). The investigations showed that valley-closure movements and strata stress changes related to mine subsidence has resulted in an increase in strata permeability within the Hawkesbury Sandstone(HGEO 2018b). The investigation found that strata permeability increases by at least an order of magnitude at some locations (S2314, S2377, S2435; also known as AD2, AD3, AD7), but with little or no apparent change in strata permeability at other locations (e.g. S2313 and S2376; or AD1 and AD6). The current data show no systematic change in strata permeability with distance from the goaf.

A local-scale numerical model was developed by HGEO (2018c) to assess the effect of the observed strata permeability changes (and variability) on estimates of seepage from Lake Avon. The model was developed using MODFLOW-USG and comprised 10 layers. The permeability of each layer was defined by interpolating the measured (post-mine) permeability from packer tests at each test bore site. An average post-mining hydraulic gradient was applied to produce an estimate of seepage adjacent to the impacted strata of 0.44 ML/day/km (noting that the shoreline length adjacent to Longwalls 12 to 14 is approximately 1 km). Therefore, the estimate from the local-scale model is slightly higher than the regional model estimate (taking account of the different timeframes and longwall completions), but of the same order of magnitude.

4. CONCLUSION

The following conclusions are made with respect to the assessment of groundwater conditions following the completion of LW14:

- The average daily inflow to Area 3B during LW14 extraction was 4.21 ML/d which represents approximately 72% of total mine inflow for the period. The average water balance for Area 3B during LW14 is approximately 10% lower than the previous longwall (4.68 ML/day; LW13).
- There is an apparent lag of two to three months between high rainfall events and peak inflow to Area 3B. The amplitude of the variation due to rainfall accounts for approximately 11% of the total inflow during LW14. To date, the concentration of tritium (an isotopic indicator of modern water) in Area 3B mine inflow water is not statistically different from deep groundwater.
- Groundwater salinity as indicated by electrical conductivity generally increases with stratigraphic depth and typically varies over a narrow range at each bore. During LW14, anomalous EC was noted in samples from S1886 (DEN94). Given the proximity of this bore to Lake Cordeaux, it is recommended that the bore is resampled as soon as practical.
- Mining of LW14 resulted in continued depressurisation of the target coal seams and overlying strata. The observed changes in groundwater levels are in line with numerical model predictions.
- Observations at monitoring bores installed above mined longwalls indicate that the Hawkesbury Sandstone undergoes fracturing to the ground surface, accompanied by depressurisation of most strata. Estimated groundwater drawdown in the Hawkesbury Sandstone since prior to the start of mining in Area 3A (November 2009) is greatest above and immediately adjacent to extracted longwalls. Maximum drawdown is in the order of 40 to 50 m and up to 52.8 m in S1910 located 125 m north of LW9. There is evidence that drainage of the Hawkesbury Sandstone above goafs is not complete in all areas and some perched groundwater horizons remain.
- As expected, the greatest depressurisation is within the Wongawilli Coal Seam, and decreases with height above the seam. Groundwater drawdown in the Scarborough and Bulgo Sandstones is most pronounced in the vicinity of the mined longwalls and to the northeast and south of Area 3B. Drawdown decreases to the northwest with distance from Area 3B.
- Between 2015 and 2018, a series of monitoring bores was installed along the barrier zone between Lake Avon reservoir and Area 3B. Groundwater levels have declined at most piezometers located adjacent to extracted longwalls, with piezometric heads in the lower Hawkesbury Sandstone and upper Colo Vale Sandstone generally below the Lake Avon FSL. Observations indicate a hydraulic gradient towards the mine in the barrier zone adjacent to LW12 to LW14 and imply seepage loss from the lake towards the mine.
- The numerical model developed by Hydrosimulations in 2014 and updated in 2016 was assessed to be accurate with respect to estimated groundwater levels within the Hawkesbury Sandstone at the end of LW14. The model overestimates drawdown in the Bulgo and Scarborough Sandstones and is therefore conservative.
- Seepage losses from Lake Avon estimated using a local scale numerical model are approximately 0.44 ML per day following the extraction of LW14. The estimate is of a similar magnitude to those from regional numerical modelling and is within the tolerable loss limit of 1 ML/day prescribed by the DSC.

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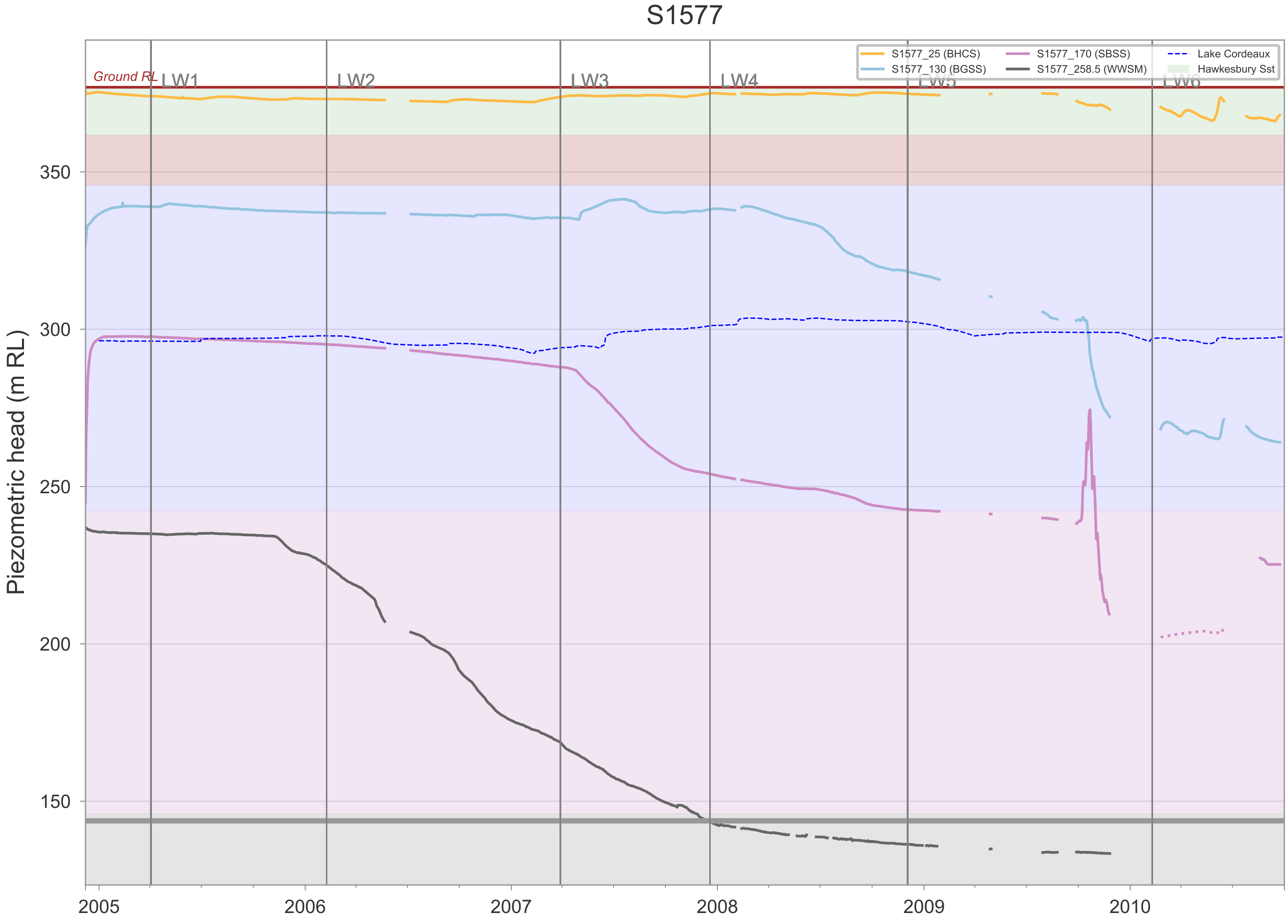
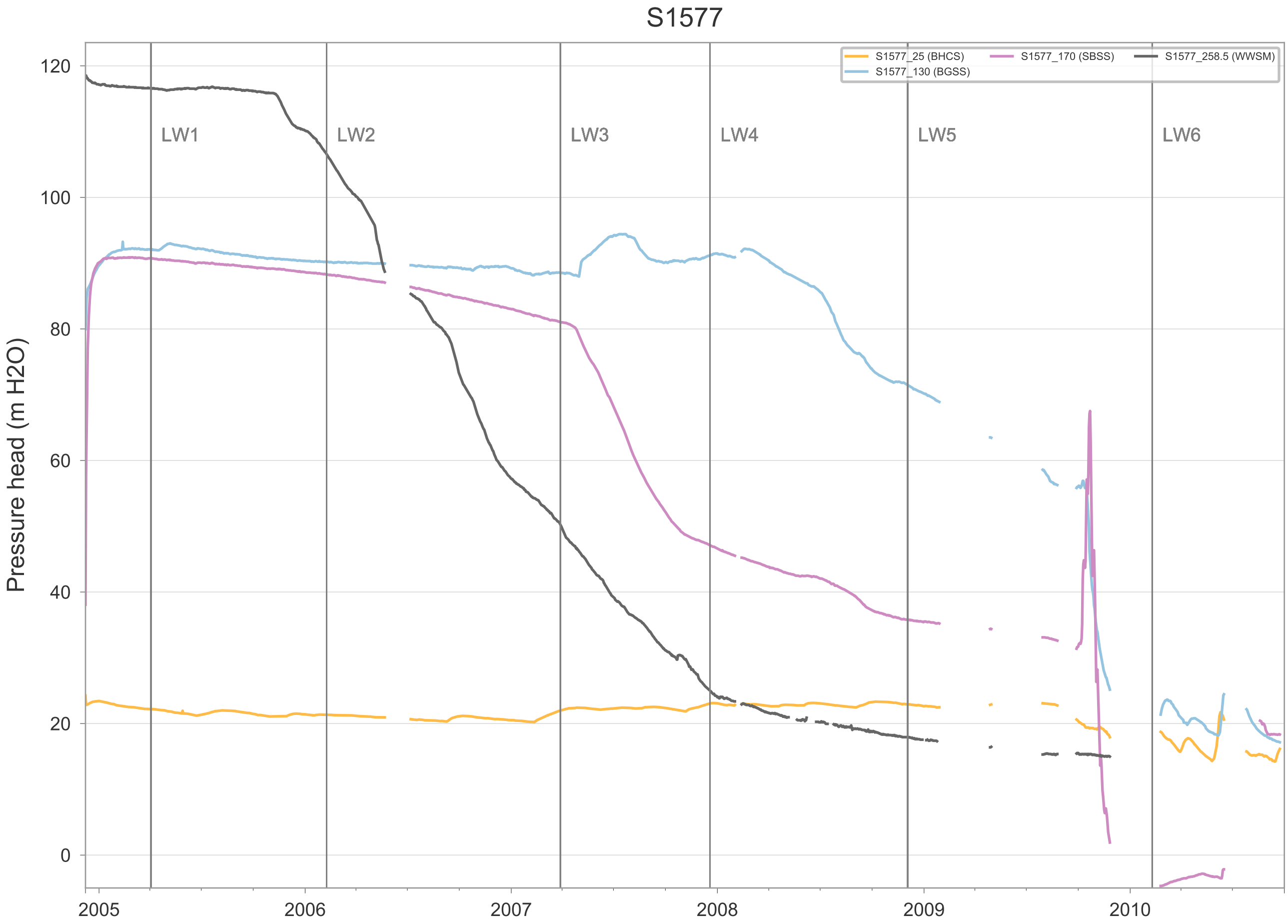
APPENDIX A: LIST OF PIEZOMETERS (AREAS 2 AND 3)

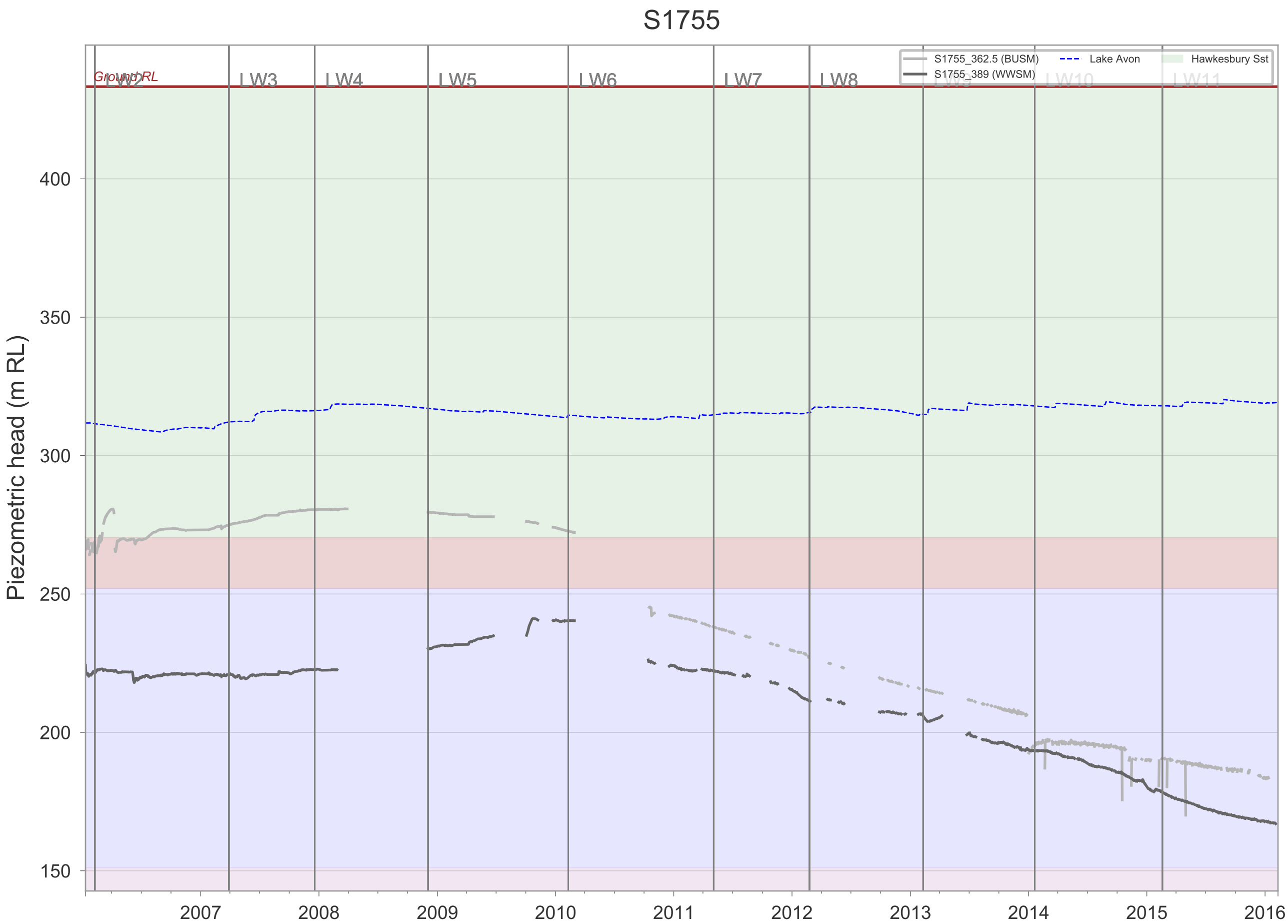
Bore ID	Alt_Name	MGA_mE	MGA_mN	Col_RL	Mine_Area	Sensors	First_record	Last_record	Years
S1096	Kemira19	292700	6191121	435.1	Den 3A	1	22/11/2007	24/02/2010	2.3
S1099	Kemira22	292041	6191531	429.9	Den 3A	1	06/12/2006	28/01/2010	3.1
S1388	DEN29	292129	6192393	427.6	Den 3A	1	04/04/2006	22/01/2010	3.8
S1577	DEN38	294558	6192447	376.9	Den 2	4	08/12/2004	23/09/2010	5.8
S1710	Eloueral09	290258	6189646	432.5	Den Other	4	19/05/2005	17/01/2019	13.7
S1719	DEN56	291202	6193277	413.6	Den 3A	1	16/06/2005	18/02/2010	4.7
S1739	DEN62	289684	6191799	423.71	Den 3B	1	02/09/2005	19/01/2017	11.4
S1755	DEN64	289475	6191380	433.3	Den 3B	2	10/01/2006	03/02/2016	10.1
S1758	DEN65	288587	6193107	408.8	Den 3B	2	26/01/2006	10/06/2014	8.4
S1796	DEN69	289947	6194587	398.6	Den 3B	1	05/04/2006	18/01/2018	11.8
S1800	DEN70	289933	6193997	392.5	Den 3B	2	25/04/2006	31/08/2011	5.4
S1844	DEN76	291391	6194869	375.62	Den 3C	2	22/08/2006	30/03/2019	12.6
S1845	DEN77	291464	6193770	399.694	Den 3A	2	29/11/2006	04/01/2010	3.1
S1855	DEN82	289747	6192833	366.639	Den 3B	2	11/12/2006	27/07/2016	9.6
S1867	DEN84	293793	6192912	345.966	Den 3A	11	20/03/2007	08/04/2019	12.1
S1870	DEN85	293593	6192648	351.456	Den 3A	12	02/02/2007	15/02/2019	12
S1871	DEN86	293525	6193287	375.644	Den 3A	12	17/02/2007	05/03/2019	12
S1878	DEN91	293842	6191994	337.102	Den 3A	11	24/04/2007	22/02/2017	9.8
S1879	DEN92	291440	6192133	379.737	Den 3A	12	07/06/2007	12/04/2019	11.8
S1885	DEN93	291504	6192668	420	Den 3A	12	07/06/2007	17/05/2012	4.9
S1888	DEN96	292487	6191987	381.3	Den 3A	8	31/05/2007	07/09/2017	10.3
S1889	DEN97	292245	6192980	435.436	Den 3A	8	02/06/2007	10/08/2011	4.2
S1890	DEN98	292637	6192491	407.1	Den 3A	8	31/07/2007	07/08/2012	5
S1892	DEN99	291014	6193952	356.1	Den 3A	8	07/08/2008	19/10/2016	8.2
S1902	DEN100	295241	6190780	343.05	Den 2	4	04/10/2007	31/05/2017	9.7
S1907	DEN103	293212	6191943	371.94	Den 3A	8	25/01/2008	12/04/2019	11.2
S1908	DEN104	288926	6193601	405.732	Den 3B	8	16/05/2008	01/05/2014	6
S1910	DEN105	289387	6194176	377.2011	Den 3B	8	29/08/2008	05/03/2019	10.5
S1911	DEN106	288803	6192549	405.1621	Den 3B	12	15/05/2008	24/05/2017	9
S1914	DEN107	289370	6192512	414.5238	Den 3B	7	29/04/2008	10/08/2017	9.3
S1925	DEN108	289252	6193041	416.712	Den 3B	8	04/08/2008	07/03/2019	10.6
S1926	DEN109	289660	6193445	408.9524	Den 3B	8	27/08/2008	08/08/2014	5.9
S1927	DEN110	290066	6192211	414.803	Den 3B	8	16/05/2008	23/01/2017	8.7
S1929	DEN111	290011	6193398	337.709	Den 3B	8	27/08/2008	08/08/2014	5.9
S1930	DEN112	290367	6193583	353.107	Den 3B	12	27/05/2008	07/03/2019	10.8
S1931	DEN113	290336	6192890	396.398	Den 3B	9	11/08/2008	31/03/2019	10.6
S1932	DEN114	288863	6191505	396.1192	Den 3B	11	31/08/2008	31/03/2019	10.6
S1934	DEN115	292128	6192398	427.51	Den 3A	4	23/04/2009	27/07/2017	8.3
S1969	DEN118	293998	6193986	368.52	Den 3C	11	12/08/2009	05/12/2016	7.3
S1992	DEN119	293732	6192707	339.119	Den 3A	8	10/05/2009	31/03/2019	9.9
S1994	DEN120	293865	6192982	345.485	Den 3A	8	13/01/2009	31/03/2019	10.2
S1995	DEN121	288212	6193662	404.451	Den 3B	2	12/06/2009	28/01/2014	4.6
S1998	DEN122	287751	6194273	410.515	Den 3B	2	11/06/2009	23/11/2018	9.5
S1999	DEN123	289233	6190844	406.431	Den 3B	2	10/07/2009	12/04/2019	9.8
S2000	DEN124	290161	6191011	441.98	Den 3B	2	10/07/2009	01/08/2016	7.1
S2001	DEN125	288463	6192020	413.876	Den 3B	10	06/08/2009	13/04/2019	9.7
S2002	DEN126	288633	6194222	399.974	Den 3B	2	21/07/2009	19/02/2012	2.6
S2003	DEN127	290571	6192478	409.42	Den 3B	2	04/08/2009	01/03/2014	4.6
S2004	DEN128	290538	6190795	443.484	Den 3B	2	14/10/2010	06/03/2019	8.4
S2006	DEN129	287263	6194204	409.105	Den 3B	10	24/07/2009	27/02/2017	7.6
S2007	DEN130	287591	6193719	405.799	Den 3B	2	17/06/2009	03/10/2018	9.3
S2009	DEN131	287828	6193092	402.534	Den 3B	10	10/08/2009	24/03/2016	6.6
S2013	DEN134	290858	6191198	399.74	Den 3B	2	22/07/2009	09/04/2019	9.7
S2059	DEN148	293246	6194795	380.7912	Den 3C	11	16/08/2011	17/12/2018	7.3
S2070	DEN150	287619	6192813	414.693	Den 3B	2	15/05/2013	12/04/2019	5.9
S2078	DEN154	288190	6192452	342.006	Den 3B	2	20/06/2010	22/11/2016	6.4

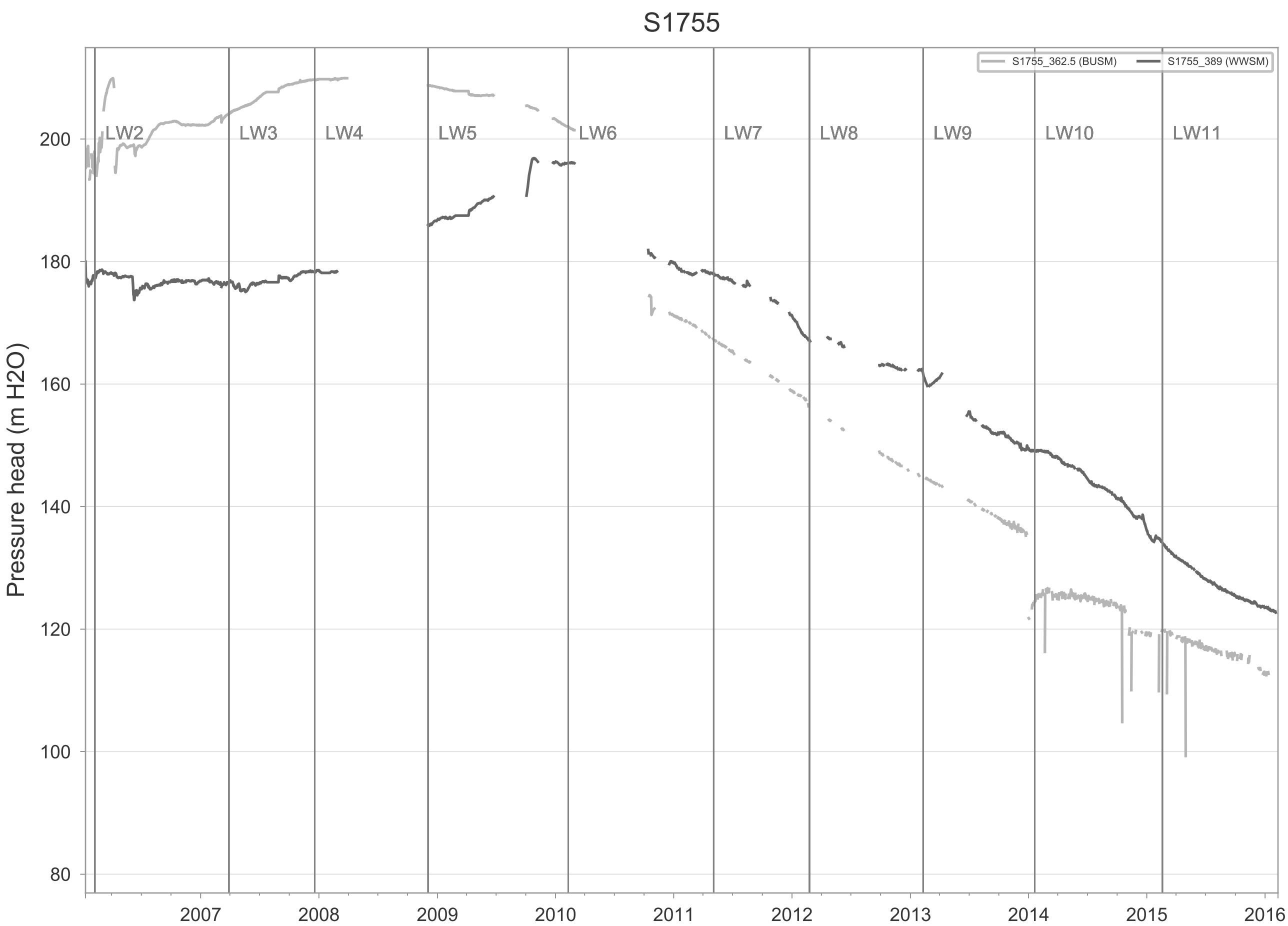
Bore ID	Alt_Name	MGA_mE	MGA_mN	Col_RL	Mine_Area	Sensors	First_record	Last_record	Years
S2192	AQ3	289827	6193849	389.32	Den 3B	6	25/03/2013	18/11/2014	1.7
S2194		288515	6190979	371.13	Den 3B	11	13/04/2013	30/04/2019	6
S2211		293247	6194106	397.73	Den 3C	2	02/10/2013	07/12/2018	5.2
S2212		293535	6194403	369.2	Den 3C	10	11/10/2013	14/08/2018	4.8
S2220	AQ5	289827	6193831	388.11	Den 3B	3	12/11/2014	30/04/2019	4.5
S2306	Swamp11_3	288643	6192484	395.51	Den 3B	4	16/09/2015	30/04/2019	3.6
S2307	Swamp11_4	288666	6192425	394.5	Den 3B	4	16/09/2015	01/05/2019	3.6
S2309		287690	6194933	412.02	Den 3D	10	15/07/2015	30/04/2019	3.8
S2313	Avon01	287609	6192816	415.28	Den 3B	3	31/10/2015	30/04/2019	3.5
S2314	Avon02	288194	6192470	342.36	Den 3B	3	13/11/2015	30/04/2019	3.5
S2335	WC21_S2_H1	289725	6192749	372.58	Den 3B	5	19/10/2016	12/11/2016	0.1
S2336	WC21_S2_H2	289722	6192758	372.35	Den 3B	2	21/10/2016	20/07/2017	0.7
S2337	WC21_S5_H1	290021	6193412	336.12	Den 3B	3	25/11/2016	08/05/2019	2.5
S2338	WC21_S5_H2	290012	6193407	336.12	Den 3B	3	24/11/2016	08/05/2019	2.5
S2341	DA5_28	287474	6195150	401.62	Den 5	10	07/12/2016	30/04/2019	2.4
S2341A	DA5_28A	287489	6195138	402.6	Den 5	4	21/12/2016	30/04/2019	2.4
S2354	S14_05	289731	6191414	424.59	Den 3B	1	07/09/2017	02/11/2018	1.2
S2355	DA5_85_DBH	288136	6194878	396.56	Den 5	5	04/08/2017	21/02/2019	1.6
S2376	Avon AD6	288400	6192527	367.79	Den 3B	3	06/10/2017	10/04/2019	1.5
S2377	Avon AD3	288333	6192020	408.18	Den 3B	3	02/06/2018	01/05/2019	0.9
S2378	Avon AD4	288407	6191770.89	379.28	Den 3B	3	15/11/2017	01/05/2019	1.5
S2379	Avon AD5	288313	6191141	356.61	Den 3B	3	17/07/2018	05/03/2019	0.6
S2401	Swamp1b_01	287752	6194265	411.08	Den 3B	6	16/11/2018	15/04/2019	0.4
S2402	Swamp1b_02	288208	6193667	403.35	Den 3B	6	06/07/2018	13/03/2019	0.7
S2403	Swamp1b_03	288345	6193761	400.65	Den 3B	6	16/11/2018	15/04/2019	0.4
S2404	Swamp1b_04	288529	6193897	396.17	Den 3B	6	22/11/2018	14/01/2019	0.1
S2405	Swamp1b_05	288730	6194088	386.05	Den 3B	6	17/11/2018	15/04/2019	0.4
S2406	Swamp1b_06	288669	6194176	396.6	Den 3B	6	17/11/2018	14/01/2019	0.2
S2408	GW14-2	289552	6192193	398.12	Den 3B	7	03/10/2018	30/11/2018	0.2
S2409	GW14-3	289546	6192270	394.65	Den 3B	6	03/10/2018	05/05/2019	0.6
S2411	LW12_2	289761	6192838	363.96	Den 3B	8	05/07/2018	30/04/2019	0.8
S2412	LW15-1	289201	6191807	427.33	Den 3B	8	12/05/2018	30/04/2019	1
S2435	Avon AD7	288081	6192412	328.2	Den 3B	3	21/11/2018	30/04/2019	0.4
S2436	Avon AD8	288314	6191500	320.306	Den 3B	3	04/12/2018	07/03/2019	0.3

APPENDIX B: GROUNDWATER HYDROGRAPHS

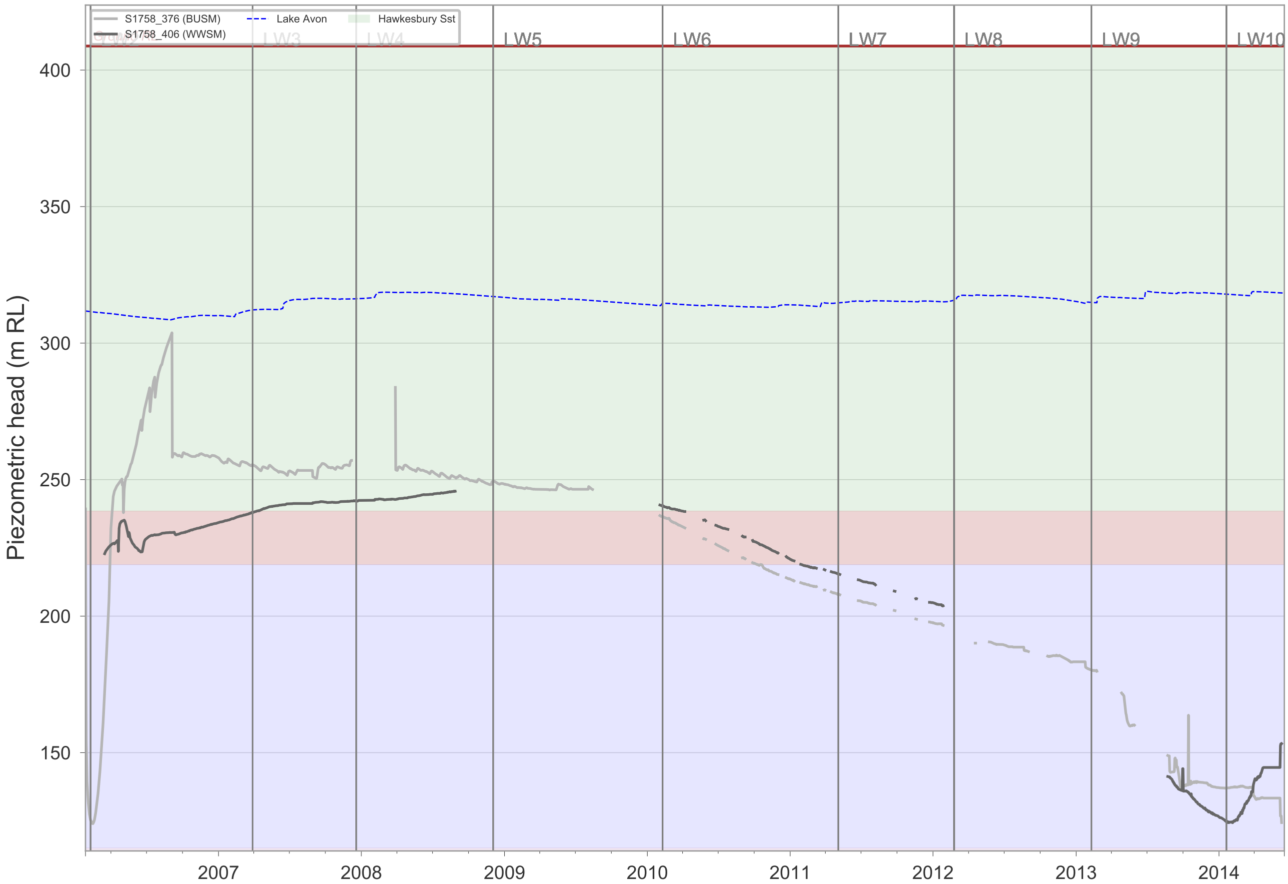

S1577
Piezometric head (m RL)
Ground RL
LW1
LW2
LW3
LW4
LW5
LW6
S1577_25 (BHCS)
S1577_130 (BGSS)
S1577_170 (SBSS)
S1577_258.5 (WWSM)
Lake Cordeaux
Hawkesbury Sst
350
300
250
200
150
2005
2006
2007
2008
2009
2010


S1577
Pressure head (m H2O)
S1577_25 (BHCS)
S1577_130 (BGSS)
S1577_170 (SBSS)
S1577_258.5 (WWSM)
LW1
LW2
LW3
LW4
LW5
LW6
120
100
80
60
40
20
0
2005
2006
2007
2008
2009
2010

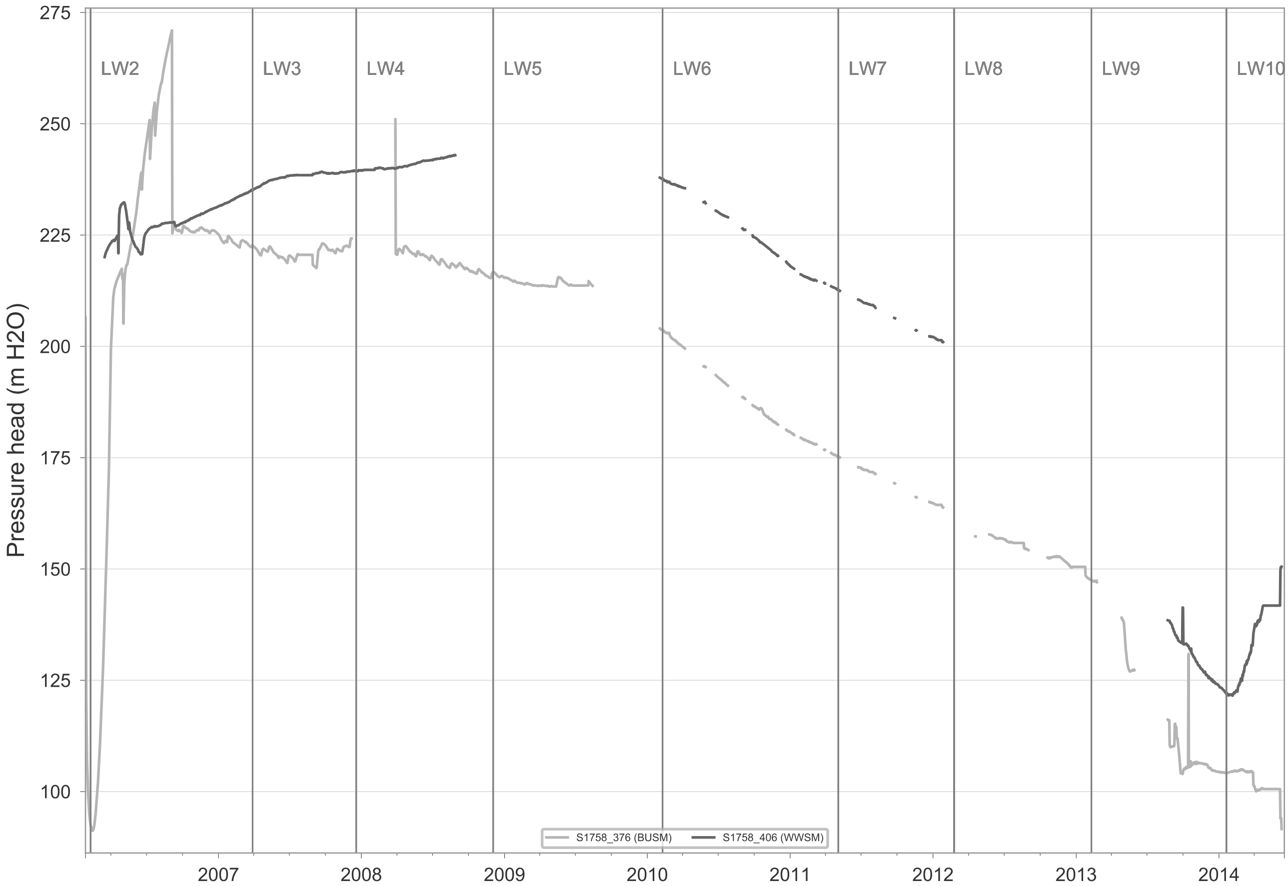

S1755
Piezometric head (m RL)
Ground RL
LW2
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
S1755_362.5 (BUSM)
S1755_389 (WWSM)
Lake Avon
Hawkesbury Sst
400
350
300
250
200
150
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

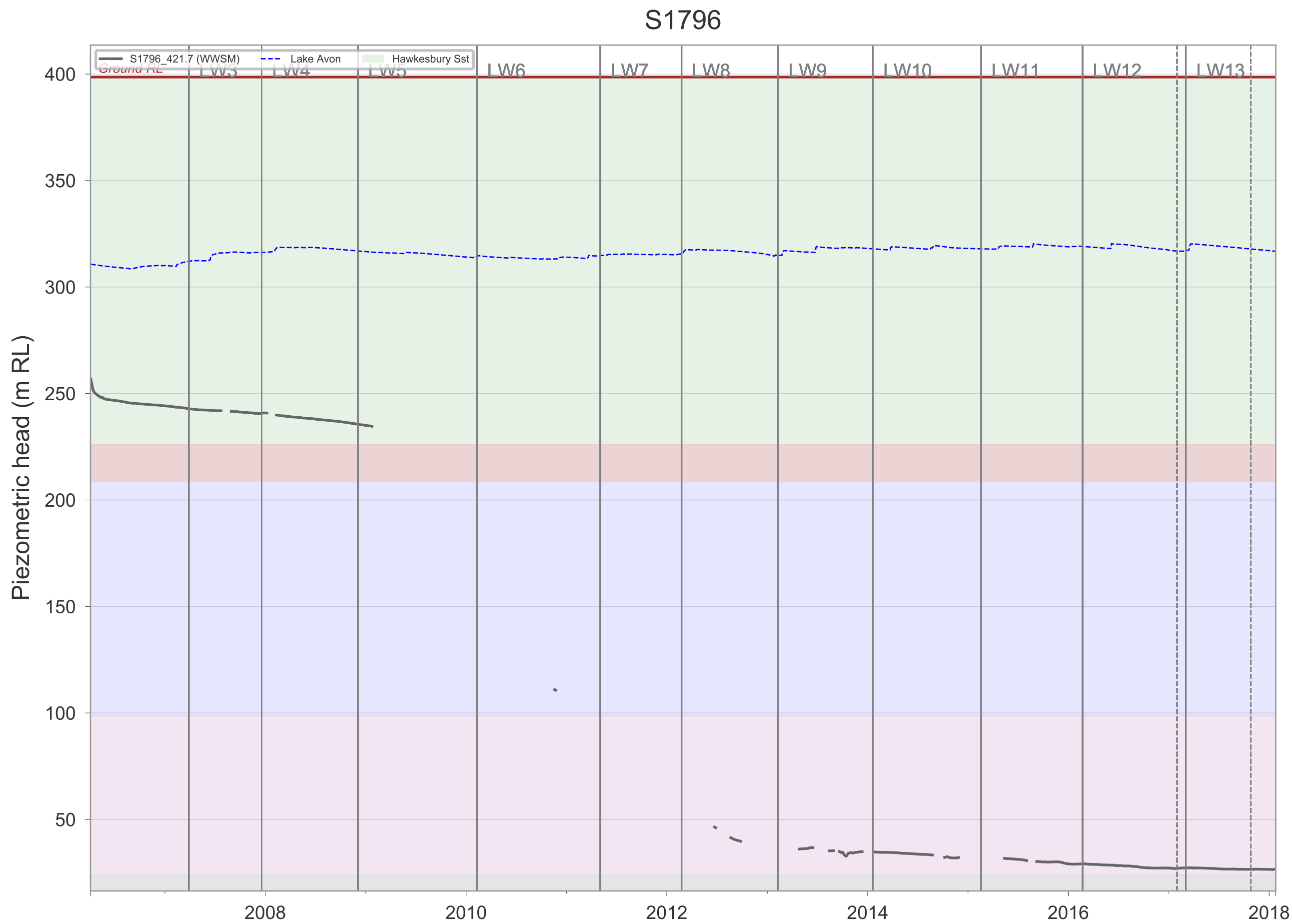

S1755
Pressure head (m H2O)
S1755_362.5 (BUSM)
S1755_389 (WWSM)
LW2
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
200
180
160
140
120
100
80
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

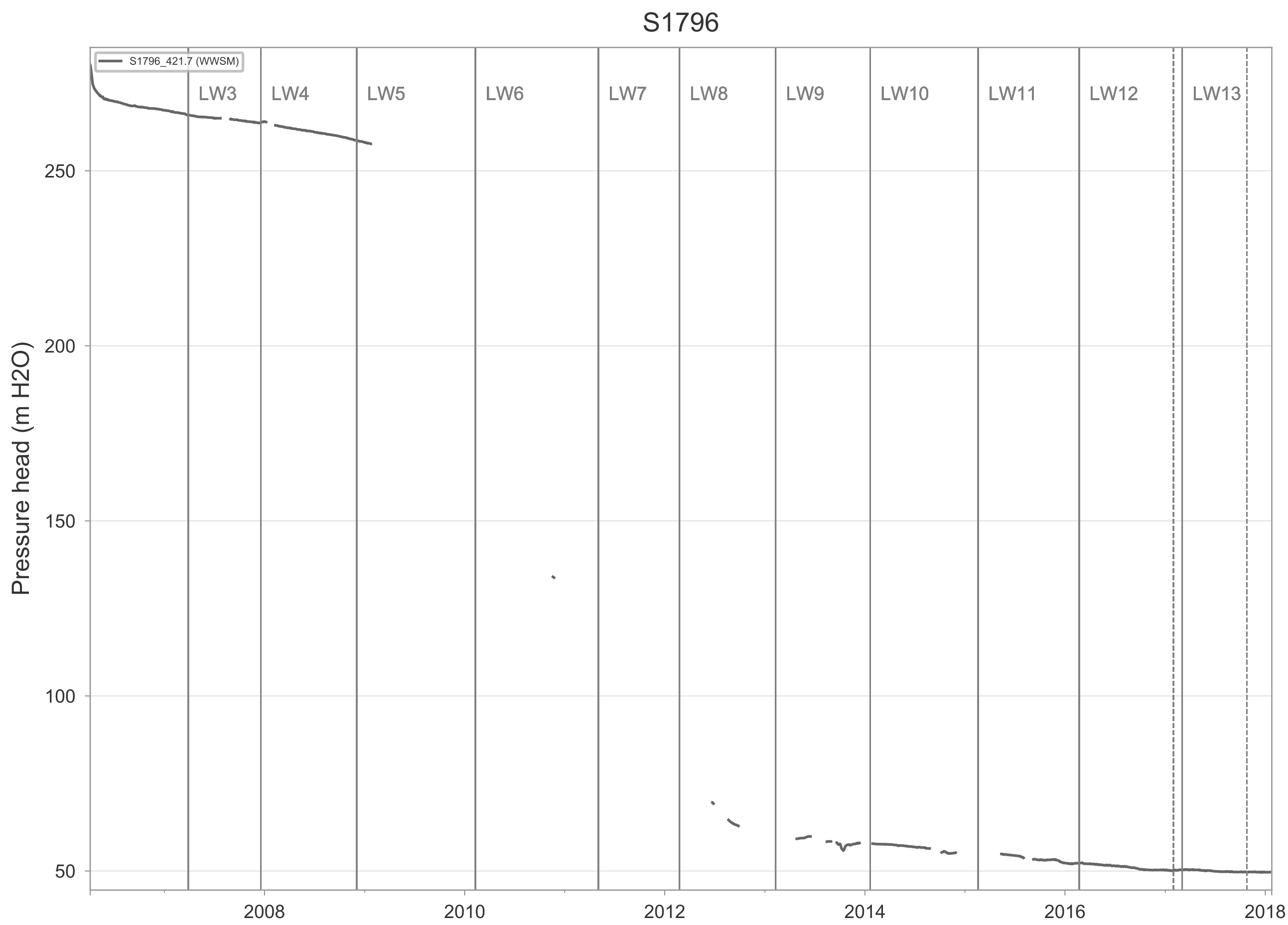
S1758

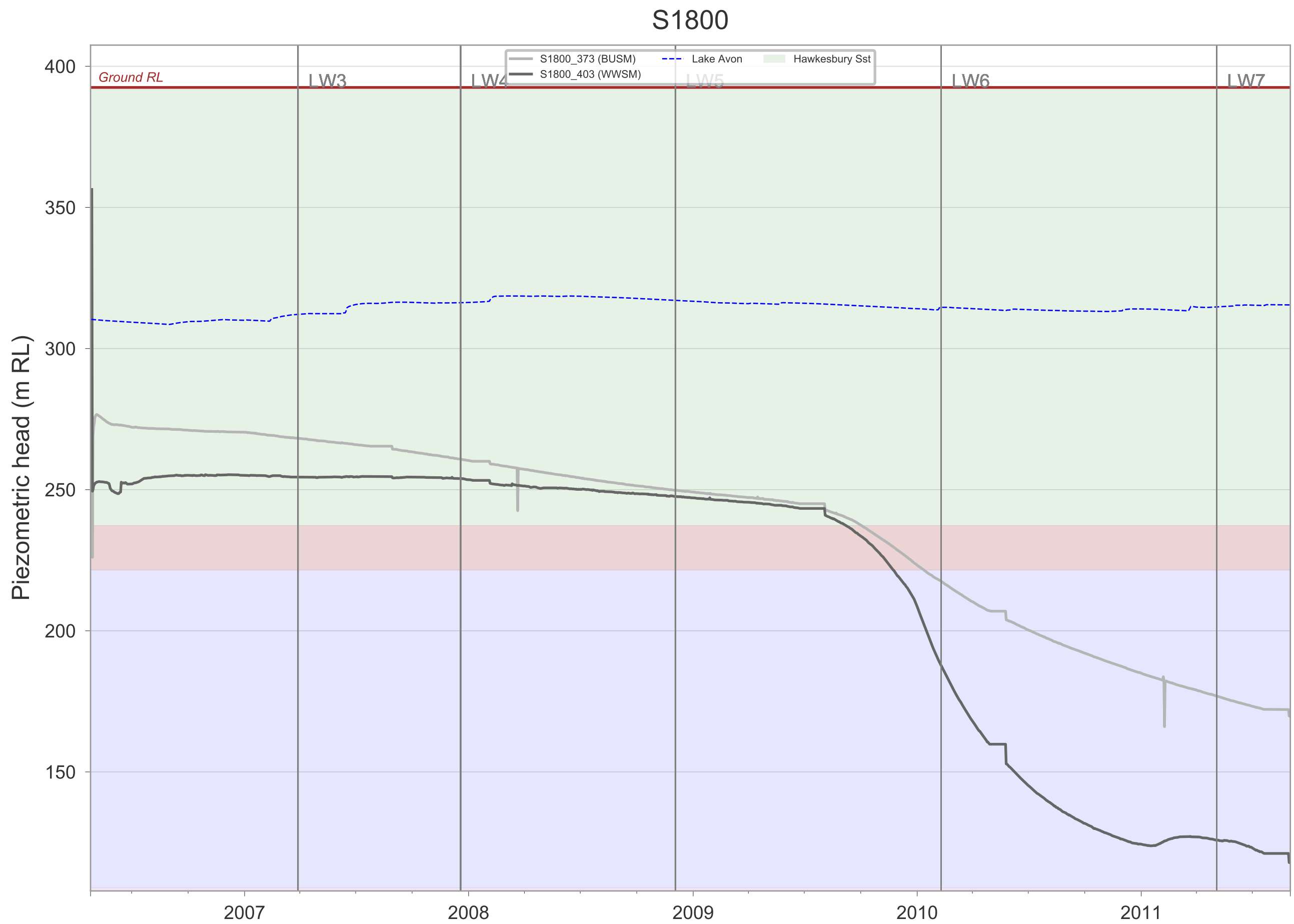

S1758_376 (BUSM)
S1758_406 (WWSM)
Lake Avon
Hawkesbury Sst
LW2
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
Piezometric head (m RL)
400
350
300
250
200
150
2007
2008
2009
2010
2011
2012
2013
2014

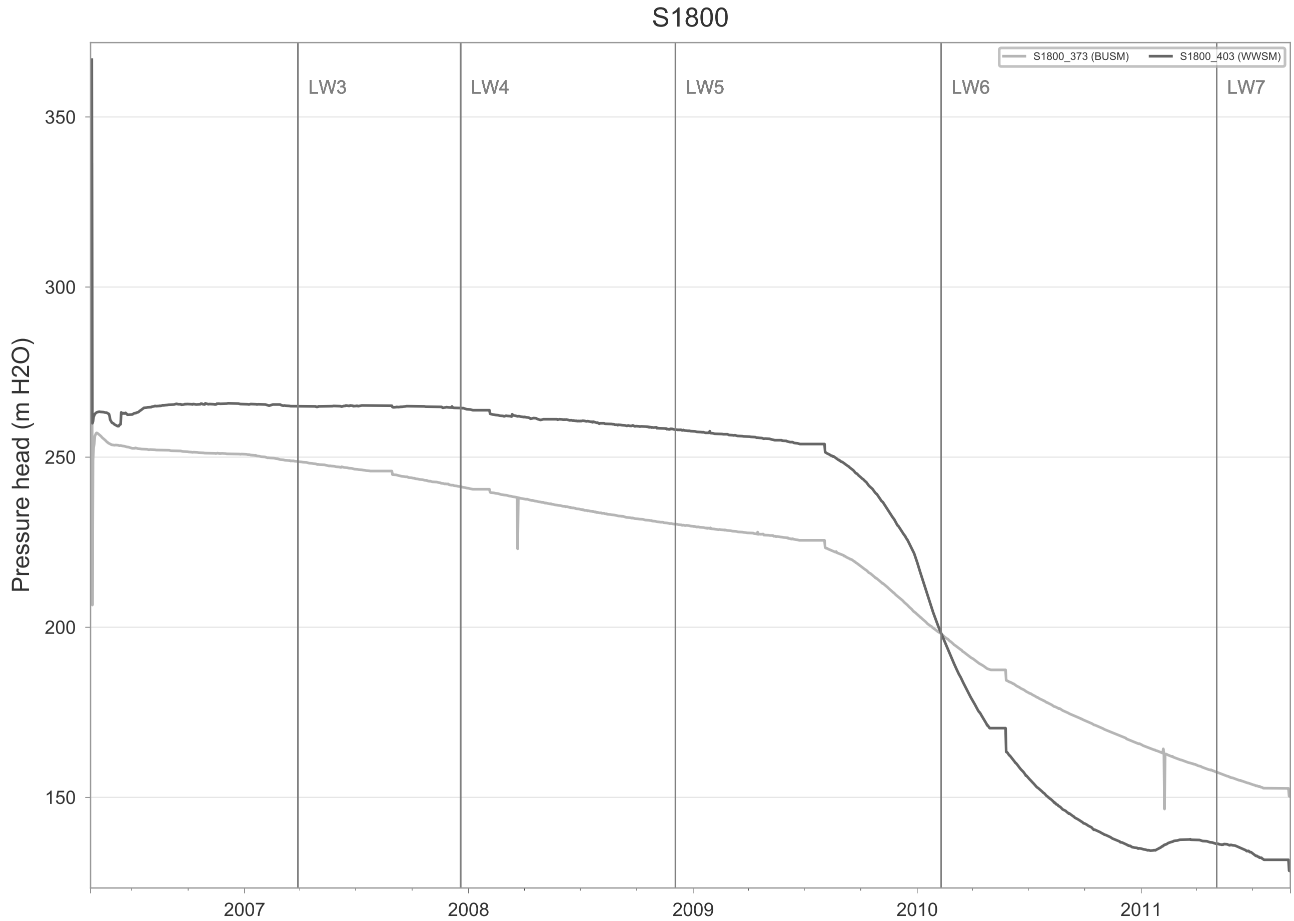
S1758

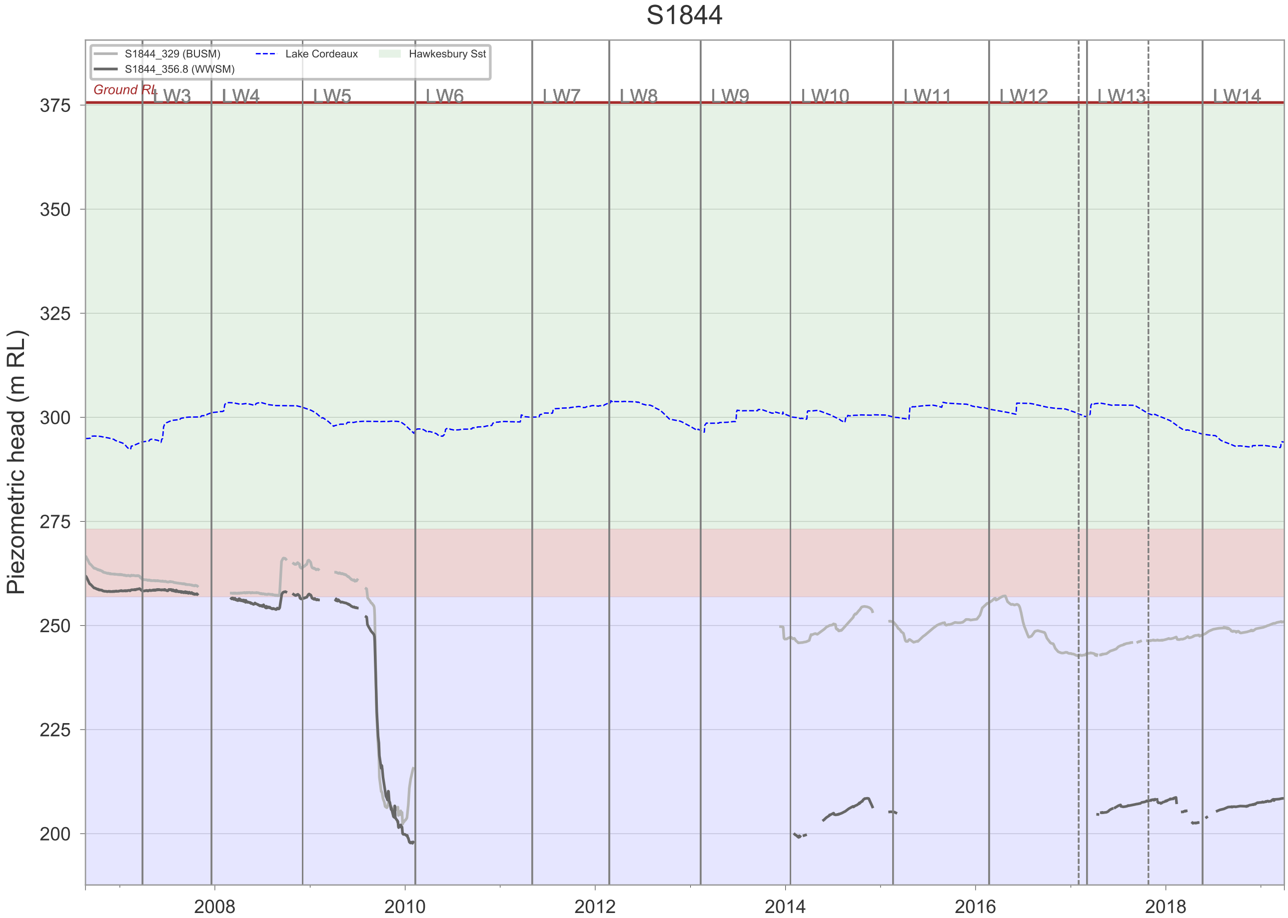

LW2
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
Pressure head (m H2O)
275
250
225
200
175
150
125
100
S1758_376 (BUSM)
S1758_406 (WWSM)
2007
2008
2009
2010
2011
2012
2013
2014

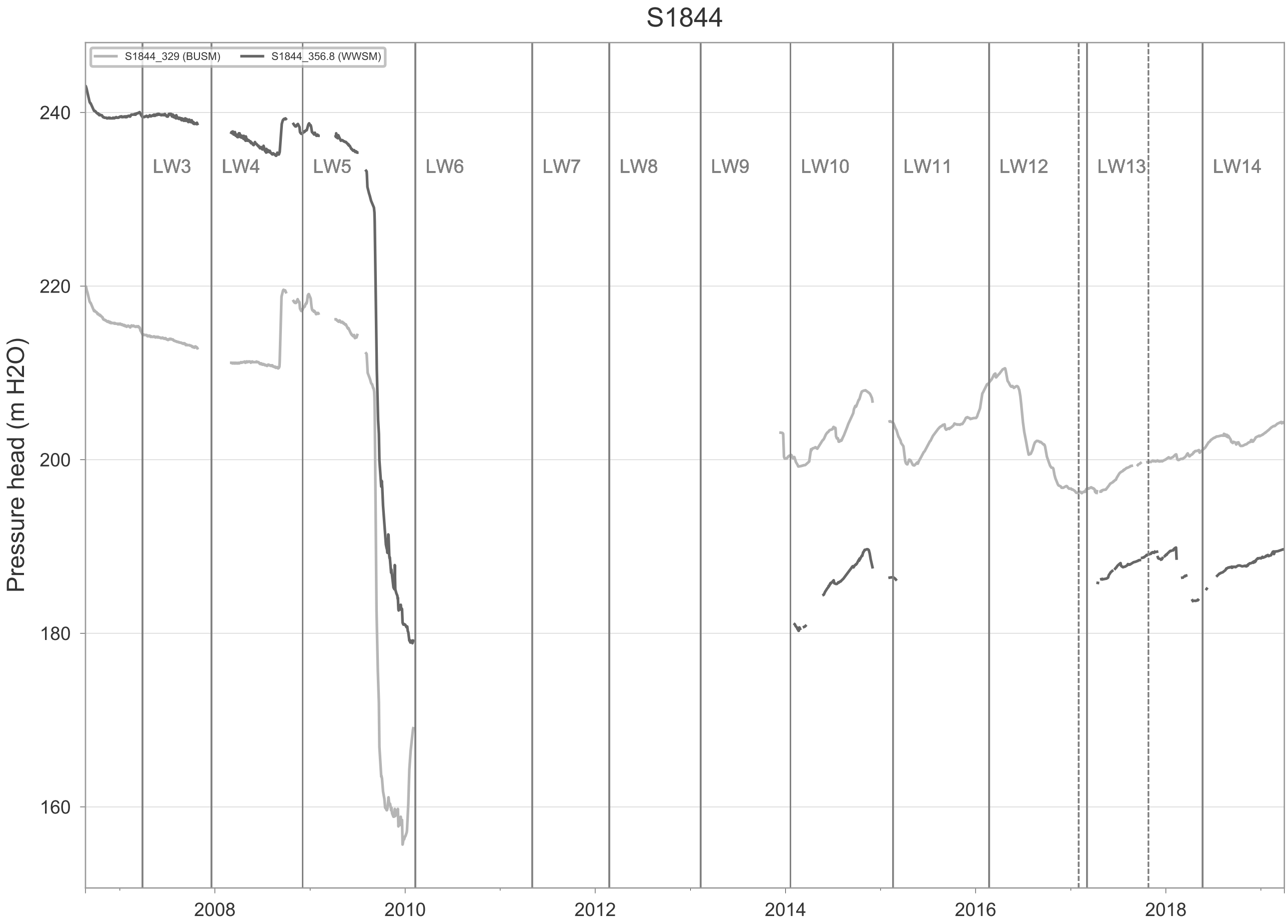

S1796
S1796_421.7 (WWSM)
Lake Avon
Hawkesbury Sst
Ground RL
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
Piezometric head (m RL)
400
350
300
250
200
150
100
50
2008
2010
2012
2014
2016
2018


S1796
S1796_421.7 (WWSM)
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
Pressure head (m H2O)
250
200
150
100
50
2008
2010
2012
2014
2016
2018

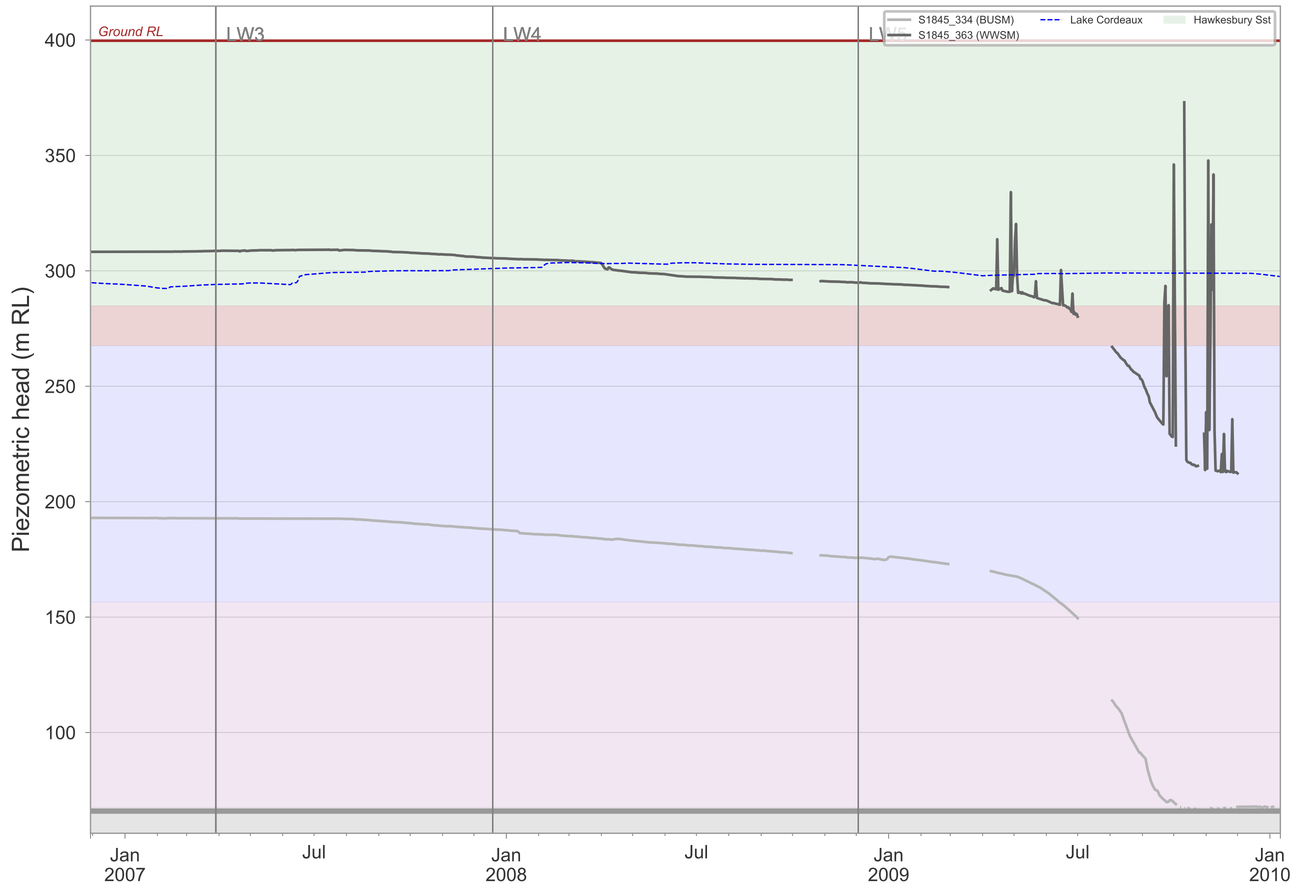

S1800
Piezometric head (m RL)
400
350
300
250
200
150
Ground RL
LW3
LW4
LW5
LW6
LW7
S1800_373 (BUSM)
S1800_403 (WWSM)
Lake Avon
Hawkesbury Sst
2007
2008
2009
2010
2011


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


S1844
S1844_329 (BUSM)
S1844_356.8 (WWSM)
Lake Cordeaux
Hawkesbury Sst
Ground RL
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
Piezometric head (m RL)
375
350
325
300
275
250
225
200
2008
2010
2012
2014
2016
2018

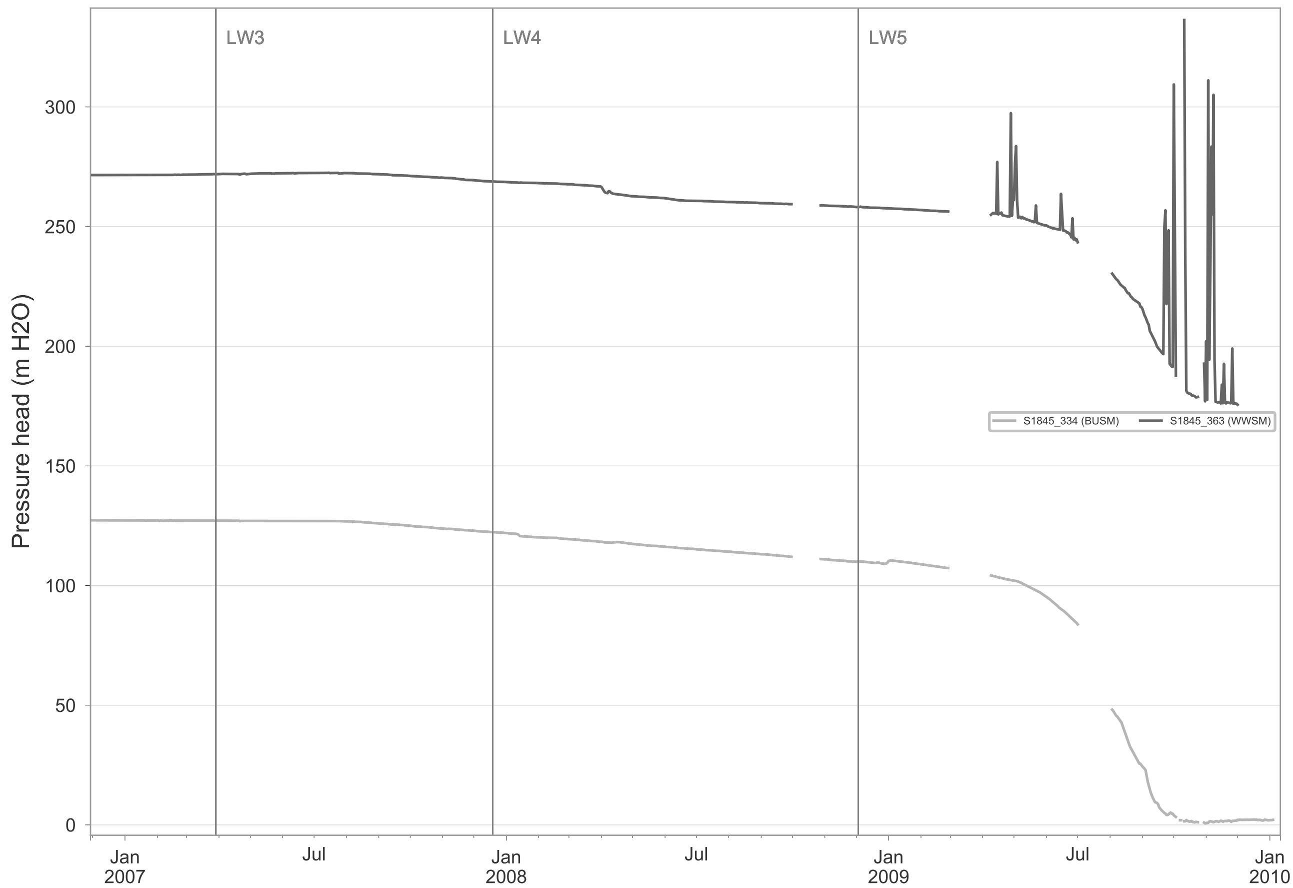

S1844
S1844_329 (BUSM)
S1844_356.8 (WWSM)
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
Pressure head (m H2O)
240
220
200
180
160
2008
2010
2012
2014
2016
2018

S1845



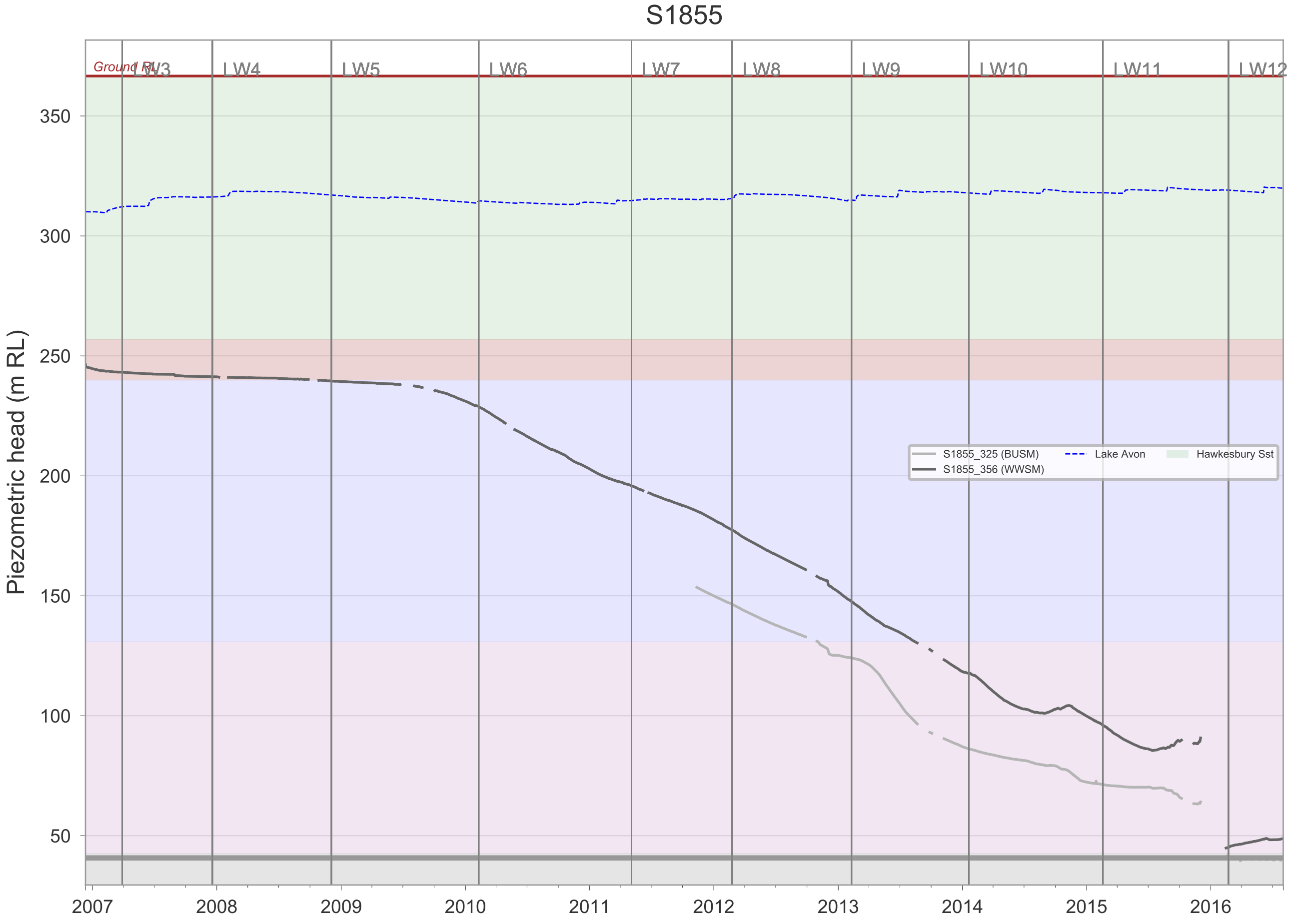
Ground RL
LW3
LW4
S1845_334 (BUSM)
S1845_363 (WWSM)
Lake Cordeaux
Hawkesbury Sst
Piezometric head (m RL)
400
350
300
250
200
150
100
Jan 2007
Jul
Jan 2008
Jul
Jan 2009
Jul
Jan 2010

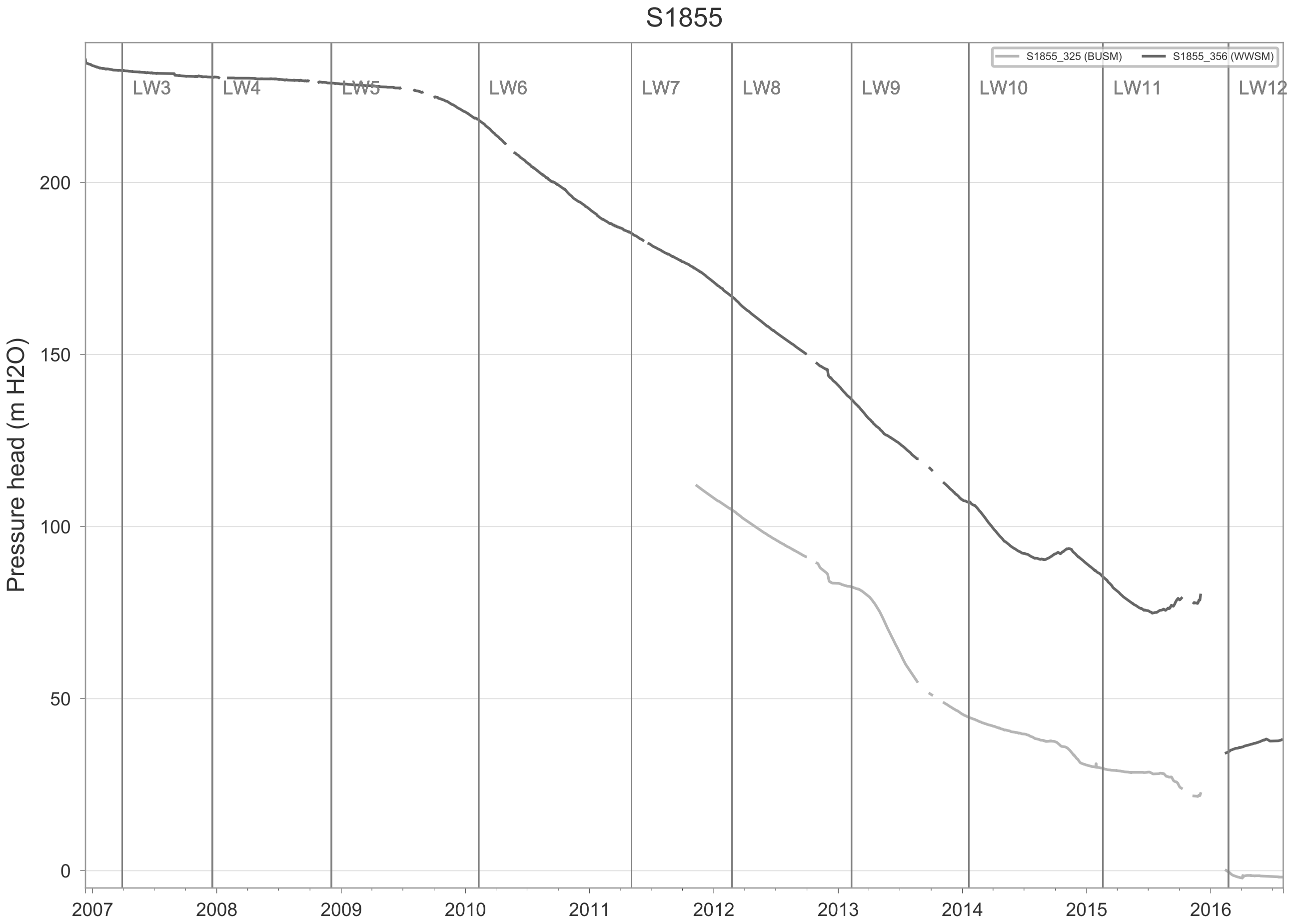
S1845

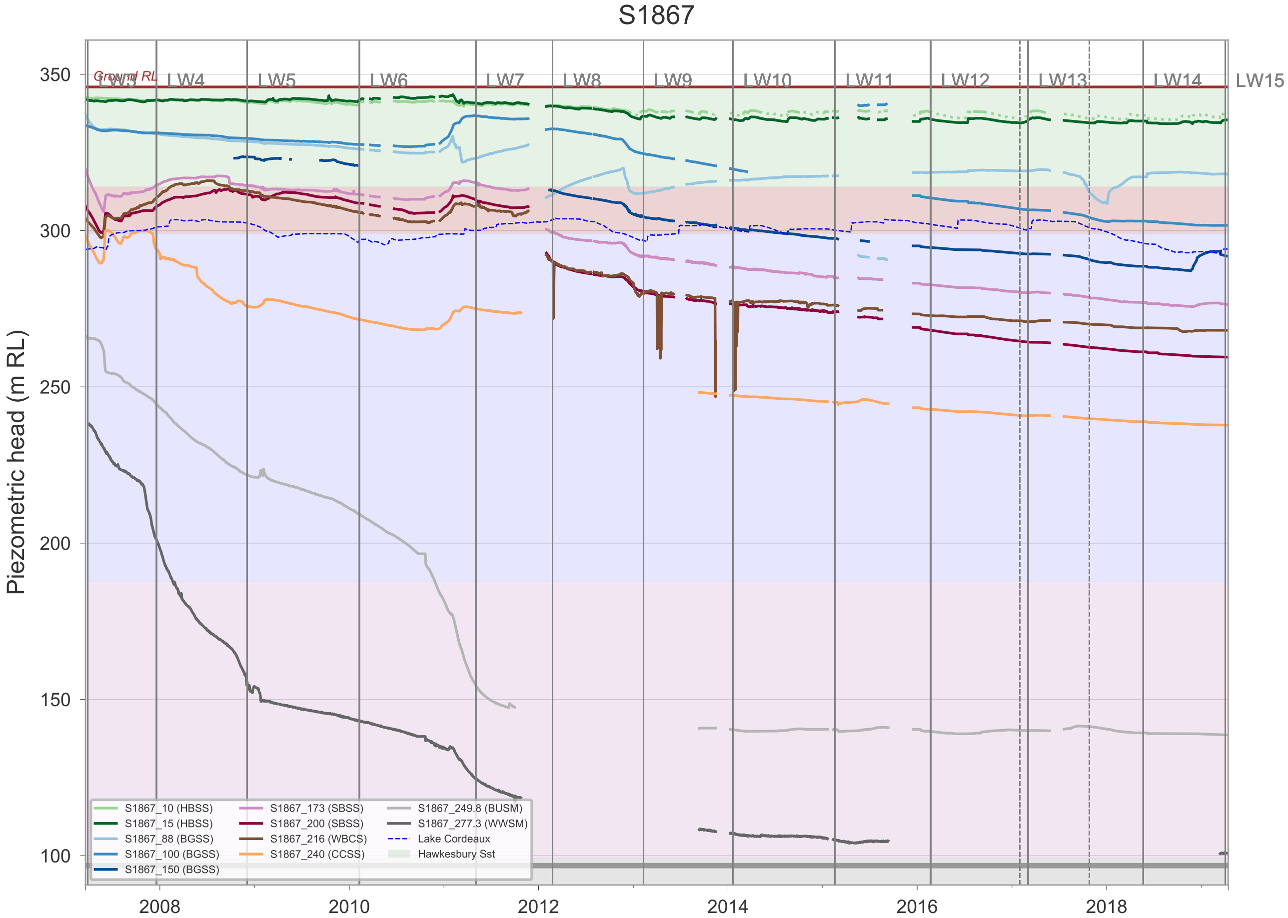


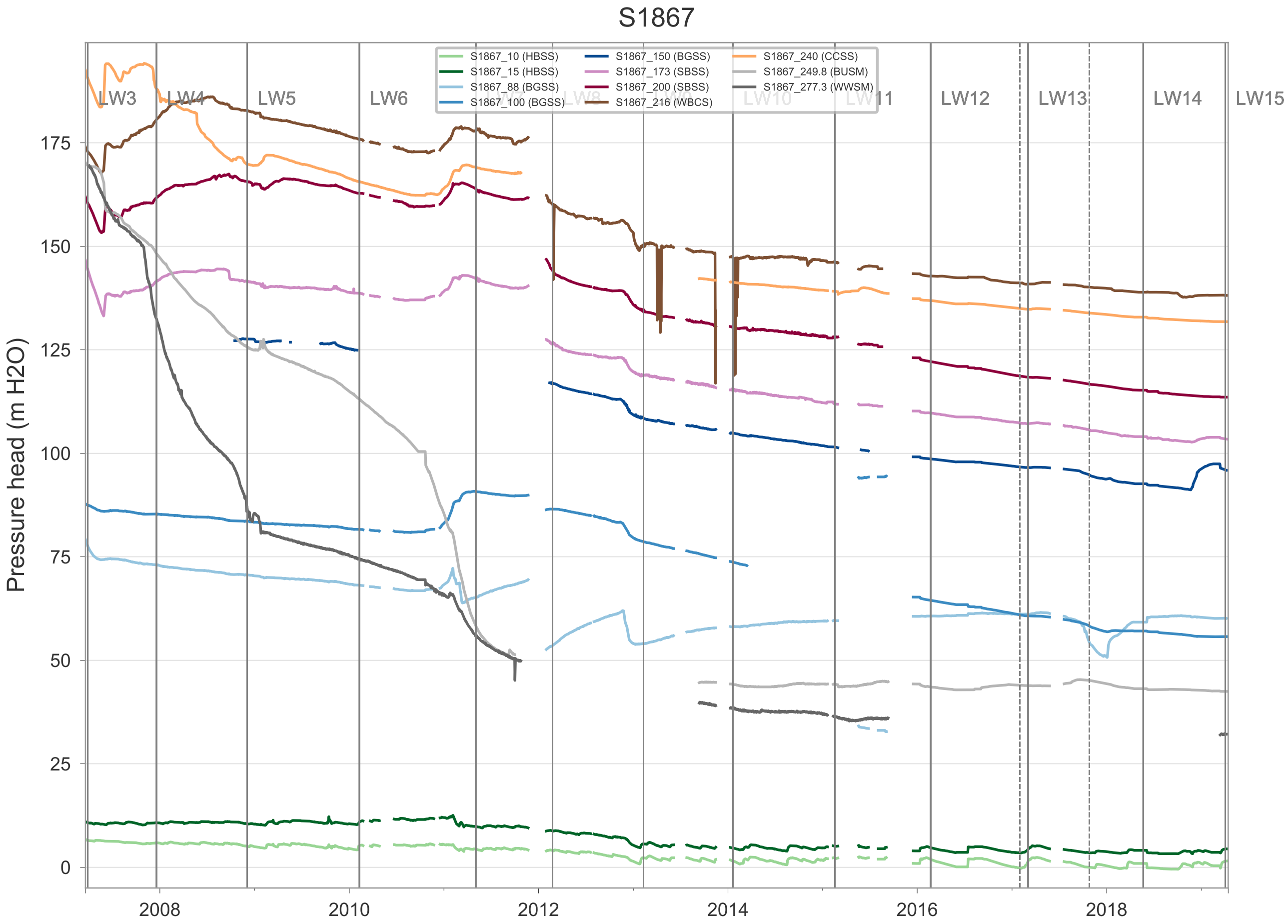
LW3
LW4
LW5
S1845_334 (BUSM)
S1845_363 (WWSM)
Pressure head (m H2O)
300
250
200
150
100
50
0
Jan 2007
Jul
Jan 2008
Jul
Jan 2009
Jul
Jan 2010

Groundwater hydrographs

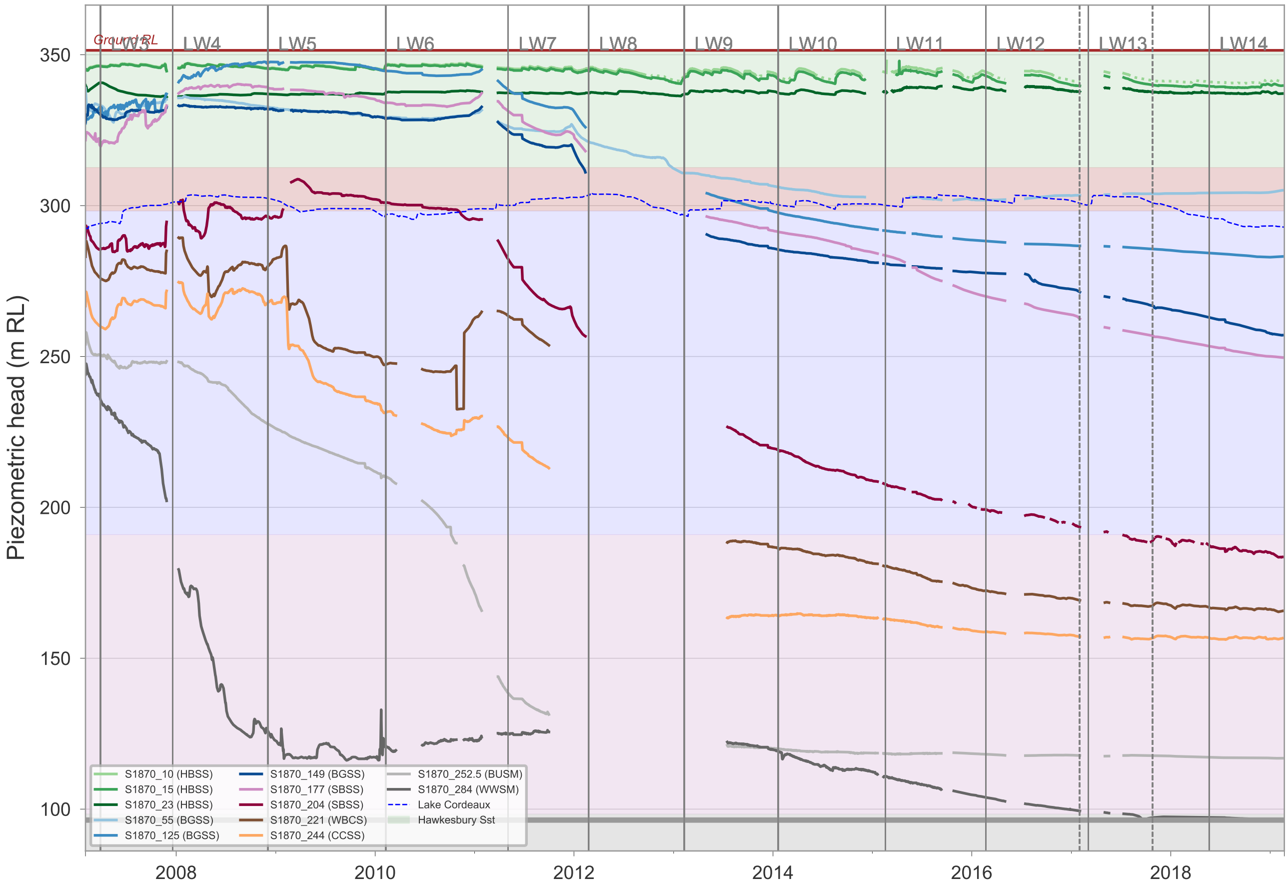




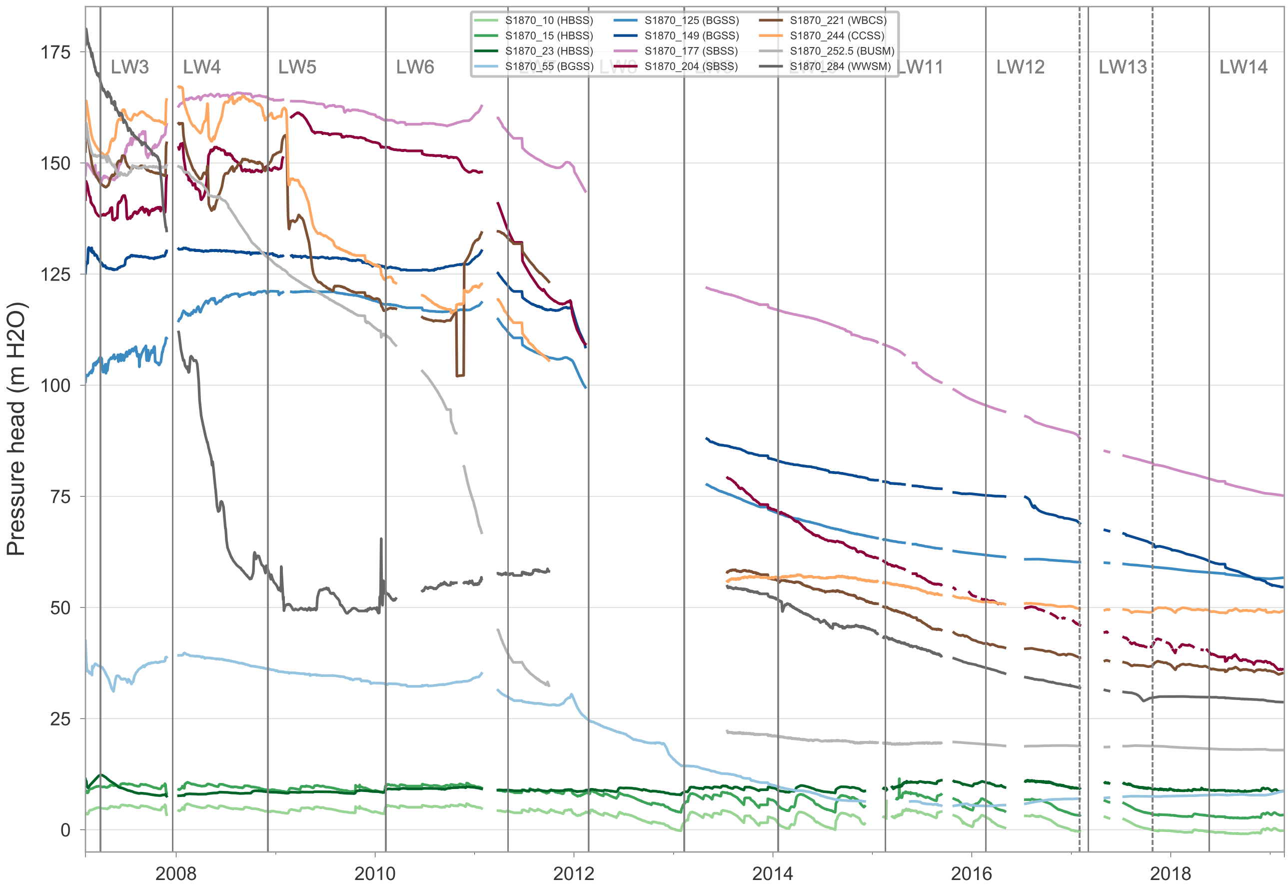

S1867
Piezometric head (m RL)
Ground RL
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
S1867_10 (HBSS)
S1867_15 (HBSS)
S1867_88 (BGSS)
S1867_100 (BGSS)
S1867_150 (BGSS)
S1867_173 (SBSS)
S1867_200 (SBSS)
S1867_216 (WBCS)
S1867_240 (CCSS)
S1867_249.8 (BUSM)
S1867_277.3 (WWSM)
Lake Cordeaux
Hawkesbury Sst
2008
2010
2012
2014
2016
2018

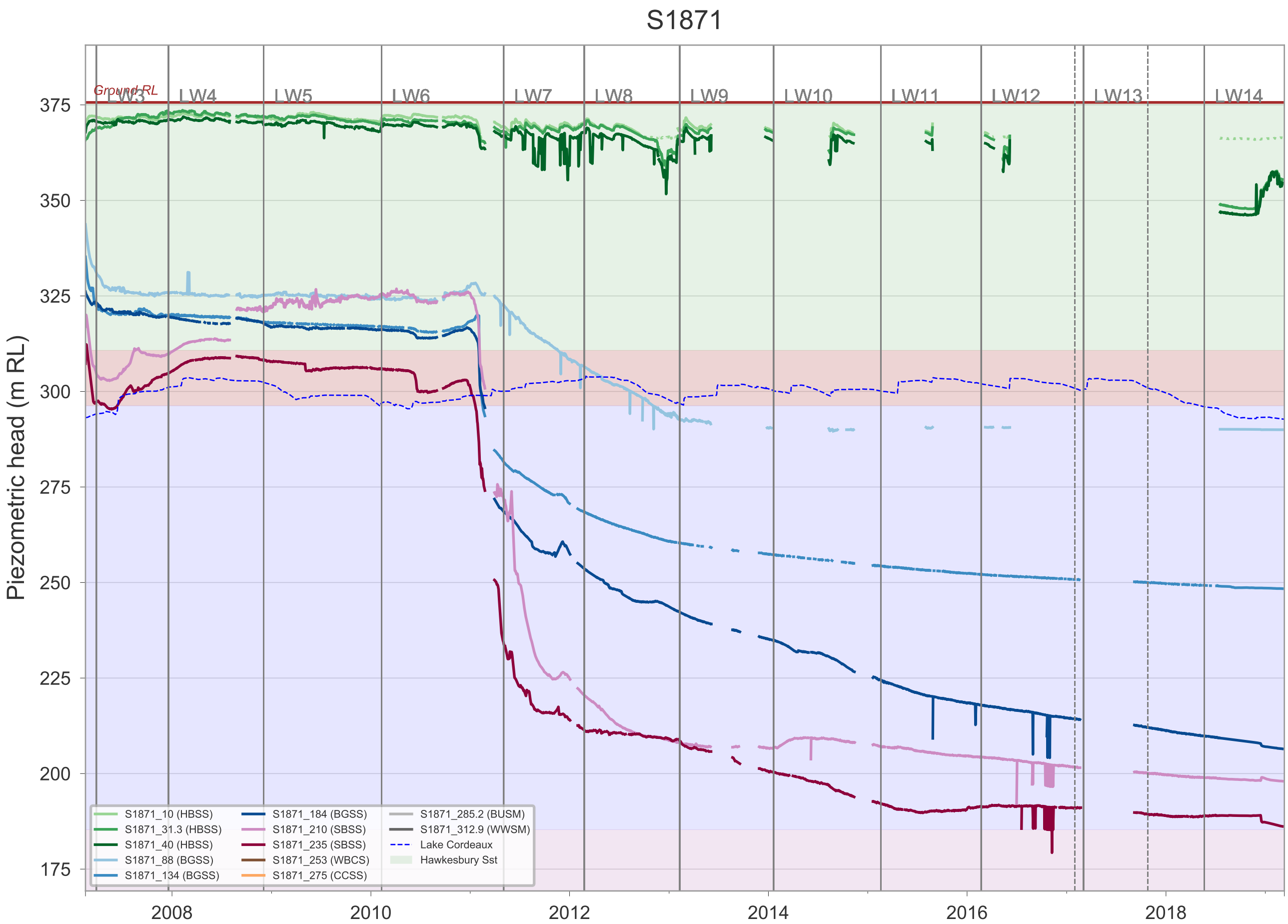

S1867
Pressure head (m H2O)
LW3
LW4
LW5
LW6
LW12
LW13
LW14
LW15
S1867_10 (HBSS)
S1867_15 (HBSS)
S1867_88 (BGSS)
S1867_100 (BGSS)
S1867_150 (BGSS)
S1867_173 (SBSS)
S1867_200 (SBSS)
S1867_216 (WBCS)
S1867_240 (CCSS)
S1867_249.8 (BUSM)
S1867_277.3 (WWSM)
2008
2010
2012
2014
2016
2018

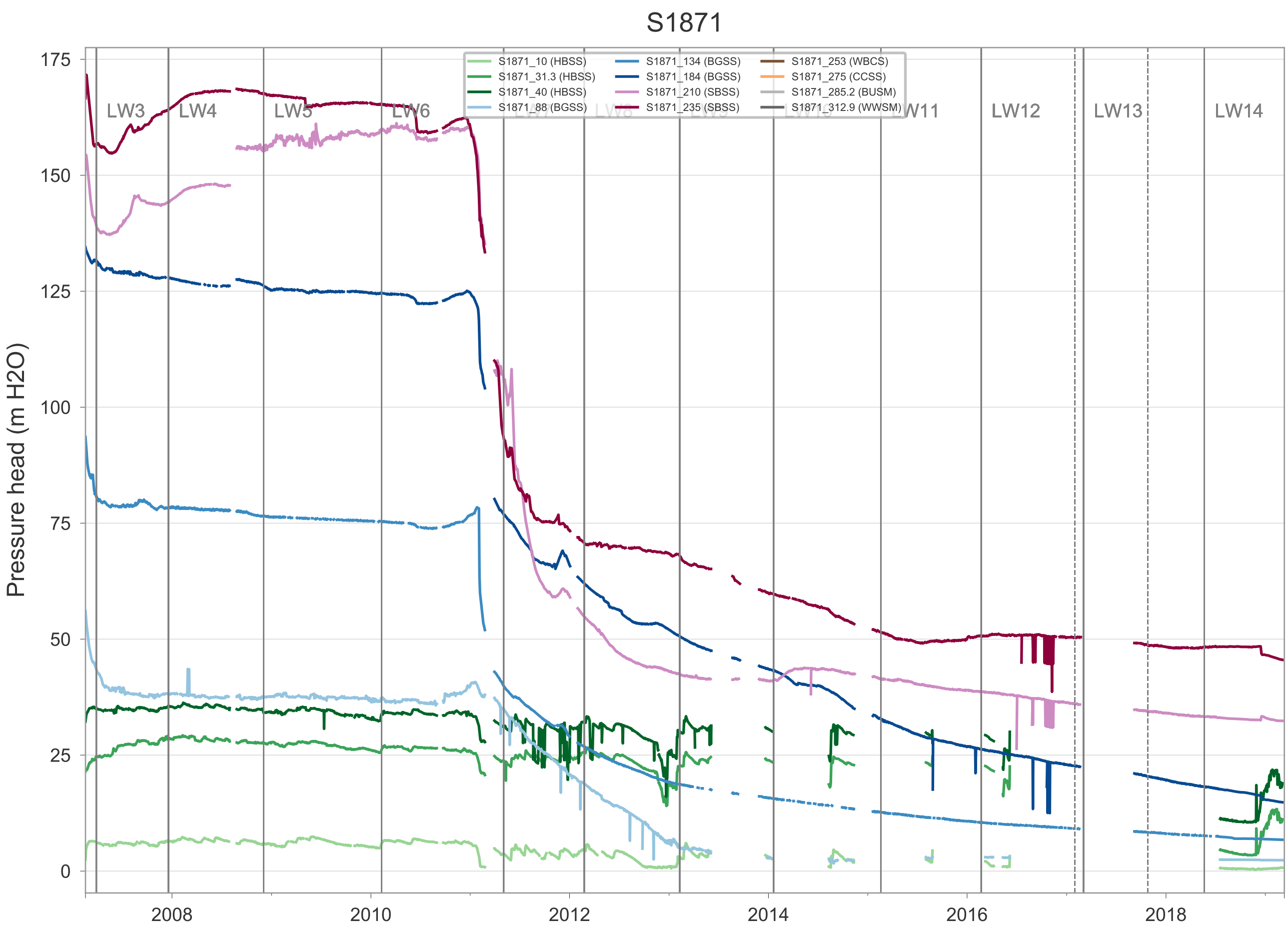
S1870

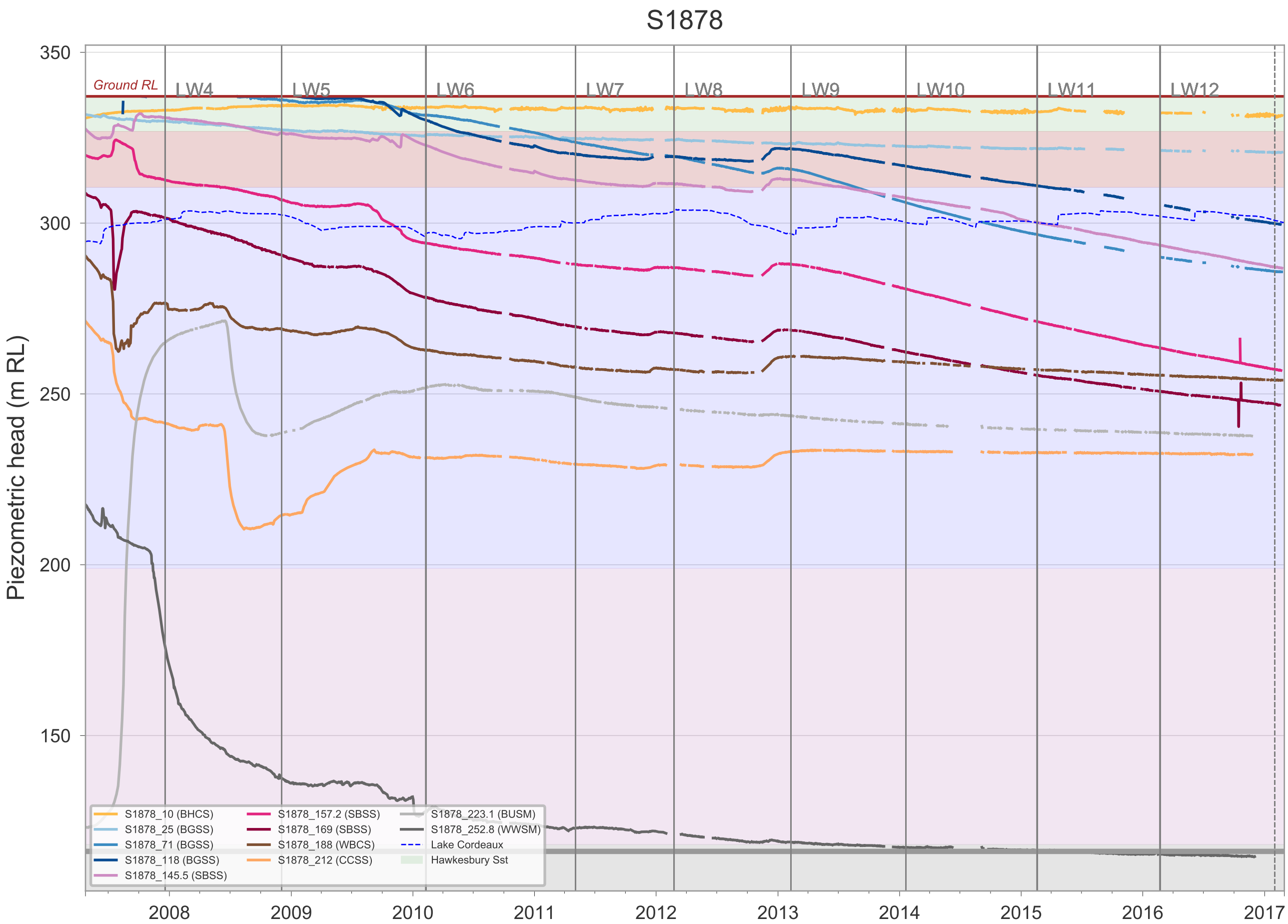

Ground RL
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
Piezometric head (m RL)
350
300
250
200
150
100
2008
2010
2012
2014
2016
2018
S1870_10 (HBSS)
S1870_15 (HBSS)
S1870_23 (HBSS)
S1870_55 (BGSS)
S1870_125 (BGSS)
S1870_149 (BGSS)
S1870_177 (SBSS)
S1870_204 (SBSS)
S1870_221 (WBCS)
S1870_244 (CCSS)
S1870_252.5 (BUSM)
S1870_284 (WWSM)
Lake Cordeaux
Hawkesbury Sst

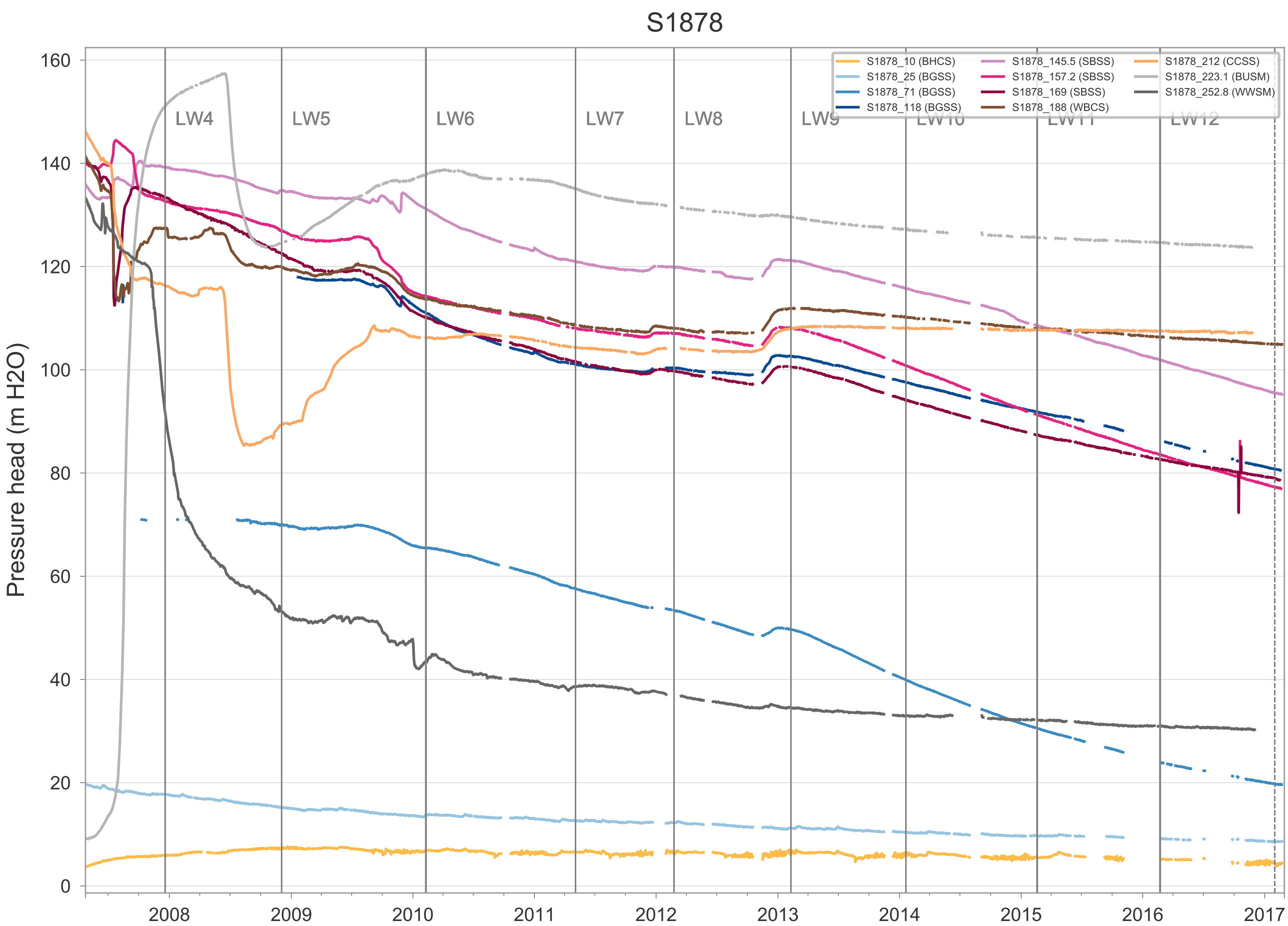
S1870


LW3
LW4
LW5
LW6
LW11
LW12
LW13
LW14
Pressure head (m H2O)
175
150
125
100
75
50
25
0
2008
2010
2012
2014
2016
2018
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)

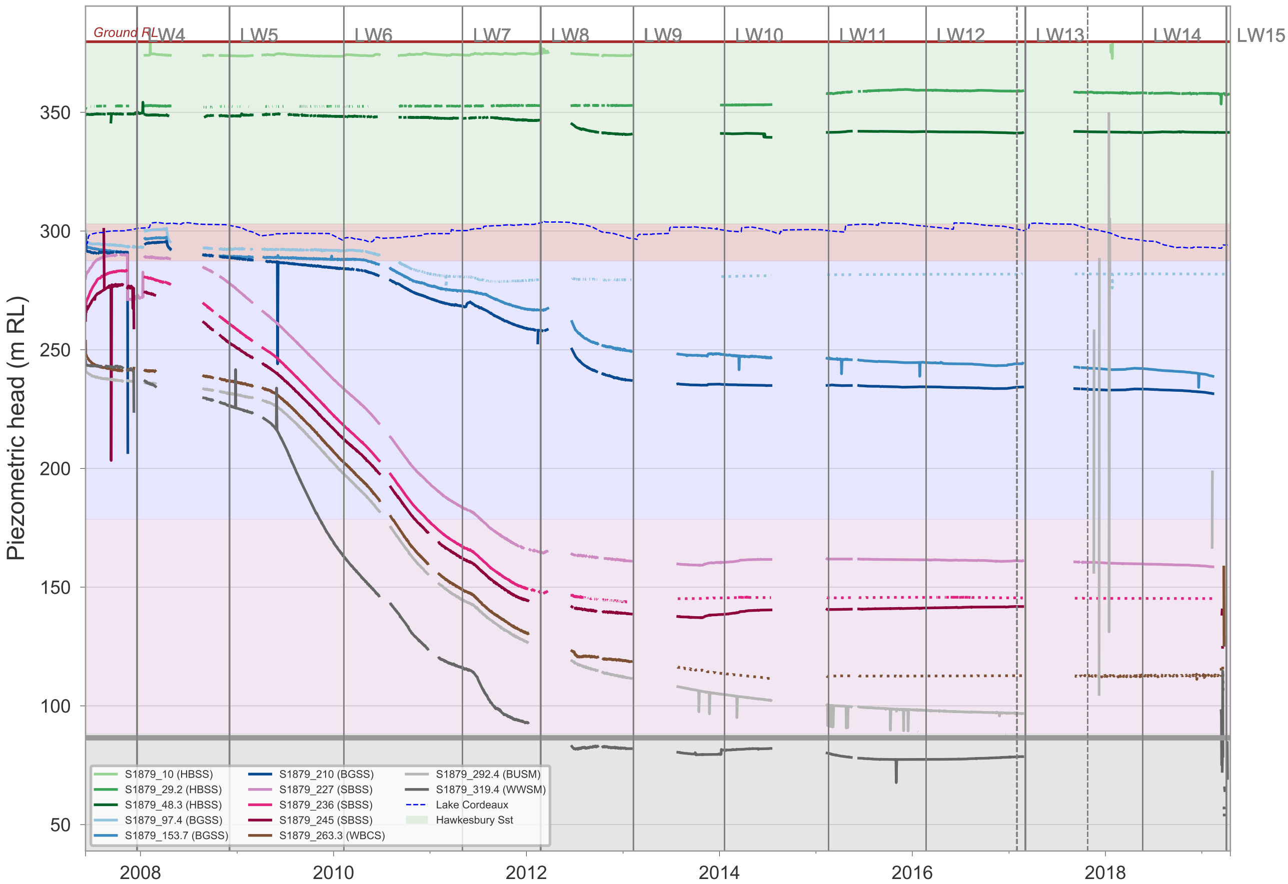

S1871
Piezometric head (m RL)
Ground RL
LW3
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
S1871_10 (HBSS)
S1871_31.3 (HBSS)
S1871_40 (HBSS)
S1871_88 (BGSS)
S1871_134 (BGSS)
S1871_184 (BGSS)
S1871_210 (SBSS)
S1871_235 (SBSS)
S1871_253 (WBCS)
S1871_275 (CCSS)
S1871_285.2 (BUSM)
S1871_312.9 (WWSM)
Lake Cordeaux
Hawkesbury Sst


S1871
Pressure head (m H2O)
LW3
LW4
LW5
LW6
LW11
LW12
LW13
LW14
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)

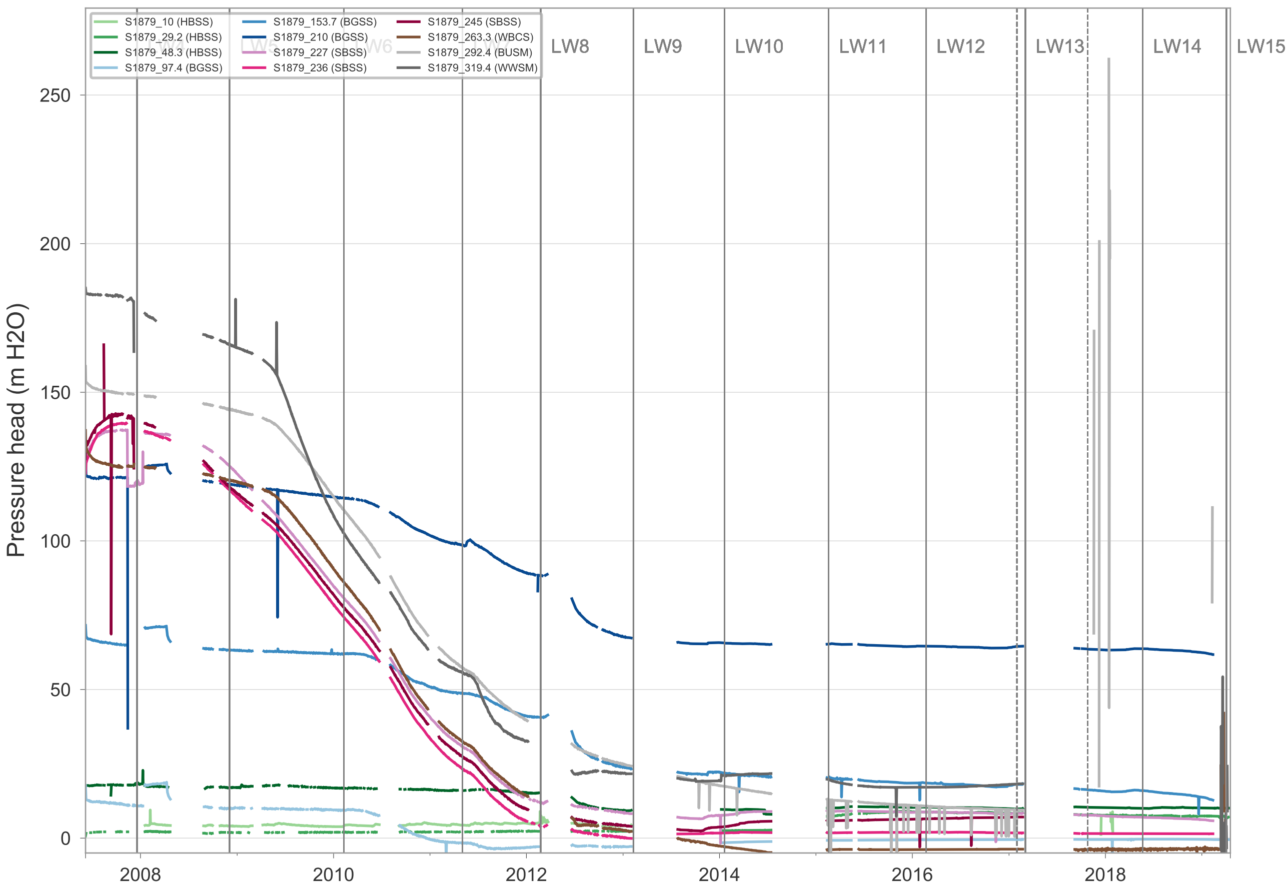

S1878
Piezometric head (m RL)
Ground RL
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
350
300
250
200
150
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
S1878_10 (BHCS)
S1878_25 (BGSS)
S1878_71 (BGSS)
S1878_118 (BGSS)
S1878_145.5 (SBSS)
S1878_157.2 (SBSS)
S1878_169 (SBSS)
S1878_188 (WBCS)
S1878_212 (CCSS)
S1878_223.1 (BUSM)
S1878_252.8 (WWSM)
Lake Cordeaux
Hawkesbury Sst


S1878
Pressure head (m H2O)
LW4
LW5
LW6
LW7
LW8
160
140
120
100
80
60
40
20
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
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)

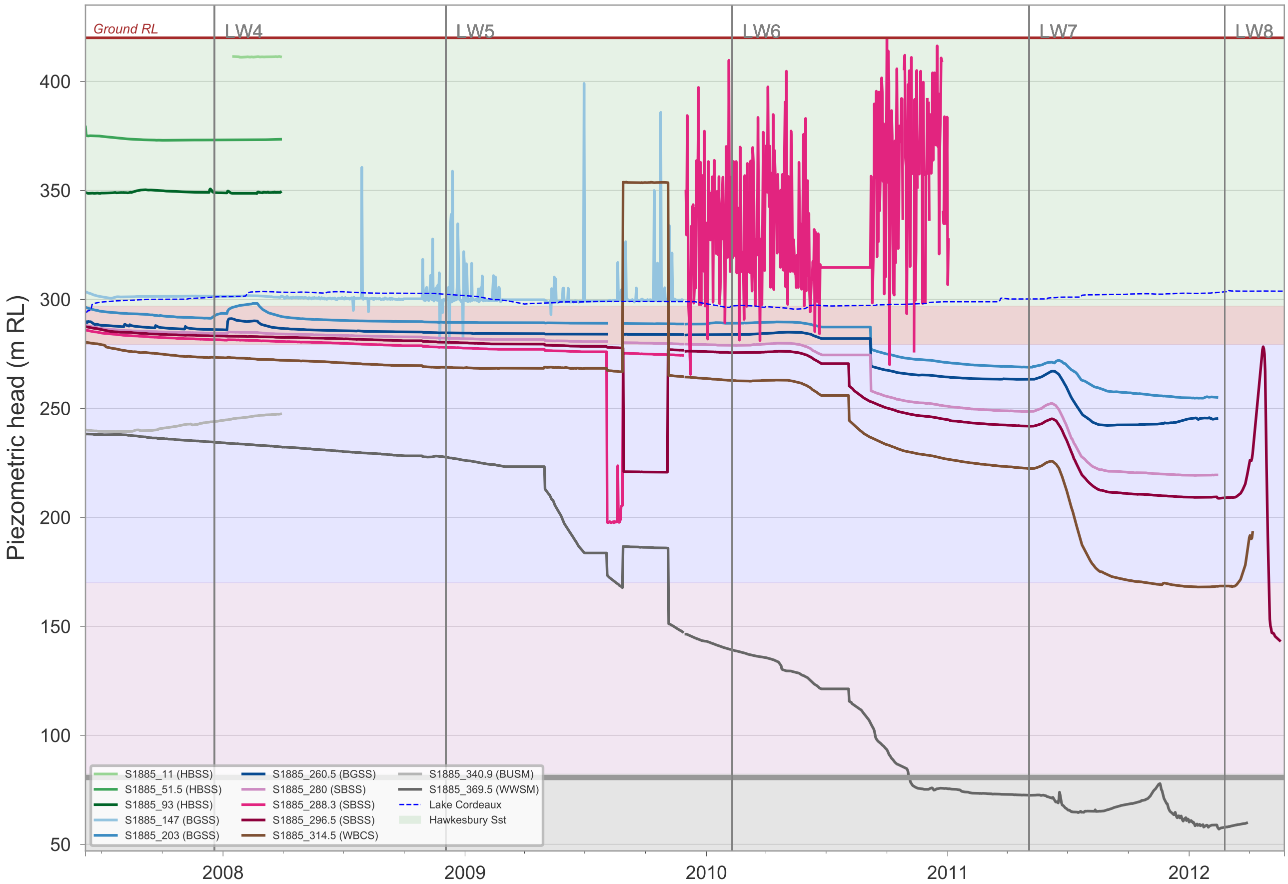
S1879


Ground RL
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
Piezometric head (m RL)
350
300
250
200
150
100
50
2008
2010
2012
2014
2016
2018
S1879_10 (HBSS)
S1879_29.2 (HBSS)
S1879_48.3 (HBSS)
S1879_97.4 (BGSS)
S1879_153.7 (BGSS)
S1879_210 (BGSS)
S1879_227 (SBSS)
S1879_236 (SBSS)
S1879_245 (SBSS)
S1879_263.3 (WBCS)
S1879_292.4 (BUSM)
S1879_319.4 (WWSM)
Lake Cordeaux
Hawkesbury Sst

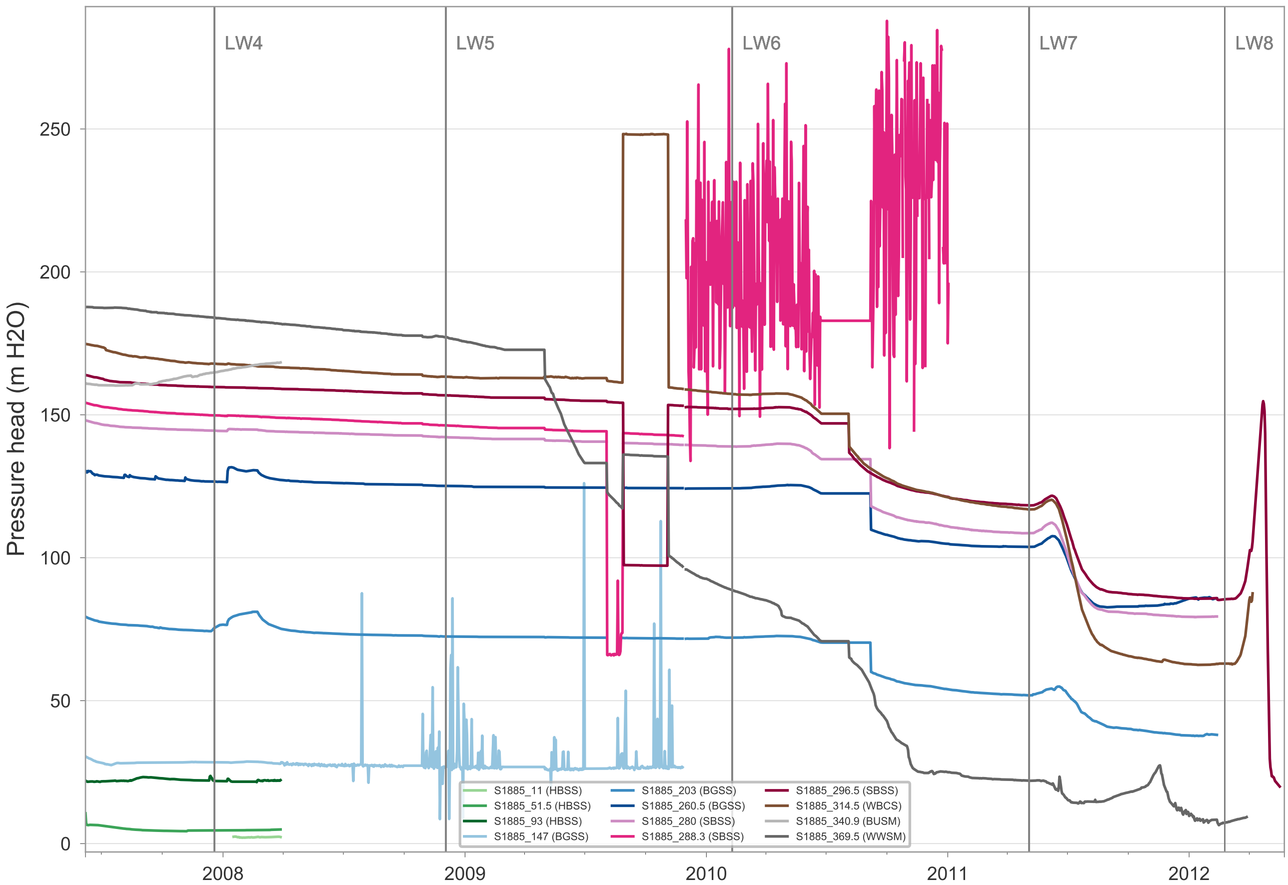
S1879

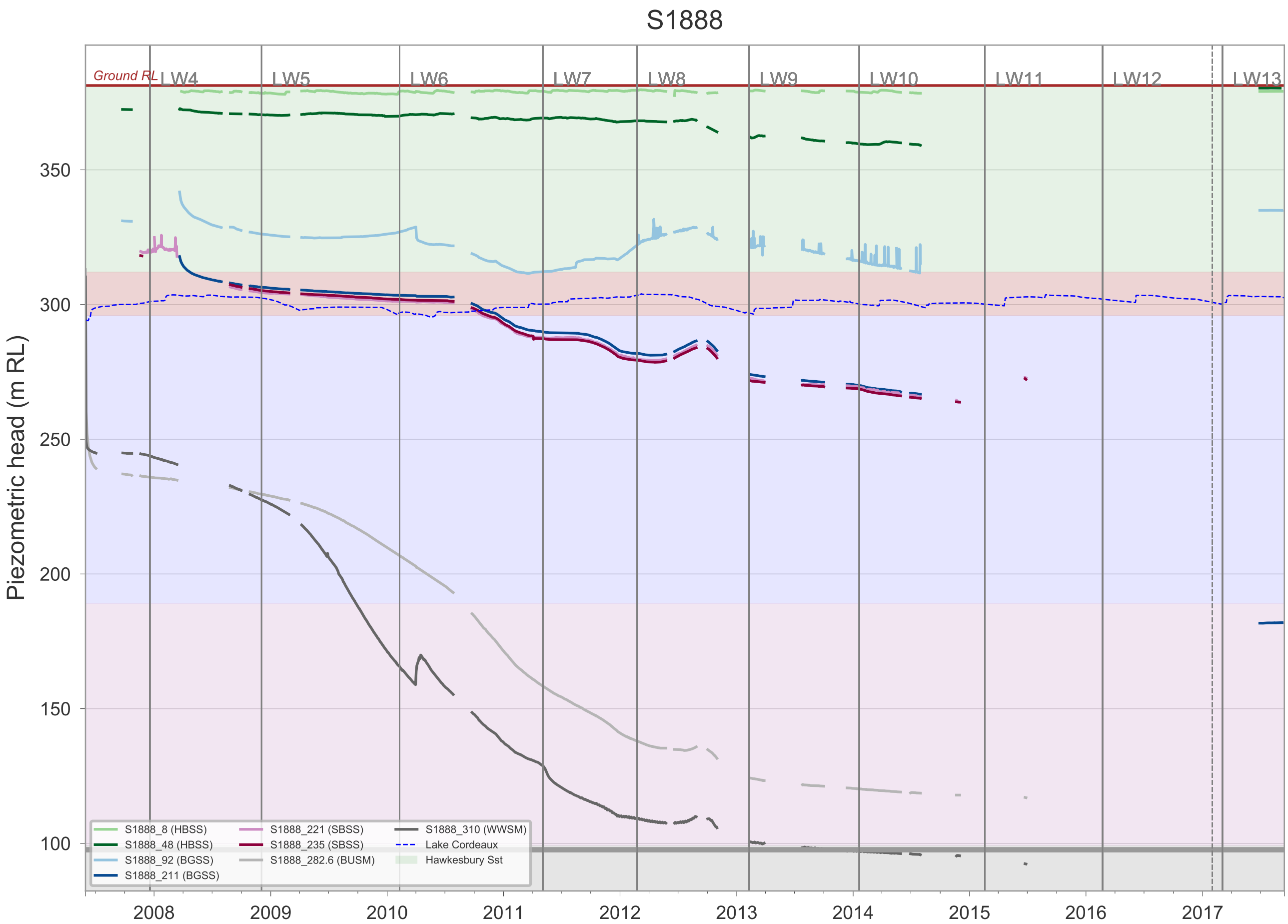

LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
Pressure head (m H2O)
250
200
150
100
50
0
2008
2010
2012
2014
2016
2018
S1879_10 (HBSS)
S1879_29.2 (HBSS)
S1879_48.3 (HBSS)
S1879_97.4 (BGSS)
S1879_153.7 (BGSS)
S1879_210 (BGSS)
S1879_227 (SBSS)
S1879_236 (SBSS)
S1879_245 (SBSS)
S1879_263.3 (WBCS)
S1879_292.4 (BUSM)
S1879_319.4 (WWSM)

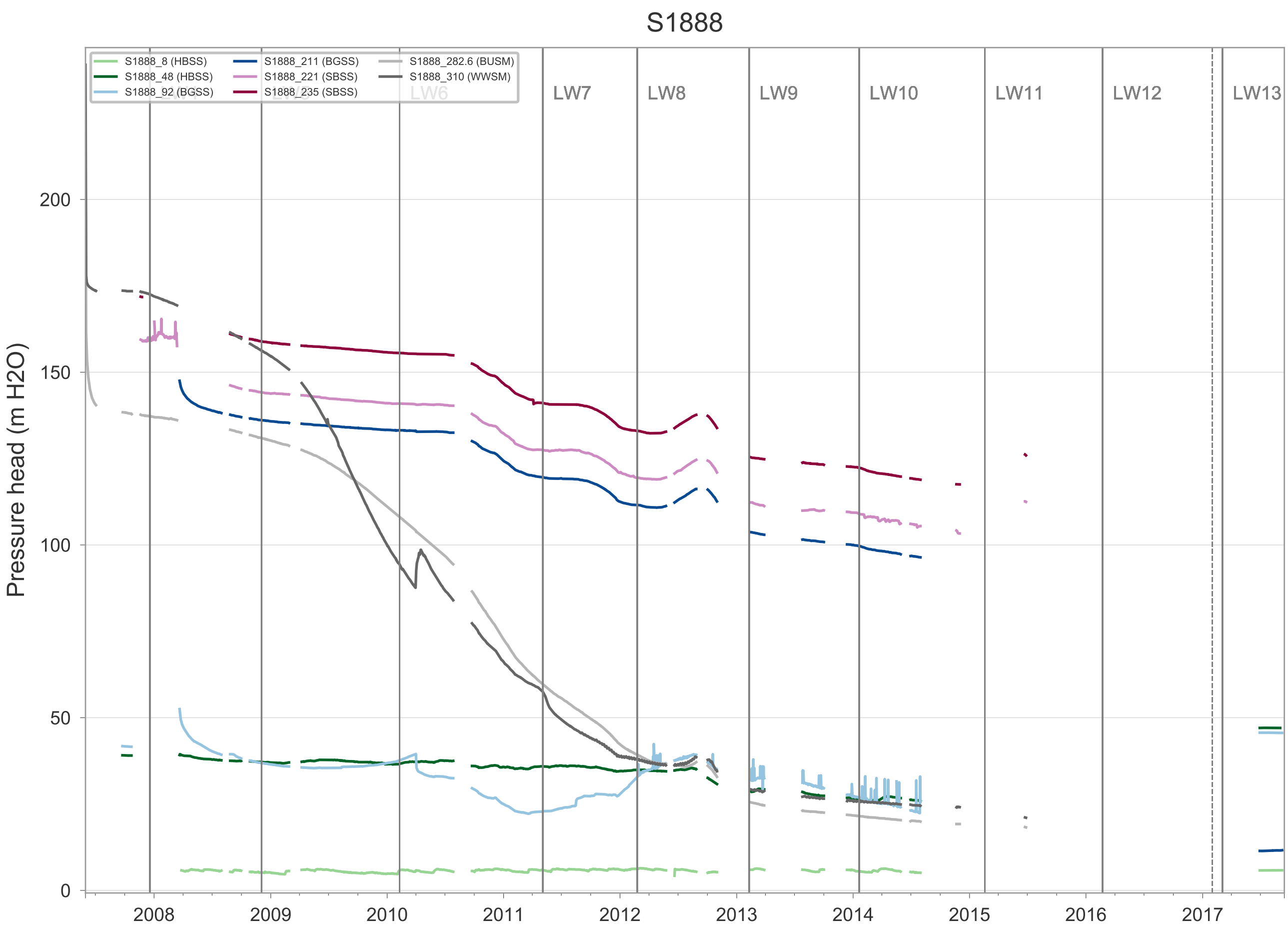
S1885


Ground RL
LW4
LW5
LW6
LW7
LW8
Piezometric head (m RL)
400
350
300
250
200
150
100
50
2008
2009
2010
2011
2012
S1885_11 (HBSS)
S1885_51.5 (HBSS)
S1885_93 (HBSS)
S1885_147 (BGSS)
S1885_203 (BGSS)
S1885_260.5 (BGSS)
S1885_280 (SBSS)
S1885_288.3 (SBSS)
S1885_296.5 (SBSS)
S1885_314.5 (WBCS)
S1885_340.9 (BUSM)
S1885_369.5 (WWSM)
Lake Cordeaux
Hawkesbury Sst

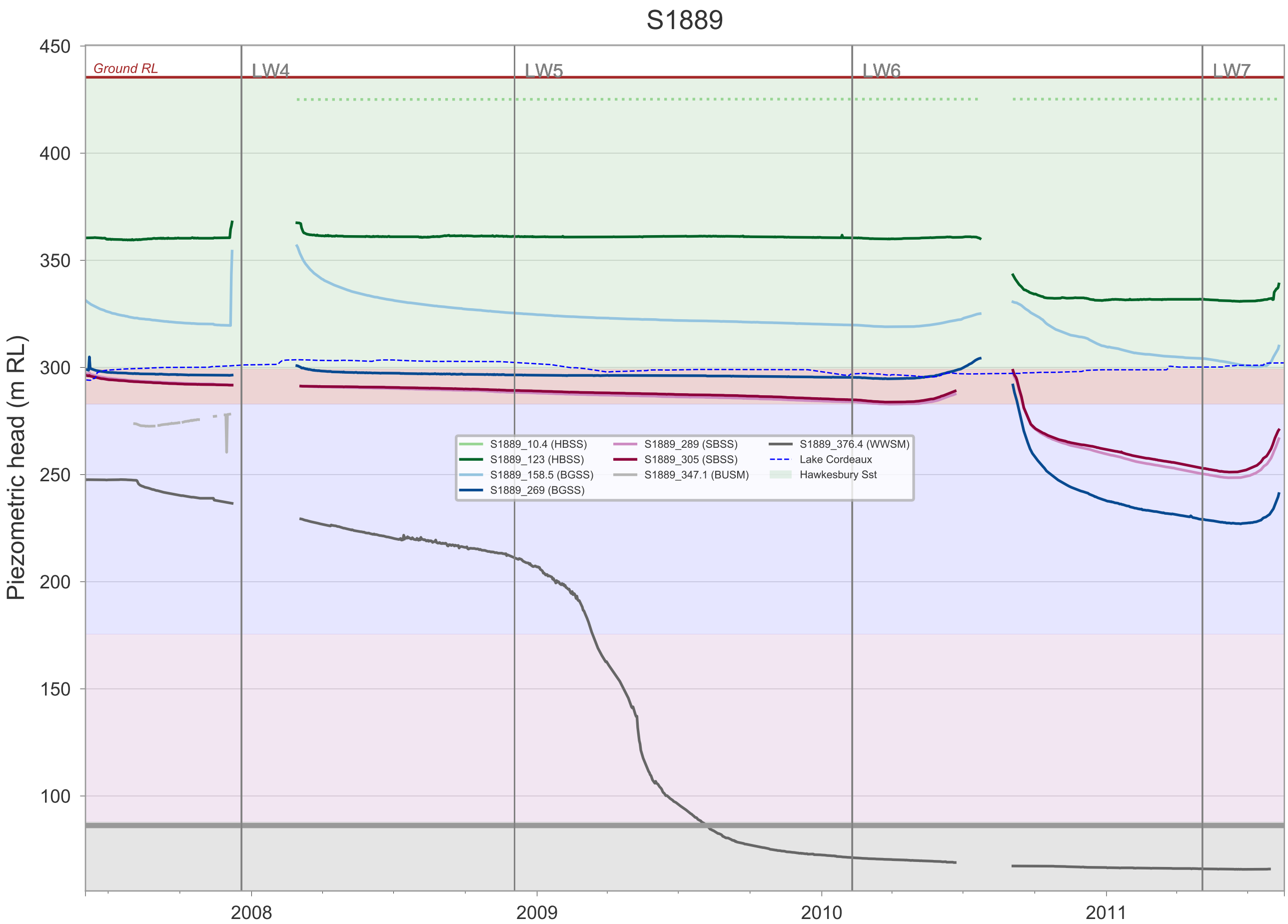
S1885

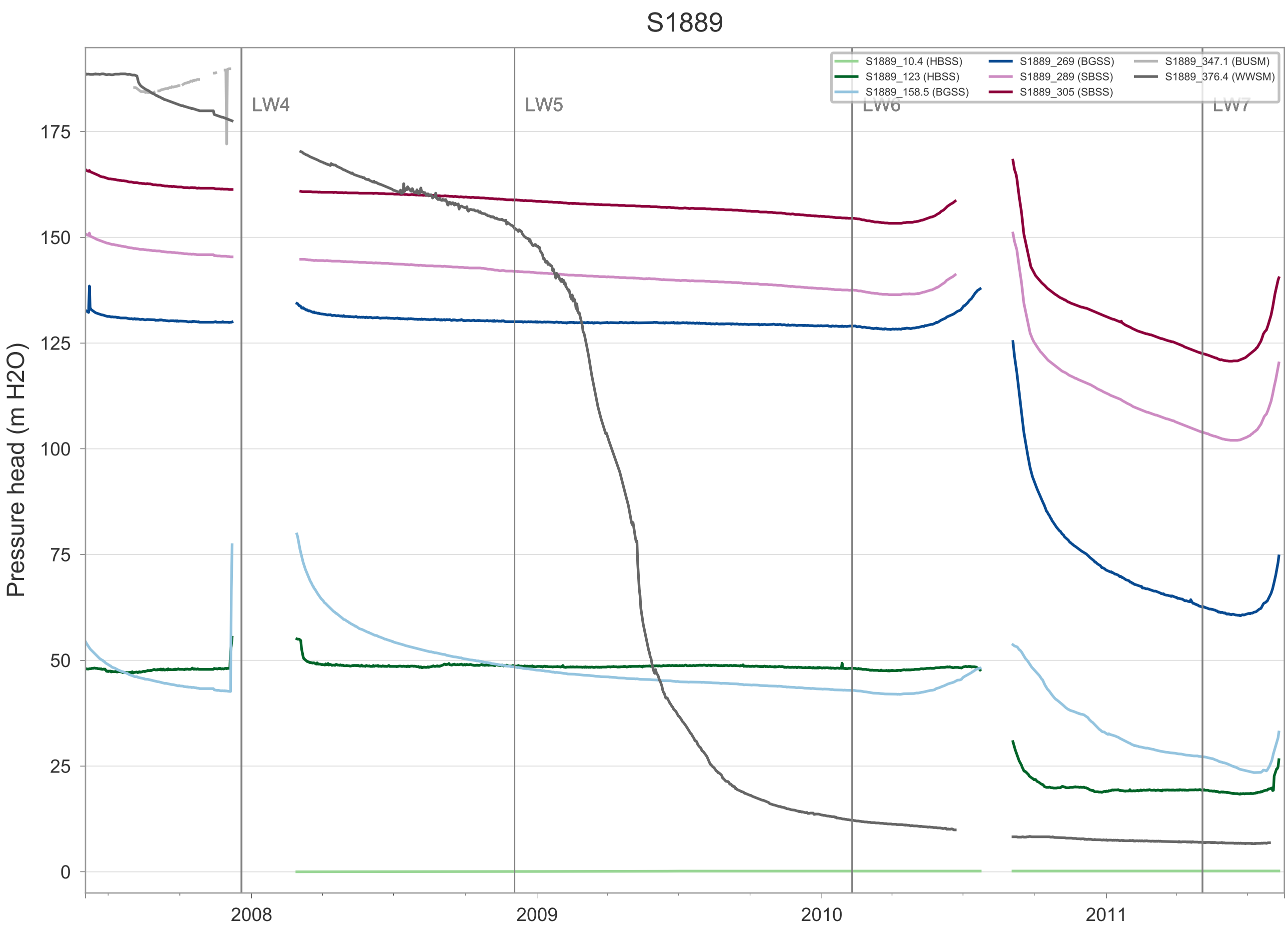

LW4
LW5
LW6
LW7
LW8
Pressure head (m H2O)
250
200
150
100
50
0
2008
2009
2010
2011
2012
S1885_11 (HBSS)
S1885_51.5 (HBSS)
S1885_93 (HBSS)
S1885_147 (BGSS)
S1885_203 (BGSS)
S1885_260.5 (BGSS)
S1885_280 (SBSS)
S1885_288.3 (SBSS)
S1885_296.5 (SBSS)
S1885_314.5 (WBCS)
S1885_340.9 (BUSM)
S1885_369.5 (WWSM)


S1888
Piezometric head (m RL)
Ground RL
LW4
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
350
300
250
200
150
100
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
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
Hawkesbury Sst

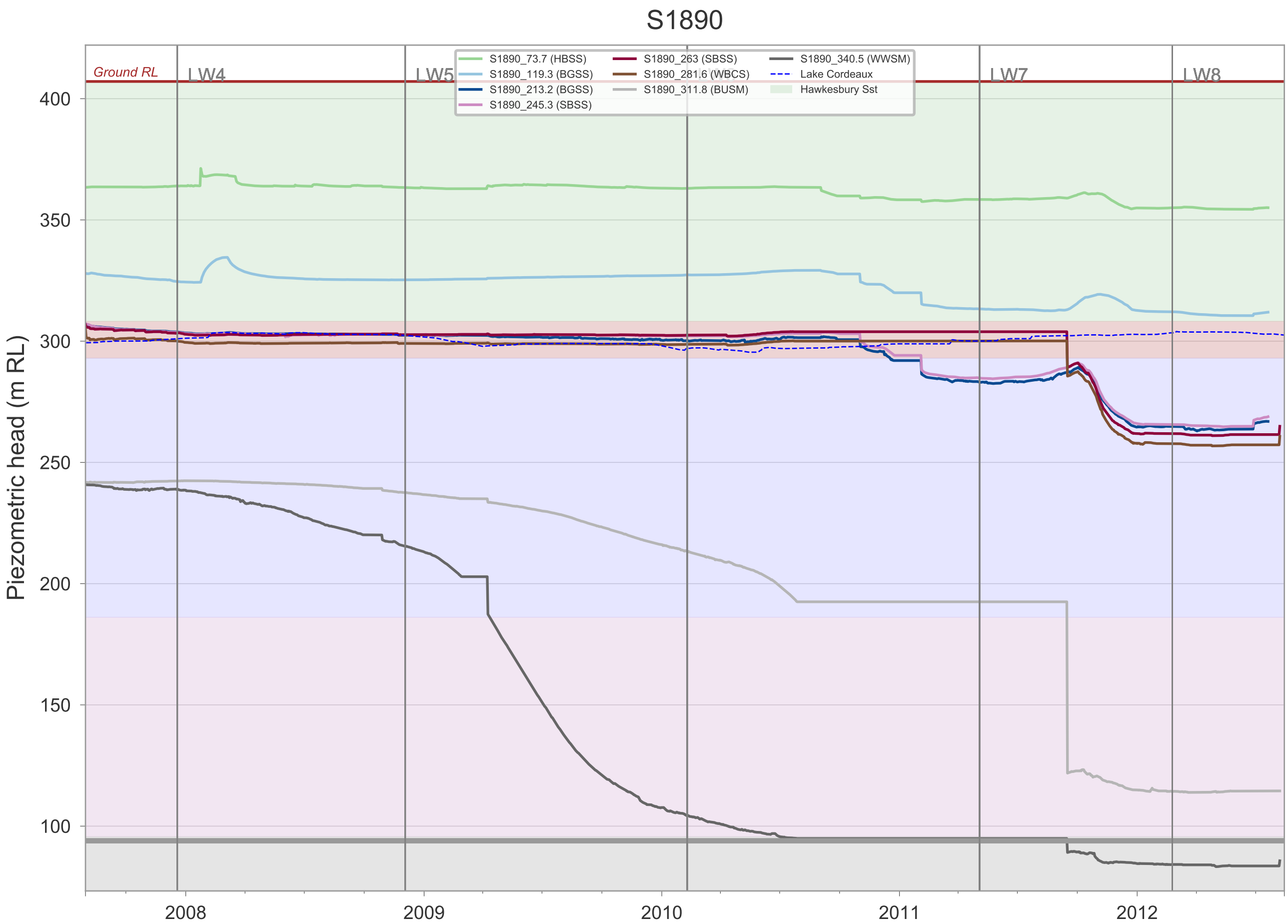

S1888
Pressure head (m H2O)
S1888_8 (HBSS)
S1888_48 (HBSS)
S1888_92 (BGSS)
S1888_211 (BGSS)
S1888_221 (SBSS)
S1888_235 (SBSS)
S1888_282.6 (BUSM)
S1888_310 (WWSM)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
200
150
100
50
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

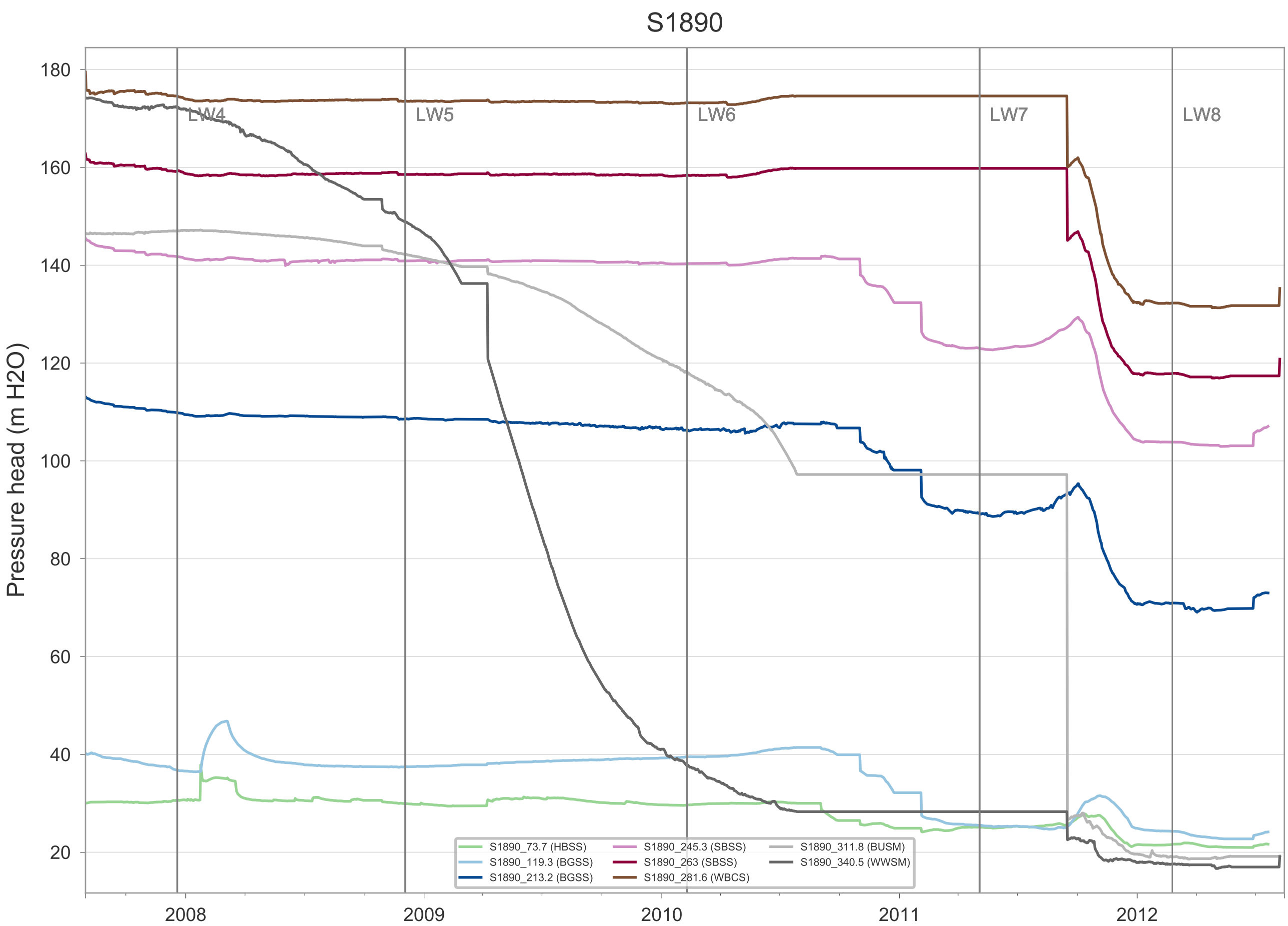
Groundwater hydrographs

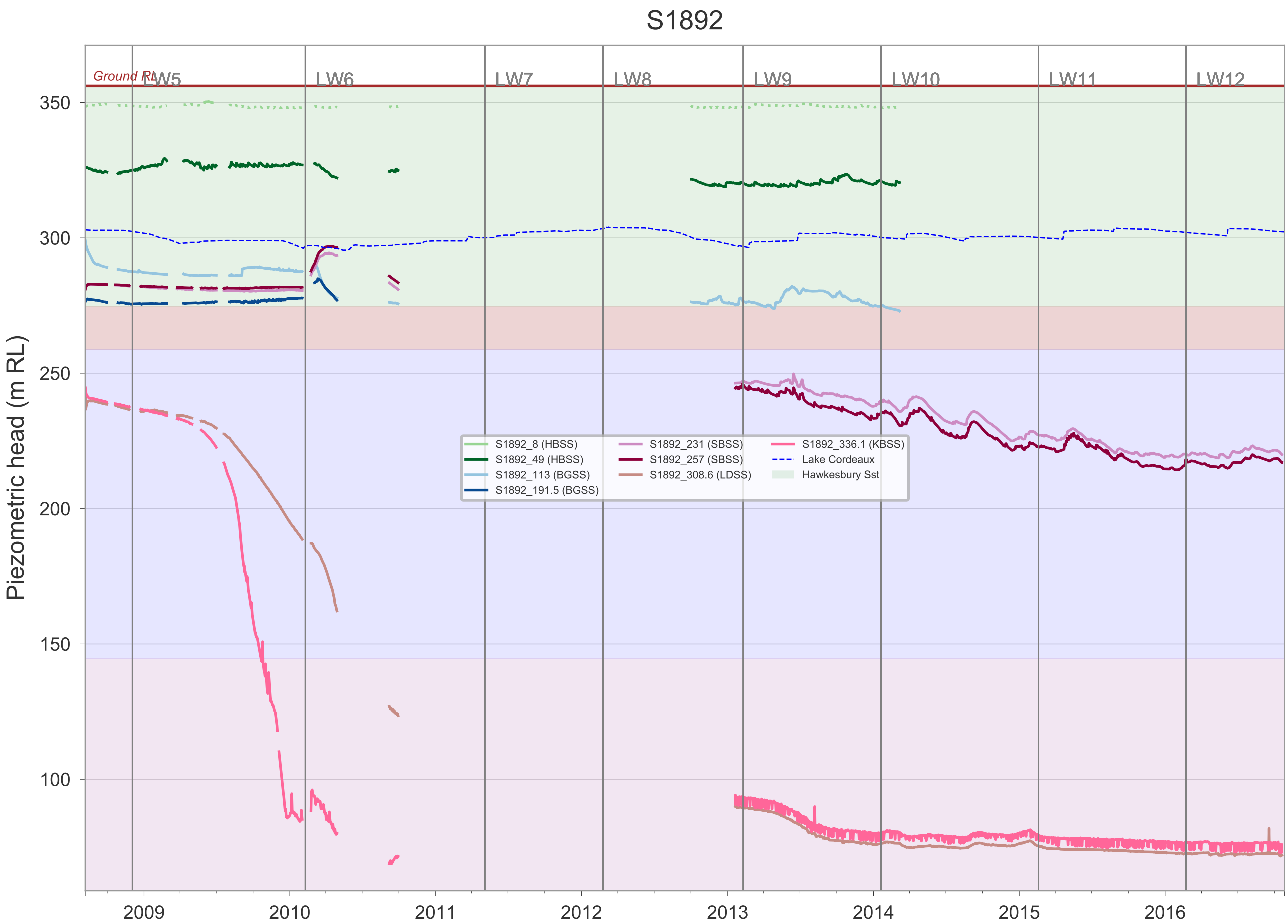




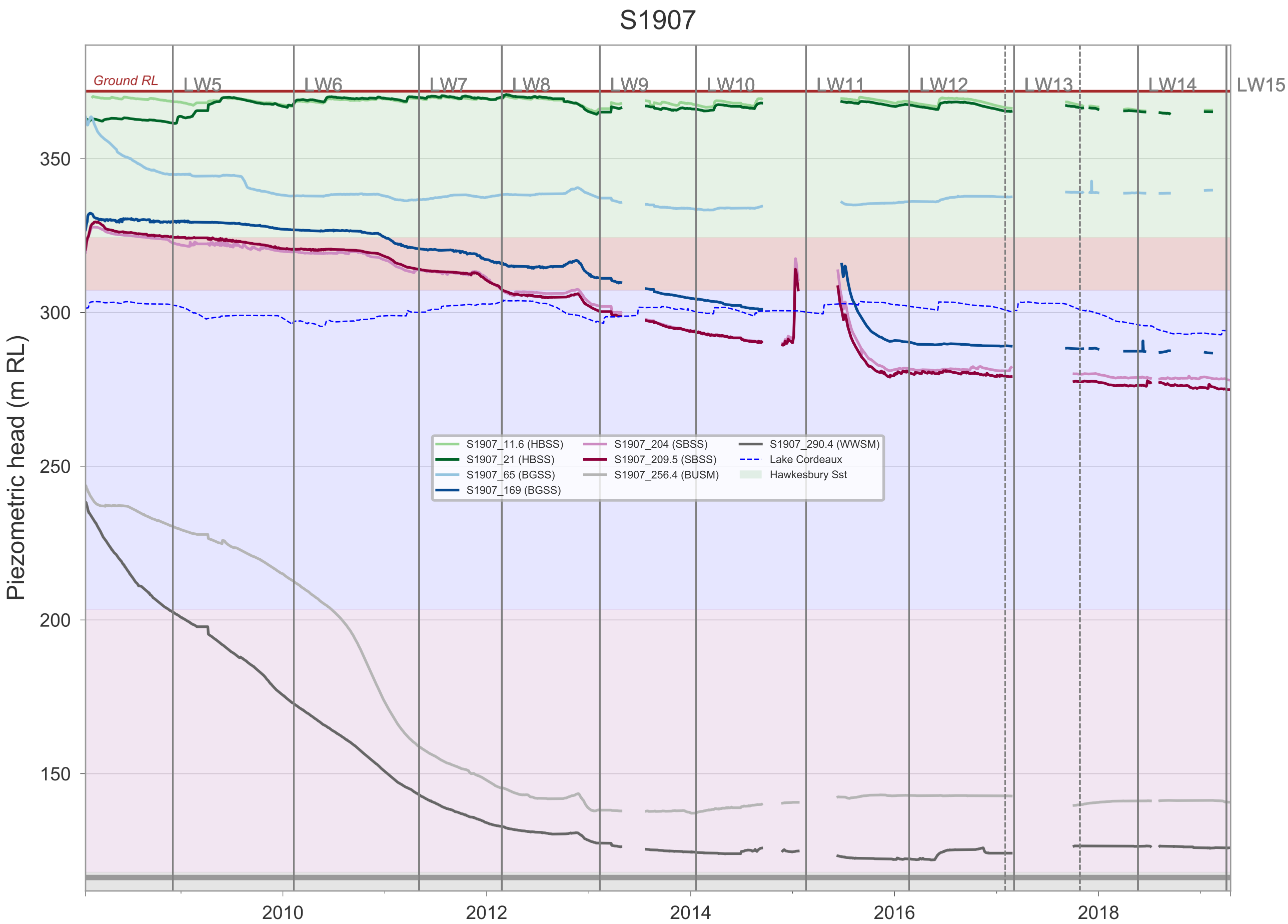
Groundwater hydrographs

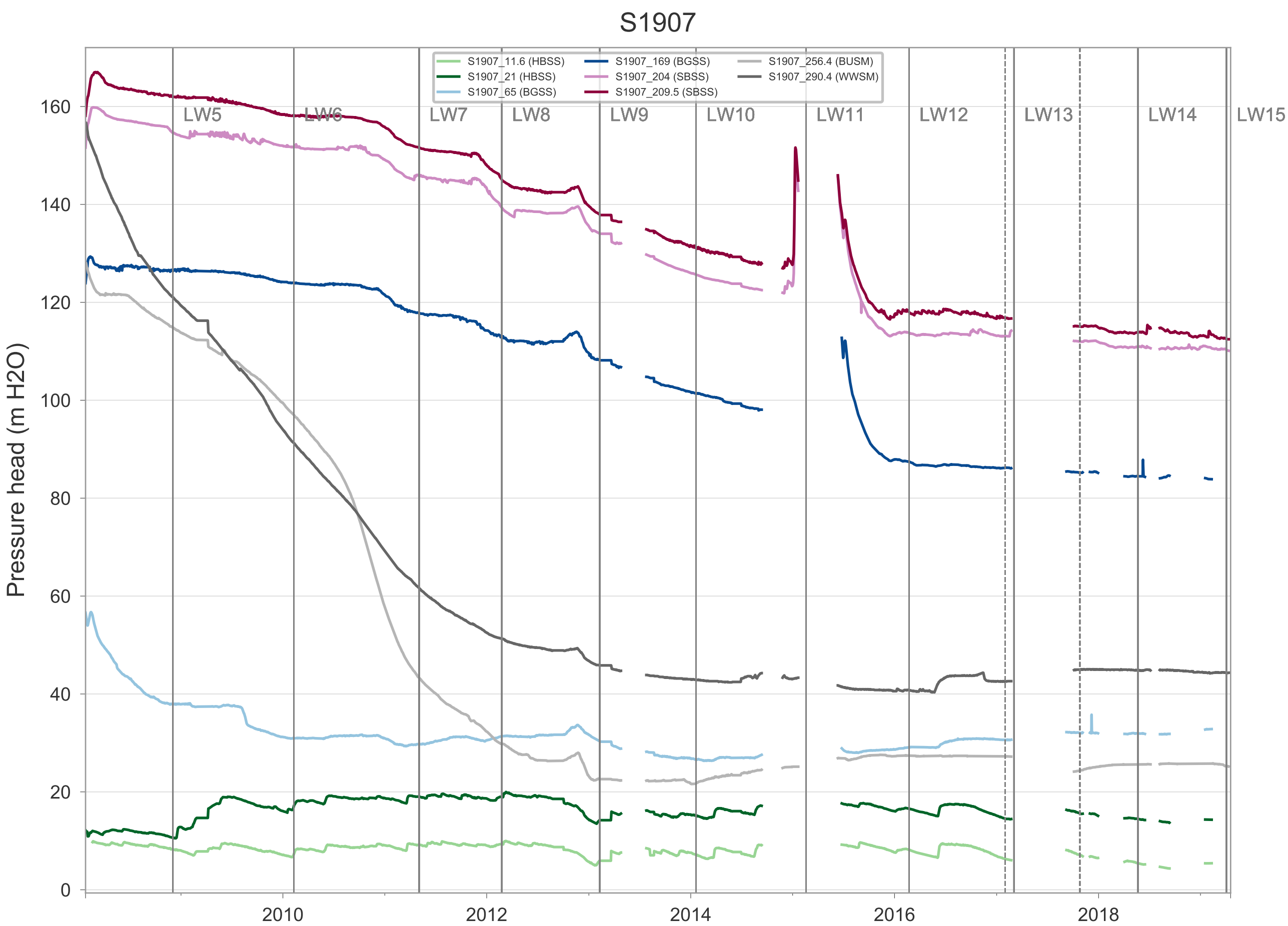


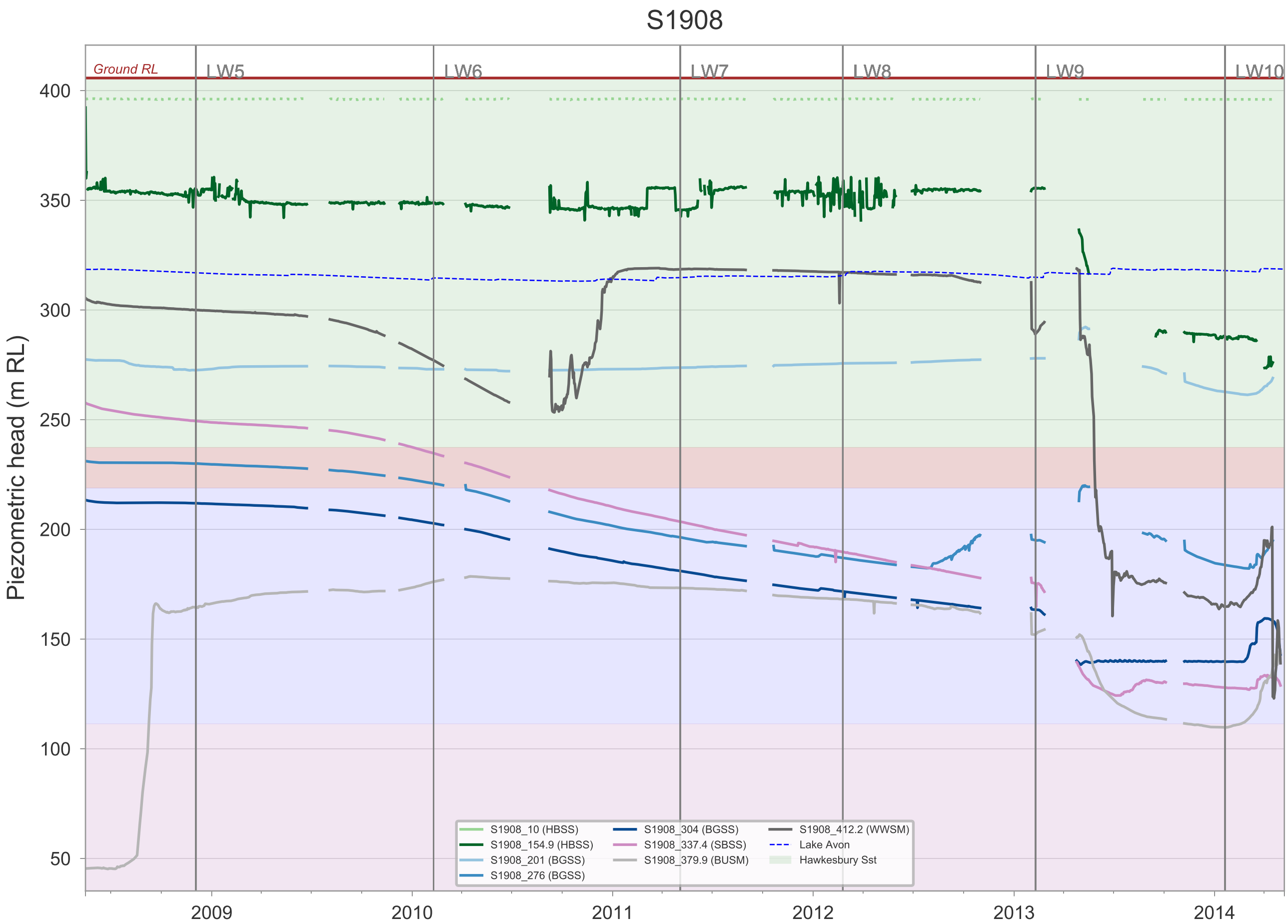


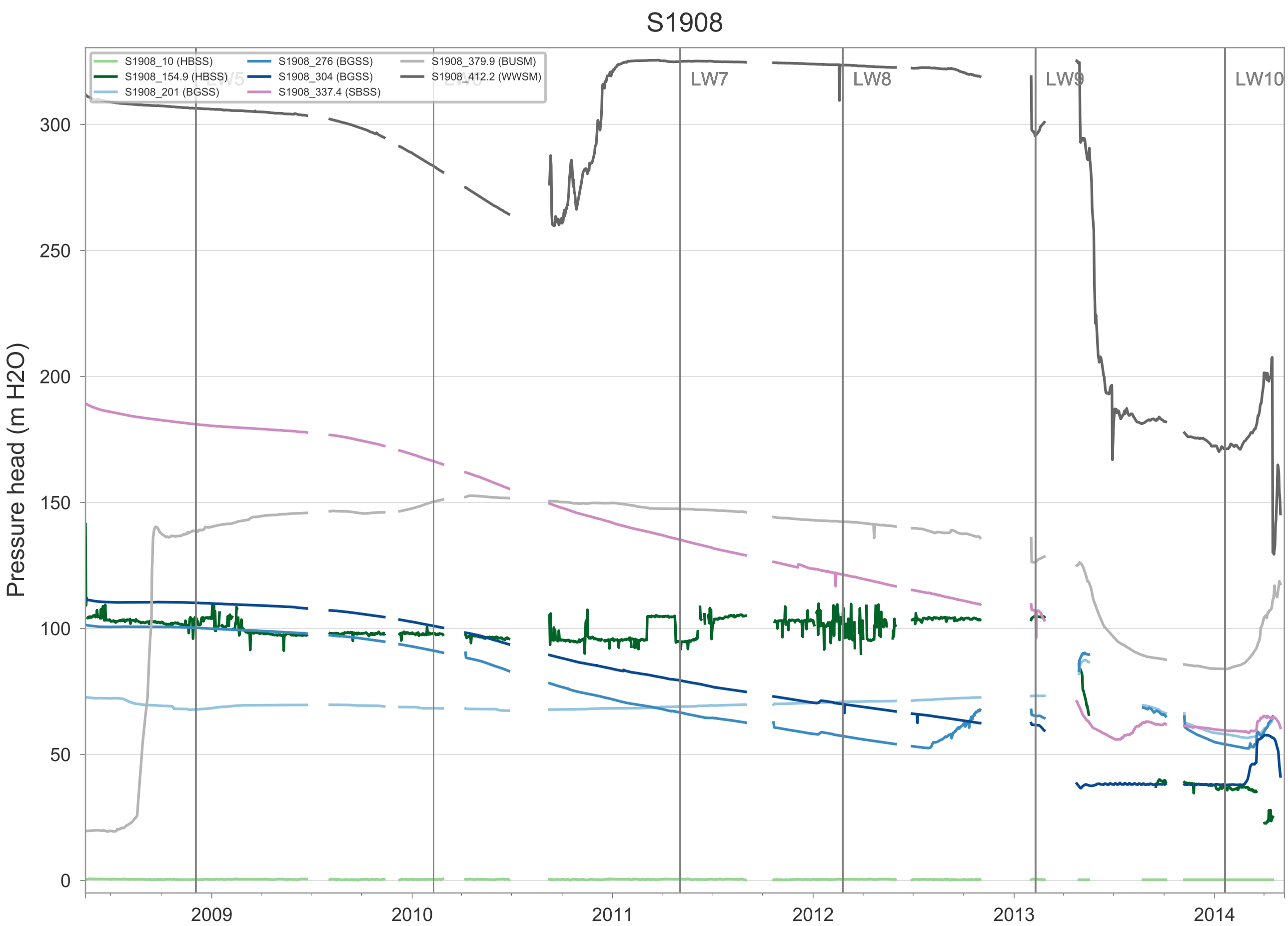

S1892
Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
Piezometric head (m RL)
350
300
250
200
150
100
2009
2010
2011
2012
2013
2014
2015
2016
S1892_8 (HBSS)
S1892_49 (HBSS)
S1892_113 (BGSS)
S1892_191.5 (BGSS)
S1892_231 (SBSS)
S1892_257 (SBSS)
S1892_308.6 (LDSS)
S1892_336.1 (KBSS)
Lake Cordeaux
Hawkesbury Sst


S1892
LW5
LW6
LW7
LW8
LW9
Pressure head (m H2O)
200
150
100
50
0
2009
2010
2011
2012
2013
2014
2015
2016
S1892_8 (HBSS)
S1892_49 (HBSS)
S1892_113 (BGSS)
S1892_191.5 (BGSS)
S1892_231 (SBSS)
S1892_257 (SBSS)
S1892_308.6 (LDSS)
S1892_336.1 (KBSS)

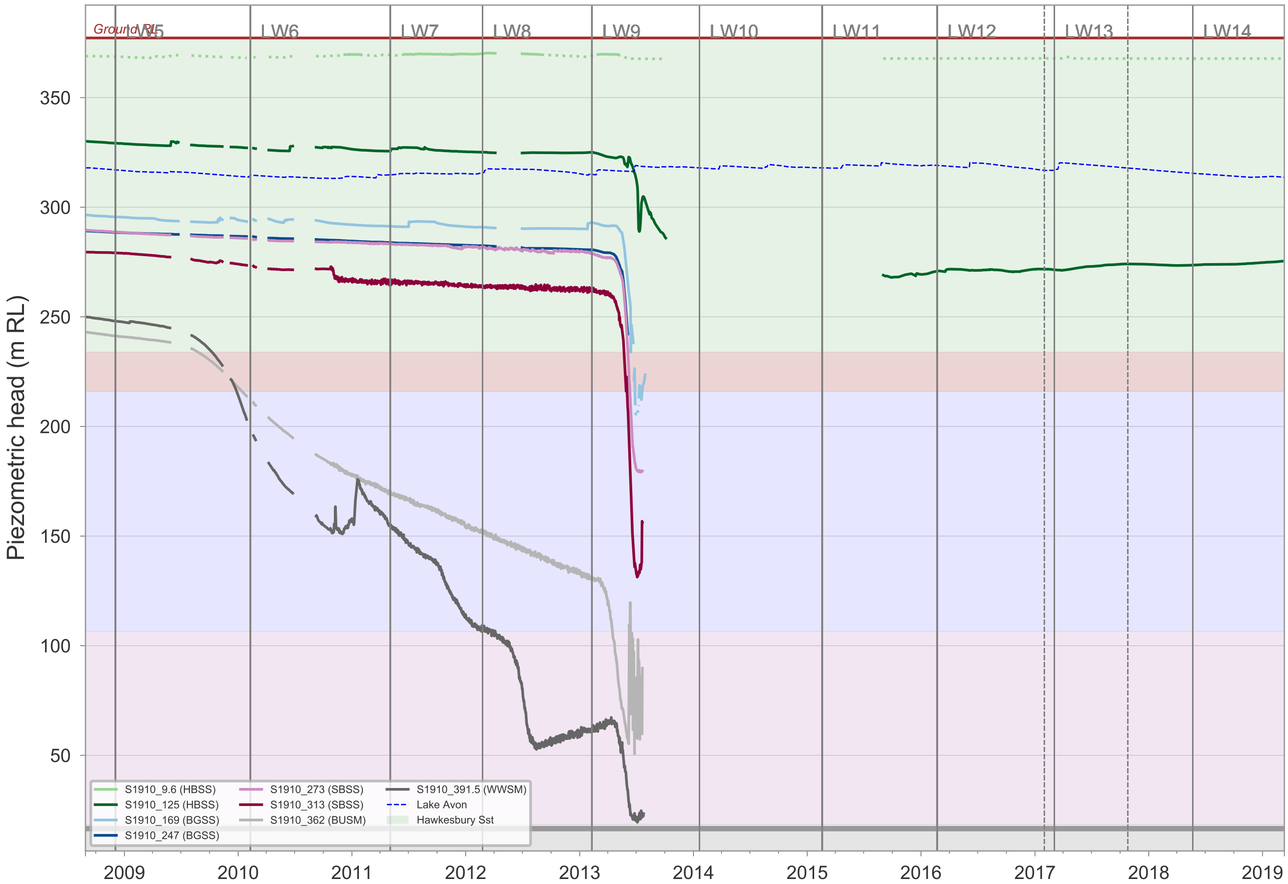

S1907
Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
Piezometric head (m RL)
350
300
250
200
150
2010
2012
2014
2016
2018
S1907_11.6 (HBSS)
S1907_21 (HBSS)
S1907_65 (BGSS)
S1907_169 (BGSS)
S1907_204 (SBSS)
S1907_209.5 (SBSS)
S1907_256.4 (BUSM)
S1907_290.4 (WWSM)
Lake Cordeaux
Hawkesbury Sst


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)
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
Pressure head (m H2O)
160
140
120
100
80
60
40
20
0
2010
2012
2014
2016
2018

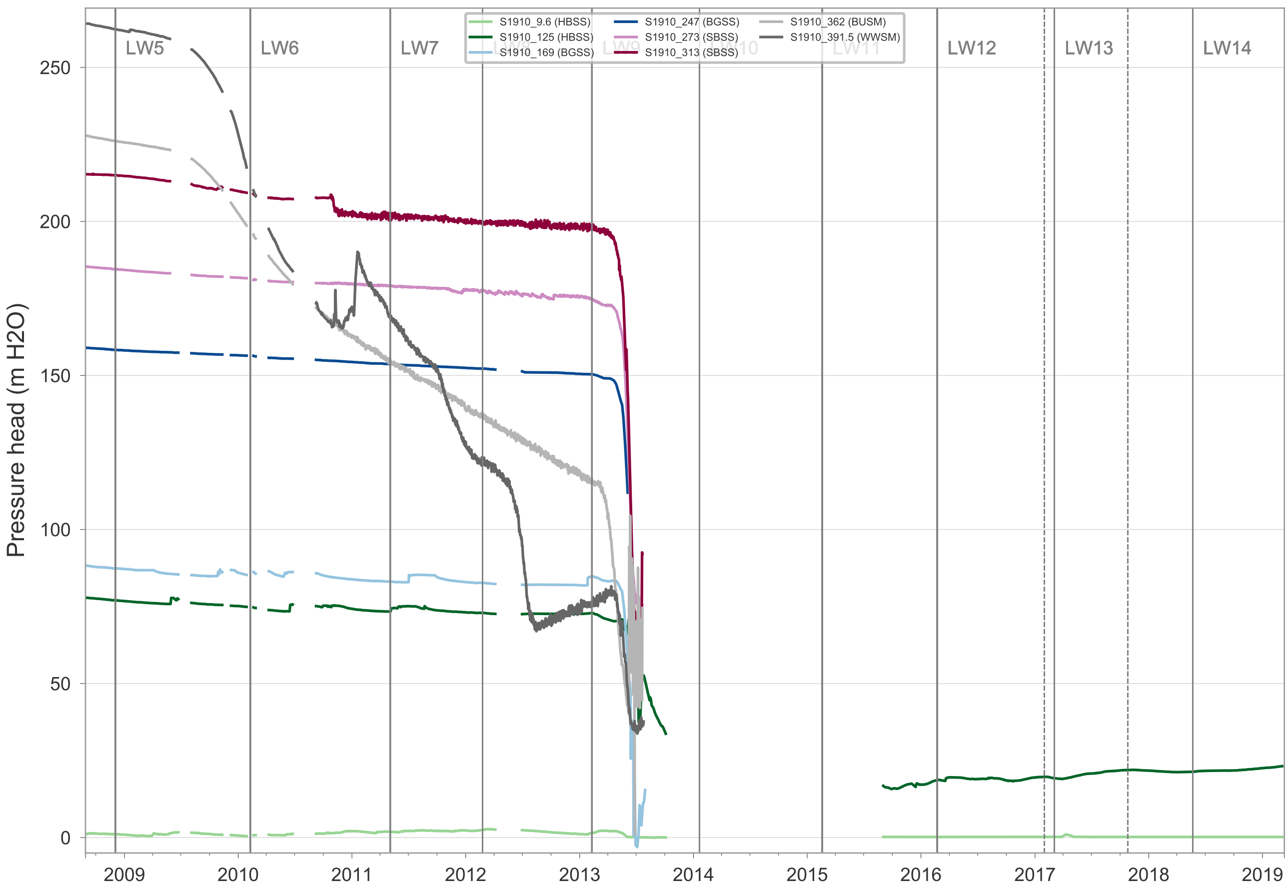

S1908
Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
Piezometric head (m RL)
400
350
300
250
200
150
100
50
2009
2010
2011
2012
2013
2014
S1908_10 (HBSS)
S1908_154.9 (HBSS)
S1908_201 (BGSS)
S1908_276 (BGSS)
S1908_304 (BGSS)
S1908_337.4 (SBSS)
S1908_379.9 (BUSM)
S1908_412.2 (WWSM)
Lake Avon
Hawkesbury Sst

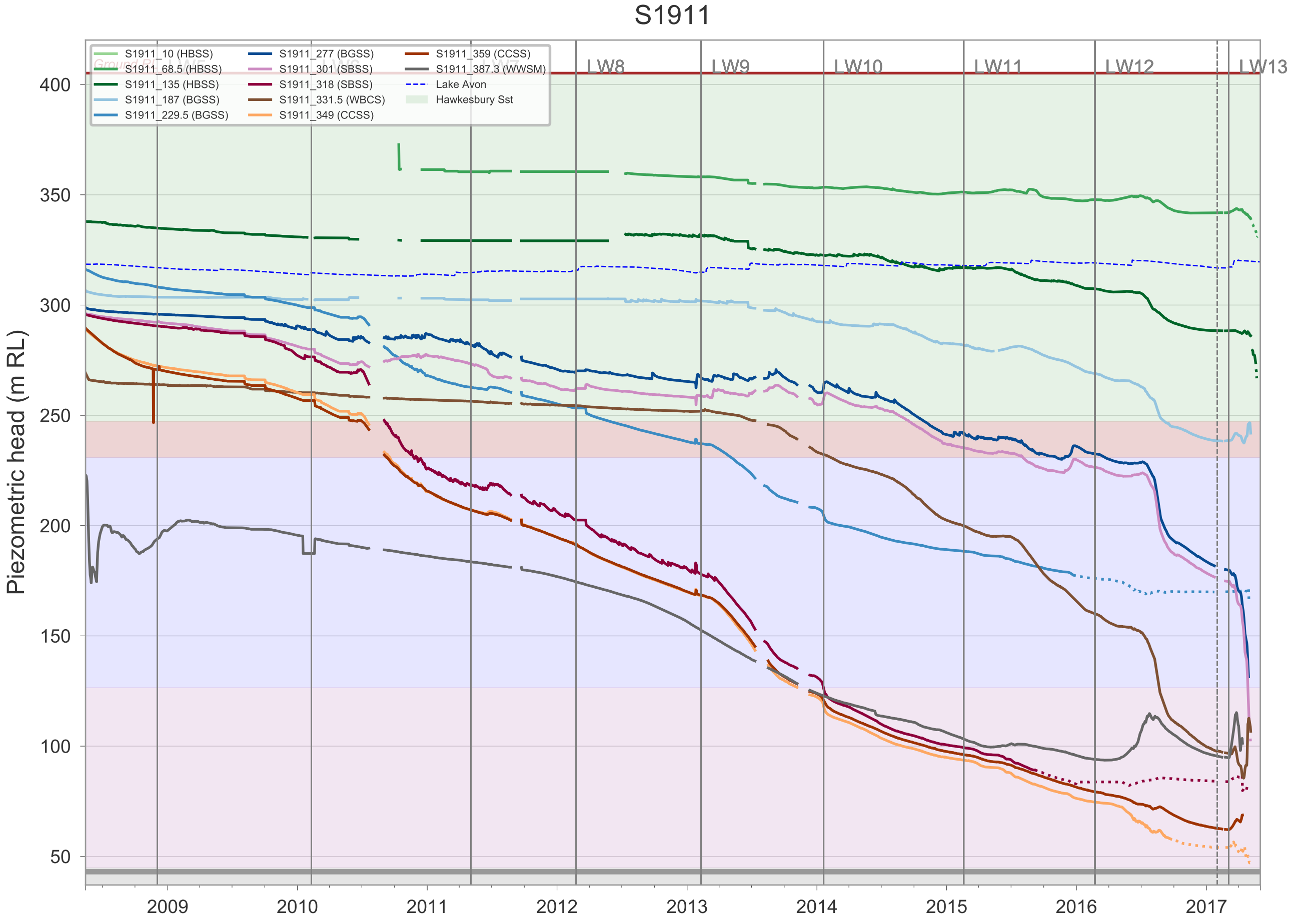

S1908
LW7
LW8
LW9
LW10
Pressure head (m H2O)
300
250
200
150
100
50
0
2009
2010
2011
2012
2013
2014
S1908_10 (HBSS)
S1908_154.9 (HBSS)
S1908_201 (BGSS)
S1908_276 (BGSS)
S1908_304 (BGSS)
S1908_337.4 (SBSS)
S1908_379.9 (BUSM)
S1908_412.2 (WWSM)

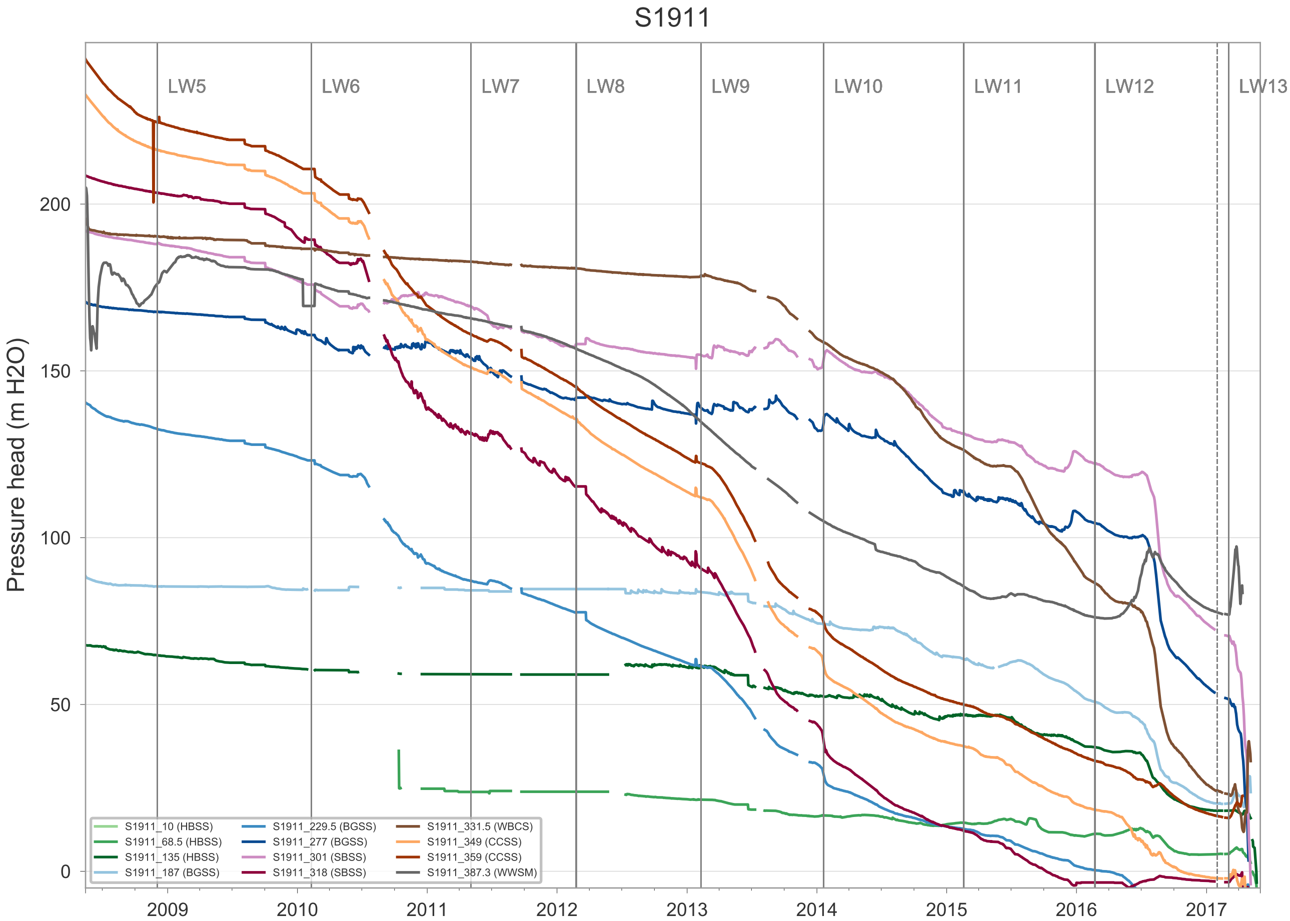
S1910

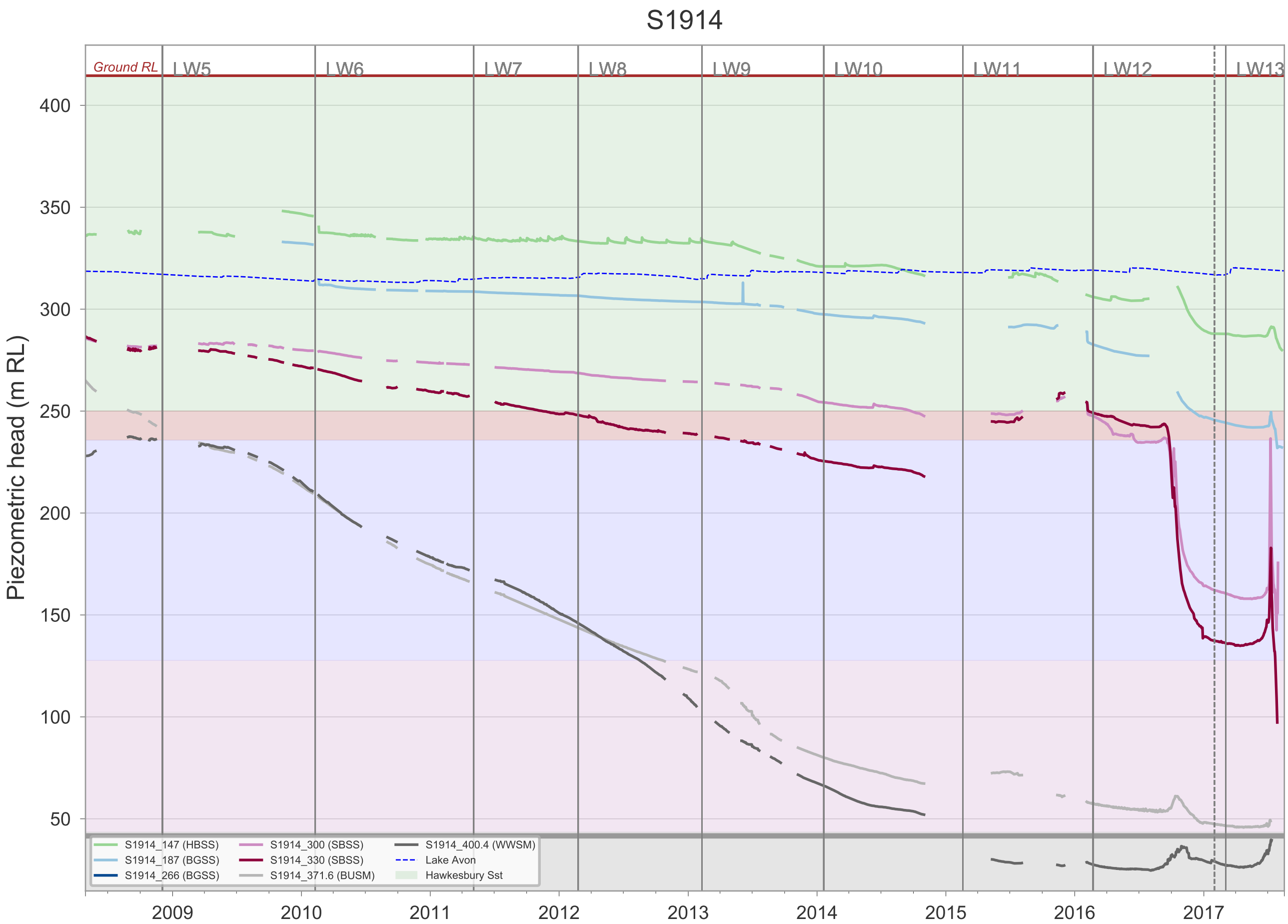

Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
Piezometric head (m RL)
350
300
250
200
150
100
50
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
S1910_9.6 (HBSS)
S1910_125 (HBSS)
S1910_169 (BGSS)
S1910_247 (BGSS)
S1910_273 (SBSS)
S1910_313 (SBSS)
S1910_362 (BUSM)
S1910_391.5 (WWSM)
Lake Avon
Hawkesbury Sst

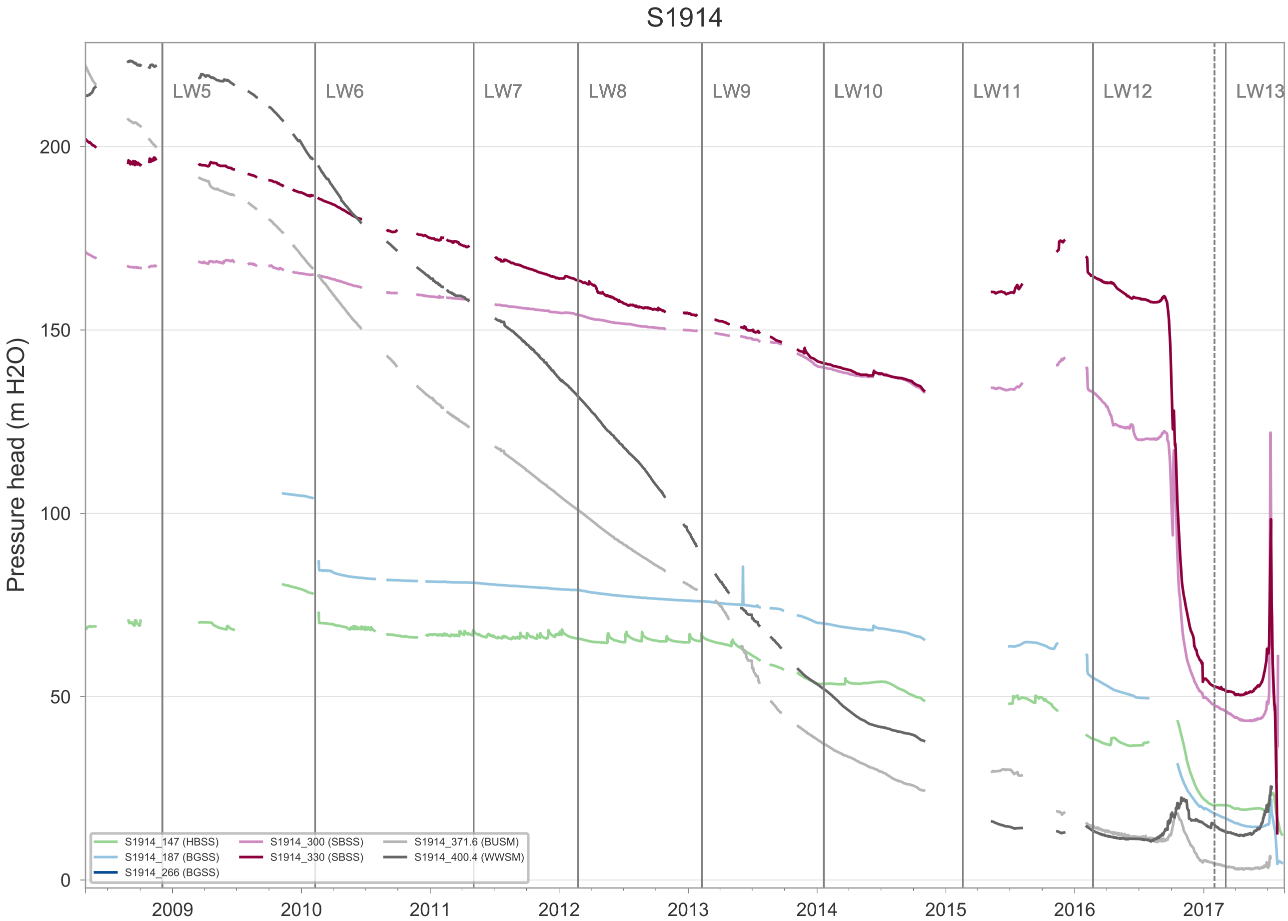
S1910

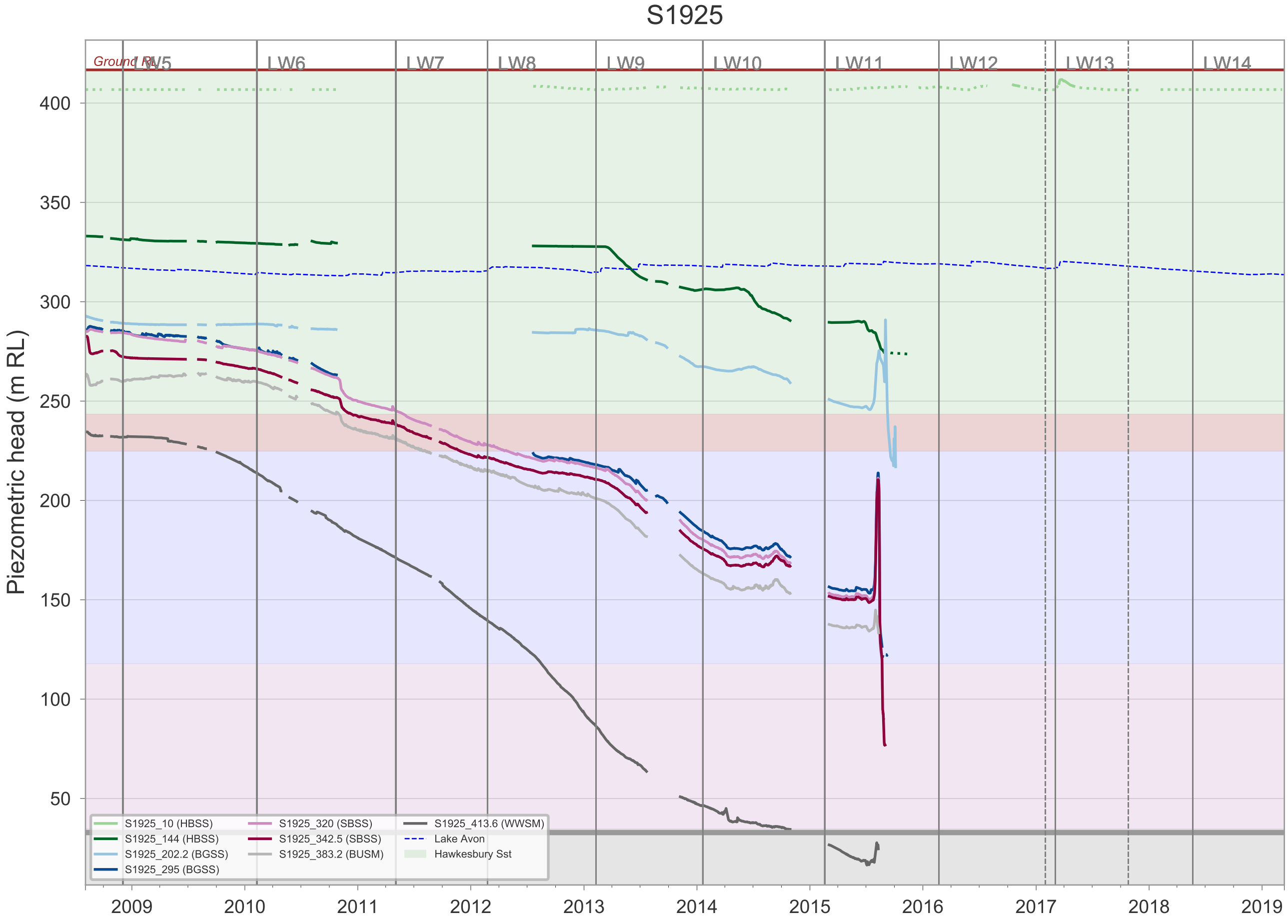

LW5
LW6
LW7
LW9
LW10
LW11
LW12
LW13
LW14
Pressure head (m H2O)
250
200
150
100
50
0
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
S1910_9.6 (HBSS)
S1910_125 (HBSS)
S1910_169 (BGSS)
S1910_247 (BGSS)
S1910_273 (SBSS)
S1910_313 (SBSS)
S1910_362 (BUSM)
S1910_391.5 (WWSM)

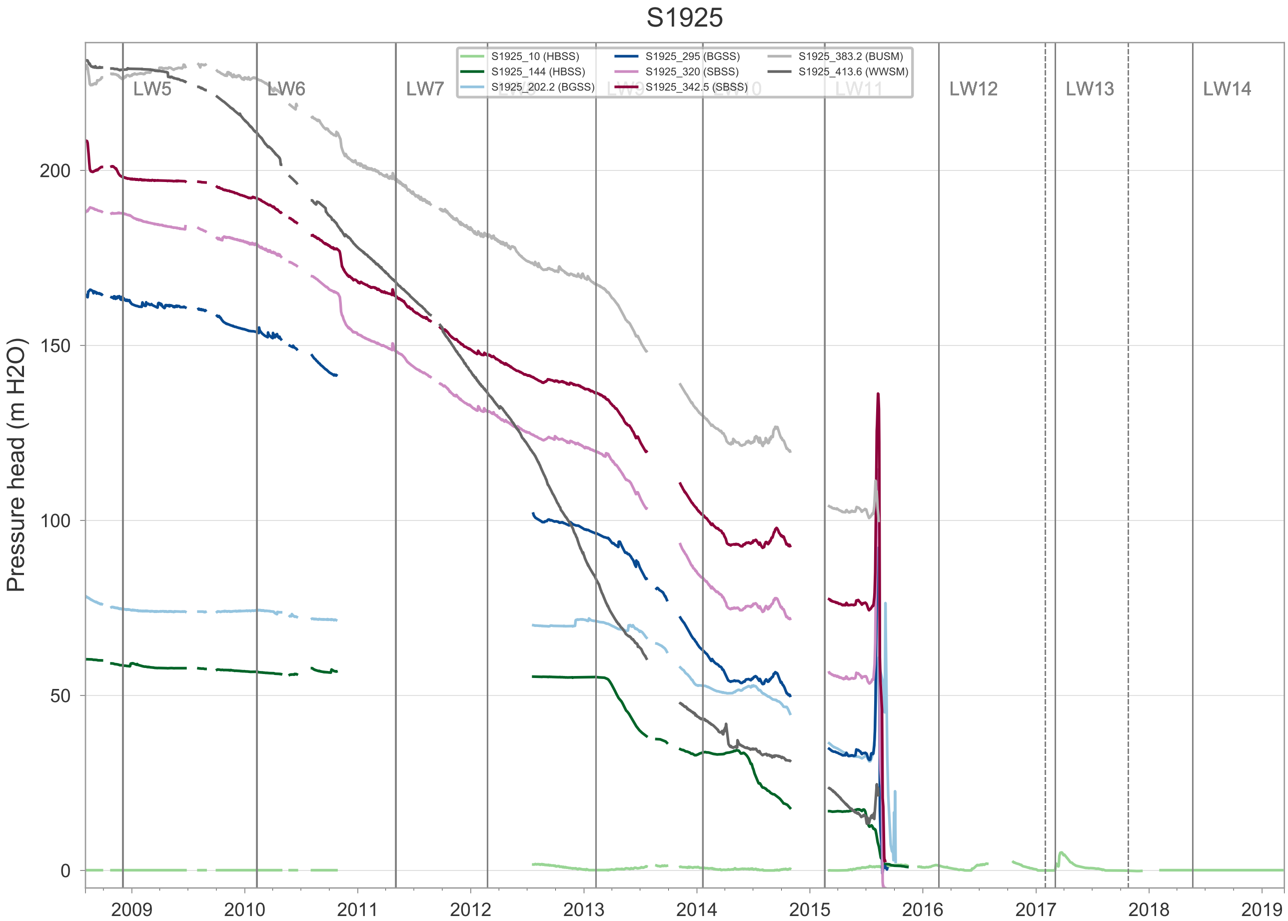

S1911
S1911_10 (HBSS)
S1911_68.5 (HBSS)
S1911_135 (HBSS)
S1911_187 (BGSS)
S1911_229.5 (BGSS)
S1911_277 (BGSS)
S1911_301 (SBSS)
S1911_318 (SBSS)
S1911_331.5 (WBCS)
S1911_349 (CCSS)
S1911_359 (CCSS)
S1911_387.3 (WWSM)
Lake Avon
Hawkesbury Sst
LW8
LW9
LW10
LW11
LW12
LW13
Piezometric head (m RL)
400
350
300
250
200
150
100
50
2009
2010
2011
2012
2013
2014
2015
2016
2017

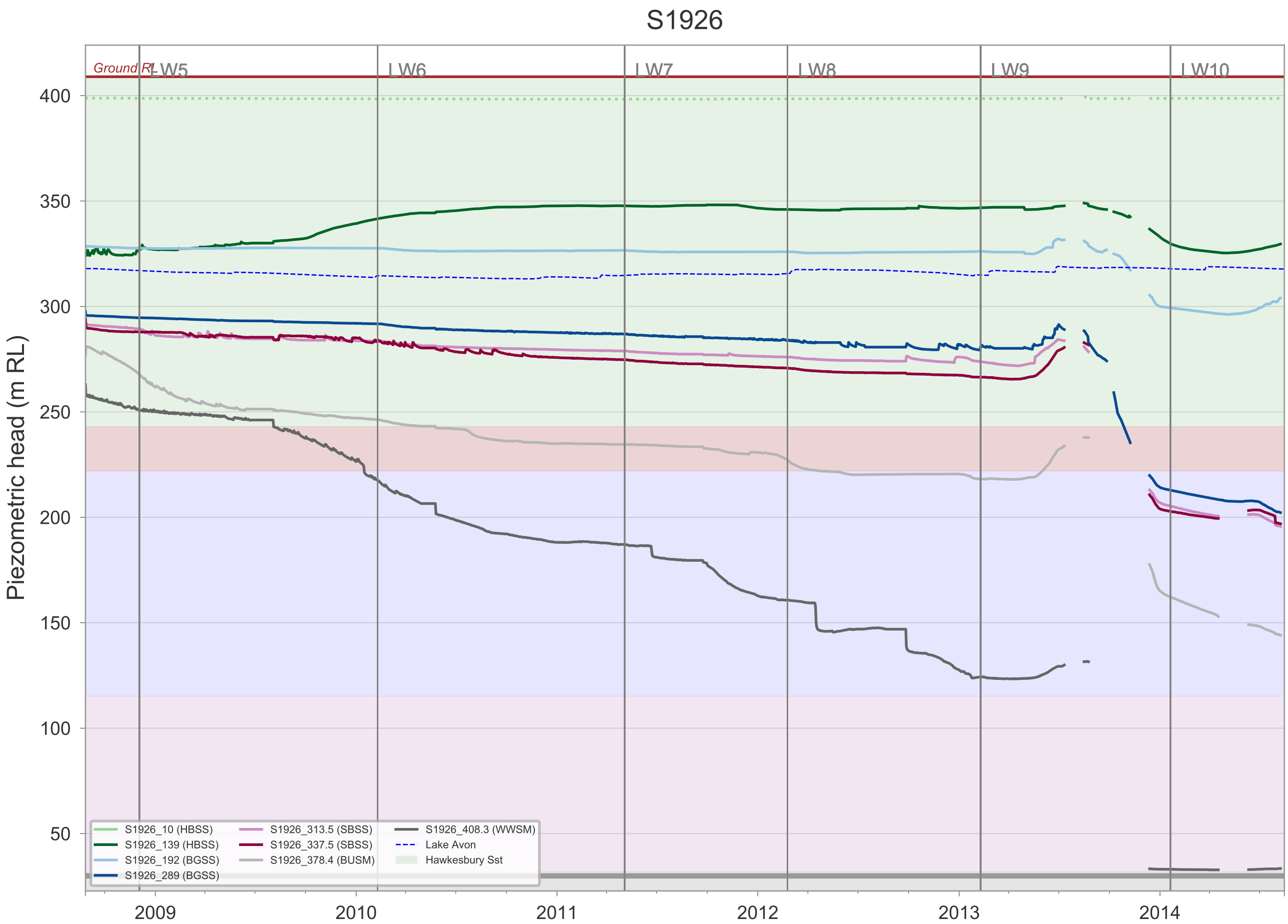

S1911
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
Pressure head (m H2O)
200
150
100
50
0
S1911_10 (HBSS)
S1911_68.5 (HBSS)
S1911_135 (HBSS)
S1911_187 (BGSS)
S1911_229.5 (BGSS)
S1911_277 (BGSS)
S1911_301 (SBSS)
S1911_318 (SBSS)
S1911_331.5 (WBCS)
S1911_349 (CCSS)
S1911_359 (CCSS)
S1911_387.3 (WWSM)
2009
2010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

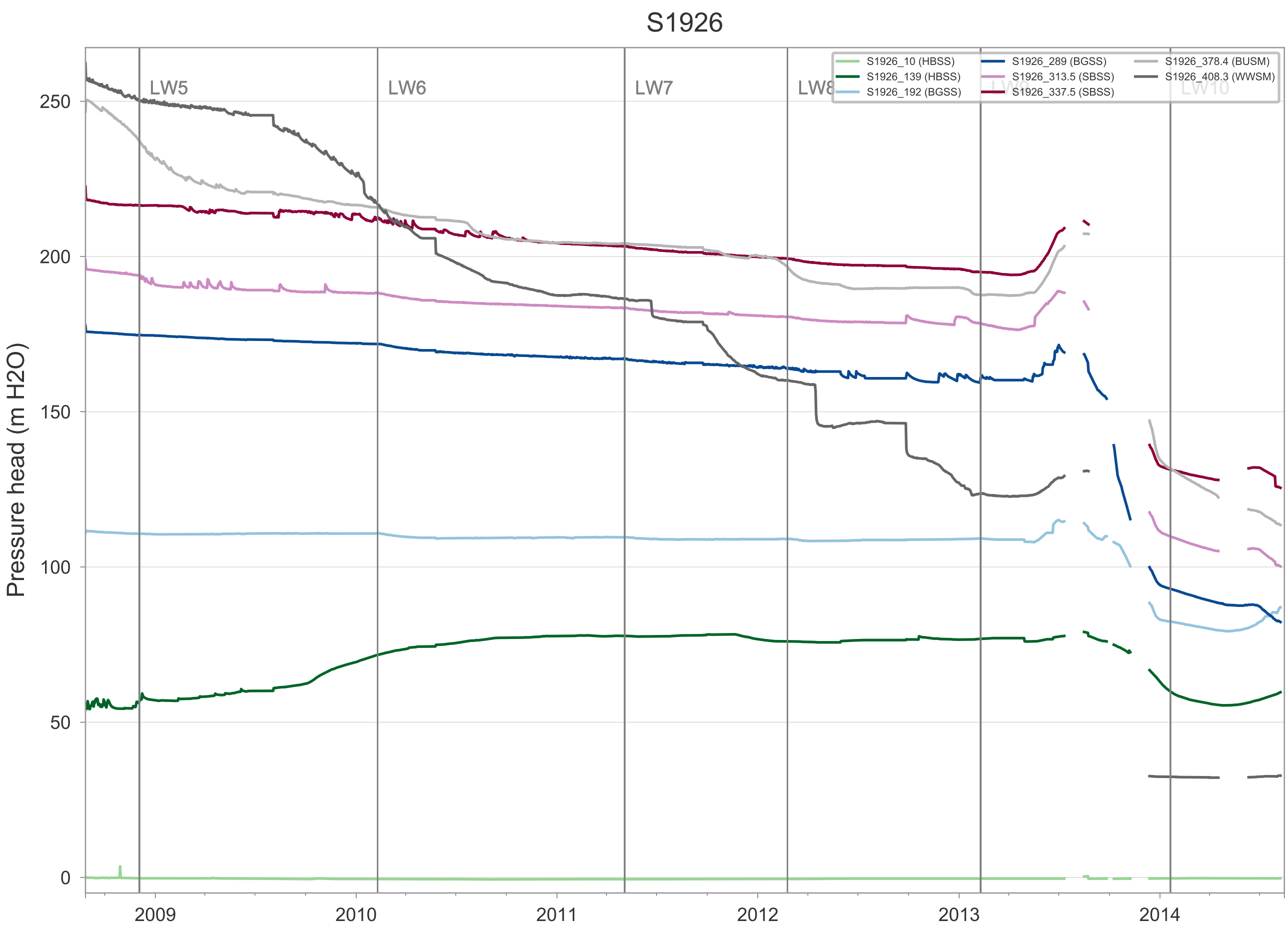

S1914
Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
Piezometric head (m RL)
400
350
300
250
200
150
100
50
S1914_147 (HBSS)
S1914_187 (BGSS)
S1914_266 (BGSS)
S1914_300 (SBSS)
S1914_330 (SBSS)
S1914_371.6 (BUSM)
S1914_400.4 (WWSM)
Lake Avon
Hawkesbury Sst
2009
2010
2011
2012
2013
2014
2015
2016
2017


S1914
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
Pressure head (m H2O)
200
150
100
50
0
S1914_147 (HBSS)
S1914_187 (BGSS)
S1914_266 (BGSS)
S1914_300 (SBSS)
S1914_330 (SBSS)
S1914_371.6 (BUSM)
S1914_400.4 (WWSM)
2009
2010
2011
2012
2013
2014
2015
2016
2017

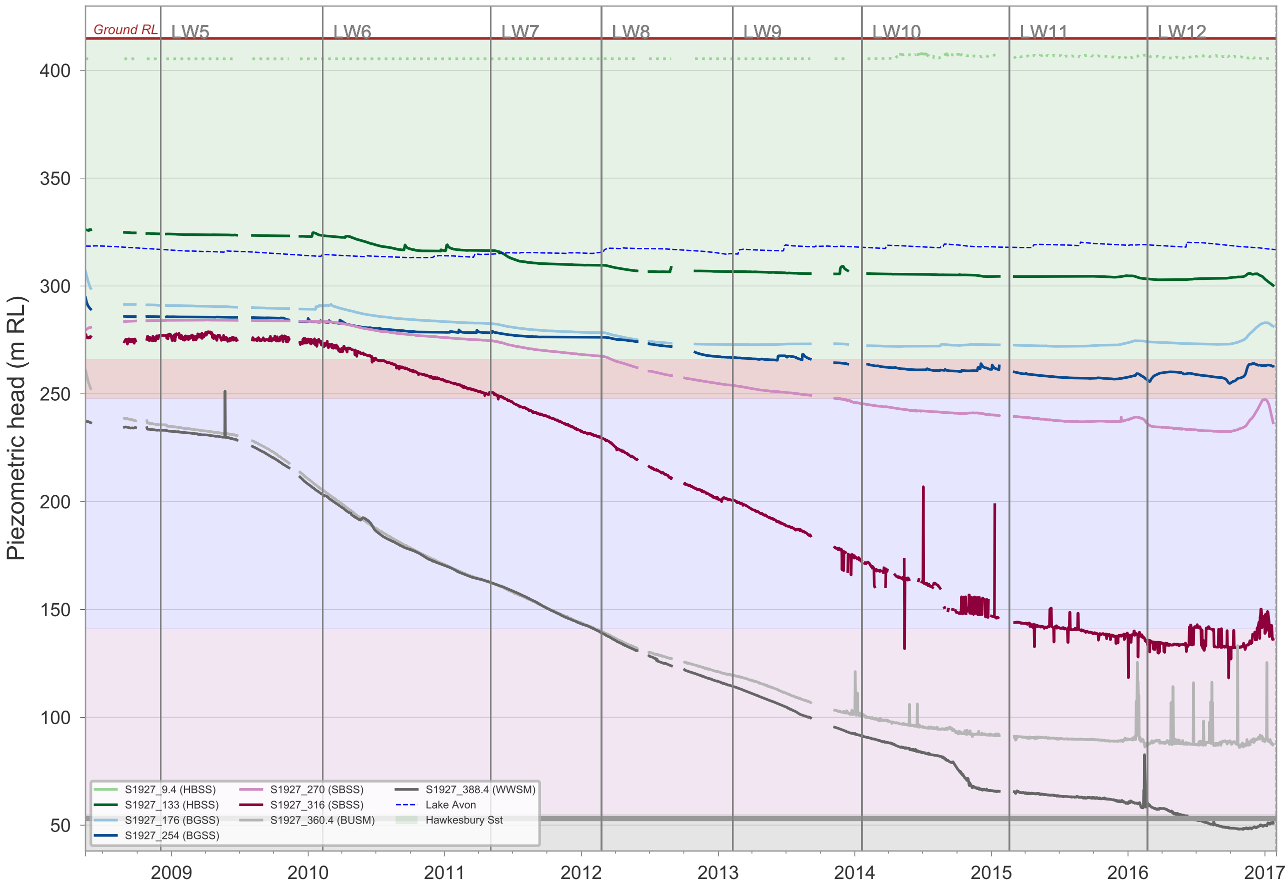

S1925
Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
Piezometric head (m RL)
400
350
300
250
200
150
100
50
S1925_10 (HBSS)
S1925_144 (HBSS)
S1925_202.2 (BGSS)
S1925_295 (BGSS)
S1925_320 (SBSS)
S1925_342.5 (SBSS)
S1925_383.2 (BUSM)
S1925_413.6 (WWSM)
Lake Avon
Hawkesbury Sst
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019


S1925
LW5
LW6
LW7
LW12
LW13
LW14
S1925_10 (HBSS)
S1925_144 (HBSS)
S1925_202.2 (BGSS)
S1925_295 (BGSS)
S1925_320 (SBSS)
S1925_342.5 (SBSS)
S1925_383.2 (BUSM)
S1925_413.6 (WWSM)
Pressure head (m H2O)
200
150
100
50
0
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

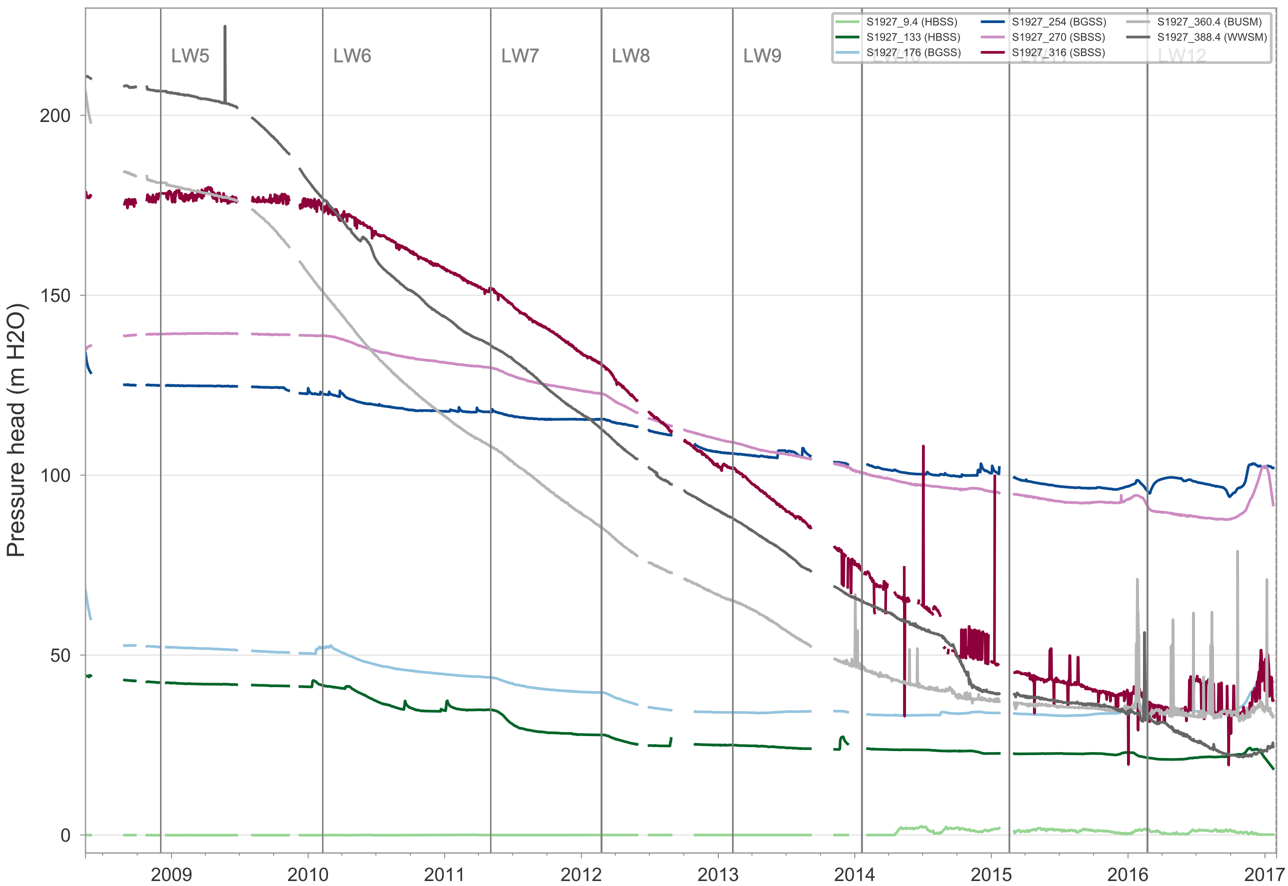

S1926
Piezometric head (m RL)
Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
400
350
300
250
200
150
100
50
2009
2010
2011
2012
2013
2014
S1926_10 (HBSS)
S1926_139 (HBSS)
S1926_192 (BGSS)
S1926_289 (BGSS)
S1926_313.5 (SBSS)
S1926_337.5 (SBSS)
S1926_378.4 (BUSM)
S1926_408.3 (WWSM)
Lake Avon
Hawkesbury Sst

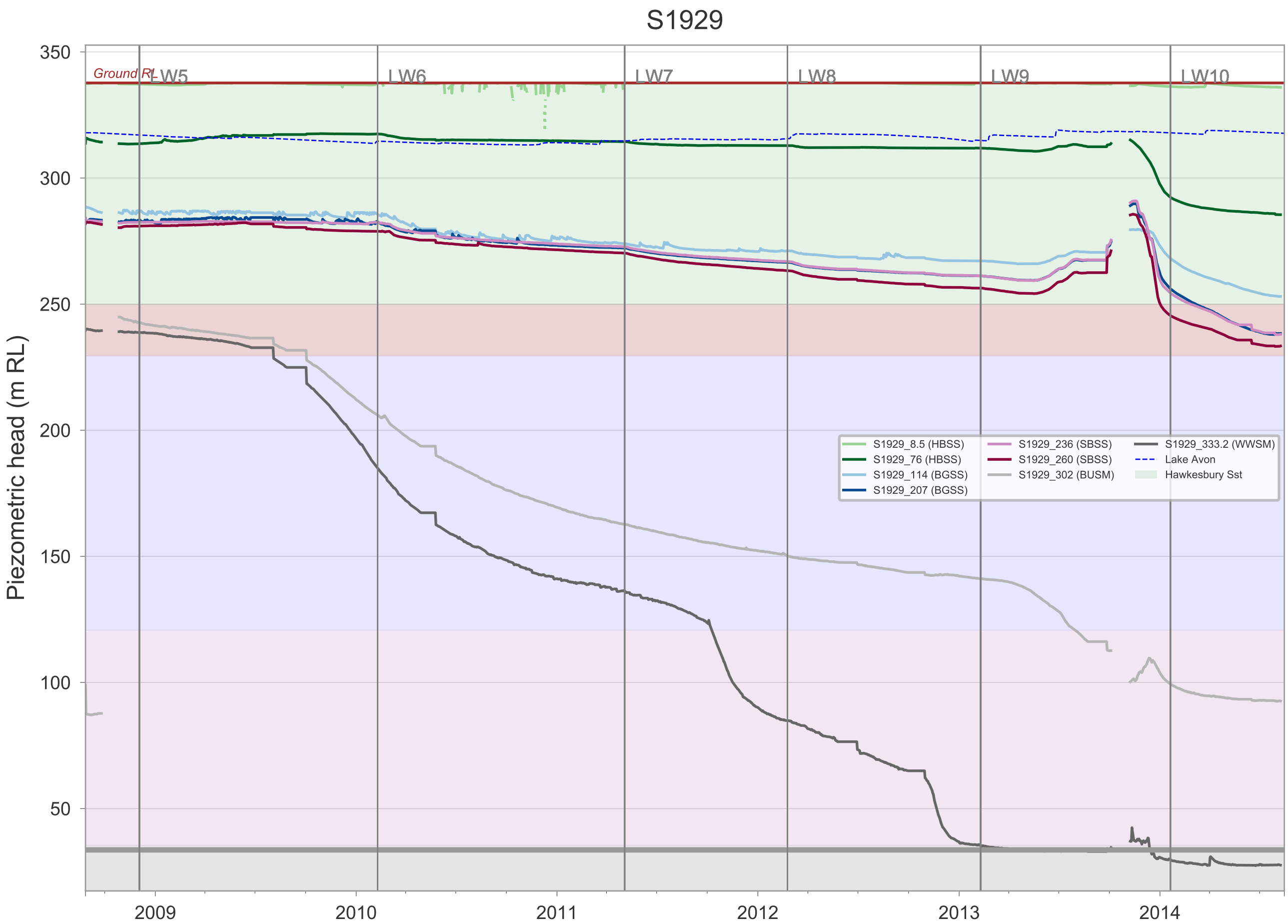

S1926
Pressure head (m H2O)
LW5
LW6
LW7
LW8
LW10
250
200
150
100
50
0
2009
2010
2011
2012
2013
2014
S1926_10 (HBSS)
S1926_139 (HBSS)
S1926_192 (BGSS)
S1926_289 (BGSS)
S1926_313.5 (SBSS)
S1926_337.5 (SBSS)
S1926_378.4 (BUSM)
S1926_408.3 (WWSM)

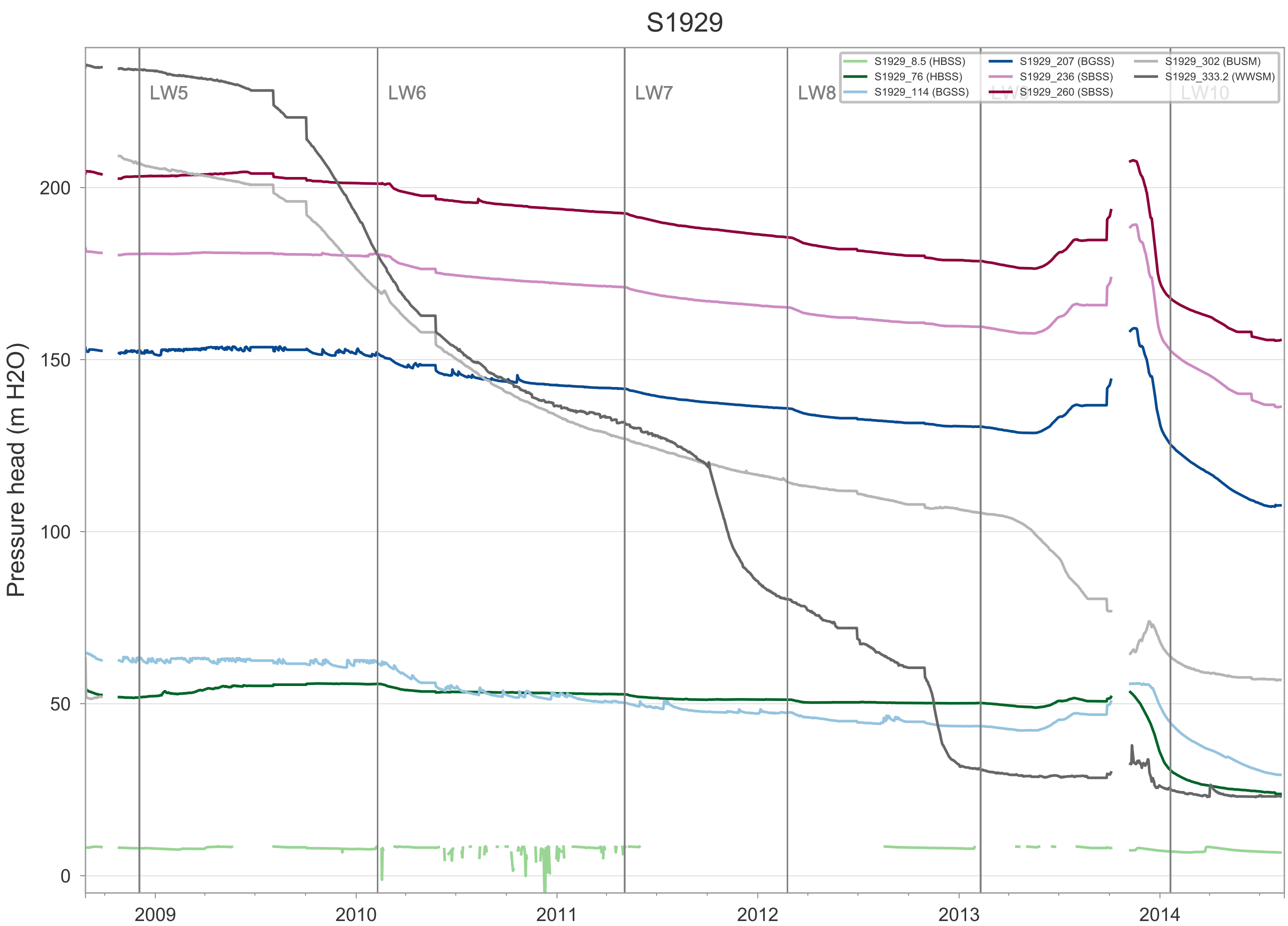
S1927


Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
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
Hawkesbury Sst

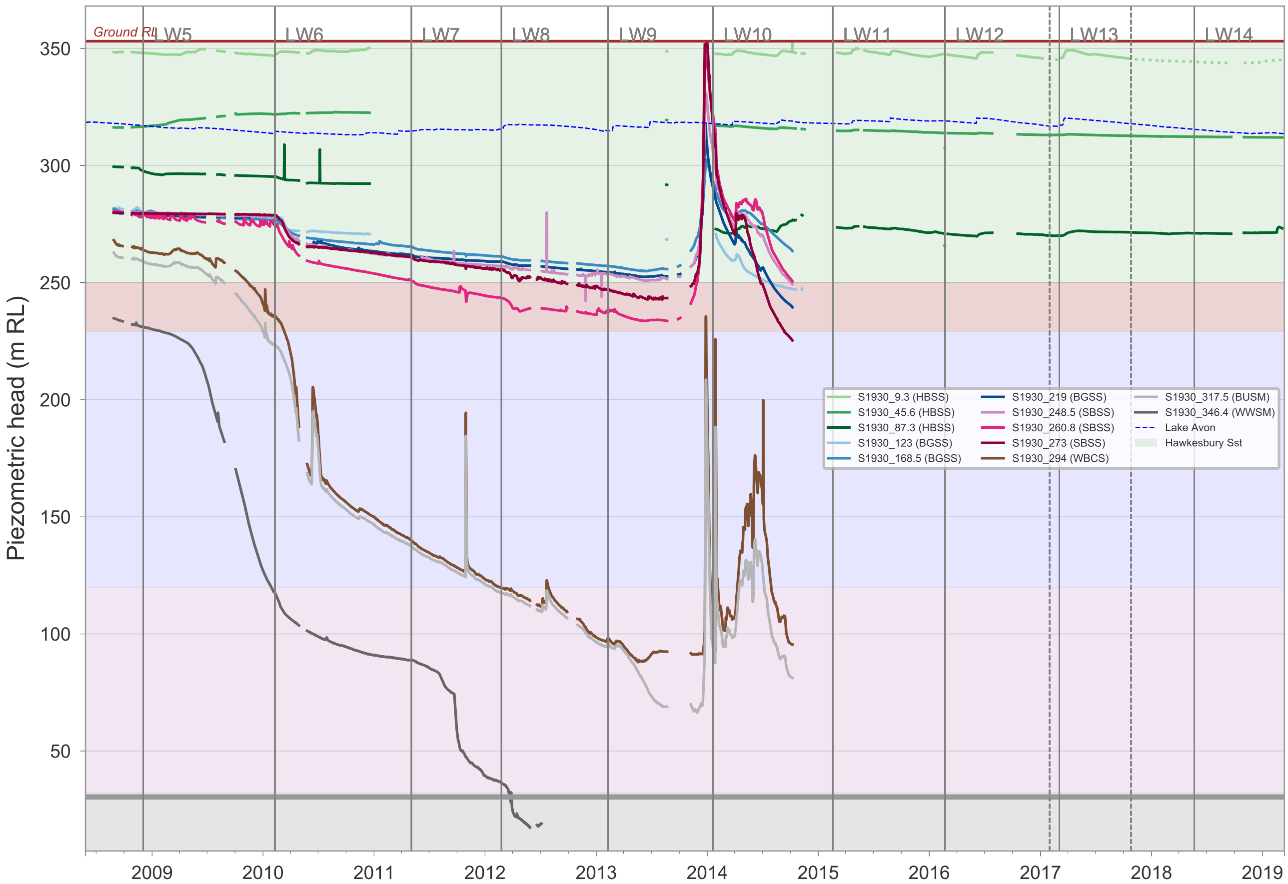
S1927


LW5
LW6
LW7
LW8
LW9
Pressure head (m H2O)
200
150
100
50
0
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)

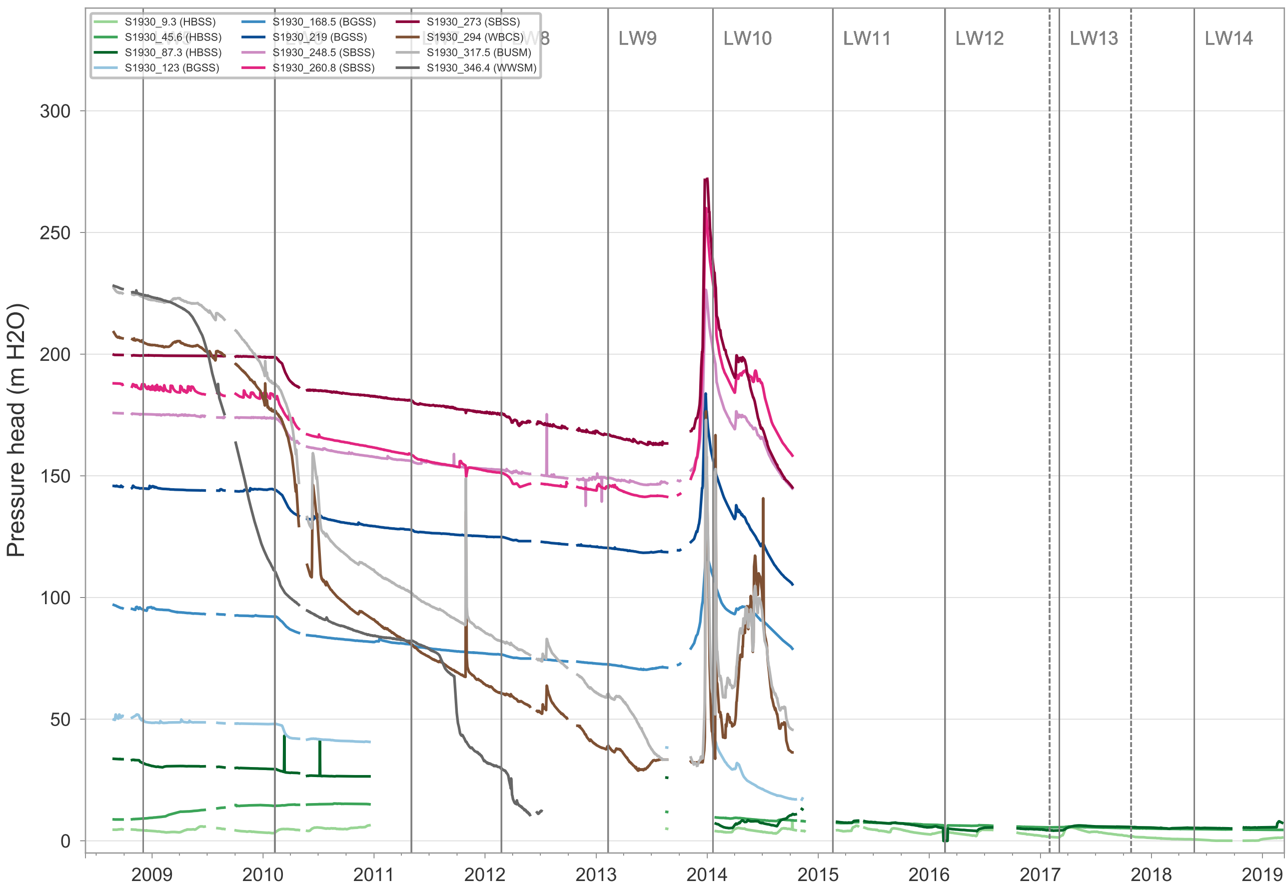

S1929
Piezometric head (m RL)
Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
S1929_8.5 (HBSS)
S1929_76 (HBSS)
S1929_114 (BGSS)
S1929_207 (BGSS)
S1929_236 (SBSS)
S1929_260 (SBSS)
S1929_302 (BUSM)
S1929_333.2 (WWSM)
Lake Avon
Hawkesbury Sst
2009
2010
2011
2012
2013
2014

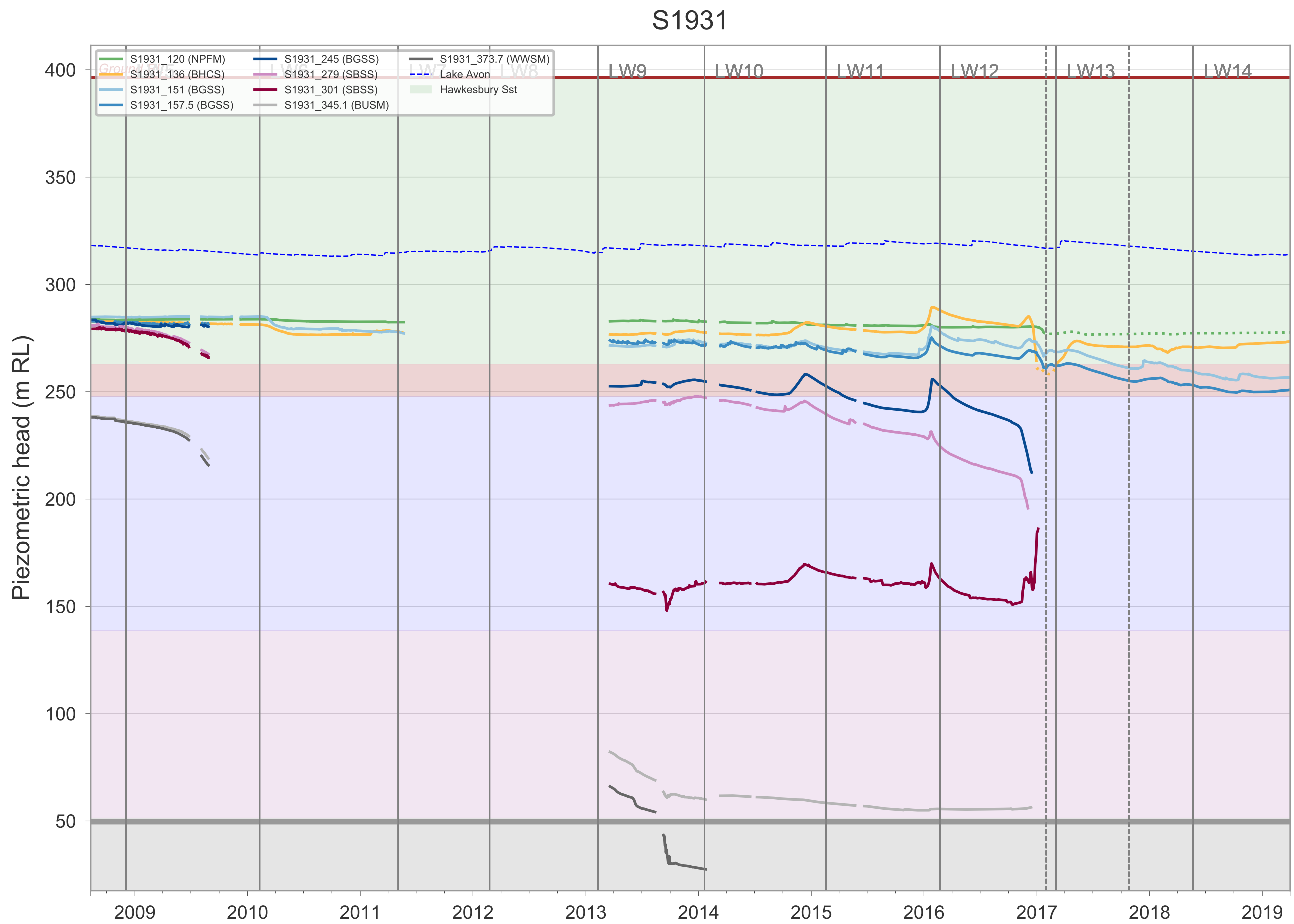

S1929
Pressure head (m H2O)
LW5
LW6
LW7
LW8
S1929_8.5 (HBSS)
S1929_76 (HBSS)
S1929_114 (BGSS)
S1929_207 (BGSS)
S1929_236 (SBSS)
S1929_260 (SBSS)
S1929_302 (BUSM)
S1929_333.2 (WWSM)
2009
2010
2011
2012
2013
2014

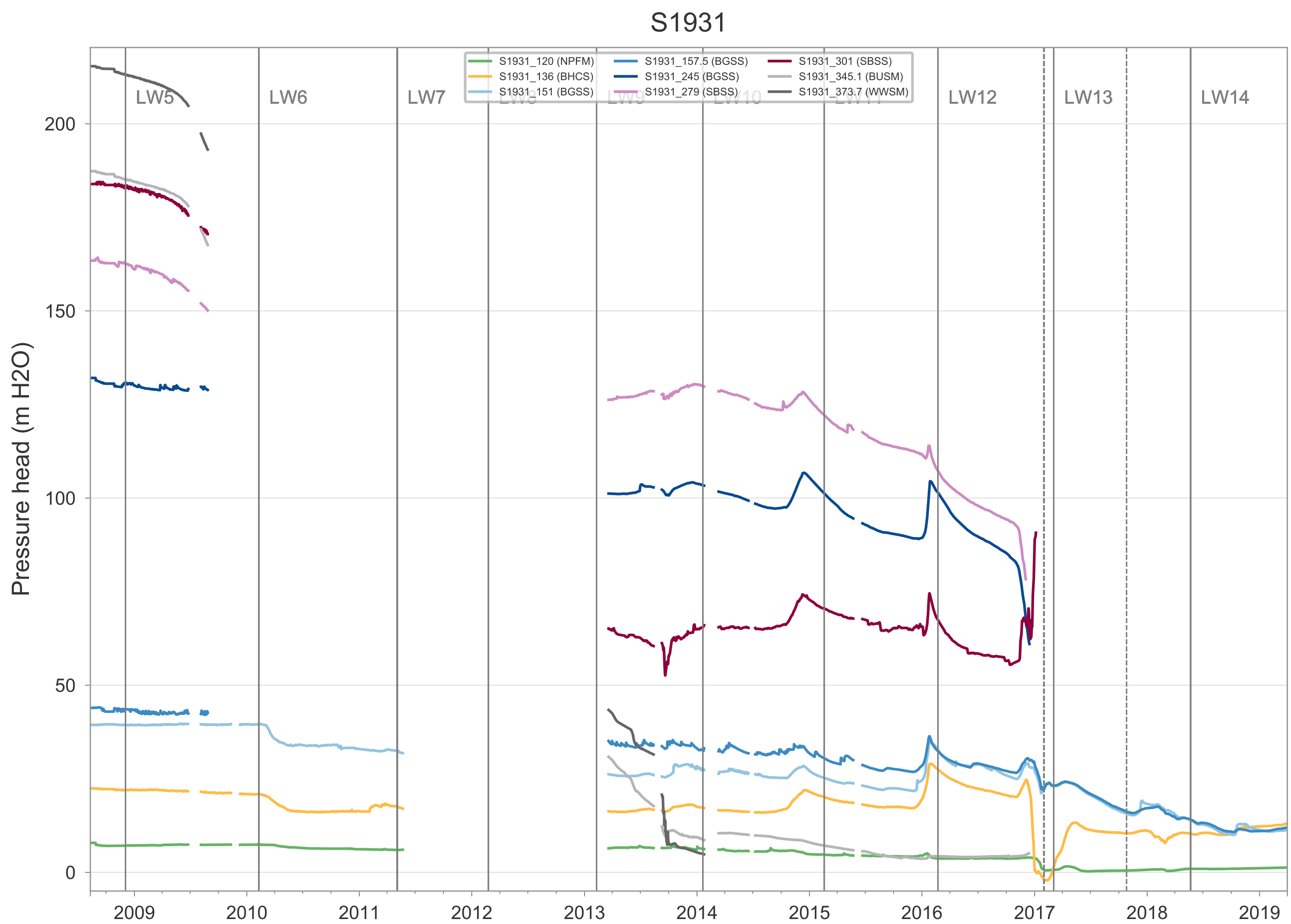
S1930

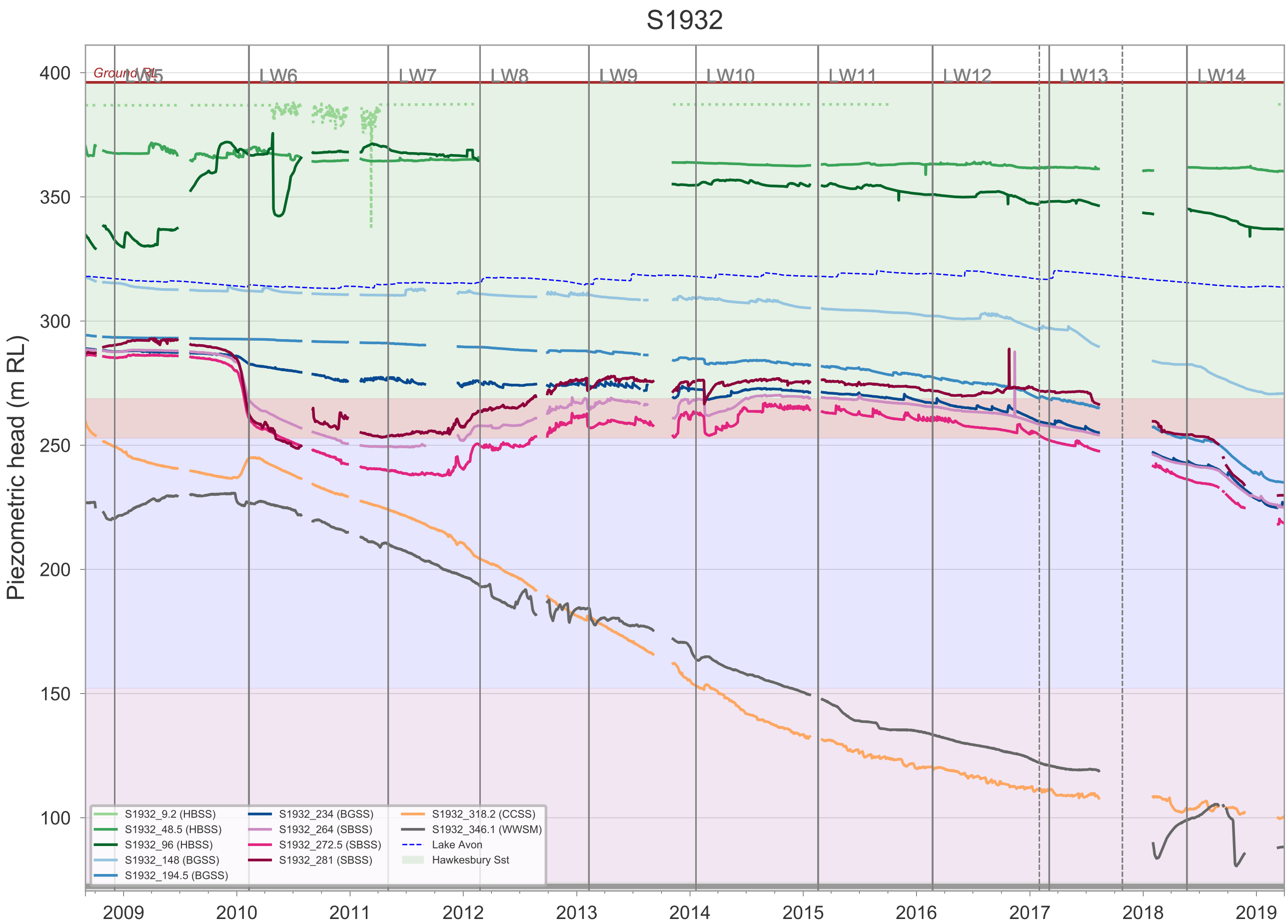

Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
Piezometric head (m RL)
350
300
250
200
150
100
50
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
S1930_9.3 (HBSS)
S1930_45.6 (HBSS)
S1930_87.3 (HBSS)
S1930_123 (BGSS)
S1930_168.5 (BGSS)
S1930_219 (BGSS)
S1930_248.5 (SBSS)
S1930_260.8 (SBSS)
S1930_273 (SBSS)
S1930_294 (WBCS)
S1930_317.5 (BUSM)
S1930_346.4 (WWSM)
Lake Avon
Hawkesbury Sst

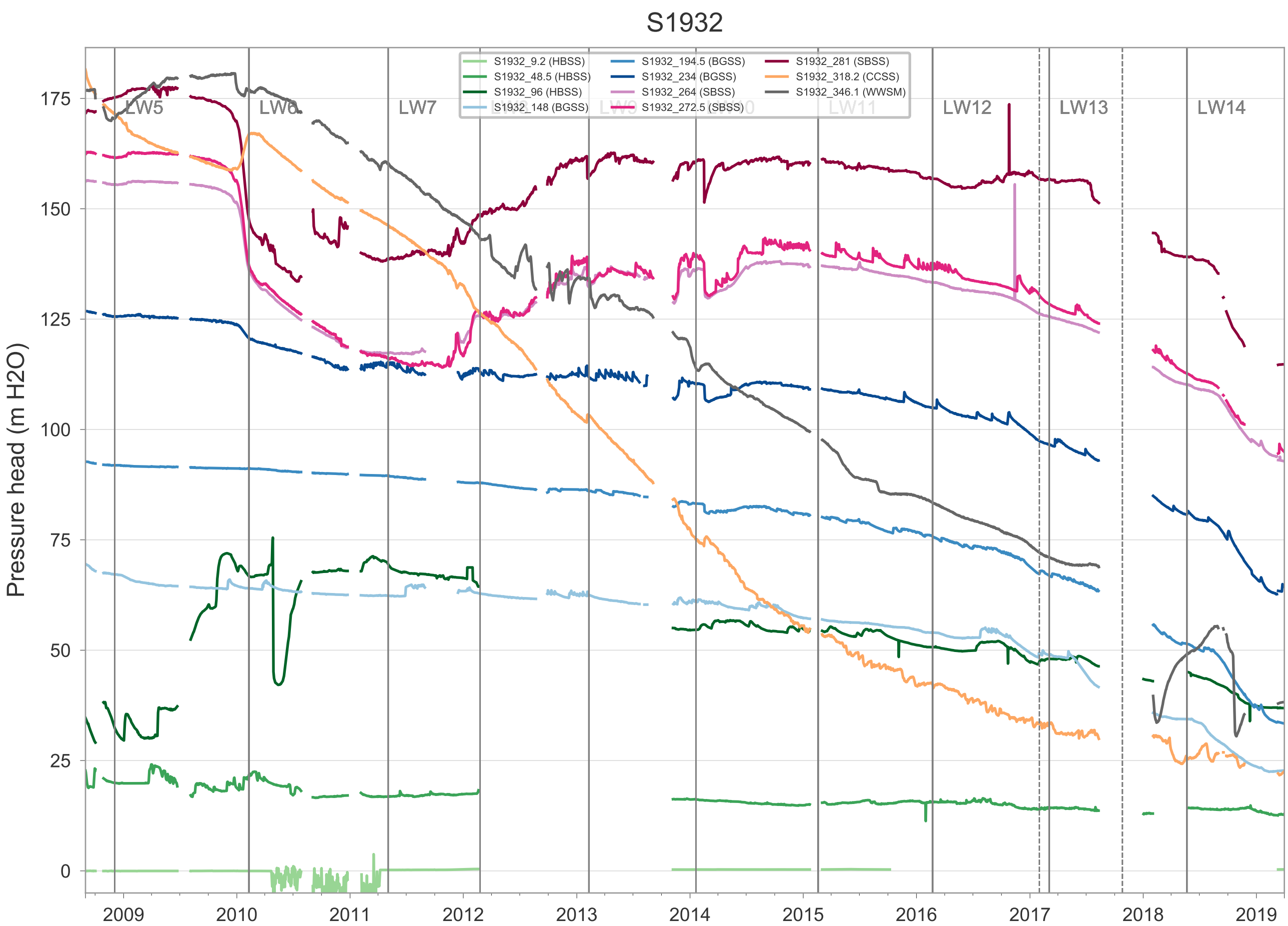
S1930

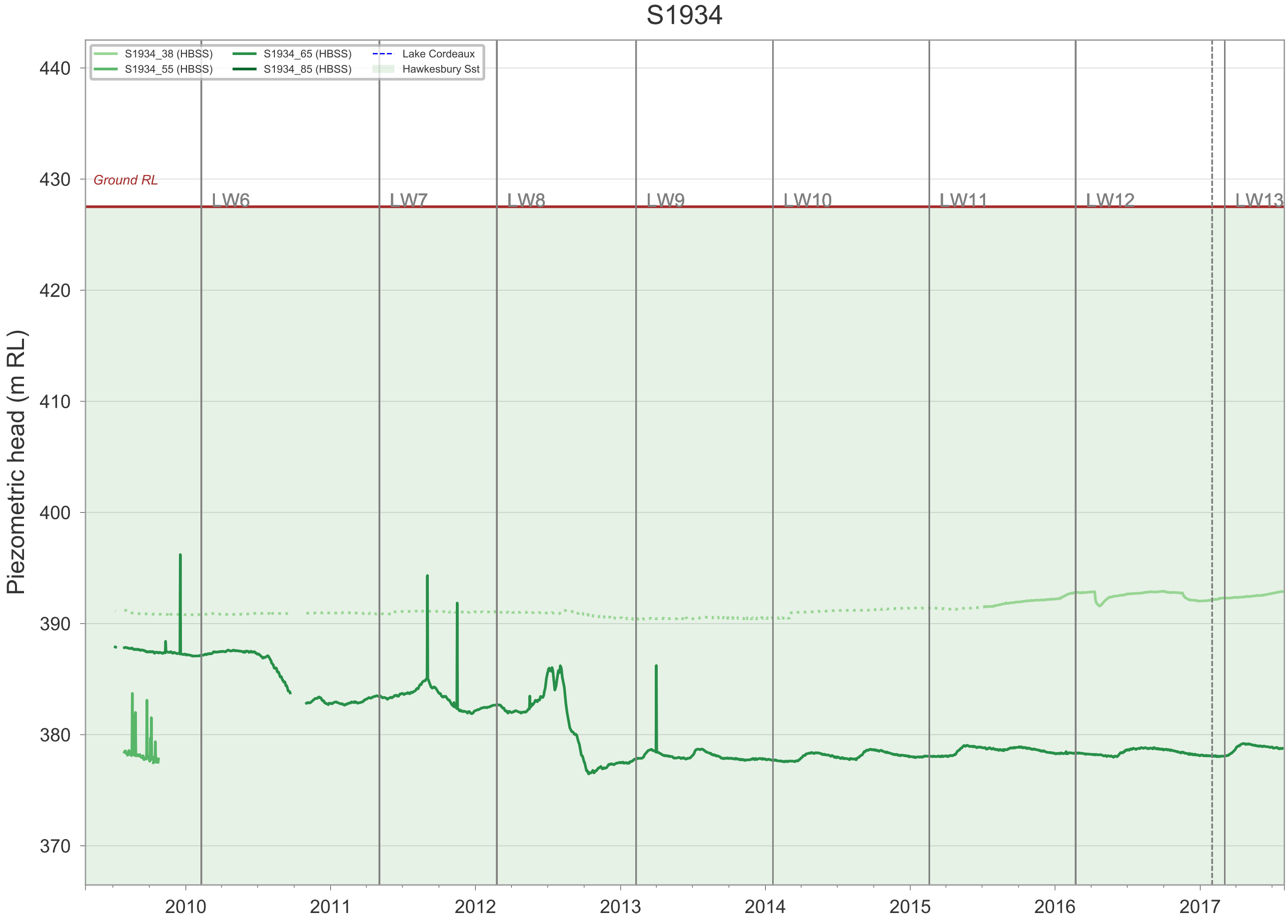

S1930_9.3 (HBSS)
S1930_45.6 (HBSS)
S1930_87.3 (HBSS)
S1930_123 (BGSS)
S1930_168.5 (BGSS)
S1930_219 (BGSS)
S1930_248.5 (SBSS)
S1930_260.8 (SBSS)
S1930_273 (SBSS)
S1930_294 (WBCS)
S1930_317.5 (BUSM)
S1930_346.4 (WWSM)
LW9
LW10
LW11
LW12
LW13
LW14
Pressure head (m H2O)
300
250
200
150
100
50
0
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

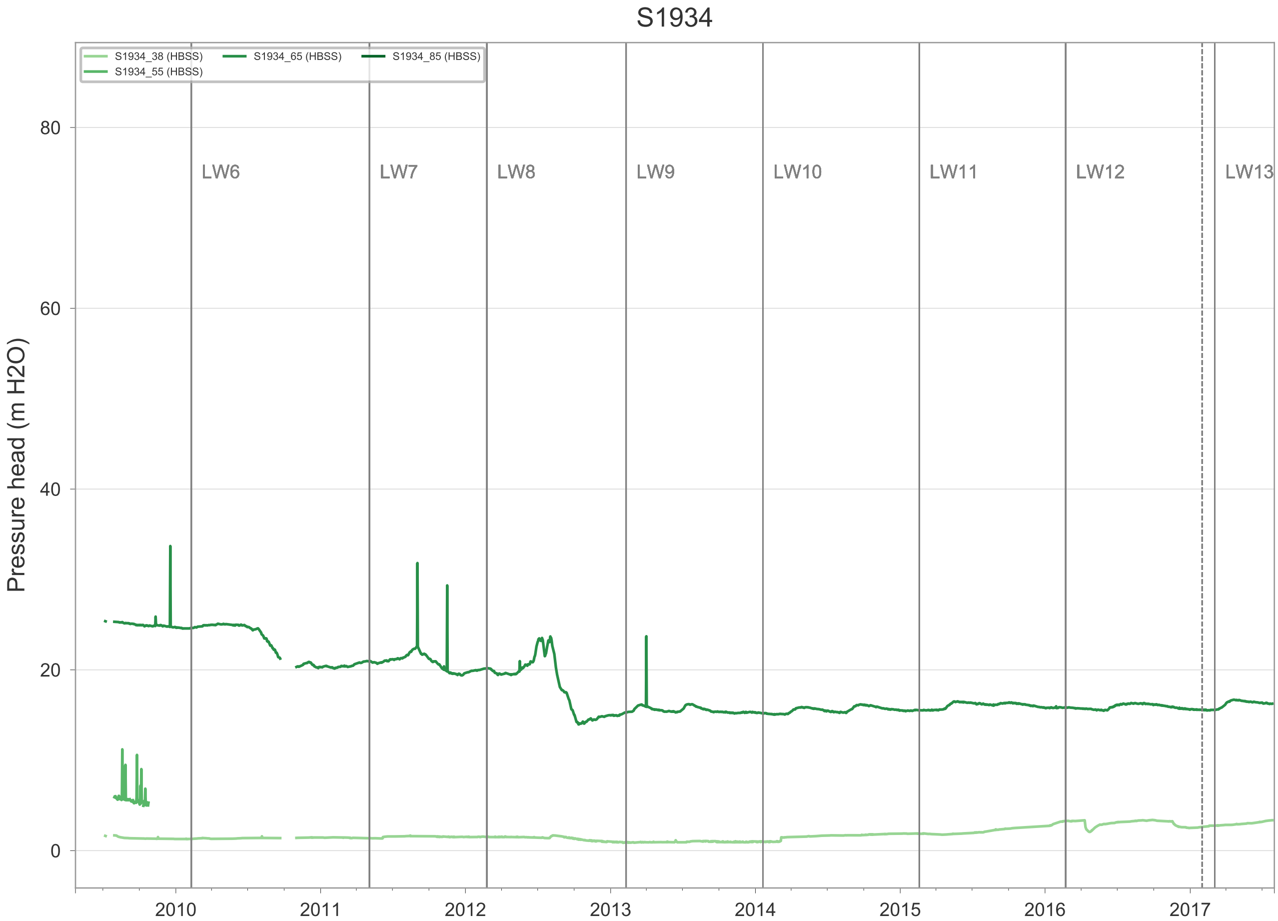

S1931
Piezometric head (m RL)
S1931_120 (NPFM)
S1931_136 (BHCS)
S1931_151 (BGSS)
S1931_157.5 (BGSS)
S1931_245 (BGSS)
S1931_279 (SBSS)
S1931_301 (SBSS)
S1931_345.1 (BUSM)
S1931_373.7 (WWSM)
Lake Avon
Hawkesbury Sst
LW9
LW10
LW11
LW12
LW13
LW14
400
350
300
250
200
150
100
50
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019


S1931
Pressure head (m H2O)
S1931_120 (NPFM)
S1931_136 (BHCS)
S1931_151 (BGSS)
S1931_157.5 (BGSS)
S1931_245 (BGSS)
S1931_279 (SBSS)
S1931_301 (SBSS)
S1931_345.1 (BUSM)
S1931_373.7 (WWSM)
LW5
LW6
LW7
LW12
LW13
LW14
200
150
100
50
0
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

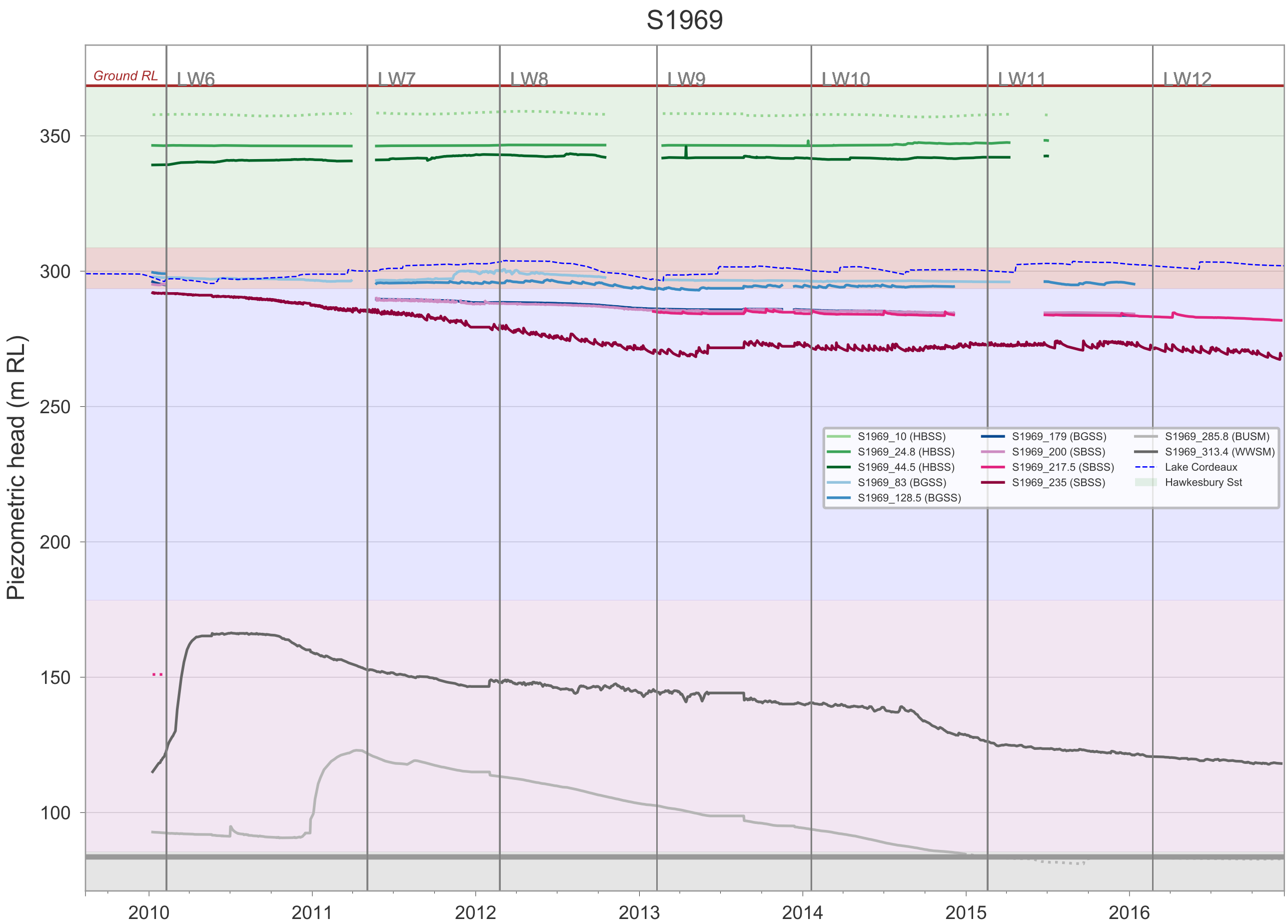

S1932
Piezometric head (m RL)
Ground RL
LW5
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
S1932_9.2 (HBSS)
S1932_48.5 (HBSS)
S1932_96 (HBSS)
S1932_148 (BGSS)
S1932_194.5 (BGSS)
S1932_234 (BGSS)
S1932_264 (SBSS)
S1932_272.5 (SBSS)
S1932_281 (SBSS)
S1932_318.2 (CCSS)
S1932_346.1 (WWSM)
Lake Avon
Hawkesbury Sst

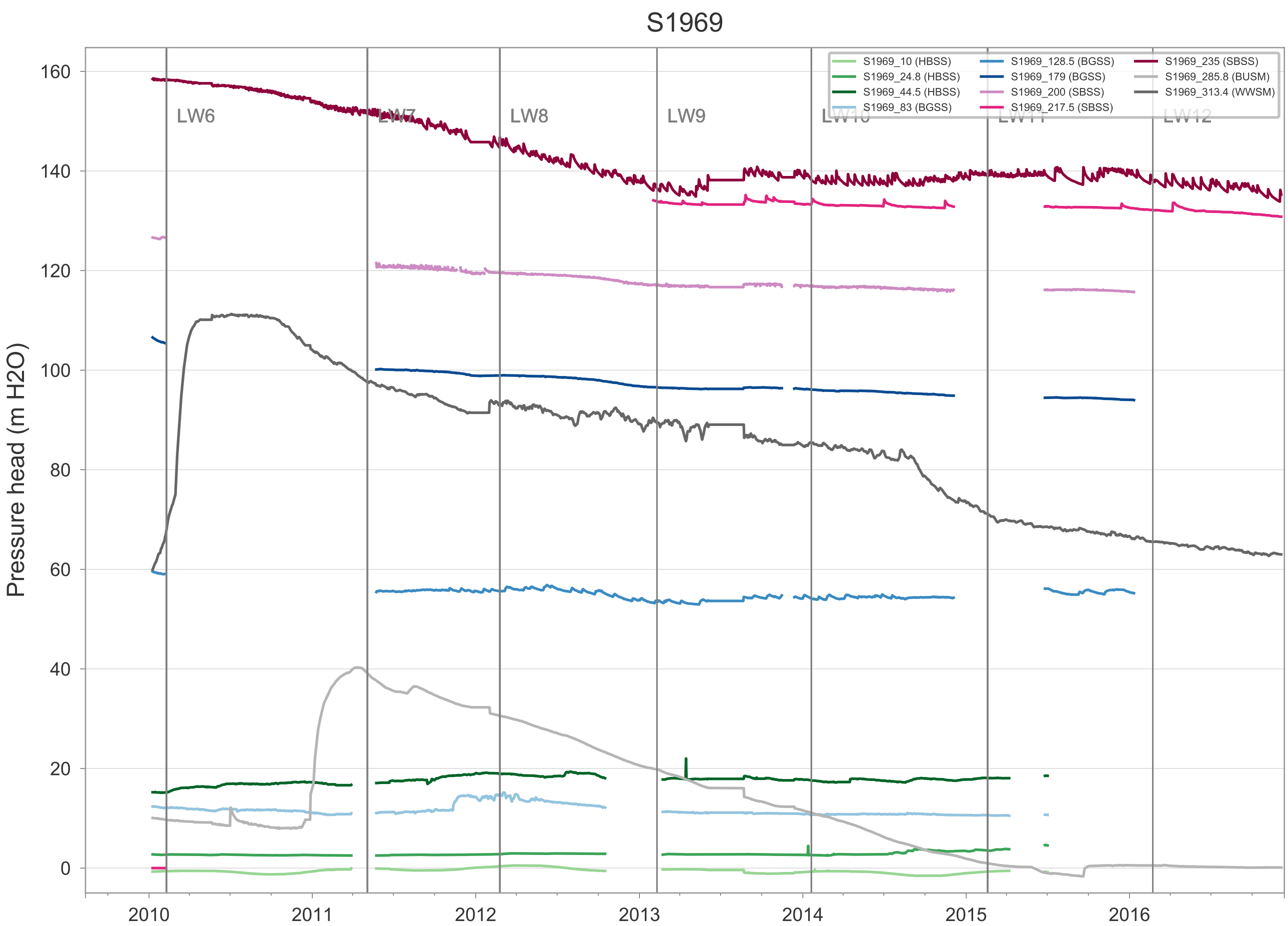

S1932
Pressure head (m H2O)
LW5
LW6
LW7
LW12
LW13
LW14
S1932_9.2 (HBSS)
S1932_48.5 (HBSS)
S1932_96 (HBSS)
S1932_148 (BGSS)
S1932_194.5 (BGSS)
S1932_234 (BGSS)
S1932_264 (SBSS)
S1932_272.5 (SBSS)
S1932_281 (SBSS)
S1932_318.2 (CCSS)
S1932_346.1 (WWSM)

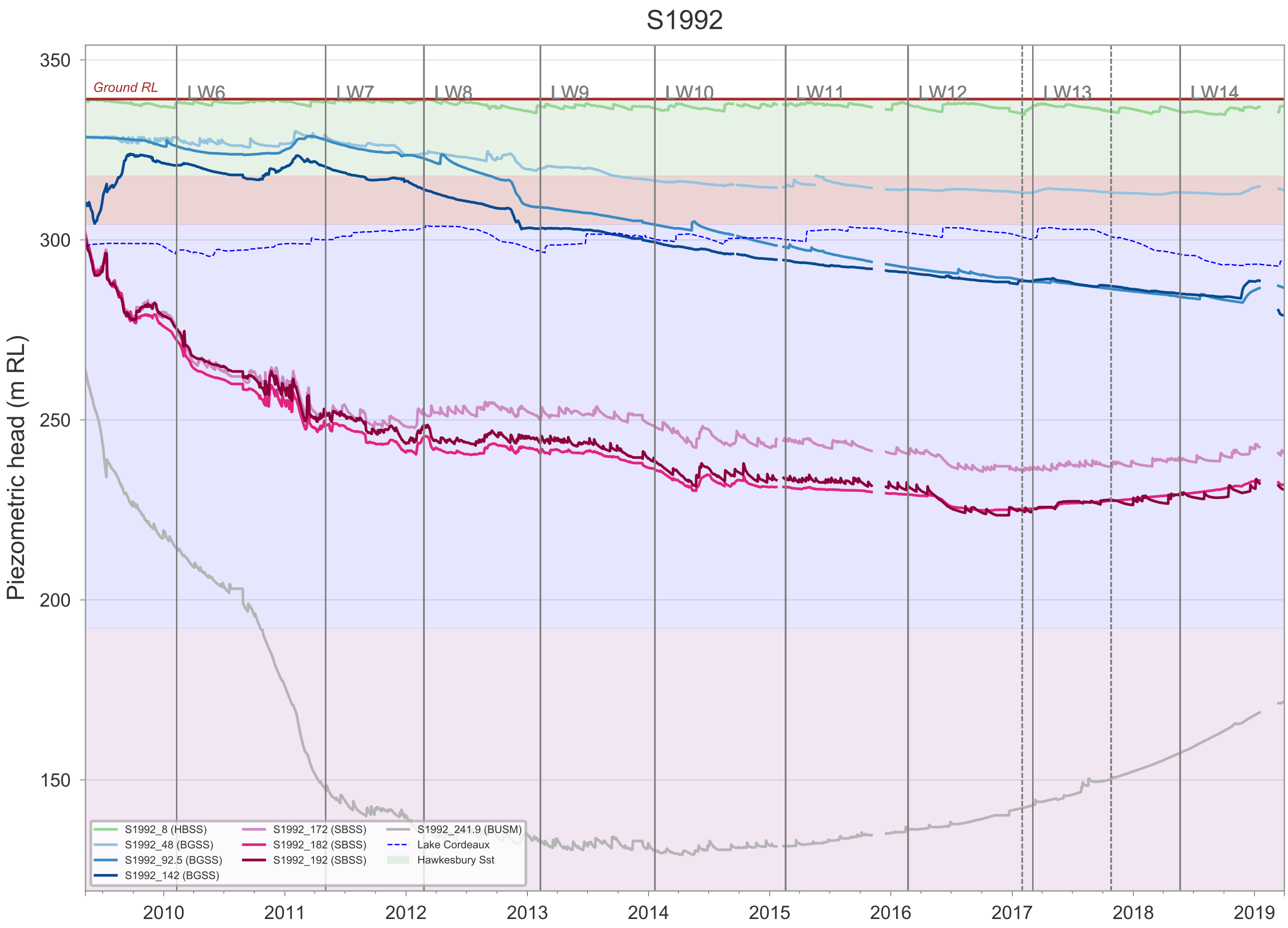

S1934
S1934_38 (HBSS)
S1934_55 (HBSS)
S1934_65 (HBSS)
S1934_85 (HBSS)
Lake Cordeaux
Hawkesbury Sst
Ground RL
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
Piezometric head (m RL)
440
430
420
410
400
390
380
370
2010
2011
2012
2013
2014
2015
2016
2017

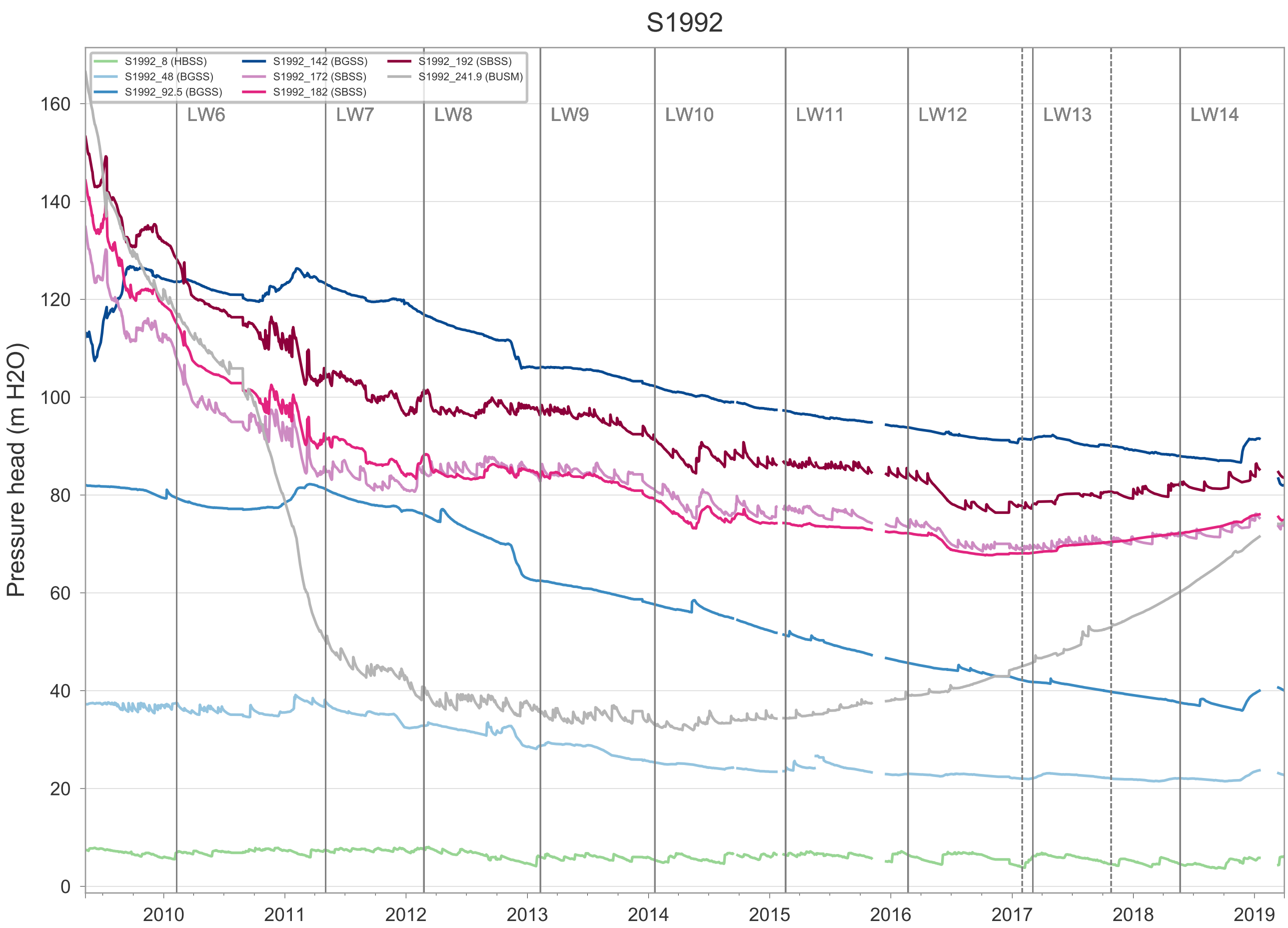

S1934
S1934_38 (HBSS)
S1934_55 (HBSS)
S1934_65 (HBSS)
S1934_85 (HBSS)
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
Pressure head (m H2O)
80
60
40
20
0
2010
2011
2012
2013
2014
2015
2016
2017

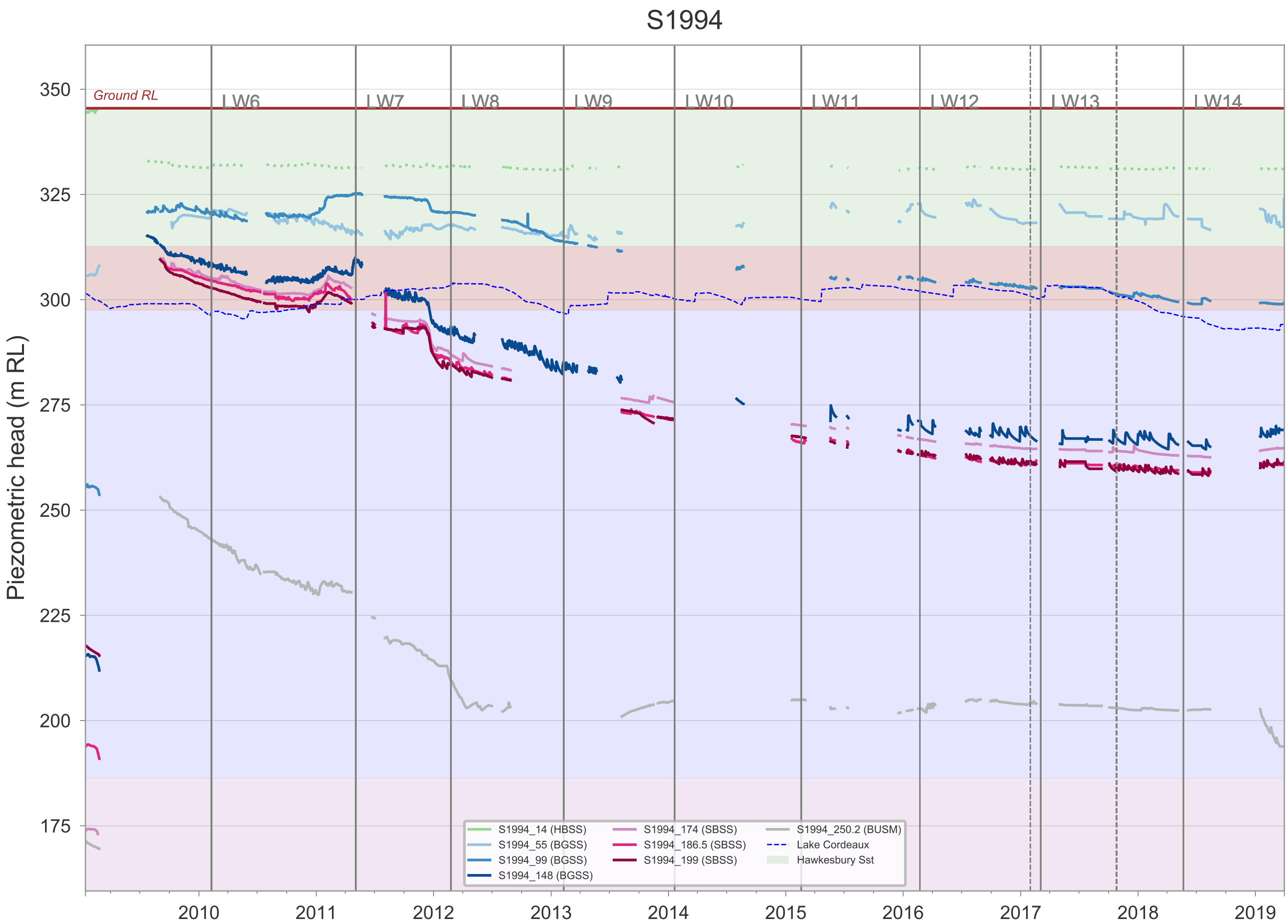
Groundwater hydrographs

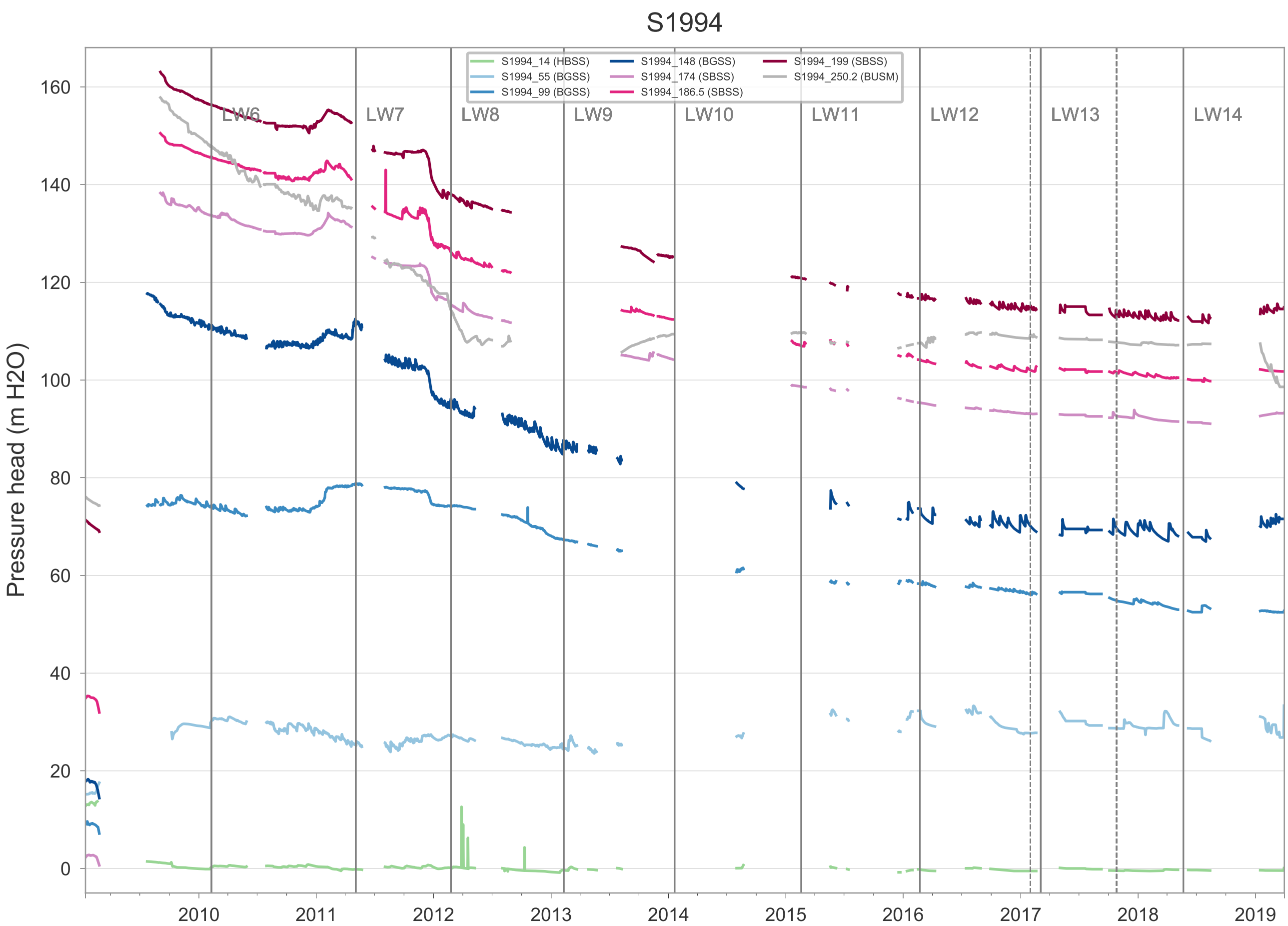


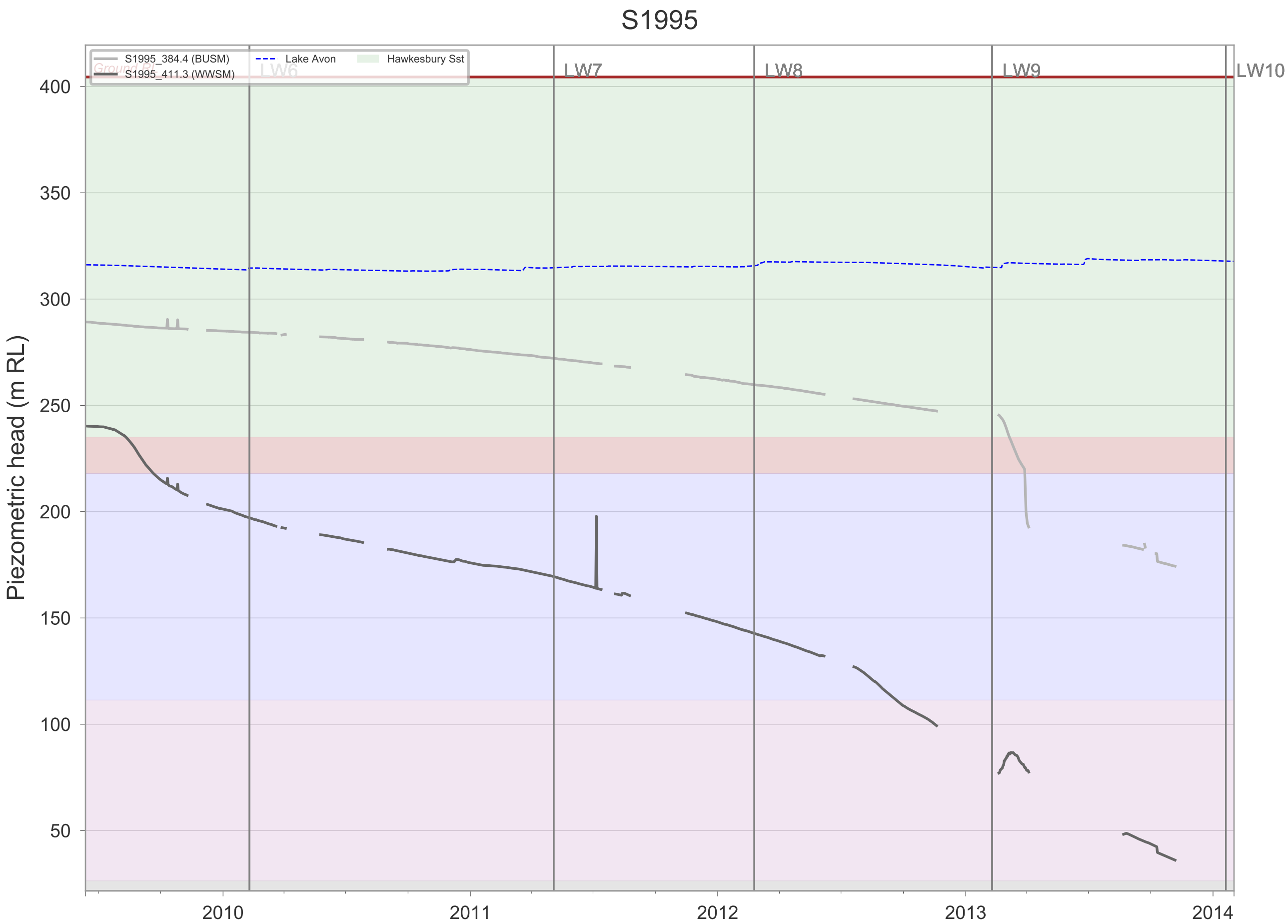


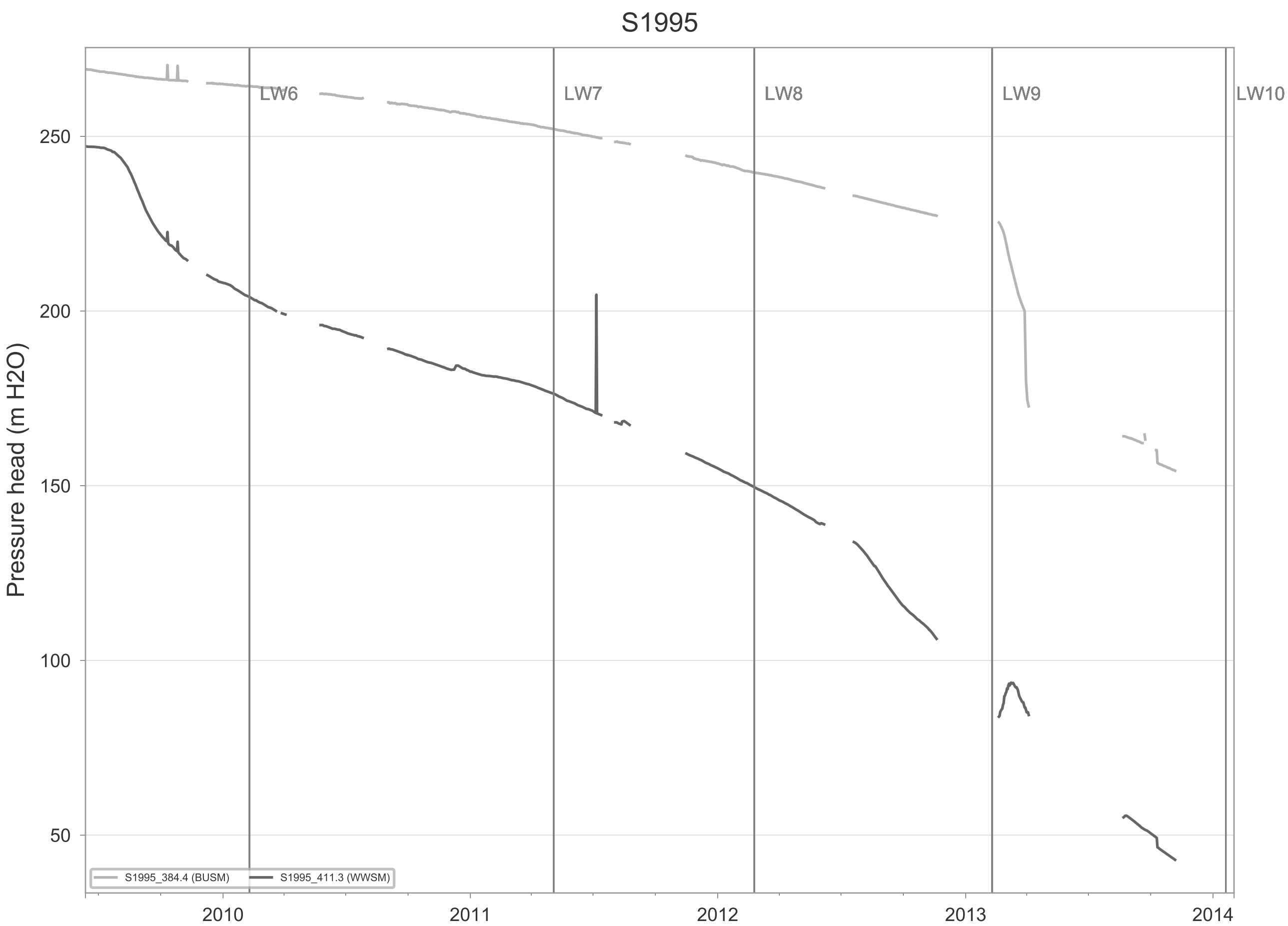

S1992
Piezometric head (m RL)
Ground RL
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
S1992_8 (HBSS)
S1992_48 (BGSS)
S1992_92.5 (BGSS)
S1992_142 (BGSS)
S1992_172 (SBSS)
S1992_182 (SBSS)
S1992_192 (SBSS)
S1992_241.9 (BUSM)
Lake Cordeaux
Hawkesbury Sst

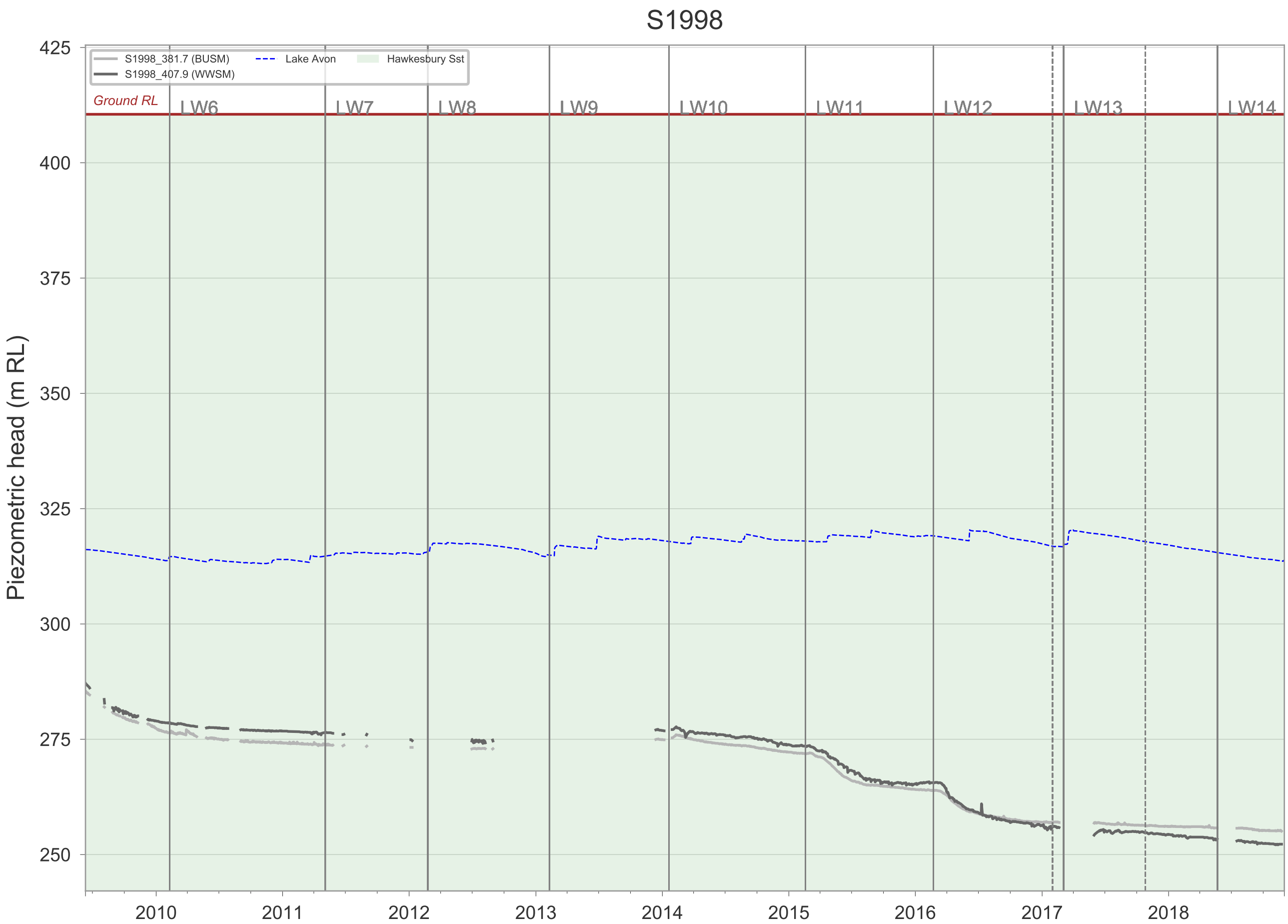

S1992
Pressure head (m H2O)
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
S1992_8 (HBSS)
S1992_48 (BGSS)
S1992_92.5 (BGSS)
S1992_142 (BGSS)
S1992_172 (SBSS)
S1992_182 (SBSS)
S1992_192 (SBSS)
S1992_241.9 (BUSM)

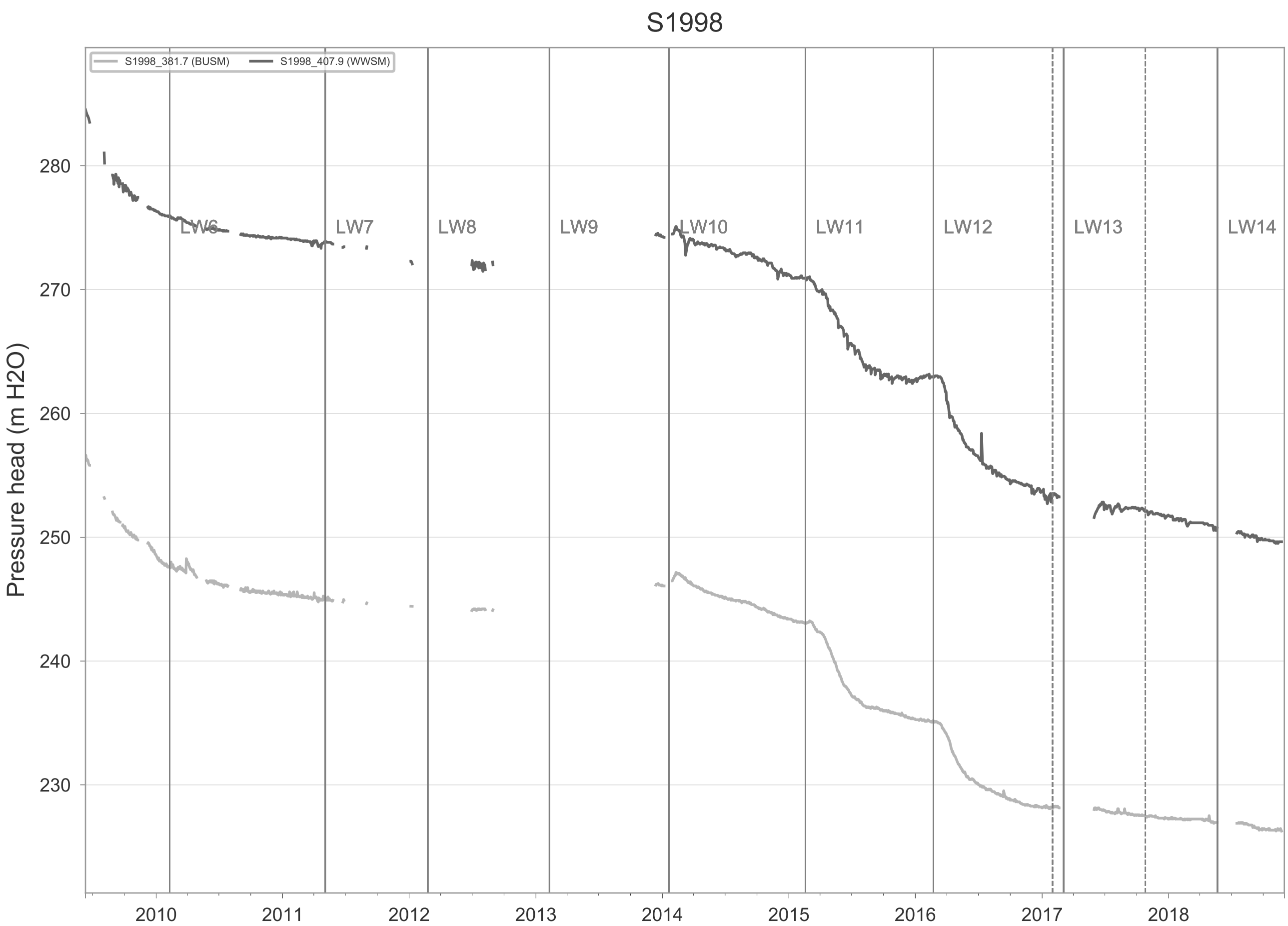

S1994
Piezometric head (m RL)
Ground RL
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
350
325
300
275
250
225
200
175
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
S1994_14 (HBSS)
S1994_55 (BGSS)
S1994_99 (BGSS)
S1994_148 (BGSS)
S1994_174 (SBSS)
S1994_186.5 (SBSS)
S1994_199 (SBSS)
S1994_250.2 (BUSM)
Lake Cordeaux
Hawkesbury Sst


S1994
Pressure head (m H2O)
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)
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
160
140
120
100
80
60
40
20
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

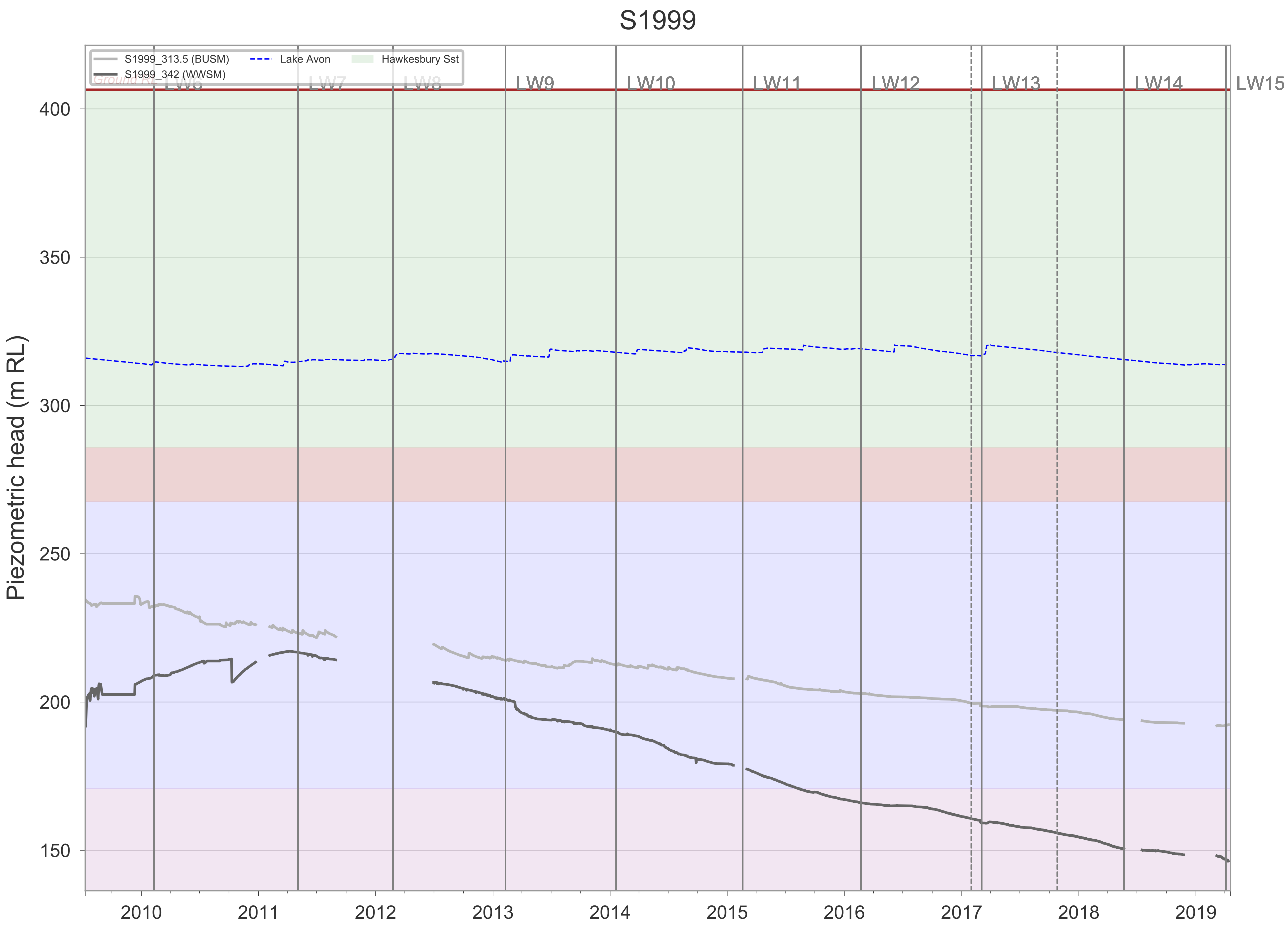

S1995
S1995_384.4 (BUSM)
S1995_411.3 (WWSM)
Lake Avon
Hawkesbury Sst
LW6
LW7
LW8
LW9
LW10
Piezometric head (m RL)
400
350
300
250
200
150
100
50
2010
2011
2012
2013
2014

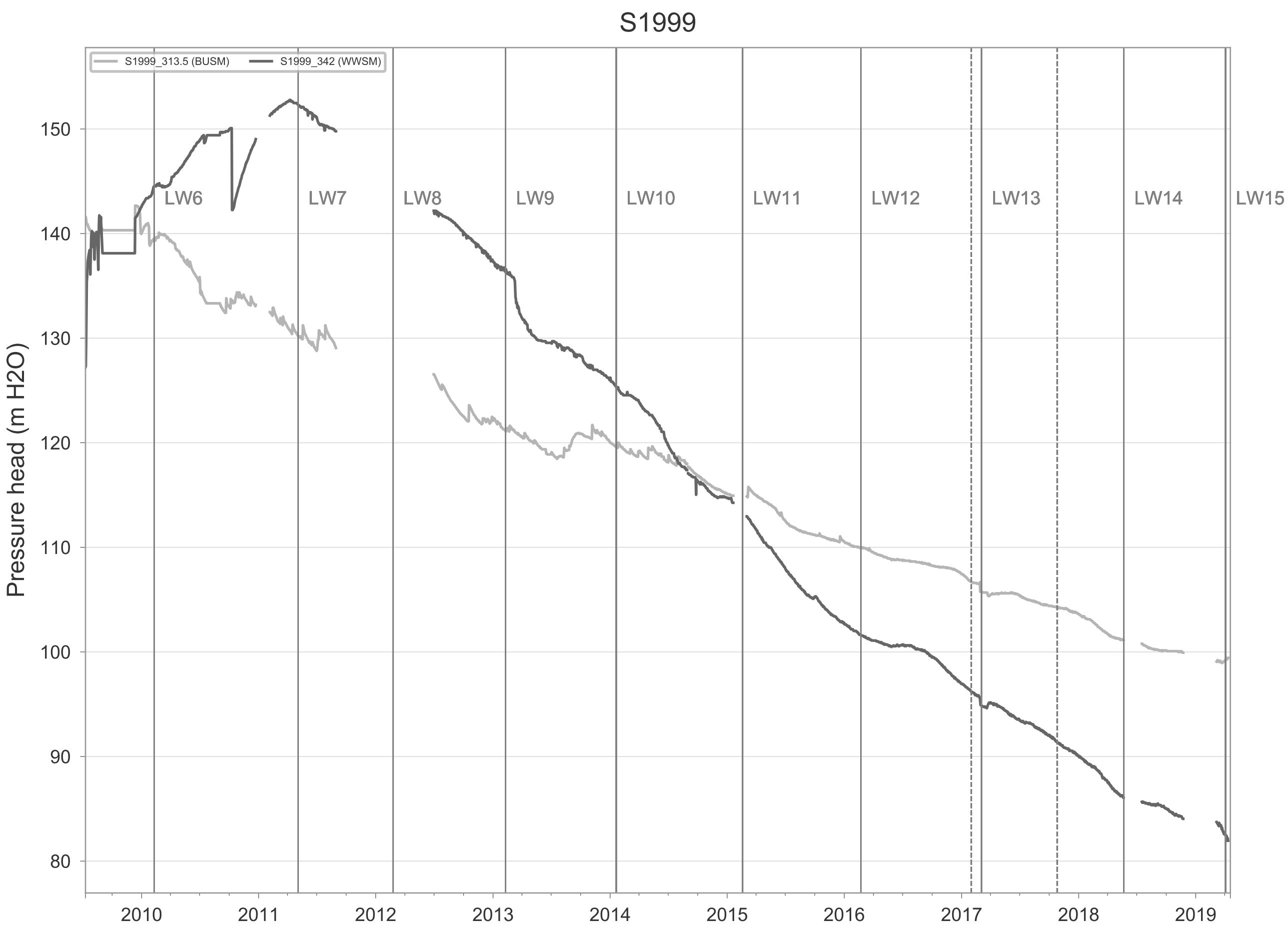

S1995
LW6
LW7
LW8
LW9
LW10
Pressure head (m H2O)
250
200
150
100
50
S1995_384.4 (BUSM)
S1995_411.3 (WWSM)
2010
2011
2012
2013
2014

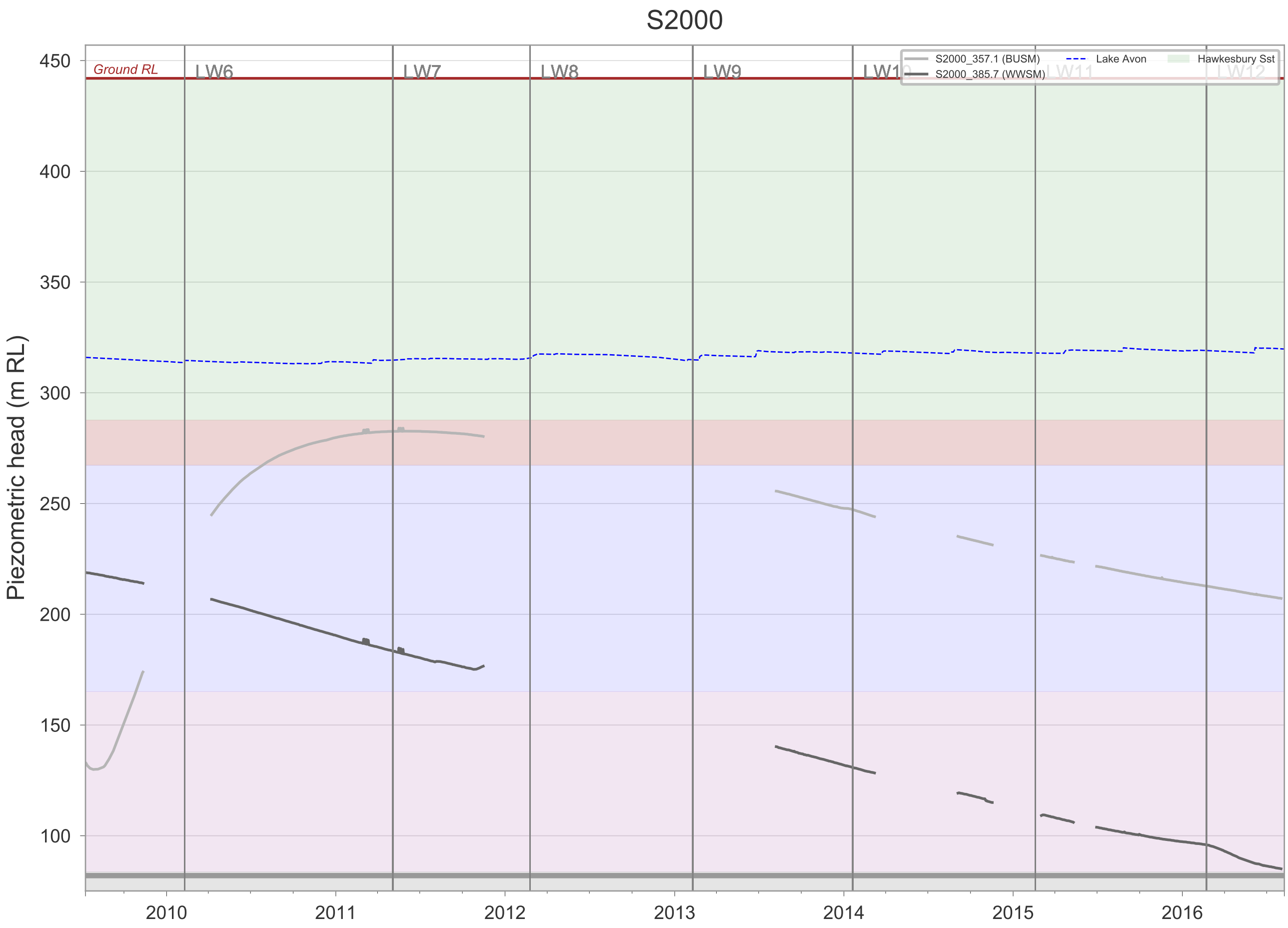

S1998
S1998_381.7 (BUSM)
S1998_407.9 (WWSM)
Lake Avon
Hawkesbury Sst
Ground RL
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
Piezometric head (m RL)
425
400
375
350
325
300
275
250
2010
2011
2012
2013
2014
2015
2016
2017
2018

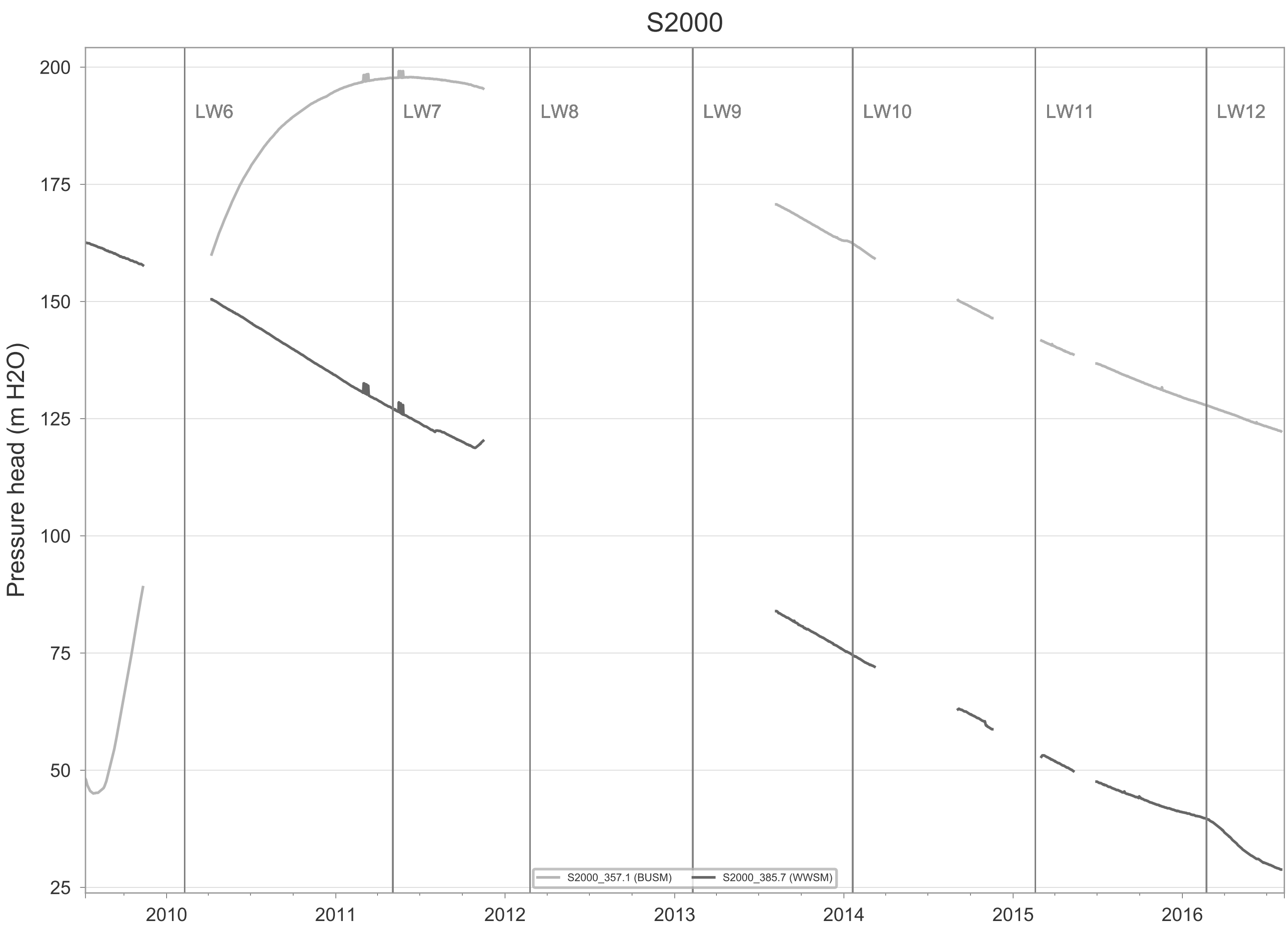

S1998
S1998_381.7 (BUSM)
S1998_407.9 (WWSM)
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
Pressure head (m H2O)
280
270
260
250
240
230
2010
2011
2012
2013
2014
2015
2016
2017
2018

Groundwater hydrographs

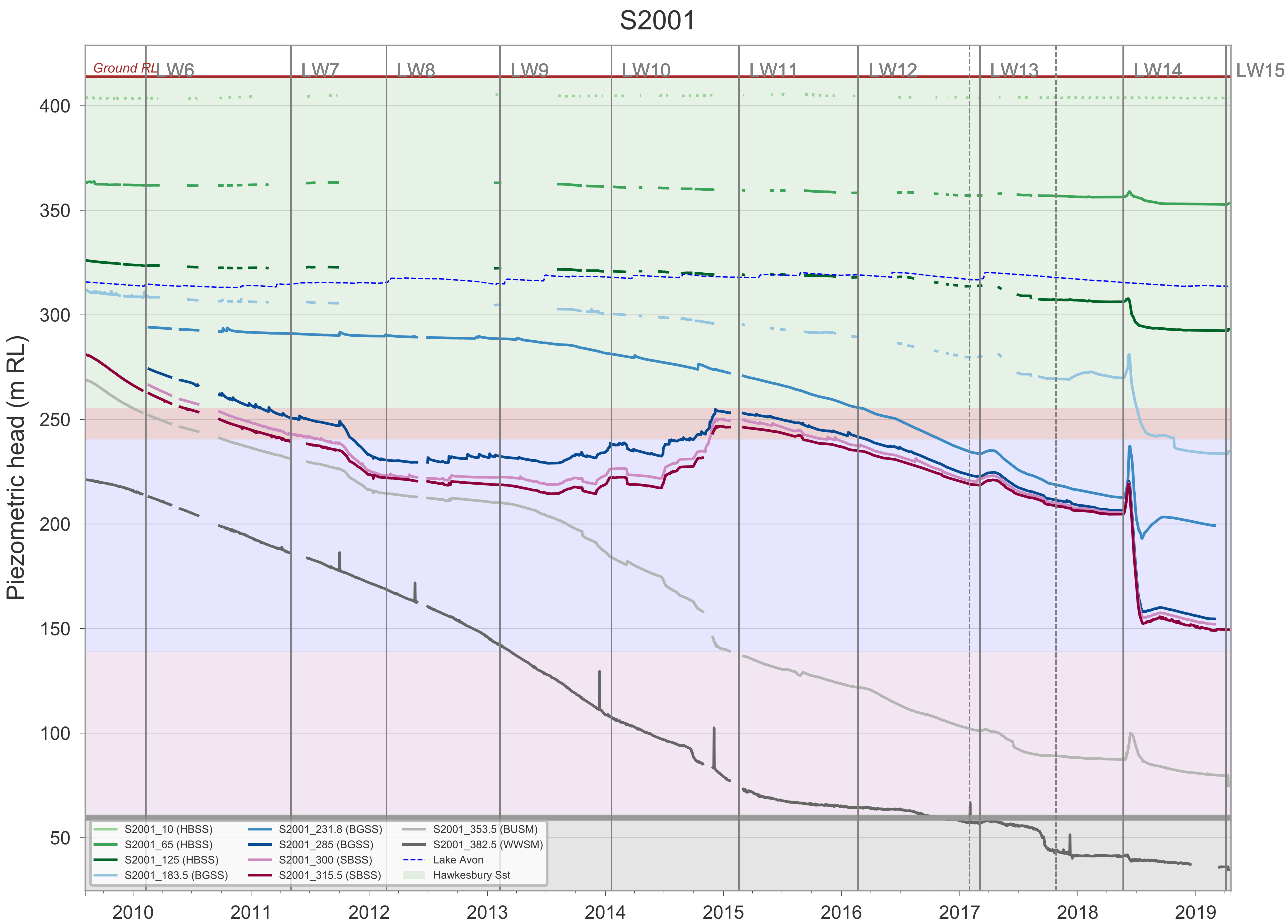


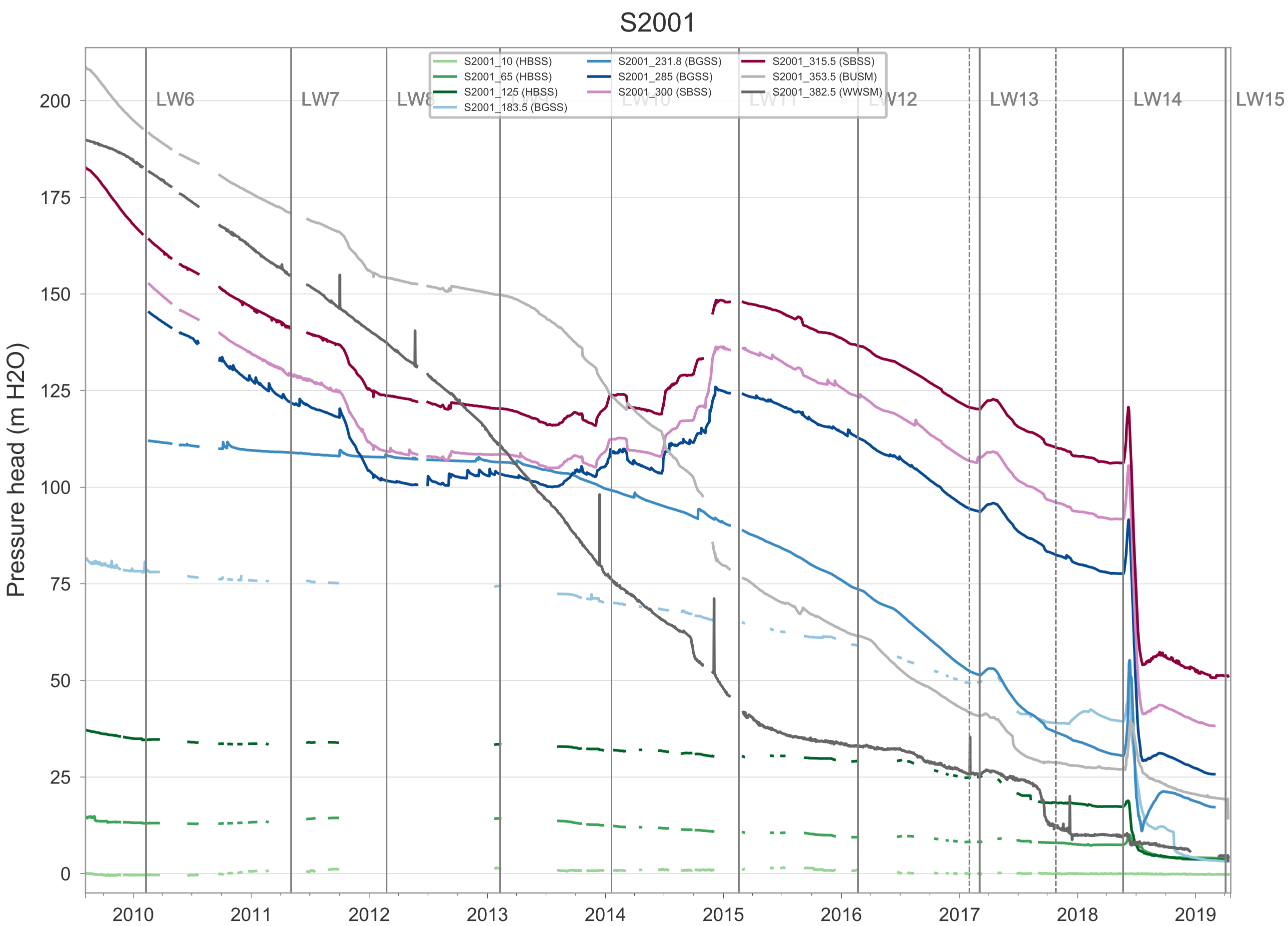


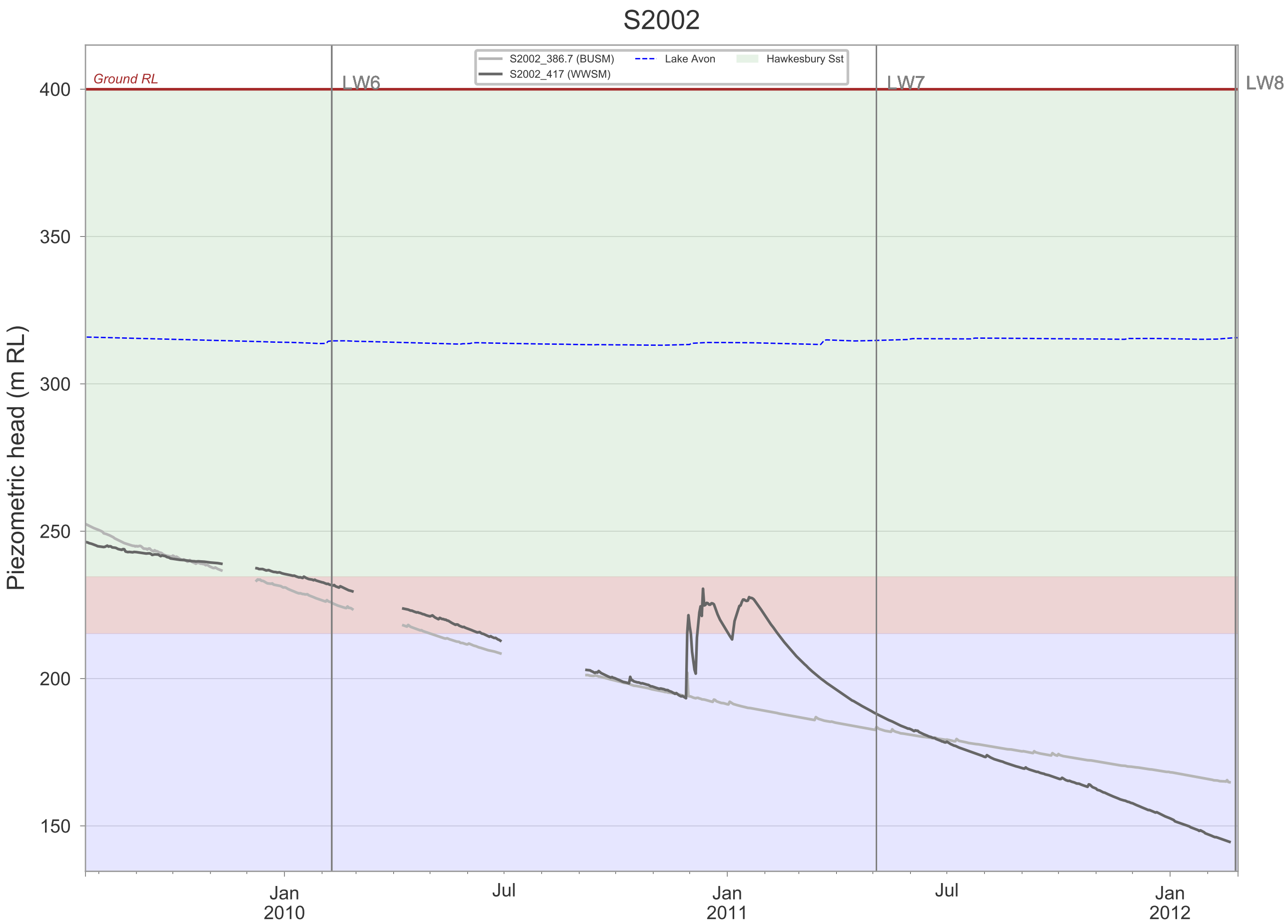

S2000
Piezometric head (m RL)
Ground RL
LW6
LW7
LW8
LW9
LW10
LW11
LW12
S2000_357.1 (BUSM)
S2000_385.7 (WWSM)
Lake Avon
Hawkesbury Sst
450
400
350
300
250
200
150
100
2010
2011
2012
2013
2014
2015
2016

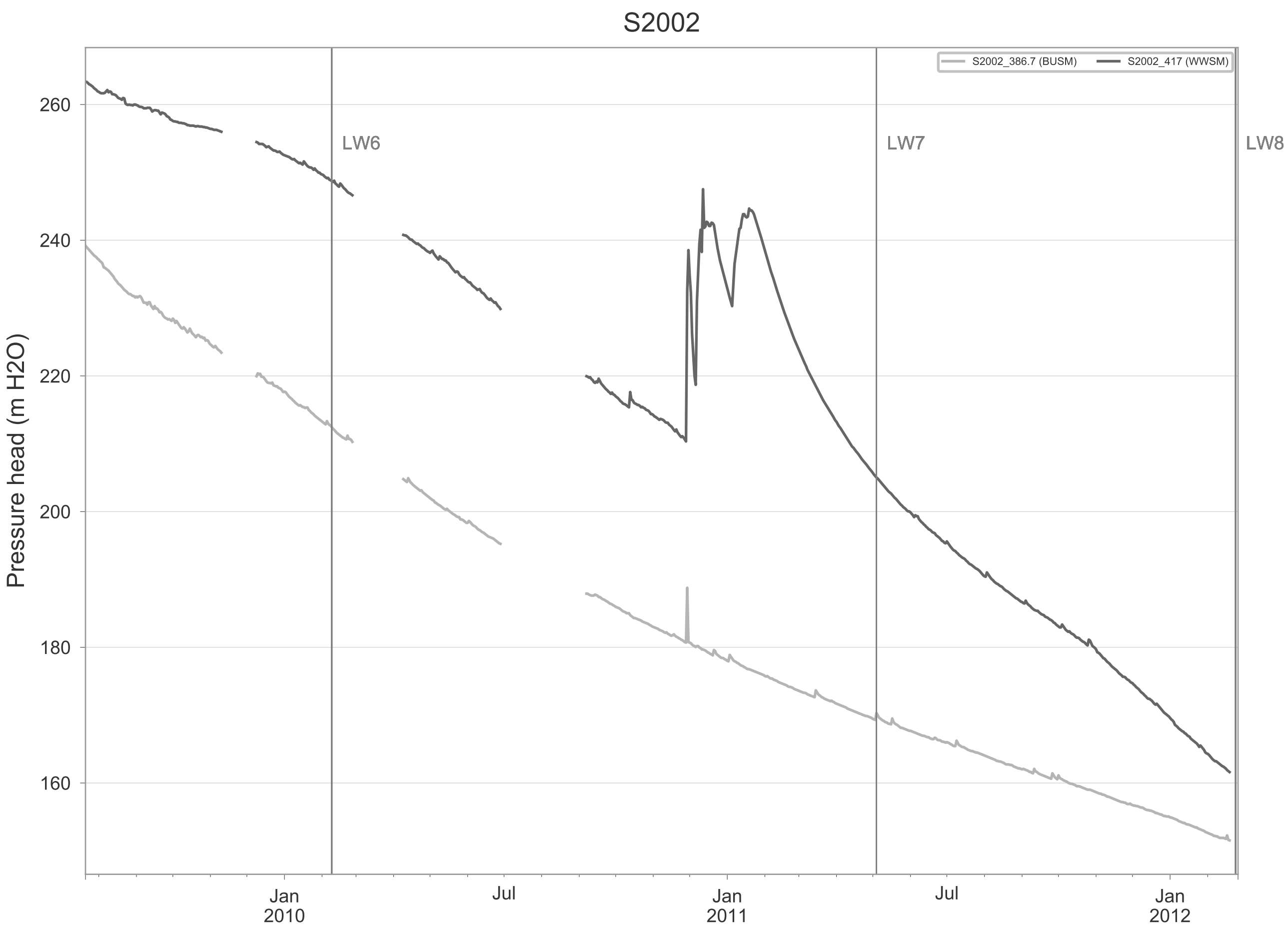

S2000
Pressure head (m H2O)
LW6
LW7
LW8
LW9
LW10
LW11
LW12
S2000_357.1 (BUSM)
S2000_385.7 (WWSM)
200
175
150
125
100
75
50
25
2010
2011
2012
2013
2014
2015
2016

Groundwater hydrographs

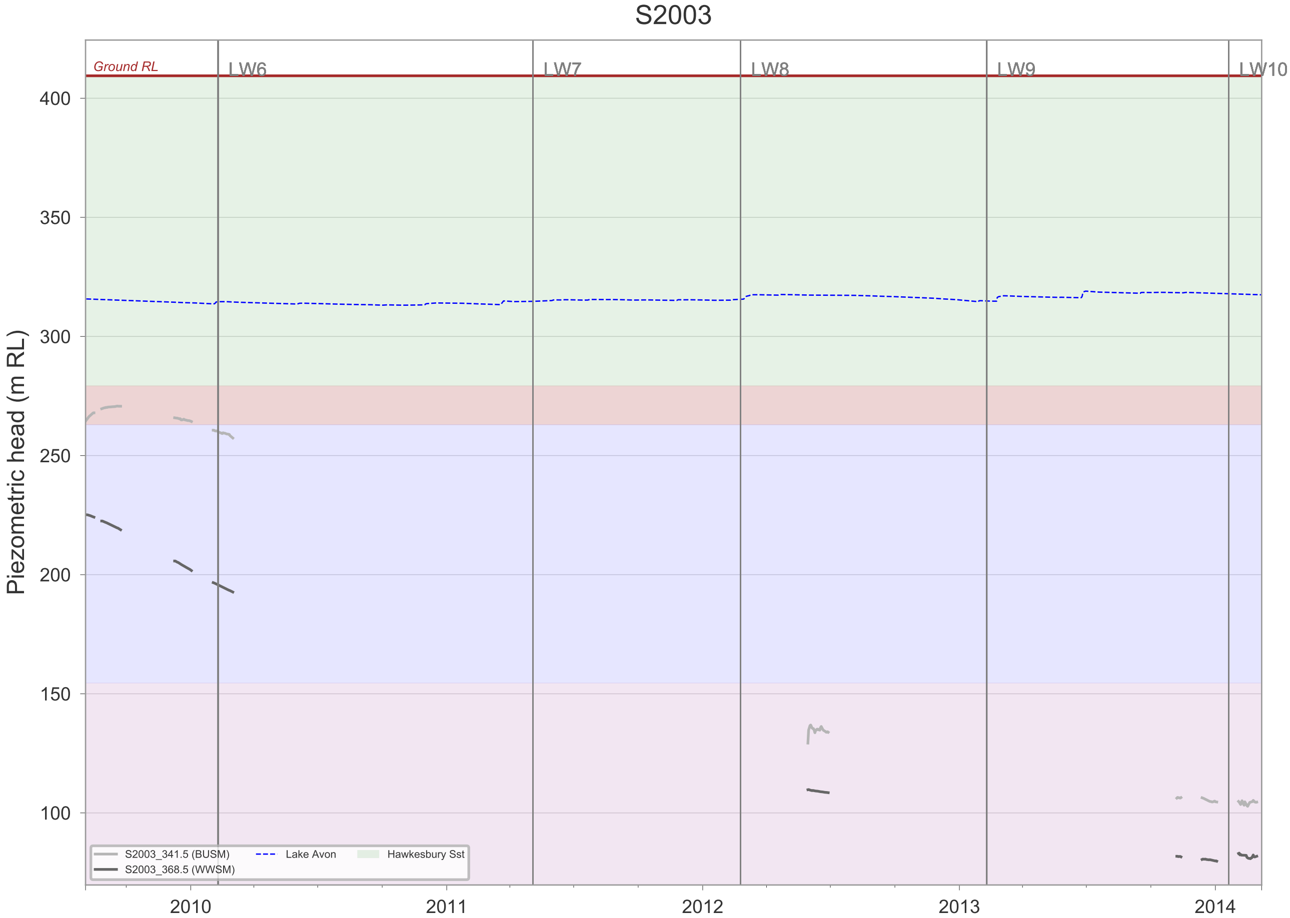


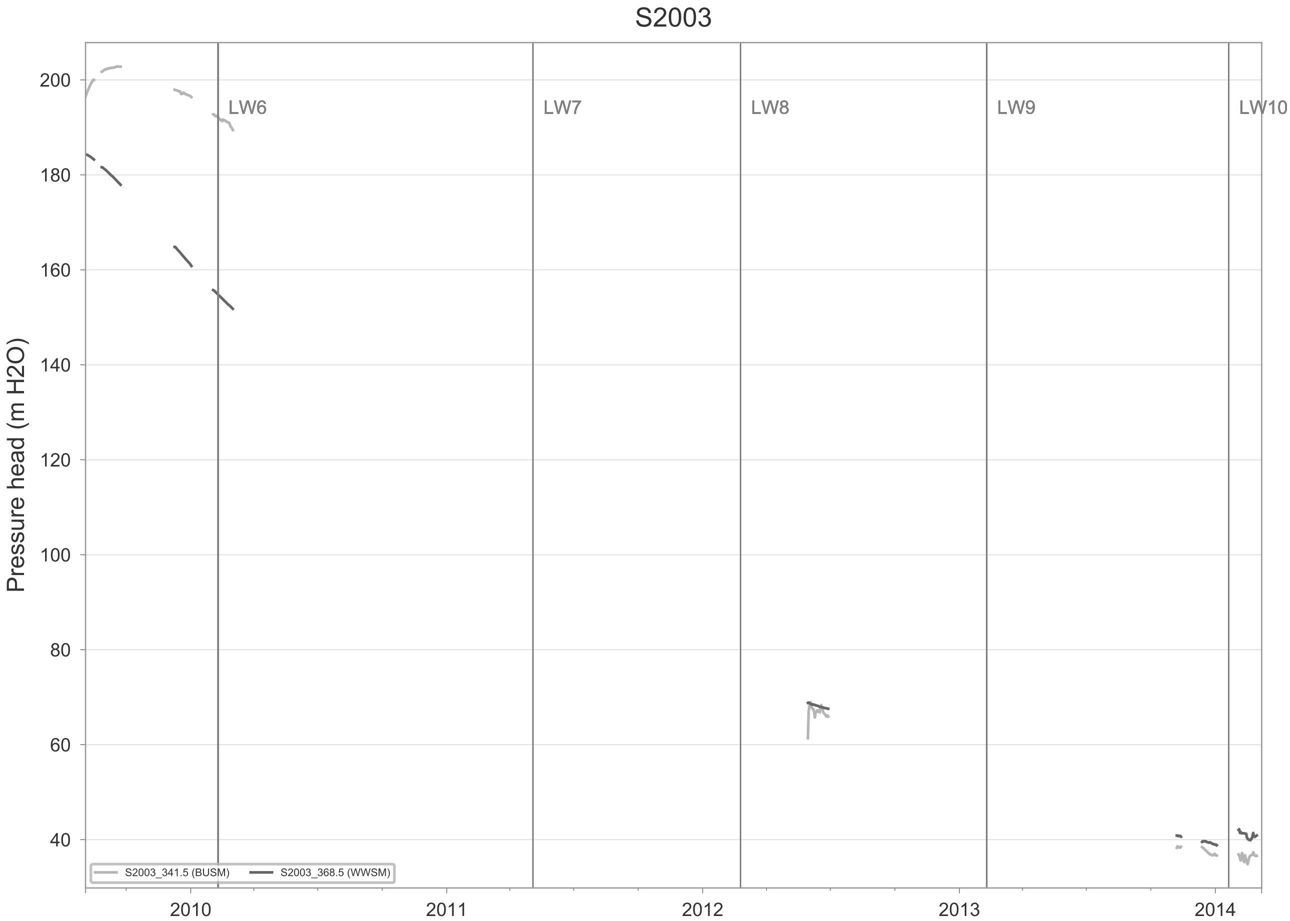


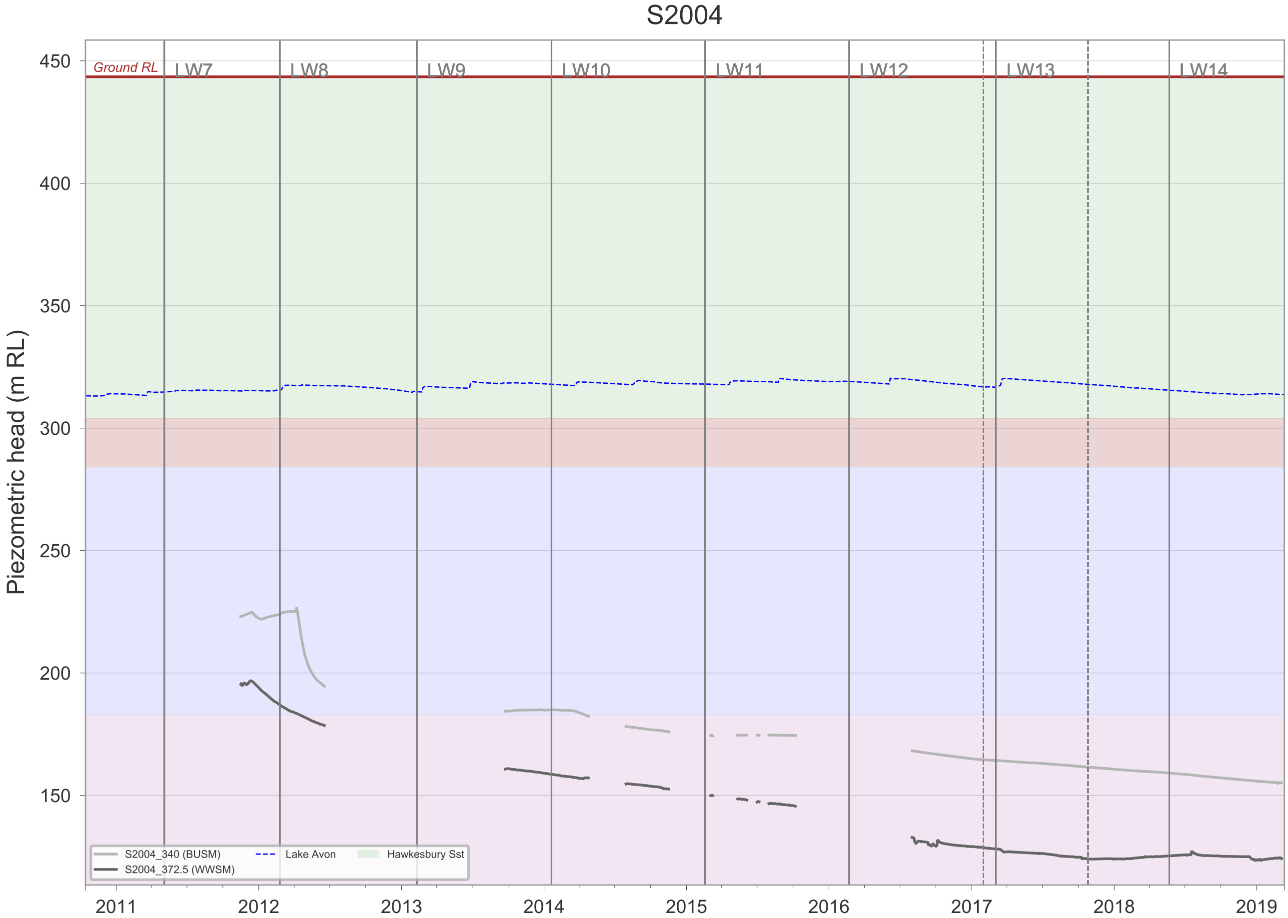

S2002
S2002_386.7 (BUSM)
S2002_417 (WWSM)
Lake Avon
Hawkesbury Sst
Ground RL
LW6
LW7
LW8
Piezometric head (m RL)
400
350
300
250
200
150
Jan 2010
Jul
Jan 2011
Jul
Jan 2012

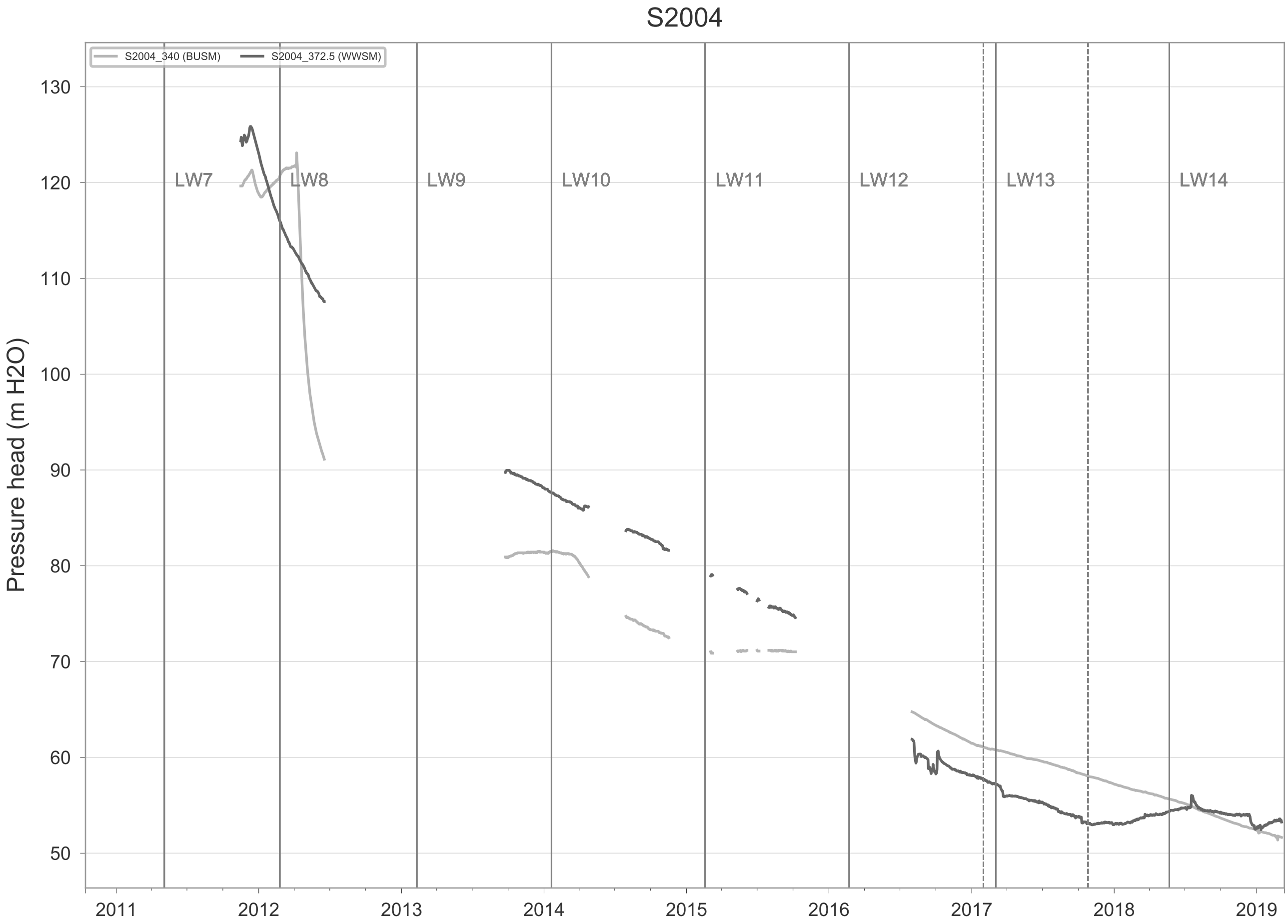

S2002
S2002_386.7 (BUSM)
S2002_417 (WWSM)
LW6
LW7
LW8
Pressure head (m H2O)
260
240
220
200
180
160
Jan 2010
Jul
Jan 2011
Jul
Jan 2012

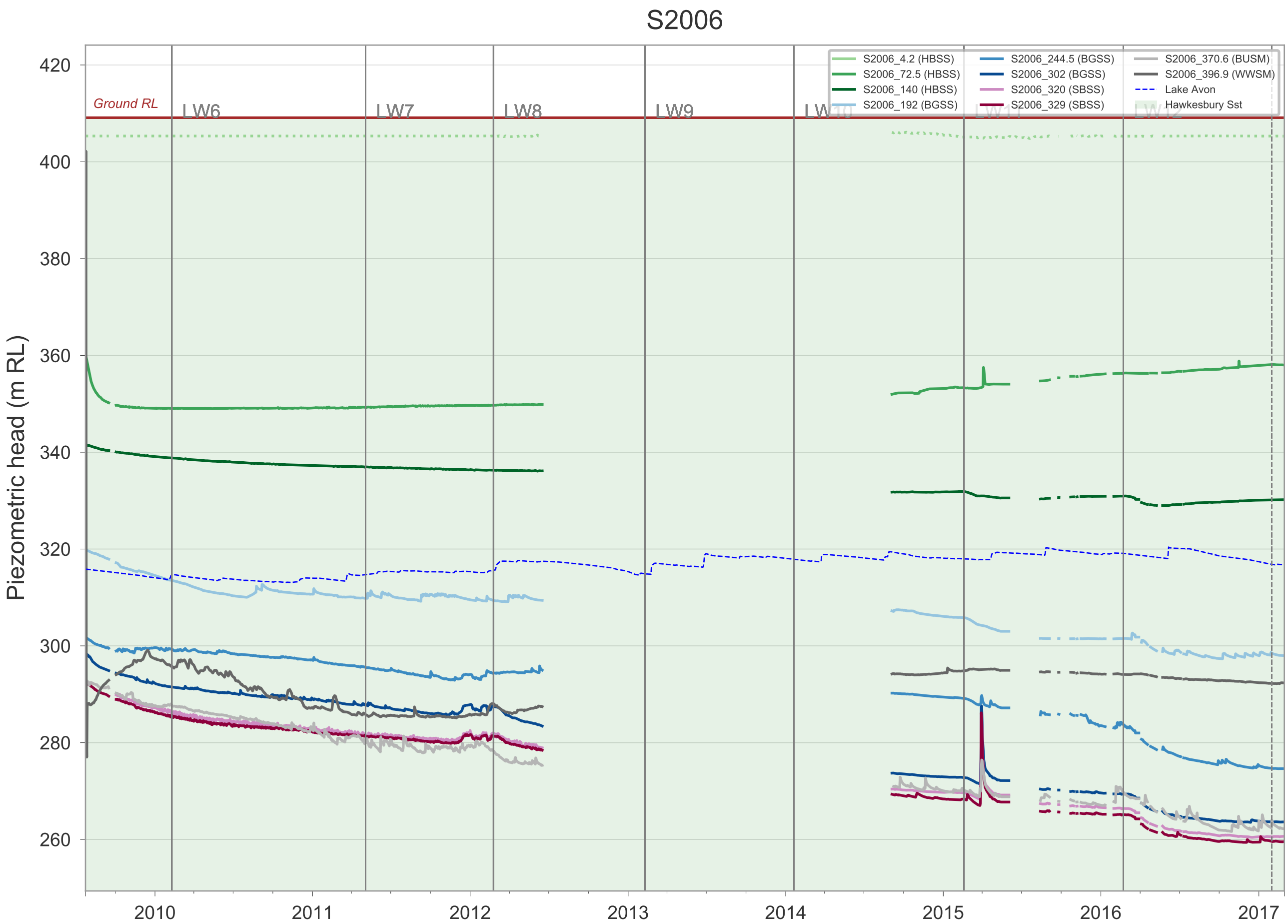
Groundwater hydrographs

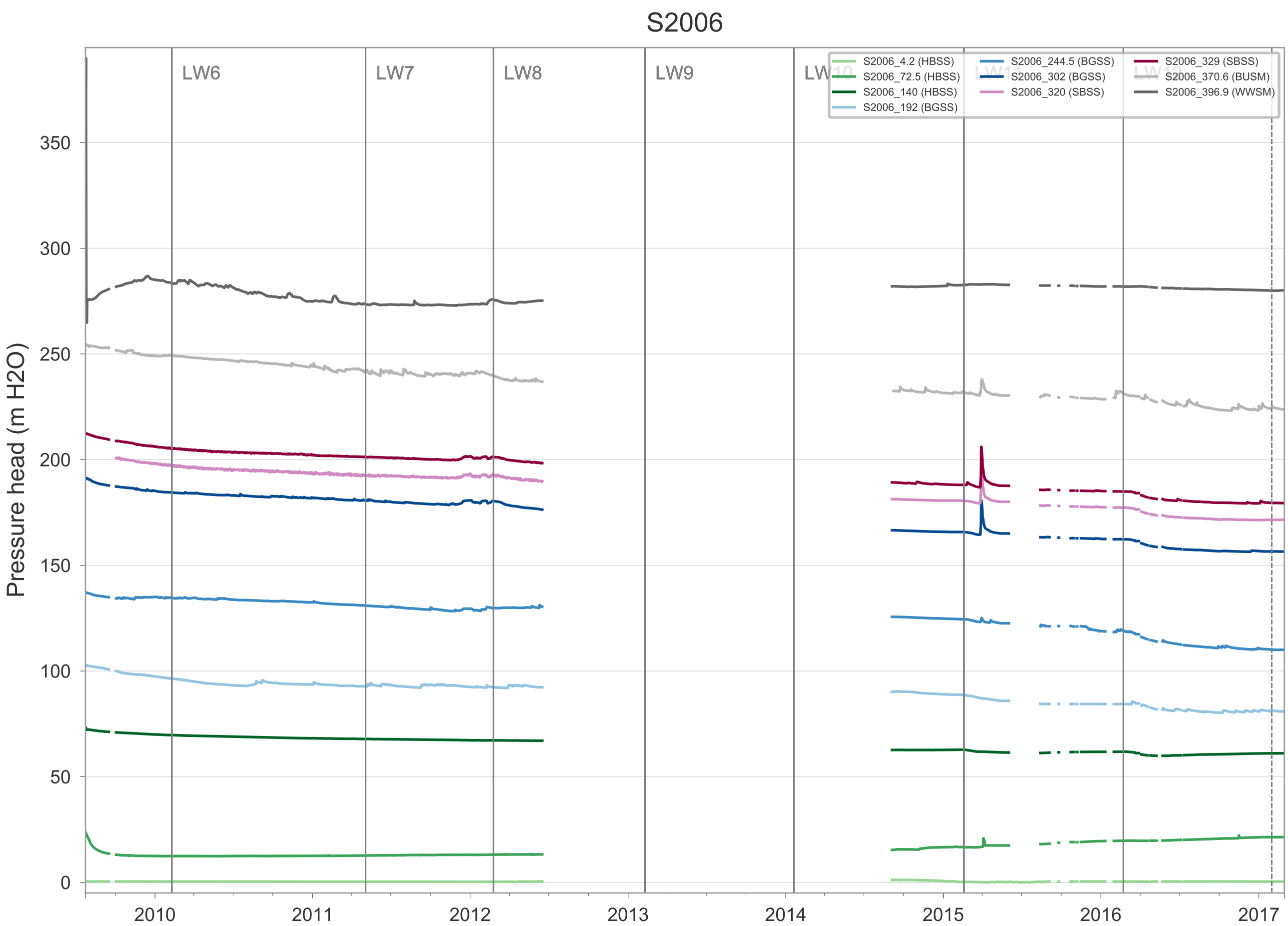




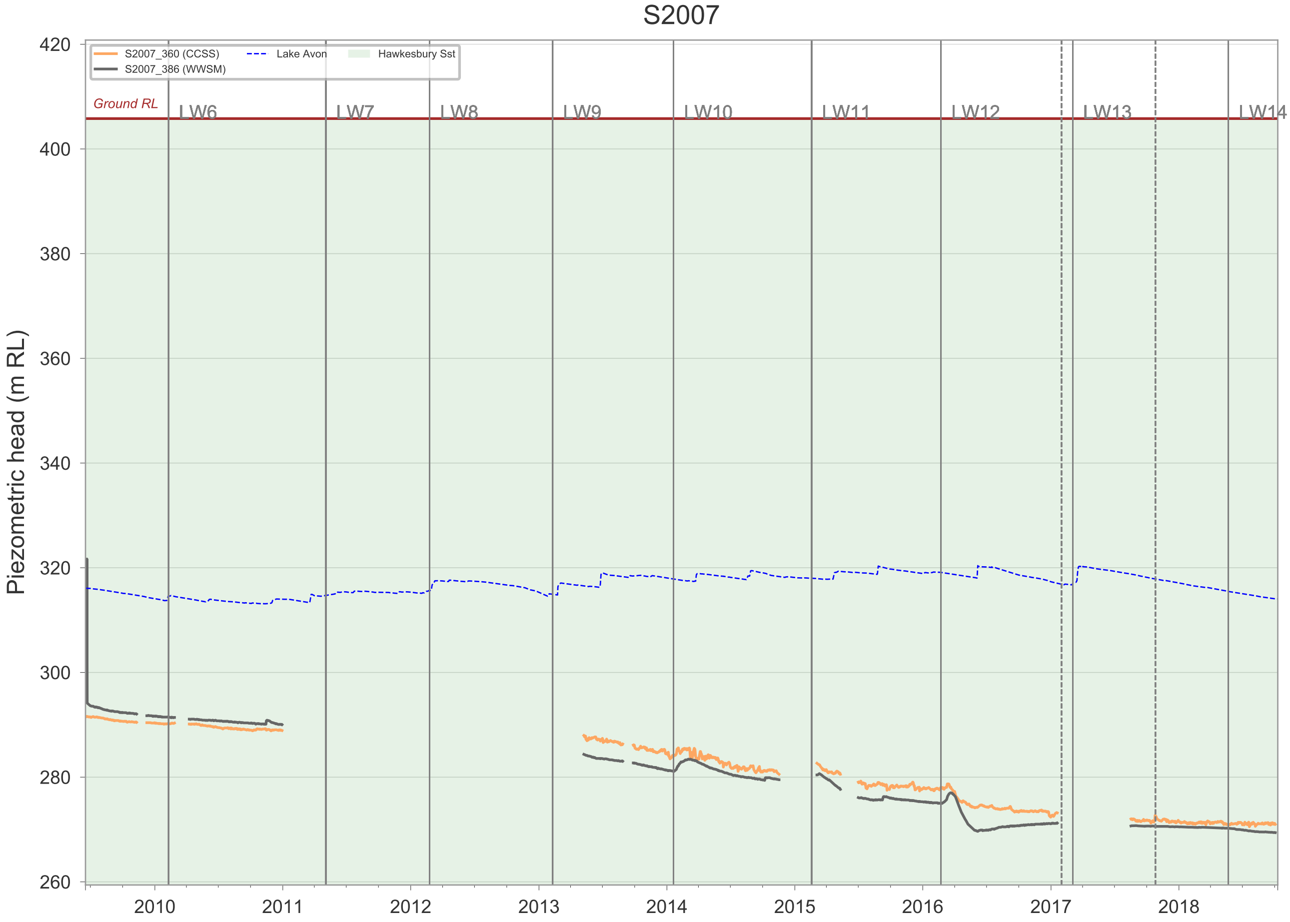

S2004
Piezometric head (m RL)
Ground RL
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
S2004_340 (BUSM)
S2004_372.5 (WWSM)
Lake Avon
Hawkesbury Sst
450
400
350
300
250
200
150
2011
2012
2013
2014
2015
2016
2017
2018
2019

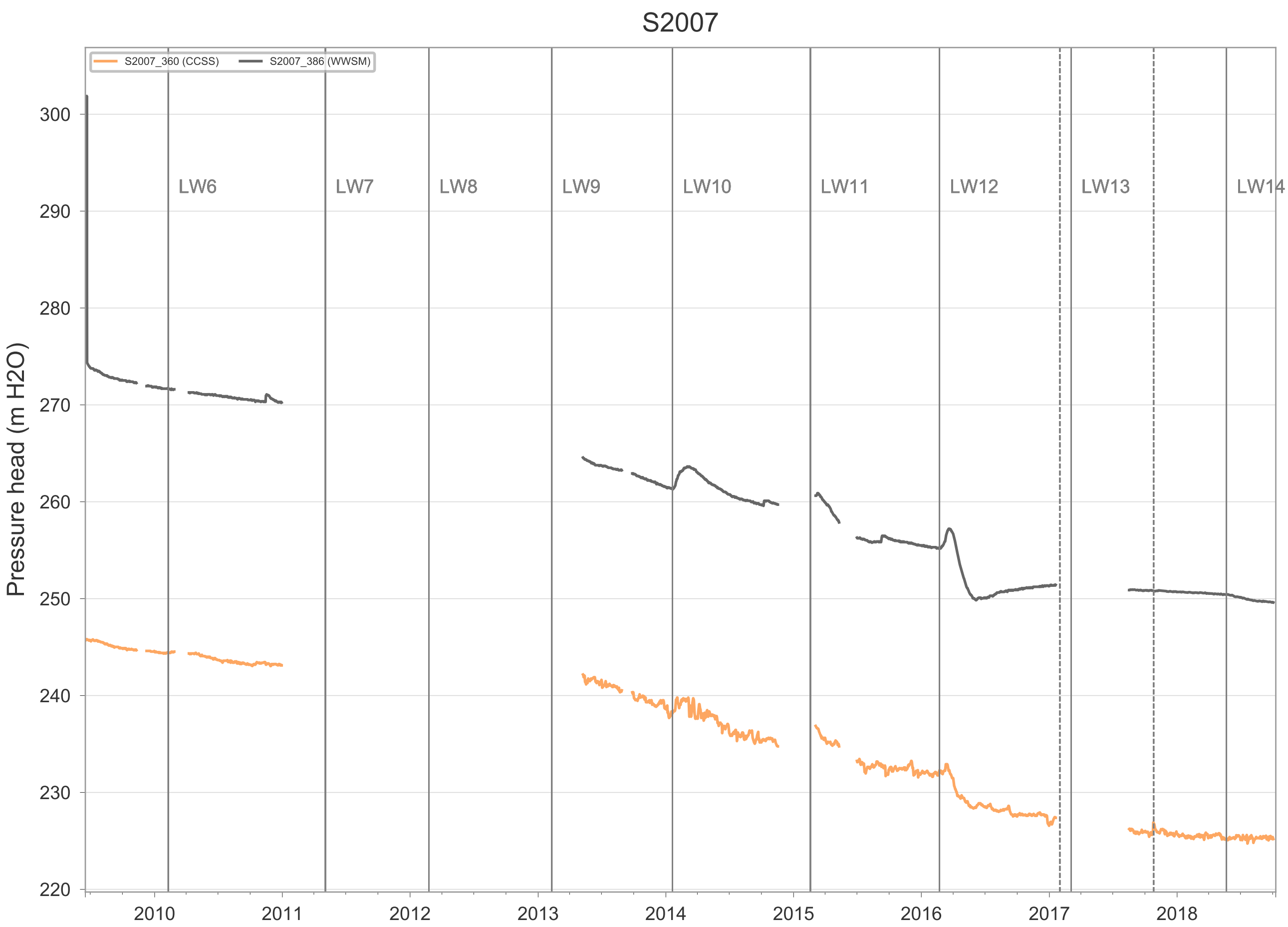

S2004
Pressure head (m H2O)
S2004_340 (BUSM)
S2004_372.5 (WWSM)
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
130
120
110
100
90
80
70
60
50
2011
2012
2013
2014
2015
2016
2017
2018
2019

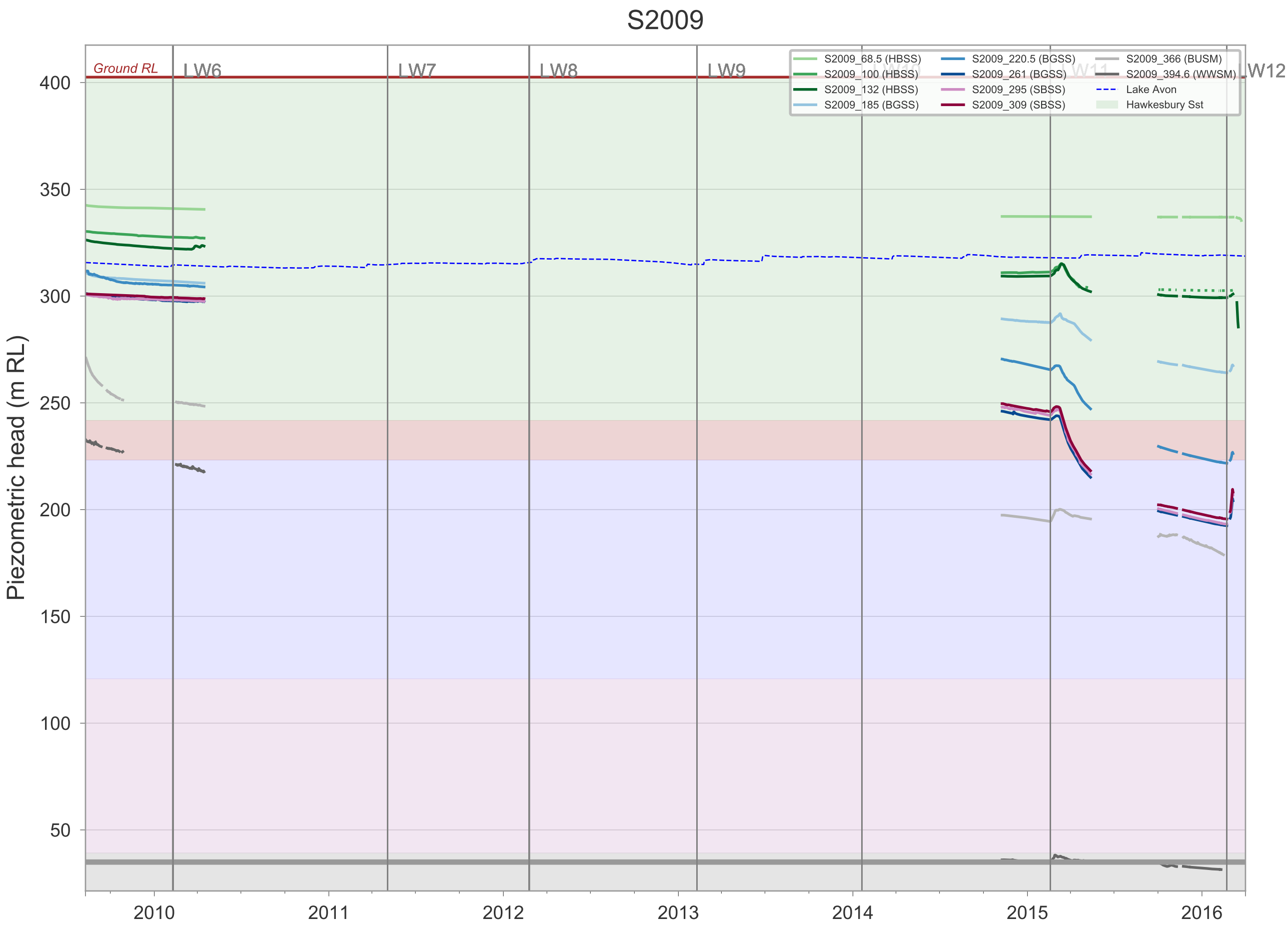

S2006
Piezometric head (m RL)
Ground RL
LW6
LW7
LW8
LW9
LW10
LW11
LW12
S2006_4.2 (HBSS)
S2006_72.5 (HBSS)
S2006_140 (HBSS)
S2006_192 (BGSS)
S2006_244.5 (BGSS)
S2006_302 (BGSS)
S2006_320 (SBSS)
S2006_329 (SBSS)
S2006_370.6 (BUSM)
S2006_396.9 (WWSM)
Lake Avon
Hawkesbury Sst
420
400
380
360
340
320
300
280
260
2010
2011
2012
2013
2014
2015
2016
2017

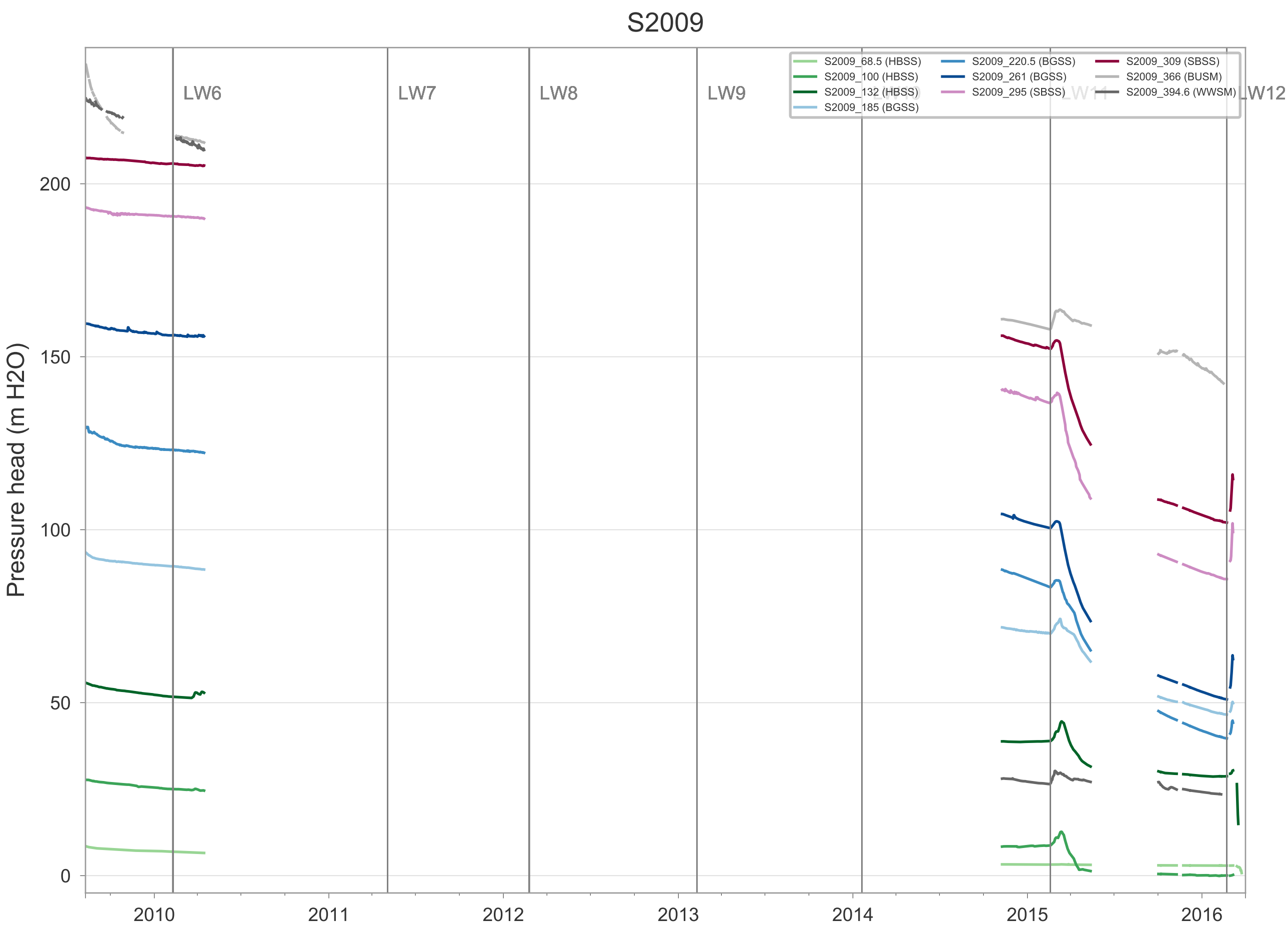

S2006
Pressure head (m H2O)
LW6
LW7
LW8
LW9
LW10
LW11
LW12
S2006_4.2 (HBSS)
S2006_72.5 (HBSS)
S2006_140 (HBSS)
S2006_192 (BGSS)
S2006_244.5 (BGSS)
S2006_302 (BGSS)
S2006_320 (SBSS)
S2006_329 (SBSS)
S2006_370.6 (BUSM)
S2006_396.9 (WWSM)
350
300
250
200
150
100
50
0
2010
2011
2012
2013
2014
2015
2016
2017

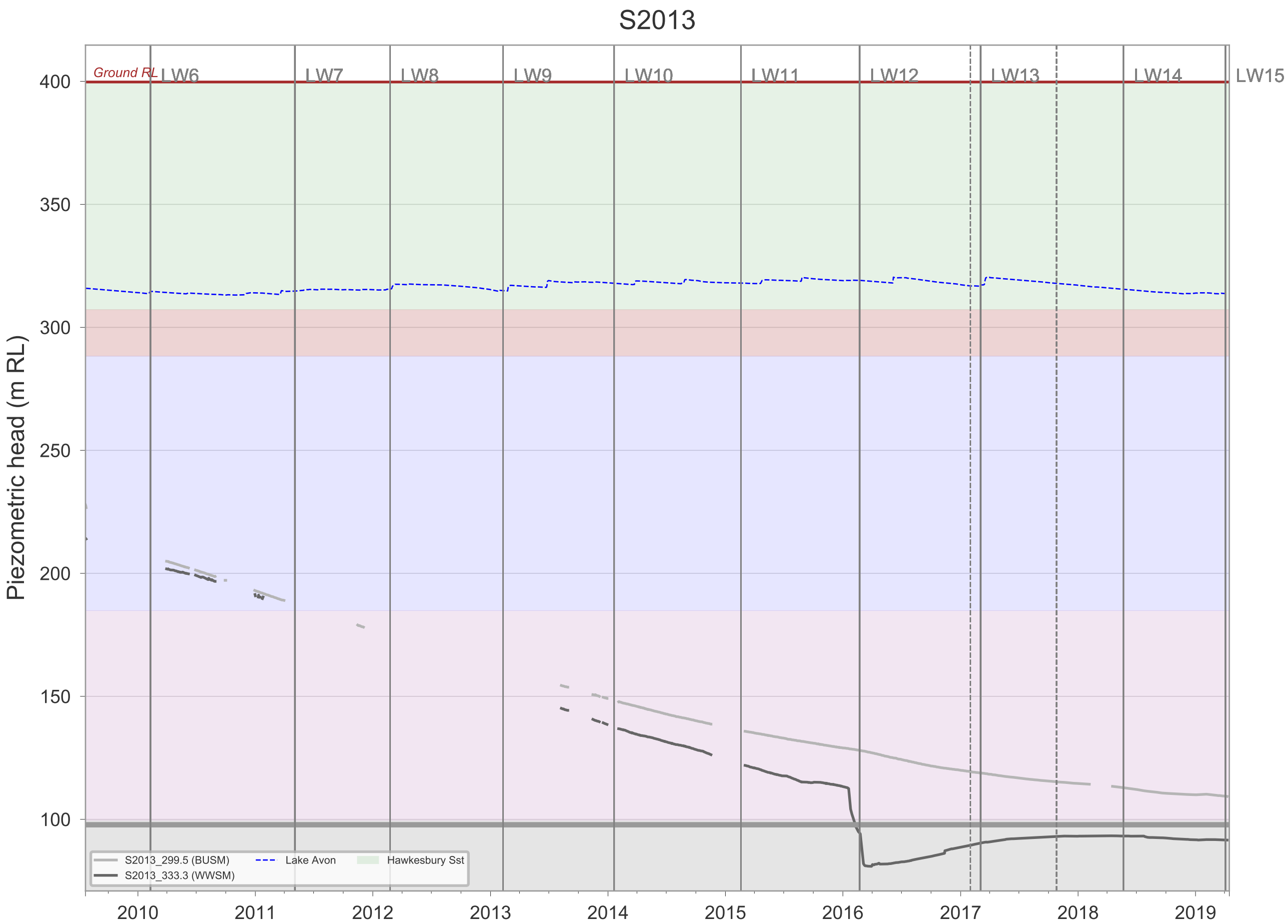
Groundwater hydrographs

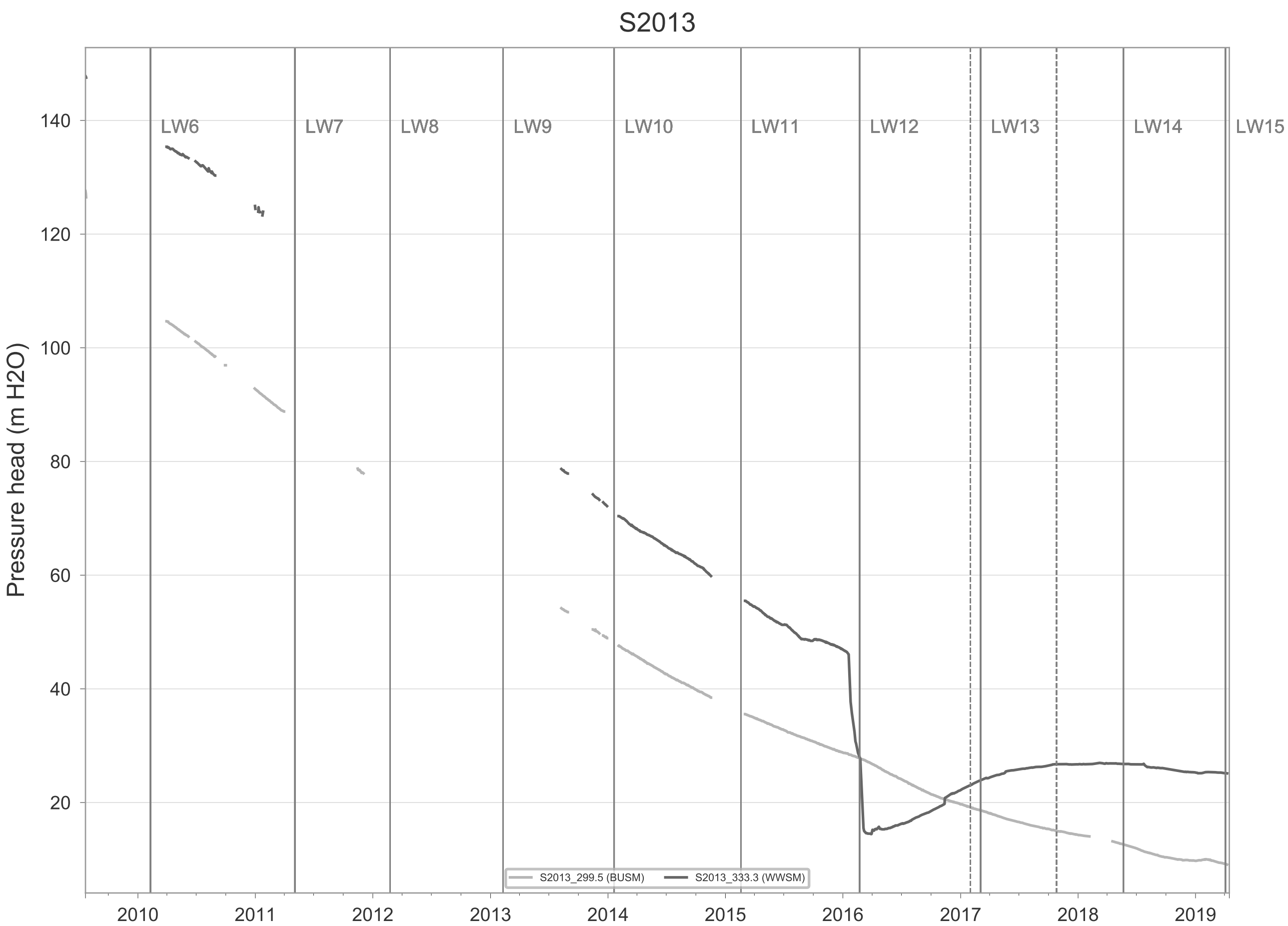


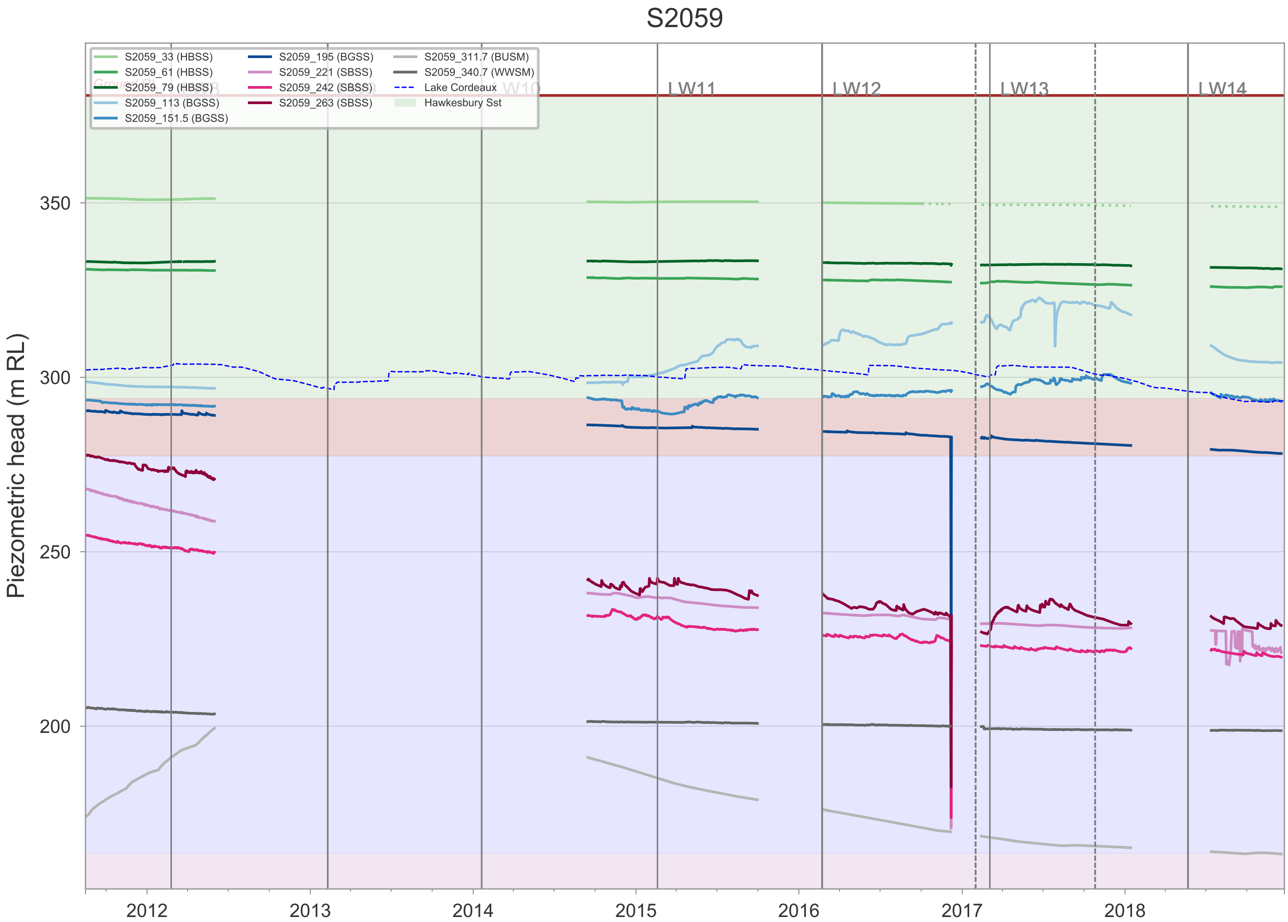


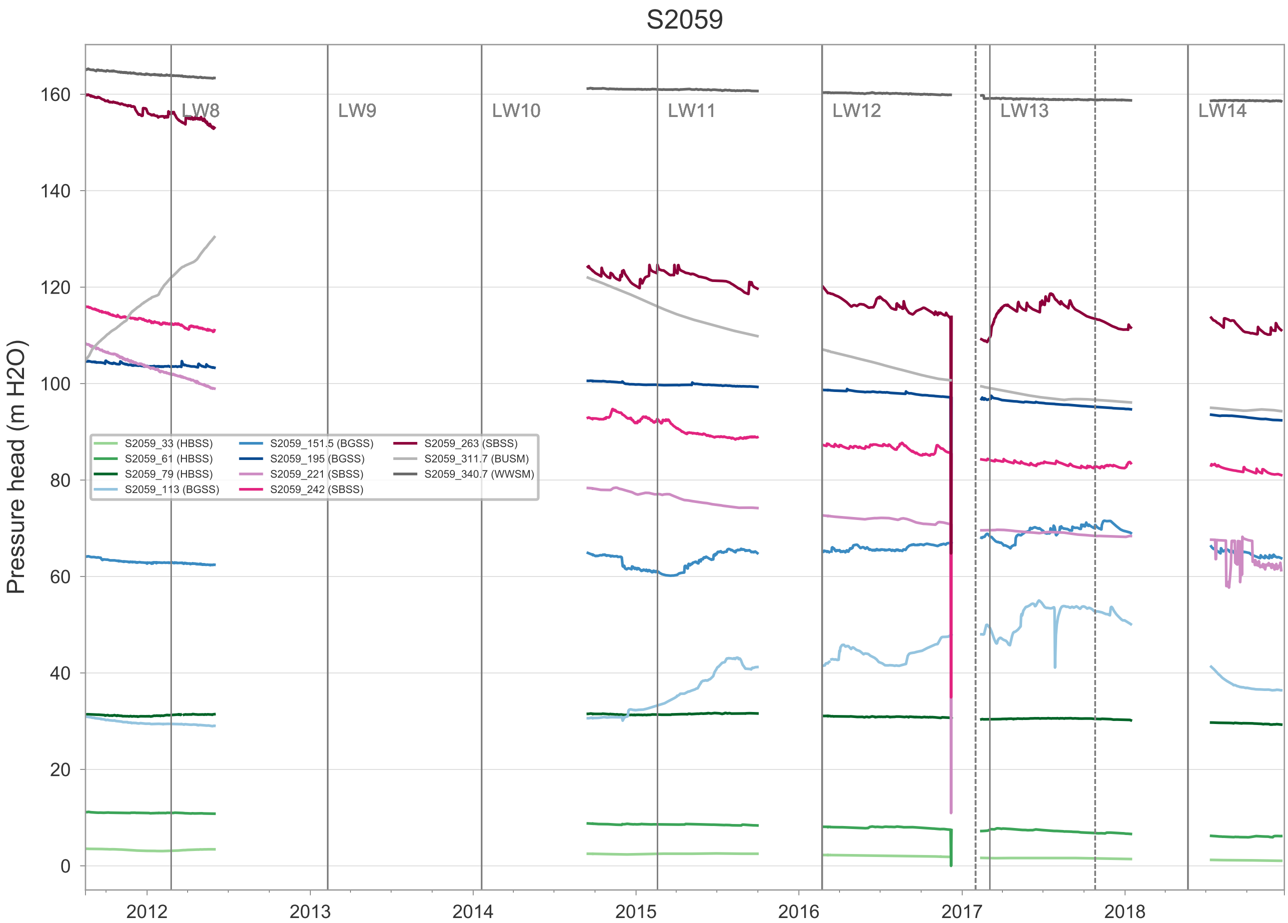

S2009
Ground RL
LW6
LW7
LW8
LW9
LW12
S2009_68.5 (HBSS)
S2009_100 (HBSS)
S2009_132 (HBSS)
S2009_185 (BGSS)
S2009_220.5 (BGSS)
S2009_261 (BGSS)
S2009_295 (SBSS)
S2009_309 (SBSS)
S2009_366 (BUSM)
S2009_394.6 (WWSM)
Lake Avon
Hawkesbury Sst
Piezometric head (m RL)
400
350
300
250
200
150
100
50
2010
2011
2012
2013
2014
2015
2016

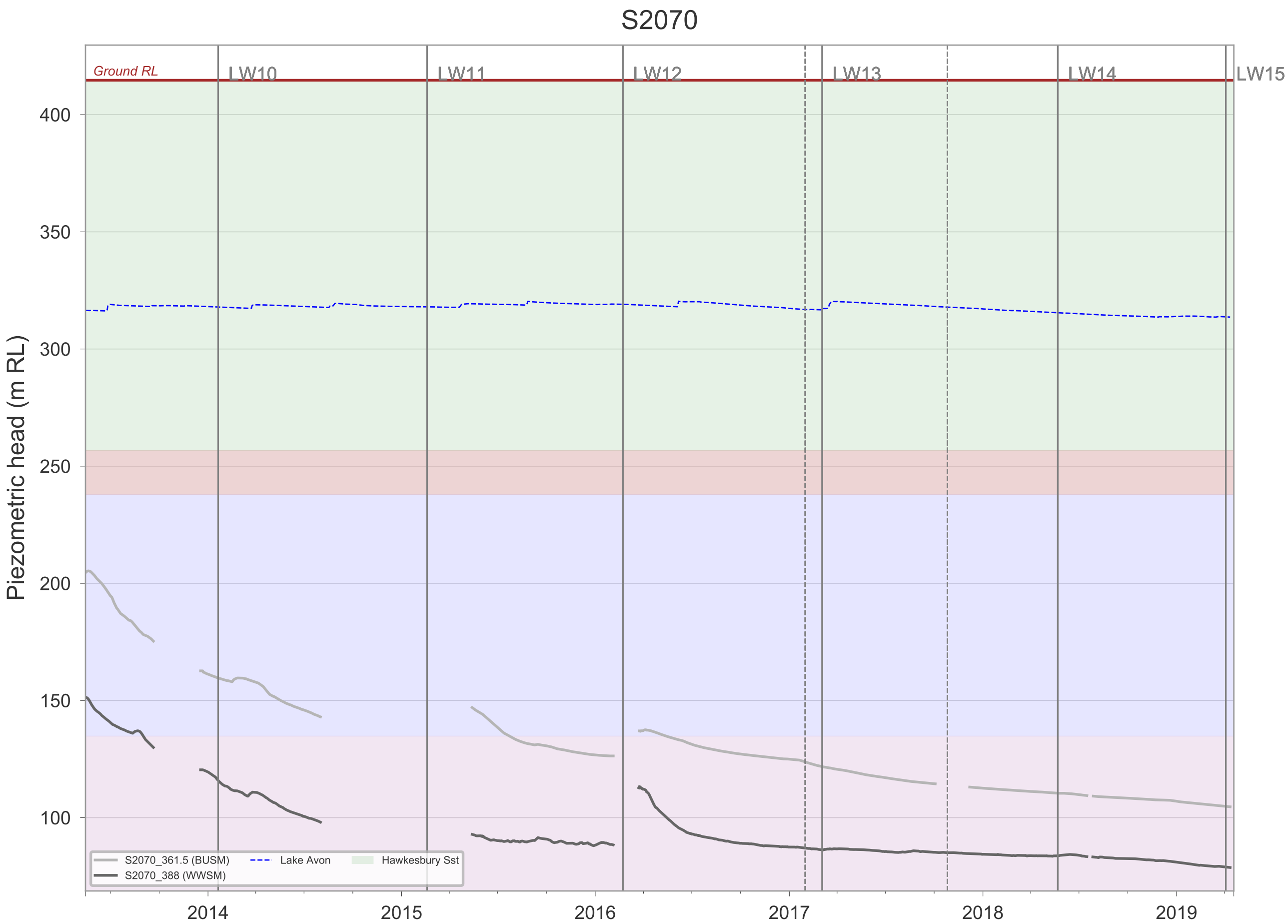

S2009
LW6
LW7
LW8
LW9
LW12
S2009_68.5 (HBSS)
S2009_100 (HBSS)
S2009_132 (HBSS)
S2009_185 (BGSS)
S2009_220.5 (BGSS)
S2009_261 (BGSS)
S2009_295 (SBSS)
S2009_309 (SBSS)
S2009_366 (BUSM)
S2009_394.6 (WWSM)
Pressure head (m H2O)
200
150
100
50
0
2010
2011
2012
2013
2014
2015
2016

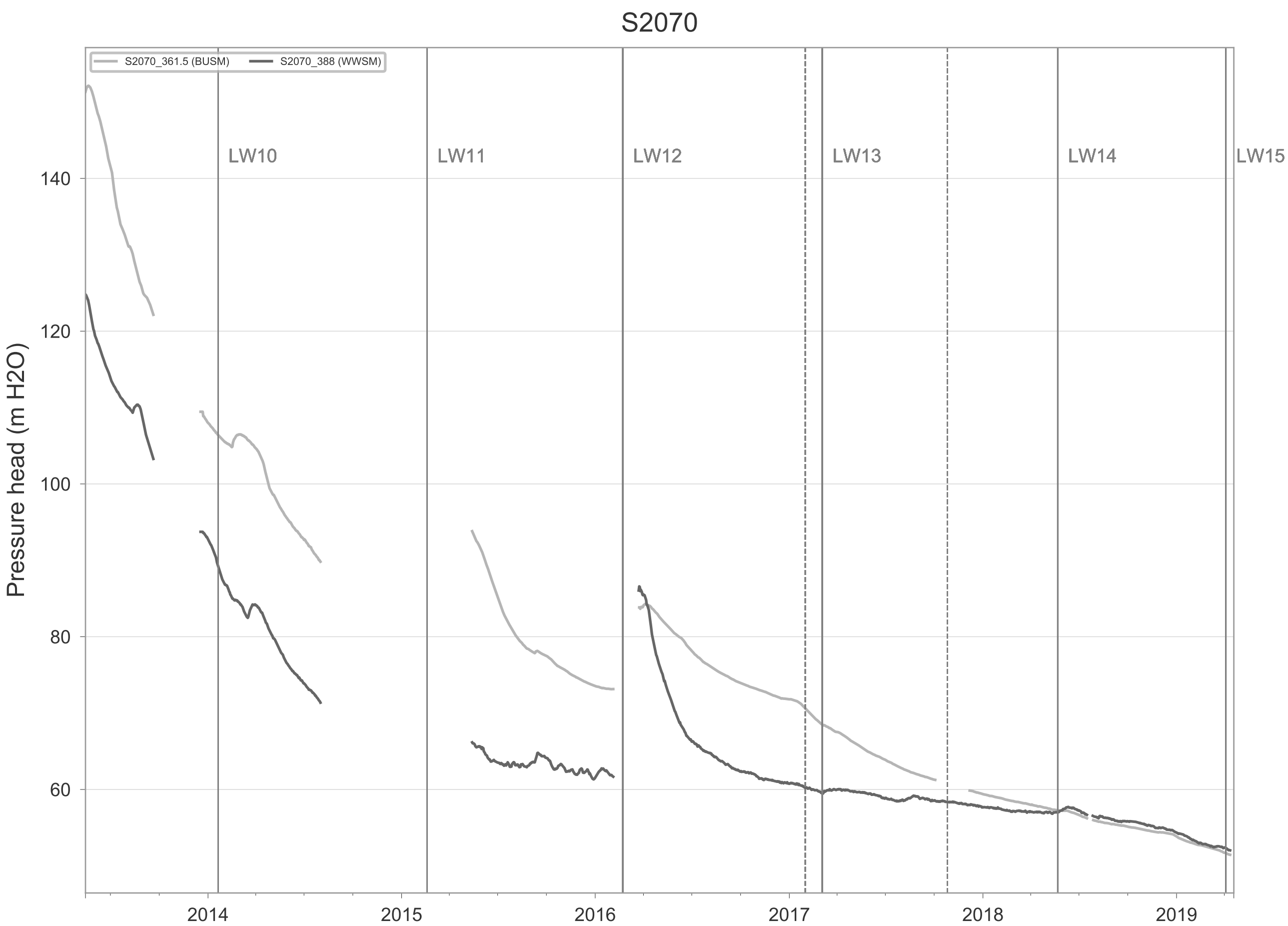

S2013
Ground RL
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
Piezometric head (m RL)
400
350
300
250
200
150
100
S2013_299.5 (BUSM)
S2013_333.3 (WWSM)
Lake Avon
Hawkesbury Sst
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019

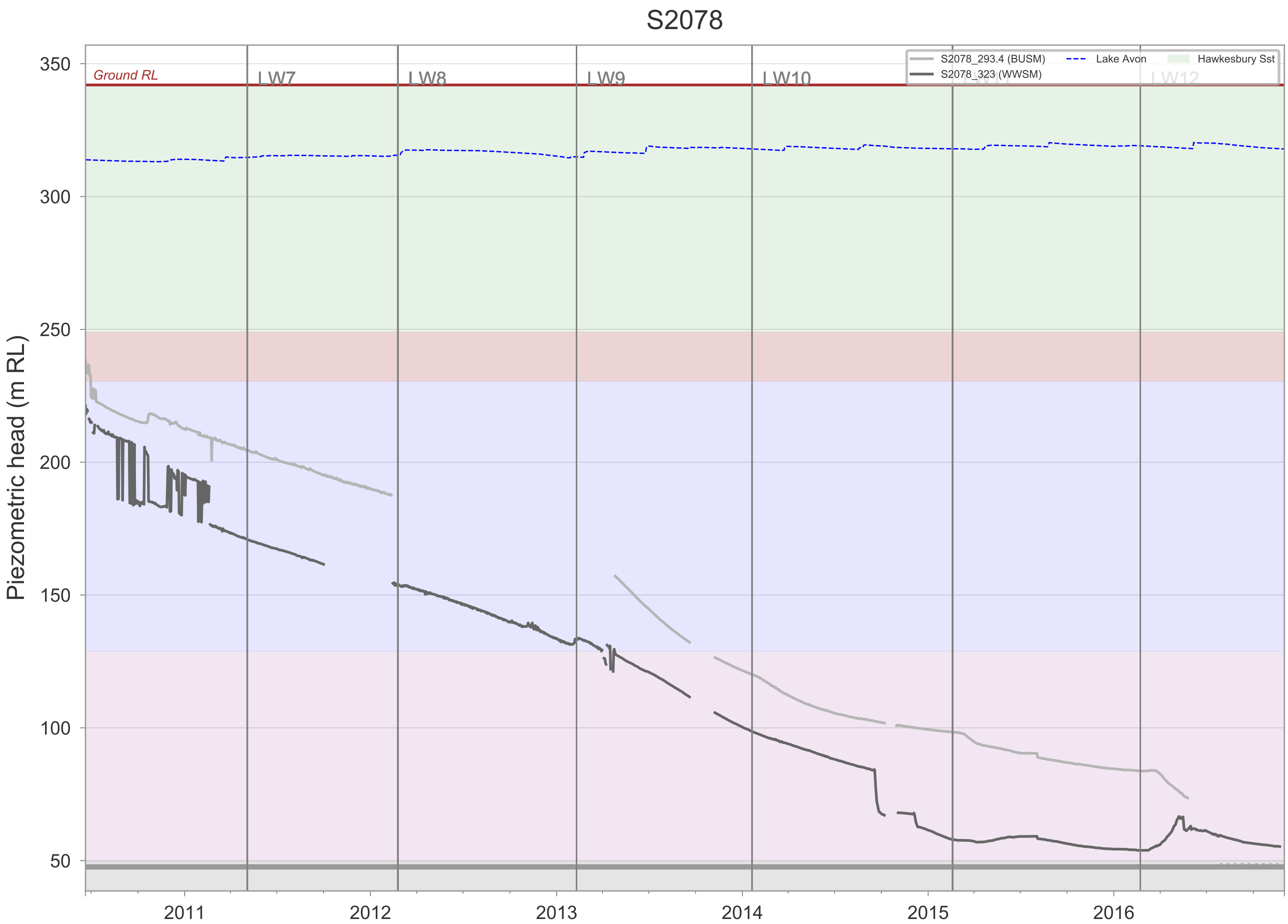

S2013
LW6
LW7
LW8
LW9
LW10
LW11
LW12
LW13
LW14
LW15
Pressure head (m H2O)
140
120
100
80
60
40
20
S2013_299.5 (BUSM)
S2013_333.3 (WWSM)
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019


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
Hawkesbury Sst
LW11
LW12
LW13
LW14
Piezometric head (m RL)
350
300
250
200
2012
2013
2014
2015
2016
2017
2018

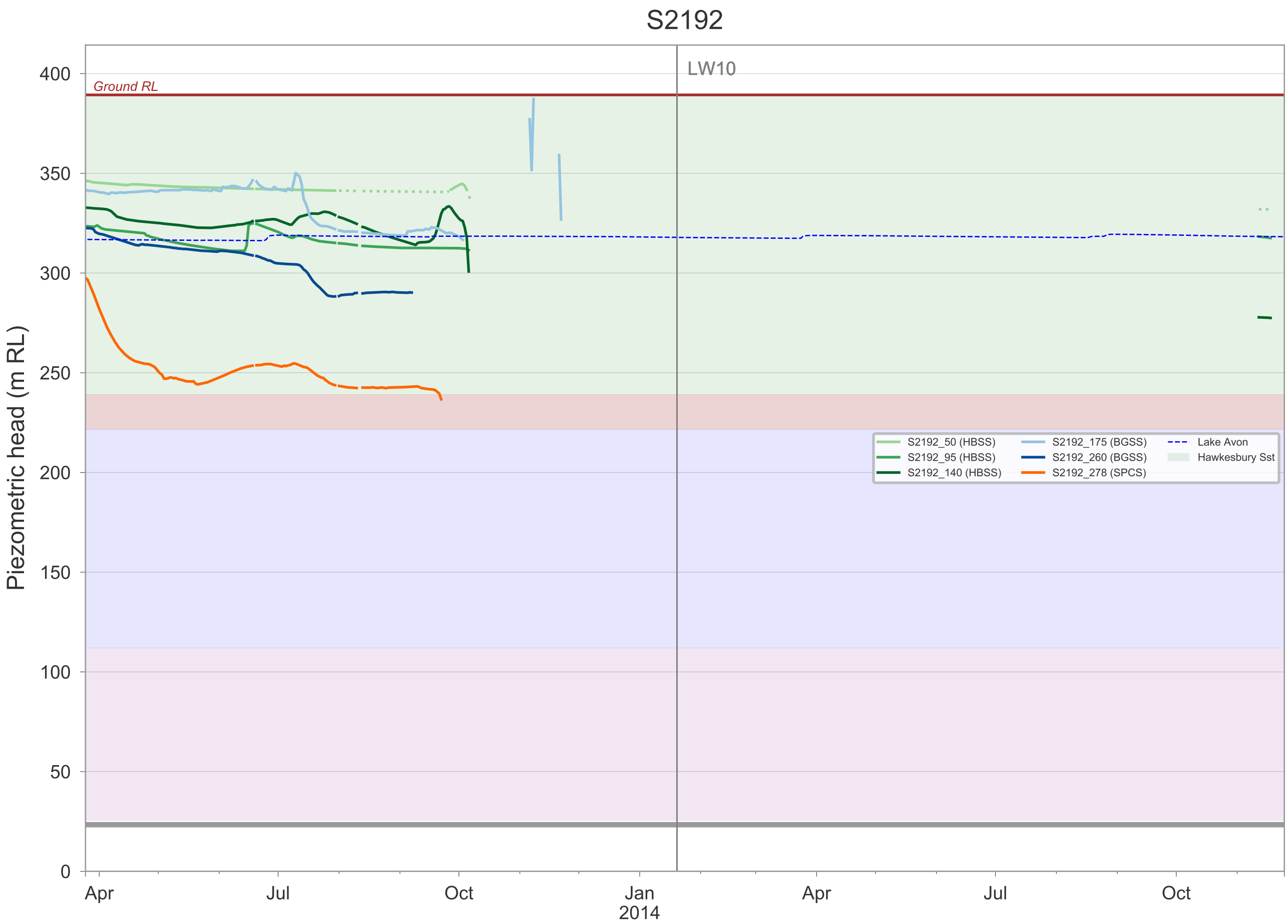

S2059
LW8
LW9
LW10
LW11
LW12
LW13
LW14
S2059_33 (HBSS)
S2059_61 (HBSS)
S2059_79 (HBSS)
S2059_113 (BGSS)
S2059_151.5 (BGSS)
S2059_195 (BGSS)
S2059_221 (SBSS)
S2059_242 (SBSS)
S2059_263 (SBSS)
S2059_311.7 (BUSM)
S2059_340.7 (WWSM)
Pressure head (m H2O)
160
140
120
100
80
60
40
20
0
2012
2013
2014
2015
2016
2017
2018

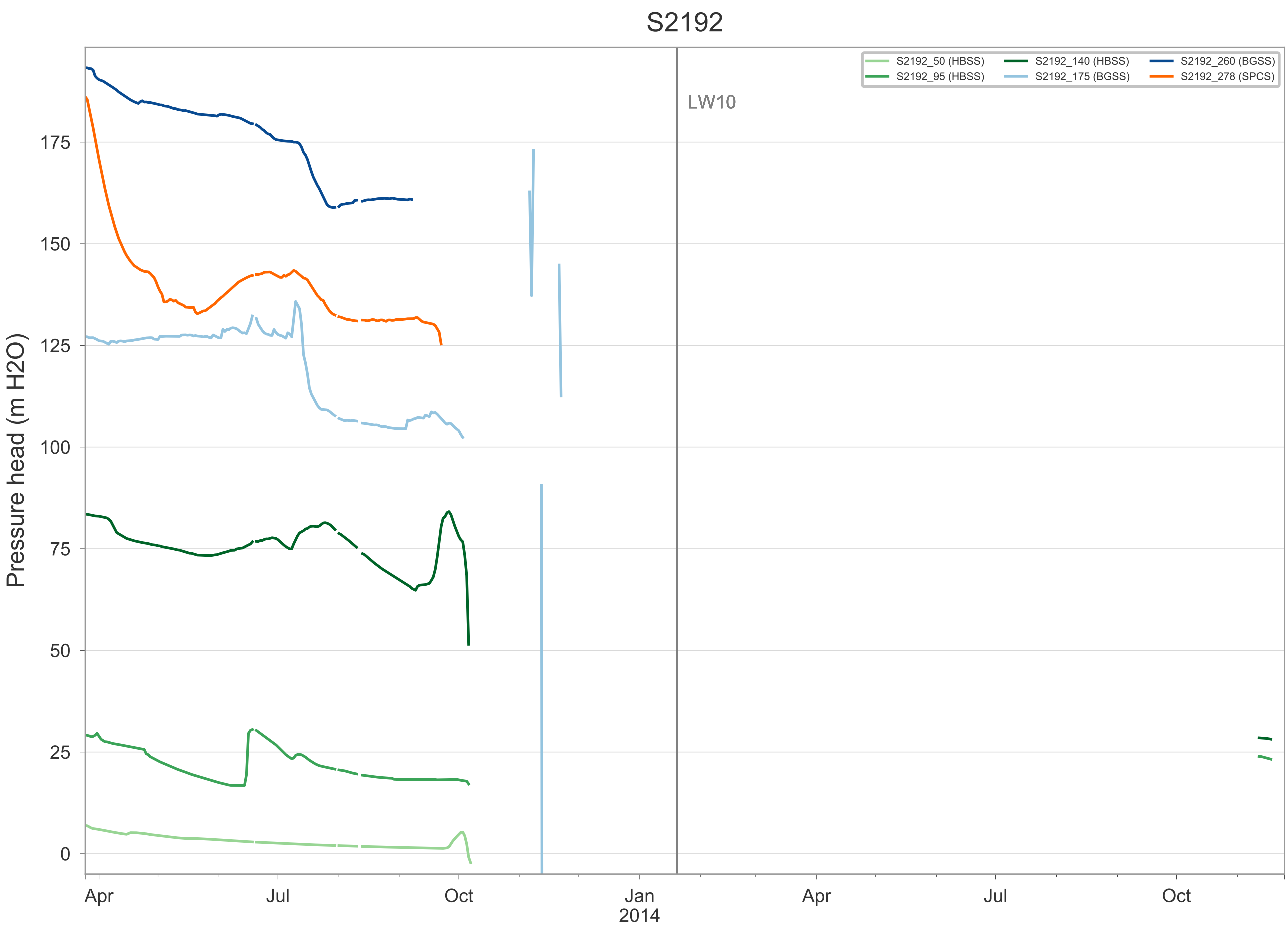

S2070
Ground RL
LW10
LW11
LW12
LW13
LW14
LW15
Piezometric head (m RL)
400
350
300
250
200
150
100
S2070_361.5 (BUSM)
S2070_388 (WWSM)
Lake Avon
Hawkesbury Sst
2014
2015
2016
2017
2018
2019

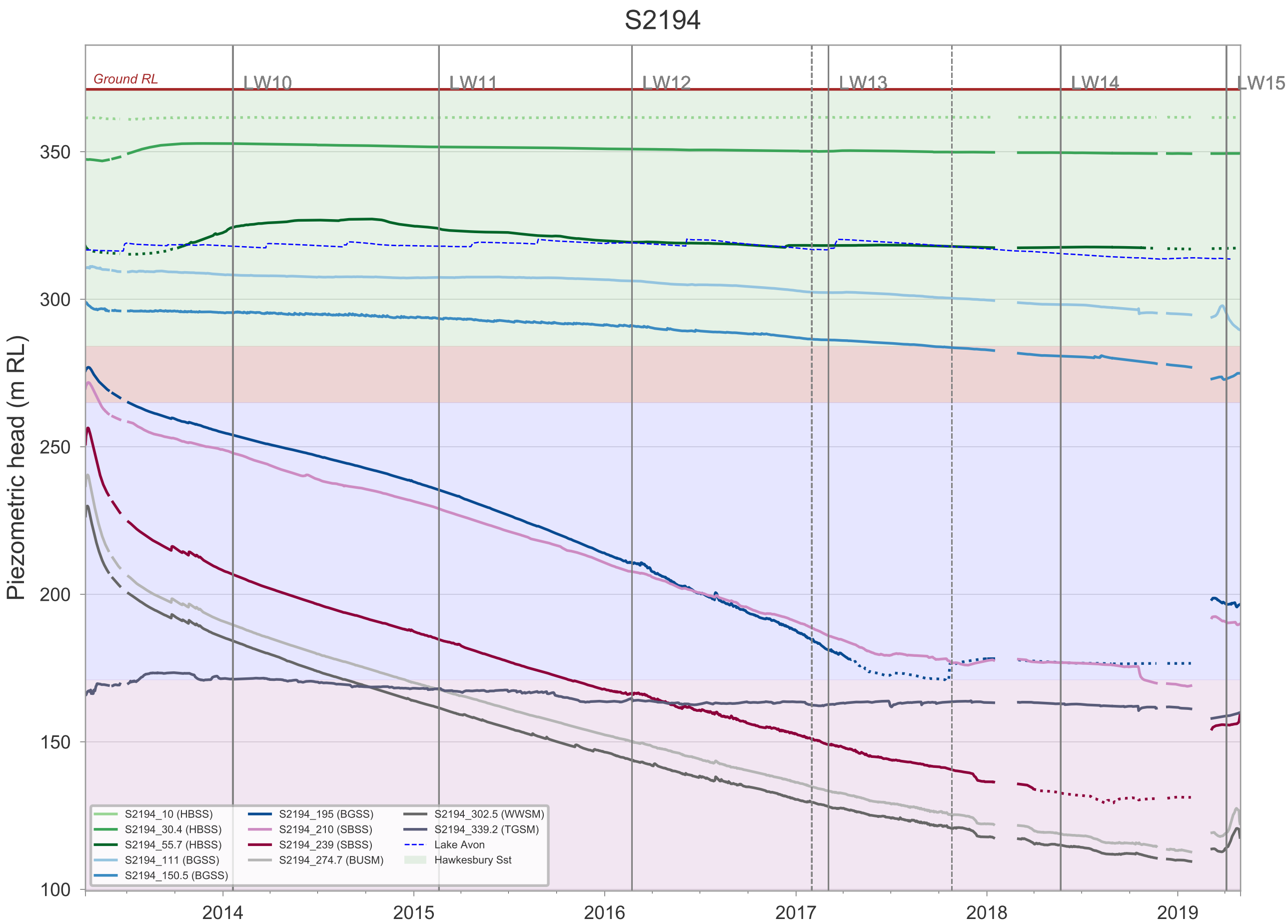

S2070
S2070_361.5 (BUSM)
S2070_388 (WWSM)
LW10
LW11
LW12
LW13
LW14
LW15
Pressure head (m H2O)
140
120
100
80
60
2014
2015
2016
2017
2018
2019

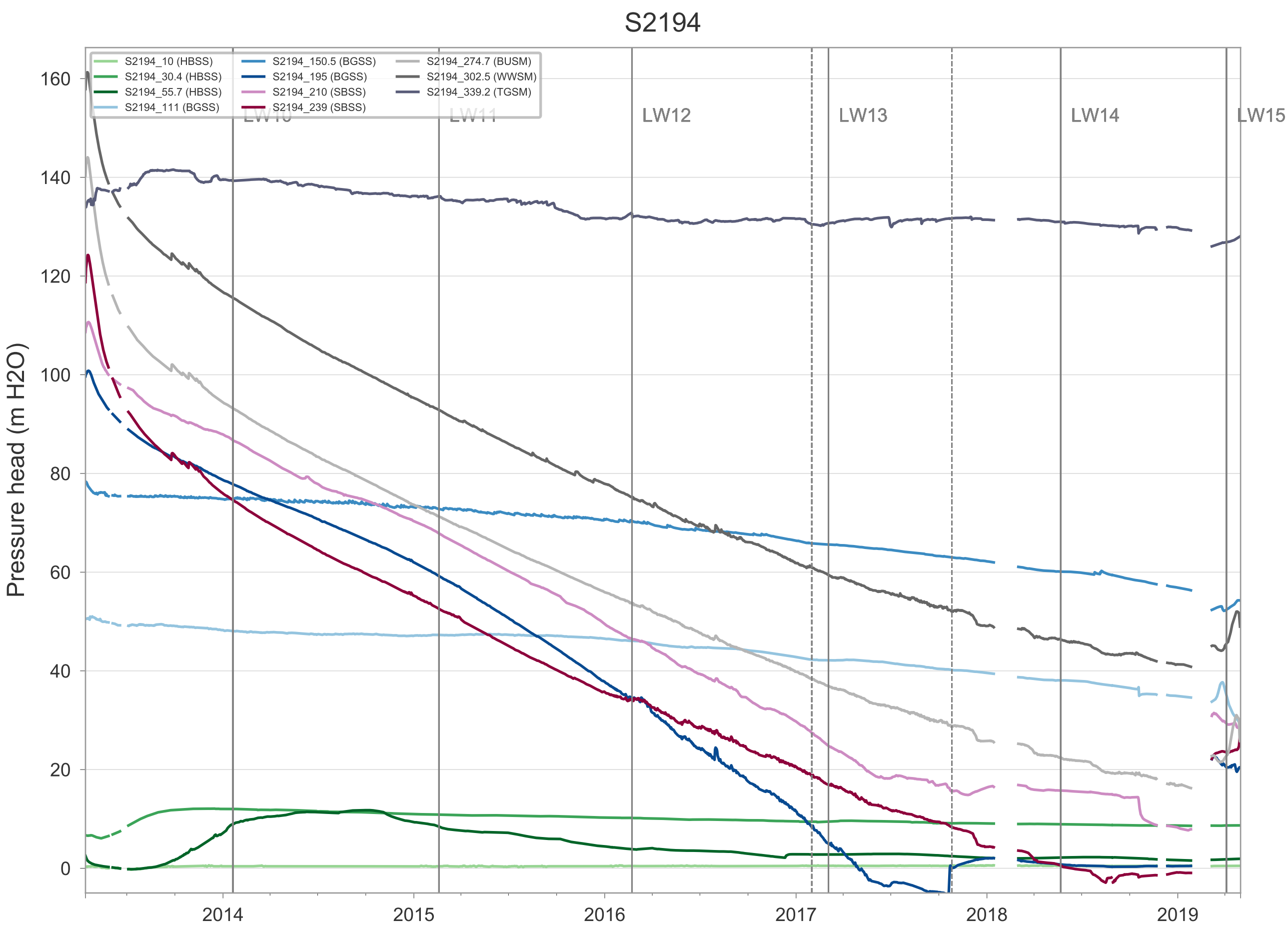

S2078
Ground RL
LW7
LW8
LW9
LW10
LW12
S2078_293.4 (BUSM)
S2078_323 (WWSM)
Lake Avon
Hawkesbury Sst
Piezometric head (m RL)
350
300
250
200
150
100
50
2011
2012
2013
2014
2015
2016

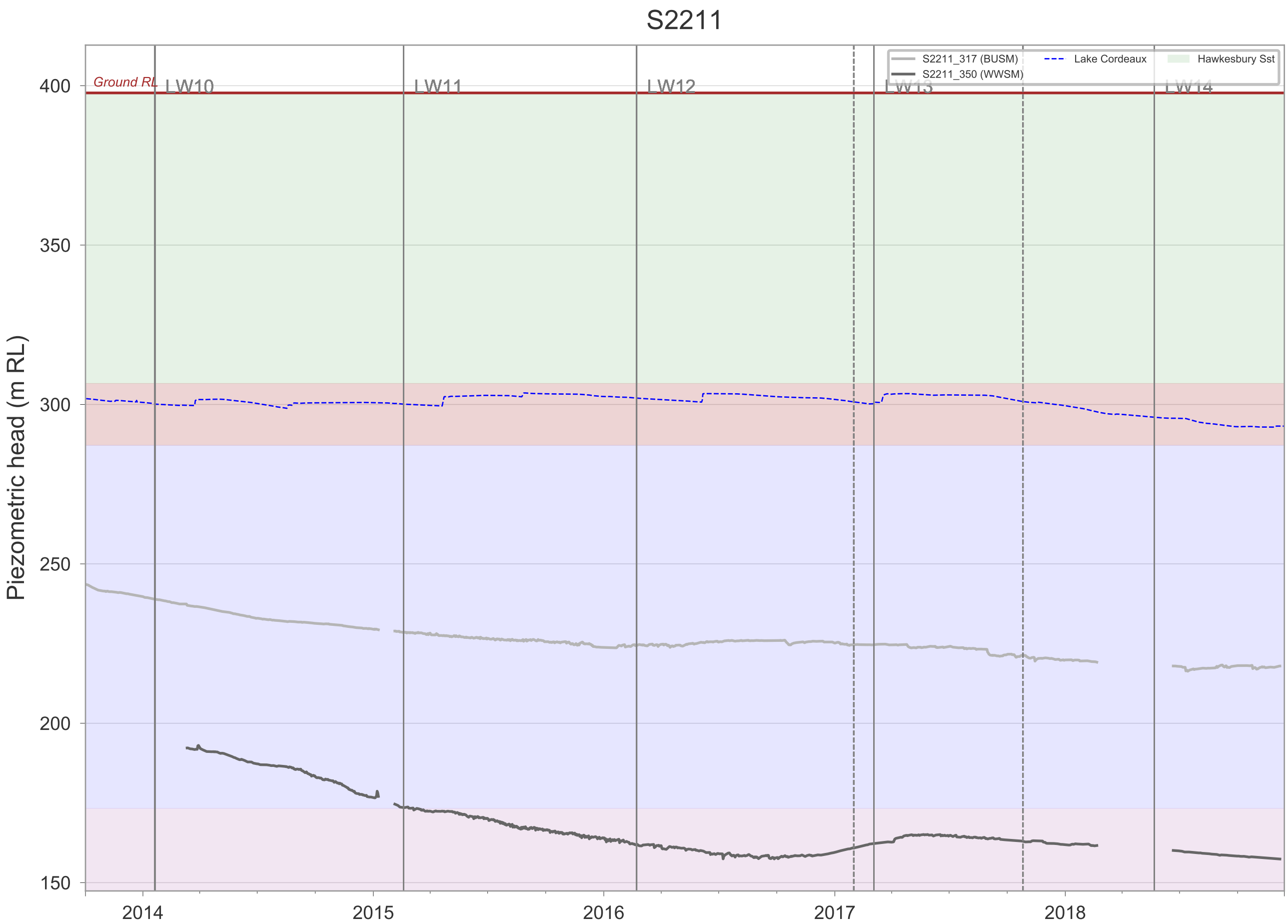

S2078
S2078_293.4 (BUSM)
S2078_323 (WWSM)
LW7
LW8
LW9
LW10
LW11
LW12
Pressure head (m H2O)
200
175
150
125
100
75
50
25
0
2011
2012
2013
2014
2015
2016

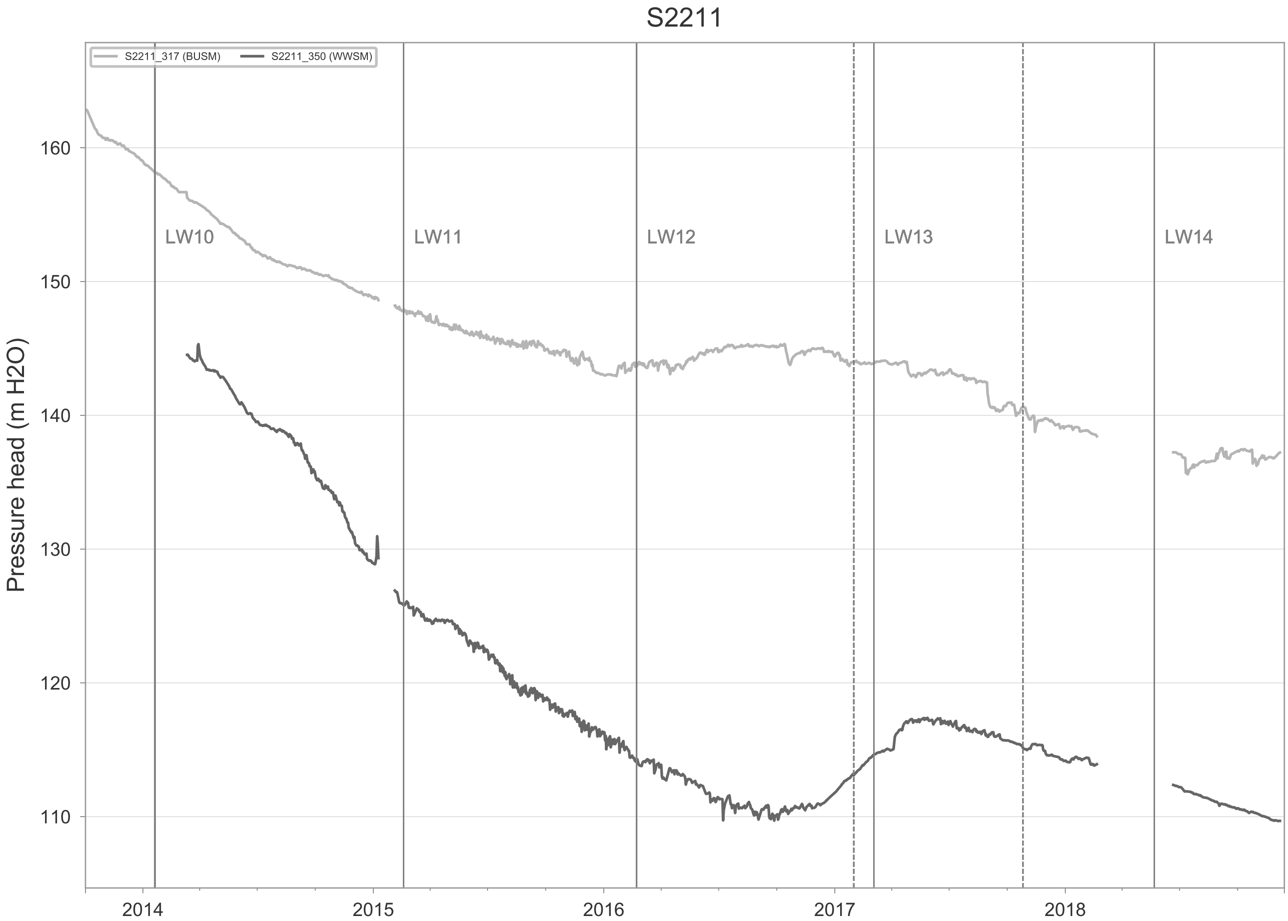

S2192
LW10
Ground RL
Piezometric head (m RL)
400
350
300
250
200
150
100
50
0
S2192_50 (HBSS)
S2192_95 (HBSS)
S2192_140 (HBSS)
S2192_175 (BGSS)
S2192_260 (BGSS)
S2192_278 (SPCS)
Lake Avon
Hawkesbury Sst
Apr
Jul
Oct
Jan
2014
Apr
Jul
Oct

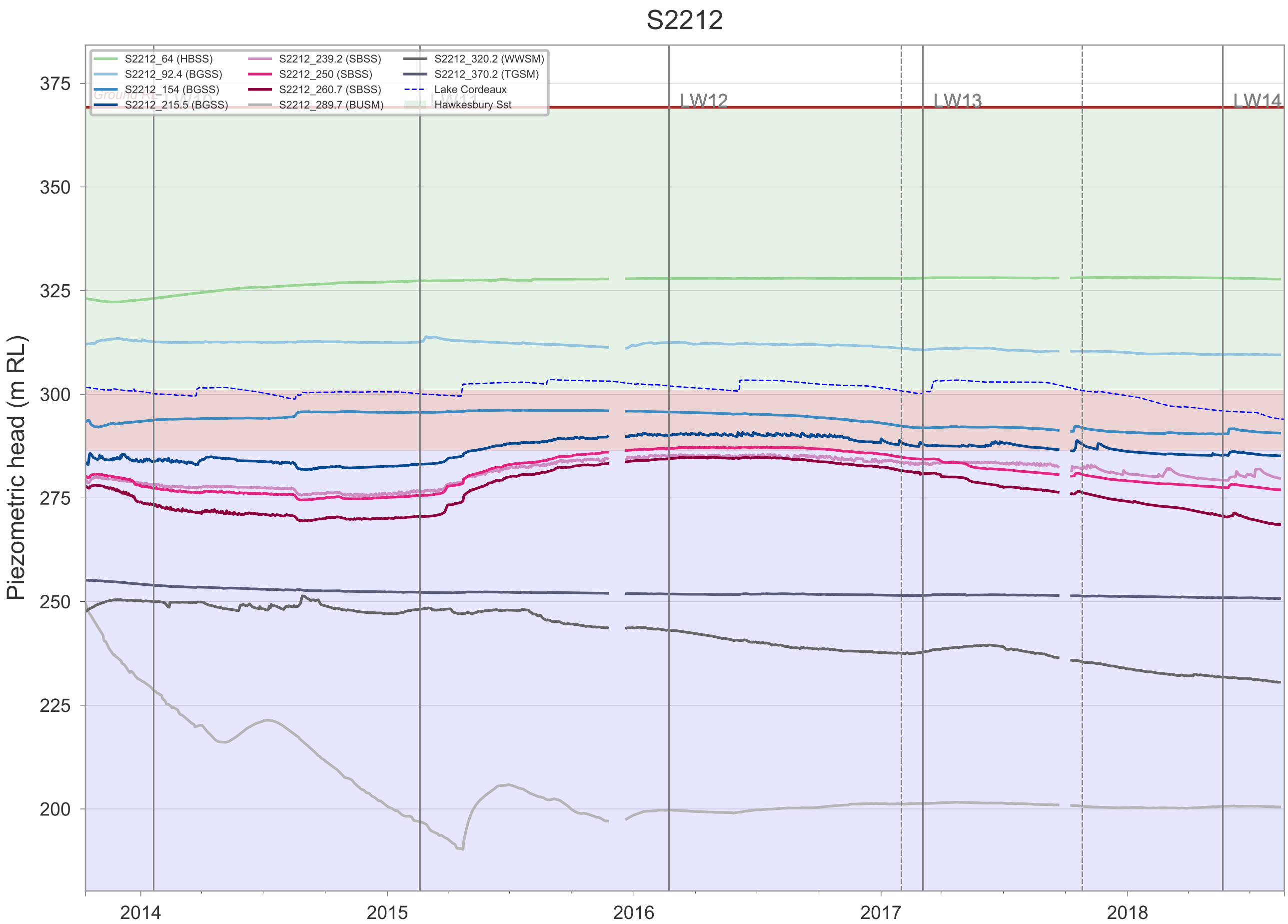

S2192
LW10
Pressure head (m H2O)
175
150
125
100
75
50
25
0
S2192_50 (HBSS)
S2192_95 (HBSS)
S2192_140 (HBSS)
S2192_175 (BGSS)
S2192_260 (BGSS)
S2192_278 (SPCS)
Apr
Jul
Oct
Jan
2014
Apr
Jul
Oct

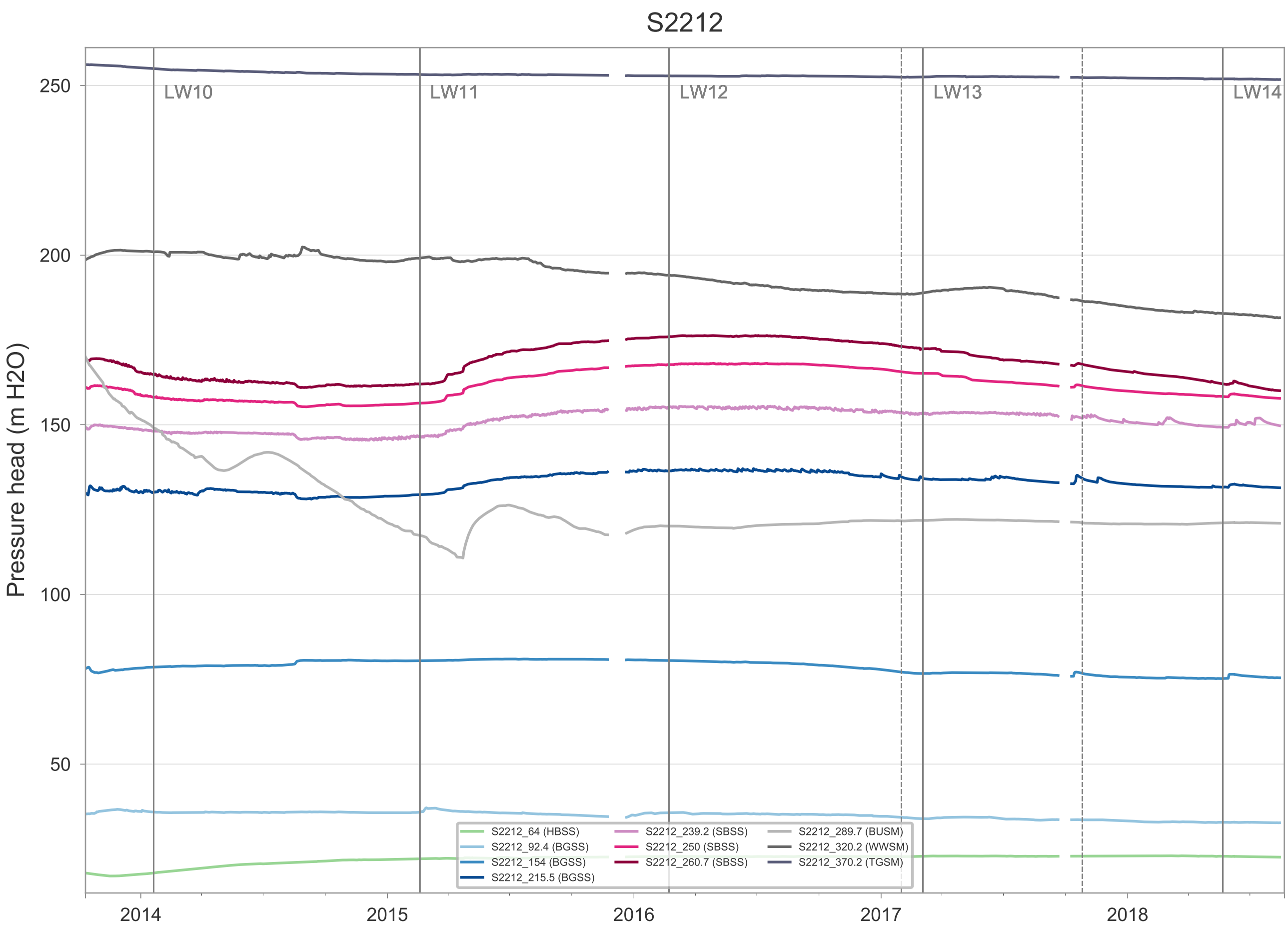

S2194
Ground RL
LW10
LW11
LW12
LW13
LW14
LW15
Piezometric head (m RL)
350
300
250
200
150
100
2014
2015
2016
2017
2018
2019
S2194_10 (HBSS)
S2194_30.4 (HBSS)
S2194_55.7 (HBSS)
S2194_111 (BGSS)
S2194_150.5 (BGSS)
S2194_195 (BGSS)
S2194_210 (SBSS)
S2194_239 (SBSS)
S2194_274.7 (BUSM)
S2194_302.5 (WWSM)
S2194_339.2 (TGSM)
Lake Avon
Hawkesbury Sst


S2194
LW10
LW11
LW12
LW13
LW14
LW15
Pressure head (m H2O)
160
140
120
100
80
60
40
20
0
2014
2015
2016
2017
2018
2019
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)

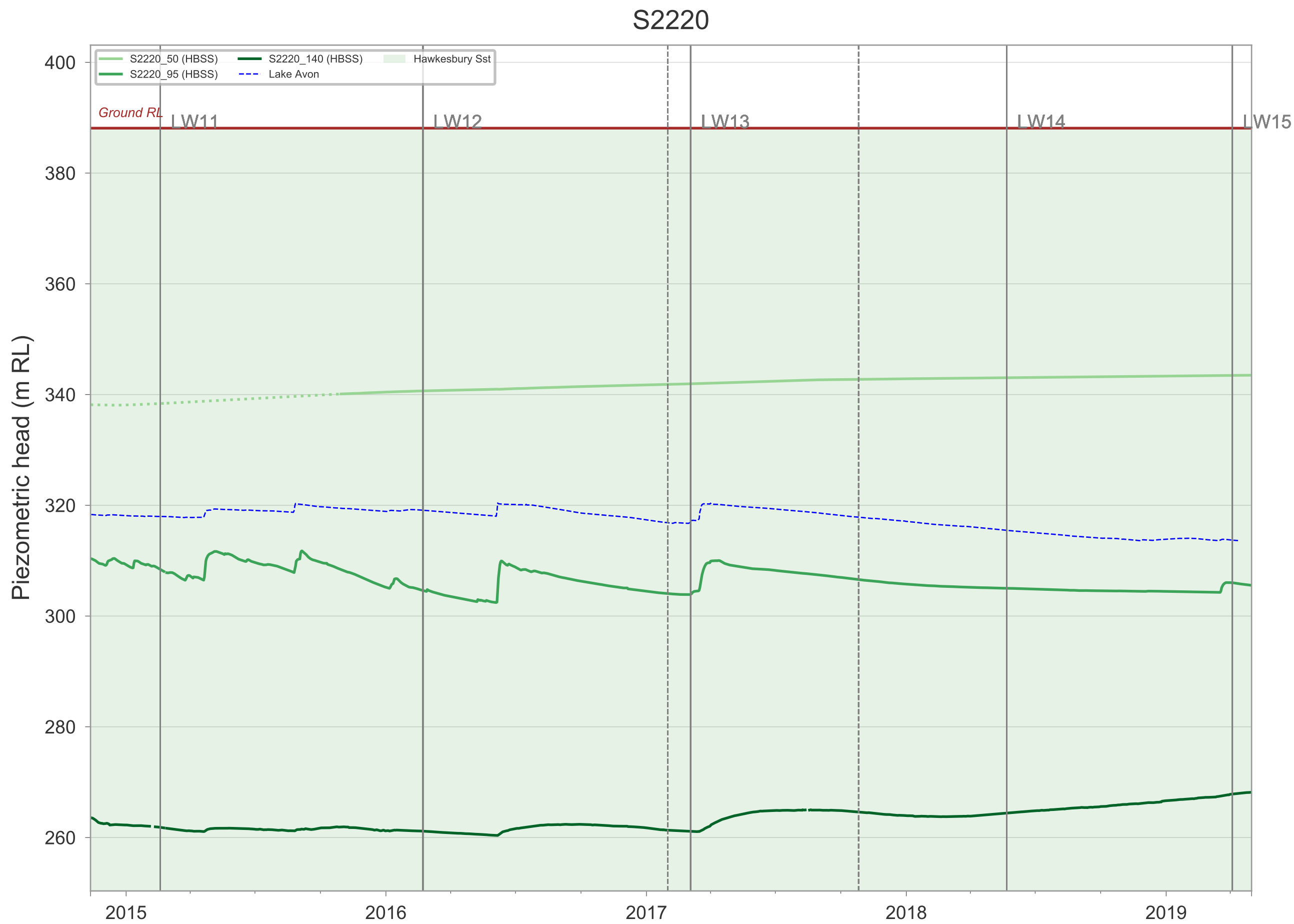

S2211
S2211_317 (BUSM)
S2211_350 (WWSM)
Lake Cordeaux
Hawkesbury Sst
Ground RL
LW10
LW11
LW12
LW13
LW14
Piezometric head (m RL)
400
350
300
250
200
150
2014
2015
2016
2017
2018

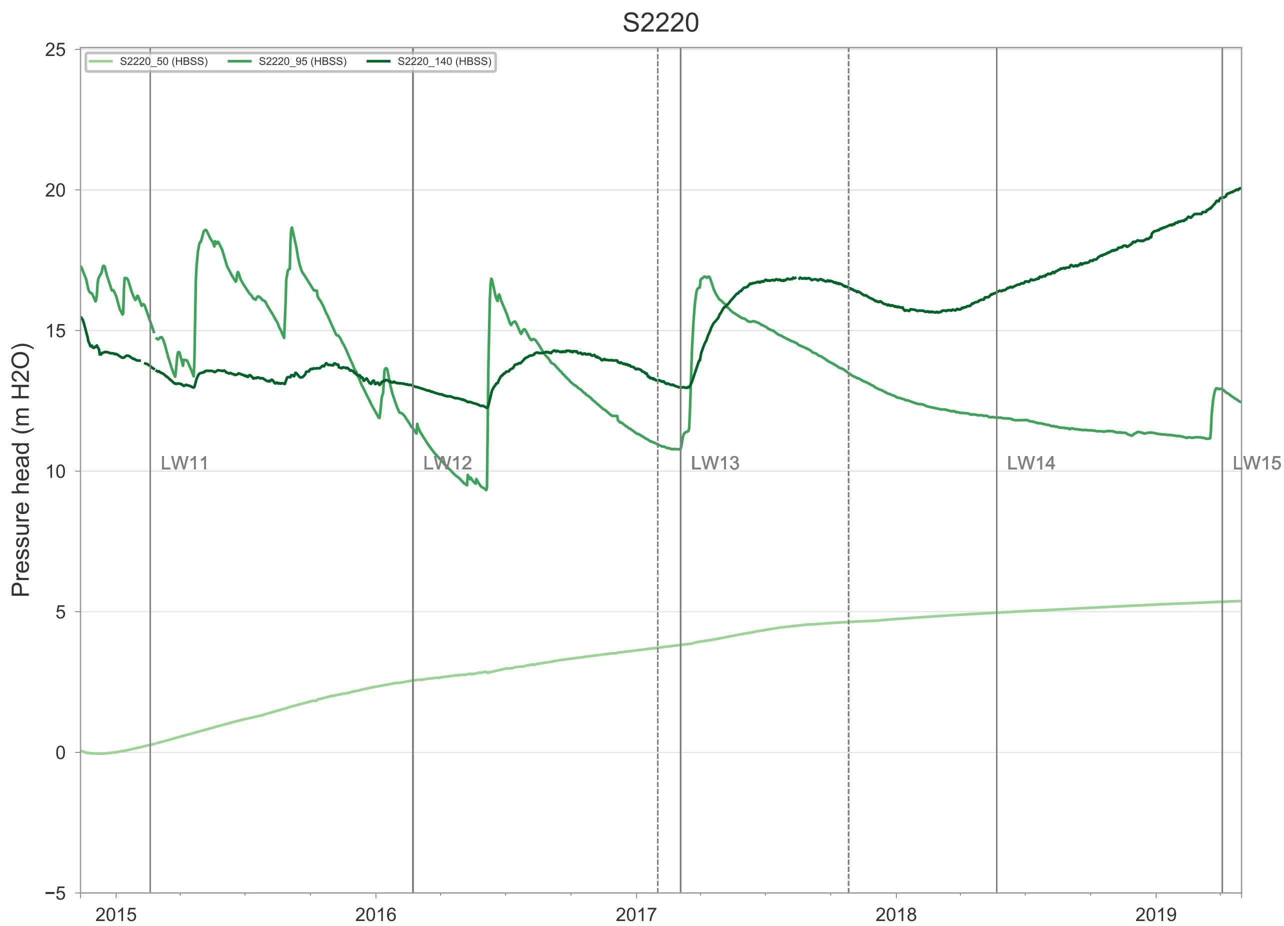

S2211
S2211_317 (BUSM)
S2211_350 (WWSM)
LW10
LW11
LW12
LW13
LW14
Pressure head (m H2O)
160
150
140
130
120
110
2014
2015
2016
2017
2018

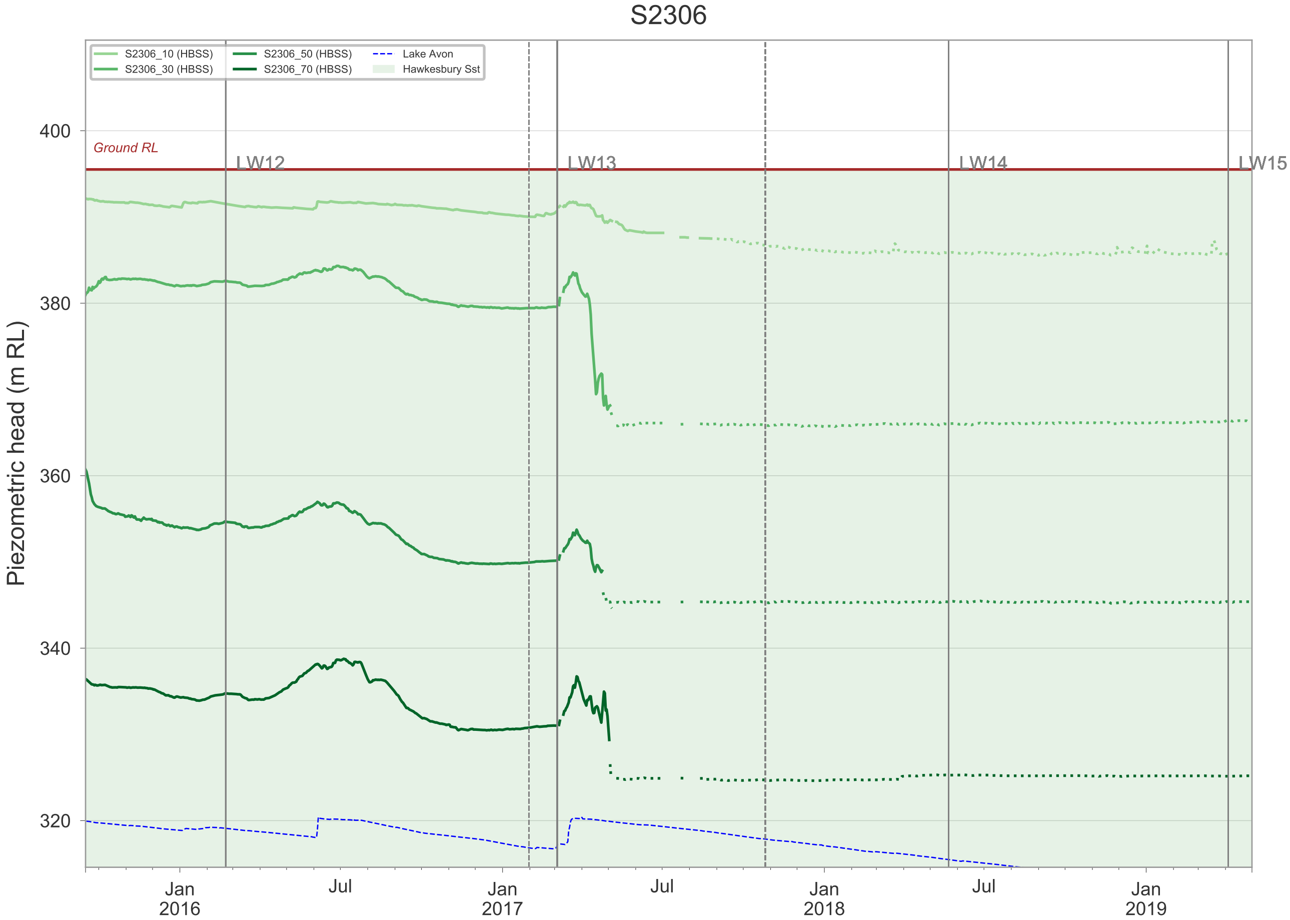

S2212
Piezometric head (m RL)
375
350
325
300
275
250
225
200
2014
2015
2016
2017
2018
LW12
LW13
LW14
S2212_64 (HBSS)
S2212_92.4 (BGSS)
S2212_154 (BGSS)
S2212_215.5 (BGSS)
S2212_239.2 (SBSS)
S2212_250 (SBSS)
S2212_260.7 (SBSS)
S2212_289.7 (BUSM)
S2212_320.2 (WWSM)
S2212_370.2 (TGSM)
Lake Cordeaux
Hawkesbury Sst

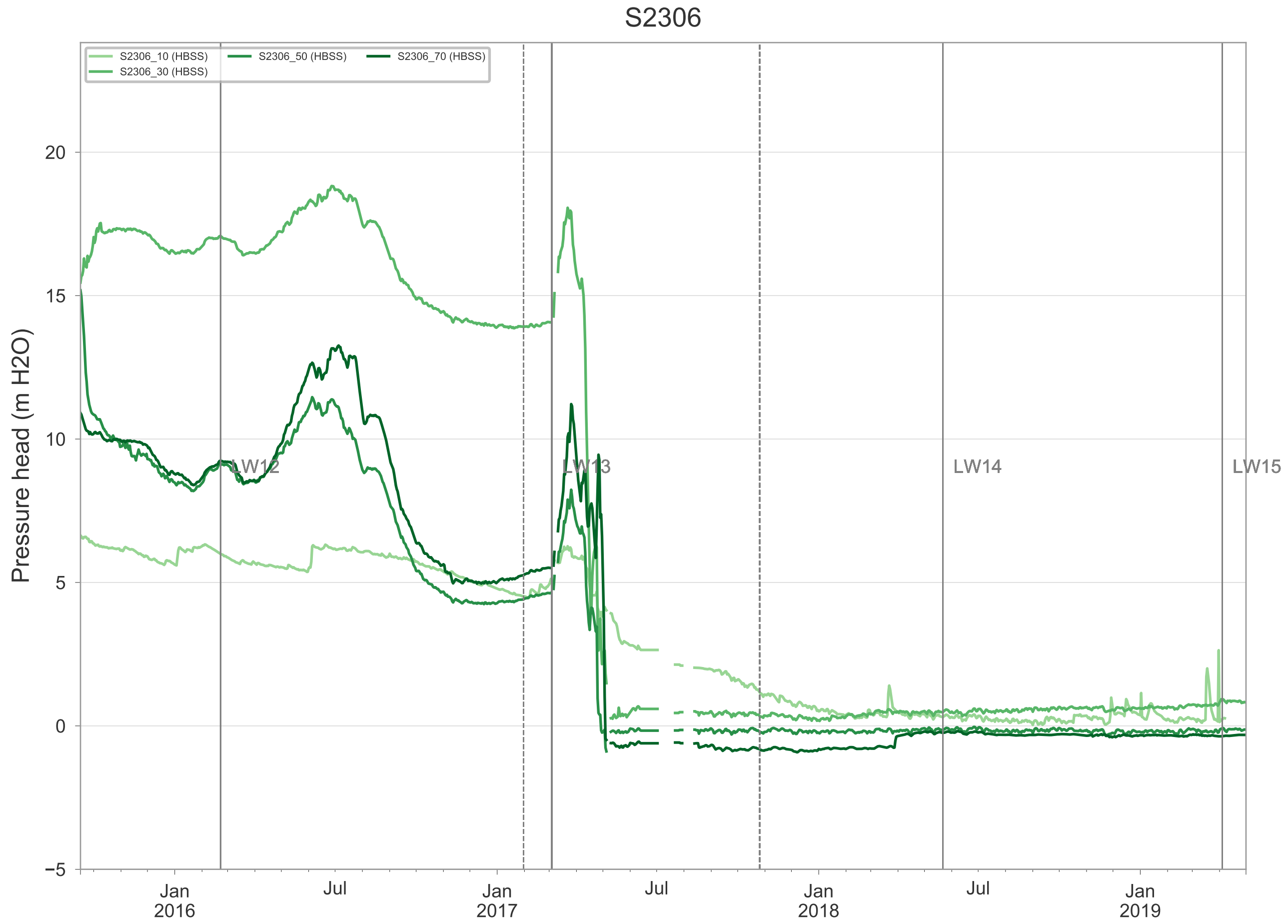

S2212
Pressure head (m H2O)
250
200
150
100
50
2014
2015
2016
2017
2018
LW10
LW11
LW12
LW13
LW14
S2212_64 (HBSS)
S2212_92.4 (BGSS)
S2212_154 (BGSS)
S2212_215.5 (BGSS)
S2212_239.2 (SBSS)
S2212_250 (SBSS)
S2212_260.7 (SBSS)
S2212_289.7 (BUSM)
S2212_320.2 (WWSM)
S2212_370.2 (TGSM)

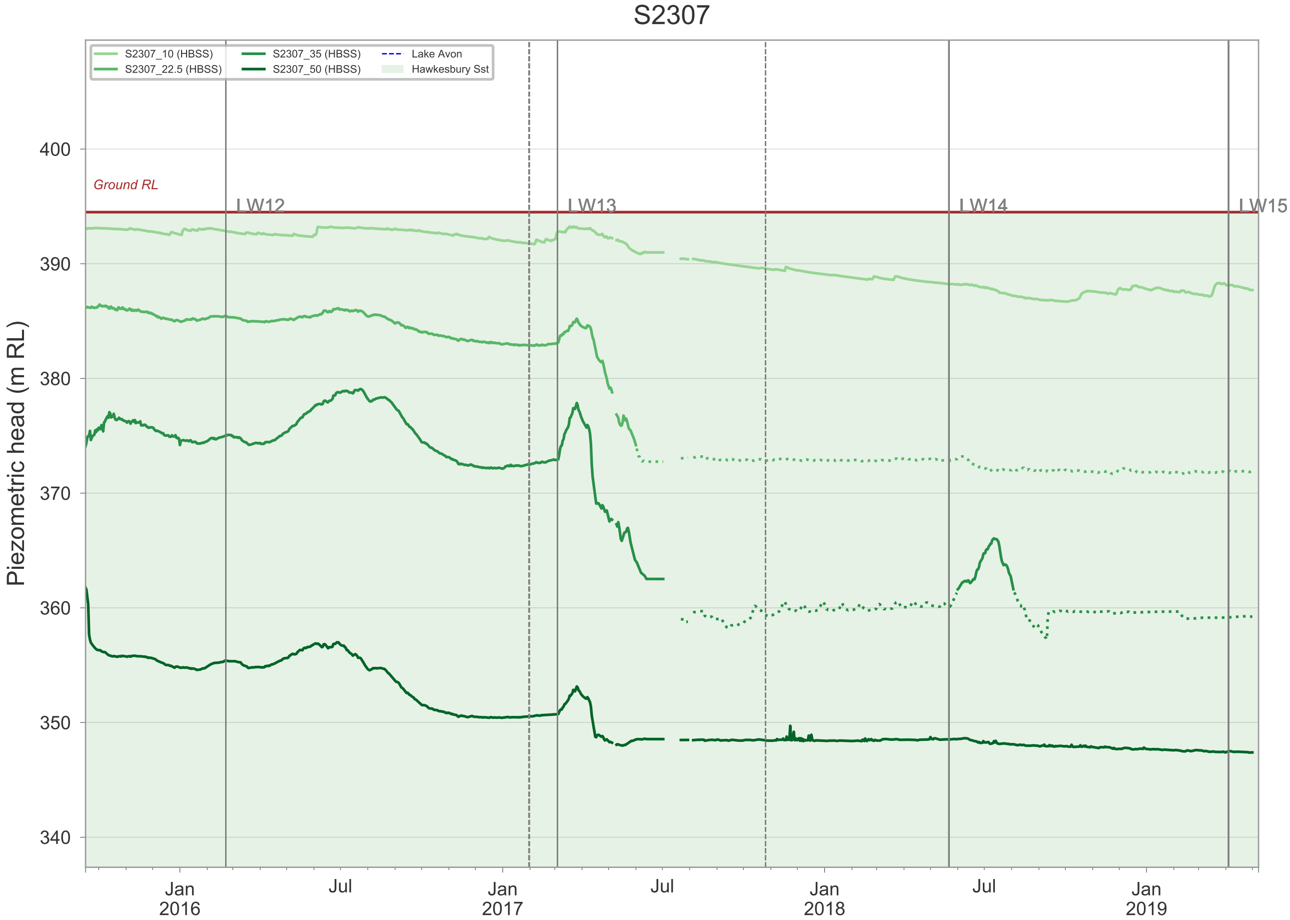
Groundwater hydrographs

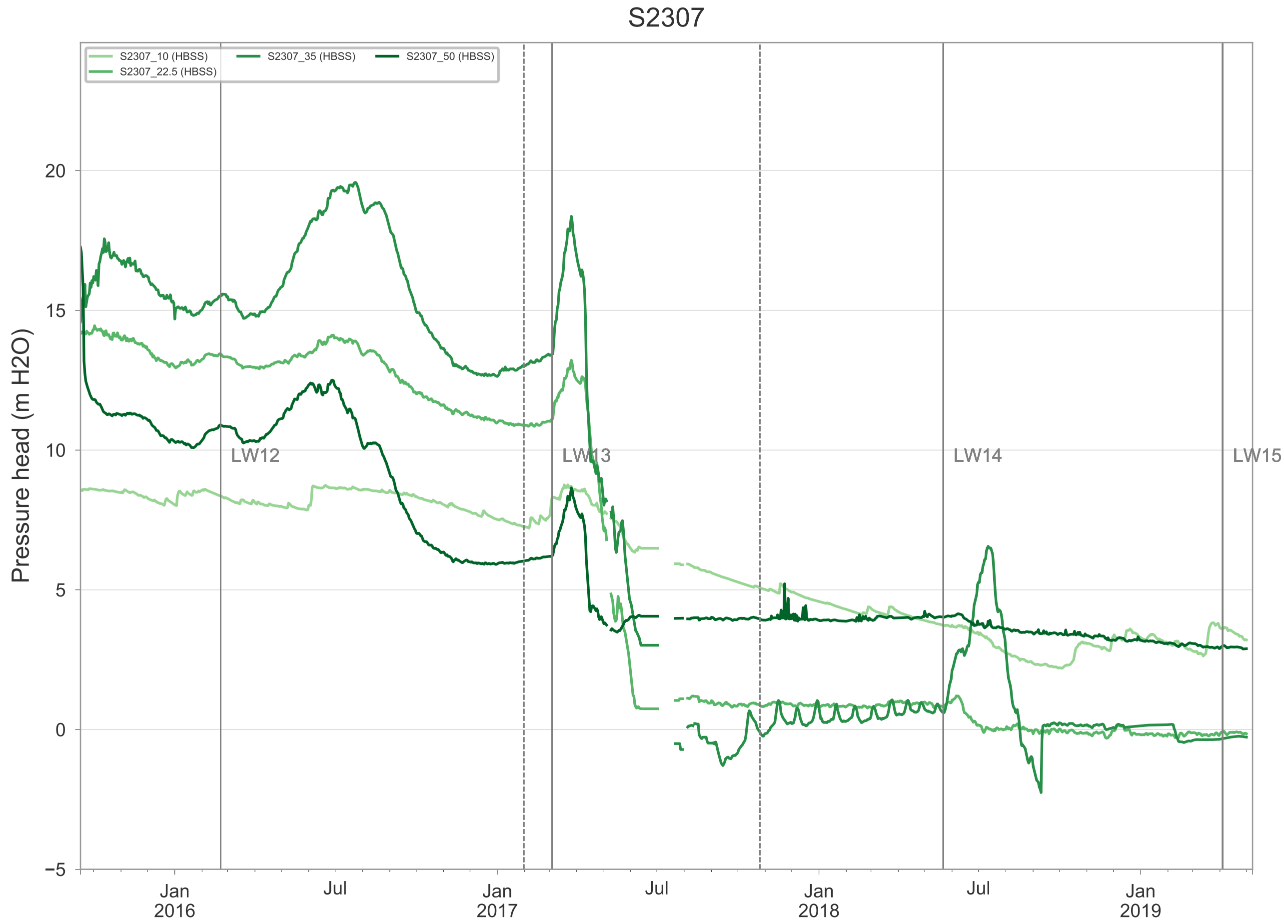




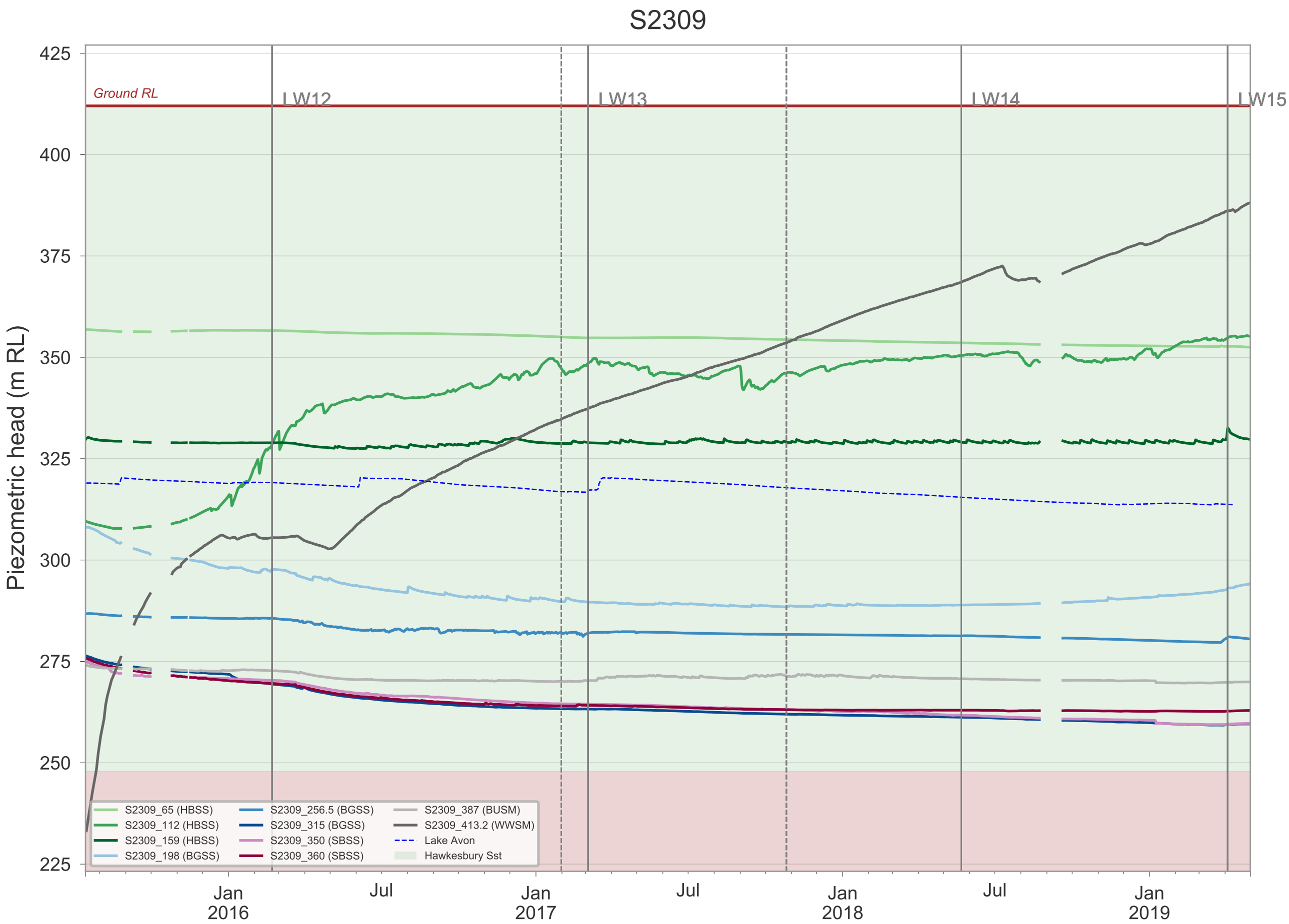

S2306
S2306_10 (HBSS)
S2306_30 (HBSS)
S2306_50 (HBSS)
S2306_70 (HBSS)
Lake Avon
Hawkesbury Sst
Ground RL
LW12
LW13
LW14
LW15
Piezometric head (m RL)
400
380
360
340
320
Jan 2016
Jul
Jan 2017
Jul
Jan 2018
Jul
Jan 2019

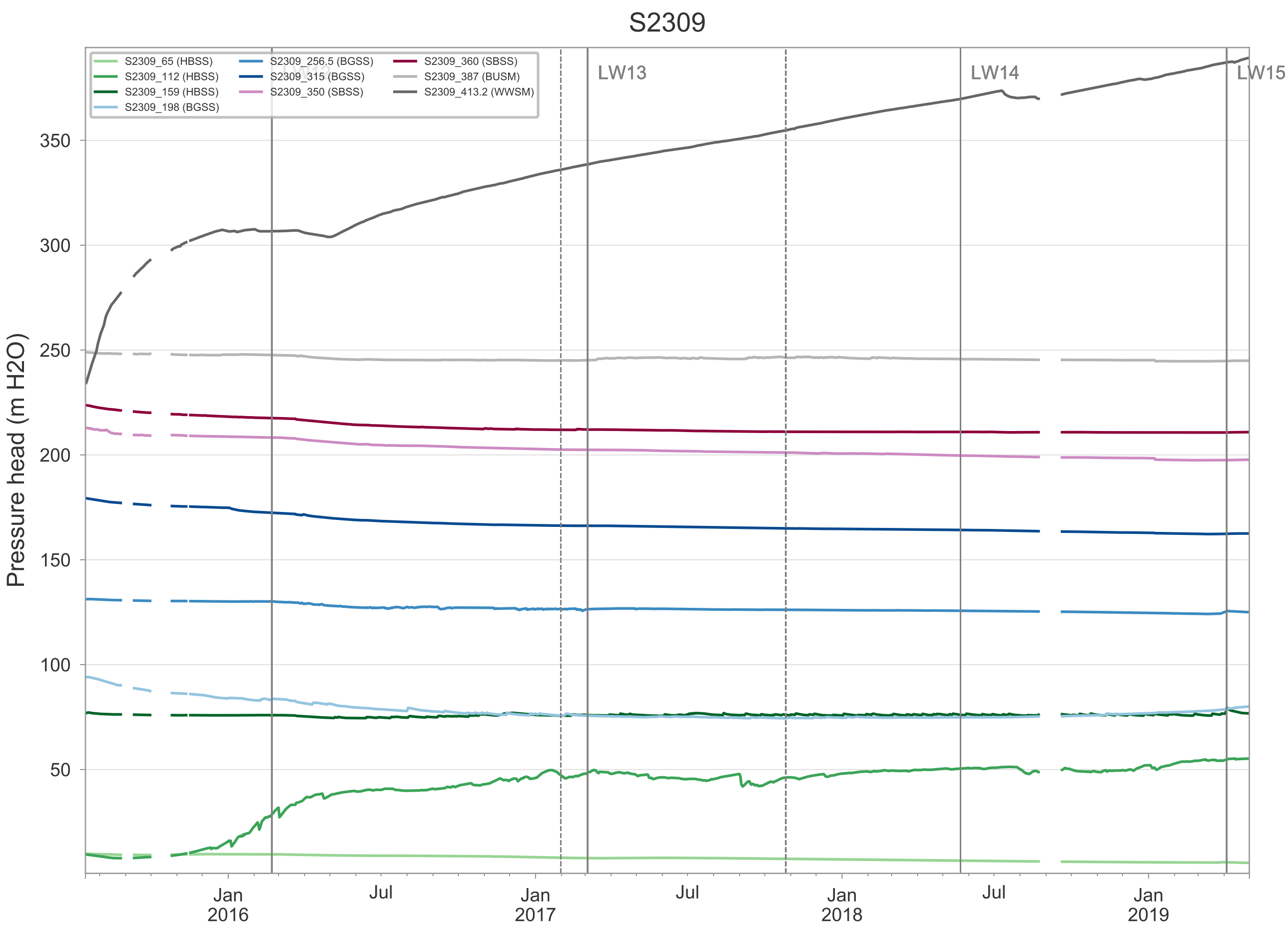

S2306
S2306_10 (HBSS)
S2306_30 (HBSS)
S2306_50 (HBSS)
S2306_70 (HBSS)
LW12
LW13
LW14
LW15
Pressure head (m H2O)
20
15
10
5
0
−5
Jan 2016
Jul
Jan 2017
Jul
Jan 2018
Jul
Jan 2019


S2307
S2307_10 (HBSS)
S2307_22.5 (HBSS)
S2307_35 (HBSS)
S2307_50 (HBSS)
Lake Avon
Hawkesbury Sst
Ground RL
LW12
LW13
LW14
LW15
Piezometric head (m RL)
400
390
380
370
360
350
340
Jan 2016
Jul
Jan 2017
Jul
Jan 2018
Jul
Jan 2019

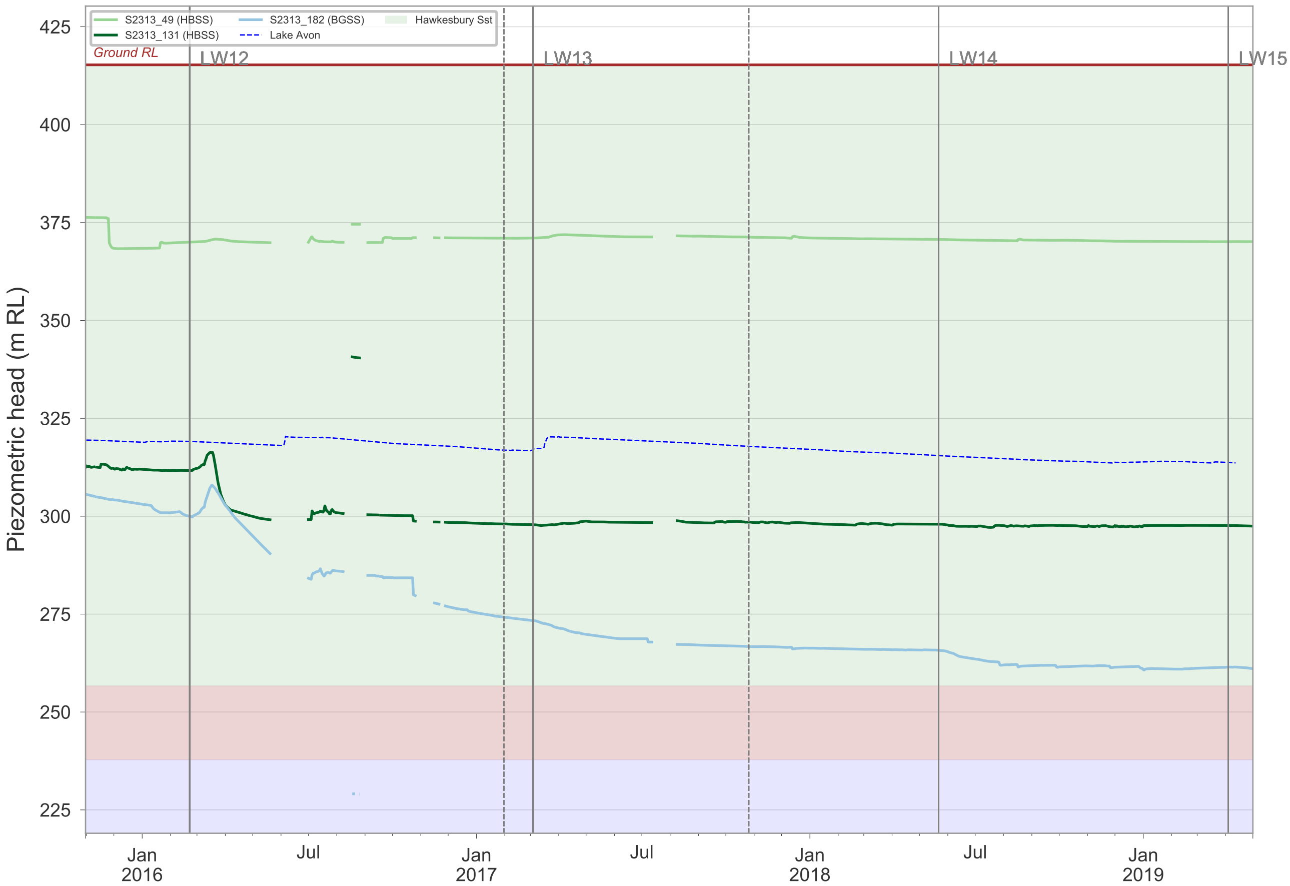

S2307
S2307_10 (HBSS)
S2307_22.5 (HBSS)
S2307_35 (HBSS)
S2307_50 (HBSS)
LW12
LW13
LW14
LW15
Pressure head (m H2O)
20
15
10
5
0
−5
Jan 2016
Jul
Jan 2017
Jul
Jan 2018
Jul
Jan 2019

Groundwater hydrographs

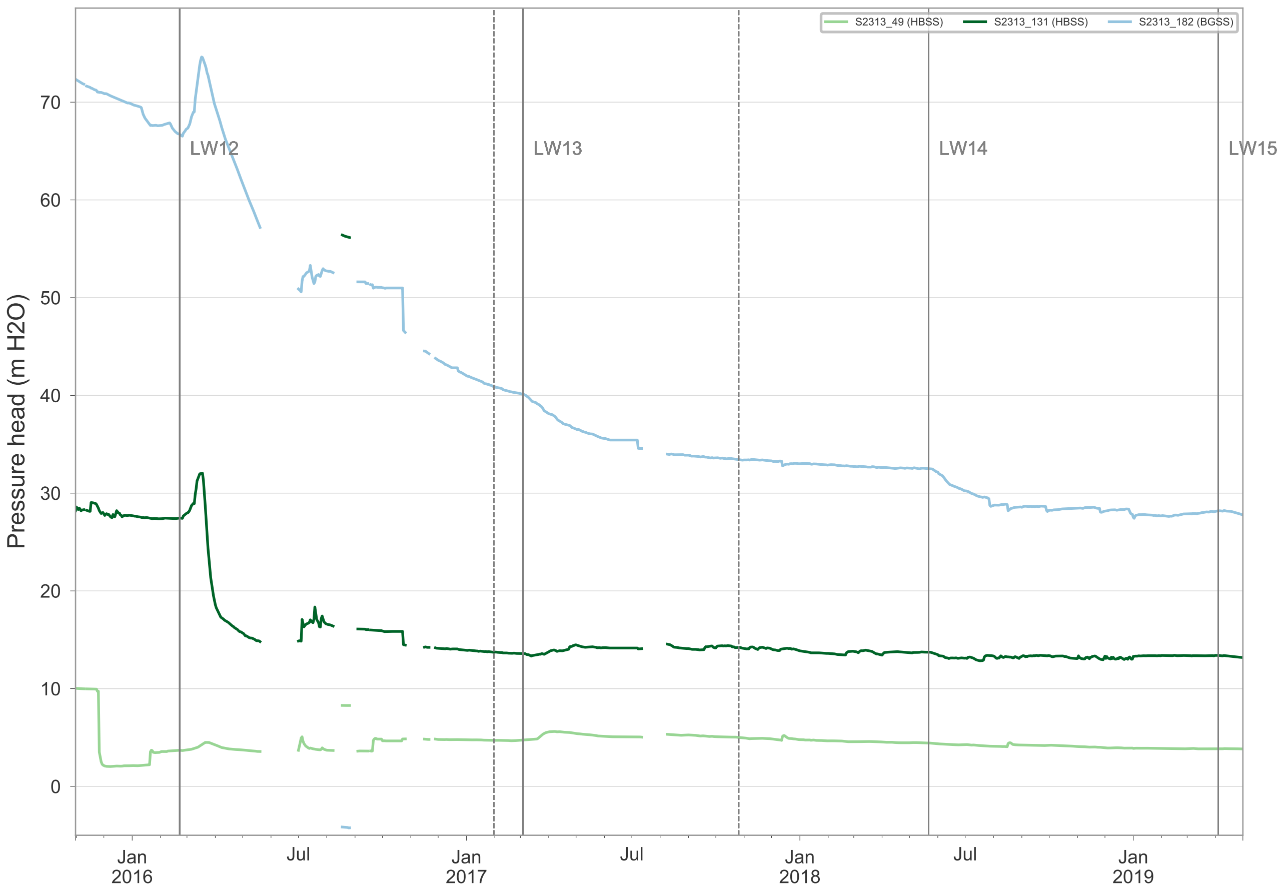


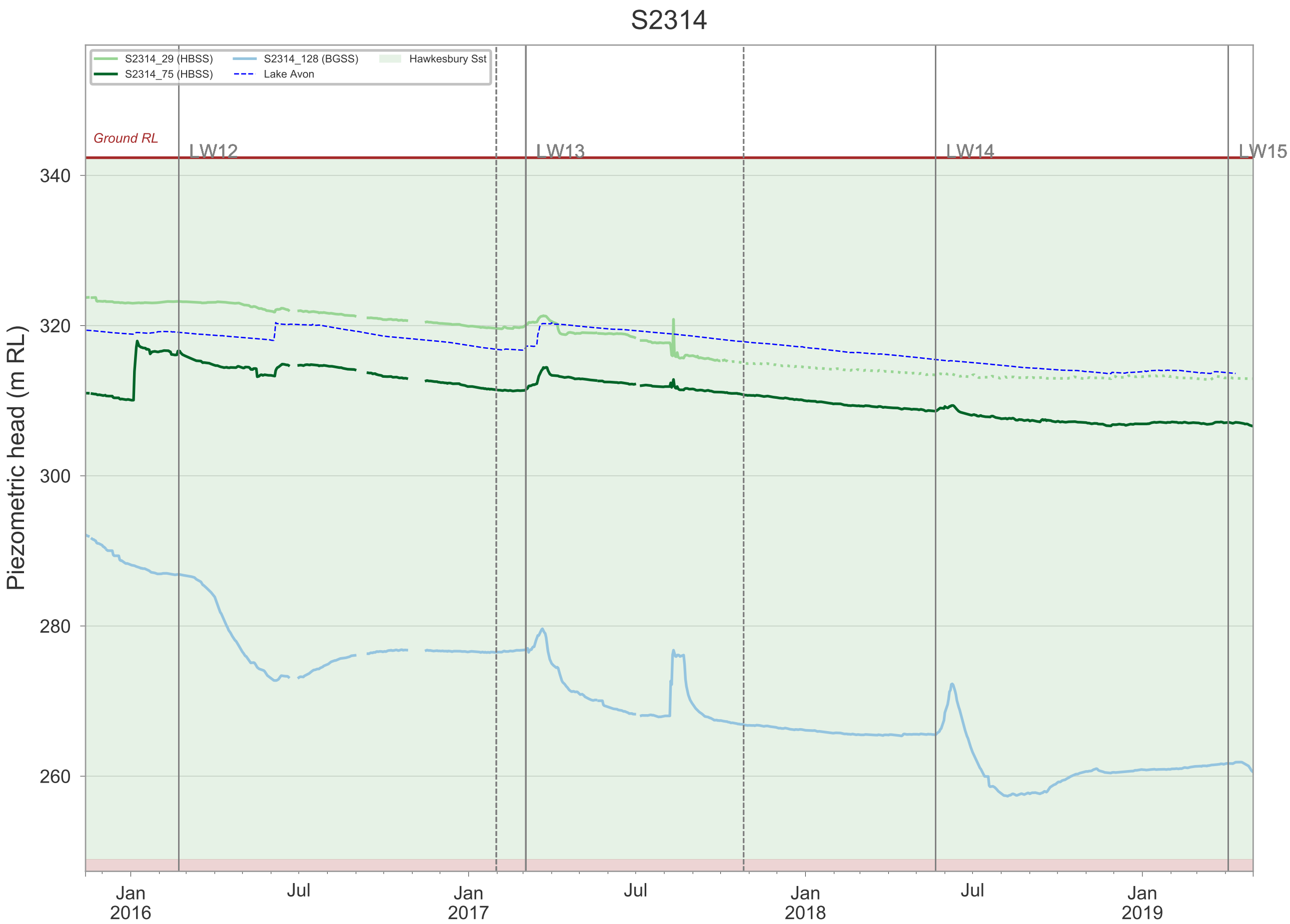


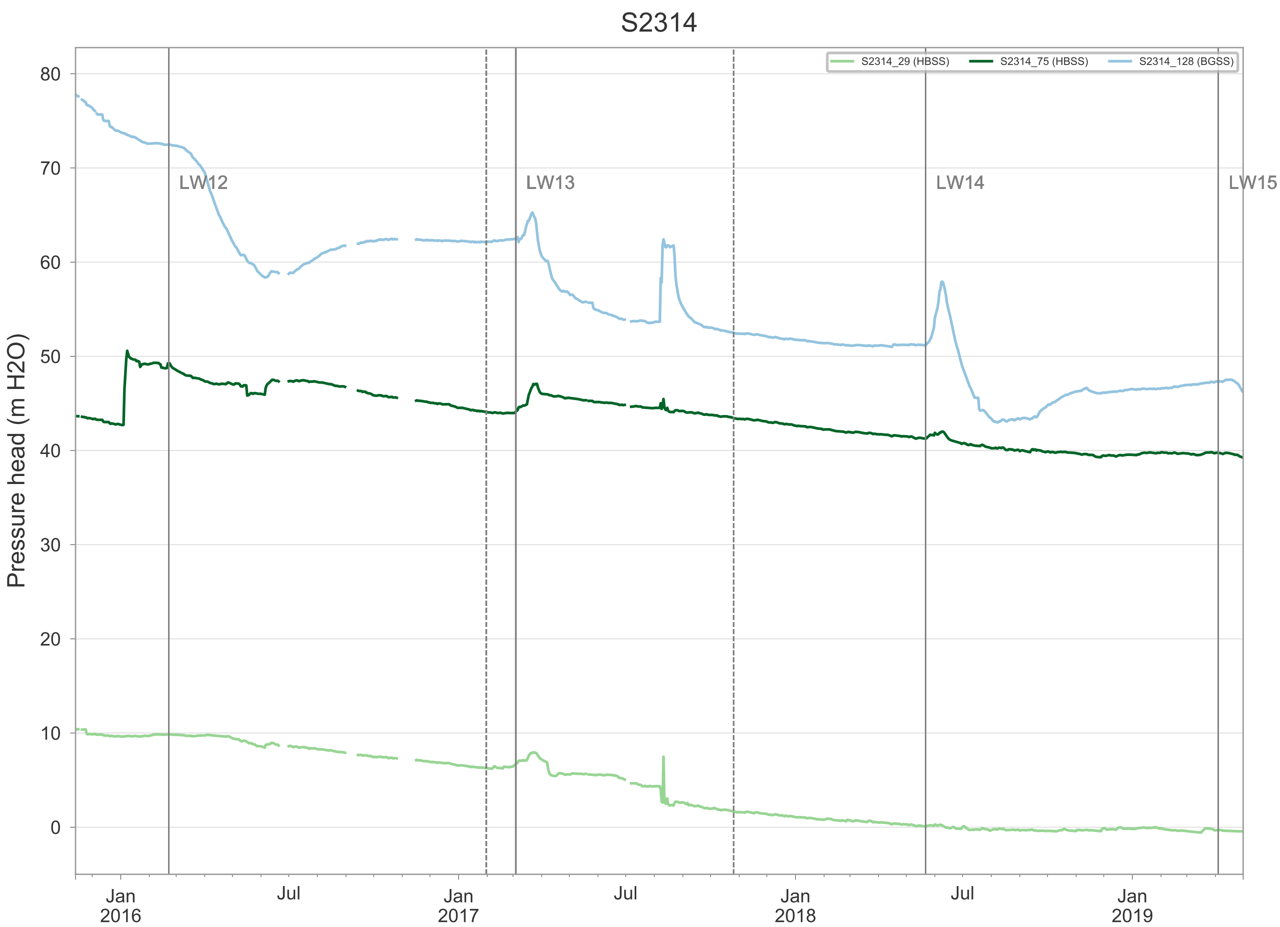
S2313


S2313_49 (HBSS)
S2313_131 (HBSS)
S2313_182 (BGSS)
Lake Avon
Hawkesbury Sst
Ground RL
LW12
LW13
LW14
LW15
Piezometric head (m RL)
425
400
375
350
325
300
275
250
225
Jan 2016
Jul
Jan 2017
Jul
Jan 2018
Jul
Jan 2019

S2313

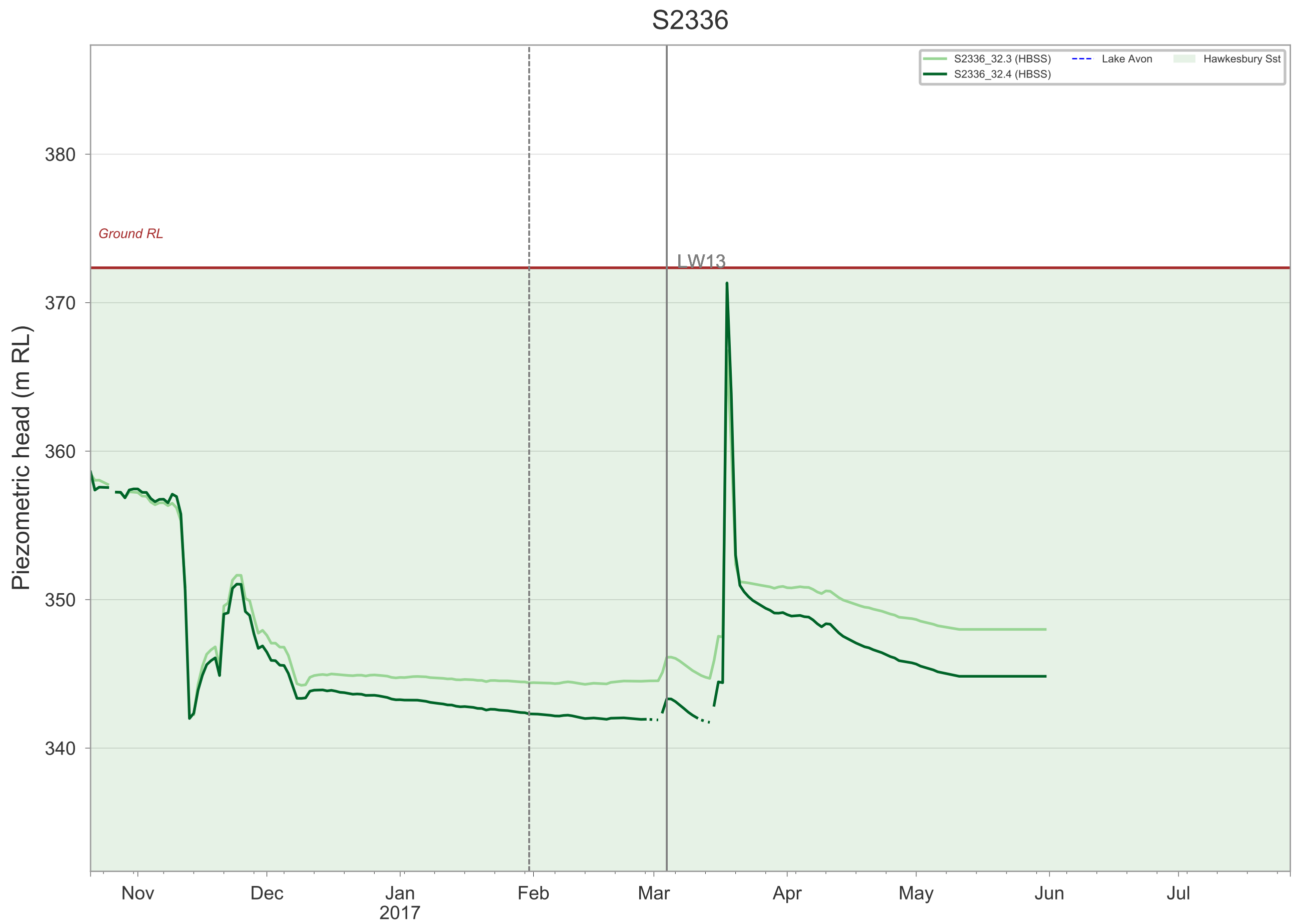

S2313_49 (HBSS)
S2313_131 (HBSS)
S2313_182 (BGSS)
LW12
LW13
LW14
LW15
Pressure head (m H2O)
70
60
50
40
30
20
10
0
Jan 2016
Jul
Jan 2017
Jul
Jan 2018
Jul
Jan 2019

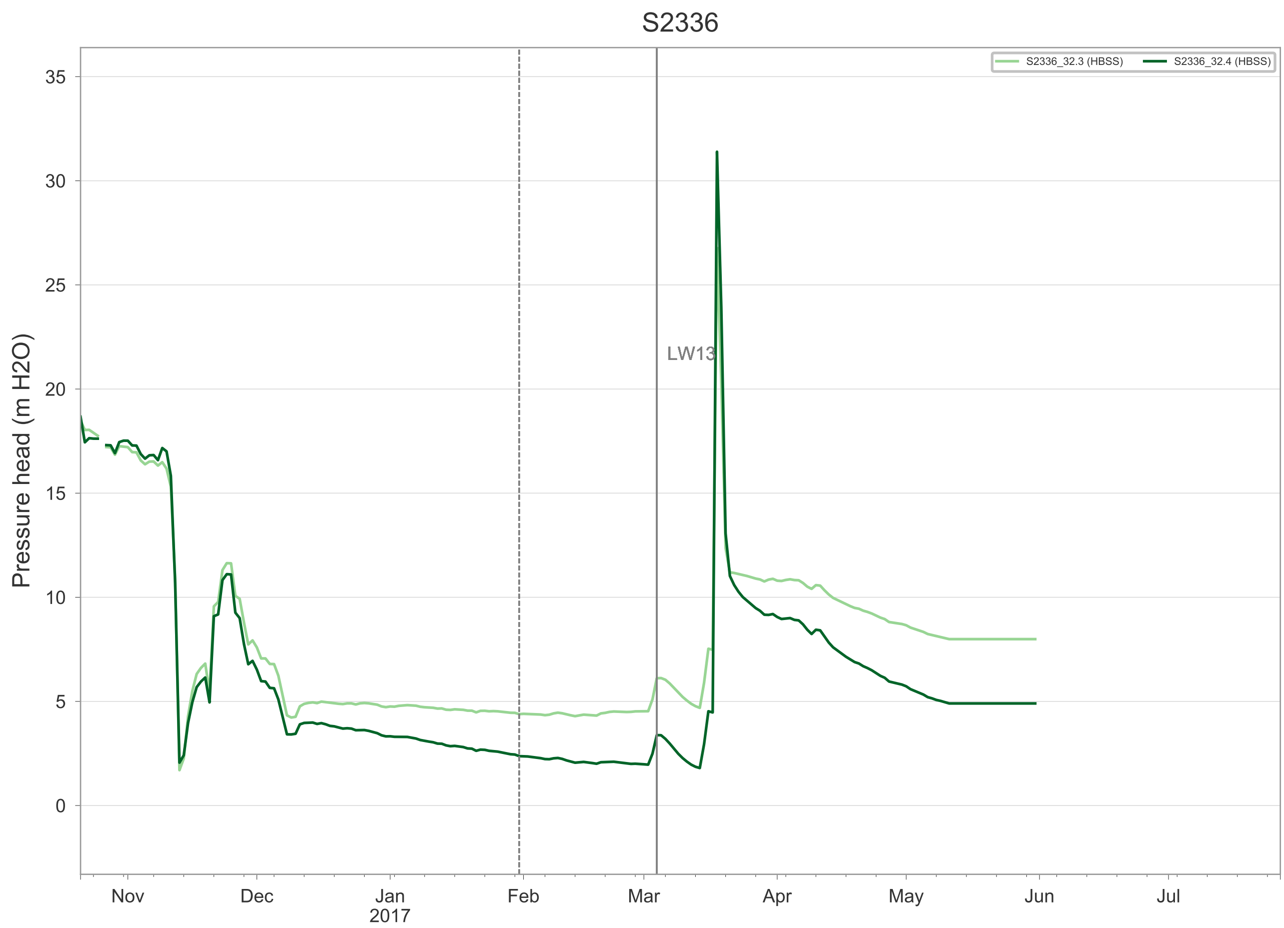

S2314
S2314_29 (HBSS)
S2314_75 (HBSS)
S2314_128 (BGSS)
Lake Avon
Hawkesbury Sst
Ground RL
LW12
LW13
LW14
LW15
Piezometric head (m RL)
340
320
300
280
260
Jan 2016
Jul
Jan 2017
Jul
Jan 2018
Jul
Jan 2019


S2314
S2314_29 (HBSS)
S2314_75 (HBSS)
S2314_128 (BGSS)
LW12
LW13
LW14
LW15
Pressure head (m H2O)
80
70
60
50
40
30
20
10
0
Jan 2016
Jul
Jan 2017
Jul
Jan 2018
Jul
Jan 2019

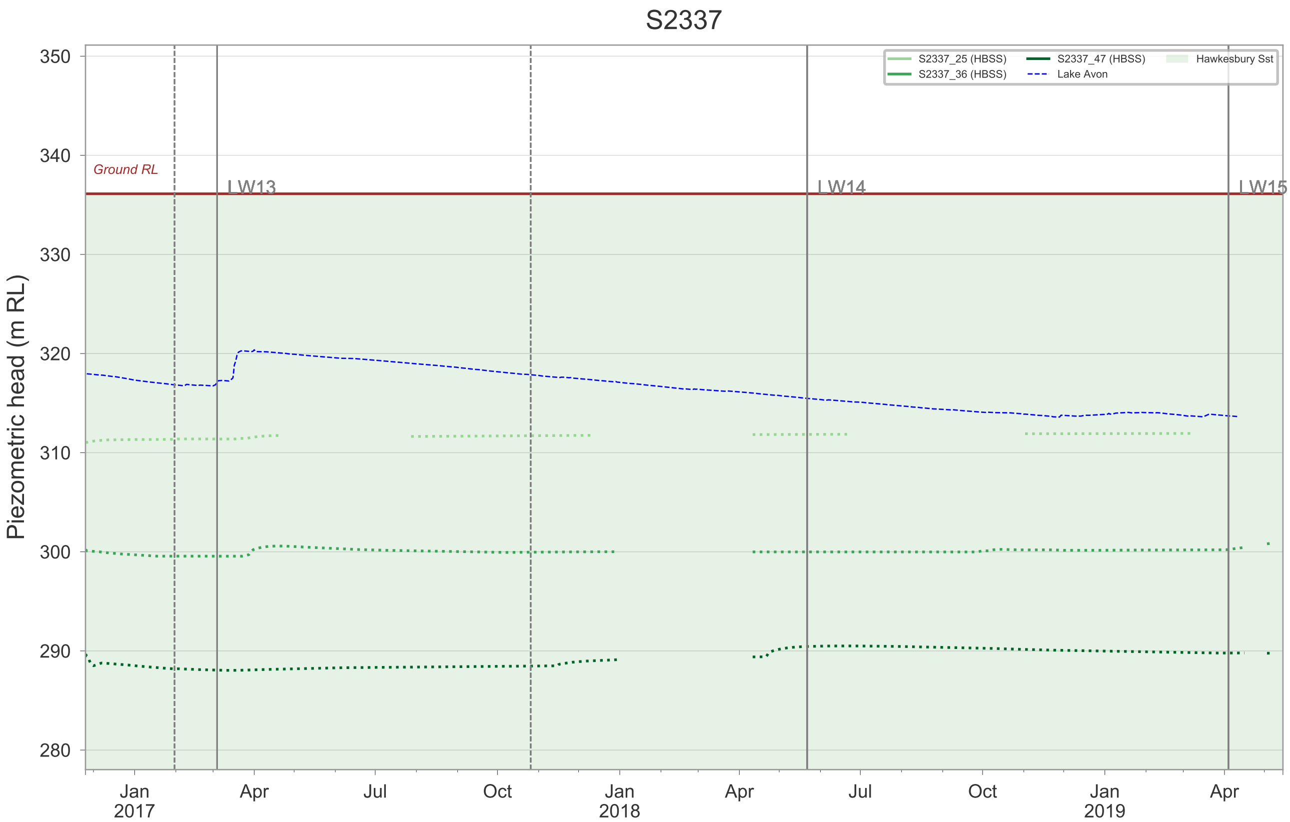
Groundwater hydrographs

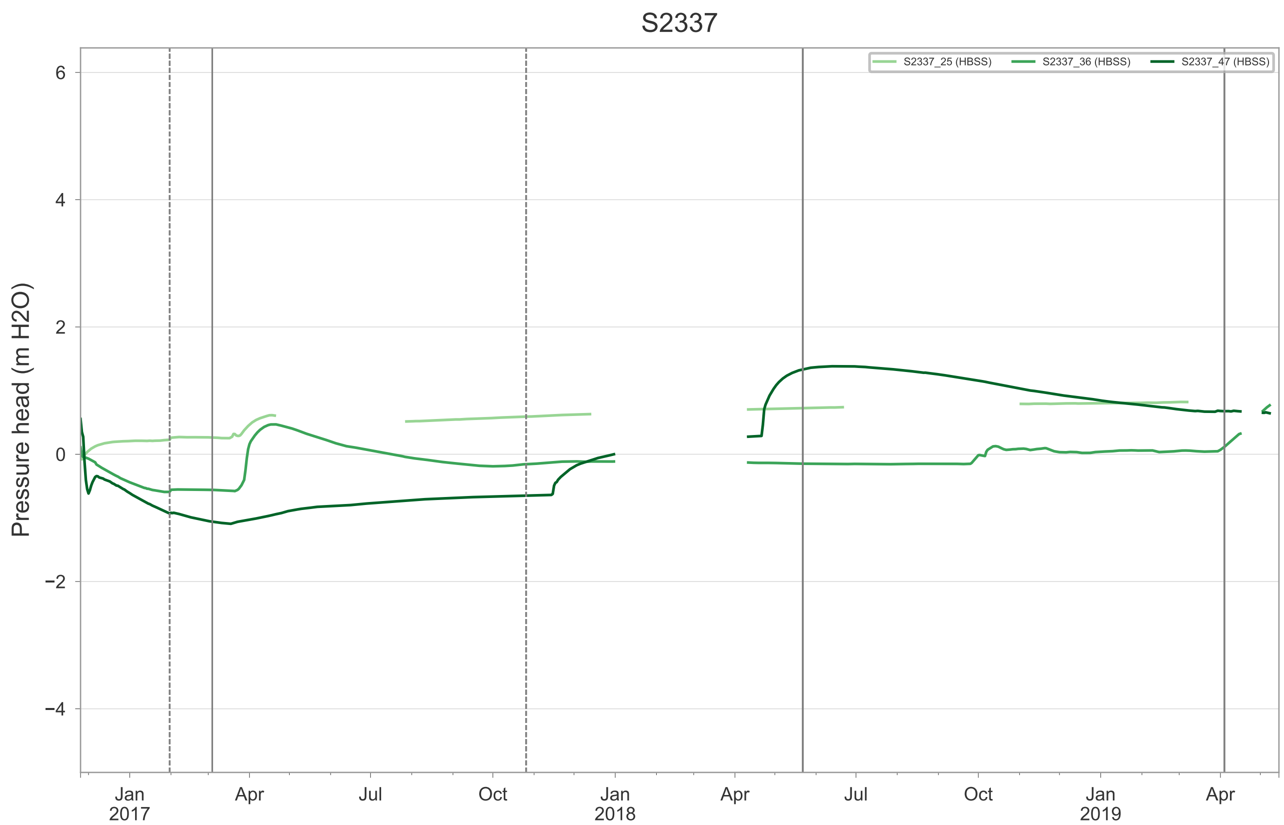
Groundwater hydrographs

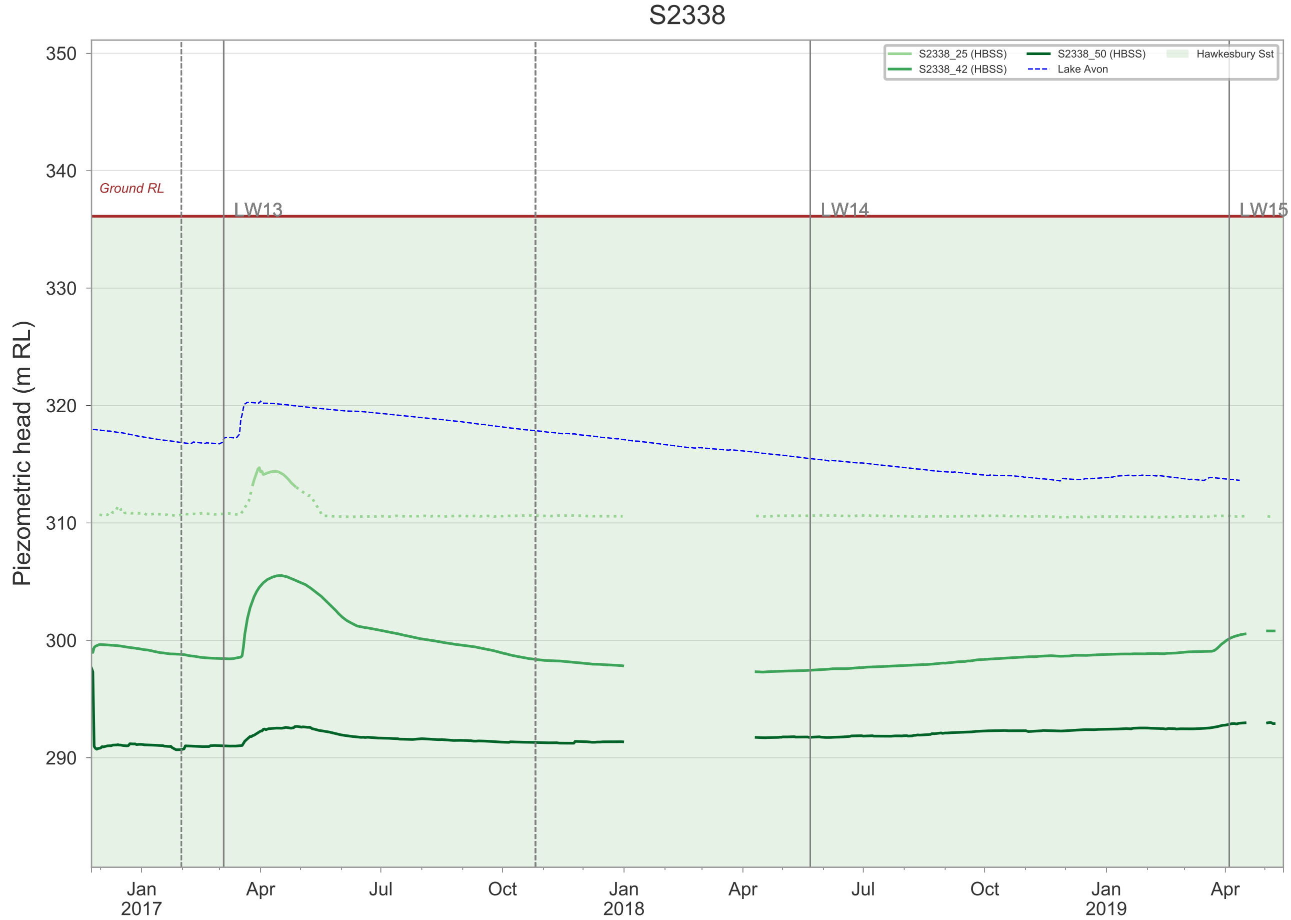


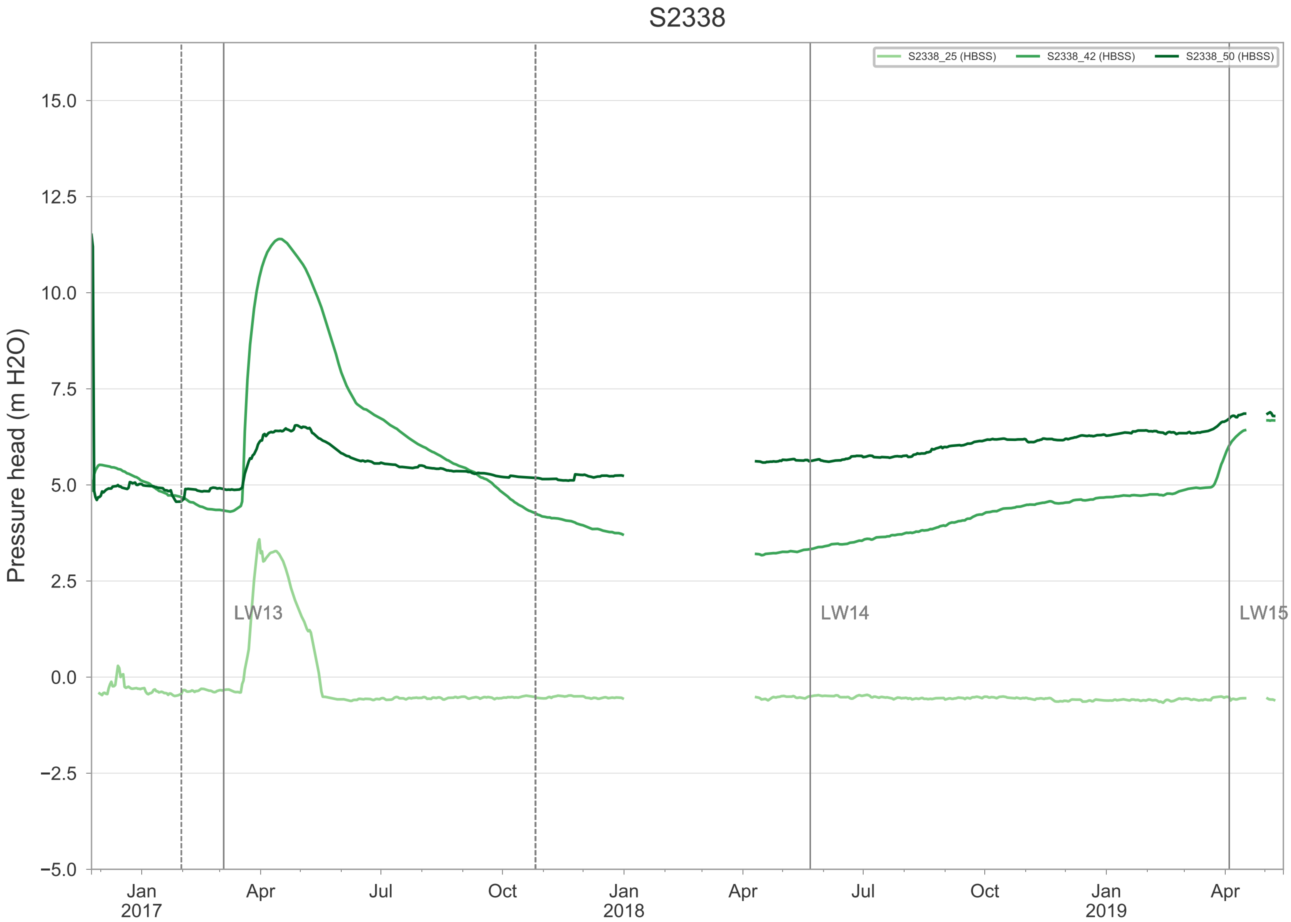


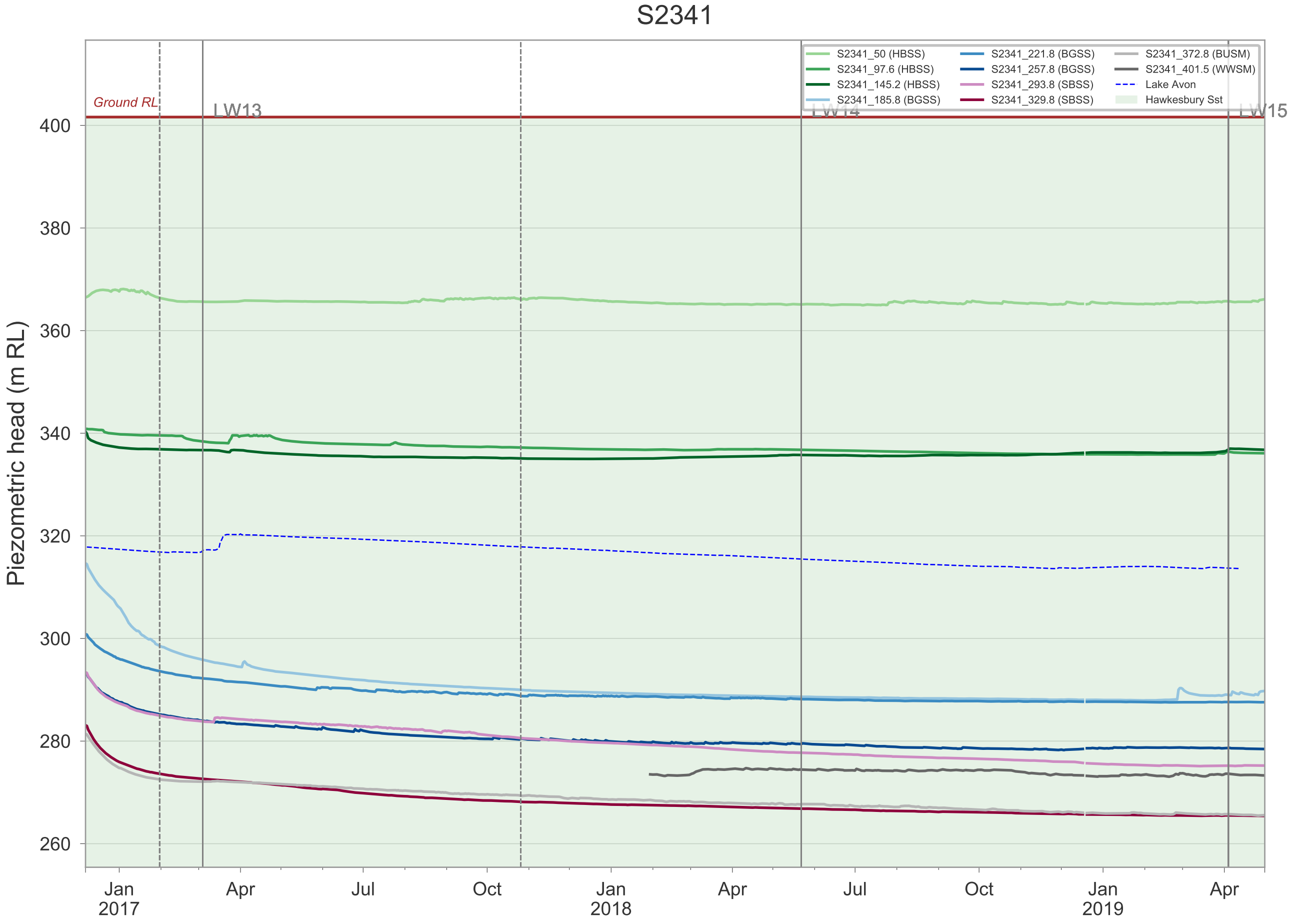
Groundwater hydrographs

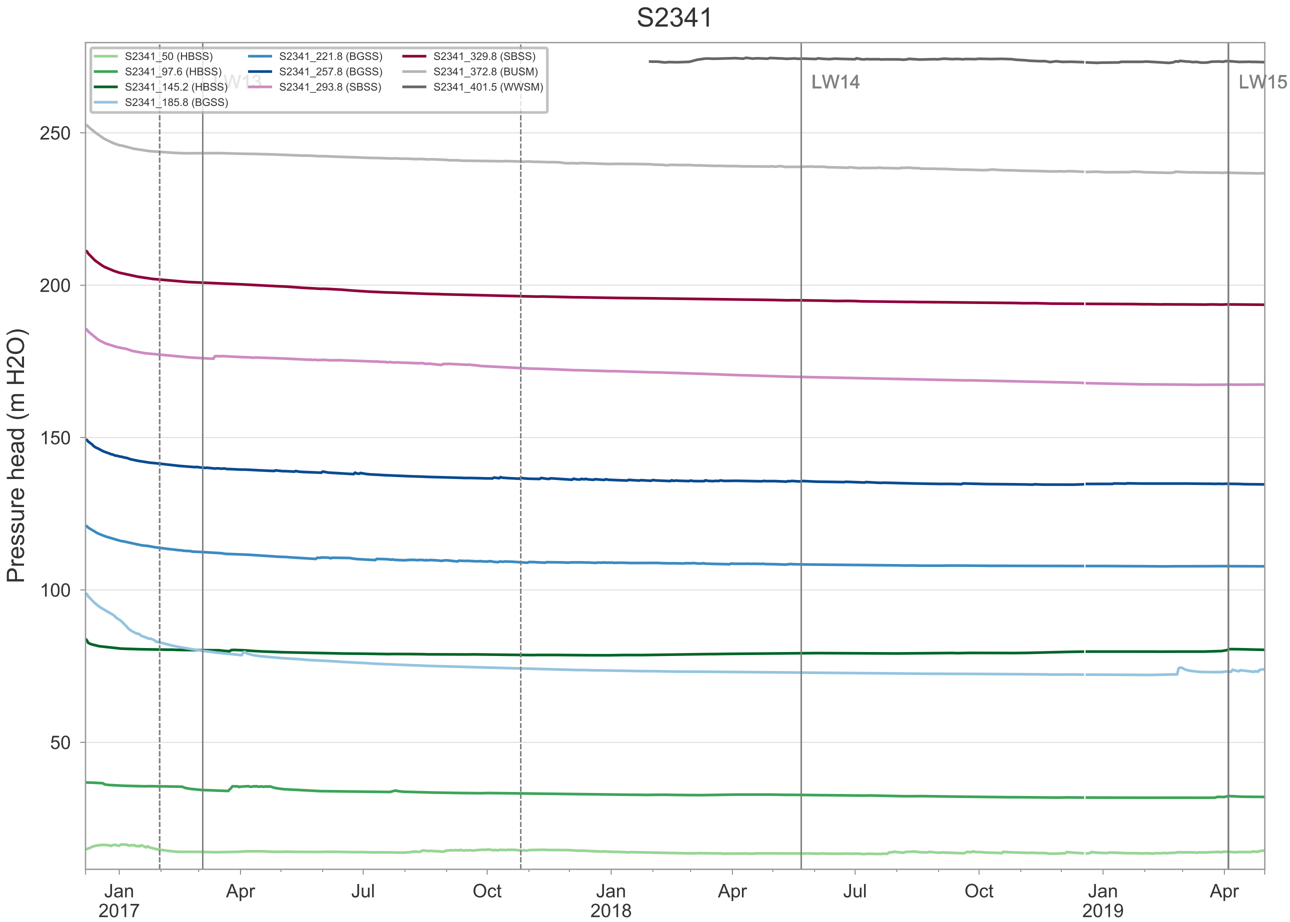




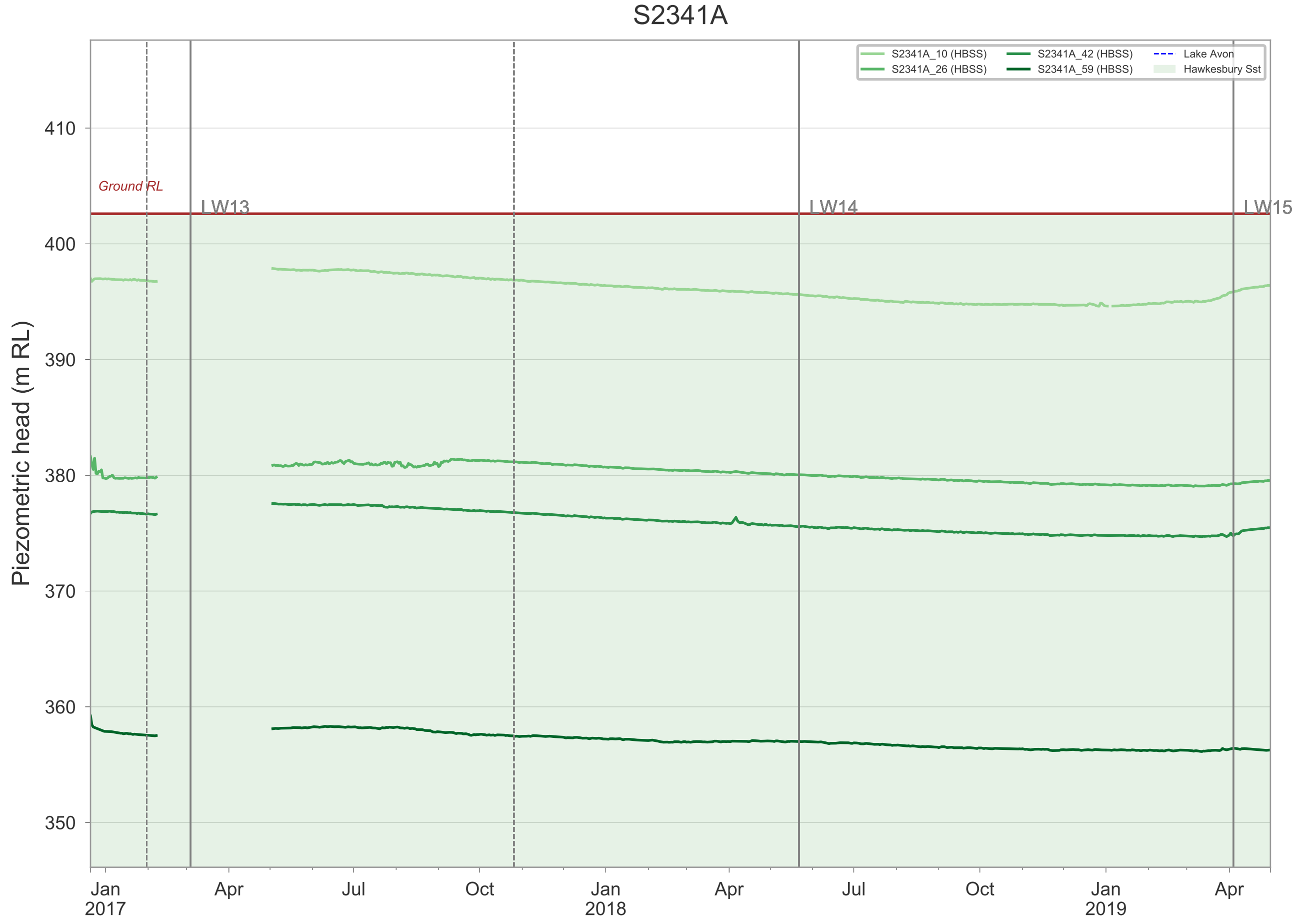

S2338
S2338_25 (HBSS)
S2338_42 (HBSS)
S2338_50 (HBSS)
Lake Avon
Hawkesbury Sst
Ground RL
LW13
LW14
LW15
Piezometric head (m RL)
350
340
330
320
310
300
290
Jan 2017
Apr
Jul
Oct
Jan 2018
Apr
Jul
Oct
Jan 2019
Apr

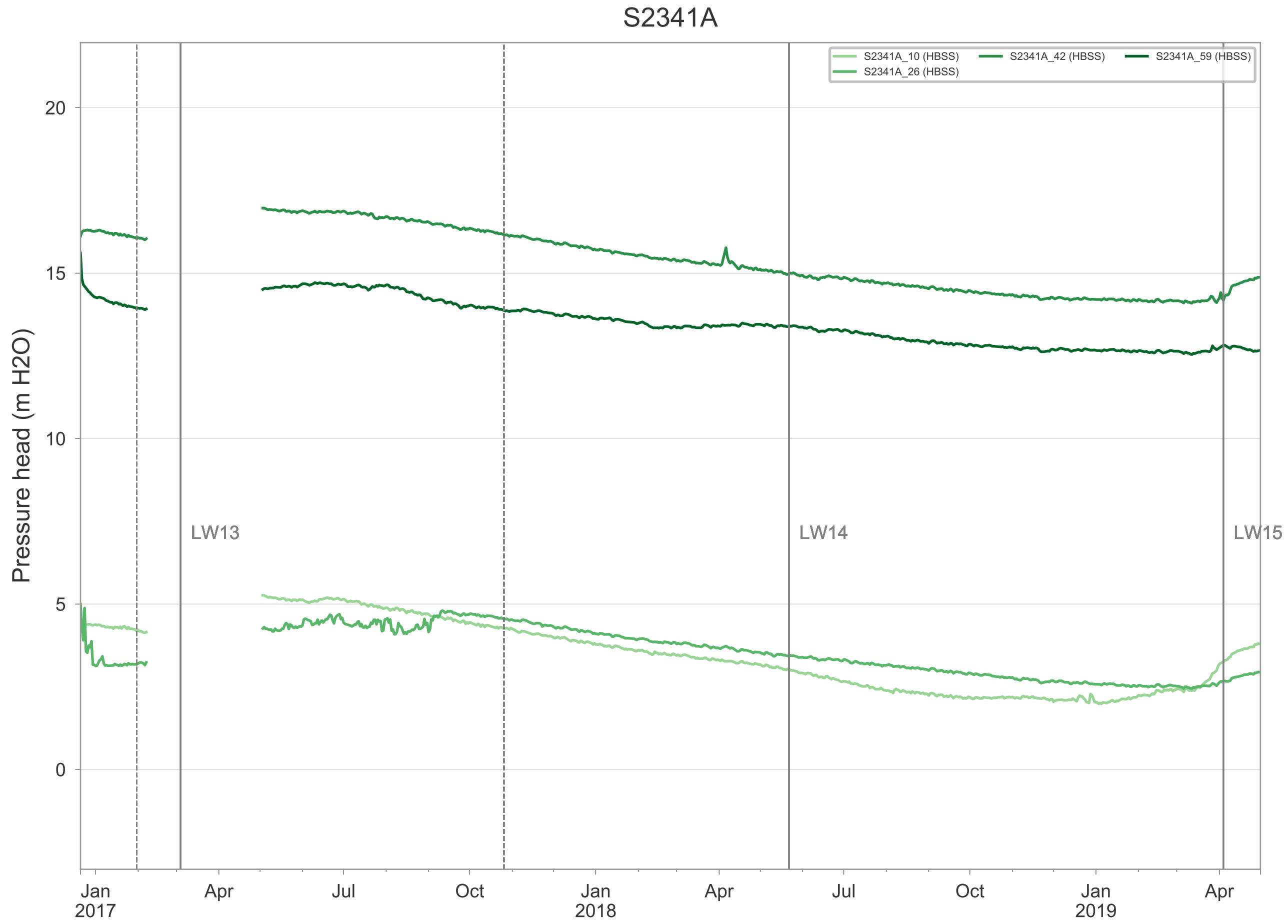

S2338
S2338_25 (HBSS)
S2338_42 (HBSS)
S2338_50 (HBSS)
LW13
LW14
LW15
Pressure head (m H2O)
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
Jan 2017
Apr
Jul
Oct
Jan 2018
Apr
Jul
Oct
Jan 2019
Apr

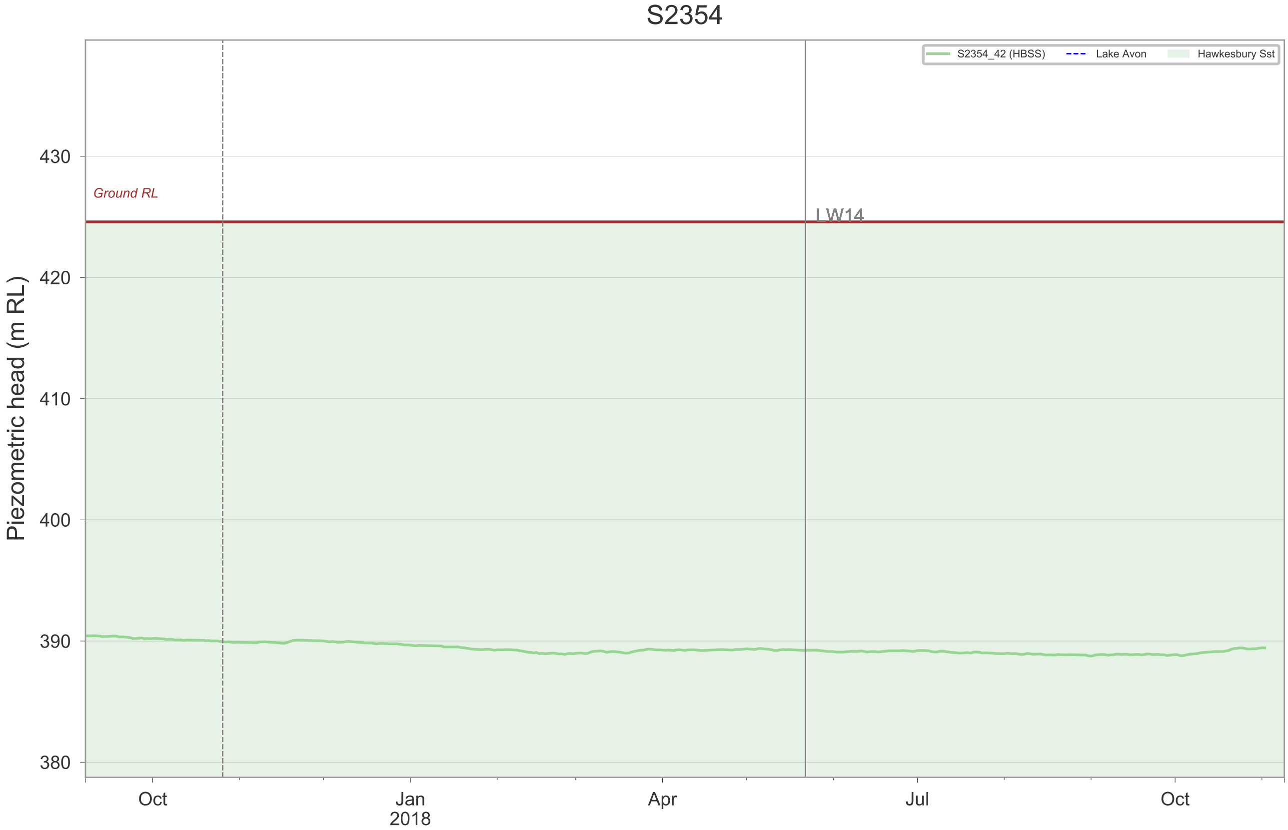

S2341
Piezometric head (m RL)
S2341_50 (HBSS)
S2341_97.6 (HBSS)
S2341_145.2 (HBSS)
S2341_185.8 (BGSS)
S2341_221.8 (BGSS)
S2341_257.8 (BGSS)
S2341_293.8 (SBSS)
S2341_329.8 (SBSS)
S2341_372.8 (BUSM)
S2341_401.5 (WWSM)
Lake Avon
Hawkesbury Sst
Ground RL
LW13
LW14
LW15
400
380
360
340
320
300
280
260
Jan 2017
Apr
Jul
Oct
Jan 2018
Apr
Jul
Oct
Jan 2019
Apr

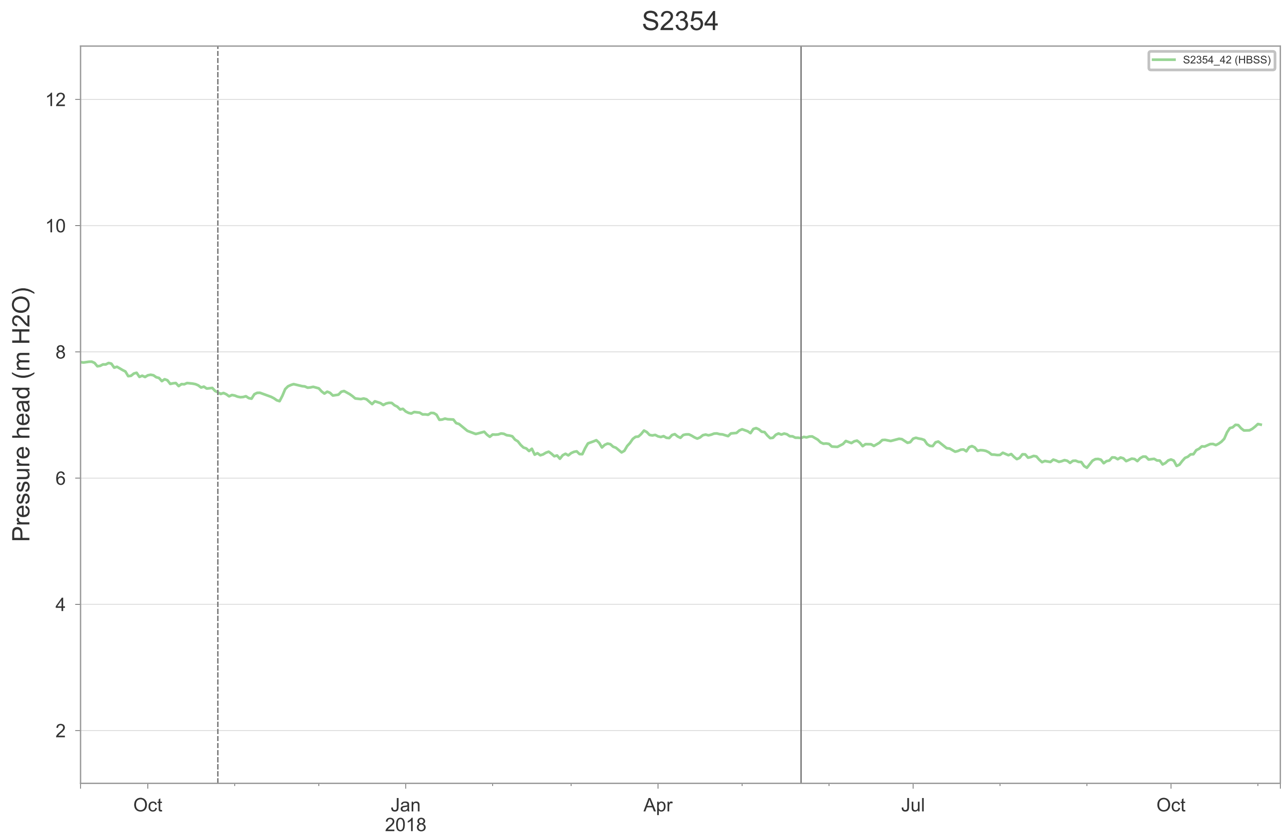

S2341
Pressure head (m H2O)
S2341_50 (HBSS)
S2341_97.6 (HBSS)
S2341_145.2 (HBSS)
S2341_185.8 (BGSS)
S2341_221.8 (BGSS)
S2341_257.8 (BGSS)
S2341_293.8 (SBSS)
S2341_329.8 (SBSS)
S2341_372.8 (BUSM)
S2341_401.5 (WWSM)
LW14
LW15
250
200
150
100
50
Jan 2017
Apr
Jul
Oct
Jan 2018
Apr
Jul
Oct
Jan 2019
Apr

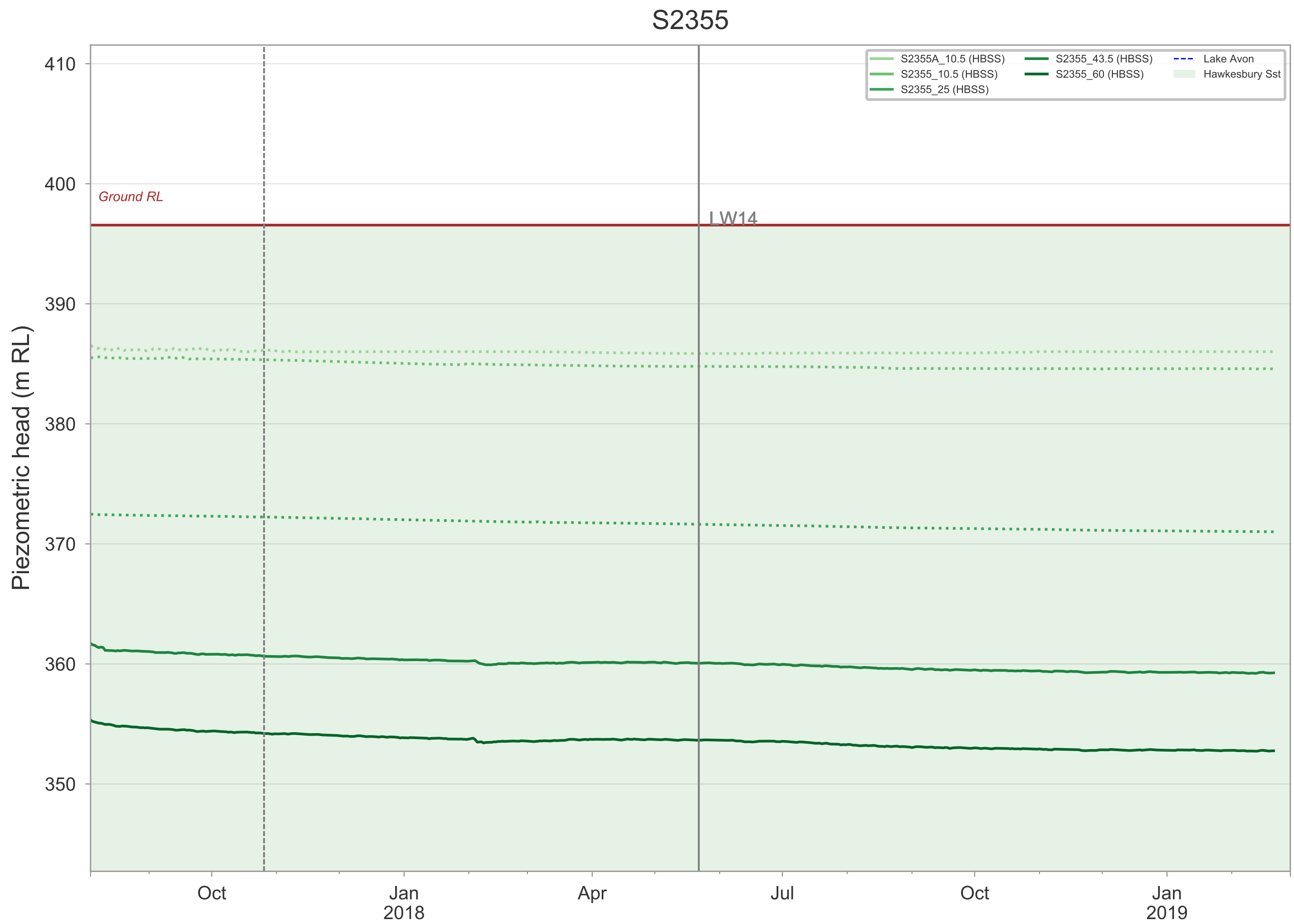
Groundwater hydrographs





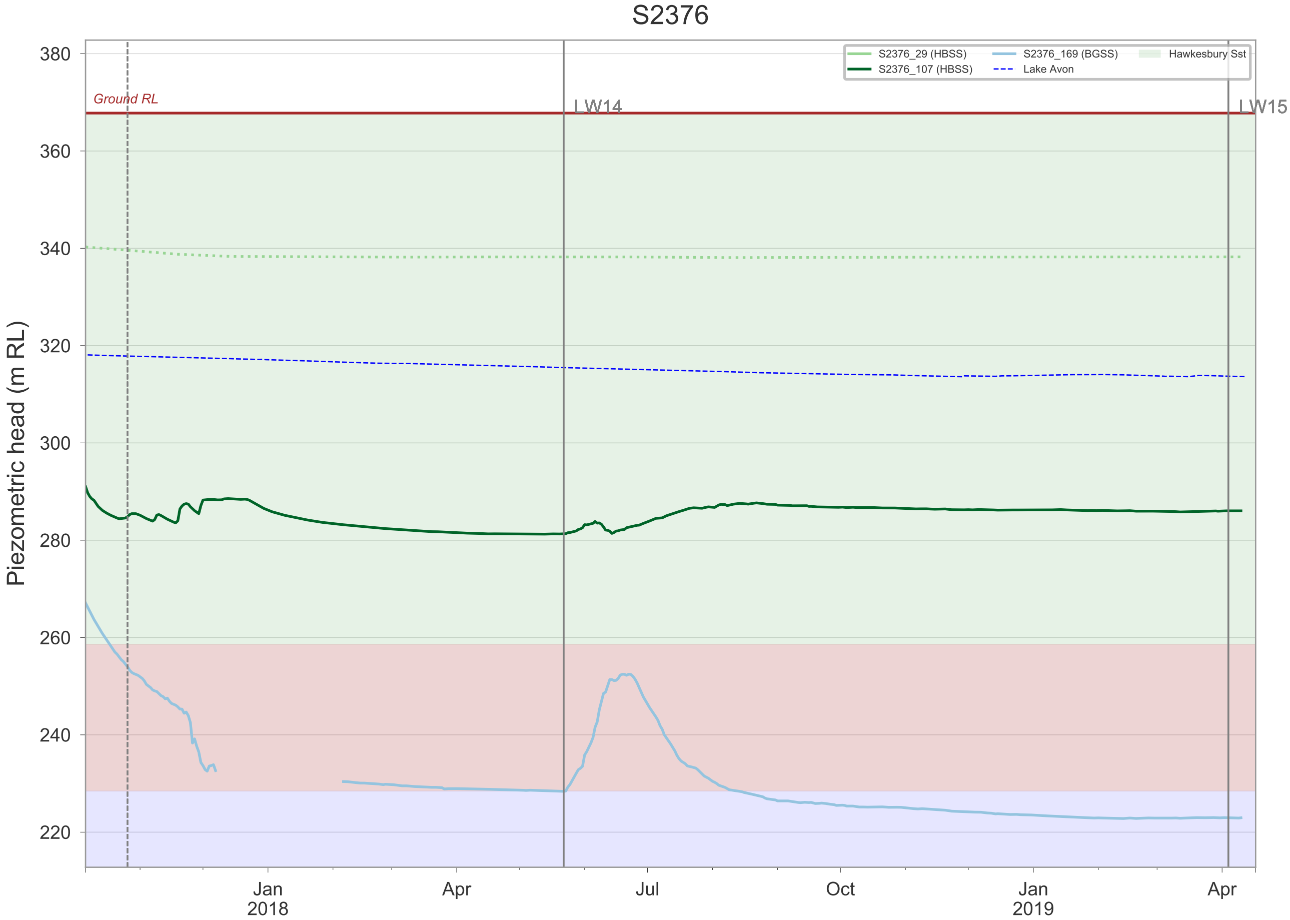

S2354
S2354_42 (HBSS)
Lake Avon
Hawkesbury Sst
Ground RL
LW14
Piezometric head (m RL)
430
420
410
400
390
380
Oct
Jan
2018
Apr
Jul
Oct

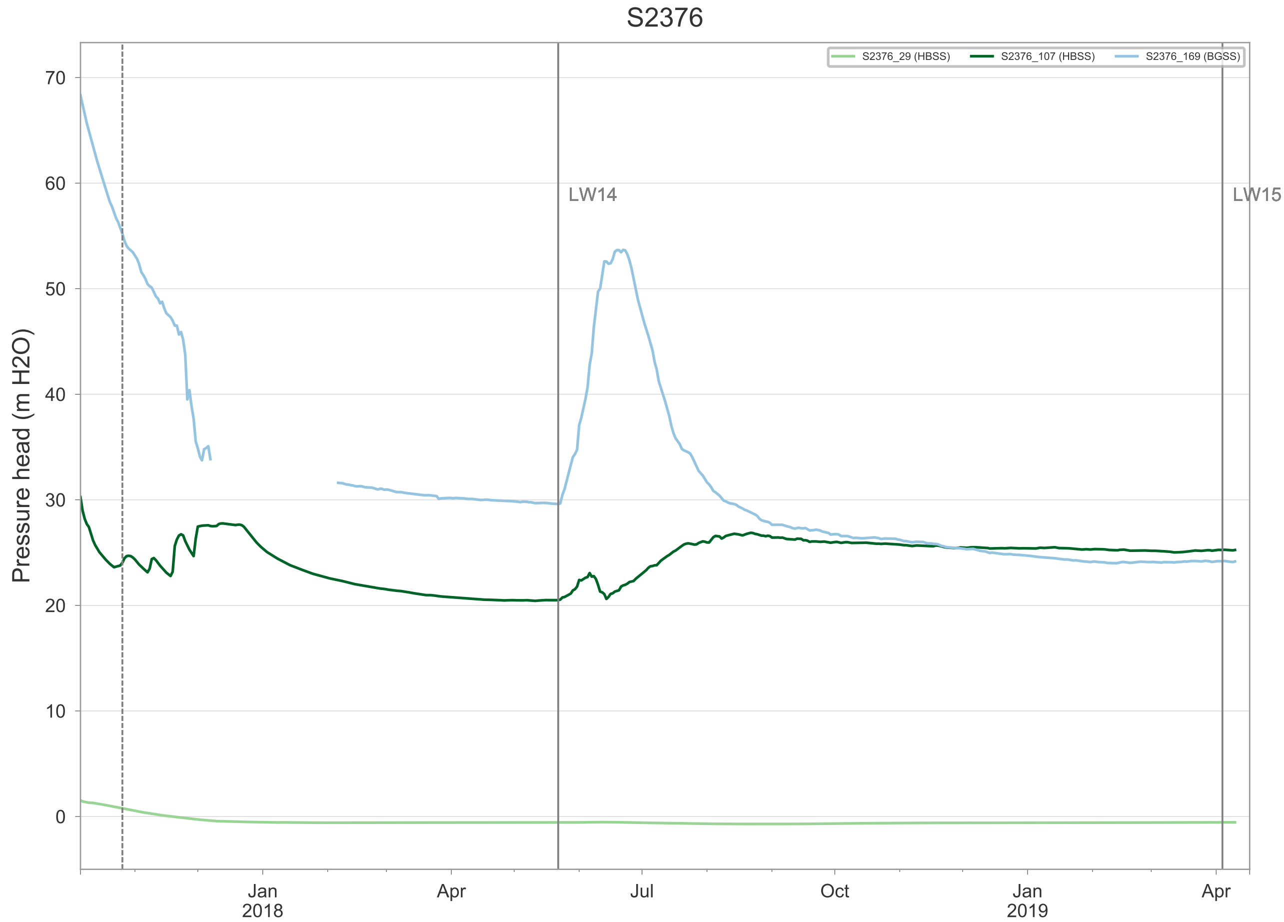

S2354
S2354_42 (HBSS)
Pressure head (m H2O)
12
10
8
6
4
2
Oct
Jan
2018
Apr
Jul
Oct

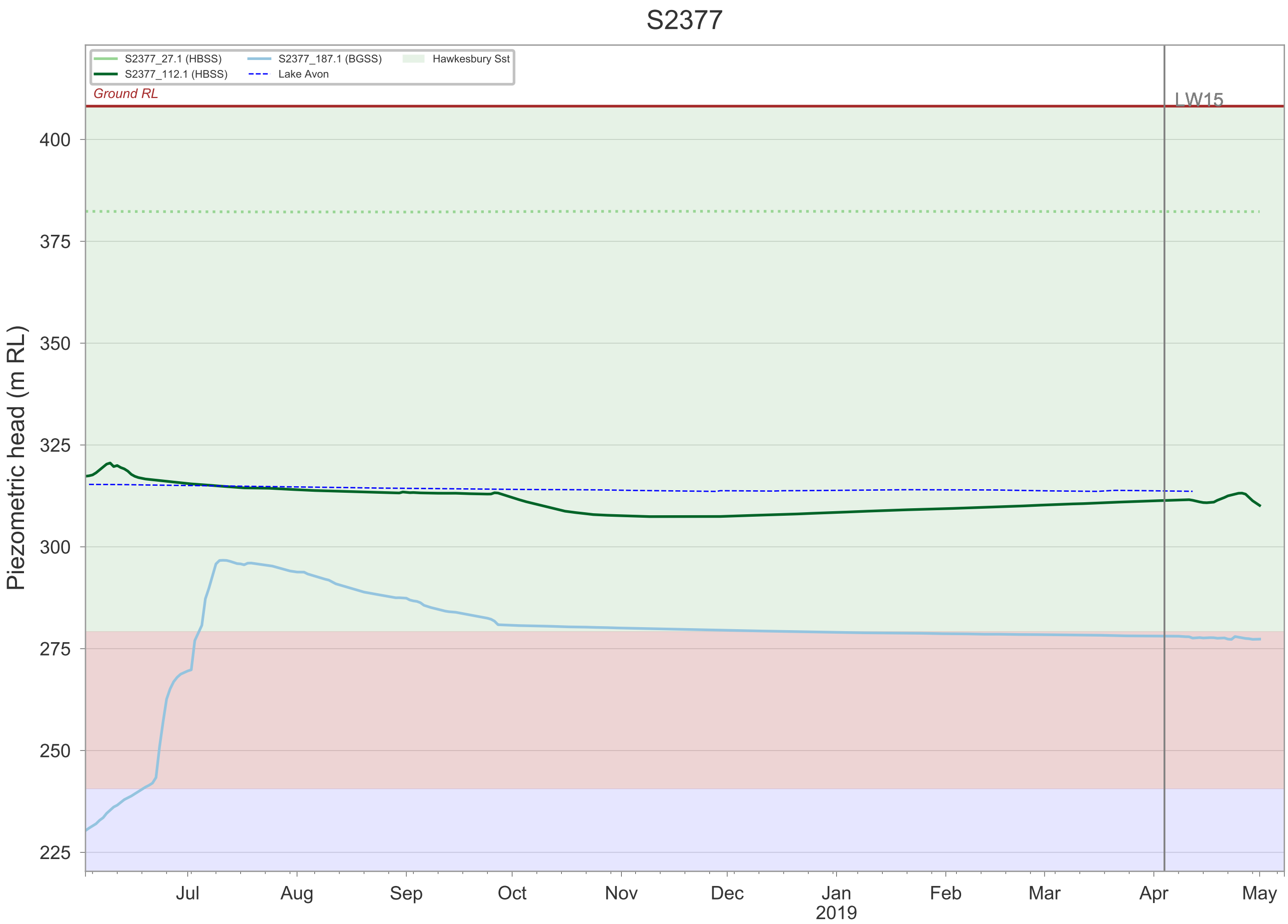

S2355
S2355A_10.5 (HBSS)
S2355_10.5 (HBSS)
S2355_25 (HBSS)
S2355_43.5 (HBSS)
S2355_60 (HBSS)
Lake Avon
Hawkesbury Sst
Ground RL
LW14
Piezometric head (m RL)
410
400
390
380
370
360
350
Oct
Jan
2018
Apr
Jul
Oct
Jan
2019

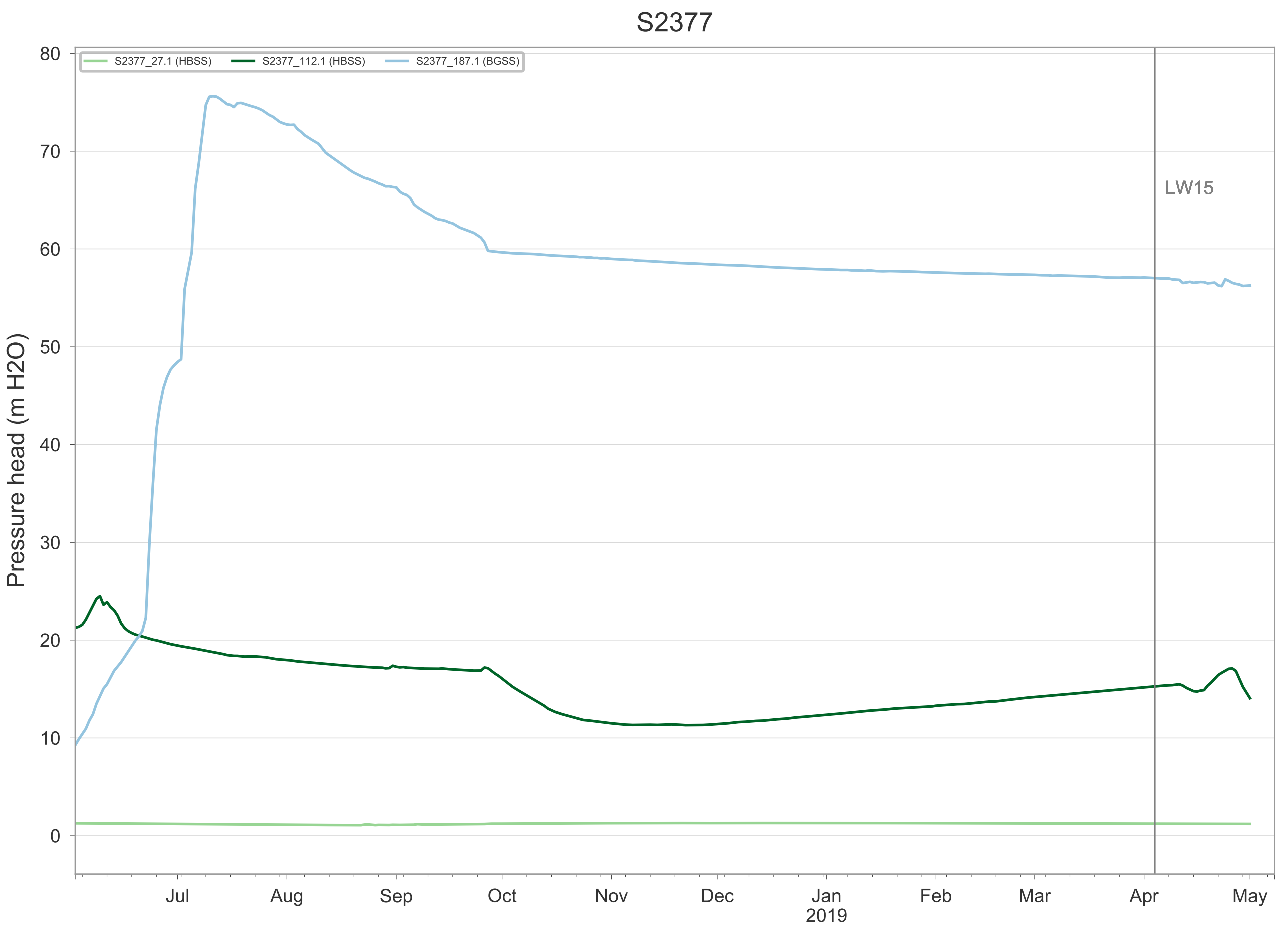

S2355
S2355A_10.5 (HBSS)
S2355_10.5 (HBSS)
S2355_25 (HBSS)
S2355_43.5 (HBSS)
S2355_60 (HBSS)
LW14
Pressure head (m H2O)
20
15
10
5
0
−5
Oct
Jan
2018
Apr
Jul
Oct
Jan
2019

Groundwater hydrographs

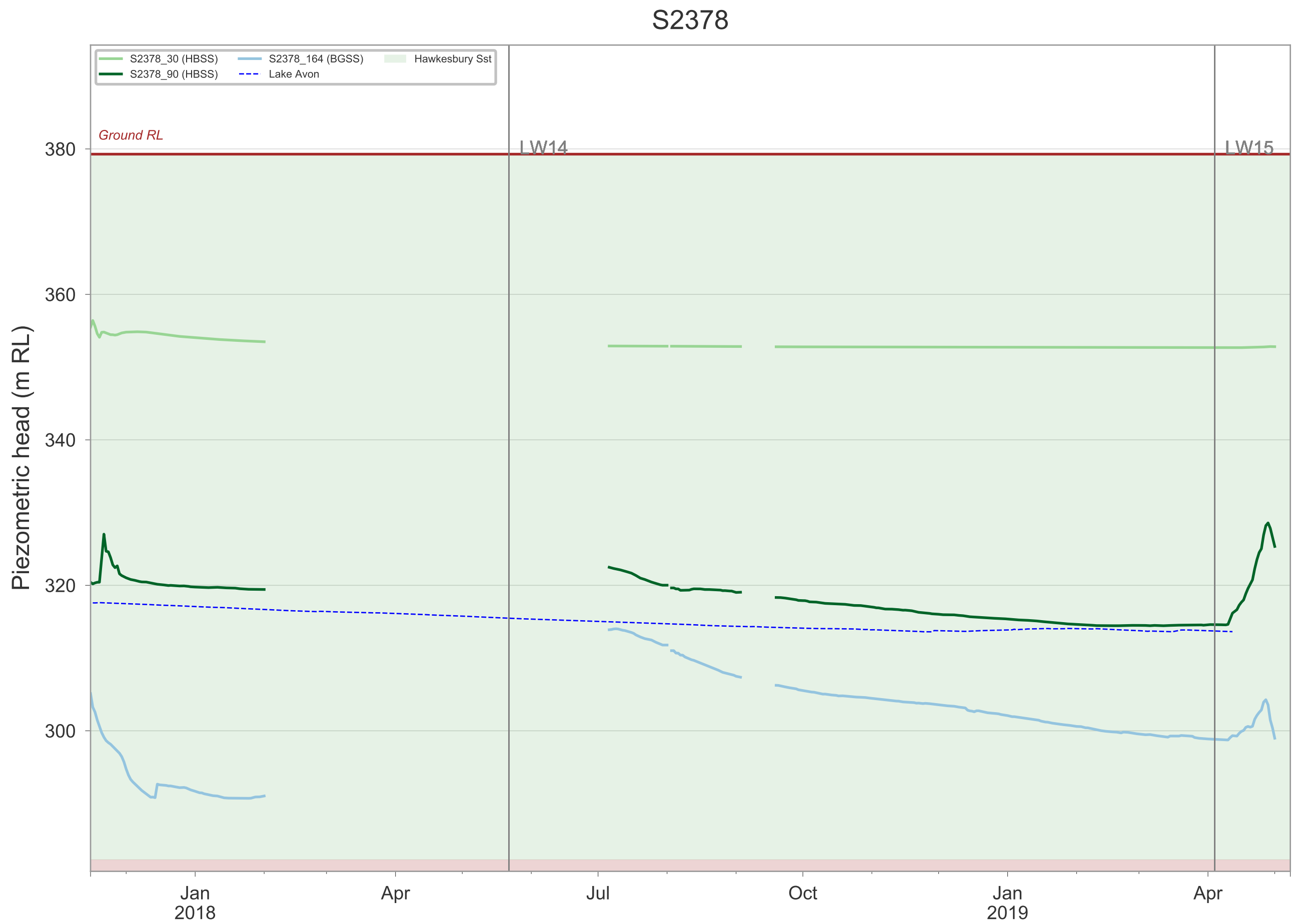


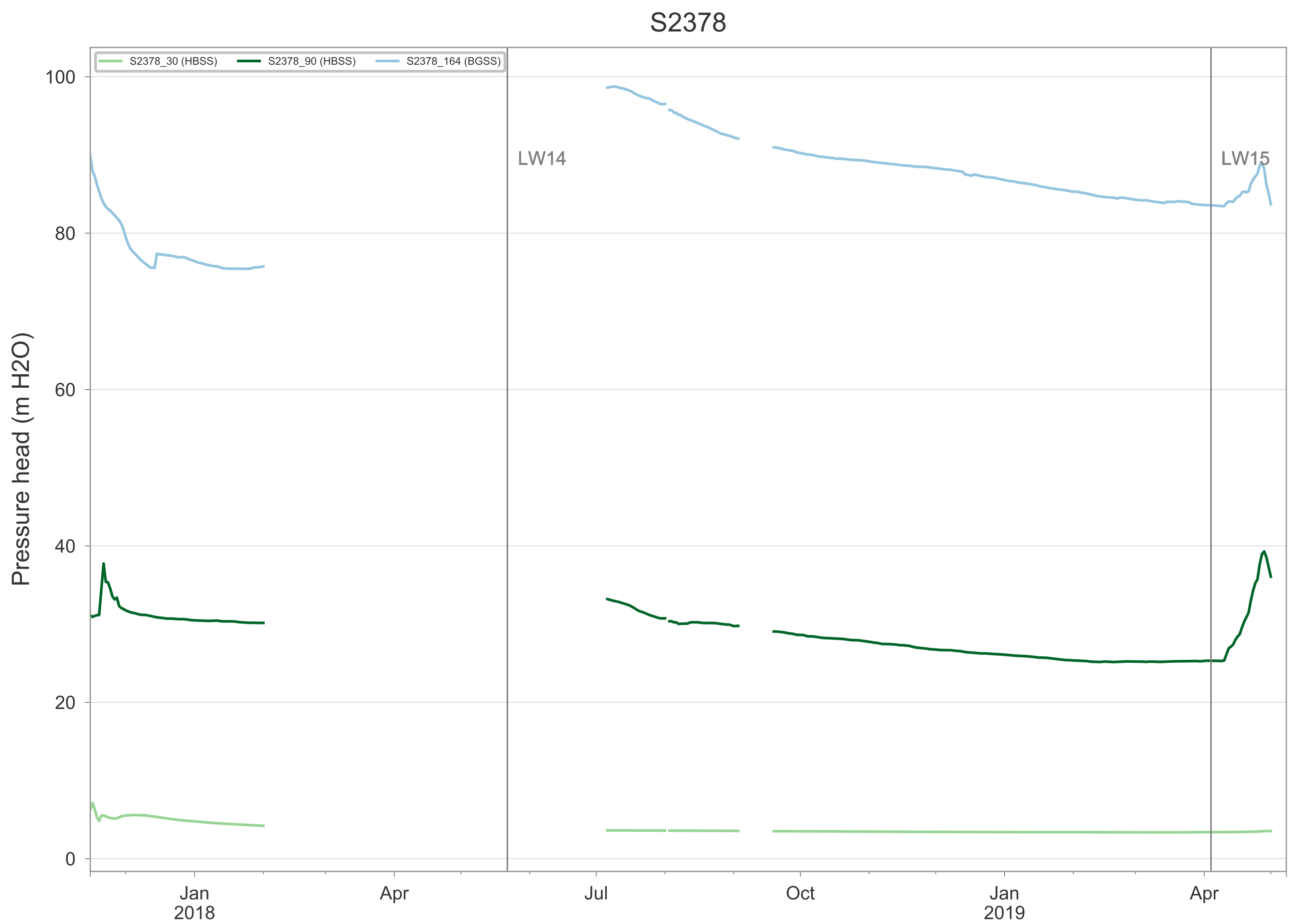



S2377
S2377_27.1 (HBSS)
S2377_112.1 (HBSS)
S2377_187.1 (BGSS)
Lake Avon
Hawkesbury Sst
Ground RL
LW15
Piezometric head (m RL)
400
375
350
325
300
275
250
225
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2019
Feb
Mar
Apr
May

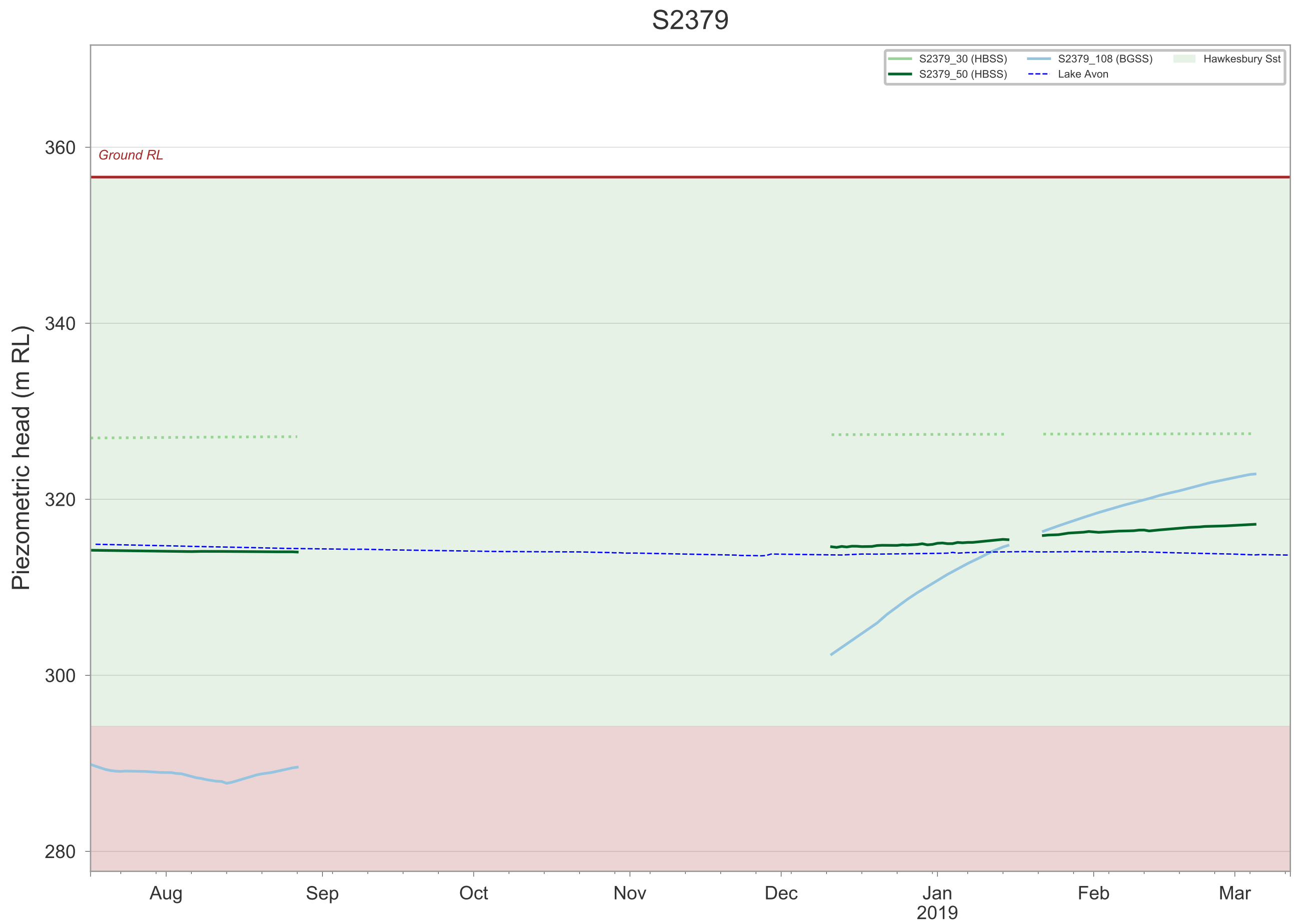

S2377
S2377_27.1 (HBSS)
S2377_112.1 (HBSS)
S2377_187.1 (BGSS)
LW15
Pressure head (m H2O)
80
70
60
50
40
30
20
10
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2019
Feb
Mar
Apr
May

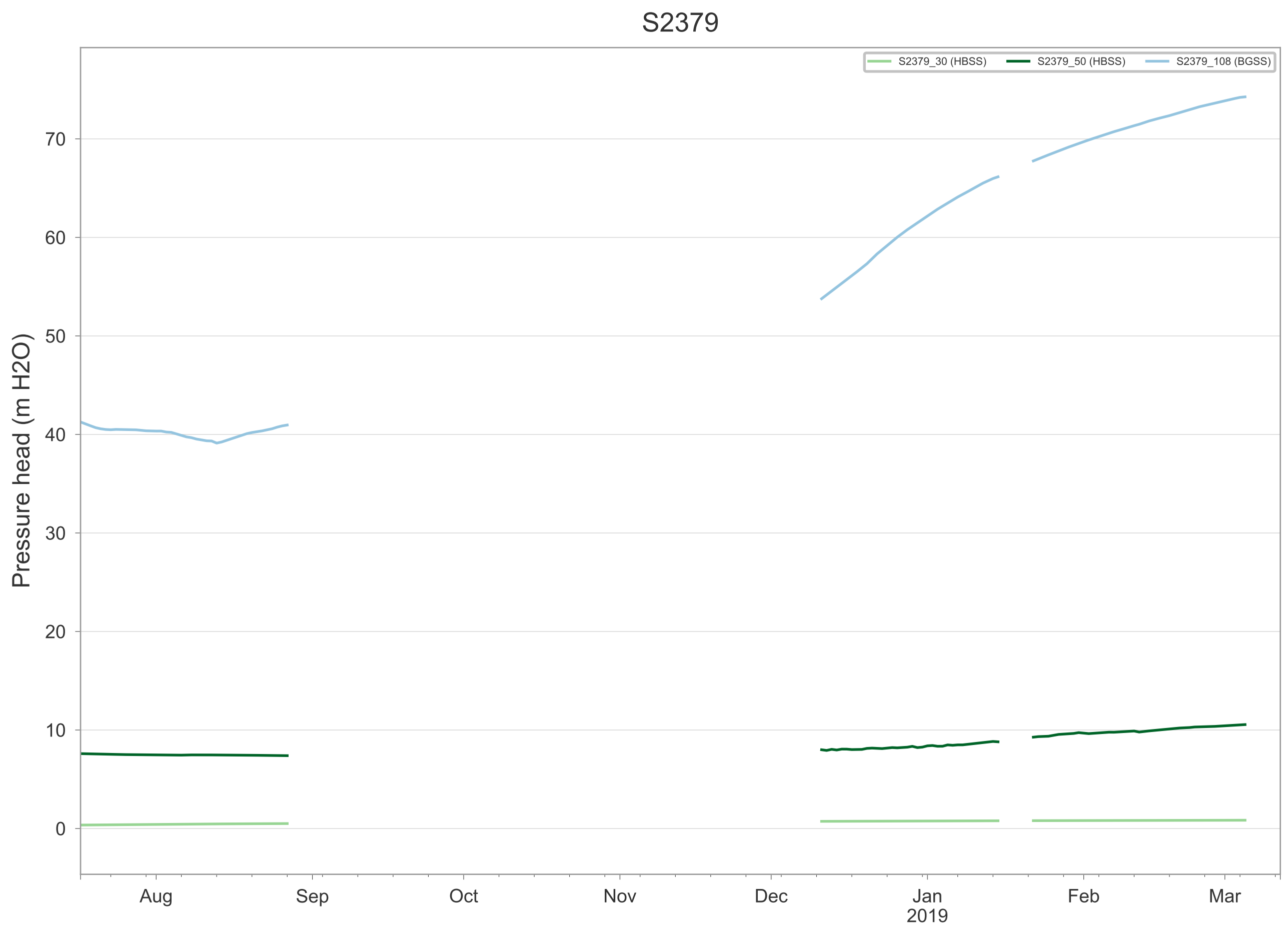
Groundwater hydrographs



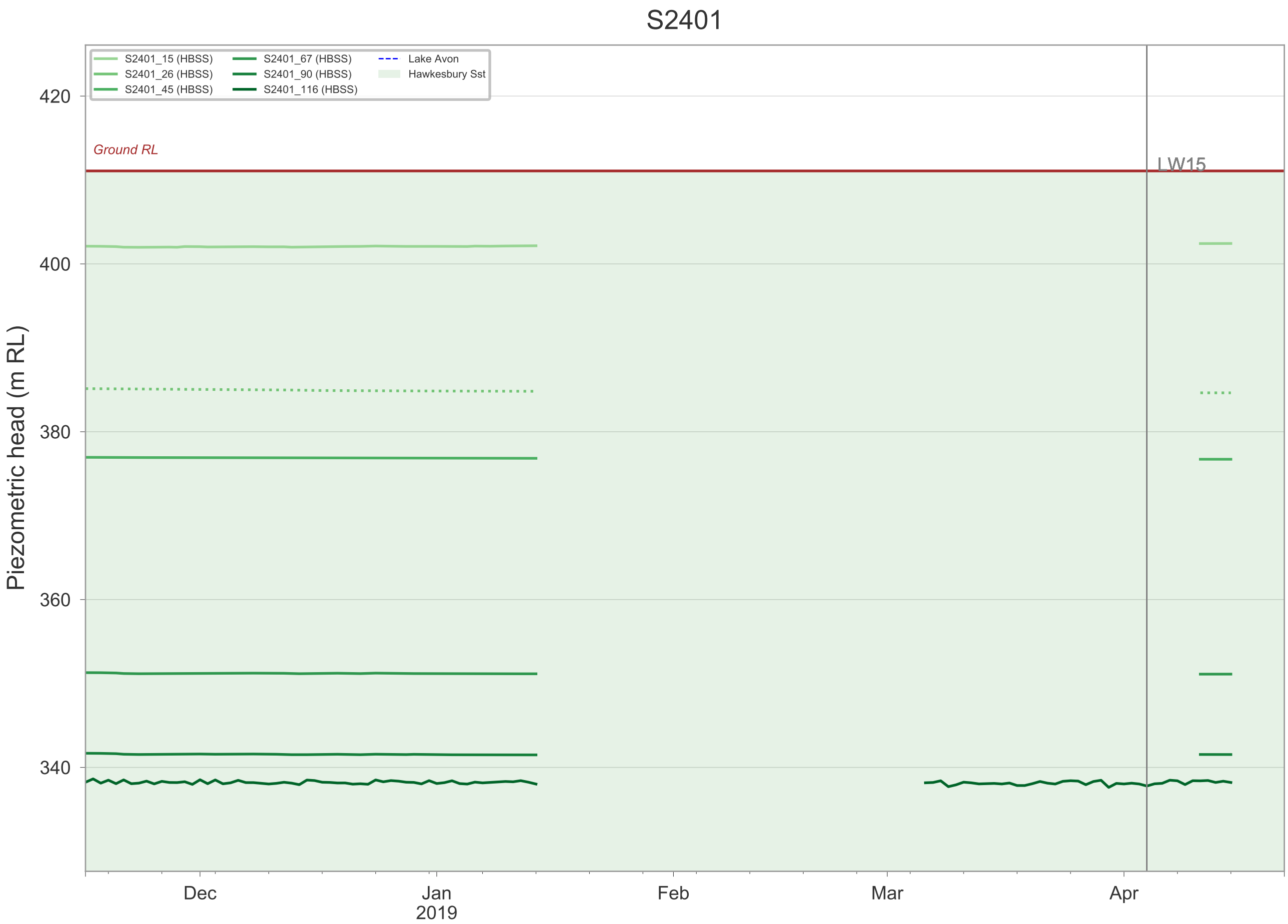


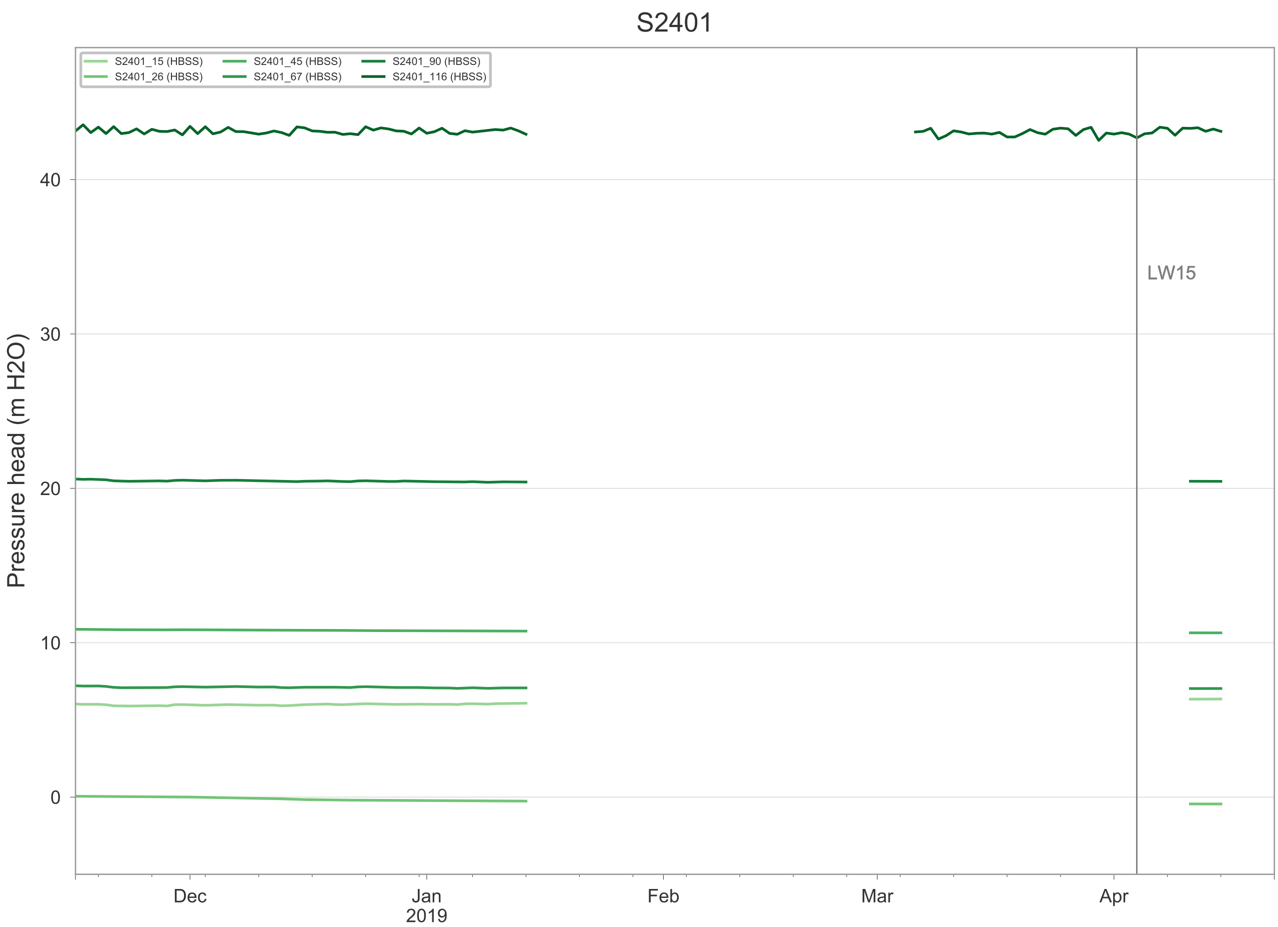
Groundwater hydrographs



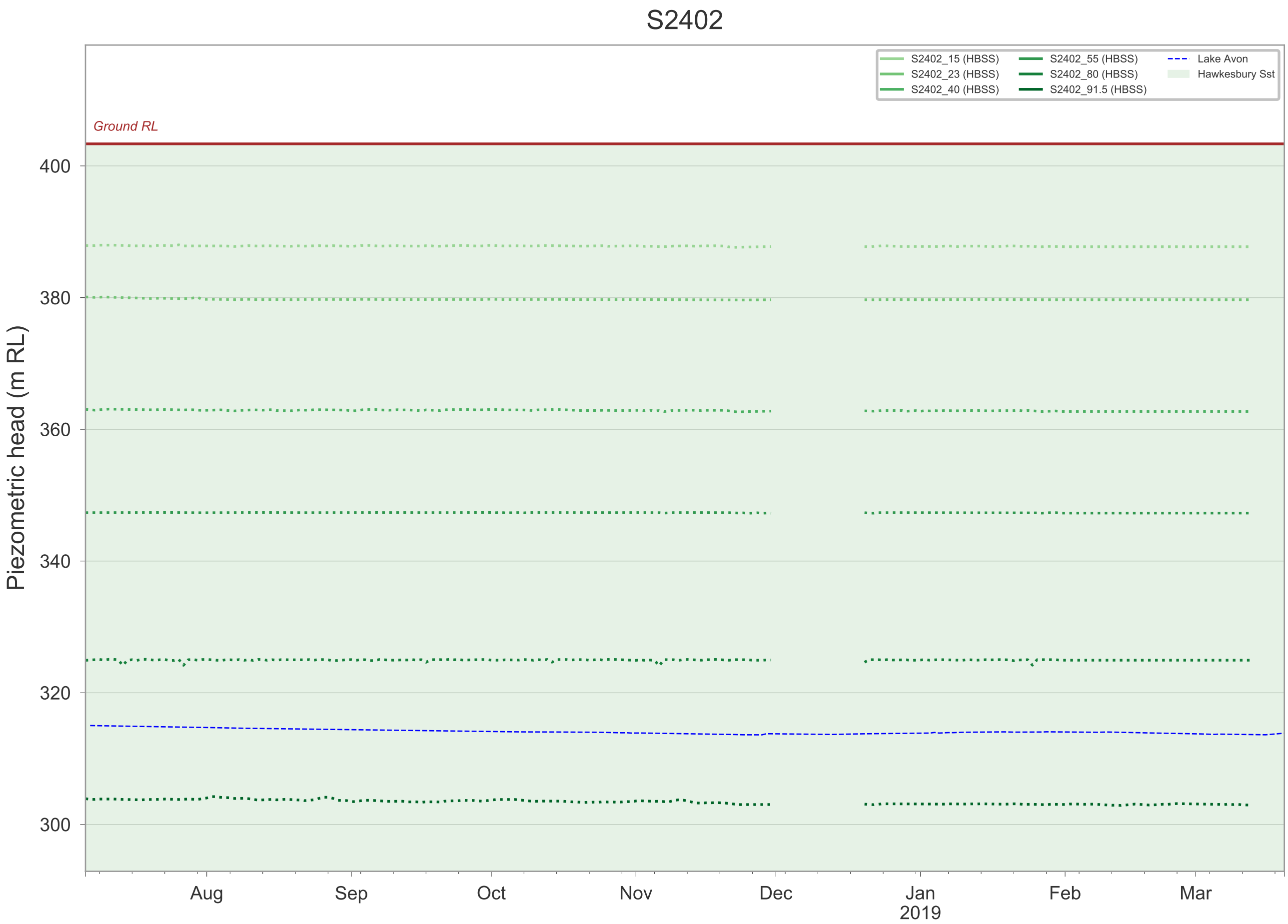


Groundwater hydrographs

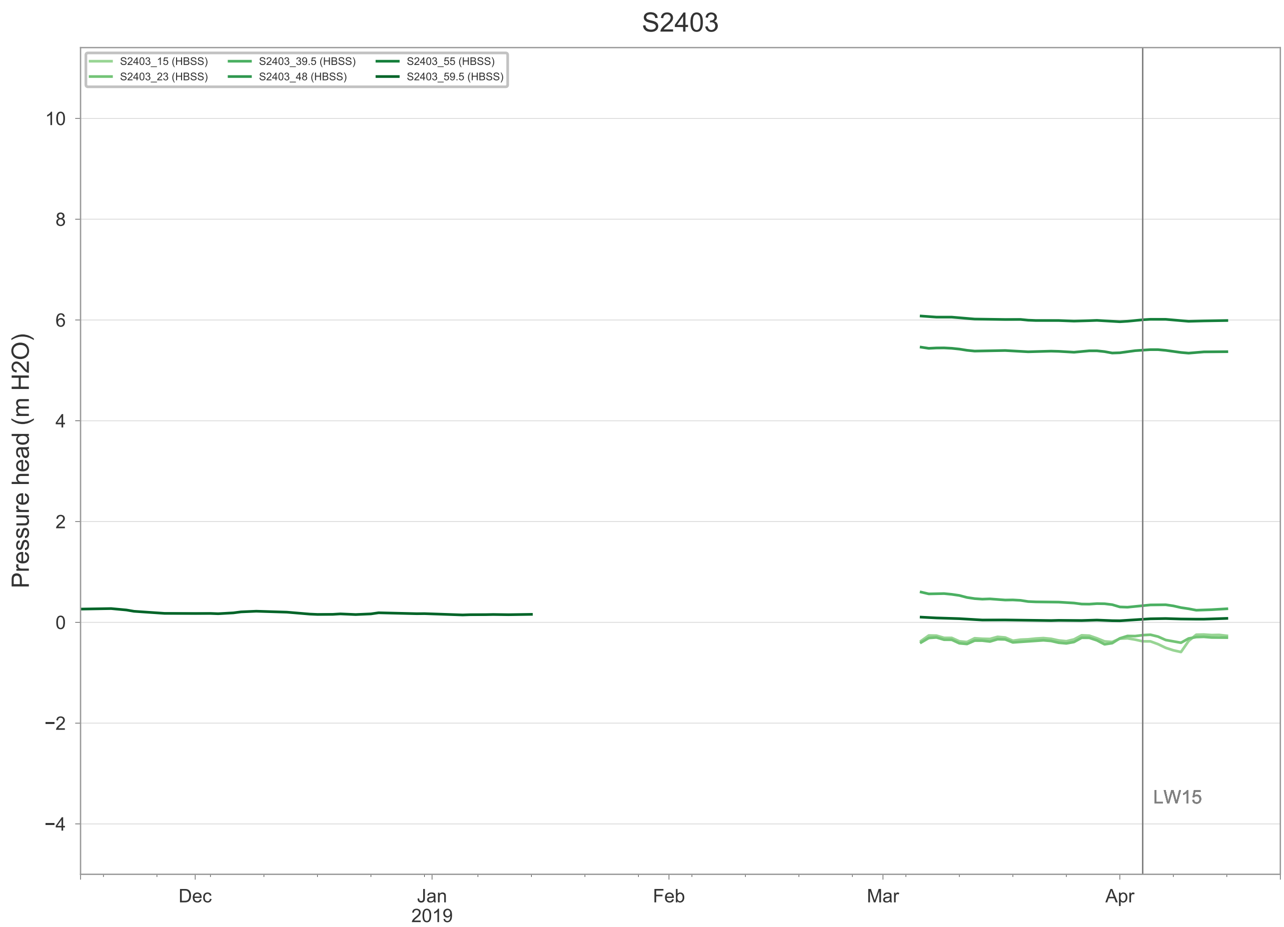


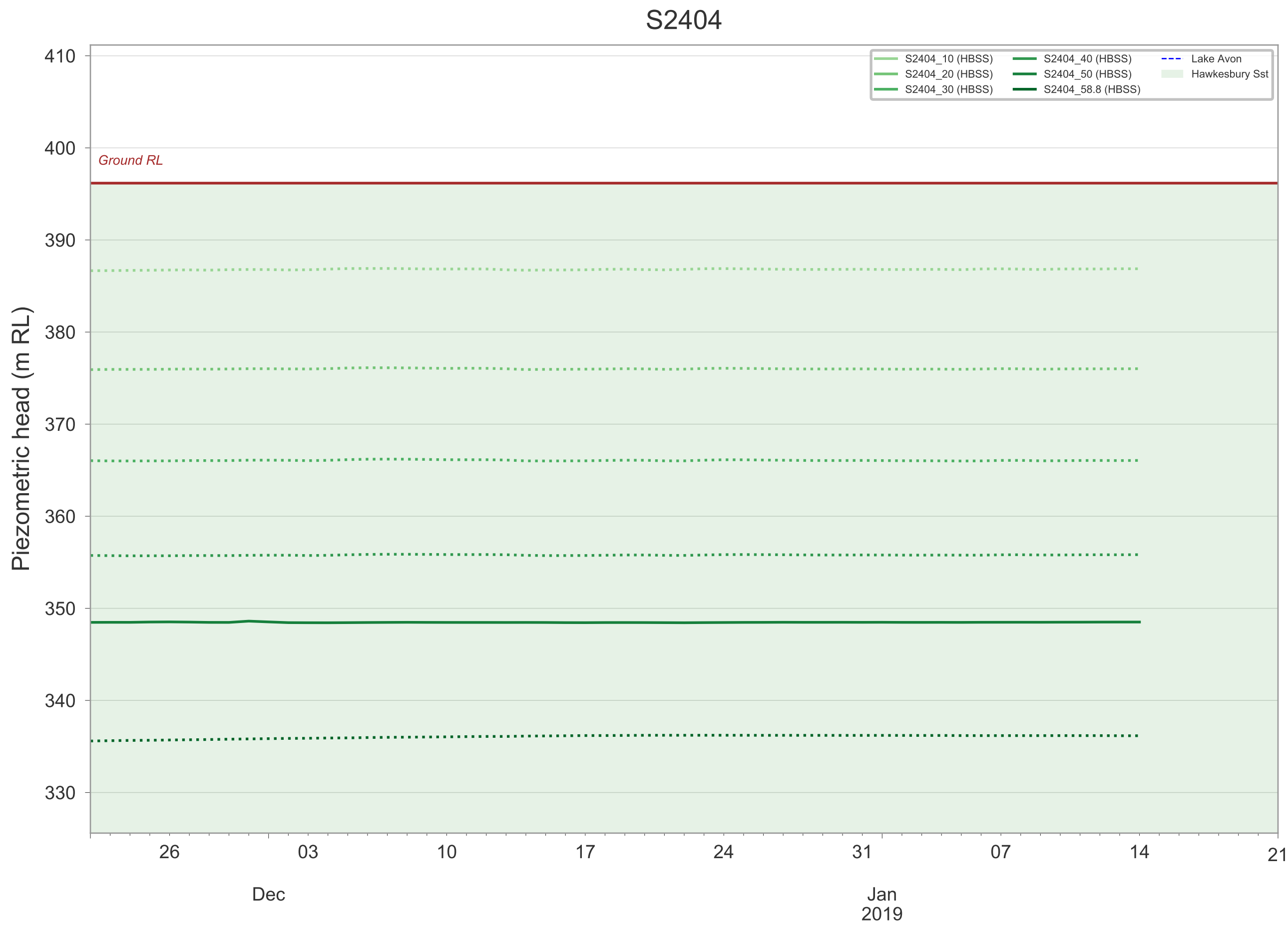


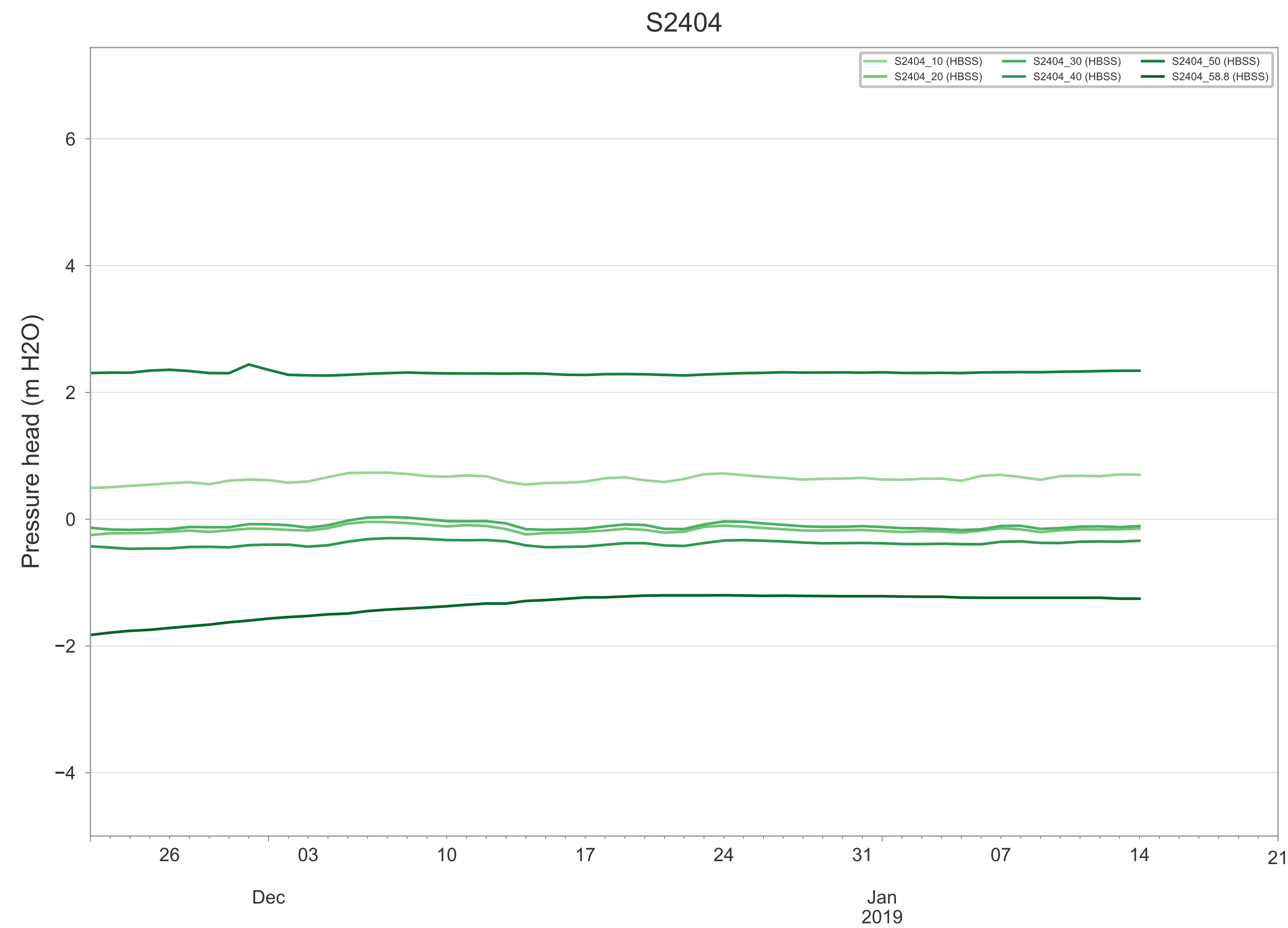
Groundwater hydrographs



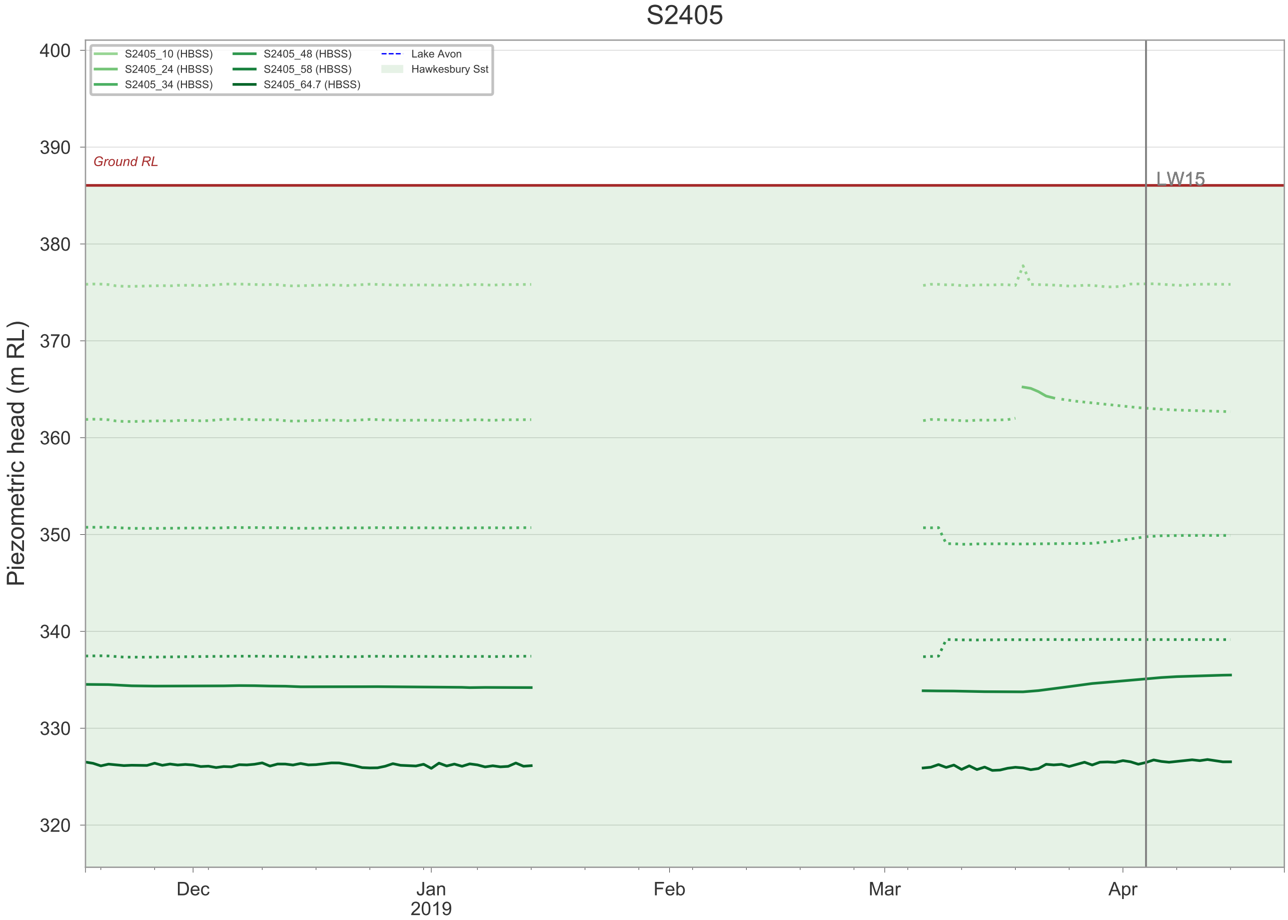

S2403
S2403_15 (HBSS)
S2403_23 (HBSS)
S2403_39.5 (HBSS)
S2403_48 (HBSS)
S2403_55 (HBSS)
S2403_59.5 (HBSS)
Lake Avon
Hawkesbury Sst
Ground RL
LW15
Piezometric head (m RL)
410
400
390
380
370
360
350
340
Dec
Jan
2019
Feb
Mar
Apr

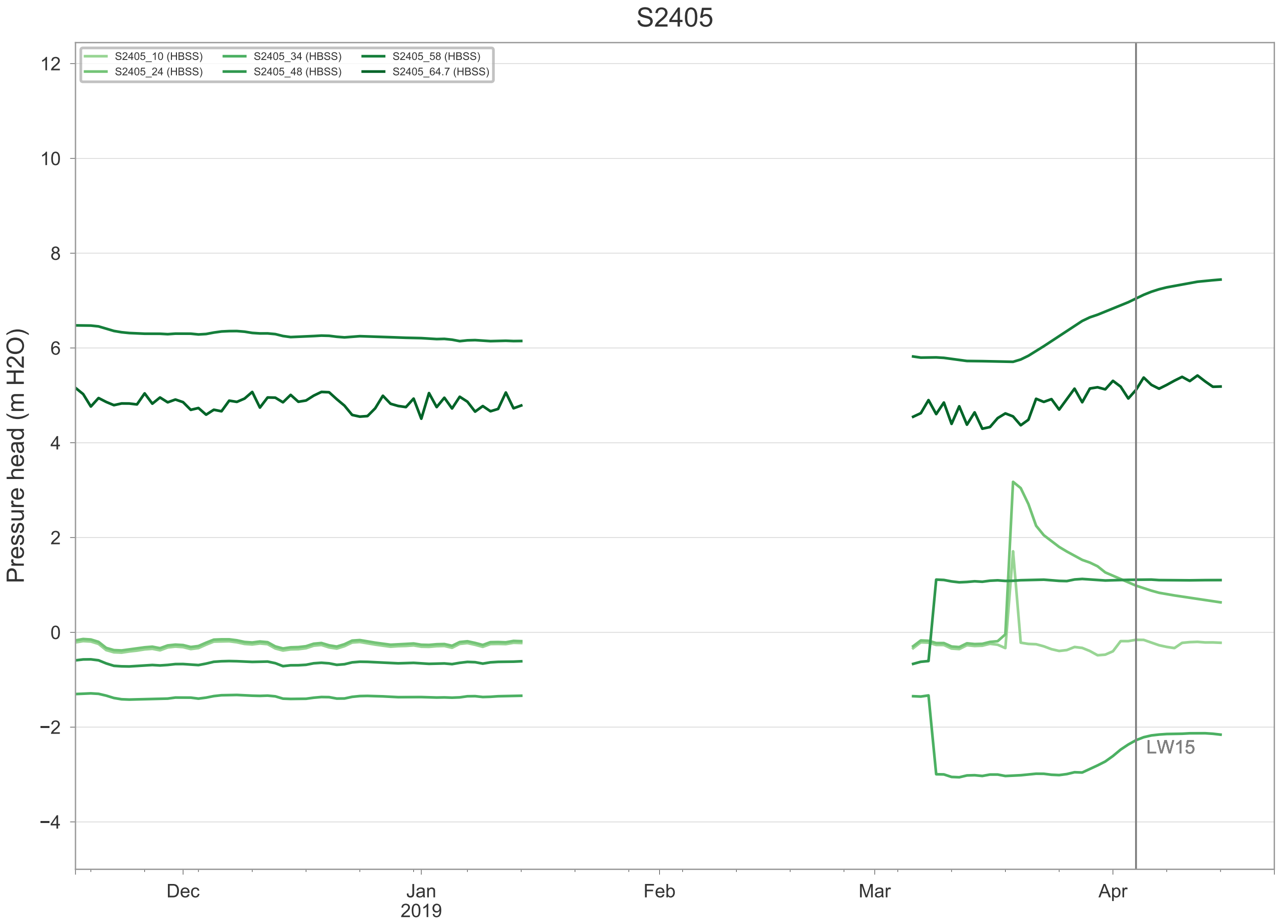

S2403
S2403_15 (HBSS)
S2403_23 (HBSS)
S2403_39.5 (HBSS)
S2403_48 (HBSS)
S2403_55 (HBSS)
S2403_59.5 (HBSS)
LW15
Pressure head (m H2O)
10
8
6
4
2
0
−2
−4
Dec
Jan
2019
Feb
Mar
Apr


S2404
Piezometric head (m RL)
410
400
390
380
370
360
350
340
330
Ground RL
S2404_10 (HBSS)
S2404_20 (HBSS)
S2404_30 (HBSS)
S2404_40 (HBSS)
S2404_50 (HBSS)
S2404_58.8 (HBSS)
Lake Avon
Hawkesbury Sst
26
03
10
17
24
31
07
14
21
Dec
Jan
2019

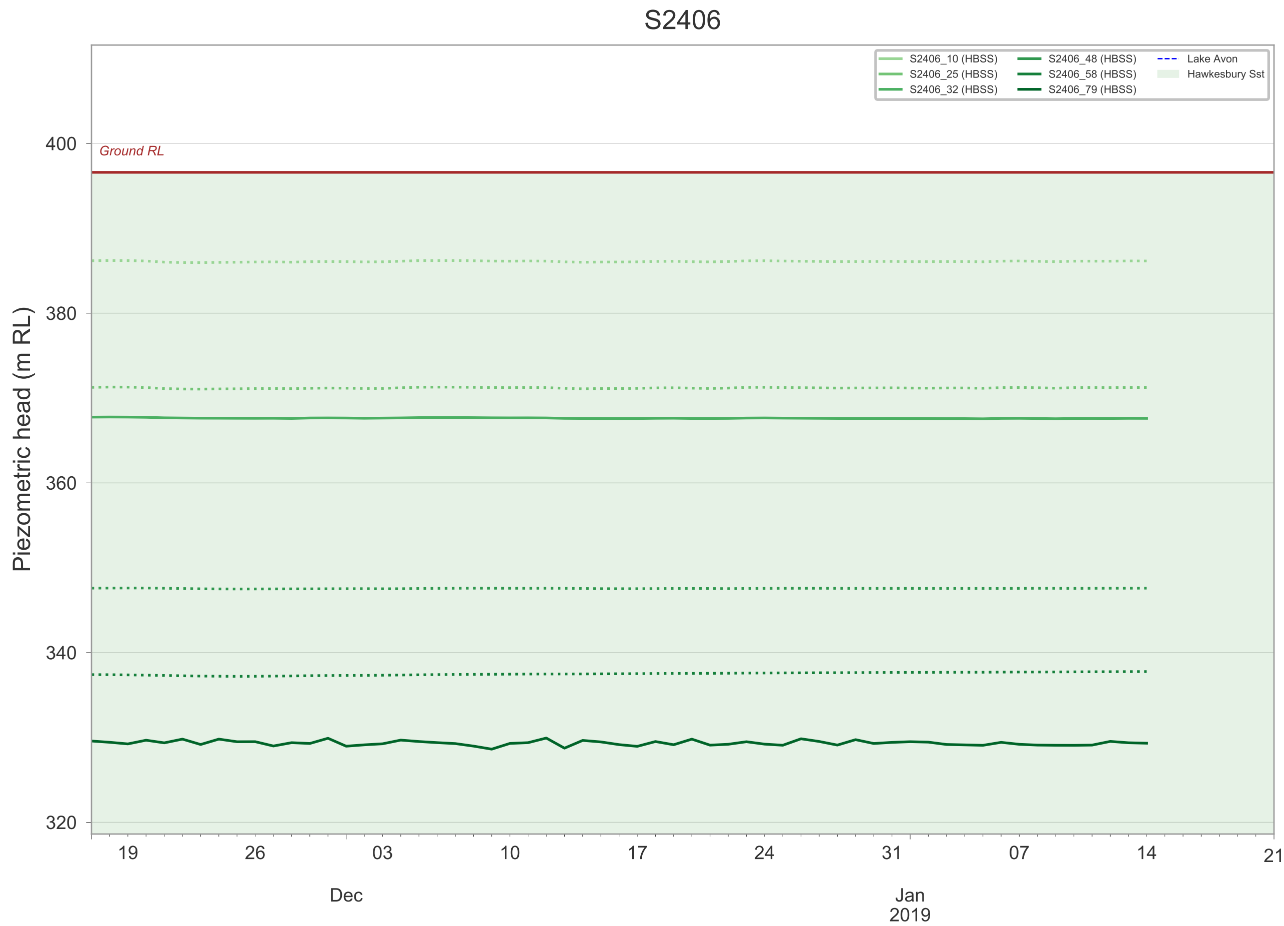

S2404
Pressure head (m H2O)
6
4
2
0
−2
−4
S2404_10 (HBSS)
S2404_20 (HBSS)
S2404_30 (HBSS)
S2404_40 (HBSS)
S2404_50 (HBSS)
S2404_58.8 (HBSS)
26
03
10
17
24
31
07
14
21
Dec
Jan
2019

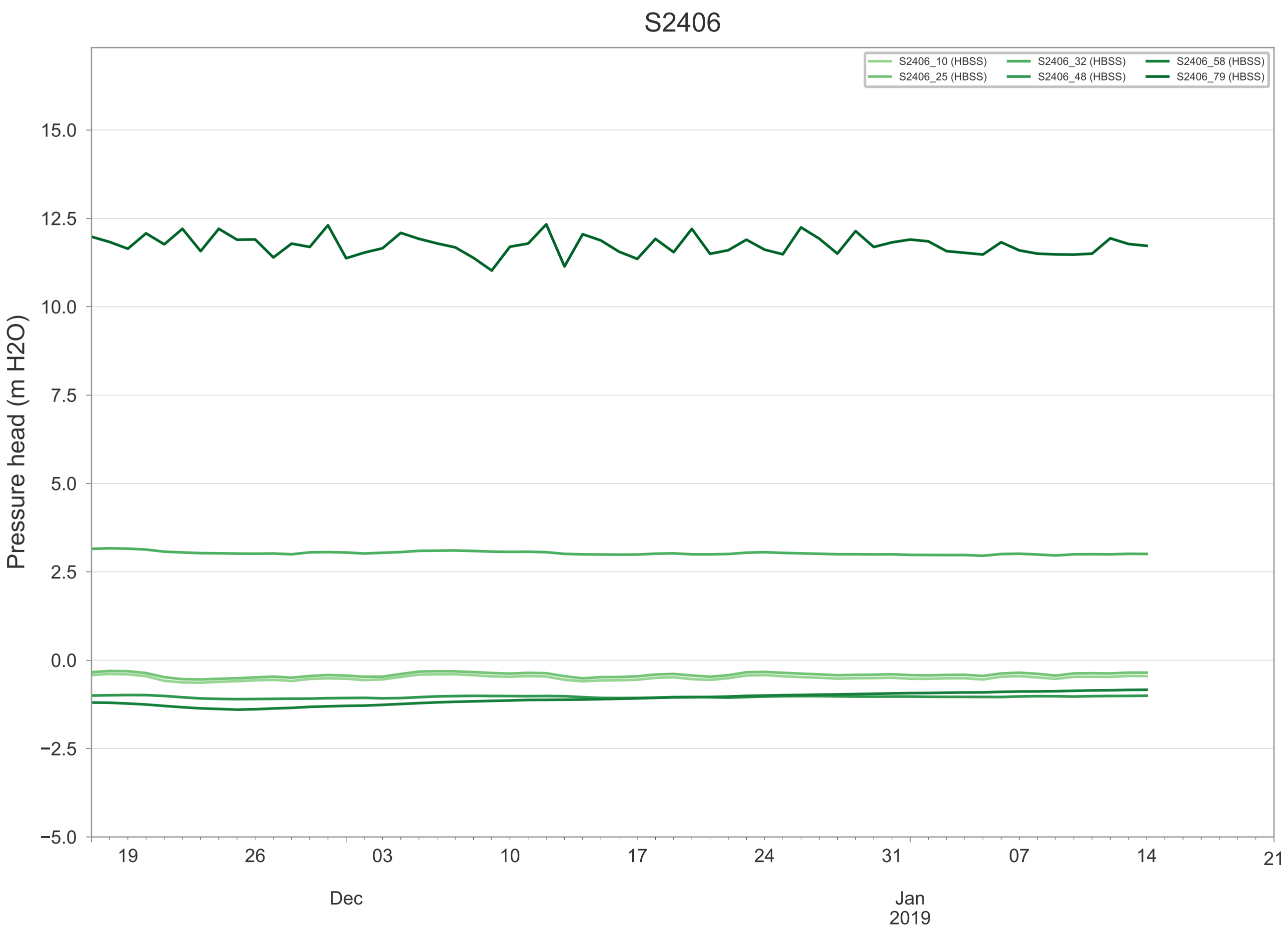
Groundwater hydrographs



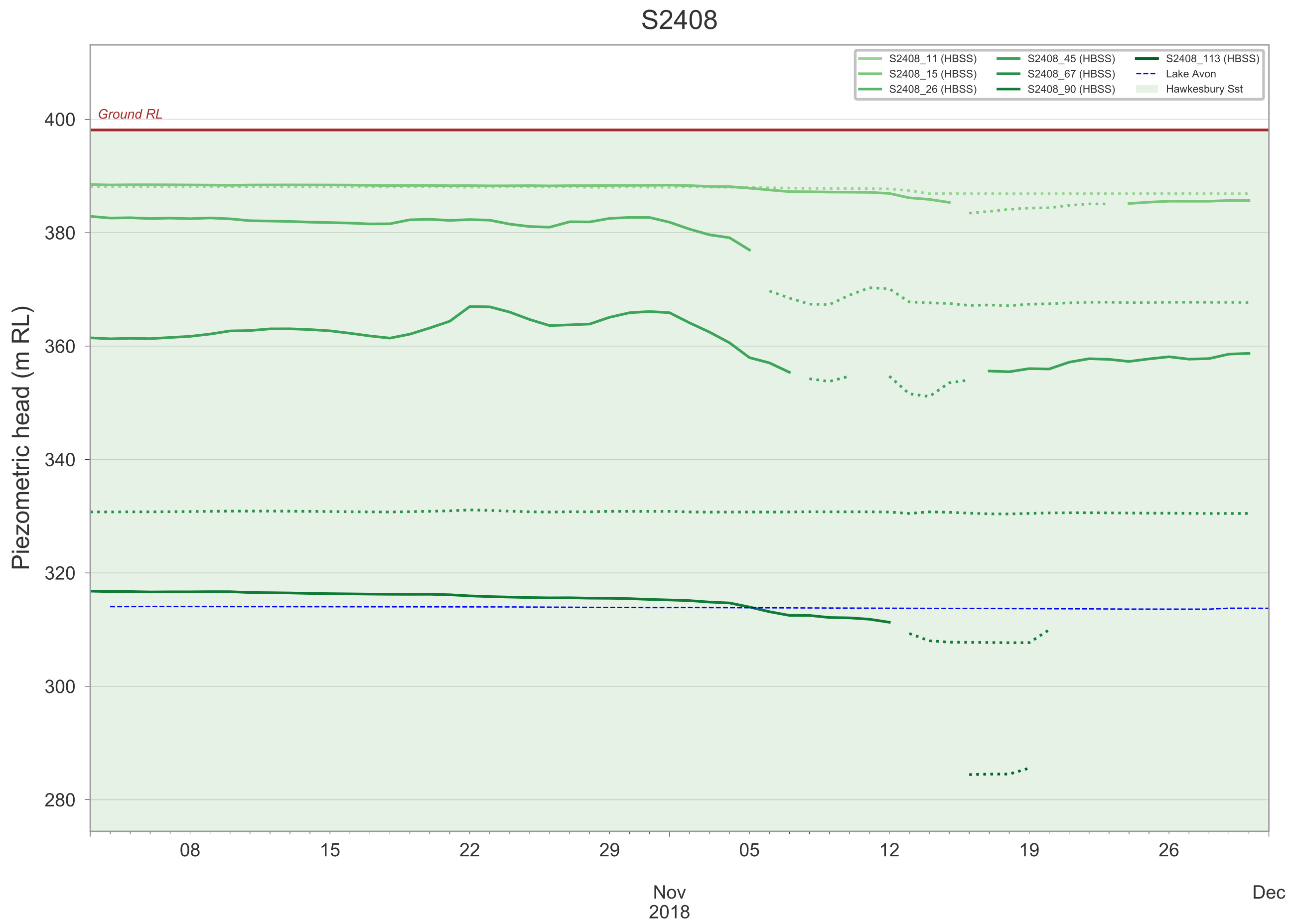


Groundwater hydrographs

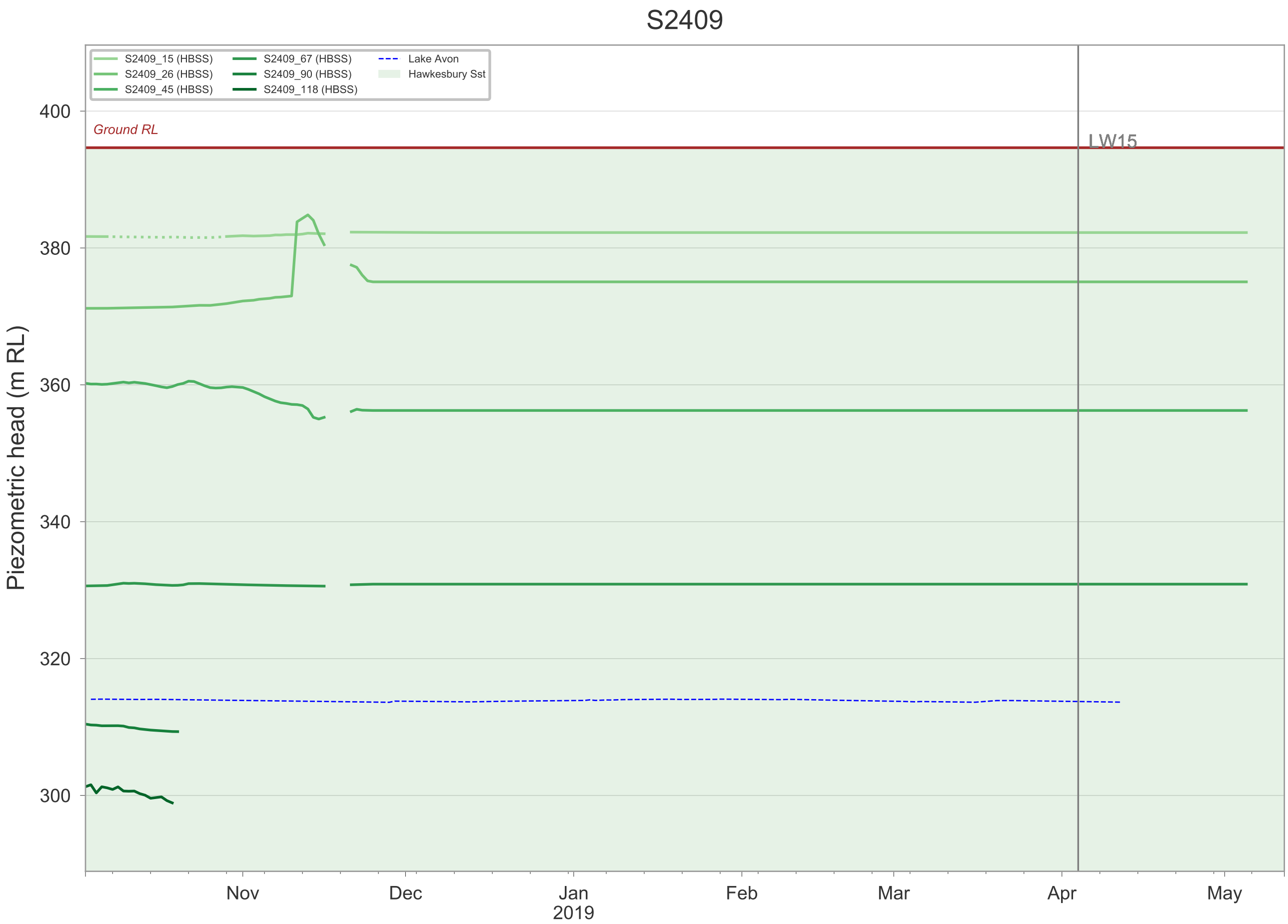




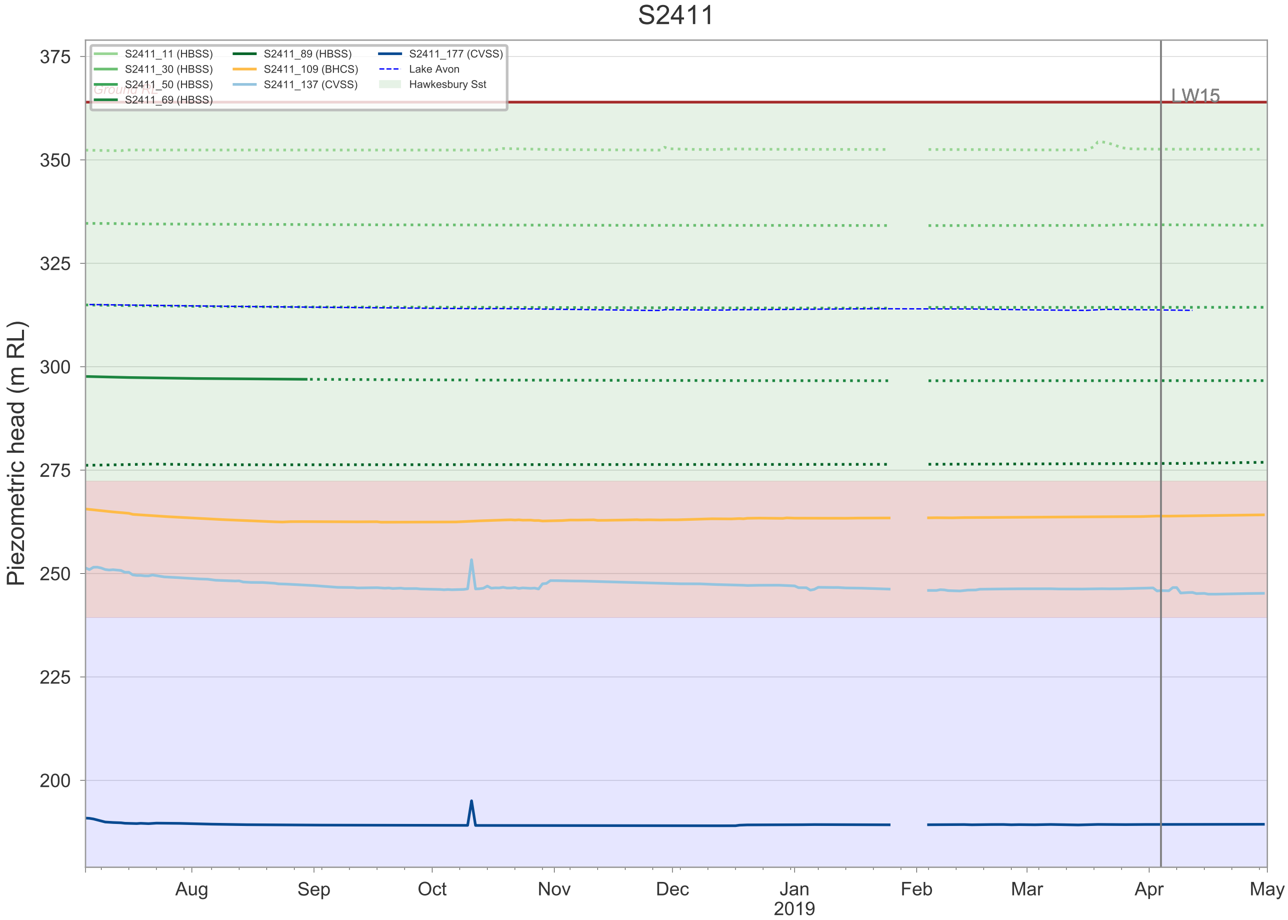
Groundwater hydrographs

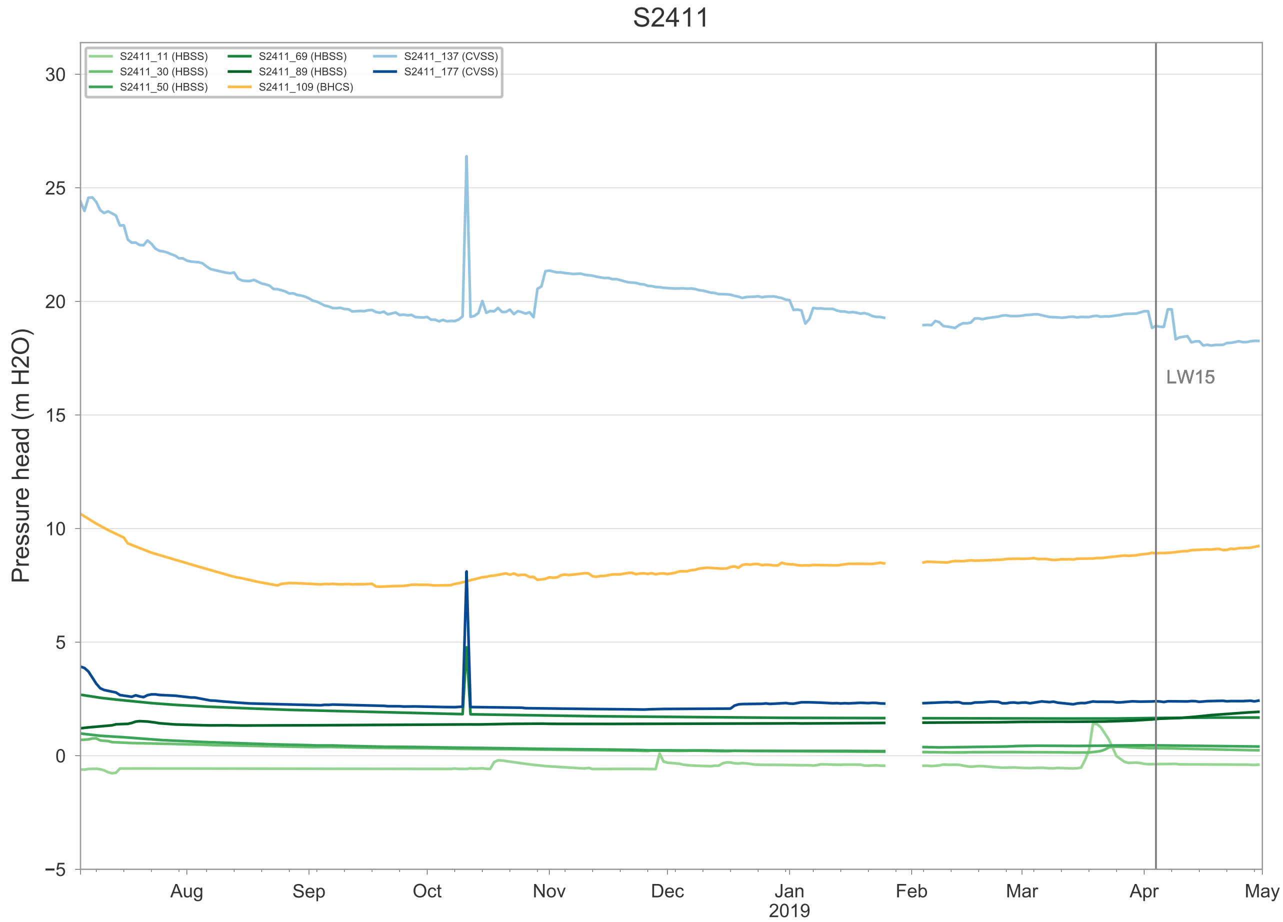


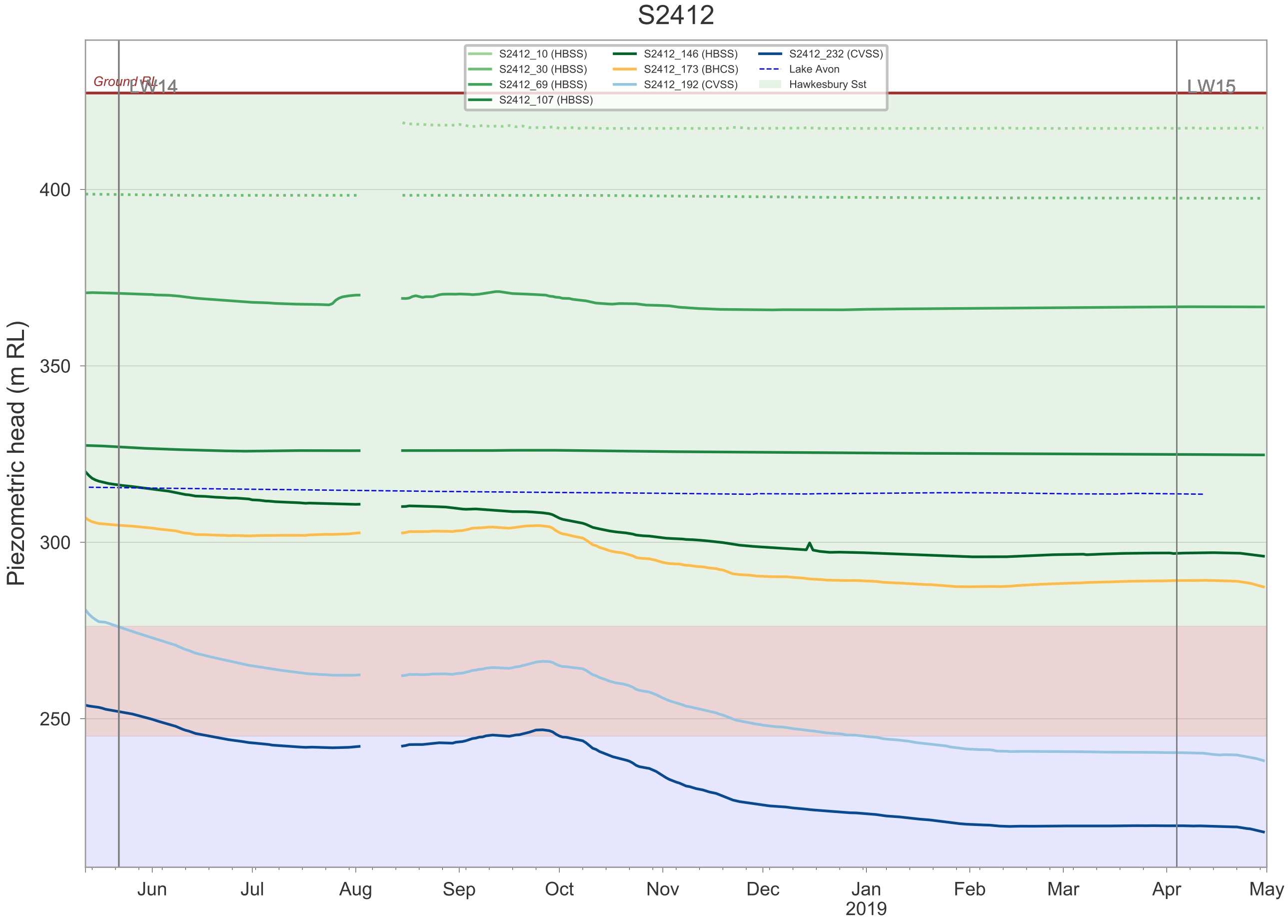
Groundwater hydrographs

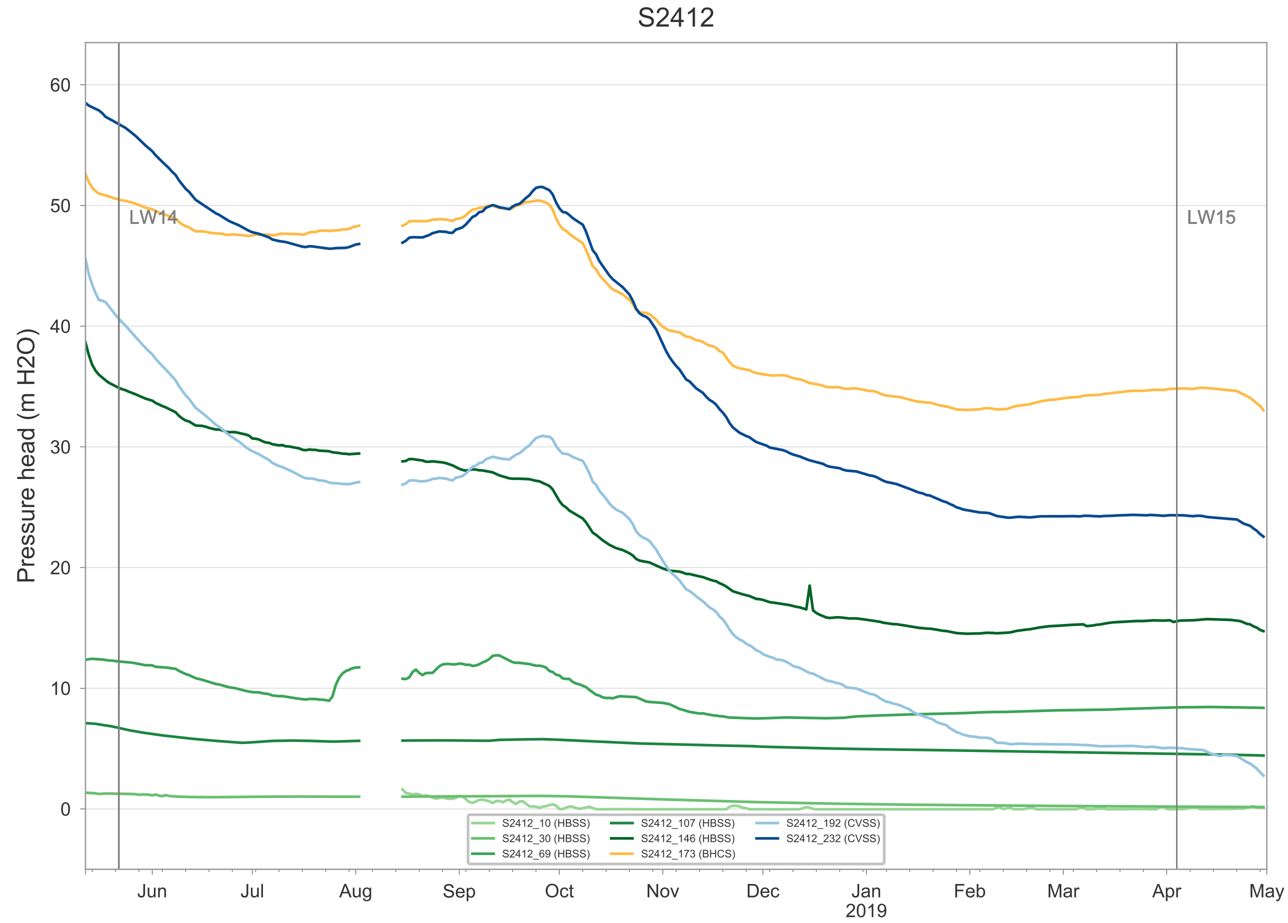


Groundwater hydrographs

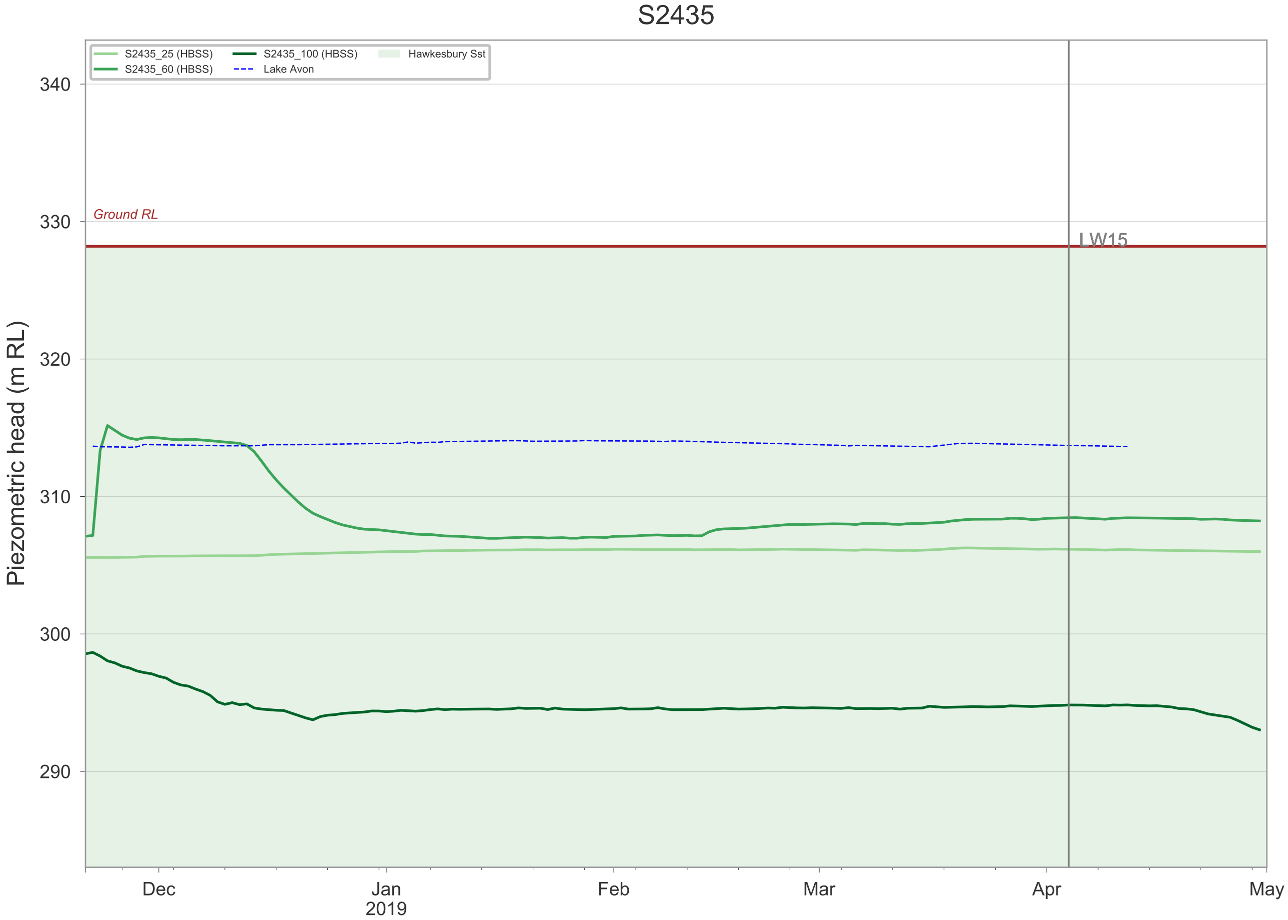





S2412
S2412_10 (HBSS)
S2412_30 (HBSS)
S2412_69 (HBSS)
S2412_107 (HBSS)
S2412_146 (HBSS)
S2412_173 (BHCS)
S2412_192 (CVSS)
S2412_232 (CVSS)
Lake Avon
Hawkesbury Sst
Ground RL
LW14
LW15
Piezometric head (m RL)
400
350
300
250
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2019
Feb
Mar
Apr
May


S2412
LW14
LW15
Pressure head (m H2O)
60
50
40
30
20
10
0
S2412_10 (HBSS)
S2412_30 (HBSS)
S2412_69 (HBSS)
S2412_107 (HBSS)
S2412_146 (HBSS)
S2412_173 (BHCS)
S2412_192 (CVSS)
S2412_232 (CVSS)
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2019
Feb
Mar
Apr
May

Groundwater hydrographs



Groundwater hydrographs