South32

Appin Mine

Area 9 Longwall 901 End of Panel surface water and groundwater monitoring review

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EXECUTIVE SUMMARY

South32 Illawarra Coal operates Appin Colliery extracting hard coking coal used for steel production. Appin Colliery is an underground mine located near the township of Douglas Park in the Southern Coalfield of New South Wales. Appin Area 9 consists of four approved longwalls (Longwalls 901 to 904), all located to the north of, and offset from, the Nepean River. Longwall 901 commenced on 19 January 2016 and was completed on 8 September 2017. At the time of reporting (January 2018), Longwall 902 had not yet commenced.

Potential impacts to watercourses and aquifers are monitored and managed through the Appin Area 9 Water Management Plan (BHPBilliton, 2014). This report presents results of the surface water and groundwater monitoring program following the end of Longwall 901 (End of Panel Report), including an assessment of data against performance criteria in the Trigger Action Response Plan (TARP).

Groundwater assessment

Groundwater levels are monitored at seven bores within and surrounding Area 9 as part of a much wider groundwater monitoring network covering the Appin, West Cliff and Dendrobium mining areas. A decline in groundwater levels occurred in the Hawkesbury Sandstone at two monitoring bores (S2281 and S1941), located 190 m and 980 m from Longwall 901 respectively. The observed groundwater level reductions are within the predicted range. No significant change in groundwater chemistry is noted for the reporting period.

Impacts to two private properties were recorded during the extraction of Longwall 901. Water Management Plans have been implemented in response to these impacts.

Groundwater inflow to the mine is calculated from the daily mine water balance. The 20-day moving average mine inflow fluctuated between ~1.0 and 0.2 ML/day following the extraction of Longwall 901, well below the TARP Level 1 trigger of 2.7 ML/day.

Surface water assessment

WaterNSW discontinued monitoring of Nepean River gauging sites at Maldon, Menangle and Broughtons Pass weirs after the completion of the WMP in 2014, and therefore the monitoring approach recommended in the WMP could not be applied. Monthly monitoring by South32 indicates a decline in pool water levels at site NR0 (upstream TARP site) relative to the baseline period. However due to the limited water level data, the cause of the decline is uncertain. Additional monitoring of this site and upstream sites is recommended.

The Longwall 901 reporting period was characterised by widely variable water quality in the Nepean River. Increases in water salinity (EC) outside the baseline range are associated with periods of low rainfall. This has resulted in the trigger of TARP criteria. However, deviations from the baseline mean (and TARP triggers) are noted in upstream locations (NR0 and NR110) and therefore the variations observed at the TARP sites are not attributed to mining activities.

Twenty-five gas release zones were identified in the Nepean River during the monitoring period. All 25 occurrences had estimated emission rates of <3000 L/min and triggered a TARP Level 1 response under the Water Management Plan.

1. INTRODUCTION

South32 Illawarra Coal operates the Appin Colliery, extracting hard coking coal used for steel production. Appin Colliery is an underground mine located near the township of Douglas Park in the Southern Coalfield of New South Wales (Figure 1).

Appin Area 9 consists of four approved longwalls (Longwalls 901 to 904), all located to the north of, and offset from, the Nepean River (Figure 2). Longwall 901 commenced on 19 January 2016 and was completed on 8 September 2017. Longwall 901 has a width of 305m, a length of 2028 m and a cutting height of between 2.7 and 2.9 m (full seam extraction). At the time of reporting (January 2018), Longwall 902 had not yet commenced.

Potential impacts to watercourses and aquifers are monitored and managed through the Appin Area 9 Water Management Plan (BHPBilliton, 2014), developed in accordance with the Bulli Seam Operations (BSO) Approval Condition 5 (h), Schedule 3. This report presents results of the surface water and groundwater monitoring program following the end of Longwall901 (End of Panel Report), including an assessment of data against management criteria defined in the WMP.

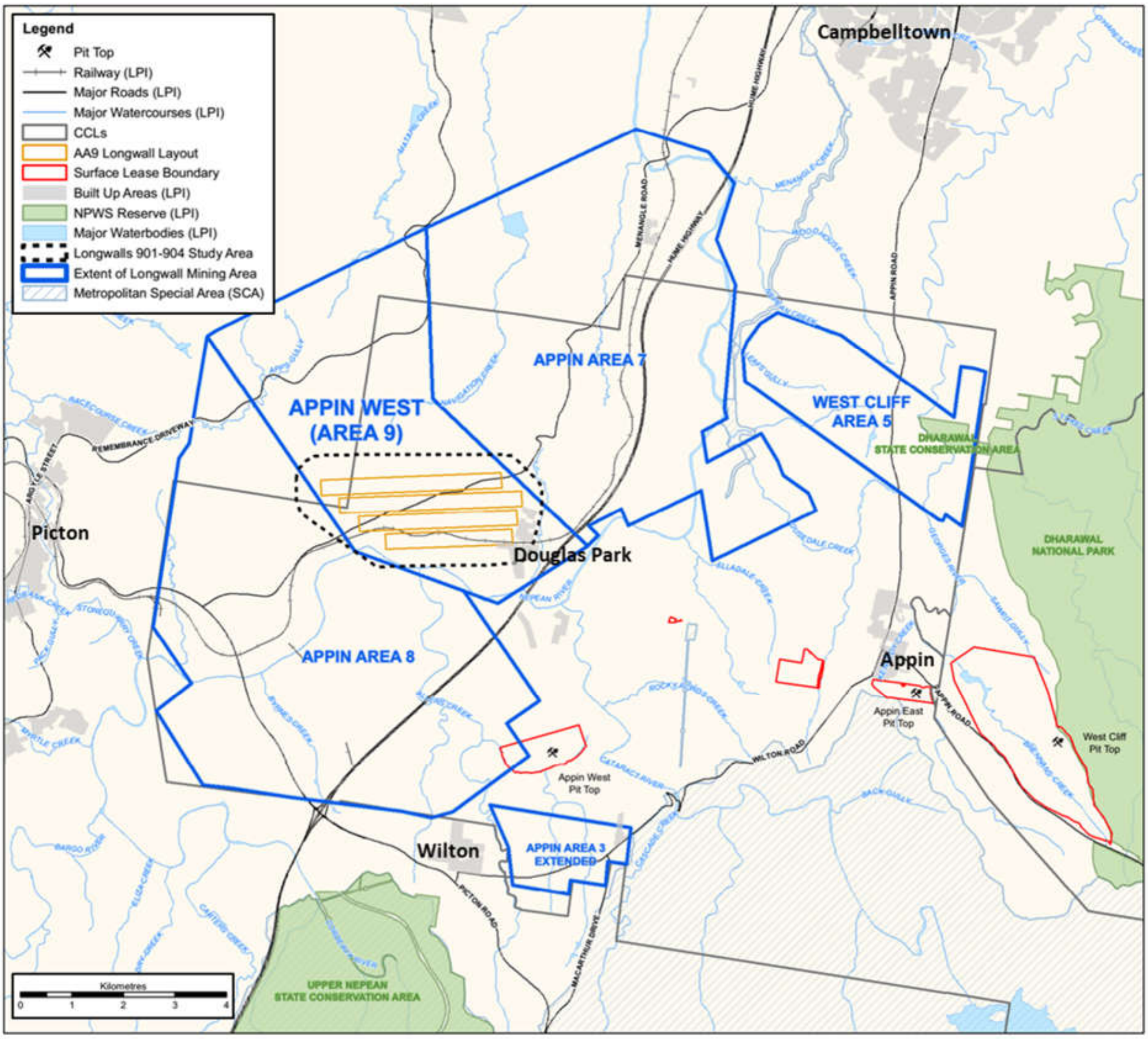
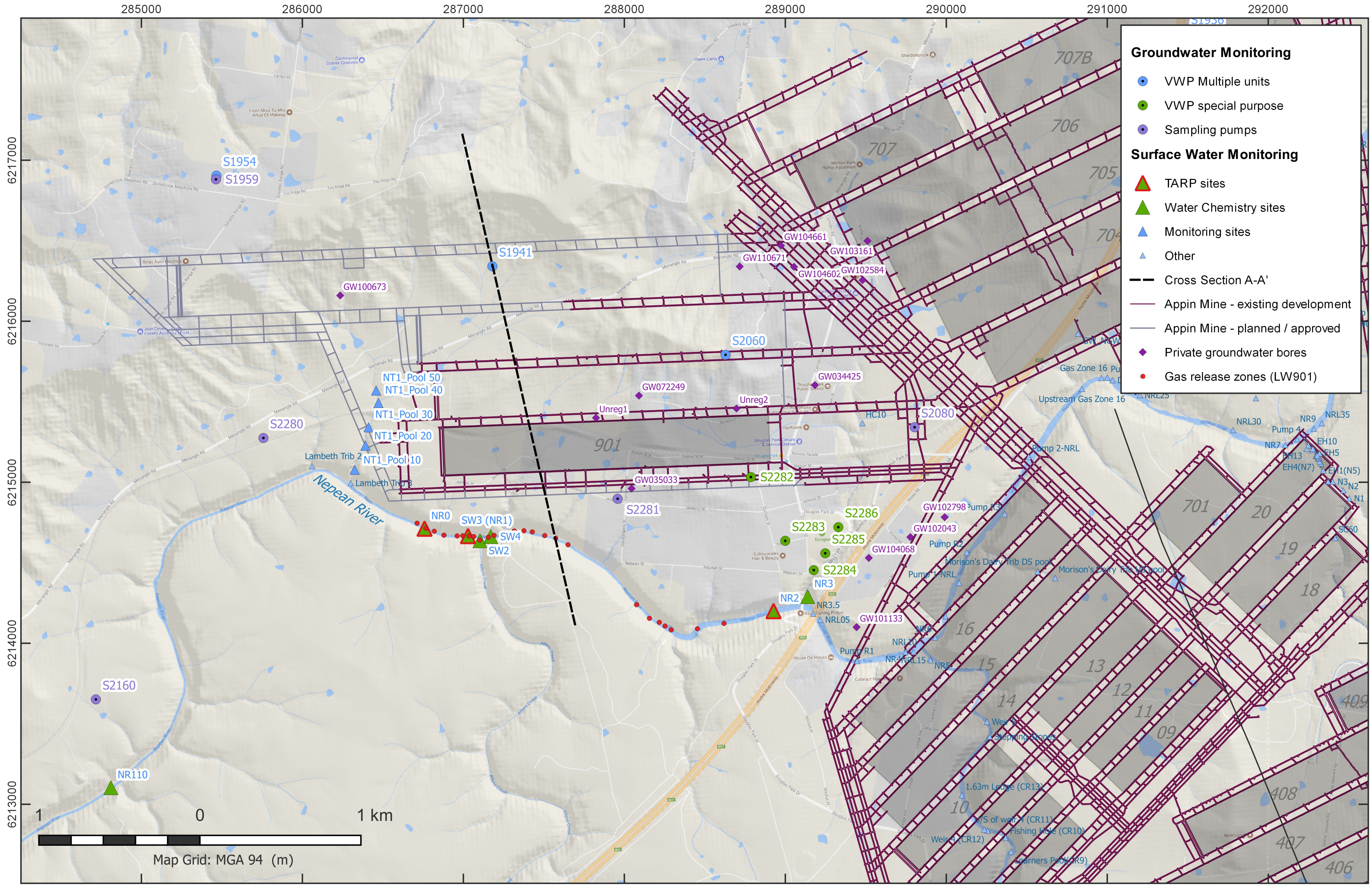


Figure 1. Location of Appin Colliery Area 9



Appin Longwall 901 EOP Surface water and groundwater monitoring

Monitoring site locations

Figure 2

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1.1 Hydrogeology

Appin Colliery is located within the Southern Coalfield which is one of the five major coalfields that lie within the Sydney Geological Basin. The Basin is a Permo-Triassic sedimentary rock sequence, underlain by undifferentiated sediments of Carboniferous and Devonian age (Figure 3). 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, the Hawkesbury Sandstone and the Wianamatta Group. The Hawkesbury Sandstone is the dominant outcropping formation adjacent to, and underlying, the Nepean River Gorge. Wianamatta Group shales and claystone-dominated units underlie elevated areas including the Razorback Range. The geology and hydrogeology of the area is illustrated in a north-south cross section in Figure 4.

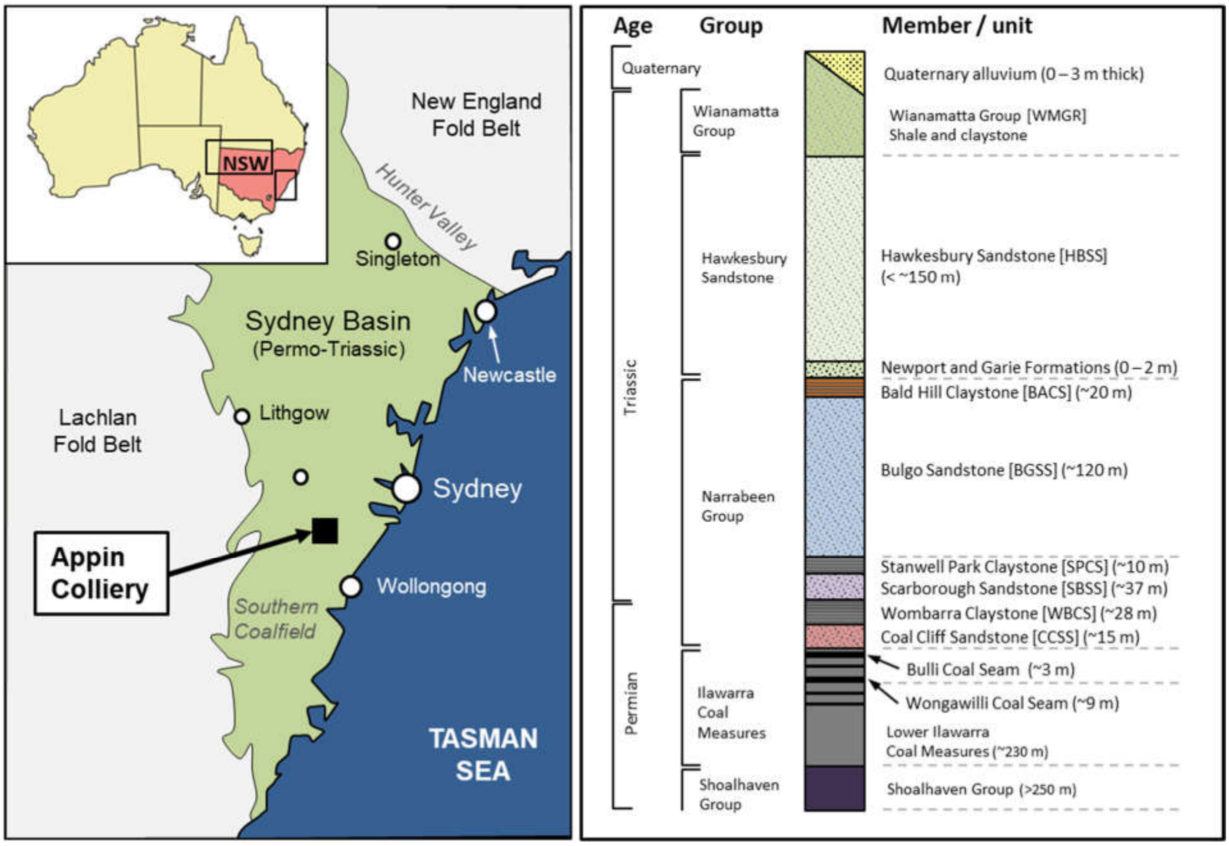

Figure 3. Stratigraphy of the Southern Sydney Basin

Three main groundwater systems are recognised:

1. Perched groundwater systems associated with fractures and bedding planes within the shallow sandstone and shale units of the Wianamatta Group and Hawkesbury 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. The highest yielding groundwater bores are typically associated with coarse sandstone units and/or fractured sandstone; and
3. Deeper groundwater systems within the Narrabeen Group and the Illawarra Coal Measures. These units typically are of much lower permeability than the Hawkesbury Sandstone and produce low bore yields and poorer water quality.

The private groundwater supply bores in the vicinity of Area 9 are between 70 m to 240 m deep, with water obtained primarily from water-bearing horizons within the Hawkesbury Sandstone, and minor perched horizons within the Wianamatta Group shale (e.g. GW104602 at 29.9 m; GeoTerra, 2011). Groundwater in the NoW registered bores, where reported, is generally fresh to brackish with salinity (total dissolved solids; TDS) between 260mg/l and 2500mg/L. The majority of aquifer intersections over the Longwalls 901 to 904 Study Area lie at or below the elevation of the Nepean River.

The Nepean River is a ‘gaining’ system, where groundwater flows from the plateau under a regional hydraulic gradient to the river. These flows are predominantly horizontal, and determined by a confined flow along discrete layers underlain by fine grained or relatively impermeable strata within the Hawkesbury Sandstone. Vibrating wire piezometers at monitoring bore S1941 show that groundwater pressures (potentiometric levels) are higher in the Narrabeen Group than in the Hawkesbury Sandstone and may be sub-artesian to artesian in some areas (the potentiometric level is near or above the ground surface). The lower groundwater pressures within the Hawkesbury Sandstone may be due to pumping from bores as well as discharges to the Nepean River gorge. These observations suggest that the Bald Hill Claystone is an effective confining unit in this area.

Recharge of the groundwater system occurs after rainfall infiltrates into the plateau soil, as well as the underlying Wianamatta Shale and/or Hawkesbury Sandstone. The majority of infiltrating water discharges from temporary seeps in the cliffs of the Nepean River gorge (“interflow”). The low permeability of the Bald Hill Claystone acts as an aquitard between the Hawkesbury Sandstone and the Bulgo Sandstone. It has been observed to maintain its low permeability after subsidence and inhibit the movement of water and gas.

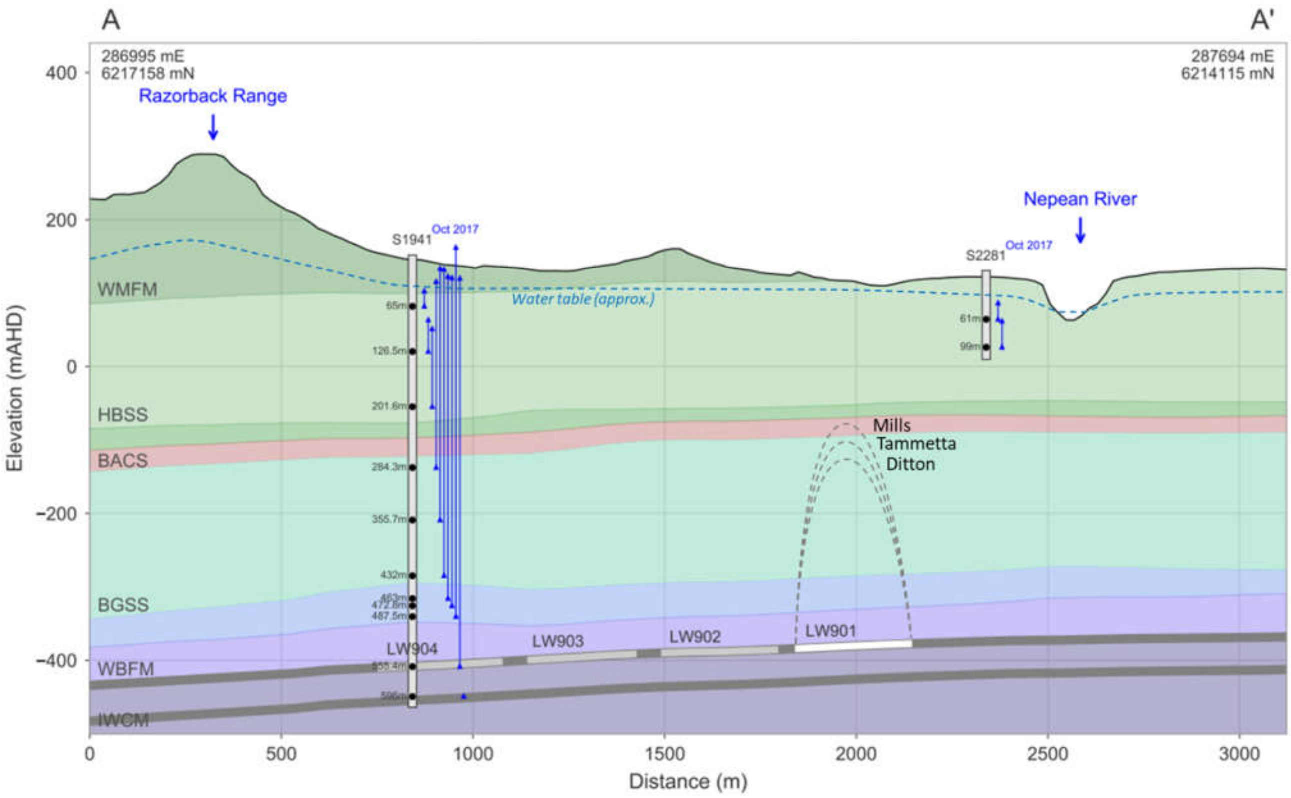

Figure 4. Hydrogeological cross section (N-S) through Appin Area 9

1.2 Surface water hydrology

Drainage lines within Area 9 predominantly flow south to the Nepean River, which itself flows in an easterly direction. MSEC (2012) subdivided the Nepean River into two sections based on streambed morphology:

- Section 1 (upstream of Allens Creek) where flow is controlled by boulder fields, two rockbars and a small weir.
- Section 2 (downstream of Allens Creek) where the river is a flooded valley controlled by the Douglas Park Causeway.

Water flows in the Nepean River are derived from a number of sources, which include flows from catchment areas, licensed discharges (including Appin Colliery and Tahmoor Colliery) and runoff from agricultural and urban areas. Within the Study Area, river flow is predominantly controlled by the Maldon Weir (upstream) and the Douglas Park Weir (downstream). Water levels down river of the Study Area (i.e. down river of Douglas Park Causeway), are regulated by the Menangle Weir.

Water flows in the Nepean River:

- Vary greatly and are highly responsive to rain events due to the significant areas of catchment.
- Reach very high levels during sustained storm events, while minimum flow is rarely less than 1.5 ML/day (approx. 5 percentile flow).
- Cease on a small number of occasions, usually only when the rate of pumping out of the River exceeds the rate of inflow under low flow/drought conditions.

Median flow in the river section adjacent to the proposed longwalls is likely to be ~15% more than the median flow rate at Maldon Weir, which is 16.5 ML/day, and a little less than the median flow rate at Menangle Weir, which is 34.7 ML/day. Therefore median (50 percentile) flow rate adjacent to Longwall 901 is about 30 ML/day.

Baseline surface water monitoring for AA9 has been ongoing since October 2008 and provides a comprehensive baseline data set prior to extraction of Longwalls 901 to 904.

Tributaries to the Nepean River within the Longwalls 901 to 904 Study Area include:

- Nepean River Tributary 1 located directly above the proposed Longwalls 902 to 904
- Harris Creek located east of the proposed longwalls and 400 m from Longwall 903 at its closest point. It is located just outside the Study Area, although Harris Creek has experienced valley related movements.

First and second order channels also flow to the Nepean River, and form smaller gullies along the cliffs of the gorge which generally discharge via elevated streams cascading down cliffs after sufficient rain. The majority of rainfall in the smaller catchments would infiltrate into these plateau soils and enter the groundwater system.

There are no areas considered flood prone and there are no upland swamps in the Study Area. A number of earth farm dams are located in the streams and are used as water sources on rural properties. All major streams have dams within their channels and catchment areas.

1.3 Potential mining effects

Extraction of coal using longwall methods commonly results in ground subsidence, deformation and fracturing of overlying strata and depressurisation of adjacent geological units (Peng and Chiang, 1984). The distribution of fracturing and its effects on aquifer characteristics has been well documented from numerous case studies (Booth, 1986; Forster and Enever, 1992; Guo et al., 2007; Mills, 2011; Tammetta, 2016; Tammetta, 2014; Tammetta, 2013).

While authors differ slightly in their terminology, there is general agreement on the overall sequence and pattern of fracturing that develops above a longwall. Immediately above a mined coal seam, the roof collapses into the void to form a caved zone that extends tens of metres above the seam. As the mining proceeds, a network of connected fractures extends above the caved zone to a height above the seam that is largely dictated by the width and mining height of the panel relative to the depth of cover (Mills, 2011; Ditton and Merrick, 2014; Tammetta, 2013). The development of fractures above (and below) the mined seam results in changes to aquifer properties; specifically, the permeability of the rock mass increases and groundwater pathways are potentially created between shallow and deeper groundwater systems. Subsidence and associated phenomena such as valley closure commonly result in increased surface cracking due to the unconfined nature of the surface rock. This type of surface cracking is typically limited to the top 10 to 20 m and may not be connected to the deeper fracture zones. Nevertheless, surface fracturing can affect shallow and perched groundwater systems and stream flow characteristics.

Calculations based on published geotechnical models indicate that the zone of connected fracturing above longwalls in Area 9 is unlikely to extend above the base of the Bald Hill Claystone (Figure 4). A recent review commissioned by the Department of Planning and the Environment (DPE) of published methods for estimating the height of fracturing (PSM, 2017) concluded that the empirical approaches of Ditton and Merrick (2014) and Tammetta (2013) may not be accurate for all mining settings and such estimates should be considered indicative only. However, the observation of low water make at Appin Area 9 and strata gas movements is consistent with the extent of connective fracturing being limited to below the Bald Hill Claystone.

1.3.1 Ground subsidence

Ground subsidence and potential effects on surface infrastructure was assessed by MSEC (2012), prior to the commencement of mining at Area 9. An End of Panel subsidence assessment was carried out by MSEC (2018), including results of ground and aerial laser scan surveys. Contours of predicted subsidence after Longwall 901 are reproduced in Figure 5 and measured changes in ground level are reproduced in Figure 6. Approximately 20 mm or less subsidence was expected at the Nepean River in response to Longwall 901.

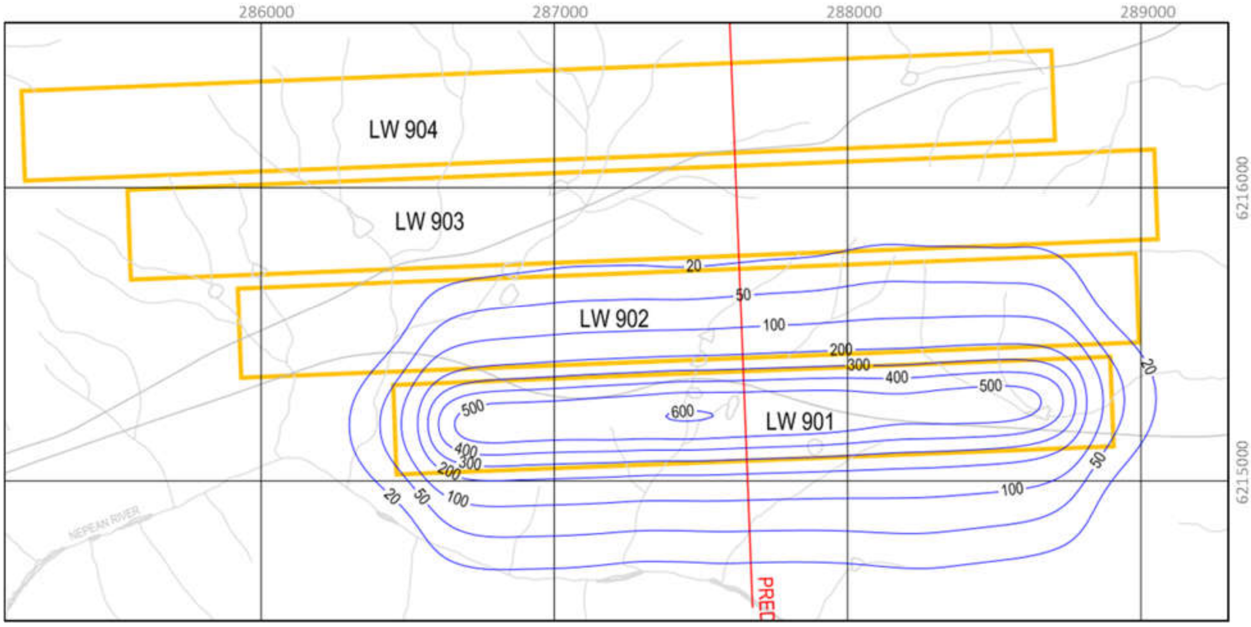

Figure 5. Contours of predicted subsidence due to Longwall 901 (in mm; MSEC 2012)

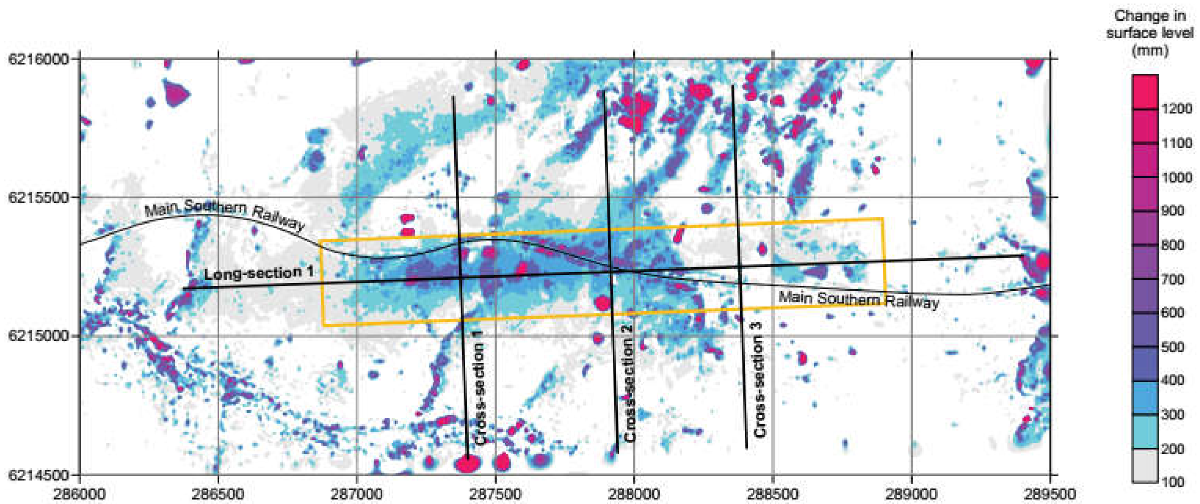

Figure 6. Measured changes in surface level due to Longwall 901 (MSEC 2018 Fig. 2.21)

1.3.2 Surface water and groundwater effects

Ecoengineers (2012) and GeoTerra (2011) identified a number of possible water related environmental consequences that may occur due to the extraction of Longwalls 901 to 904. Those consequences are summarised in **Error! Reference source not found.**.

Table 1. Summary of potential water-related mining impacts

Consequence	Description	Impact / Likelihood
Gas emissions in the Nepean River and other areas	Based on observations at Appin Area 7 it is likely that “minor” gas emissions will appear in the Nepean River as a consequence of mining Longwalls 901 to 904. Potential effects may include Dissolved Oxygen “sags”, and visible iron precipitates (localised iron staining).	Impact: Negligible Likelihood: Likely (Ecoengineers, 2012)

Consequence	Description	Impact / Likelihood
Groundwater outflows and ferruginous springs	The appearance of ferruginous springs due to mining has been noted in some Bulli Seam mining areas especially along margins of outcropping Wianamatta Shale. Ferruginous springs have not been detected in relation to mining of Longwalls 701 and 702, either in the walls of the Nepean River gorge or along adjacent tributaries.	Impact: Negligible Likelihood: Low (Ecoengineers, 2012)
Sub-bed flow diversions and un-natural pool drainage	Section 1 of the Nepean River is characterised by boulder fields, which are less susceptible to fracturing than rockbars. Two rockbars have been identified in the Study Area: Rockbar NR-A9-RB01 is located 370 m from the nearest longwall. Rockbar NR-A9RB02 is submerged at times of high flow, and therefore does not restrict the surface water at these times.	Impact: Negligible Likelihood: Low (Ecoengineers, 2012) Nepean River Tributary 1: Likely impact
Impacts to streams and farm dams	Many farm dams have been mined under and monitored, with only a small number of dams exhibiting impacts (becoming dry) following mining. It is predicted that the impact on farm dams from mining Longwalls 901 to 904 will be similar.	Impact: Minor Likelihood: Likely (Ecoengineers, 2012)
Reduced groundwater yield	Six NoW registered bores within or near the proposed Longwalls 901 to 904 may be affected by subsidence, where the bores predominantly obtain water from the Hawkesbury Sandstone, rather than the overlying Wianamatta Group shale and sandstones. Groundwater levels in the Hawkesbury Sandstone are predicted to reduce by up to 10 m (WMP, p.14)	Impact: Negligible Likelihood: Likely (GeoTerra, 2011)
Groundwater quality impacts	It is likely that some [minor and localised] water quality changes will occur but there is a relatively low level of groundwater resource use in the area. Monitoring of potentially affected bores within AA9 is conducted in consultation with the owners.	Impact: Negligible Likelihood: Likely (GeoTerra, 2011)
Gas emissions	There is potential for strata gas emissions into private bores. Any such emissions are likely to diminish over time. Any bores with gas releases are decommissioned during the mining period.	Impact: Negligible Likelihood: Likely (GeoTerra, 2011)

1.4 Water management framework

Groundwater monitoring and reporting is carried out according to the Appin Area 9 Water Management Plan (BHPBilliton, 2014). The objectives of the WMP are to identify at risk surface water and groundwater features and characteristics within the Longwalls 901 to 904 Study Area and to manage the potential impacts and/or environmental consequences of the proposed workings on watercourses and aquifers, with specific focus on the Nepean River and its tributaries.

1.4.1 Trigger Action Response Plan (TARP)

Effects of mining on surface water and groundwater are managed through ongoing monitoring and regular reporting against agreed performance measures. The Water Management Plan (BHPBilliton, 2014) includes a Trigger Action Response Plan (TARP) which outlines specific performance measures and management actions to be taken in the event of a trigger event. The water related performance levels are listed in Table 2. Water chemistry TARP trigger levels calculated from baseline data (prior to the start of mining on 19/1/2016) are presented in Table 3.

Table 2. TARP Performance Criteria for Appin Area 9

Type / Location	Parameter	Level 1	Level 2	Level 3
Surface water quality				
Nepean River: ▪ NR0 ▪ SW3 (NR1) ▪ NR2 If and where gas plumes above 3000 L/min are detected ** Compared with baseline monitoring prior to mining*	pH	Reduction* > 1SD < 2SD for two consecutive months	Reduction > 2SD for two consecutive months	As for level 2, for 6 consecutive months
	DO	Reduction > 1SD < 2SD for two consecutive months	Reduction > 2SD for two consecutive months	
	EC, Total Fe, Total Mn	N/A	Increase > 2SD for 2 consecutive months	
	Gas plumes	Plume <3000 L/min	Plume >3000 L/min	
	Cloudiness, iron staining	More than negligible		
Groundwater inflow to the mine	Inflow from the goaf (Over 20-day average)	Increase of between 2.7 and 3.0 ML/day	Increase of between 3.0 and 3.4 ML/day	Abnormal increase greater than 3.4 ML/day
Groundwater levels				
Private bores South32 Piezometers: ▪ S1913 (EAW5) ▪ S1936 (EAW7) ▪ S1941 (EAW9) ▪ S1954 (EAW18) ▪ S2080 (EAW58) ▪ S2280 (Harris Ck 6) ▪ S2281 (Harris Ck 7)	Reduction below predicted standing water level or pressure head in the Hawkesbury Sandstone.	5.0 to 7.5 m over a minimum two-month period.	7.5 to 10.0 m over a minimum two-month period.	>10 m over a minimum two-month period.

In relation to surface water flows, BSO Approval Condition 1, Schedule 3 stipulates that there should be *negligible diversion of flows or changes in the natural drainage behaviour of pools* in the Nepean River. In relation to other watercourses, there should be *no greater subsidence impact or environmental consequences than predicted in the Environmental Assessment and PPR.* The term “negligible” is defined within the Project Approval as “small and unimportant, such as not to be worth considering”.

Table 3. Baseline water chemistry TARP trigger levels

Parameter		NR0	SW3 (NR1)	NR2
Baseline samples (n):		39	39	111
pH	**Mean**	**7.90**	**7.92**	**7.75**
	Mean – -1SD	7.59	7.61	7.39
	Mean – -2SD	7.29	7.31	7.03
EC	**Mean**	**245.3**	**257.3**	**256.5**
	Mean – +1SD	332.4	349.9	348.8
	Mean – +2SD	419.4	442.5	441.0
DO	**Mean**	**93.0**	**88.9**	**86.6**
	Mean – -1SD	79.2	77.1	73.4
	Mean – -2SD	65.3	65.3	60.2
Fe (Total)	**Mean**	**0.35**	**0.32**	**0.40**
	Mean – +2SD	0.65	0.59	0.77
Mn (Total)	**Mean**	**0.025**	**0.020**	**0.028**
	Mean – +2SD	0.051	0.039	0.059

2. MONITORING NETWORK

2.1 Groundwater monitoring

Groundwater levels are monitored using multi-level vibrating wire piezometers (VWP) which are grouted into boreholes. There are seven groundwater monitoring sites relevant to Area 9 operations and specified in the TARP, shown in Figure 2, and listed in Table 4.

Table 4. Groundwater monitoring sites in Area 9

Bore ID	Alternate name	Total depth	Number of piezometers	Formations monitored	Date installed
S1913	EAW5	612.1	10	HBSS, BGSS, SBSS, BUSM	2008
S1936	EAW2	611.0	10	HBSS, BGSS, SBSS, BUSM	2008
S1941	EAW9	605.2	11	HBSS, BGSS, SBSS, BUSM	2008
S1954	EAW18	797.2	13	WMGR, HBSS, BUSM	2008
S2080	EAW58	524.2	10	HBSS, BGSS, SBSS, CCSS	2010
S2280	Harris Creek 6	110.0	2	HBSS	2014
S2281	Harris Creek 7	110.0	2	HBSS	2014

Deep groundwater responses to mining are assessed primarily through the use of time-series hydrographs for multi-level piezometer sites (VWPs). Noisy data are filtered and removed where practical. Hydrographs are presented in Appendix 1 and discussed 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 the ground elevation at the bore site and the elevation of the Nepean River adjacent to Longwall 901. 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. This condition is not always apparent from plots of total piezometric head alone. Hydrographs of pressure head are also presented in Appendix 1.

2.1.1 Mine inflow

Groundwater inflow to Area 9 is calculated from the daily mine water balance by accounting for water pumped in and out of the mine area.

2.2 Surface water monitoring

Surface water levels and chemistry are monitored at the sites shown in Figure 2 and listed in Table 5.

Table 5. Surface water monitoring sites

Site	Watercourse	MGA_mE	MGA_mN	Field Observations	Chemistry (Lab)	Flow
NR0	Nepean River	286759	6214712	Y	Y	
SW3 (NR1)	Nepean River	287029	6214666	Y	Y	
NR2	Nepean River	288927	6214200	Y	Y	
NR3	Harris Creek	289139	6214290	Y	Y	
SW2	Allens Creek	287103	6214637	Y	Y	
SW4	Nepean River	287170	6214663	Y	Y	
NR110	Nepean River	284812	6213103	Y	Y	
NT1_Pool 10	Nepean Trib. 1	286324	6215077	Y		
NT1_Pool 20	Nepean Trib. 1	286391	6215227	Y		
NT1_Pool 30	Nepean Trib. 1	286411	6215341	Y		
NT1_Pool 40	Nepean Trib. 1	286472	6215492	Y		
NT1_Pool 50	Nepean Trib. 1	286458	6215569	Y		
Maldon Weir	Nepean River	WaterNSW site				N*
Menangle Weir	Nepean River	WaterNSW site				N*
Broughtons Pass weir	Nepean River	WaterNSW site				N*

Note* WaterNSW no longer monitors flow at these locations

2.2.1 Weather observations

Rainfall and solar exposure data has been collected at Douglas Park (Bureau of meteorology site 068200) since 1974 (with some gaps). Monthly rainfall, cumulative rainfall residual and solar radiation since the start of 2013 are plotted in Figure 7. Daily temperatures range between 20 to 45 °C in January and between 10 and 27 °C in July (at Campbelltown). Evapotranspiration also varies seasonally in line with temperature and solar radiation, peaking during the summer months.

Average annual rainfall since 1974 is 751 mm (2.06 mm/day). Rain falls year-round with slightly higher monthly average rainfall in late summer months (February-March). It is common for a substantial proportion of the annual rainfall to be delivered in one or two large rainfall events, during which significant surface water runoff and groundwater recharge is generated. This was the case during the reporting period with heavy rainfall events in June 2016 and March 2017.

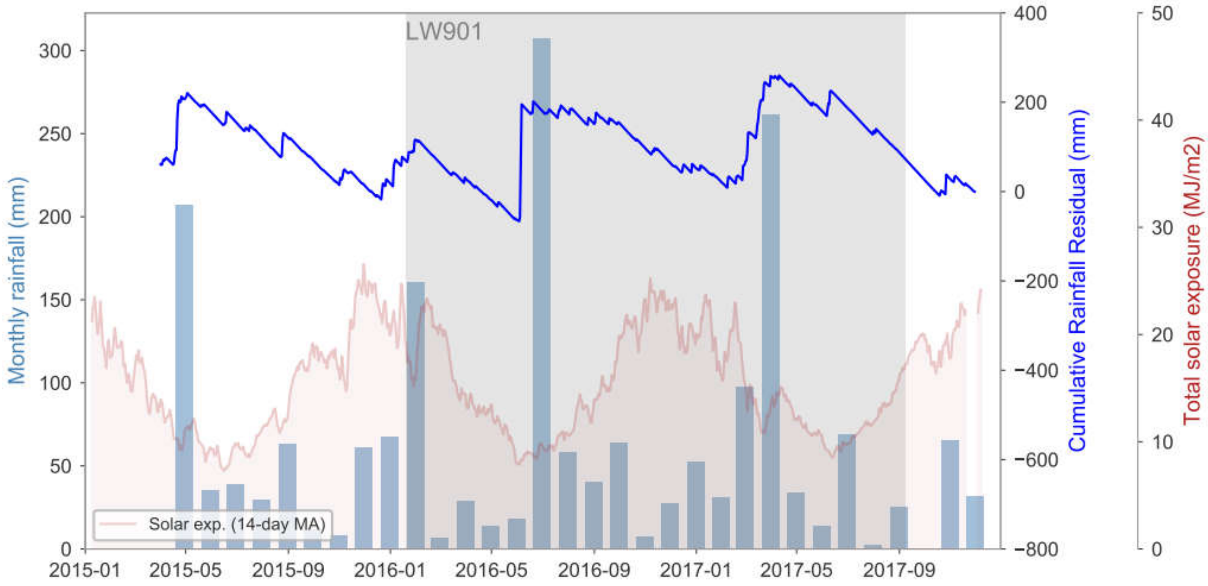

Figure 7. Rainfall and solar exposure at Douglas Park

3. GROUNDWATER ASSESSMENT

3.1 Groundwater levels

Groundwater bore hydrographs are presented in Appendix 1. Observations in relation to temporal trends in groundwater pressures are listed in Table 6.

Table 6. Groundwater level observations

Bore	Observations	TARP Level
S1913 (EAW5)	S1913 is located 3.2 km north of Longwall 901. It has three sensors in the Hawkesbury Sandstone at 65 m, 137 m and 194 m depth. Groundwater pressures in the upper tow Hawkesbury sandstone sensors have remained relatively stable or increased slightly during LW901 compared with the previous 2 years. The 194 m sensor shows a slight declining trend during LW901 which is unlikely to be associated with mining (due to distance).	Not triggered
S1936 (EAW7)	S1936 is located 3.5 km north east of Longwall 901 and above Longwall 706 in Area 7. All sensors apart from the shallowest Hawkesbury Sandstone sensor (65 m) failed in 2014 due to subsidence in Area 7. The 65 m sensor shows a slight declining trend during LW901 which is unlikely to be associated with mining in Area 9.	Not triggered
S1941 (EAW9)	S1941 is located 980 m north of Longwall 901 (and above planned Longwall 904). It has three sensors in the Hawkesbury Sandstone at 65 m, 126.5 m and 201.6 m depth. All three sensors show declines in groundwater pressure starting in March 2016, following the start of mining at LW901. Sensors at 126.5 m and 201.6 m declined by approximately 5 m and 10 m respectively, to a level at or below that of the Nepean River. The uppermost sensor (65 m) declined by 4 m, but recovered to pre-mining levels by August 2017 and the potentiometric head at that sensor remains above the level of the Nepean River. Average head in the Hawkesbury sandstone declined by a maximum of 6.3 m, but recovered to 3.4 m below pre-LW901 levels by the end of the longwall at which time recovery continued (see Figure 8). The observed decline is less than the predicted maximum reduction in groundwater level of 10 m.	Not triggered
S1954 (EAW 18)	S1954 is located 2.1 km northwest of Longwall 901, on the far side of the Razorback range from Area 9. S1954 has seven sensors within the Wianamatta Group shales and five sensors within the Hawkesbury Sandstone. All sensors were inoperative from early 2014 to mid-2017. Piezometric levels in all sensors in late 2017 were above the elevation of the Nepean River.	Not triggered
S2080 (EAW58)	S2080 is located 1.1 km west of Longwall 901. It has three sensors in the Hawkesbury Sandstone at 65 m, 95 m and 170 m depth. Groundwater pressures in the uppermost HBSS sensor (65 m) declined by ~6m during LW901but remains ~20 m above the elevation of the Nepean River. Average pressure head for all three sensors declined by approximately 3 m by the end of LW901.	Not triggered
S2280 (Harris Ck 6)	S2280 is located 900 m east of Longwall 901 and has two sensors within the Hawkesbury Sandstone (60 m and 99 m depth). Groundwater pressures at both sensors was relatively stable during mining of LW90, and piezometric head in both sensors remains above the elevation of the Nepean River.	Not triggered
S2281 (Harris Ck 7)	S2281 is located 190 m south of Longwall 901, between the longwall edge and the Nepean River. It has two sensors within the Hawkesbury sandstone at 61 m and 99 m depth. Groundwater pressures at both sensors responded to the passage of Longwall 901, initially increasing (due to strata compression) as the longwall approached and declining in August 2017 as the longwall moved away. Pressure head declined by 3.1 m and 6.4 m (respectively) compared with conditions prior to LW901, with an average decline of 5.3 m for the Hawkesbury Sandstone. The piezometric head in S2281_99 declined to a level just above the Nepean River whereas the pressure in S2281_99 remains ~25 m above the elevation of the Nepean River. The observed decline is less than the predicted maximum reduction in groundwater level of 10 m.	Not triggered

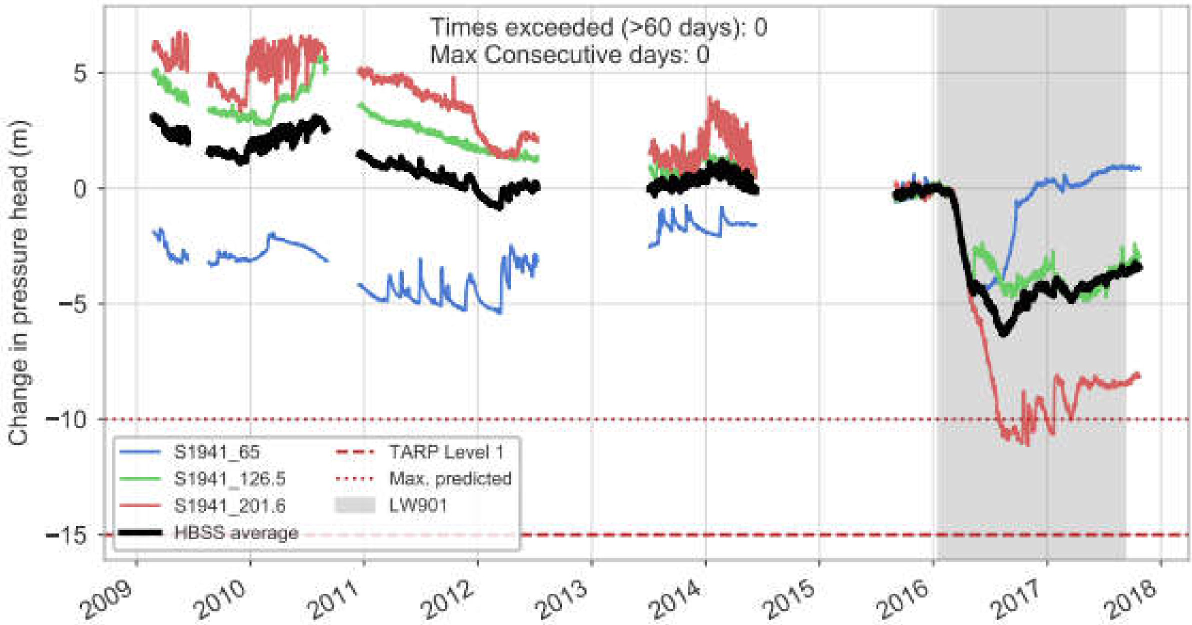

Figure 8. Pressure head change hydrograph for S1941

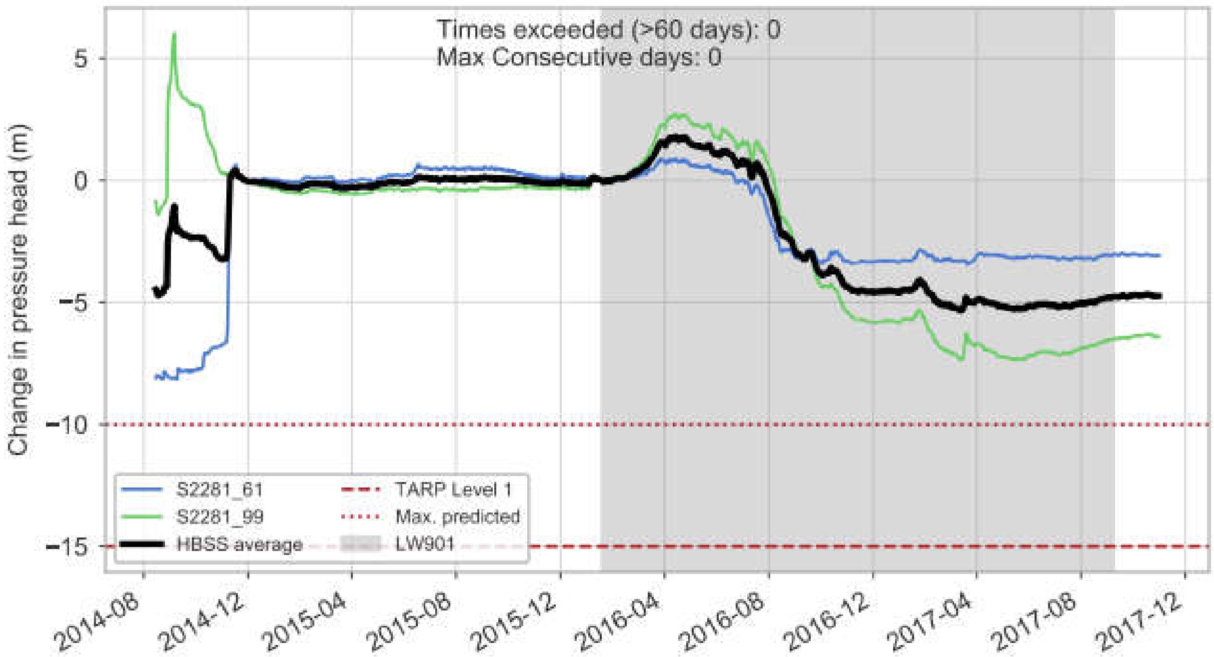

Figure 9. Pressure head change hydrograph for S2281

3.2 Groundwater chemistry

Groundwater samples are collected from four monitoring bores in the vicinity of Area 9. Two bores (S1954, S2080) are sampled at multiple depths. Key groundwater quality parameters are summarised in Table 7 and water chemistry time-series plots are in Appendix 2. Groundwater in the Hawkesbury Sandstone is typically brackish (EC ~ 1400 to 6100 µS/cm; TDS ~ 840 to 3660 mg/L) and near neutral in pH. In contrast, the Nepean River has water of low salinity (fresh; EC typically 140 to 460 µS/cm; TDS 85 to 280 mg/L).

Time-series plots of key water quality parameters (Appendix 2) show no significant change in water quality as a result of mining at Longwall 901.

Table 7. Summary of groundwater quality near Appin Area 9

Site / depth	Statistic	Field EC (µS/cm)	Field pH	Na/Cl (meq)
S1954_198m (Wianamatta Grp)	P5%	2803	8.84	1.26
	Median	2996	8.90	1.35
	P95%	3163	9.48	1.44
S1954_255m (Hawkesbury Sst)	P5%	2732	7.77	0.84
	Median	2940	7.85	0.88
	P95%	3071	8.45	0.93
S2080_158m (Hawkesbury Sst)	P5%	1337	6.83	N/A
	Median	1441	6.92	N/A
	P95%	1544	7.01	N/A
S2080_290m (Bulgo Sst)	P5%	5471	6.90	N/A
	Median	5660	6.95	N/A
	P95%	5849	6.99	N/A
S2280_60m (Hawkesbury Sst)	P5%	3225	6.78	0.71
	Median	3480	6.88	0.76
	P95%	4550	7.08	0.82
S2281_60m (Hawkesbury Sst)	P5%	1999	6.56	0.63
	Median	6115	6.59	0.66
	P95%	7457	6.79	0.73
Nepean River (NR0, SW3 / NR1, NR2)	P5%	140	7.15	1.00
	Median	270	7.89	1.62
	P95%	464	8.35	2.76

3.3 Private groundwater bores

Post-mining inspection of dams, boreholes and natural features above Appin Area 9 (set out in the Built Feature Management Plans) are conducted by the ICEFT with the consent of the relevant property/infrastructure owner and tenant. Significant changes or impacts are reported in the End of Panel Landscape Report (South32, 2017).

Impacts to two private properties, located near the northern margin of Longwall 901, were reported during the extraction of Longwall 901:

1. Lots 59 – 69, DP1321: Decline in water level within the bore likely due to mining
2. Lot 22, DP803255: Decline in water level within the bore likely due to mining

These impacts are described in the End of Panel Landscape Report and in the relevant property reports. Water Management Plans have been implemented in response to these impacts.

3.4 Mine water balance

A daily water balance is maintained by South32. The balance tracks daily volumes of water pumped into the mine (supply), within the mine, and from the mine into storage and/or discharge. The rate of groundwater inflow to Appin Area 9 is determined by subtracting the estimated water supply volume (to Area 9) from the total volume of water pumped to storage. Total mine inflow to Area 9 is calculated from 31/7/2017.

The TARP level for mine inflow is based on the 20-day rolling average inflow to Area 9, with level triggers listed in Table 2. A time-series of groundwater inflow to Area 9 based on water balance calculations is shown in Figure 10, including the 20-day rolling mean and TARP trigger levels. No TARP was triggered during the reporting period.

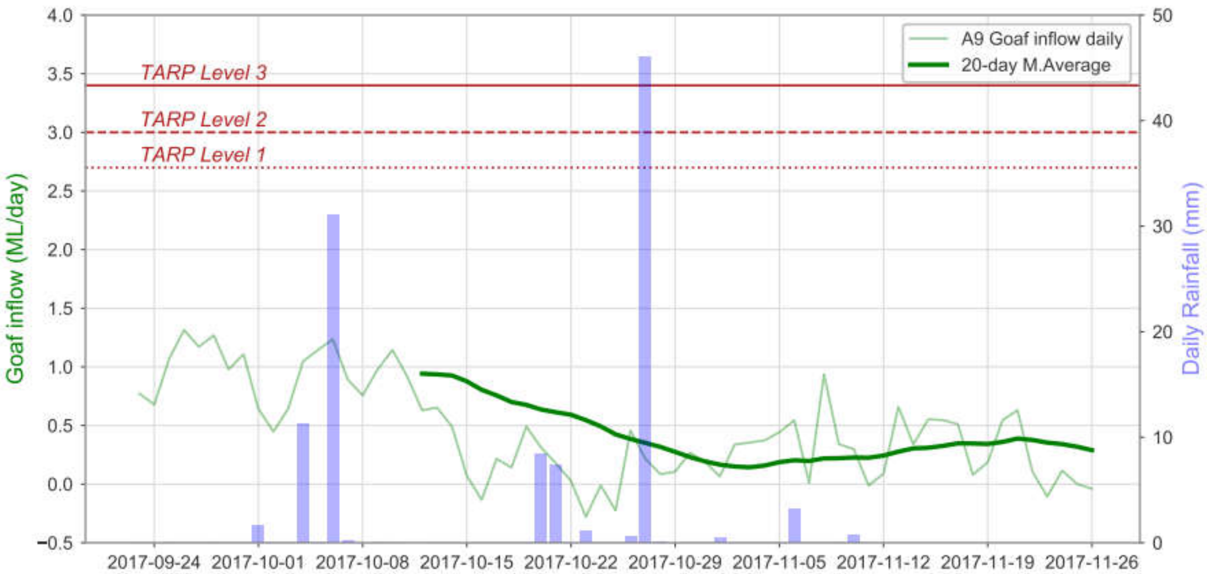

Figure 10. Appin Area 9 mine water balance

4. SURFACE WATER ASSESSMENT

Observations and laboratory analyses of surface water level and chemistry are presented as time-series plots (hydrographs) in Appendix 3.

4.1 Water level and flow

The Water Management Plan recommends that flow in the Nepean River is monitored by assessing dry weather recession characteristics for the Maldon, Menangle and Broughtons Pass weirs, based on daily flow records from those sites, in the same way as for Appin Area 7 monitoring reviews. However, it is noted that WaterNSW discontinued monitoring of those sites after the completion of the WMP in 2014, and therefore the recommended monitoring approach cannot be applied for the current reporting period.

Water levels are monitored at some pools during regular sampling events. Pool water levels are measured relative to a reference nail adjacent to the pool. Water levels are displayed as a time-series with other field observation in Appendix 3. The 5th to 95th percentile range for water levels measured during the pre-mining baseline period is also shown for reference. Of the sites where water levels are measured, most show water levels during the reporting period that are within the baseline range. An exception is the Nepean River upstream monitoring site NR0, which shows a decline in water level relative to the reference nail after the start of Longwall 901, with most observations during the reporting period plotting below the baseline 5th percentile. Water levels at site NR110 located 3.5 km further upstream of Longwall 901 shows a similar decline in early 2016 (with no data after May 2016). It is recommended that monitoring of water levels at NR0 and NR110 be continued to assess flow in the Nepean River, particularly in the absence of monitoring by WaterNSW at the previously monitored gauging sites.

4.2 Water chemistry

TARP performance criteria for surface water chemistry parameters are listed in Table 2. Criteria for triggering response levels are based on both magnitude and duration. For example, a TARP Level 1 is triggered for pH at site NR0 if the pH at that location is lower than the baseline mean minus 1 standard deviation (at that location), for at least 2 consecutive months but less than 6 consecutive months. To facilitate comparison between sites with different sampling frequencies, each time-series is resampled to monthly, whereby a mean value is considered where there is more than one sampling event per month. In addition to the three nominated TARP sites for the Nepean River, the WMP recommends comparison with site NR110, located more than 3.5 km upstream of Longwall 901.

Time-series plots of key water chemistry parameters are presented in Appendix 1. Analysis of the hydrographs in relation to the TARP criteria is provided in tabular format in Appendix 3 and summarised in Table 8, below. In summary, the reporting period (Longwall 901) is characterised by widely variable water quality in the Nepean River, with many parameters deviating by more than one or two standard deviations from the baseline mean on several occasions. Increases in water salinity (EC) are associated with periods of low rainfall (e.g. December 2016 and August 2017). This has resulted in the triggers of TARP criteria. However, deviations from the baseline mean (and TARP triggers) are noted in upstream locations (NR0 and NR110) and therefore the variations observed at the TARP sites are not attributed to mining activities. Nevertheless, it is recommended to maintain monitoring at all sites to assess the trends in water chemistry as mining progresses.

Table 8. Summary of surface water TARP levels for reporting period

TARP Site	NR110 (Upstream control)	NR0 (Upstream)	SW3/NR1 (Adjacent)	NR2 (Downstream)
EC	Level 2 criteria in Dec 2016 and July 2017	Level 2 criteria in Dec 2016 and July 2017	Level 2 criteria in Dec 2016 and July 2017	Level 2 criteria in July 2017
pH	Below Level 1 criteria	Level 1 criteria in Aug 2016	Level 1 criteria in Aug 2016	Level 1 criteria in Aug 2016
DO	Below Level 1 criteria	Below Level 1 criteria	Level 1 criteria in Dec 2016	Level 1 criteria in Apr 2016
Fe (Total)	Below Level 1 criteria	Below Level 1 criteria	Below Level 1 criteria	Below Level 1 criteria
Mn (Total)	Level 2 criteria in Dec 2016	Level 2 criteria in Dec 2016	Level 2 criteria in Dec 2016	Level 2 criteria in Dec 2016
Clarity / staining	None noted	None noted	None noted	None noted
TARP Level	Upstream Control Site	**TARP not triggered**; Deviations from the baseline of a similar or greater magnitude are observed at upstream monitoring points and therefore are not attributed to mining activities.		

4.3 Gas emissions

Twenty-five gas release zones were identified in the Nepean River by the ICEFT during the monitoring period. All 25 occurrences had estimated emission rates of <3000 L/min, and are classified as TARP Level 1. The locations of the emissions are shown in Figure 2. Gas emissions are described in detail in the End of Panel Landscape Report (South32, 2017).

The following actions were initiated in response to the Level 1 triggers, in accordance with the WMP:

• Continue monitoring program

• Submit an Impact Report to relevant stakeholders

• Report in the End of Panel Report

• Summarise actions and monitoring in the AEMR

5. CONCLUSIONS

An assessment of groundwater and surface water monitoring data was carried out to assess the potential impacts from mining of Longwall 901 at Appin Colliery, in accordance with the WMP. The following conclusions are made:

Groundwater assessment

- A moderate decline in groundwater levels occurred in the Hawkesbury Sandstone at two monitoring bores (S2281 and S1941), located 190 m and 980 m from Longwall 901 respectively. The observed groundwater level reductions are within the predicted range. No significant change in groundwater chemistry is noted for the reporting period.
- Impacts to two private properties were recorded during the extraction of Longwall 901. Water Management Plans have been implemented in response to these impacts.
- Groundwater inflow to the mine is calculated from the daily mine water balance. The 20-day moving average mine inflow fluctuated between ~1.0 and 0.2 ML/day following the extraction of Longwall 901, well below the TARP Level 1 trigger of 2.7 ML/day.

Surface water assessment

- WaterNSW discontinued monitoring of Nepean River gauging sites at Maldon, Menangle and Broughtons Pass weirs after the completion of the WMP in 2014, and therefore the recommended monitoring approach could not be applied. Monthly monitoring by South32 indicates a decline in pool water levels at site NR0 (upstream TARP site) relative to the baseline period. However, due to limited water level data, the cause of the decline is uncertain.
- The Longwall 901 reporting period was characterised by widely variable water quality in the Nepean River. Increases in water salinity (EC) outside the baseline range are associated with periods of low rainfall. This has resulted in the triggers of TARP criteria. However, deviations from the baseline mean (and TARP triggers) are noted in upstream locations (NR0 and NR110) and therefore the variations observed at the TARP sites are not attributed to mining activities.
- Twenty-five gas release zones were identified in the Nepean River during the monitoring period. All 25 occurrences had estimated emission rates of <3000 L/min, and triggered a TARP Level 1 response under the WMP.

6. RECOMMENDATIONS

1. WaterNSW discontinued monitoring of Nepean River gauging sites at Maldon, Menangle and Broughtons Pass weirs after the completion of the WMP in 2014, and therefore the monitoring approach recommended in the WMP could not be applied. It is recommended that monitoring of Nepean River Pool levels at NR110, NR0, SW3 (NR1) and NR2 are continued.

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APPENDIX 1 – Groundwater bore hydrographs

Appin Area 9 End of Panel Surface Water TARP Assessment

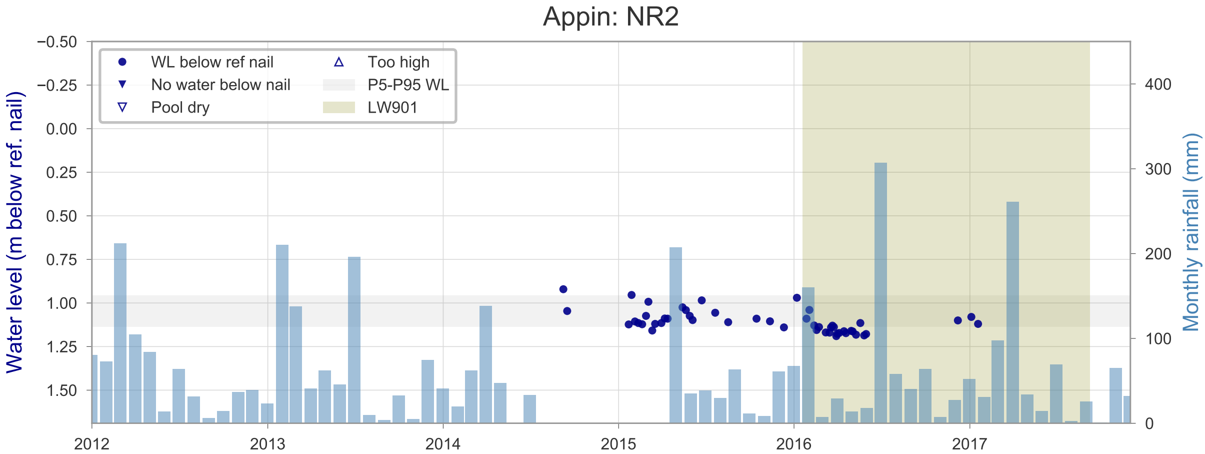
Longwall 901

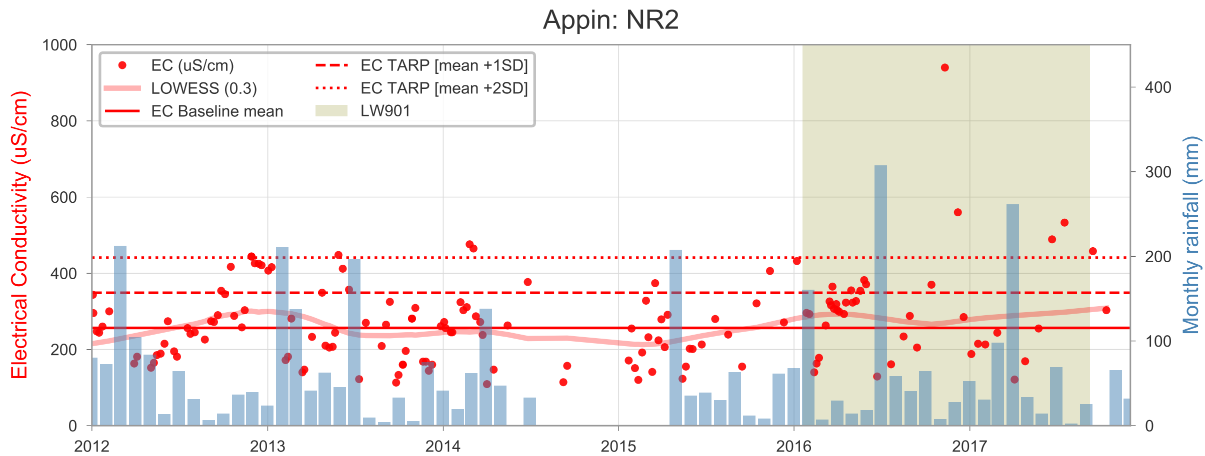
Date	NR0 (Upstream)					SW3(NR1) (Adjacent)					NR2 (Downstream)					NR110 (Upstream - control)				
	EC	pH	DO	Fe_tot	Mn_tot	EC	pH	DO	Fe_tot	Mn_tot	EC	pH	DO	Fe_tot	Mn_tot	EC	pH	DO	Fe_tot	Mn_tot
2015-10-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015-11-30	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2015-12-31	0	0	2	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0
2016-01-31	1	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0
2016-02-29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2016-03-31	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
2016-04-30	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0
2016-05-31	1	0	0	0	0	1	0	0	0	0	1	0	1	0	0	1	0	0	0	0
2016-06-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2016-07-31	0	1	0	1	0	0	2	0	1	0	0	2	0	0	0	0	0	0	0	0
2016-08-31	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
2016-09-30	0	0	1	1	0	0	0	0	1	0	0	0	0	2	2	0	0	0	1	0
2016-10-31	1	0	0	0	1	1	0	0	0	2	1	0	0	0	0	2	0	0	0	1
2016-11-30	2	0	1	0	2	2	0	1	0	2	2	0	0	0	2	2	0	0	2	2
2016-12-31	2	0	0	0	2	2	0	1	0	2	1	0	0	1	2	2	0	0	0	2
2017-01-31	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017-02-28	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017-03-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017-04-30	0	1	0	1	0	0	1	0	1	0	0	0	0	1	1	0	0	0	1	0
2017-05-31	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
2017-06-30	2	0	0	0	0	2	0	0	0	0	2	0	0	0	0	2	0	0	0	0
2017-07-31	2	0	0	0	0	2	0	0	0	0	2	0	0	0	0	2	0	0	0	0
2017-08-31	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1
2017-09-30	2	0	0	0	0	1	0	0	0	0	2	0	0	0	0	2	0	0	0	0
2017-10-31	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0

2 — Numbers refer to the Tarp trigger level exceeded in each month (based on monthly average where more than one sample collected per month)

TARP Level 1

TARP Level 2


Appin: NR2
Water level (m below ref. nail)
Monthly rainfall (mm)
WL below ref nail
No water below nail
Pool dry
Too high
P5-P95 WL
LW901
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
400
300
200
100
0
2012
2013
2014
2015
2016
2017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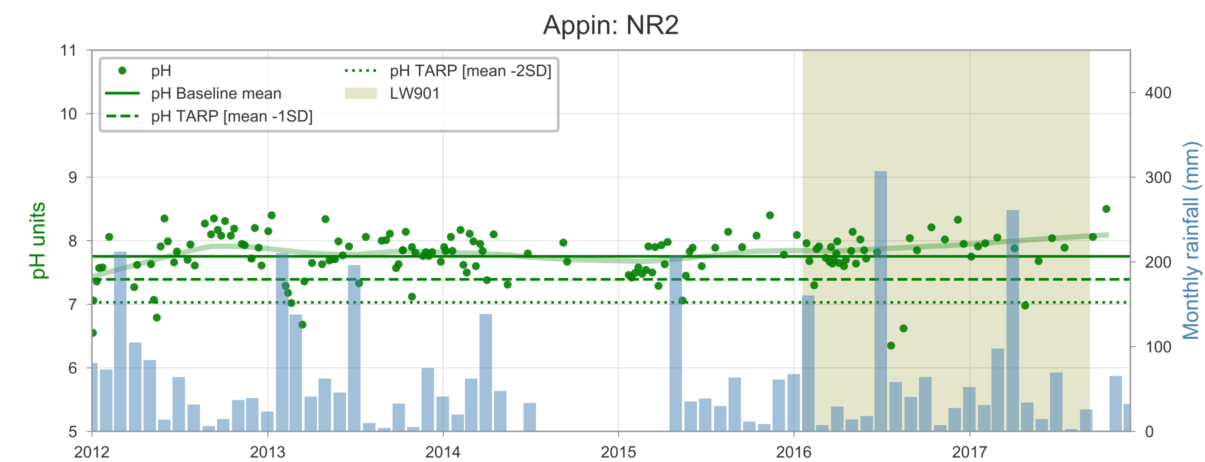
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
EC (uS/cm)
LOWESS (0.3)
EC Baseline mean
EC TARP [mean +1SD]
EC TARP [mean +2SD]
LW901
1000
800
600
400
200
0
400
300
200
100
0
2012
2013
2014
2015
2016
2017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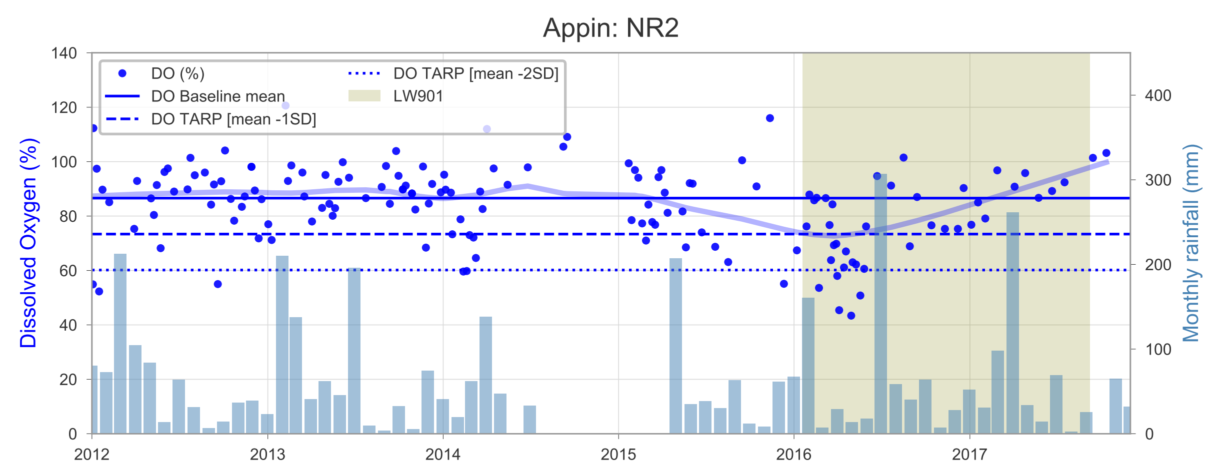
pH units
Monthly rainfall (mm)
pH
pH Baseline mean
pH TARP [mean -1SD]
pH TARP [mean -2SD]
LW901
11
10
9
8
7
6
5
400
300
200
100
0
2012
2013
2014
2015
2016
2017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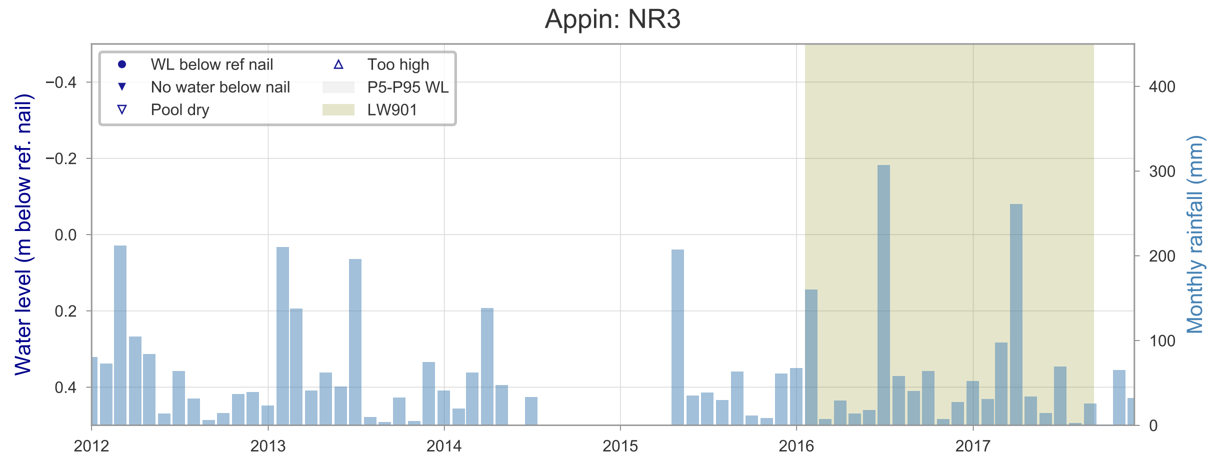
Dissolved Oxygen (%)
Monthly rainfall (mm)
DO (%)
DO Baseline mean
DO TARP [mean -1SD]
DO TARP [mean -2SD]
LW901
140
120
100
80
60
40
20
0
400
300
200
100
0
2012
2013
2014
2015
2016
2017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No water below nail
Pool dry
Too high
P5-P95 WL
LW901
Water level (m below ref. nail)
Monthly rainfall (mm)
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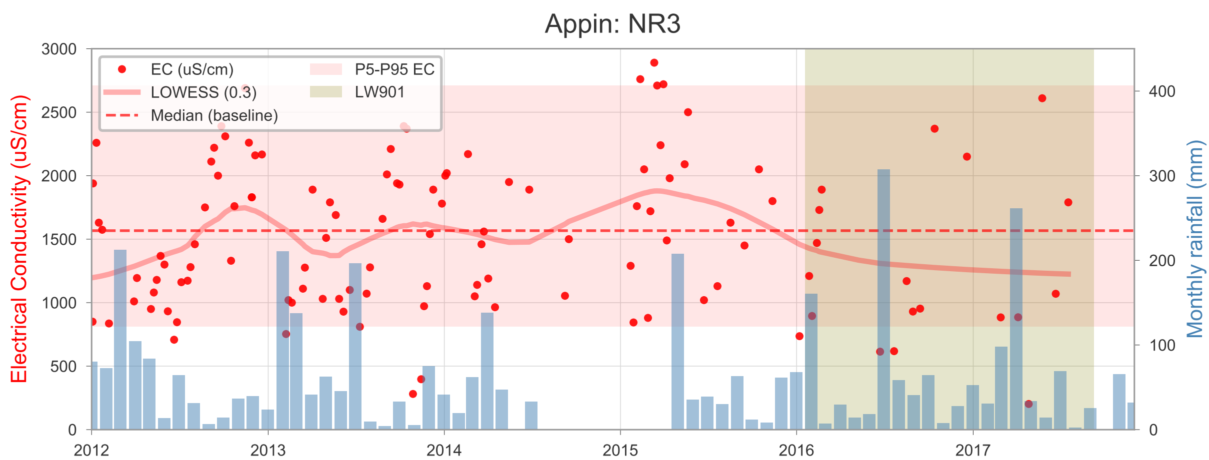
−0.2
0.0
0.2
0.4
0
100
200
300
400
2012
2013
2014
2015
2016
2017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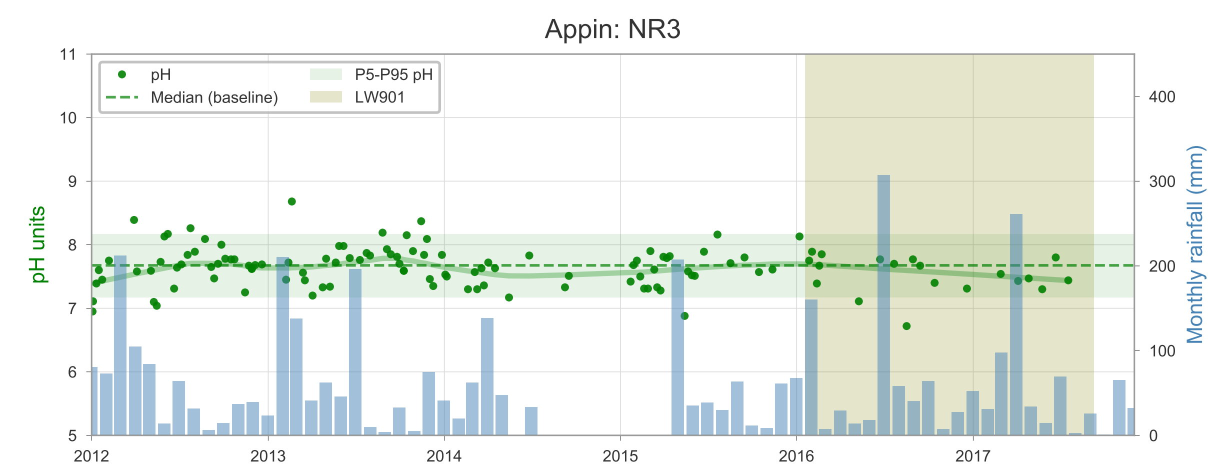
EC (uS/cm)
LOWESS (0.3)
Median (baseline)
P5-P95 EC
LW901
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
0
500
1000
1500
2000
2500
3000
0
100
200
300
400
2012
2013
2014
2015
2016
2017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P5-P95 pH
LW901
pH units
Monthly rainfall (mm)
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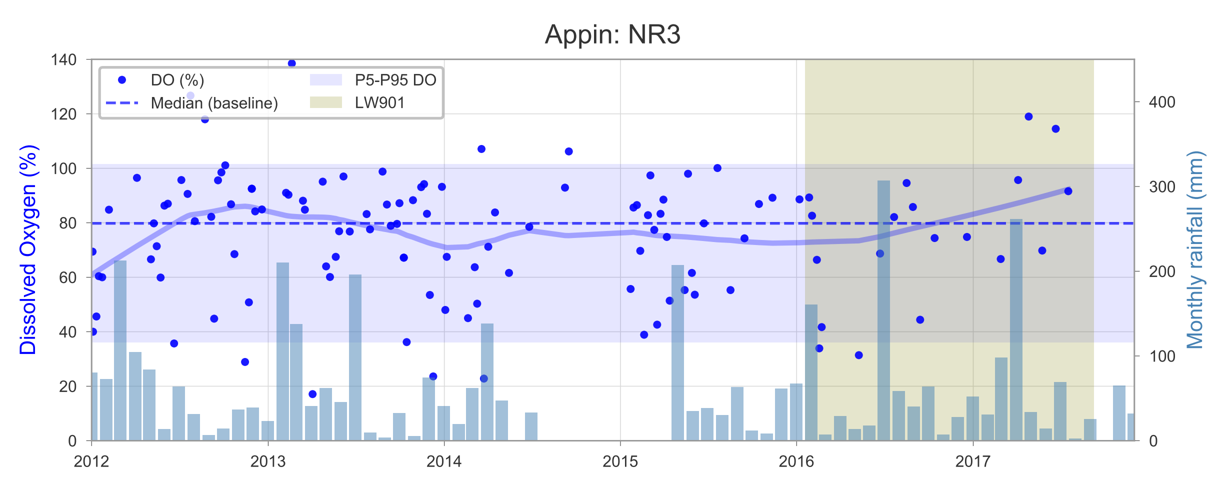
11
0
100
200
300
400
2012
2013
2014
2015
2016
2017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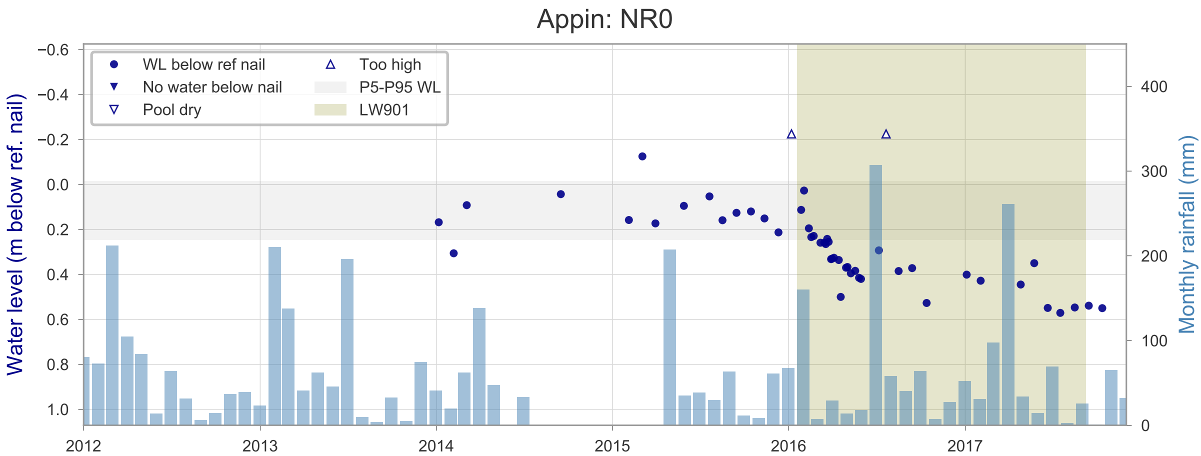
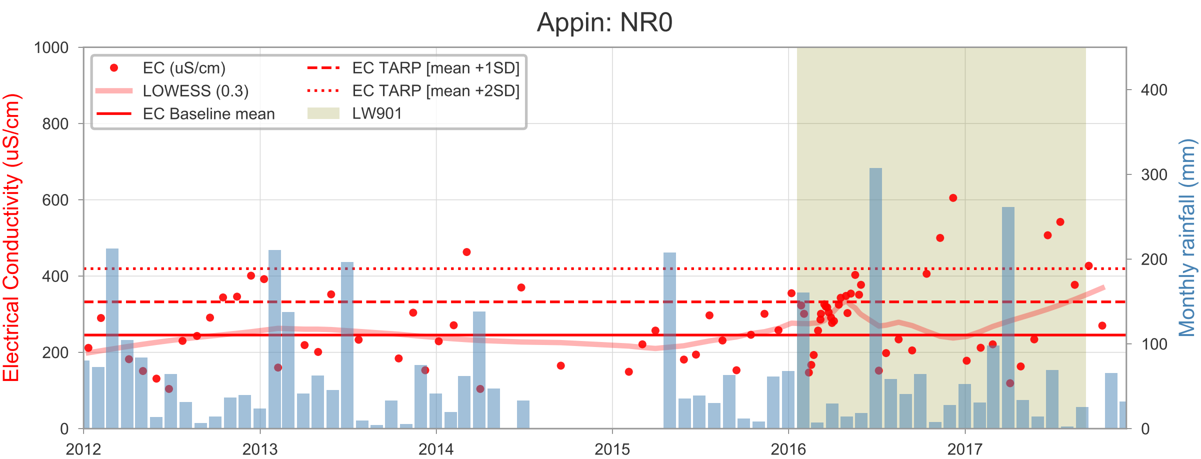
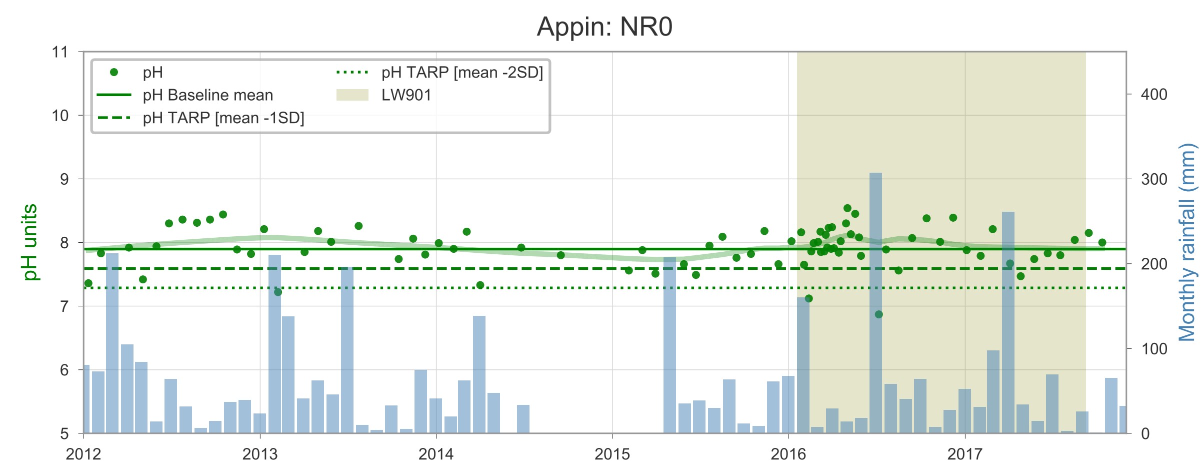
DO (%)
Median (baseline)
P5-P95 DO
LW901
Dissolved Oxygen (%)
Monthly rainfall (mm)
0
20
40
60
80
100
120
140
0
100
200
300
400
2012
2013
2014
2015
2016
2017



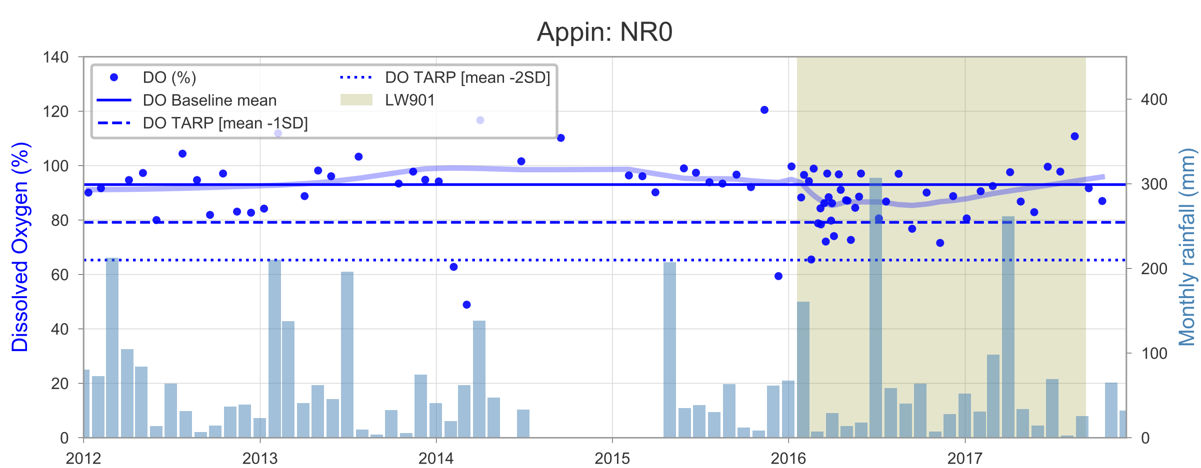
Appin: NR0
WL below ref nail
No water below nail
Pool dry
Too high
P5-P95 WL
LW901
Water level (m below ref. nail)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017



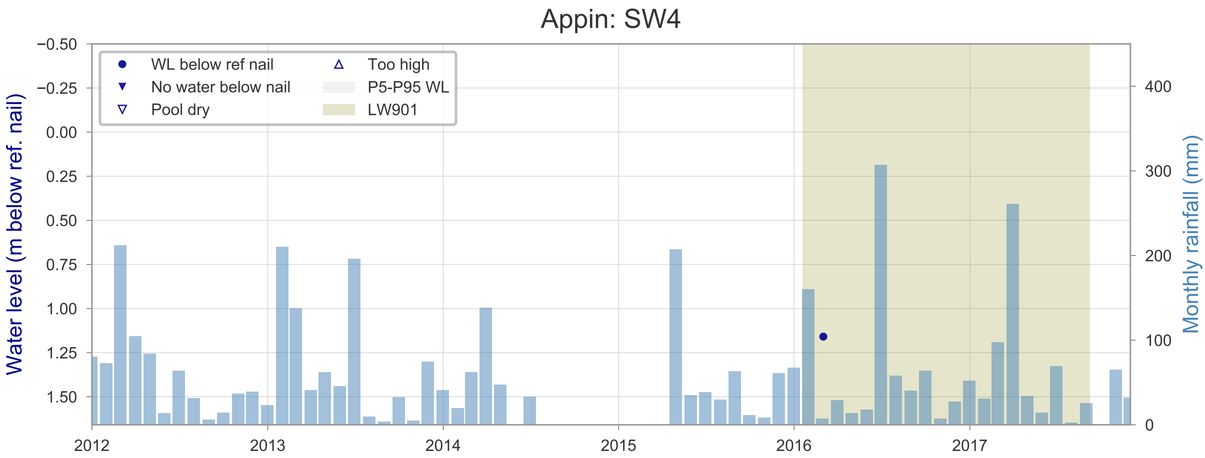
Appin: NR0
EC (uS/cm)
LOWESS (0.3)
EC Baseline mean
EC TARP [mean +1SD]
EC TARP [mean +2SD]
LW901
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

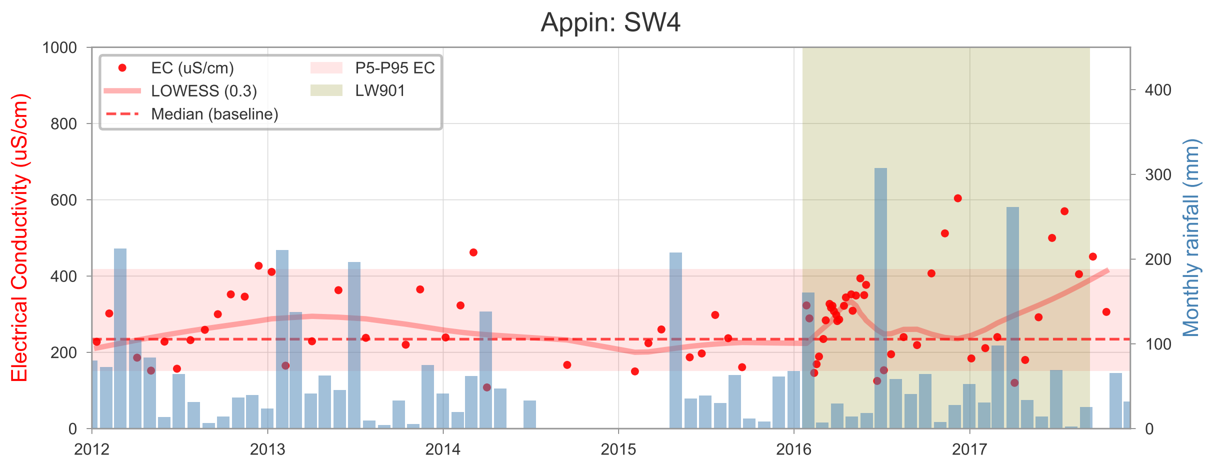


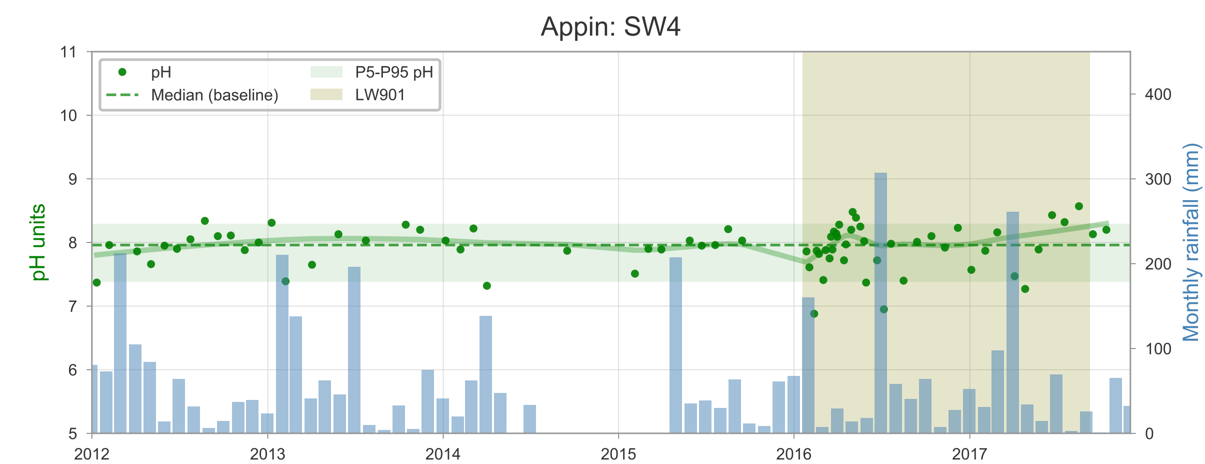
Appin: NR0
pH
pH Baseline mean
pH TARP [mean -1SD]
pH TARP [mean -2SD]
LW901
pH units
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

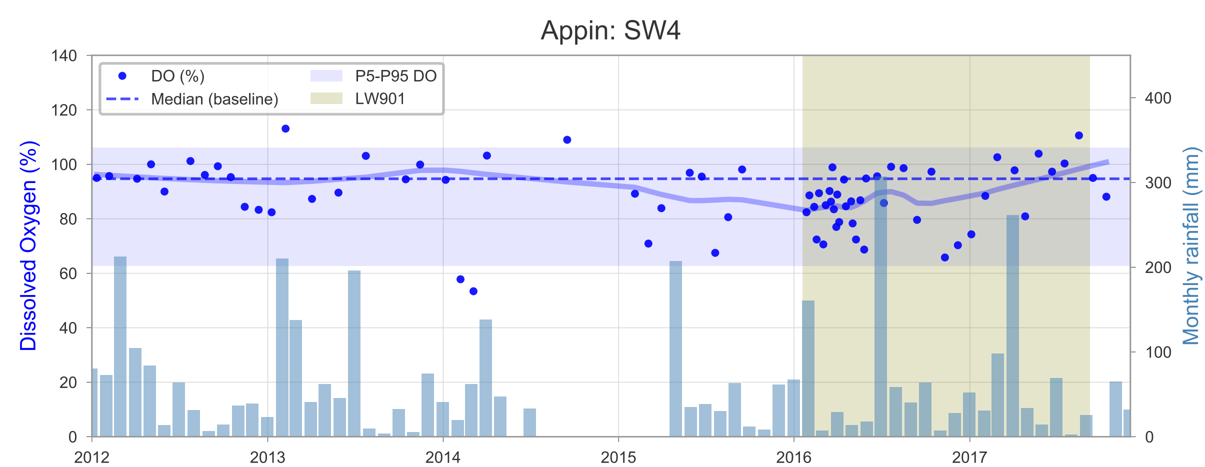


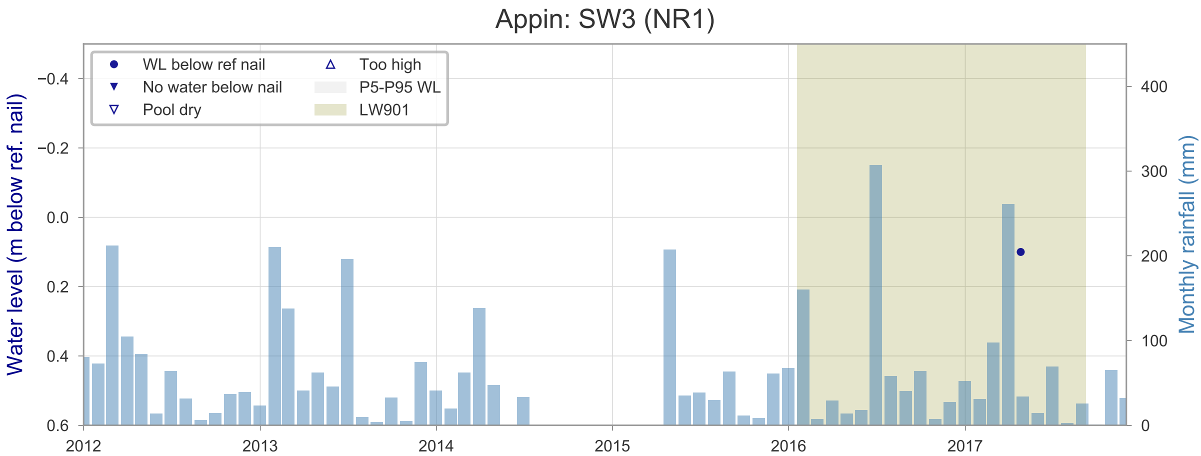
Appin: NR0
DO (%)
DO Baseline mean
DO TARP [mean -1SD]
DO TARP [mean -2SD]
LW901
Dissolved Oxygen (%)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

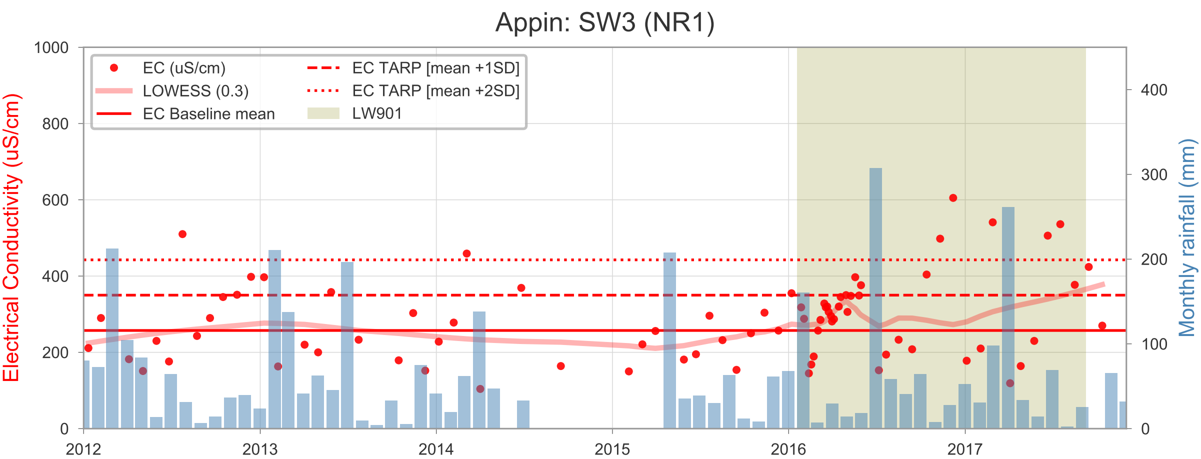

Appin: SW4
WL below ref nail
No water below nail
Pool dry
Too high
P5-P95 WL
LW901
Water level (m below ref. nail)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

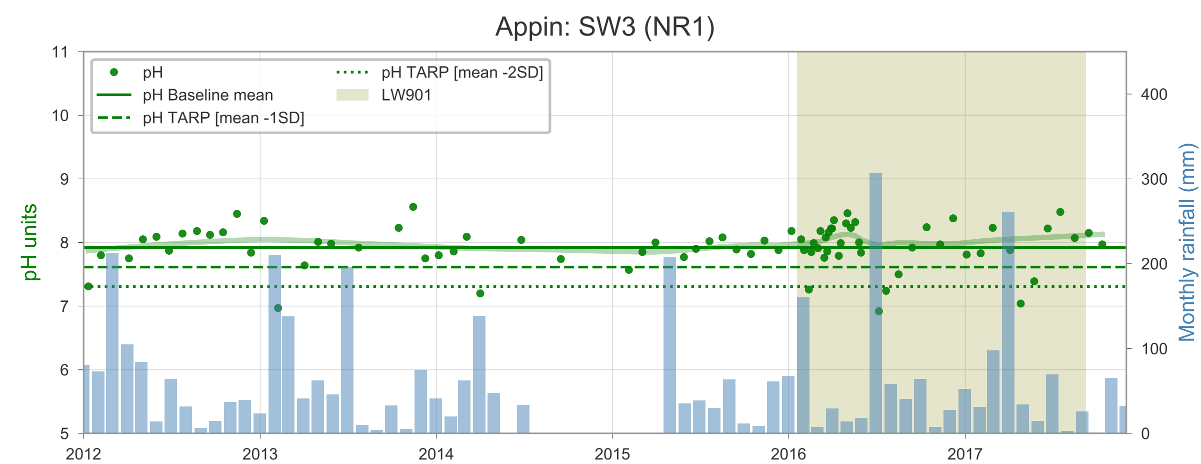

Appin: SW4
EC (uS/cm)
LOWESS (0.3)
Median (baseline)
P5-P95 EC
LW901
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

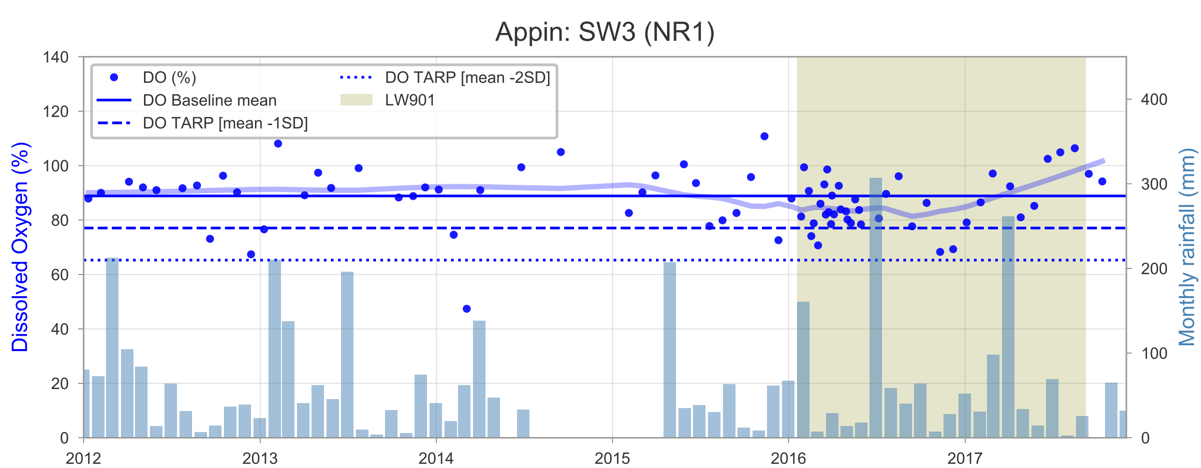

Appin: SW4
pH
Median (baseline)
P5-P95 pH
LW901
pH units
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

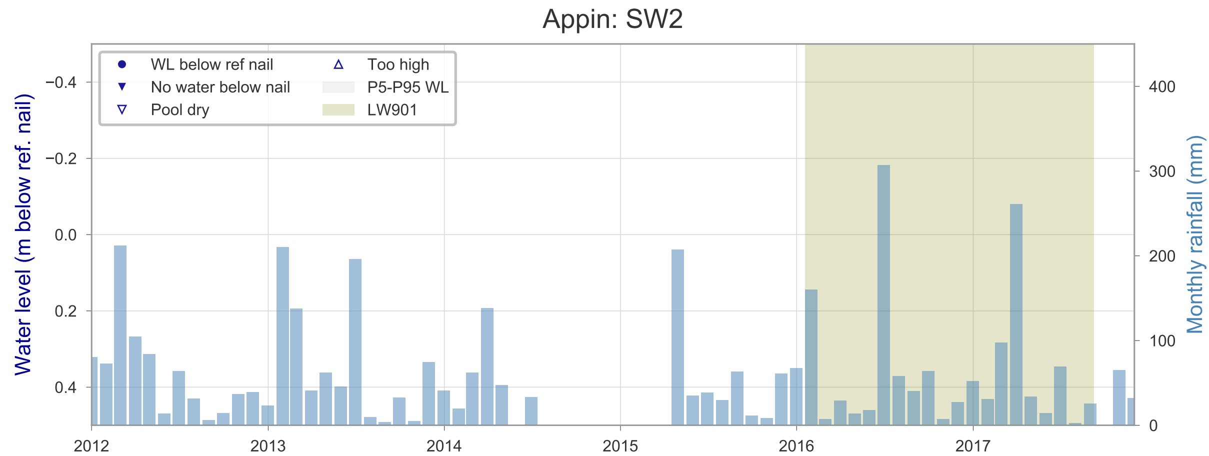

Appin: SW4
DO (%)
Median (baseline)
P5-P95 DO
LW901
Dissolved Oxygen (%)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

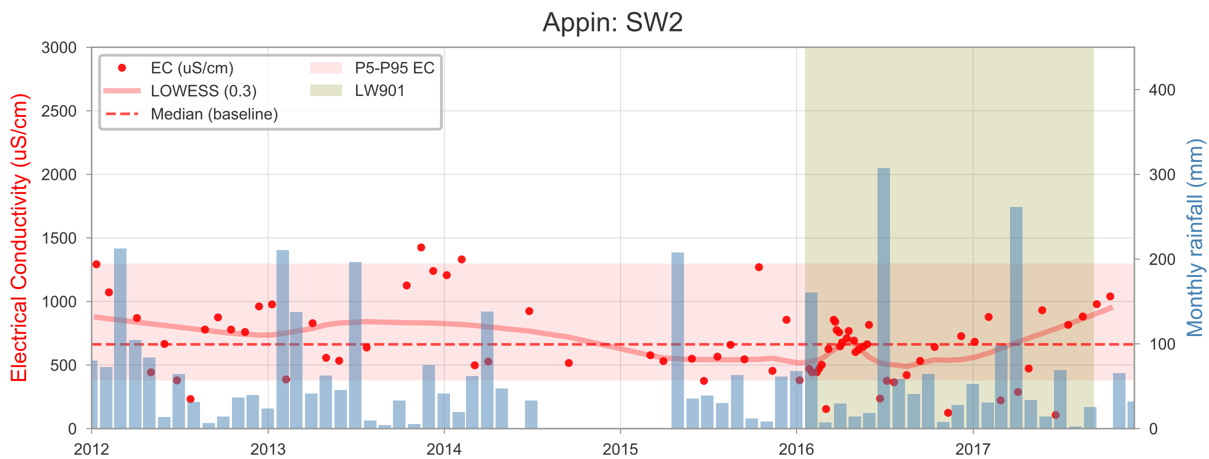

Appin: SW3 (NR1)
WL below ref nail
No water below nail
Pool dry
Too high
P5-P95 WL
LW901
Water level (m below ref. nail)
Monthly rainfall (mm)
−0.4
−0.2
0.0
0.2
0.4
0.6
400
300
200
100
0
2012
2013
2014
2015
2016
2017

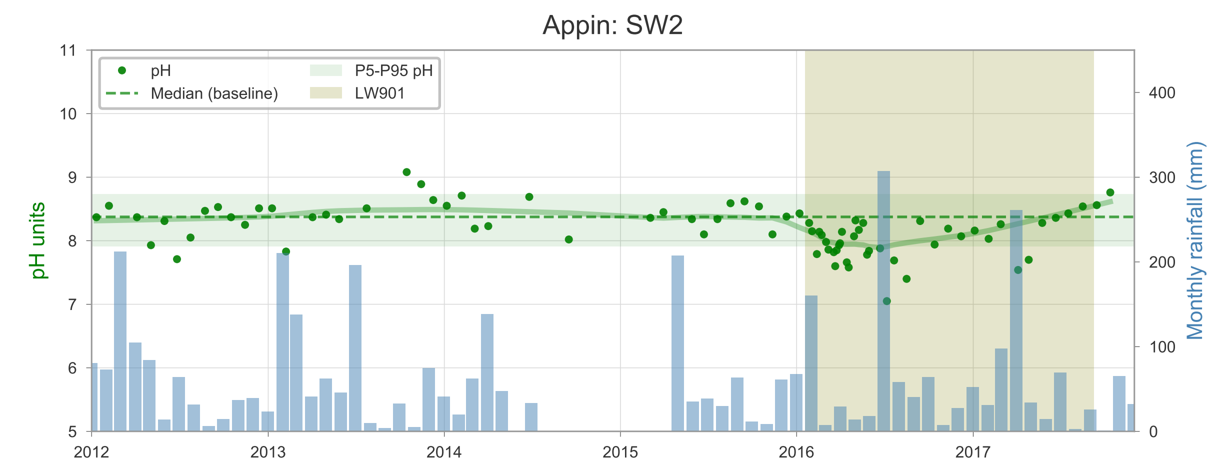

Appin: SW3 (NR1)
EC (uS/cm)
LOWESS (0.3)
EC Baseline mean
EC TARP [mean +1SD]
EC TARP [mean +2SD]
LW901
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
1000
800
600
400
200
0
400
300
200
100
0
2012
2013
2014
2015
2016
2017

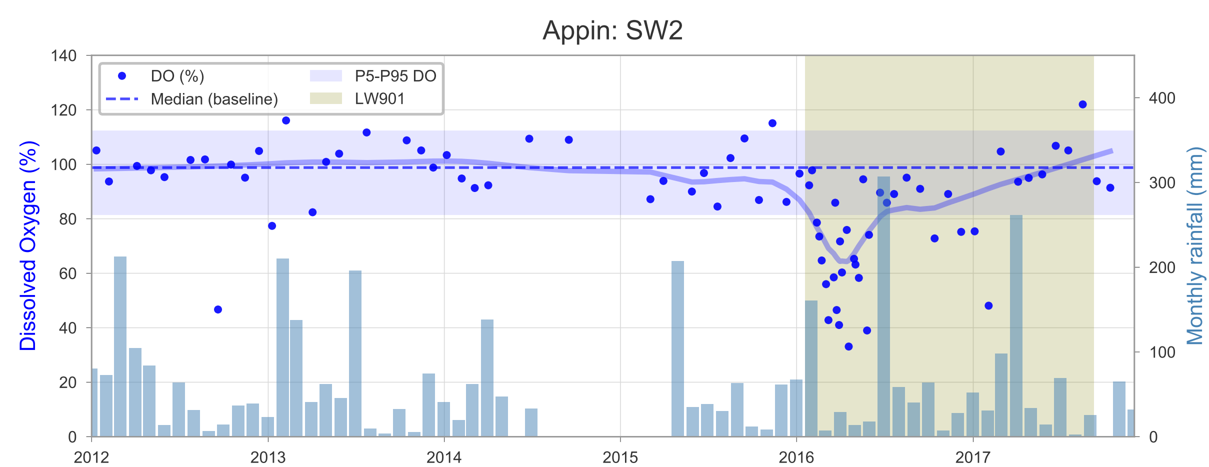

Appin: SW3 (NR1)
pH
pH Baseline mean
pH TARP [mean -1SD]
pH TARP [mean -2SD]
LW901
pH units
Monthly rainfall (mm)
11
10
9
8
7
6
5
400
300
200
100
0
2012
2013
2014
2015
2016
2017

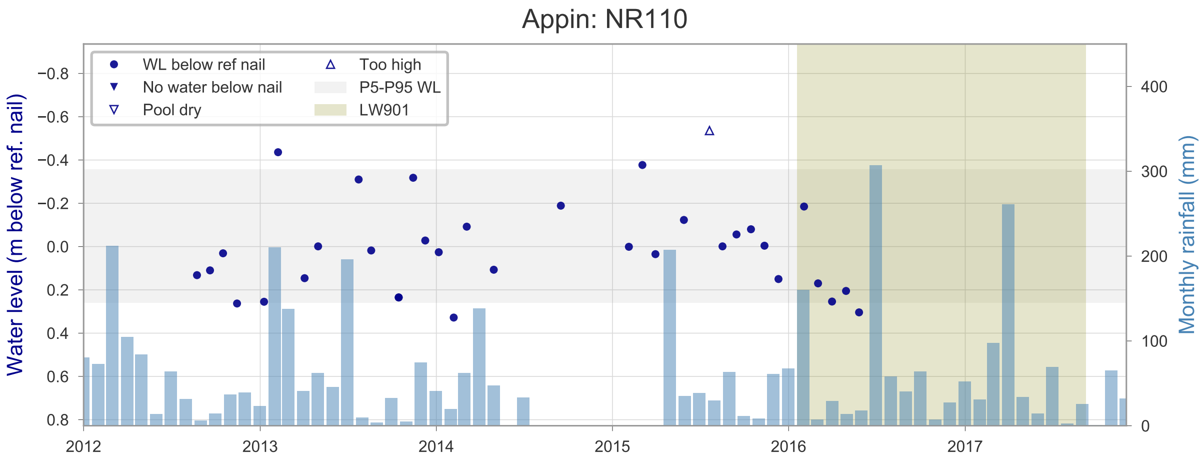

Appin: SW3 (NR1)
DO (%)
DO Baseline mean
DO TARP [mean -1SD]
DO TARP [mean -2SD]
LW901
Dissolved Oxygen (%)
Monthly rainfall (mm)
140
120
100
80
60
40
20
0
400
300
200
100
0
2012
2013
2014
2015
2016
2017

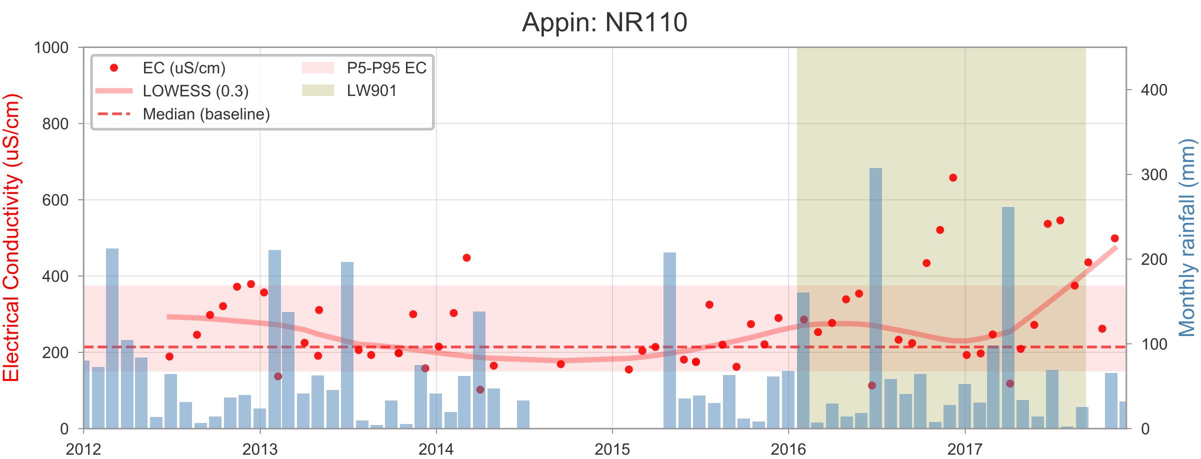

Appin: SW2
WL below ref nail
No water below nail
Pool dry
Too high
P5-P95 WL
LW901
Water level (m below ref. nail)
Monthly rainfall (mm)
−0.4
−0.2
0.0
0.2
0.4
0
100
200
300
400
2012
2013
2014
2015
2016
2017

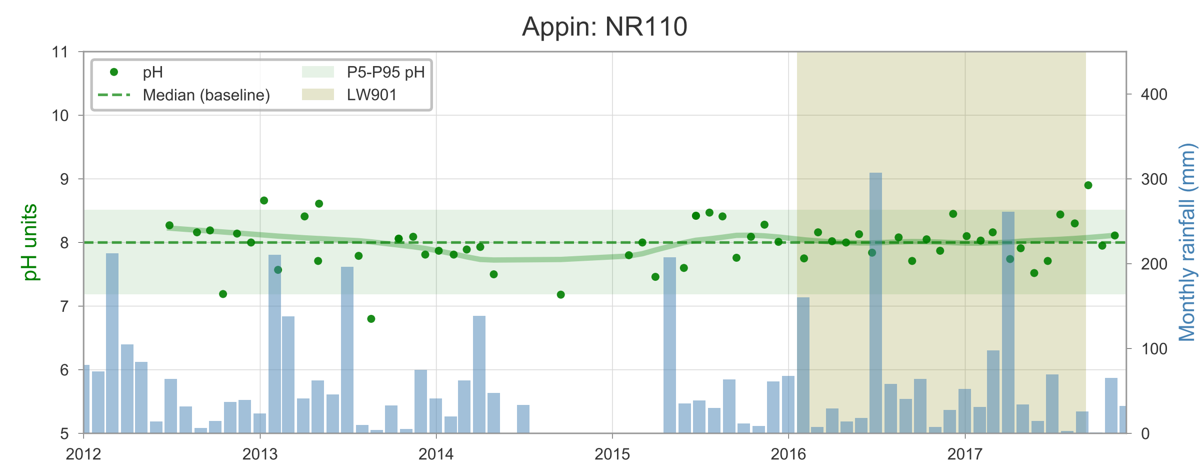

Appin: SW2
EC (uS/cm)
LOWESS (0.3)
Median (baseline)
P5-P95 EC
LW901
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
0
500
1000
1500
2000
2500
3000
0
100
200
300
400
2012
2013
2014
2015
2016
2017

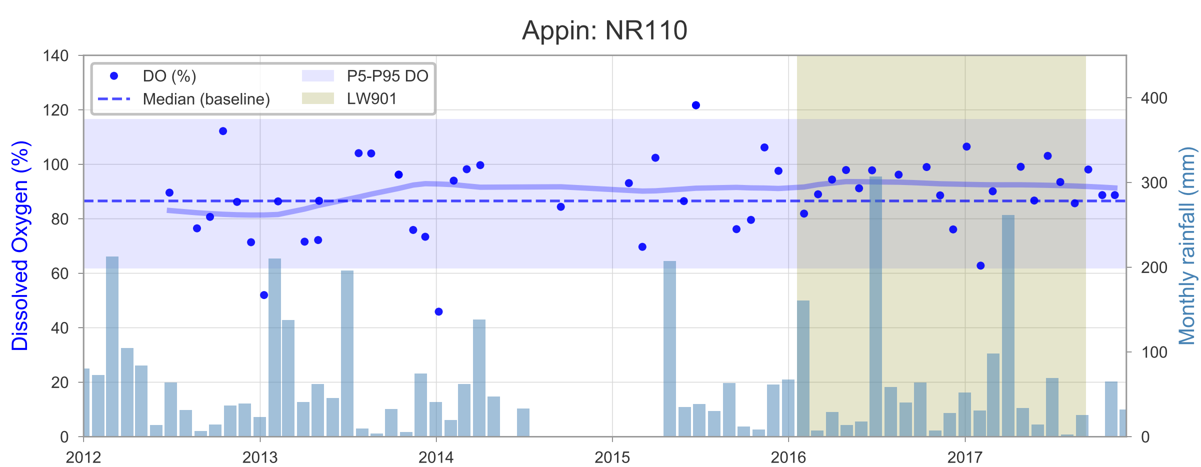

Appin: SW2
pH
Median (baseline)
P5-P95 pH
LW901
pH units
Monthly rainfall (mm)
5
6
7
8
9
10
11
0
100
200
300
400
2012
2013
2014
2015
2016
2017

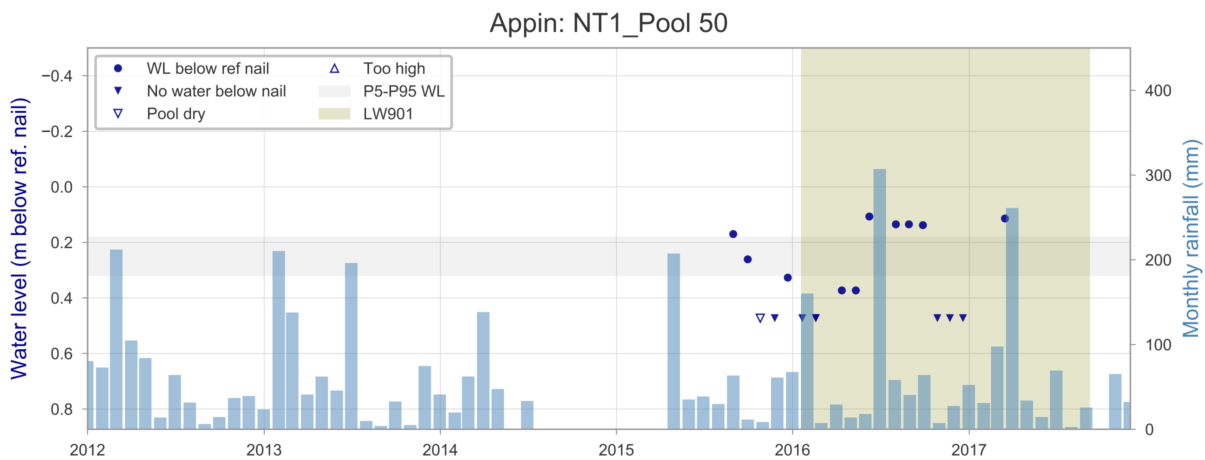

Appin: SW2
DO (%)
Median (baseline)
P5-P95 DO
LW901
Dissolved Oxygen (%)
Monthly rainfall (mm)
0
20
40
60
80
100
120
140
0
100
200
300
400
2012
2013
2014
2015
2016
2017

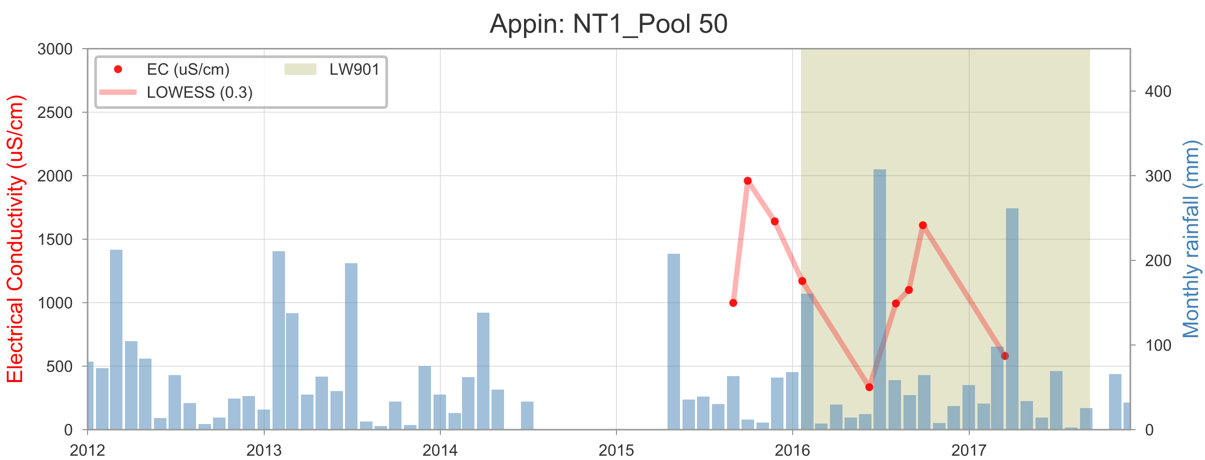

Appin: NR110
WL below ref nail
No water below nail
Pool dry
Too high
P5-P95 WL
LW901
Water level (m below ref. nail)
Monthly rainfall (mm)
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
0
100
200
300
400
2012
2013
2014
2015
2016
2017

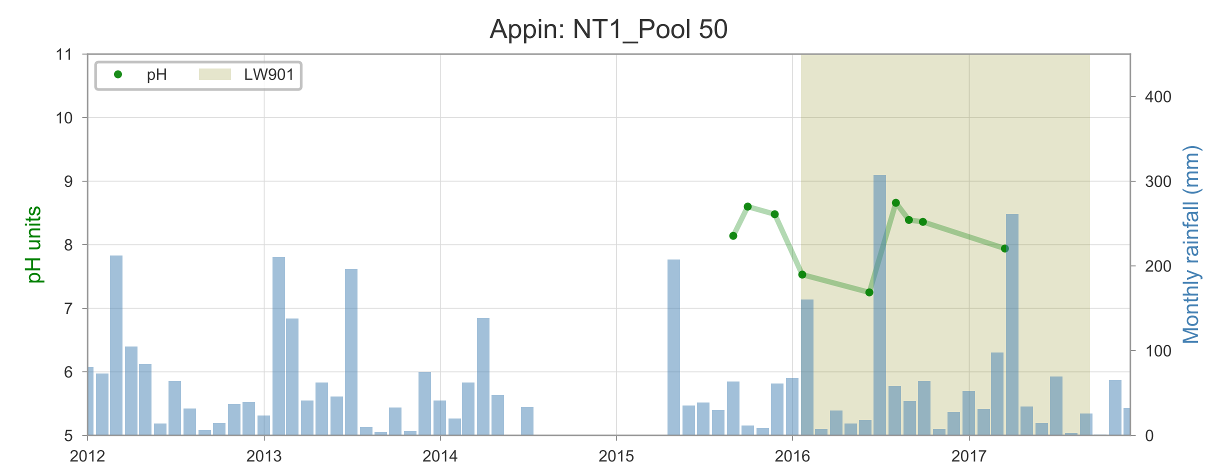

Appin: NR110
EC (uS/cm)
LOWESS (0.3)
Median (baseline)
P5-P95 EC
LW901
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
0
200
400
600
800
1000
0
100
200
300
400
2012
2013
2014
2015
2016
2017

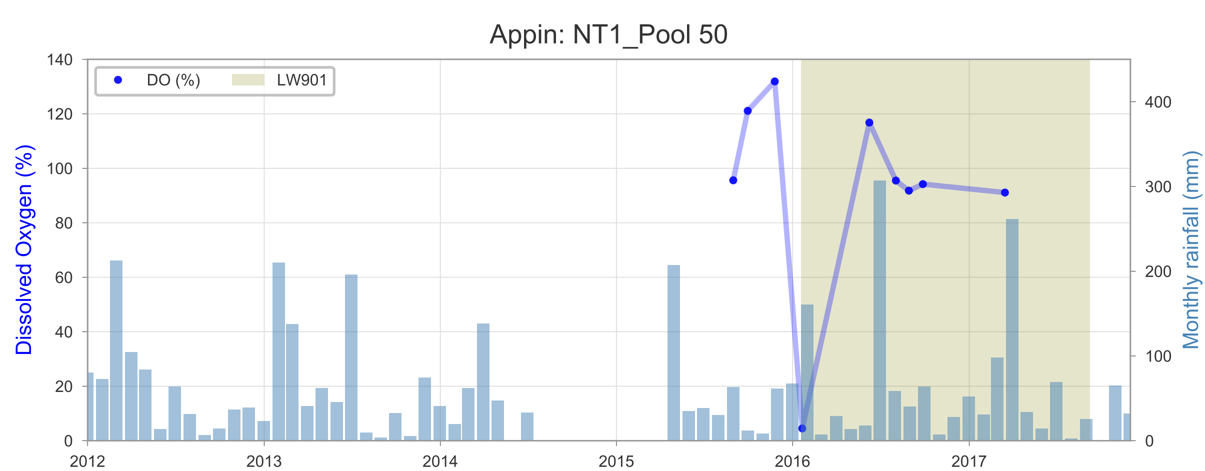

Appin: NR110
pH
Median (baseline)
P5-P95 pH
LW901
pH units
Monthly rainfall (mm)
5
6
7
8
9
10
11
0
100
200
300
400
2012
2013
2014
2015
2016
2017

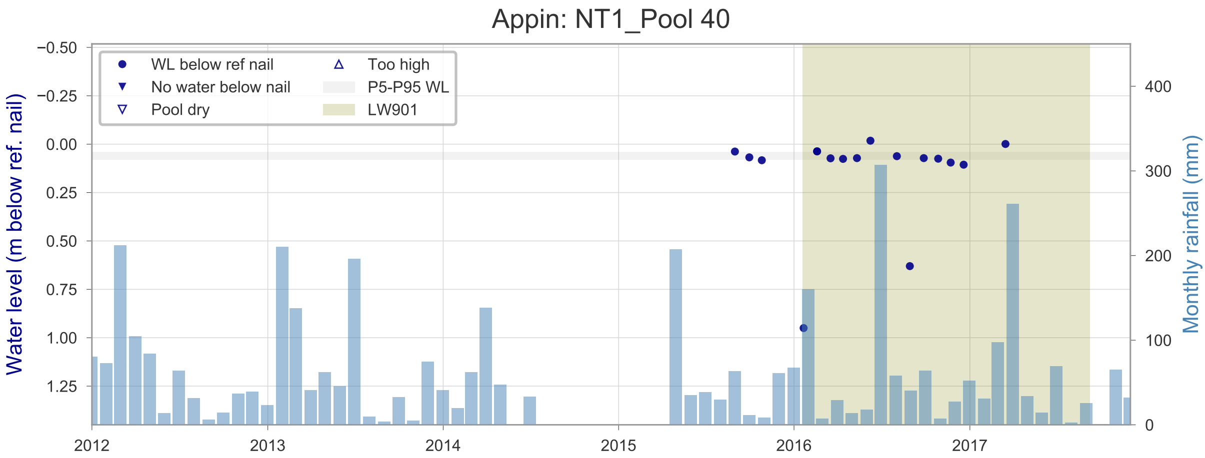

Appin: NR110
DO (%)
Median (baseline)
P5-P95 DO
LW901
Dissolved Oxygen (%)
Monthly rainfall (mm)
0
20
40
60
80
100
120
140
0
100
200
300
400
2012
2013
2014
2015
2016
2017

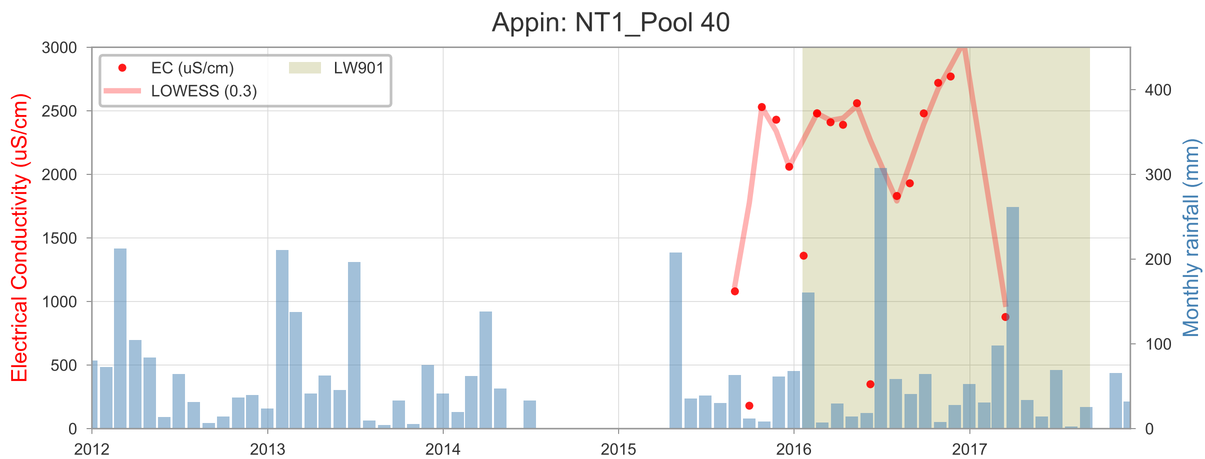

Appin: NT1_Pool 50
WL below ref nail
No water below nail
Pool dry
Too high
P5-P95 WL
LW901
Water level (m below ref. nail)
Monthly rainfall (mm)
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
0
100
200
300
400
2012
2013
2014
2015
2016
2017

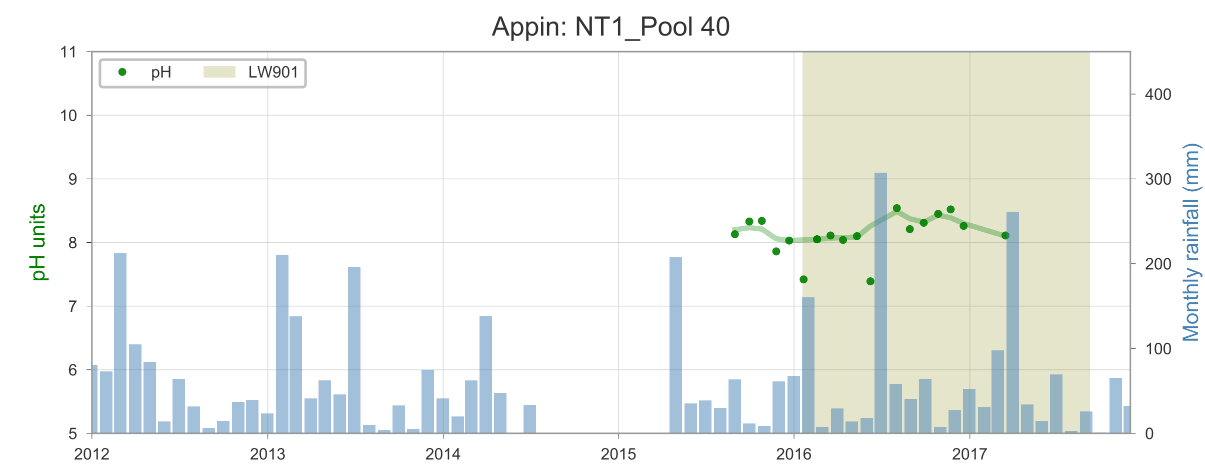

Appin: NT1_Pool 50
EC (uS/cm)
LOWESS (0.3)
LW901
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
0
500
1000
1500
2000
2500
3000
0
100
200
300
400
2012
2013
2014
2015
2016
2017

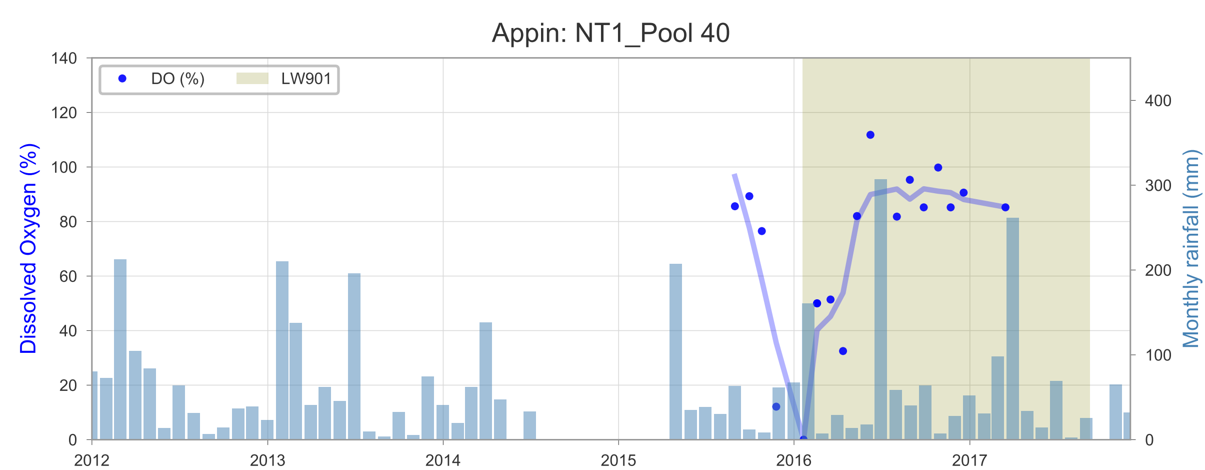

Appin: NT1_Pool 50
pH
LW901
pH units
Monthly rainfall (mm)
5
6
7
8
9
10
11
0
100
200
300
400
2012
2013
2014
2015
2016
2017

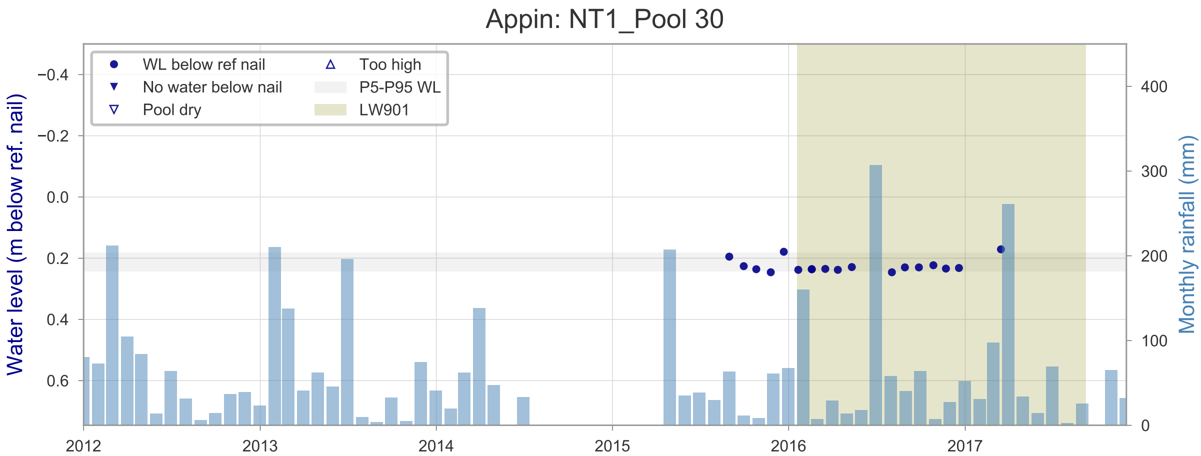

Appin: NT1_Pool 50
DO (%)
LW901
Dissolved Oxygen (%)
Monthly rainfall (mm)
0
20
40
60
80
100
120
140
0
100
200
300
400
2012
2013
2014
2015
2016
2017

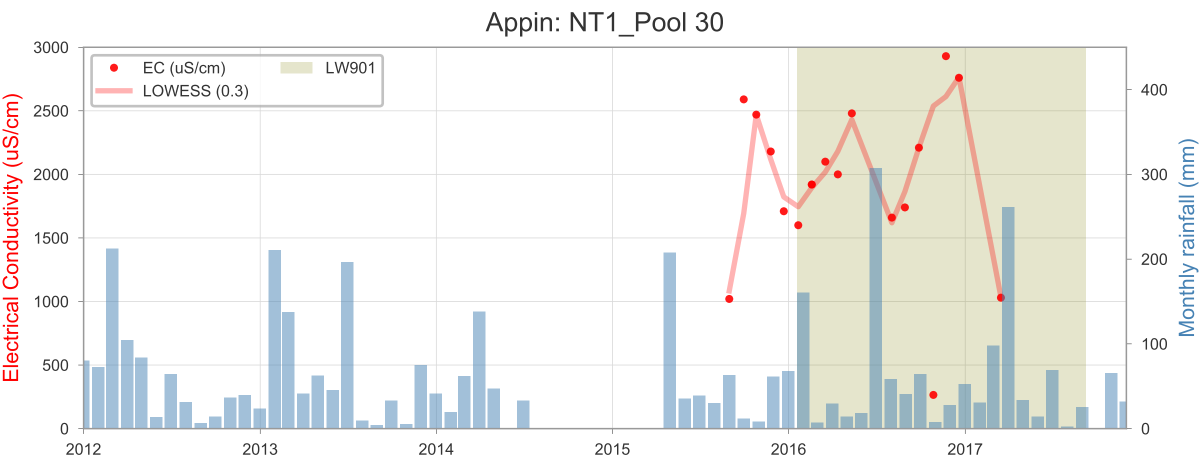

Appin: NT1_Pool 40
WL below ref nail
No water below nail
Pool dry
Too high
P5-P95 WL
LW901
Water level (m below ref. nail)
Monthly rainfall (mm)
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00
1.25
400
300
200
100
0
2012
2013
2014
2015
2016
2017

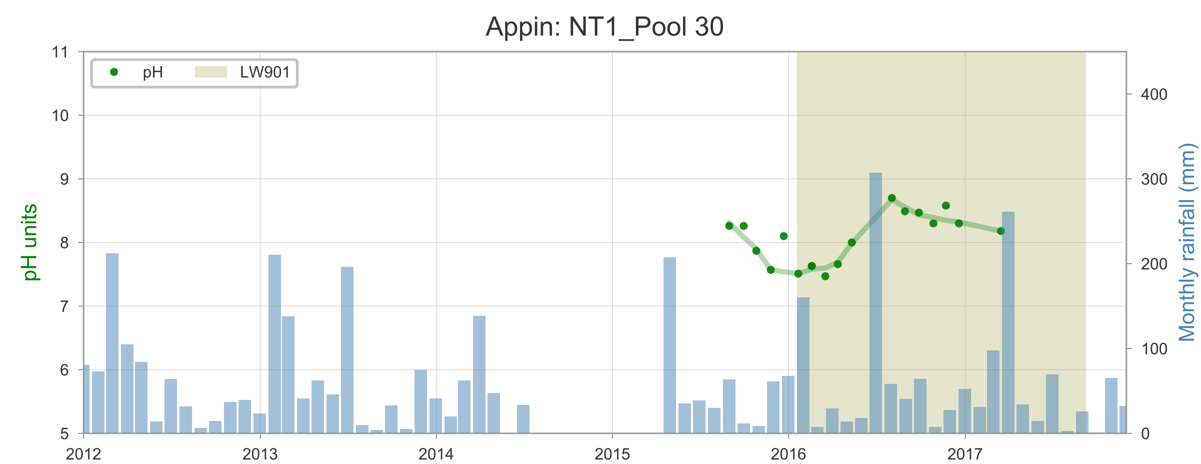

Appin: NT1_Pool 40
EC (uS/cm)
LOWESS (0.3)
LW901
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
3000
2500
2000
1500
1000
500
0
400
300
200
100
0
2012
2013
2014
2015
2016
2017

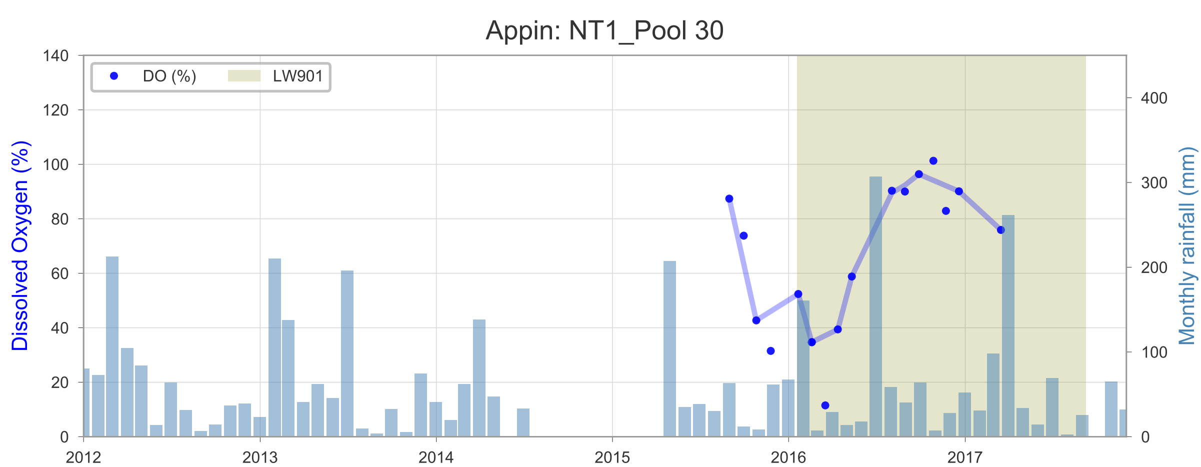

Appin: NT1_Pool 40
pH
LW901
pH units
Monthly rainfall (mm)
11
10
9
8
7
6
5
400
300
200
100
0
2012
2013
2014
2015
2016
2017

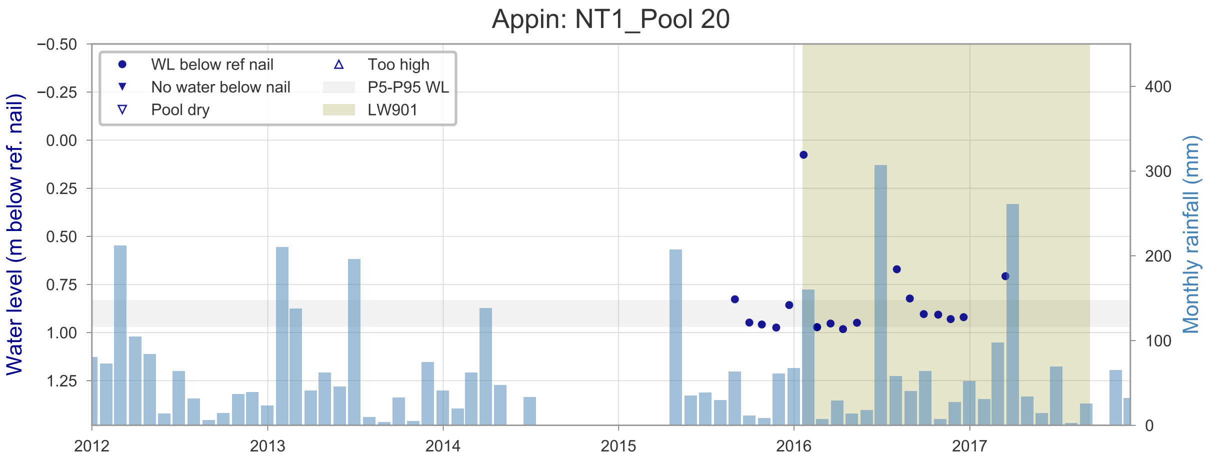

Appin: NT1_Pool 40
DO (%)
LW901
Dissolved Oxygen (%)
Monthly rainfall (mm)
140
120
100
80
60
40
20
0
400
300
200
100
0
2012
2013
2014
2015
2016
2017


Appin: NT1_Pool 30
WL below ref nail
No water below nail
Pool dry
Too high
P5-P95 WL
LW901
Water level (m below ref. nail)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

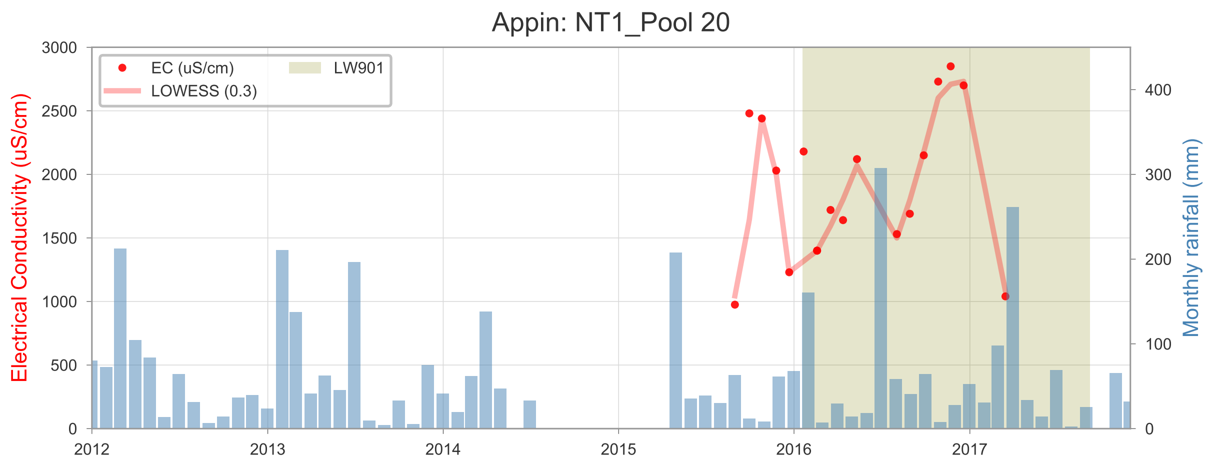

Appin: NT1_Pool 30
EC (uS/cm)
LOWESS (0.3)
LW901
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017


Appin: NT1_Pool 30
pH
LW901
pH units
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

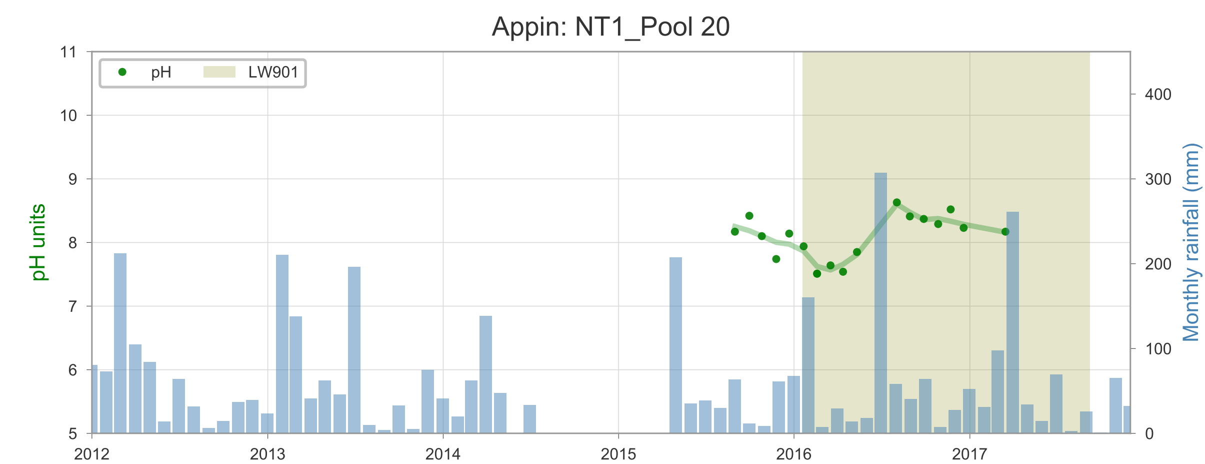

Appin: NT1_Pool 30
DO (%)
LW901
Dissolved Oxygen (%)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017



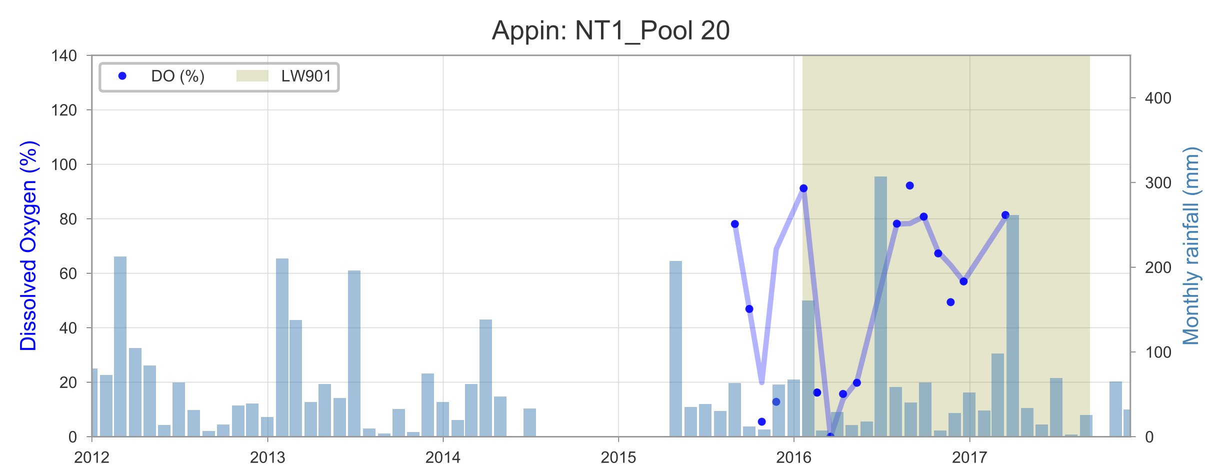
Appin: NT1_Pool 20
WL below ref nail
No water below nail
Pool dry
Too high
P5-P95 WL
LW901
Water level (m below ref. nail)
Monthly rainfall (mm)



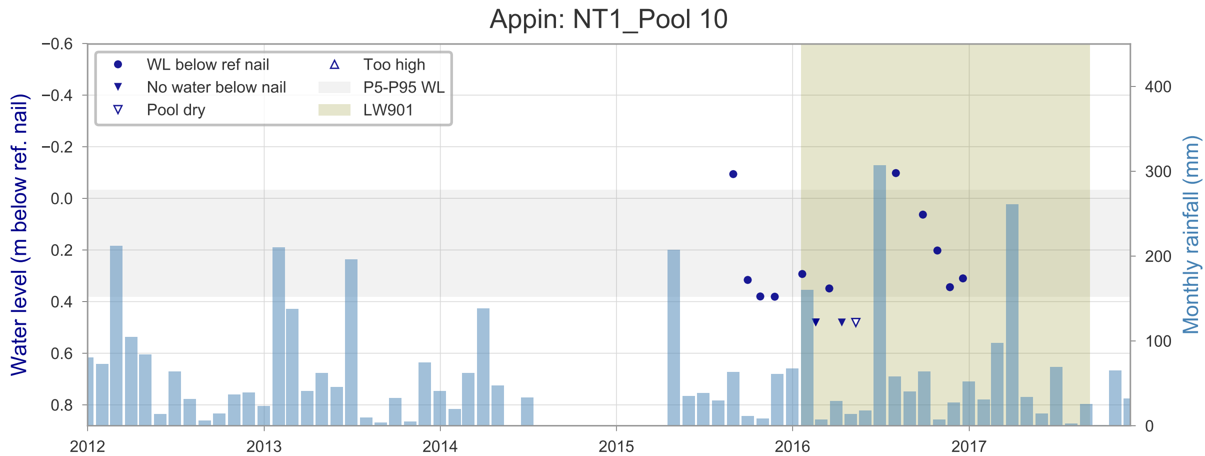
Appin: NT1_Pool 20
EC (uS/cm)
LOWESS (0.3)
LW901
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)

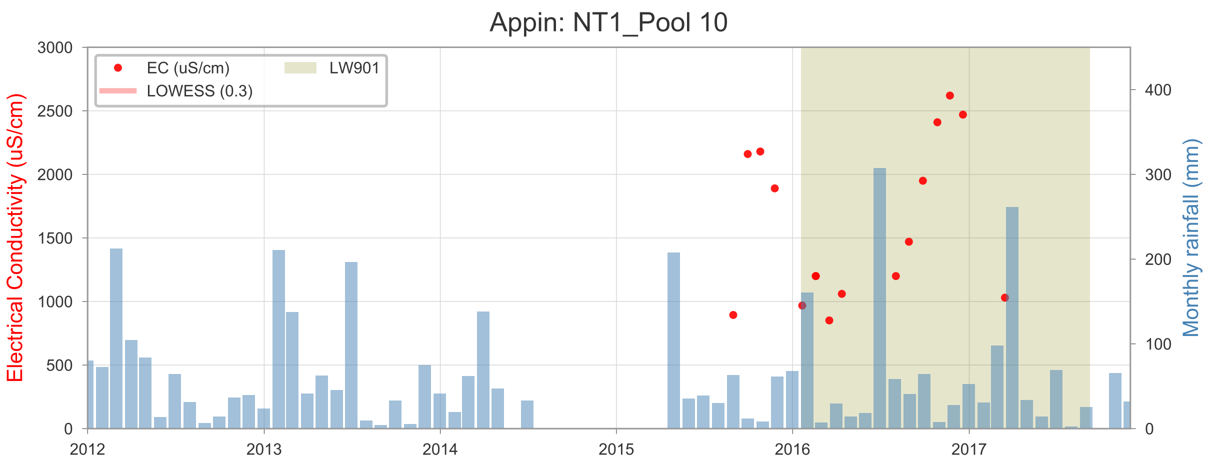


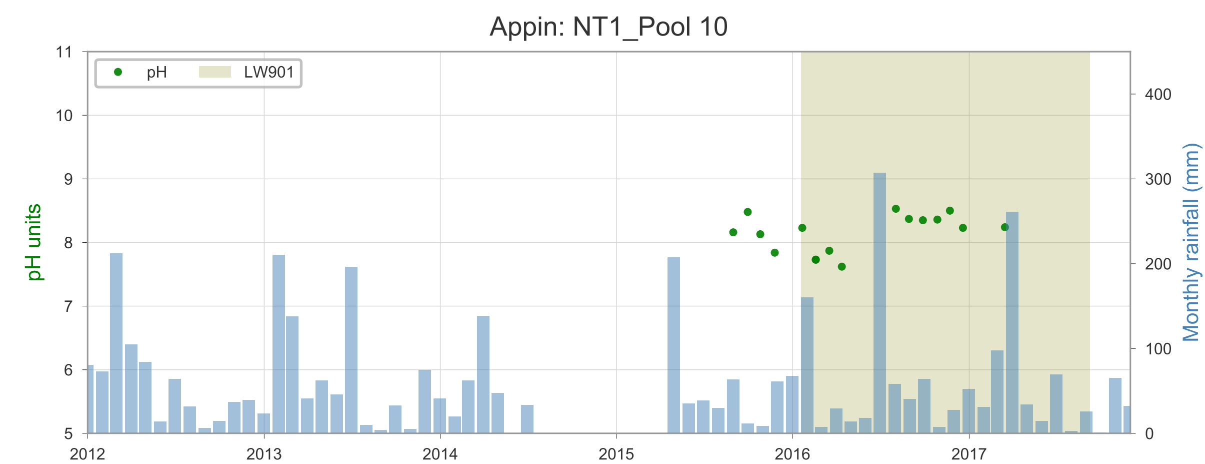
Appin: NT1_Pool 20
pH
LW901
pH units
Monthly rainfall (mm)

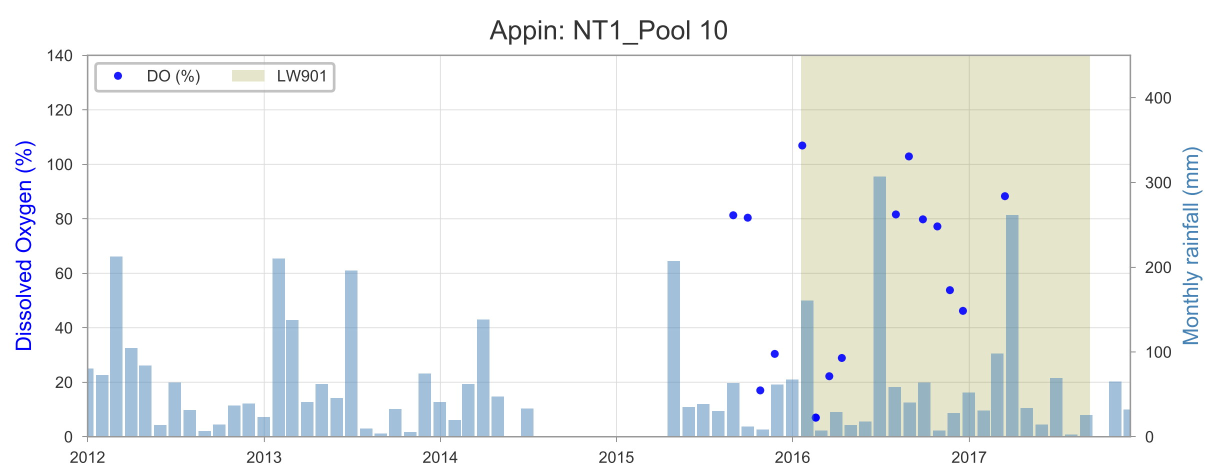


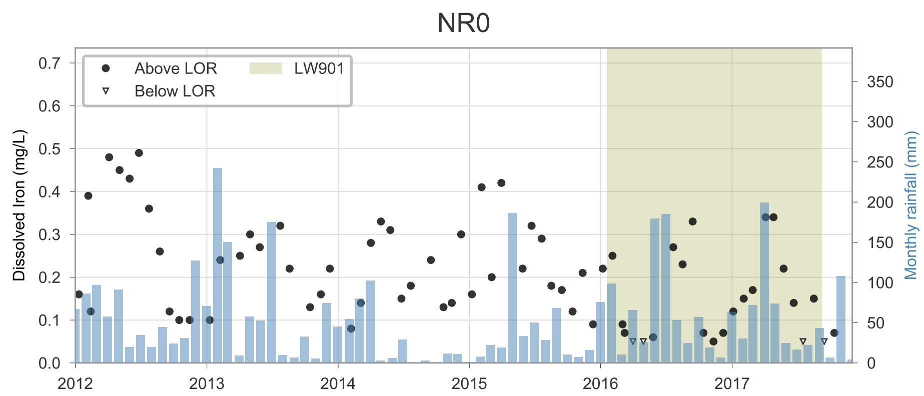
Appin: NT1_Pool 20
DO (%)
LW901
Dissolved Oxygen (%)
Monthly rainfall (mm)

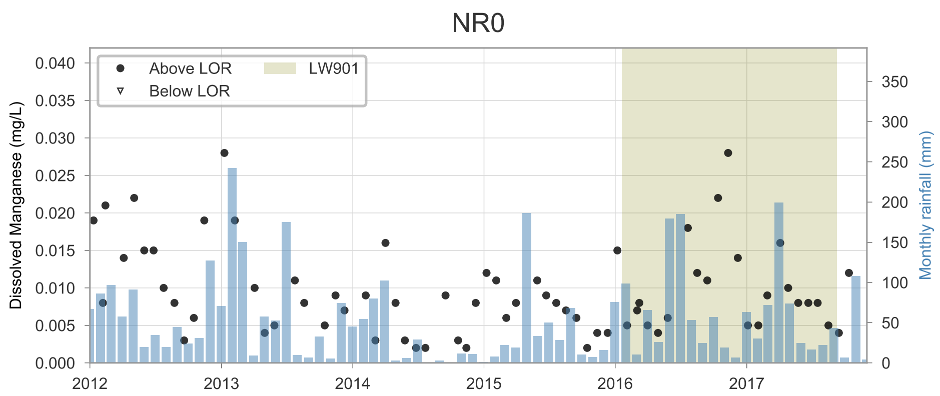

Appin: NT1_Pool 10
WL below ref nail
No water below nail
Pool dry
Too high
P5-P95 WL
LW901
Water level (m below ref. nail)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

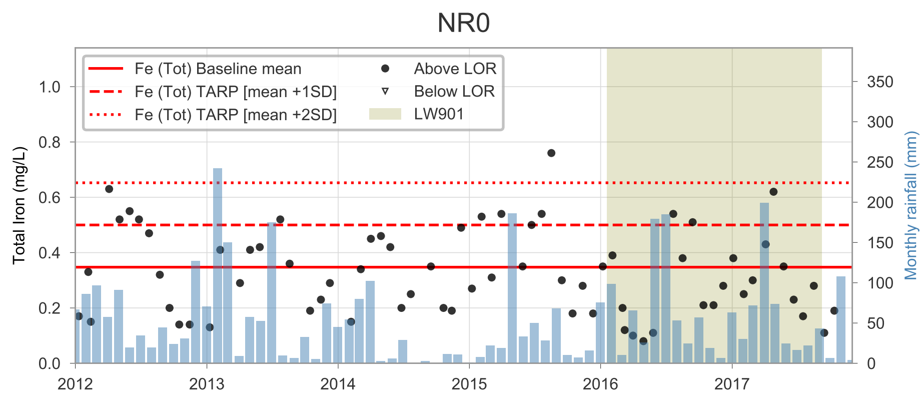

Appin: NT1_Pool 10
EC (uS/cm)
LOWESS (0.3)
LW901
Electrical Conductivity (uS/cm)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

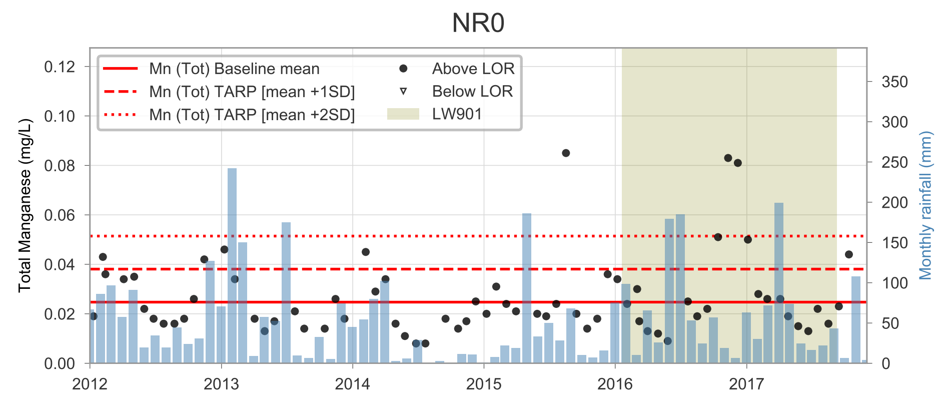

Appin: NT1_Pool 10
pH
LW901
pH units
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

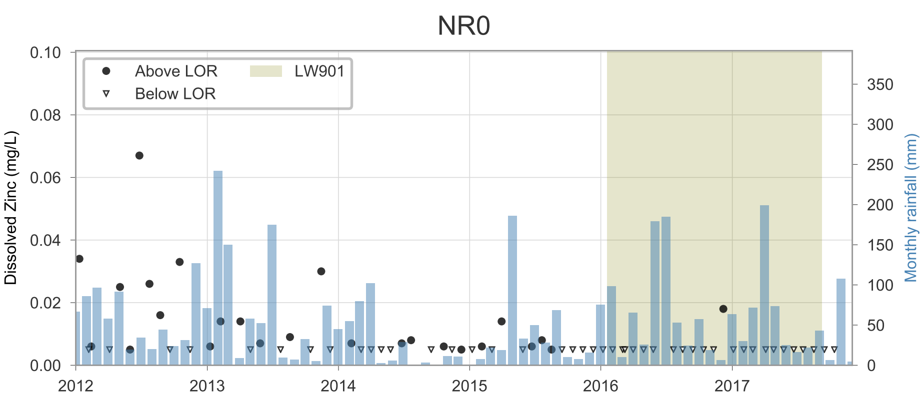

Appin: NT1_Pool 10
DO (%)
LW901
Dissolved Oxygen (%)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

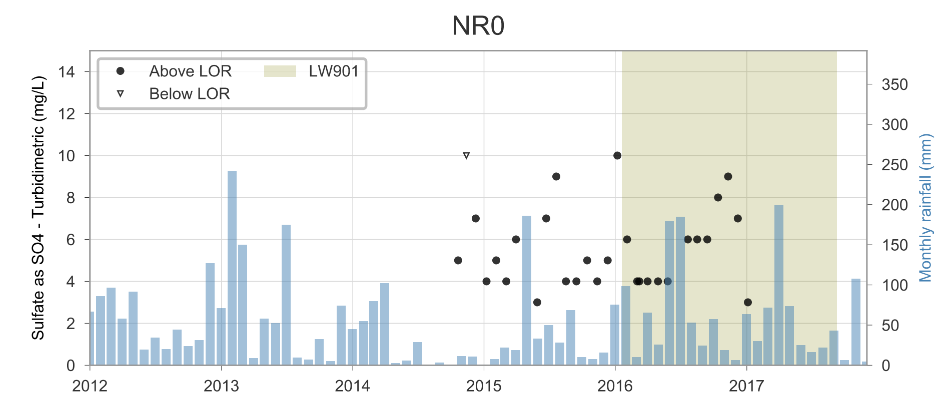

NR0
Above LOR
Below LOR
LW901
Dissolved Iron (mg/L)
Monthly rainfall (mm)

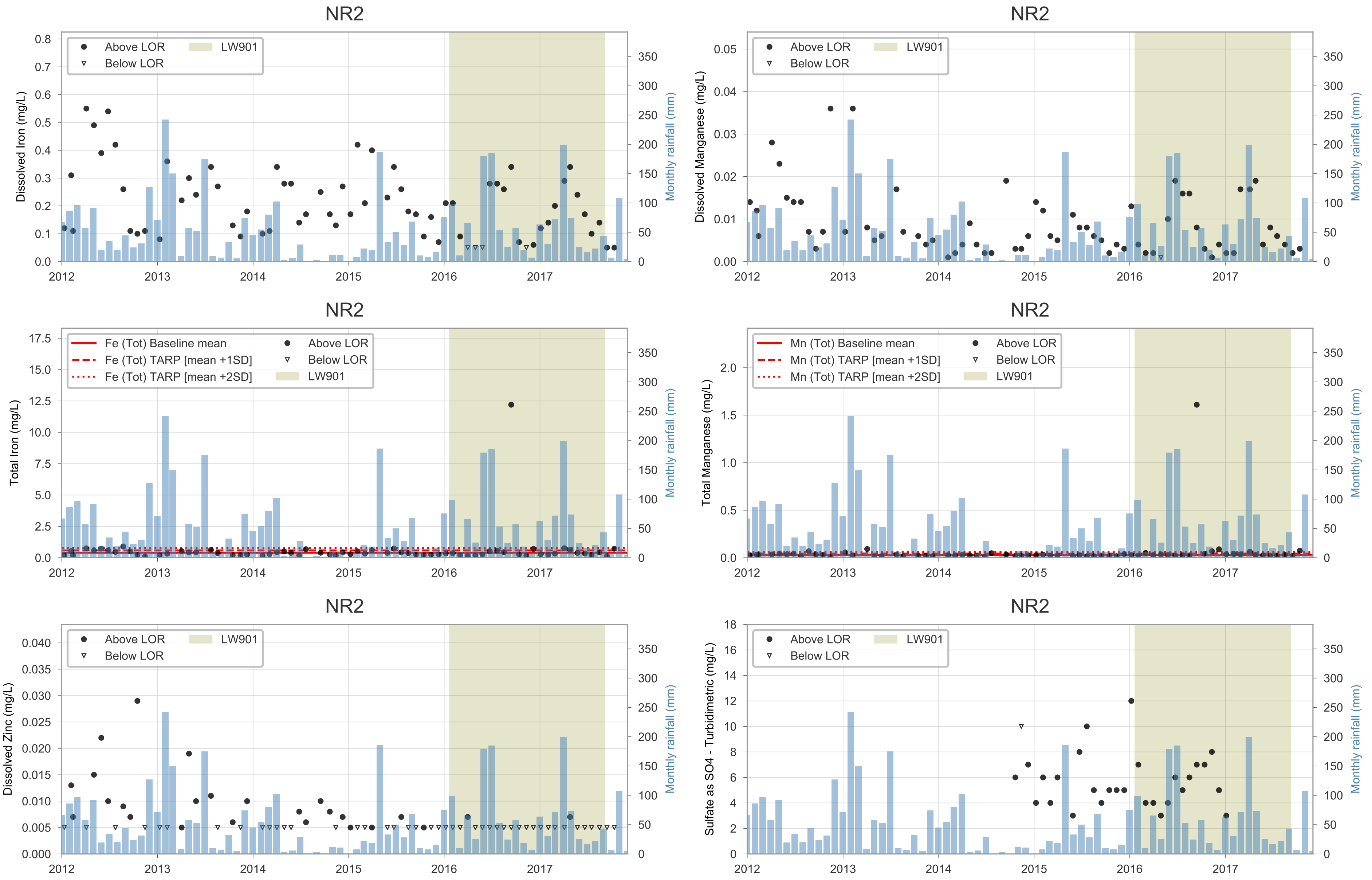

NR0
Above LOR
Below LOR
LW901
Dissolved Manganese (mg/L)
Monthly rainfall (mm)

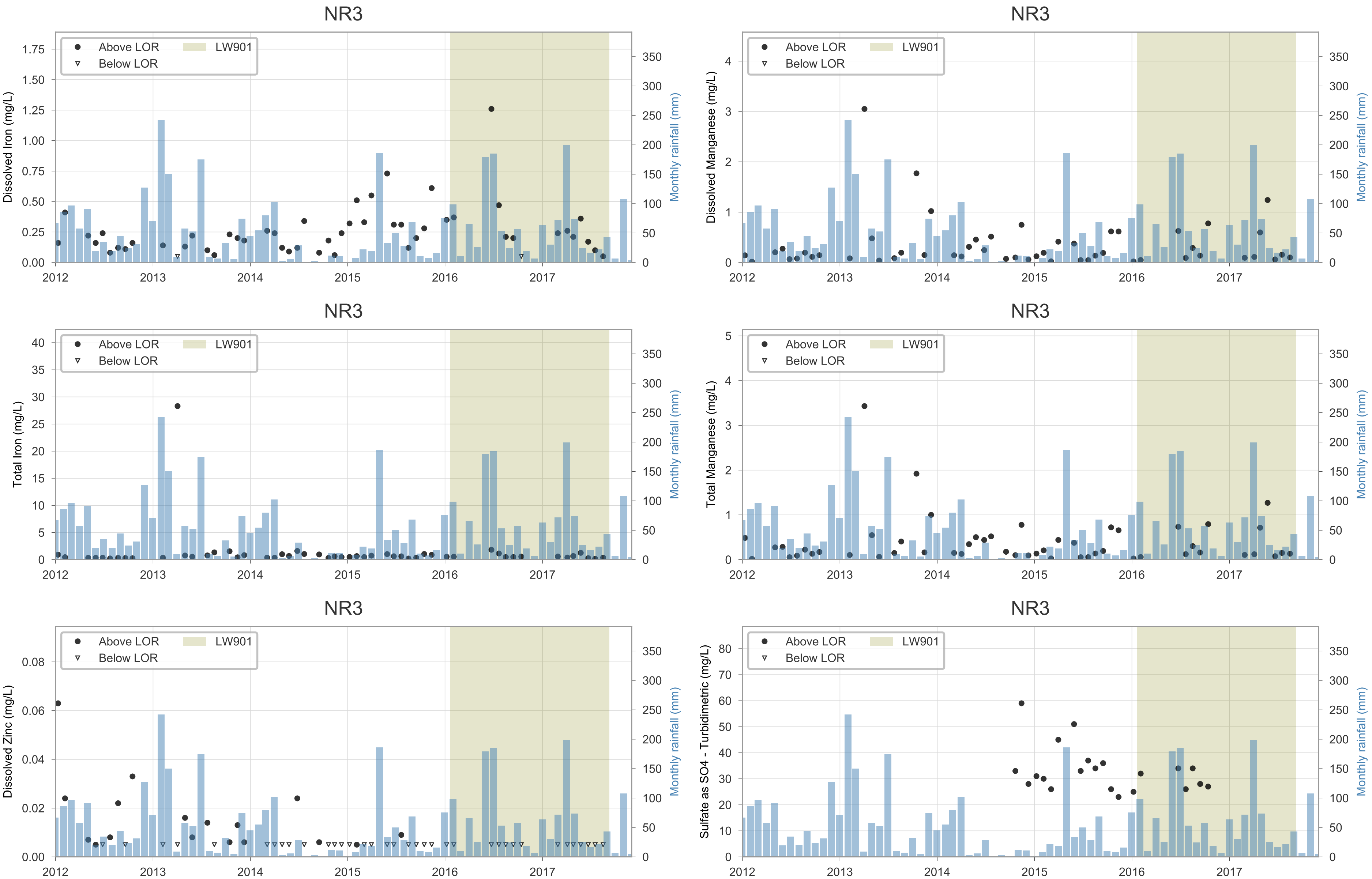

NR0
Fe (Tot) Baseline mean
Fe (Tot) TARP [mean +1SD]
Fe (Tot) TARP [mean +2SD]
Above LOR
Below LOR
LW901
Total Iron (mg/L)
Monthly rainfall (mm)

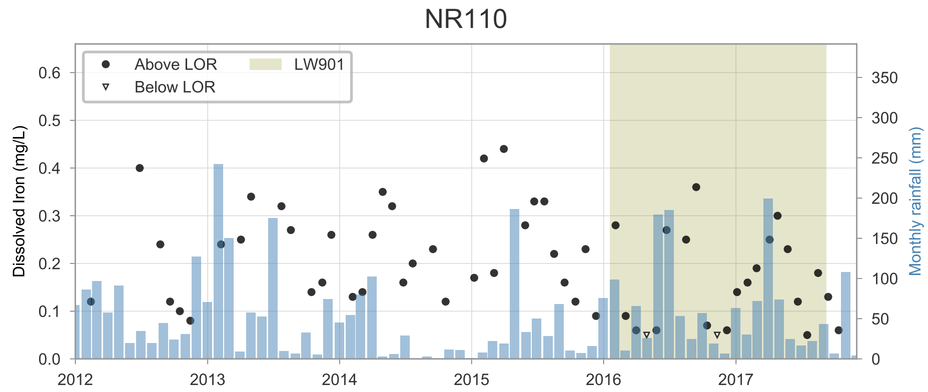

NR0
Mn (Tot) Baseline mean
Mn (Tot) TARP [mean +1SD]
Mn (Tot) TARP [mean +2SD]
Above LOR
Below LOR
LW901
Total Manganese (mg/L)
Monthly rainfall (mm)

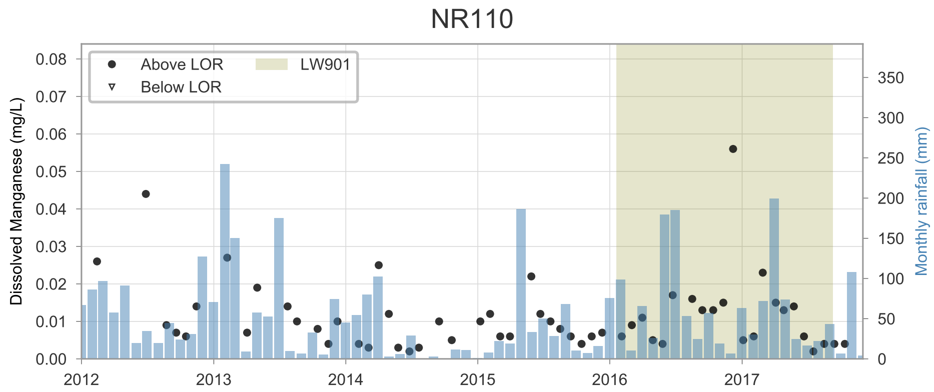

NR0
Above LOR
Below LOR
LW901
Dissolved Zinc (mg/L)
Monthly rainfall (mm)

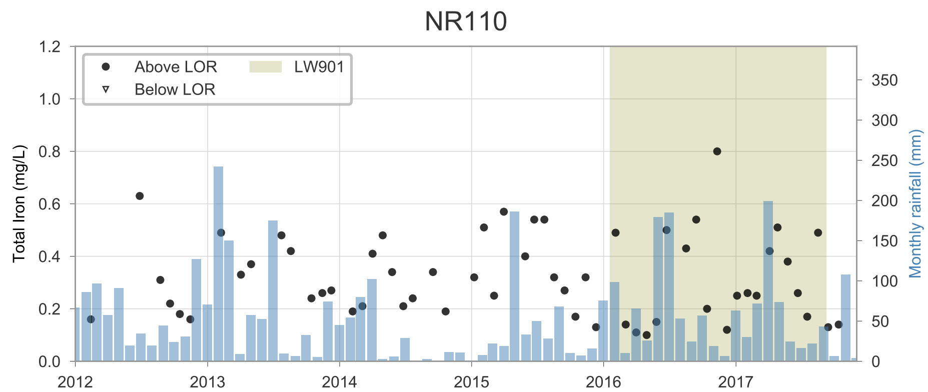

NR0
Above LOR
Below LOR
LW901
Sulfate as SO4 - Turbidimetric (mg/L)
Monthly rainfall (mm)

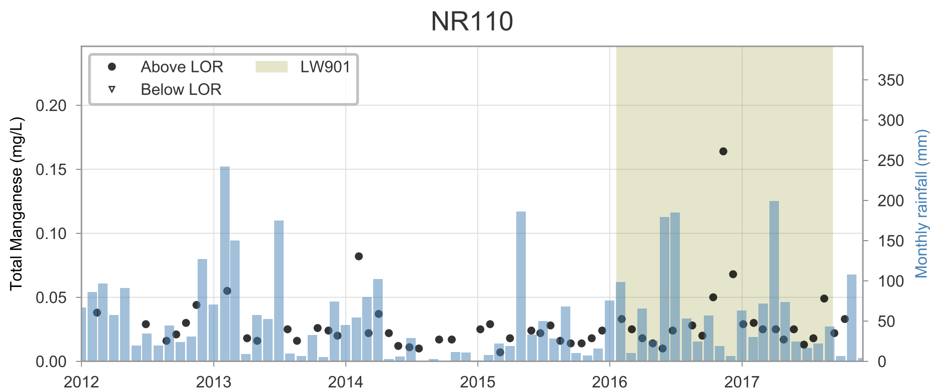

NR2
Dissolved Iron (mg/L)
Monthly rainfall (mm)
Above LOR
Below LOR
LW901
NR2
Dissolved Manganese (mg/L)
Monthly rainfall (mm)
Above LOR
Below LOR
LW901
NR2
Total Iron (mg/L)
Monthly rainfall (mm)
Fe (Tot) Baseline mean
Fe (Tot) TARP [mean +1SD]
Fe (Tot) TARP [mean +2SD]
Above LOR
Below LOR
LW901
NR2
Total Manganese (mg/L)
Monthly rainfall (mm)
Mn (Tot) Baseline mean
Mn (Tot) TARP [mean +1SD]
Mn (Tot) TARP [mean +2SD]
Above LOR
Below LOR
LW901
NR2
Dissolved Zinc (mg/L)
Monthly rainfall (mm)
Above LOR
Below LOR
LW901
NR2
Sulfate as SO4 - Turbidimetric (mg/L)
Monthly rainfall (mm)
Above LOR
Below LOR
LW901
2012
2013
2014
2015
2016
2017

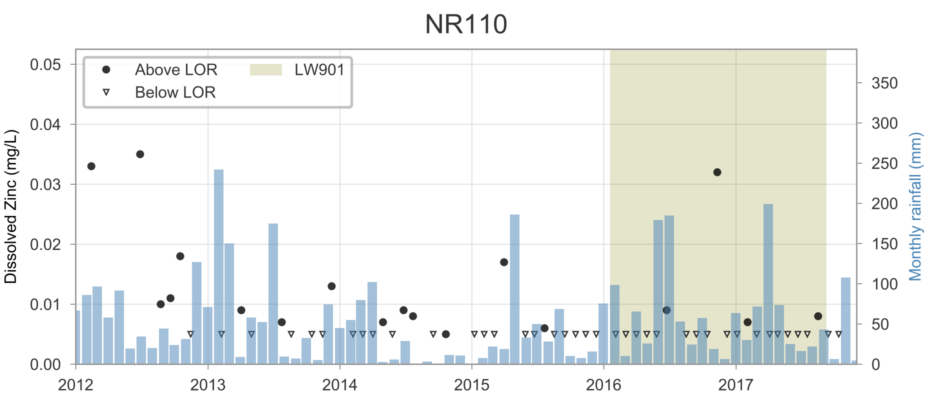

NR3
Above LOR
Below LOR
LW901
Dissolved Iron (mg/L)
Monthly rainfall (mm)
NR3
Dissolved Manganese (mg/L)
Monthly rainfall (mm)
NR3
Total Iron (mg/L)
Monthly rainfall (mm)
NR3
Total Manganese (mg/L)
Monthly rainfall (mm)
NR3
Dissolved Zinc (mg/L)
Monthly rainfall (mm)
NR3
Sulfate as SO4 - Turbidimetric (mg/L)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

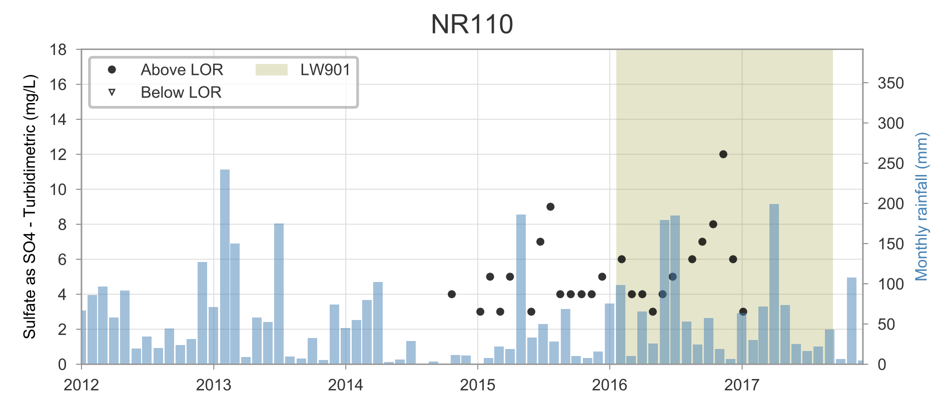

NR110
Above LOR
Below LOR
LW901
Dissolved Iron (mg/L)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

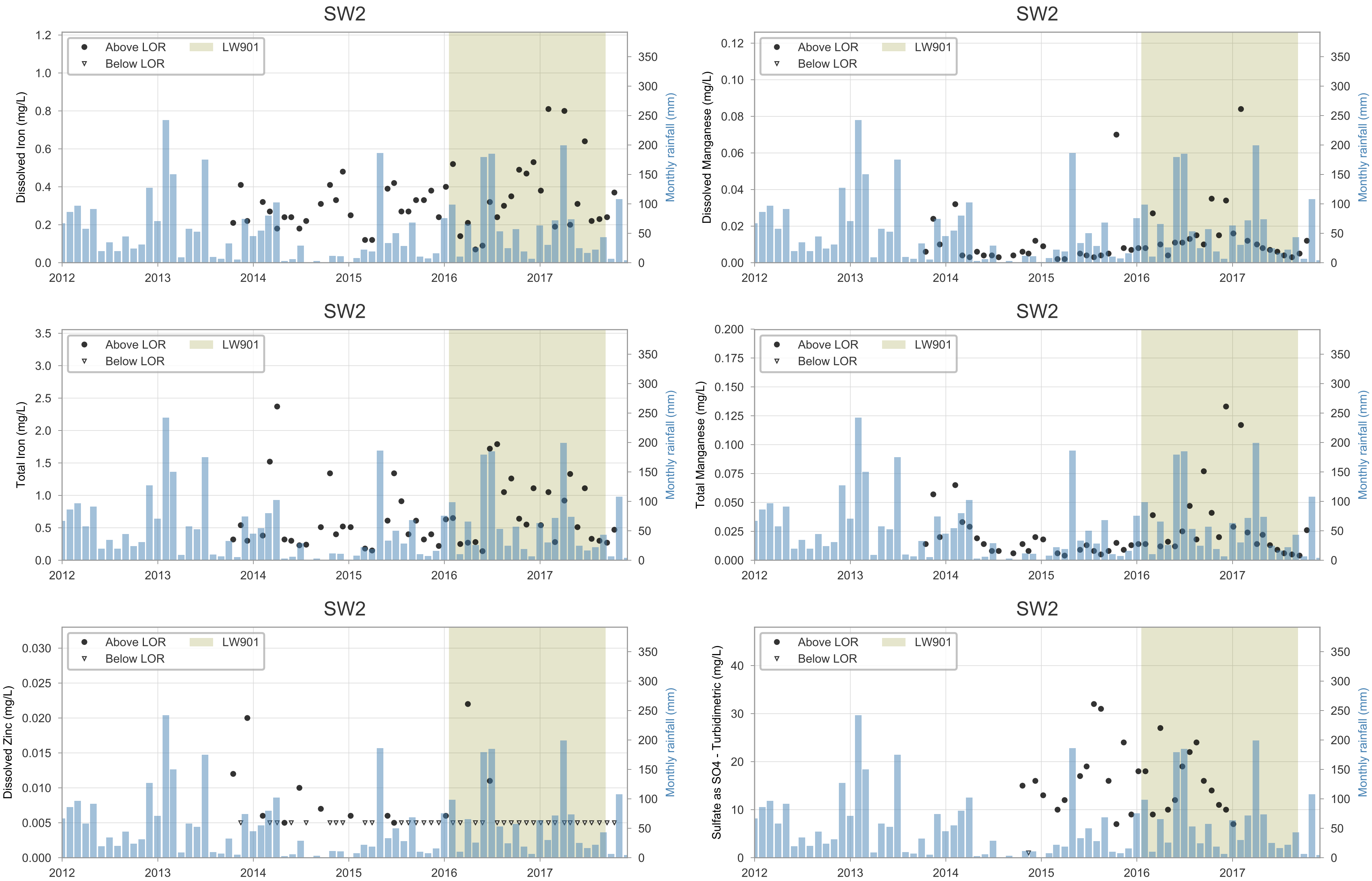

NR110
Above LOR
Below LOR
LW901
Dissolved Manganese (mg/L)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

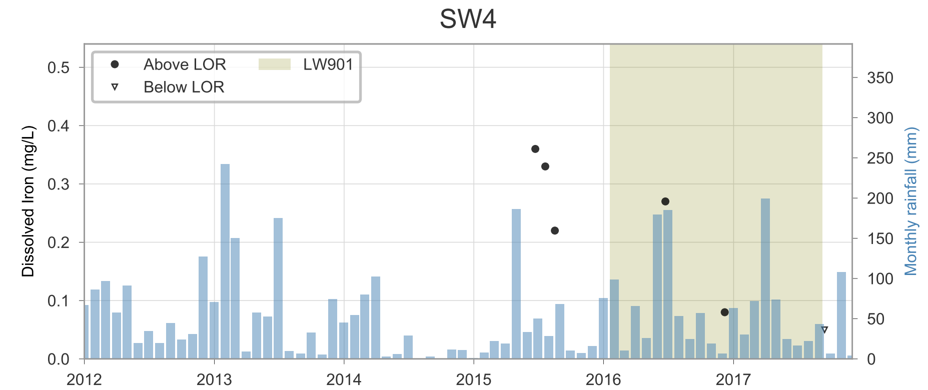

NR110
Above LOR
Below LOR
LW901
Total Iron (mg/L)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

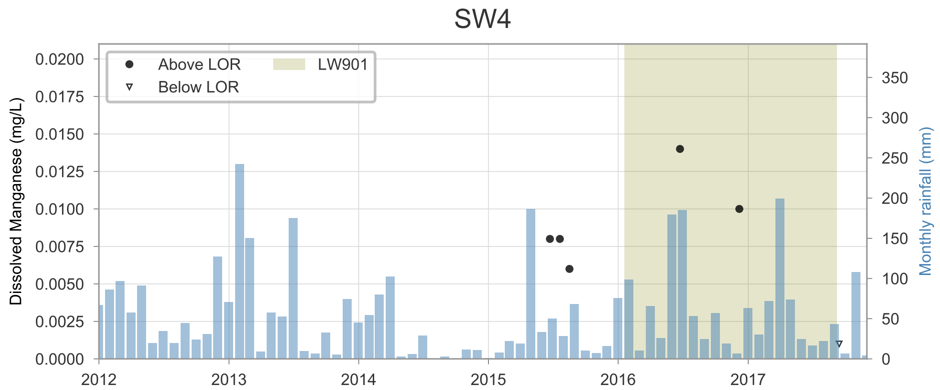

NR110
Above LOR
Below LOR
LW901
Total Manganese (mg/L)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

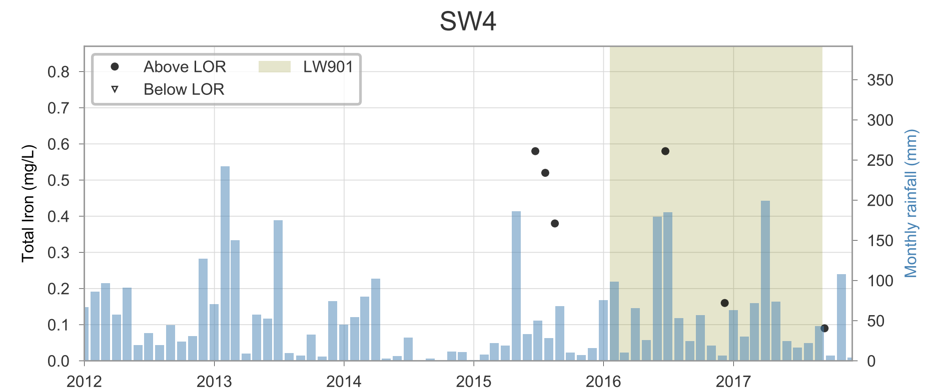

NR110
Above LOR
Below LOR
LW901
Dissolved Zinc (mg/L)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

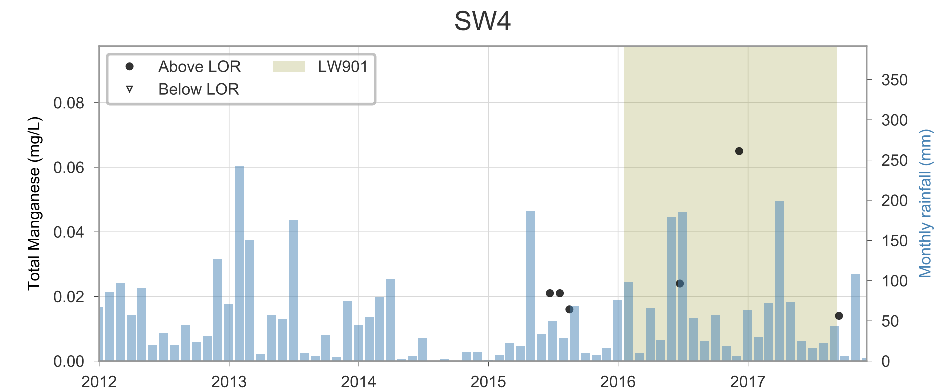

NR110
Above LOR
Below LOR
LW901
Sulfate as SO4 - Turbidimetric (mg/L)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

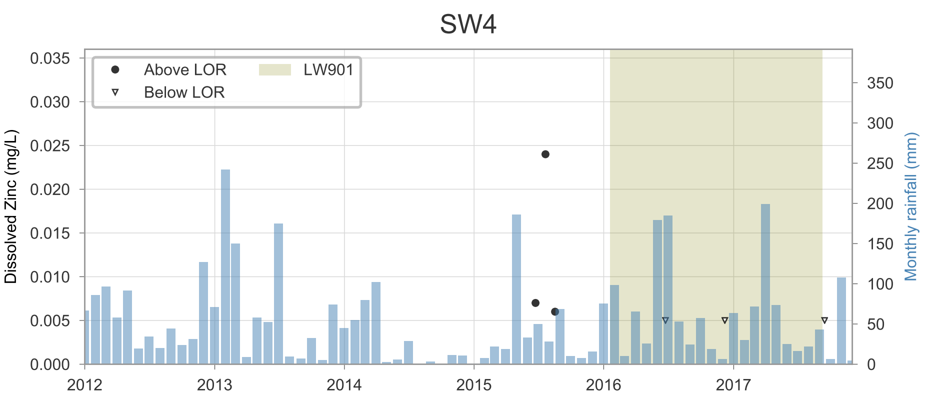

SW2
Dissolved Iron (mg/L)
Monthly rainfall (mm)
Above LOR
Below LOR
LW901
SW2
Dissolved Manganese (mg/L)
Monthly rainfall (mm)
SW2
Total Iron (mg/L)
Monthly rainfall (mm)
SW2
Total Manganese (mg/L)
Monthly rainfall (mm)
SW2
Dissolved Zinc (mg/L)
Monthly rainfall (mm)
SW2
Sulfate as SO4 - Turbidimetric (mg/L)
Monthly rainfall (mm)
2012
2013
2014
2015
2016
2017

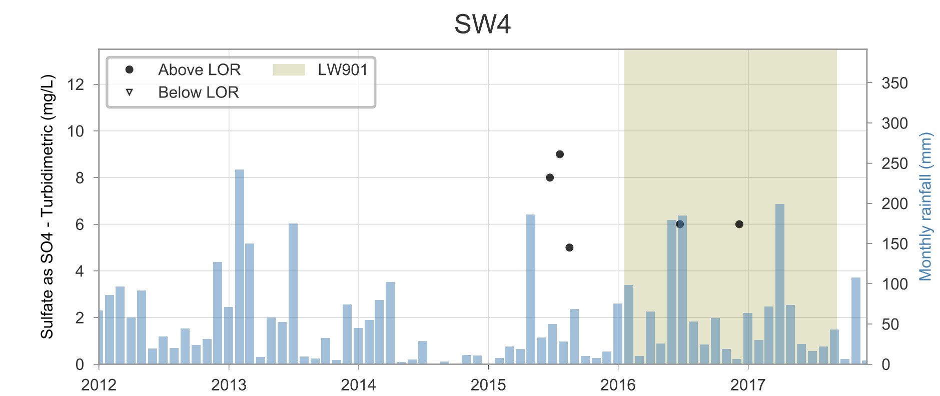

SW4
Above LOR
Below LOR
LW901
Dissolved Iron (mg/L)
Monthly rainfall (mm)
0.0
0.1
0.2
0.3
0.4
0.5
0
50
100
150
200
250
300
350
2012
2013
2014
2015
2016
2017


SW4
Above LOR
Below LOR
LW901
Dissolved Manganese (mg/L)
Monthly rainfall (mm)
0.0000
0.0025
0.0050
0.0075
0.0100
0.0125
0.0150
0.0175
0.0200
0
50
100
150
200
250
300
350
2012
2013
2014
2015
2016
2017


SW4
Above LOR
Below LOR
LW901
Total Iron (mg/L)
Monthly rainfall (mm)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
50
100
150
200
250
300
350
2012
2013
2014
2015
2016
2017

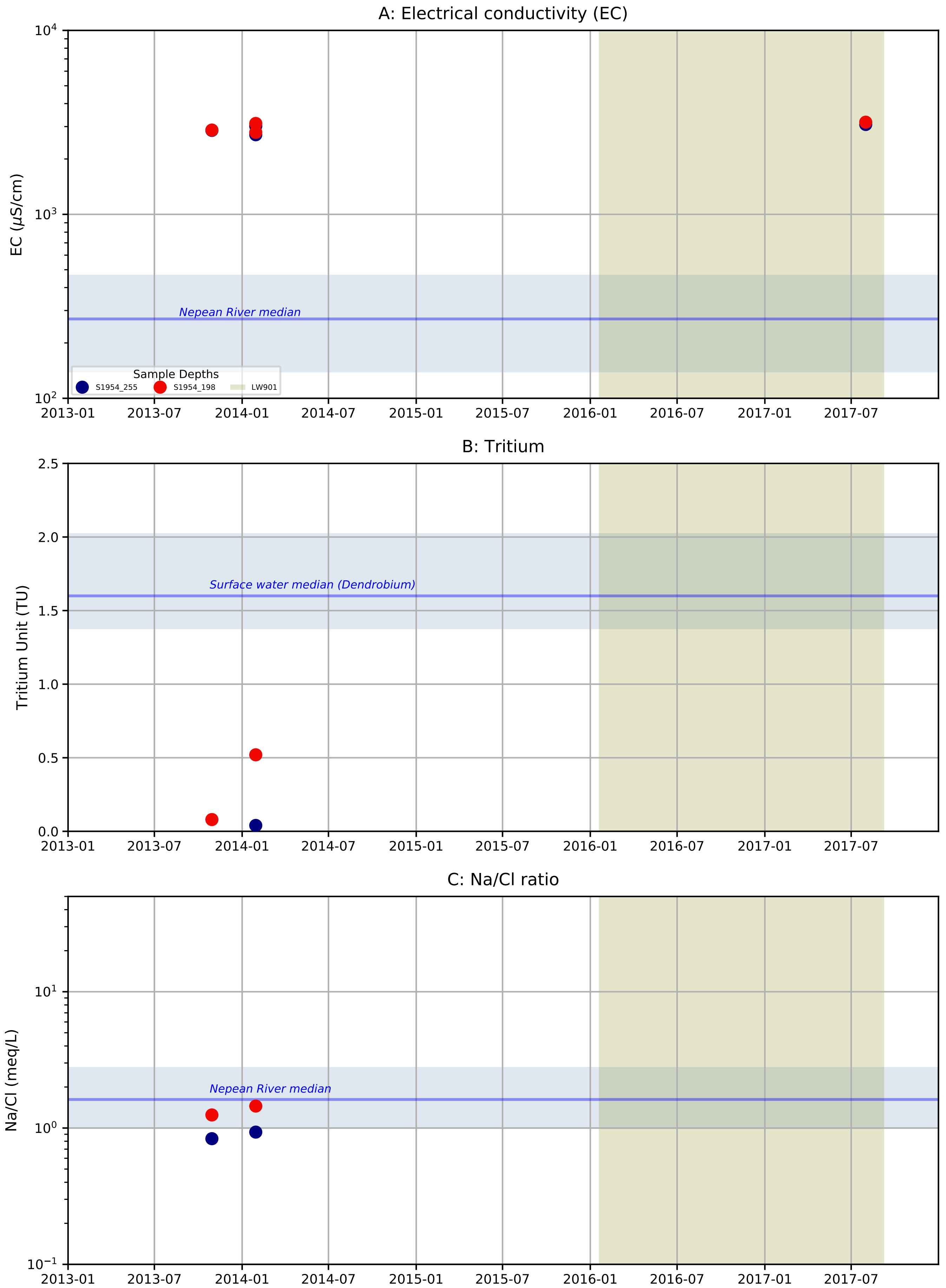

SW4
Above LOR
Below LOR
LW901
Total Manganese (mg/L)
Monthly rainfall (mm)
0.00
0.02
0.04
0.06
0.08
0
50
100
150
200
250
300
350
2012
2013
2014
2015
2016
2017


SW4
Above LOR
Below LOR
LW901
Dissolved Zinc (mg/L)
Monthly rainfall (mm)
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0
50
100
150
200
250
300
350
2012
2013
2014
2015
2016
2017

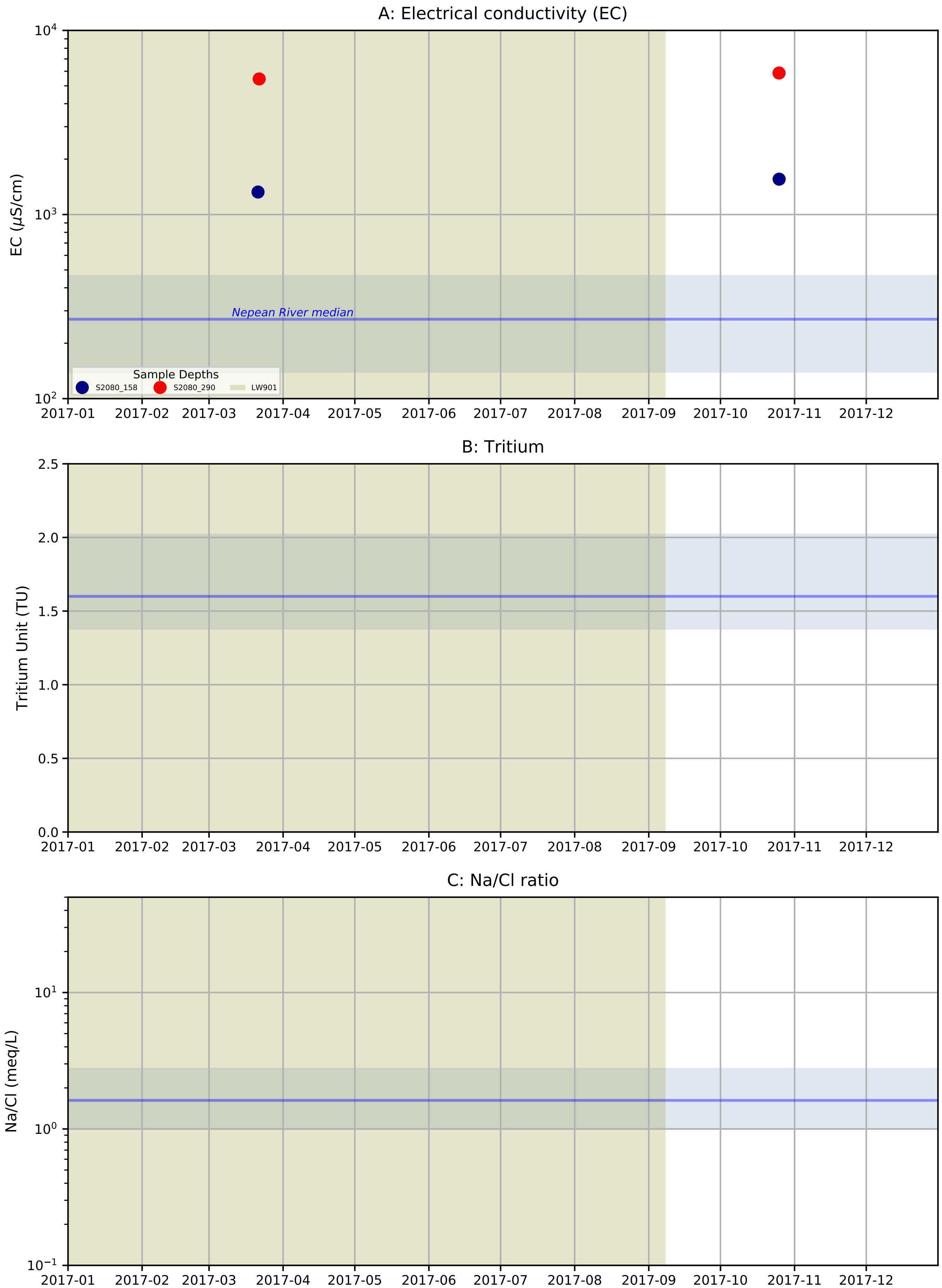

SW4
Above LOR
Below LOR
LW901
Sulfate as SO4 - Turbidimetric (mg/L)
Monthly rainfall (mm)
0
2
4
6
8
10
12
0
50
100
150
200
250
300
350
2012
2013
2014
2015
2016
2017

APPENDIX 2 – Groundwater chemistry time-series plots

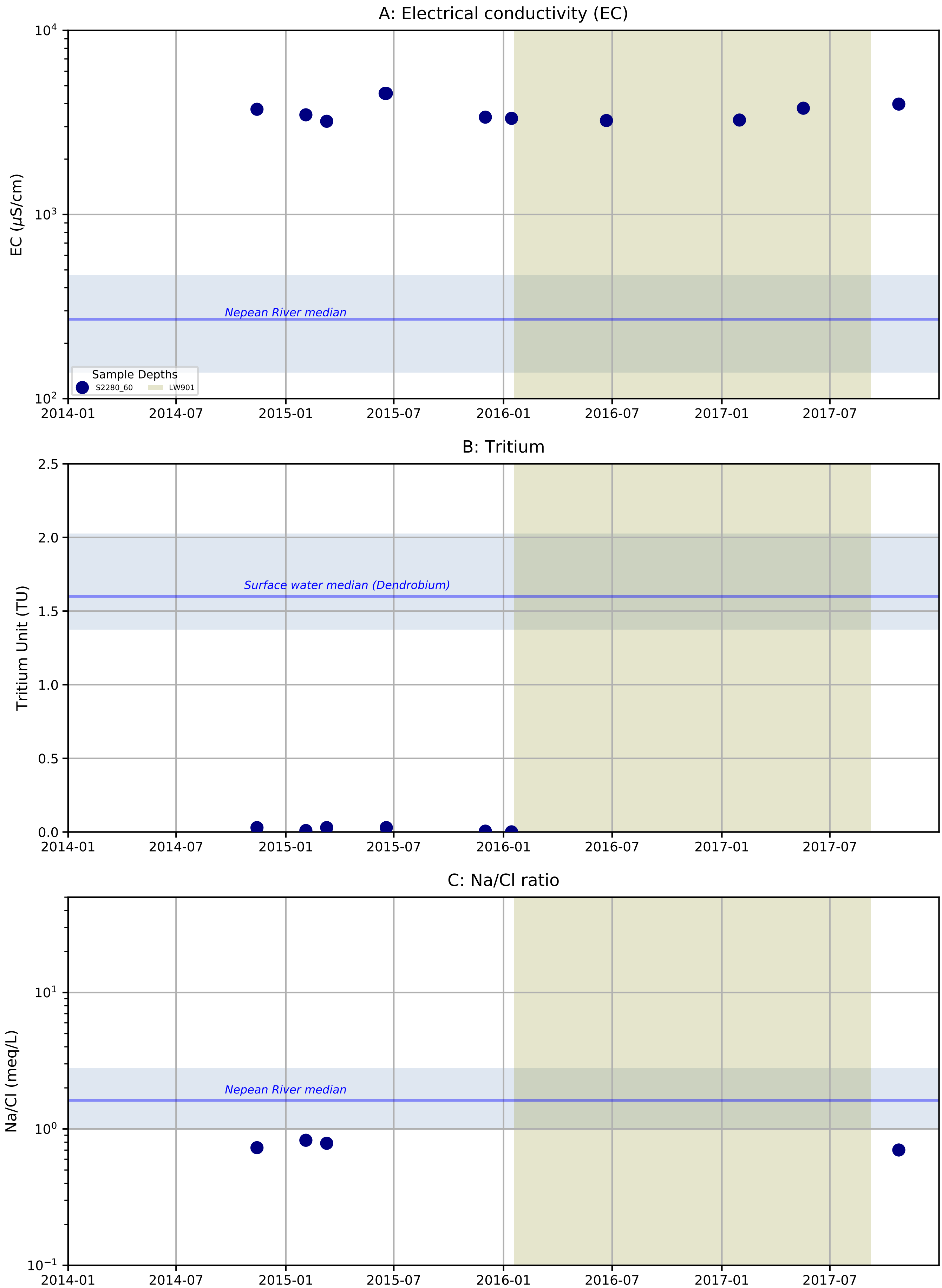
Groundwater chemistry: Appin Bore S1954



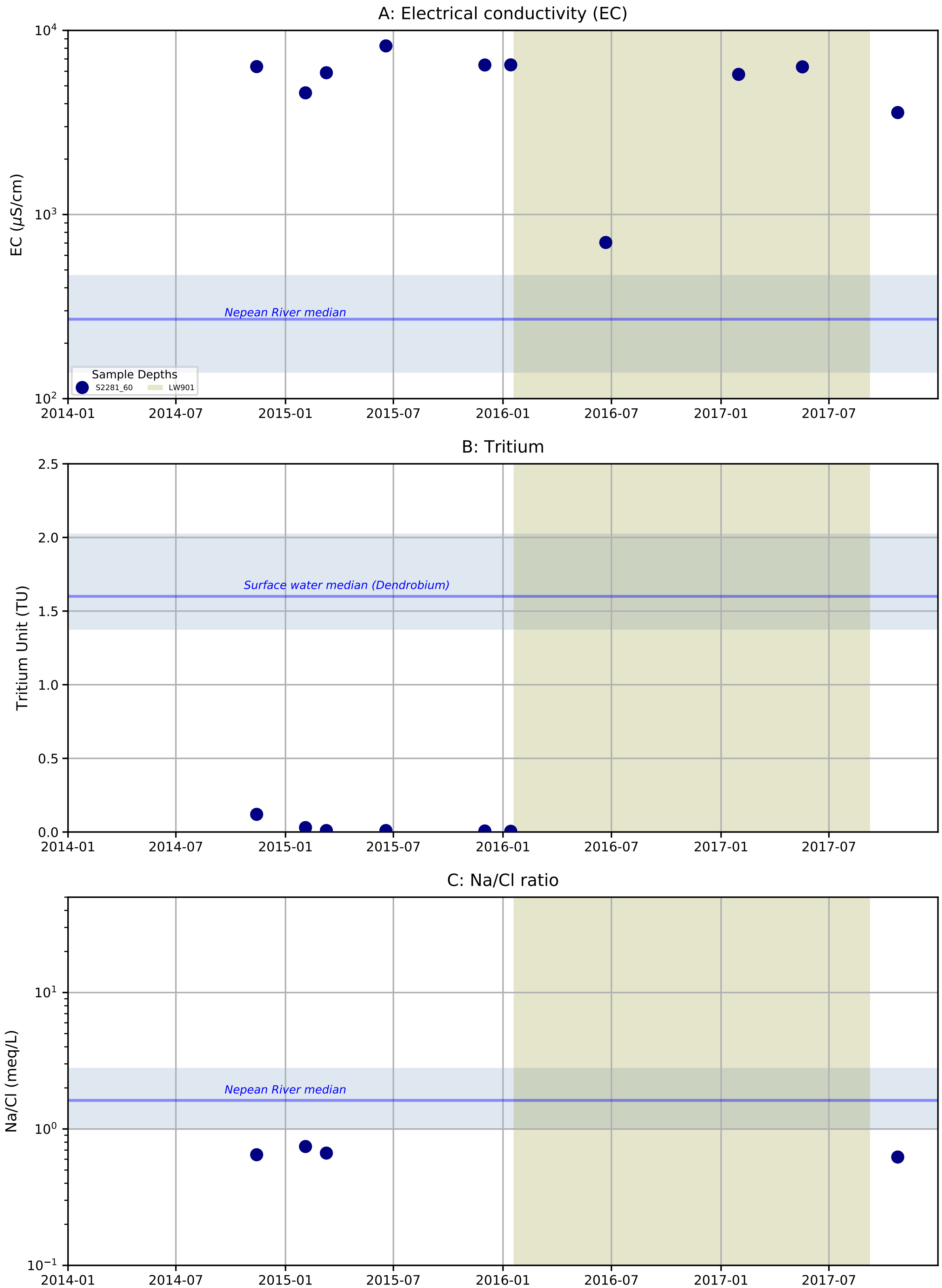
Groundwater chemistry: Appin Bore S2080



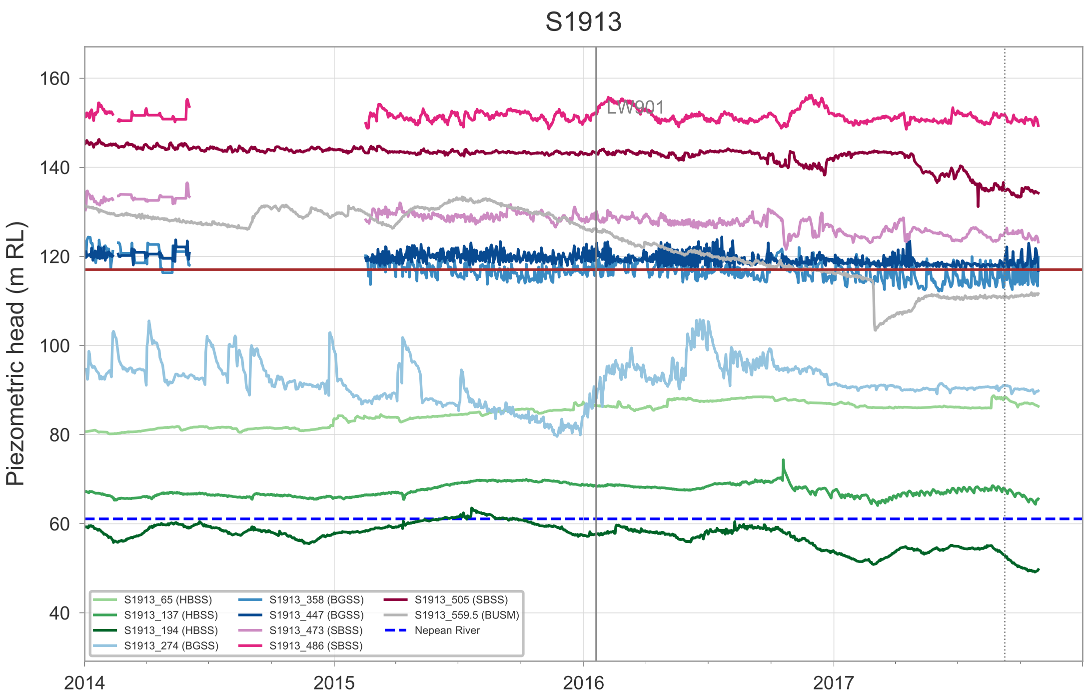
Groundwater chemistry: Appin Bore S2280



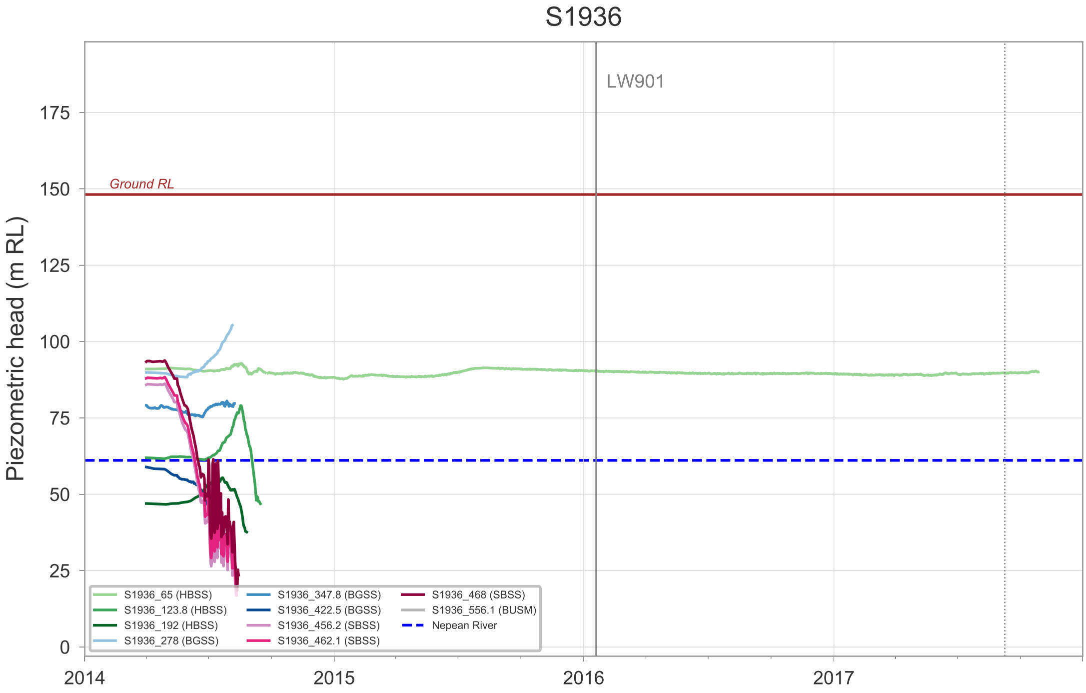
Groundwater chemistry: Appin Bore S2281



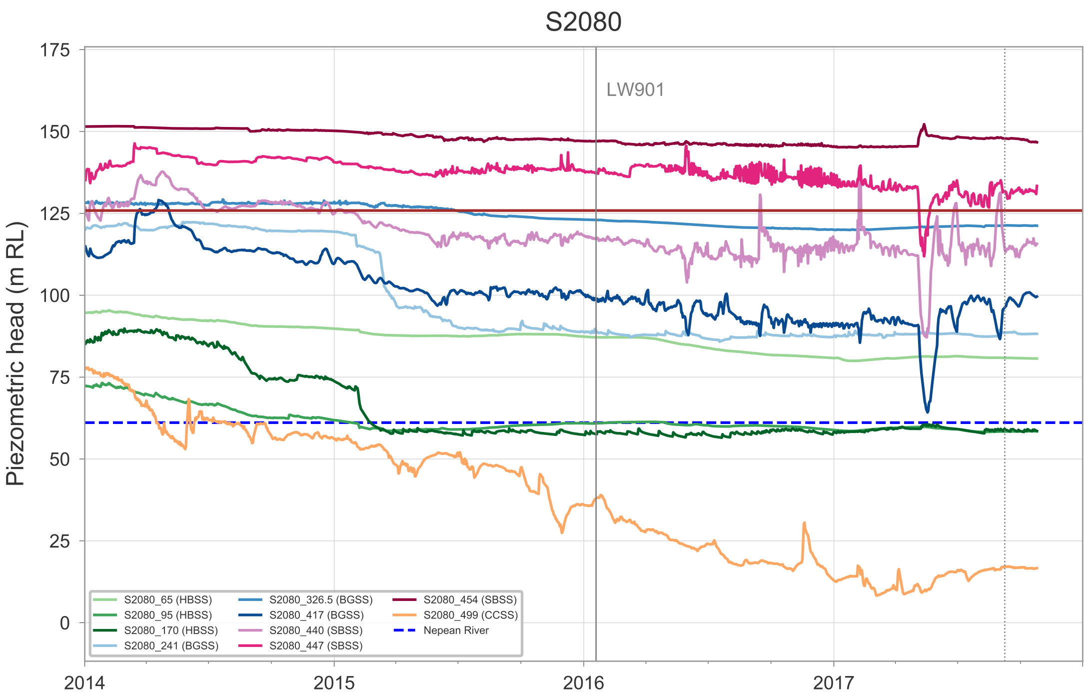
APPENDIX 3 – Surface water chemistry time-series plots



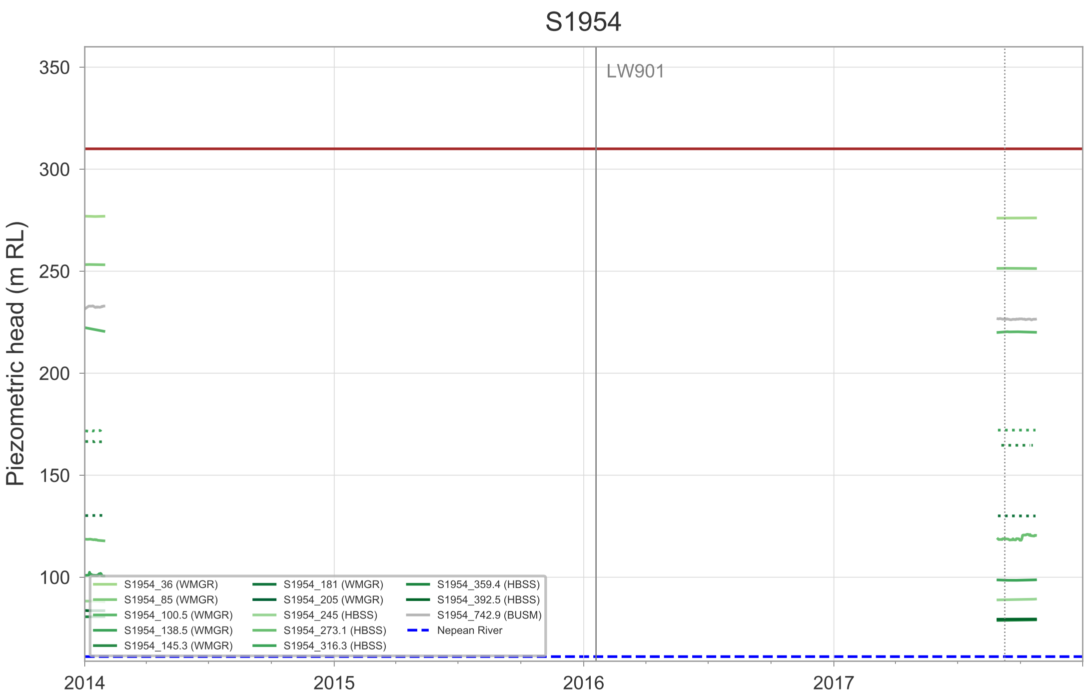
S1913
Piezometric head (m RL)
160
140
120
100
80
60
40
2014
2015
2016
2017
LW901
S1913_65 (HBSS)
S1913_137 (HBSS)
S1913_194 (HBSS)
S1913_274 (BGSS)
S1913_358 (BGSS)
S1913_447 (BGSS)
S1913_473 (SBSS)
S1913_486 (SBSS)
S1913_505 (SBSS)
S1913_559.5 (BUSM)
Nepean River


S1936
LW901
Ground RL
Piezometric head (m RL)
175
150
125
100
75
50
25
0
2014
2015
2016
2017
S1936_65 (HBSS)
S1936_123.8 (HBSS)
S1936_192 (HBSS)
S1936_278 (BGSS)
S1936_347.8 (BGSS)
S1936_422.5 (BGSS)
S1936_456.2 (SBSS)
S1936_462.1 (SBSS)
S1936_468 (SBSS)
S1936_556.1 (BUSM)
Nepean River

S1941
LW901
Piezometric head (m RL)
180
160
140
120
100
80
60
40
2014
2015
2016
2017
S1941_65 (HBSS)
S1941_126.5 (HBSS)
S1941_201.6 (HBSS)
S1941_284.3 (BGSS)
S1941_355.7 (BGSS)
S1941_432 (BGSS)
S1941_463 (SBSS)
S1941_472.8 (SBSS)
S1941_487.5 (SBSS)
S1941_555.4 (BUSM)
S1941_596 (WWSM)
Nepean River

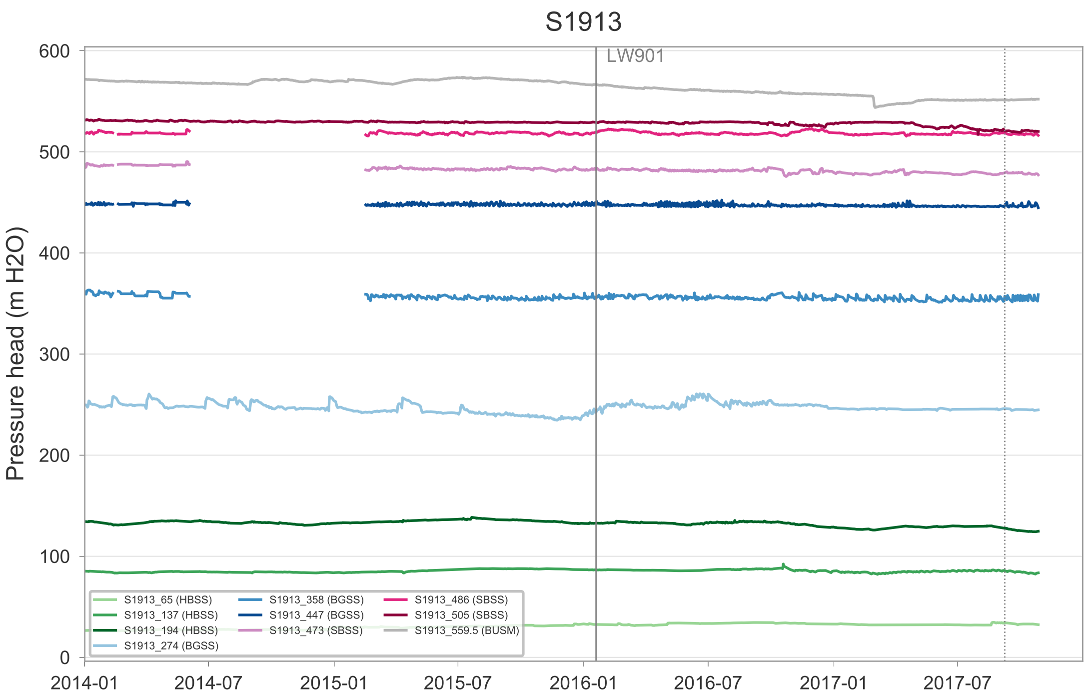


S2080
LW901
Piezometric head (m RL)
175
150
125
100
75
50
25
0
2014
2015
2016
2017
S2080_65 (HBSS)
S2080_95 (HBSS)
S2080_170 (HBSS)
S2080_241 (BGSS)
S2080_326.5 (BGSS)
S2080_417 (BGSS)
S2080_440 (SBSS)
S2080_447 (SBSS)
S2080_454 (SBSS)
S2080_499 (CCSS)
Nepean River

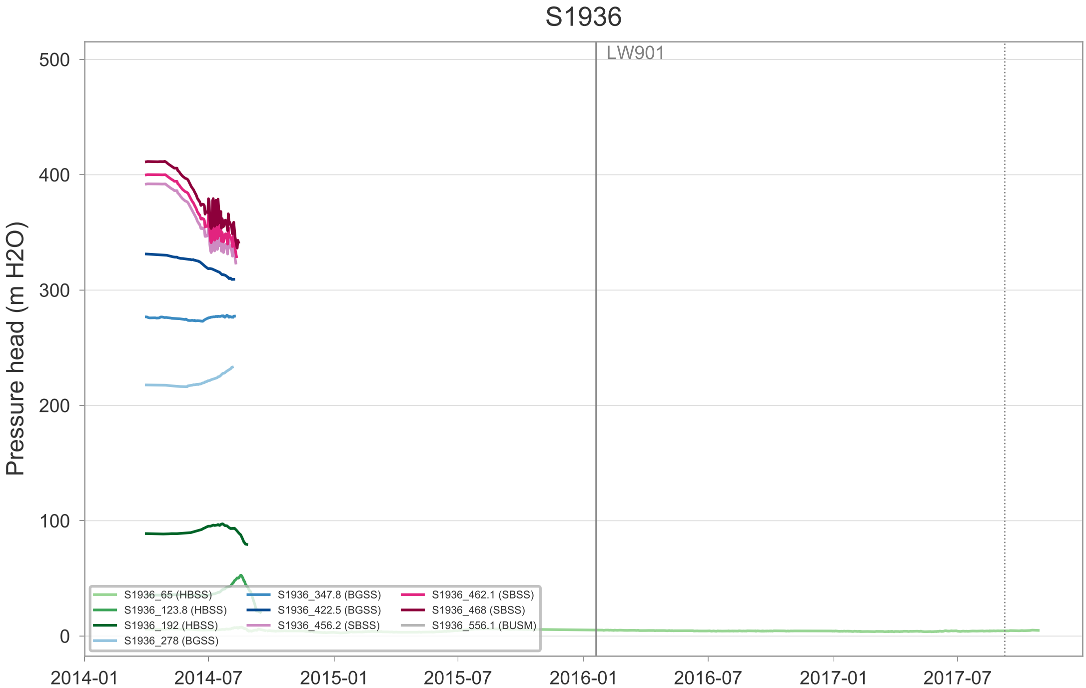

S1954
Piezometric head (m RL)
350
300
250
200
150
100
2014
2015
2016
2017
LW901
S1954_36 (WMGR)
S1954_85 (WMGR)
S1954_100.5 (WMGR)
S1954_138.5 (WMGR)
S1954_145.3 (WMGR)
S1954_181 (WMGR)
S1954_205 (WMGR)
S1954_245 (HBSS)
S1954_273.1 (HBSS)
S1954_316.3 (HBSS)
S1954_359.4 (HBSS)
S1954_392.5 (HBSS)
S1954_742.9 (BUSM)
Nepean River

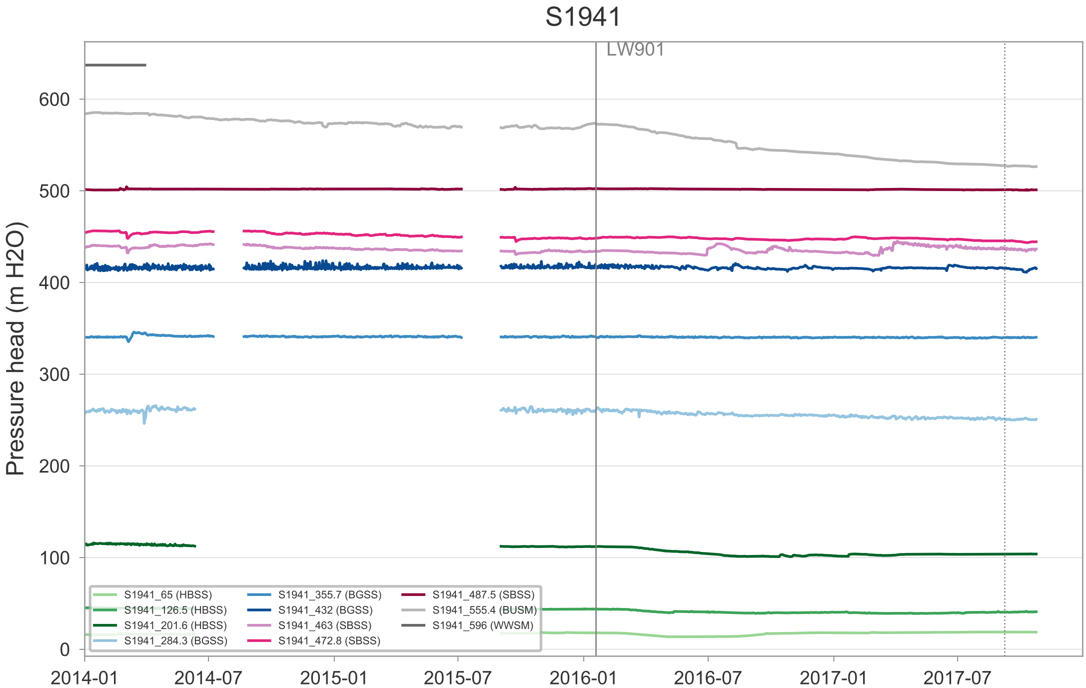

S2280
LW901
Ground RL
Piezometric head (m RL)
160
140
120
100
80
60
2014
2015
2016
2017
S2280_60 (HBSS)
S2280_99 (HBSS)
Nepean River

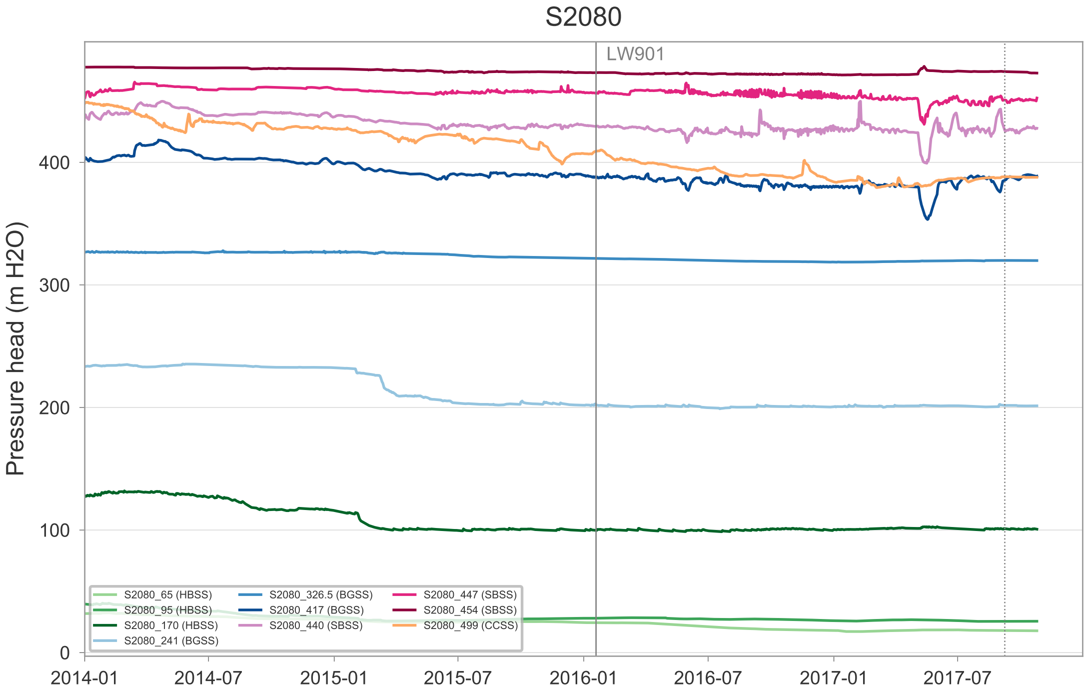

S2281
LW901
Ground RL
Piezometric head (m RL)
160
140
120
100
80
60
2014
2015
2016
2017
S2281_61 (HBSS)
S2281_99 (HBSS)
Nepean River

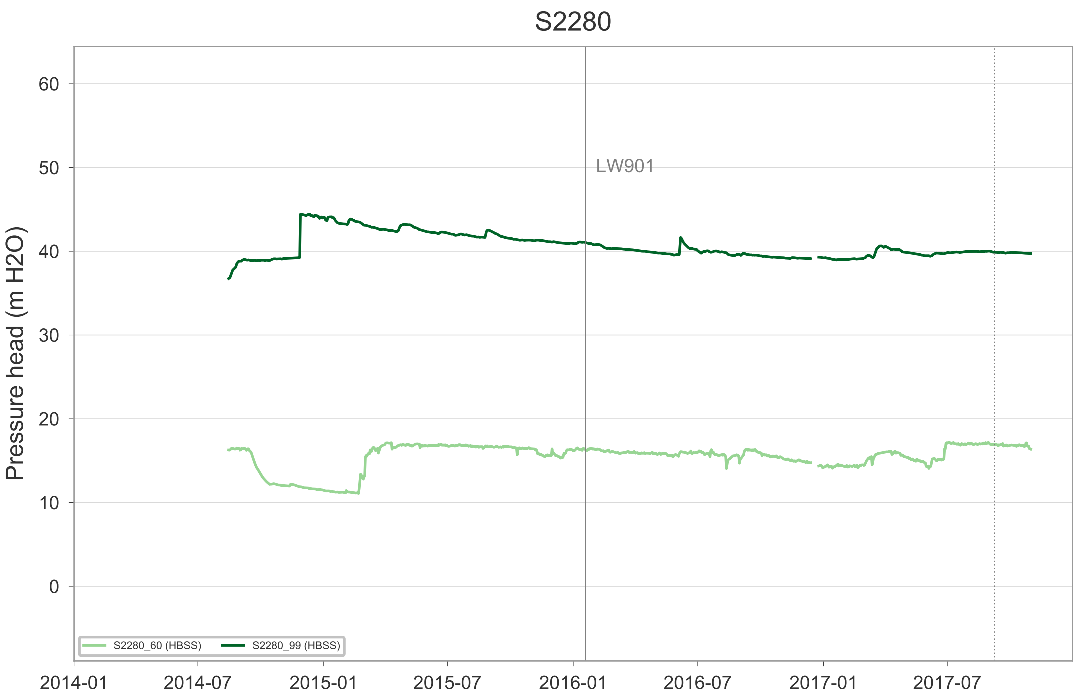


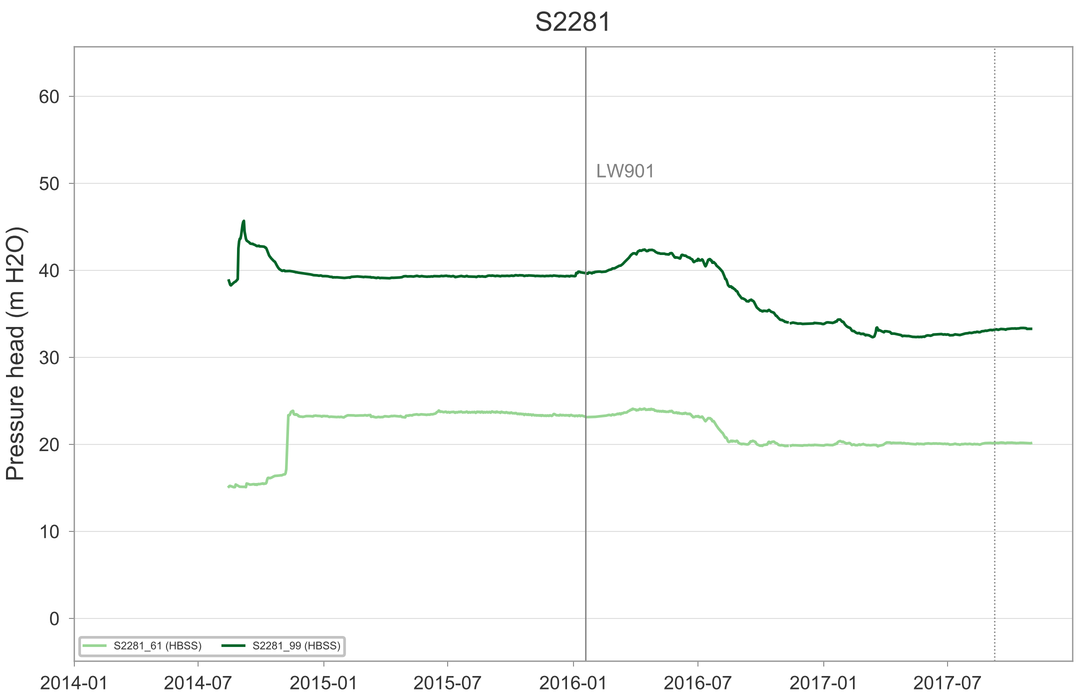
S1913
Pressure head (m H2O)
600
500
400
300
200
100
0
2014-01
2014-07
2015-01
2015-07
2016-01
2016-07
2017-01
2017-07
LW901
S1913_65 (HBSS)
S1913_137 (HBSS)
S1913_194 (HBSS)
S1913_274 (BGSS)
S1913_358 (BGSS)
S1913_447 (BGSS)
S1913_473 (SBSS)
S1913_486 (SBSS)
S1913_505 (SBSS)
S1913_559.5 (BUSM)


S1936
LW901
Pressure head (m H2O)
500
400
300
200
100
0
2014-01
2014-07
2015-01
2015-07
2016-01
2016-07
2017-01
2017-07
S1936_65 (HBSS)
S1936_123.8 (HBSS)
S1936_192 (HBSS)
S1936_278 (BGSS)
S1936_347.8 (BGSS)
S1936_422.5 (BGSS)
S1936_456.2 (SBSS)
S1936_462.1 (SBSS)
S1936_468 (SBSS)
S1936_556.1 (BUSM)


S1941
LW901
Pressure head (m H2O)
600
500
400
300
200
100
0
2014-01
2014-07
2015-01
2015-07
2016-01
2016-07
2017-01
2017-07
S1941_65 (HBSS)
S1941_126.5 (HBSS)
S1941_201.6 (HBSS)
S1941_284.3 (BGSS)
S1941_355.7 (BGSS)
S1941_432 (BGSS)
S1941_463 (SBSS)
S1941_472.8 (SBSS)
S1941_487.5 (SBSS)
S1941_555.4 (BUSM)
S1941_596 (WWSM)


S2080
LW901
Pressure head (m H2O)
0
100
200
300
400
2014-01
2014-07
2015-01
2015-07
2016-01
2016-07
2017-01
2017-07
S2080_65 (HBSS)
S2080_95 (HBSS)
S2080_170 (HBSS)
S2080_241 (BGSS)
S2080_326.5 (BGSS)
S2080_417 (BGSS)
S2080_440 (SBSS)
S2080_447 (SBSS)
S2080_454 (SBSS)
S2080_499 (CCSS)


S2280
LW901
Pressure head (m H2O)
60
50
40
30
20
10
0
2014-01
2014-07
2015-01
2015-07
2016-01
2016-07
2017-01
2017-07
S2280_60 (HBSS)
S2280_99 (HBSS)


S2281
Pressure head (m H2O)
0
10
20
30
40
50
60
LW901
S2281_61 (HBSS)
S2281_99 (HBSS)
2014-01
2014-07
2015-01
2015-07
2016-01
2016-07
2017-01
2017-07