METROPOLITAN COAL GROUNDWATER

Monitoring report
1 January - 30 June 2020

Prepared for:

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SLR Ref: 665.10000-R04
Version No: -v2.0
September 2020

SLR

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Metropolitan Collieries Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
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665.10000-R04-v1.0	1 September 2020	Nafisa Akhter, Ines Epari	Dr Noel Merrick	Ines Epari

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Appendix A Swamp Performance Assessment – semi-quantitative analysis

1 Introduction

Metropolitan Coal is wholly owned by Peabody Energy Australia Pty Ltd and is located adjacent to the township of Helensburgh and approximately 30 kilometres (km) north of Wollongong in New South Wales.

A comprehensive Metropolitan Coal Catchment Monitoring Program (Metropolitan Coal, 2018a) has been prepared in accordance with Condition 2, Schedule 3 of the Project Approval. The Catchment Monitoring Program includes detailed baseline data of existing surface water and groundwater resources, a program for the ongoing development and use of appropriate surface water and groundwater models, a program to monitor and assess impacts on surface water and groundwater resources, and a program to validate and calibrate the surface water and groundwater models.

This Groundwater Monitoring and Environmental Performance Assessment Report has been prepared by SLR Consulting Australia Pty Ltd (SLR) to review the environmental performance of the Project in relation to groundwater during the six-monthly reporting period (1 January to 30 June 2020).

1.1 Management plan

The Metropolitan Coal Longwall 305-307 Water Management Plan (WMP) (Peabody, 2020a) was prepared to manage the potential environmental consequences of the Metropolitan Coal Longwall 305-307 Extraction Plan (Peabody, 2020b) on water resources and watercourses (including the Woronora Reservoir), aquifers and catchment yield in accordance with Condition 6, Schedule 3 of the Project Approval (Metropolitan Coal, 2018b).

The Metropolitan Coal Longwalls 305-307 Biodiversity Management Plan (BMP) (Peabody, 2020c) was prepared to manage the potential environmental consequences of the Metropolitan Coal Longwall 305-307 Extraction Plan on aquatic and terrestrial flora and fauna, with a specific focus on swamps.

The WMP and BMP have been prepared to manage the potential environmental consequences of the Extraction Plan on watercourses (including the Woronora Reservoir), aquifers and catchment yield. This six-monthly review will present the results of the on-going groundwater related monitoring and assess the environmental performance against the Trigger Action Response Plan (TARP) in the two management plans.

The previous iterations of the WMP and BMP for Longwall 304 (Peabody, 2019a and 2019b) were applicable during the period between 1 January 2020 and 28 January 2020, when Longwall 304 was completed.

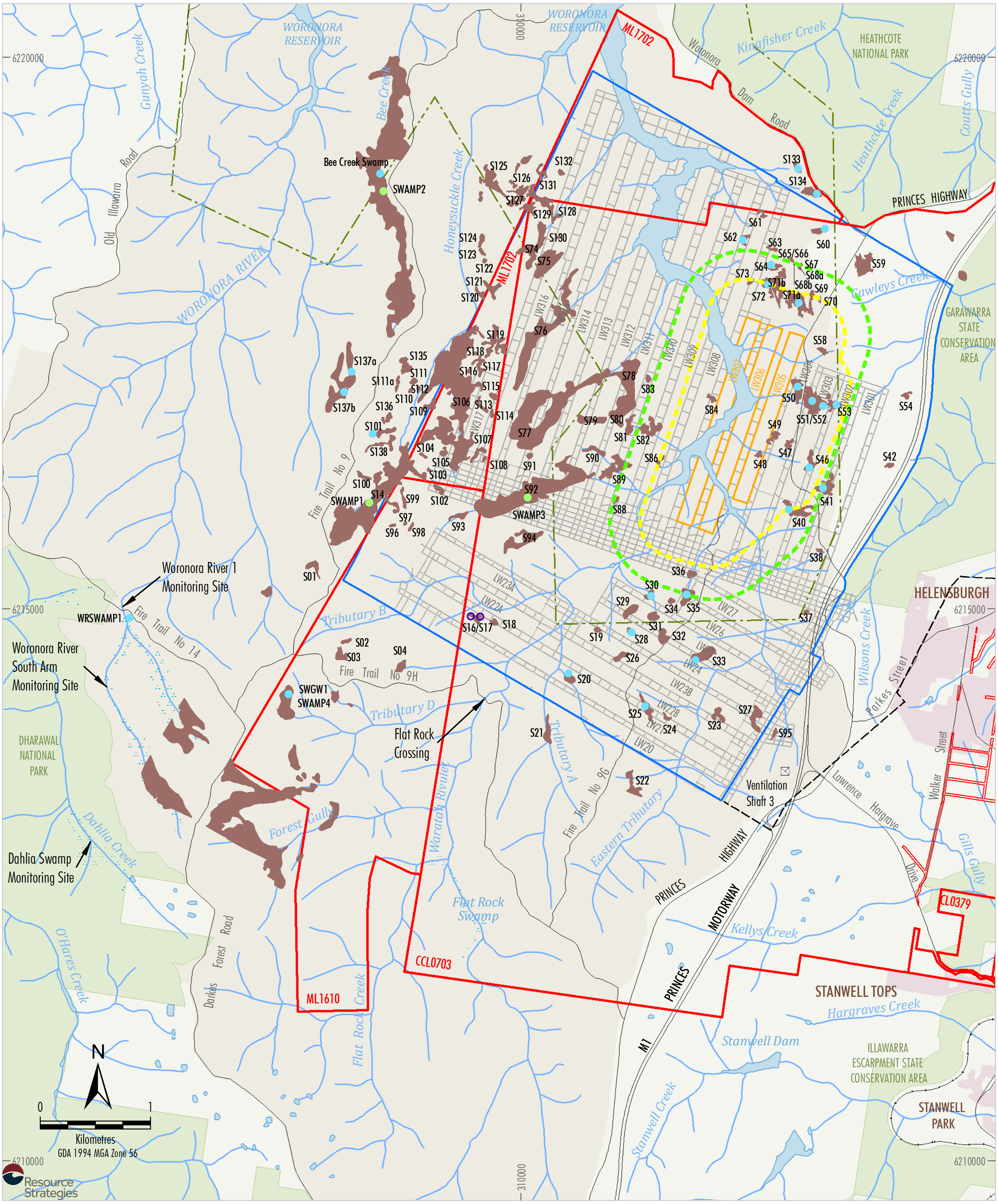
1.2 Mining progression

1.2.1 Longwalls 23-27 (complete)

Swamps S28, S30, S33 and S35 overlie Longwalls 23-27 or the associated pillars (Figure 1). The timing of Longwall 23-27 extraction in relation to these swamps is summarised in Table 1.

Table 1 Passage of Longwall Panels 23-27 near or beneath Swamps

Longwall panel	Swamp 28	Swamp 30	Swamp 33	Swamp 35
23B	Passed, Oct. 2014	Passed (500 m), Oct 2014	Passed (200 m), Dec 2014	-
24	Beneath, May 2015	Passed (250 m), May 2015	Beneath, July 2015	Passed (450 m), May 2015
25	Passed, Nov 2015	Passed (50 m), Nov 2015	Passed (50 m), Feb. 2016	Passed (250 m), Dec 2015
26	500 m away, June 2016	250 m away, May 2016	Passed (250 m), July 2016	Passed (50 m), May 2016
27	-	300 m away, Sep 2016	Passed (450 m), Nov 2016	Beneath, Sep 2016



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- Existing Underground Access Drive (Main Drift)
- Woronora Notification Area
- Upland Swamp
- Swamp Substrate and Shallow Groundwater Piezometer
- Swamp Substrate Groundwater Piezometer
- Swamp Shallow Groundwater Piezometer

Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019); after NPWS (2003), Bangalay Botanical Surveys (2008); Eco Logical Australia (2015; 2016; 2018)

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Figure 1 Mine Plan and Upland Swamp Groundwater Piezometer Locations

1.2.2 Longwalls 301-304 (complete)

Longwall 301 commenced on 28 June 2017, Longwall 302 commenced on 29 March 2018, Longwall 303 commenced on 13 November 2018, Longwall 304 commenced on 27 July 2019 and finished on 28 January 2020. The currently active Longwall 305 commenced on 12 April 2020 and continued for the remainder of the reporting period (refer to Section 1.2.3).

Swamps S40, S41, S46, S50, S51, S52 and S53 overlie Longwalls 301-304 or the associated pillars (Figure 1). The timing of Longwall 301-304 extraction in relation to these swamps is summarised in Table 2.

Table 2 Passage of Longwall Panels 301-304 near Swamps

Longwall panel	Swamp 51	Swamp 52	Swamp 53	Swamp 46	Swamp 41	Swamp 40	Swamp 50
301	~400 m away, Aug 2017	~300 m away, Aug 2017	~150 m away, Aug 2017	~200 m away, Nov 2017	Passed, Dec 2017	Passed, 50 m away Dec 2017	-
302	Passed ~150 m away, Apr 2018	Passed ~50 m away, Apr 2018	Passed, Apr2018	Passed, June 2018	Passed, Jul 2018	Passed, Jul 2018	-
303	Passed, Nov 2018	Passed, Nov 2018	Passed, Nov 2018	Passed, Jan 2019	Passed ~150 m away, Feb 2019	Passed, March, 2019	-
304	~300 m away, Sept., 2019	-	-	-	-	-	Passed, Sept 2019
305	~450 m away, May 2020	-	-	-	-	-	Passed, May 2020, ~200 m away

1.2.3 Longwalls 305-309 (current)

The currently active Longwall 305 commenced on 12 April 2020 and continued for the remainder of the reporting period. Currently, there are two swamps listed in the BMP, as listed in Table 3. Further Swamp piezometers to monitor the longwall progression of LW305-309 were installed in August 2020 (Golders, 2020). These swamps will be added to the table in the next six-monthly review when data becomes available.

Table 3 Passage of Longwall Panels 305-309 near Swamps 71a and 72

Longwall panel	Swamp 71a	Swamp 72
305	Passed April 2020, ~270 m away	Passed April 2020, ~470 m away
306	NA	NA
307	NA	NA
308	NA	NA
309	NA	NA

2 Monitoring network

2.1 Climate

There are several local rainfall stations (pluviometers) on site. The locations are shown in Figure 2. The pluviometer that is used to discuss the rainfall on site is PV01 (Waratah). Figure 3 shows the monthly rainfall at PV01 from 2006 to date. The figure also depicts the Cumulative Rainfall Departure (CRD), that has been calculated using the actual rainfall observations with a scaled, long-term average derived from the SILO data point at the same location. The procedure is explained in the paragraph below.

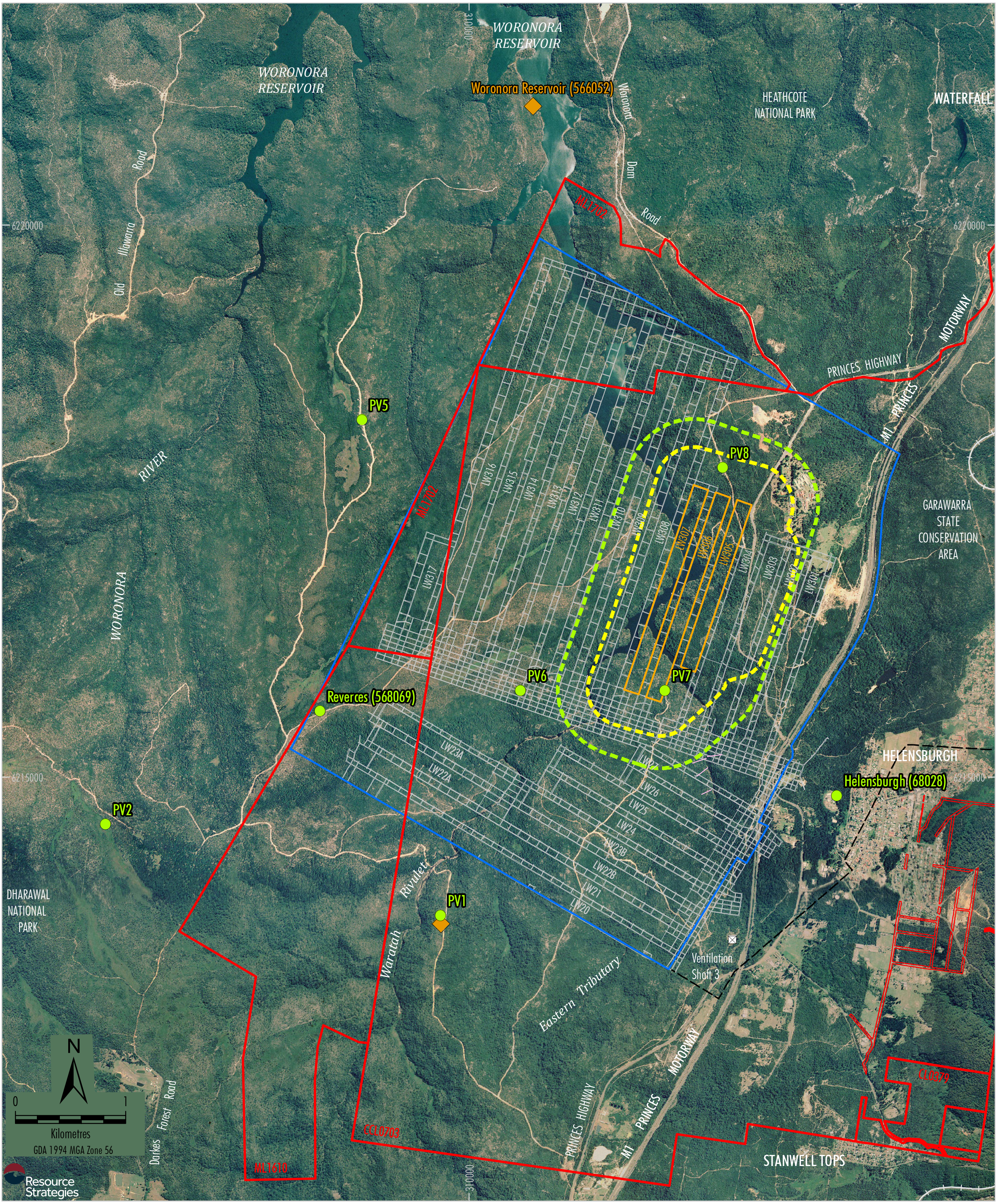
SILO is a climate database that uses data from the Bureau of Meteorology (BoM) stations and interpolates the data onto a 0.05° grid. With this method, data is available for a long time period (in this instance 1900-2020 was used to calculate the long-term averages). A linear regression between PV01 and the SILO point for the time period of 2006 to 2020 (i.e. the overlapping data range) showed that the SILO data point overestimates the observed rainfall by 14%, with an R^2 of 0.89. Hence the long-term average of the SILO data point was scaled back by a factor of 0.88, which was then used to calculate the CRD. The resulting long-term monthly averages for PV01 used to calculate the CRD are presented in Table 4.

Table 4 Average monthly rainfall

Month	PV01 (2006-2020) mm	Silo point (1900-2020) mm	PV01 (scaled) (1900-2020) mm
Jan	80.5	128.8	113.0
Feb	158.1	146.9	128.9
Mar	147.0	151.3	132.7
Apr	113.3	132.1	115.9
May	55.2	126.9	111.3
Jun	149.8	136.4	119.7
Jul	48.1	93.9	82.4
Aug	66.2	84.0	73.7
Sep	76.0	74.1	65.1
Oct	56.4	88.3	77.5
Nov	94.5	100.2	87.9
Dec	72.5	98.1	86.1

The resulting CRD curve is shown in Figure 3. This curve is also shown in most of the groundwater hydrographs to put the changes in the groundwater into climatic context. In summary:

- A rising slope in the CRD indicates wetter than average rainfall conditions.
- A stable slope (i.e. no increase of decrease) in the CRD indicates average rainfall conditions.
- A decreasing slope in the CRD indicates drier than average rainfall conditions.



LEGEND

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- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- Existing Underground Access Drive (Main Drift)
- Evaporimeter
- Pluviometer

Notes:
1. The Bureau of Meteorology pluviometer at Darkes Forest (68024) is not shown. It is located approximately 3.75 km south of the Metropolitan Coal pluviometer (PV2).
2. The Bureau of Meteorology pluviometer at Lucas Heights (66078) is not shown. It is located approximately 12.5 km north of the Metropolitan Coal pluviometer (PV8).

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019)

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Figure 2 Meteorological Sites

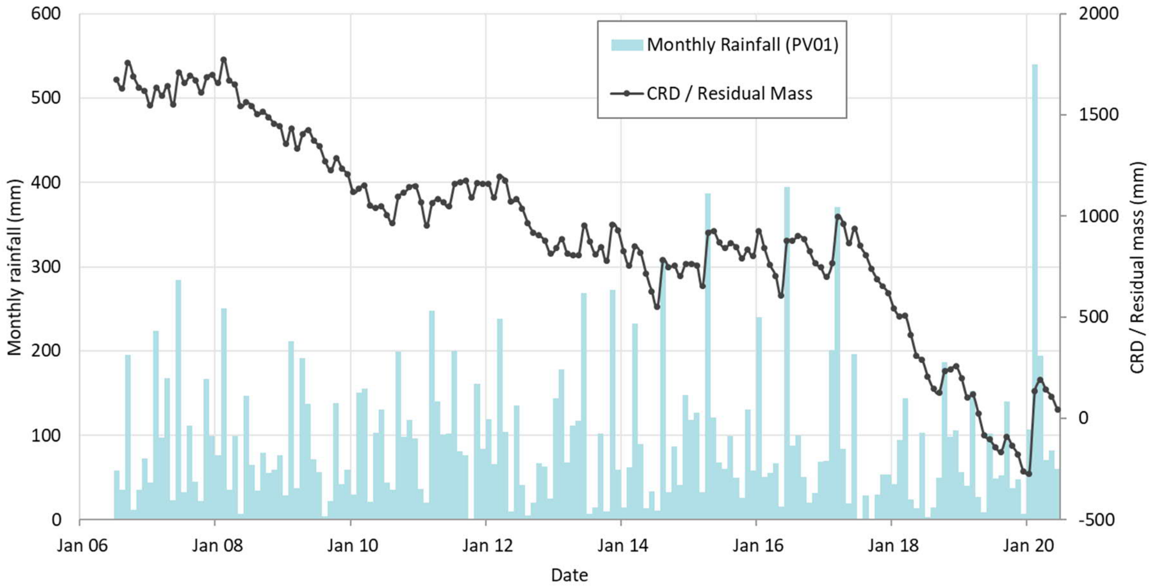


Figure 3 Monthly rainfall and cumulative rainfall departure

During the reporting timeframe (2006-2020), the rainfall condition on site can be classified as drier than average (2008-2014, and more pronounced 2017-date) with some periods of average conditions (2006-2008 and 2014-2017). A large rain event in February 2020 broke the dry conditions, as indicated by a sudden increase in the CRD; however, the CRD has been decreasing since, which again indicates drier than average conditions.

Figure 4 shows the monthly rainfall observations for the reporting period (January to June 2020) in comparison with the long-term average monthly rainfall. The January 2020 rainfall was approximately at the average. February 2020 was very wet with the observed rainfall four times greater than the average. March 2020 was slightly above average and the second quarter (April, May and June) saw the monthly rainfall return to below average.

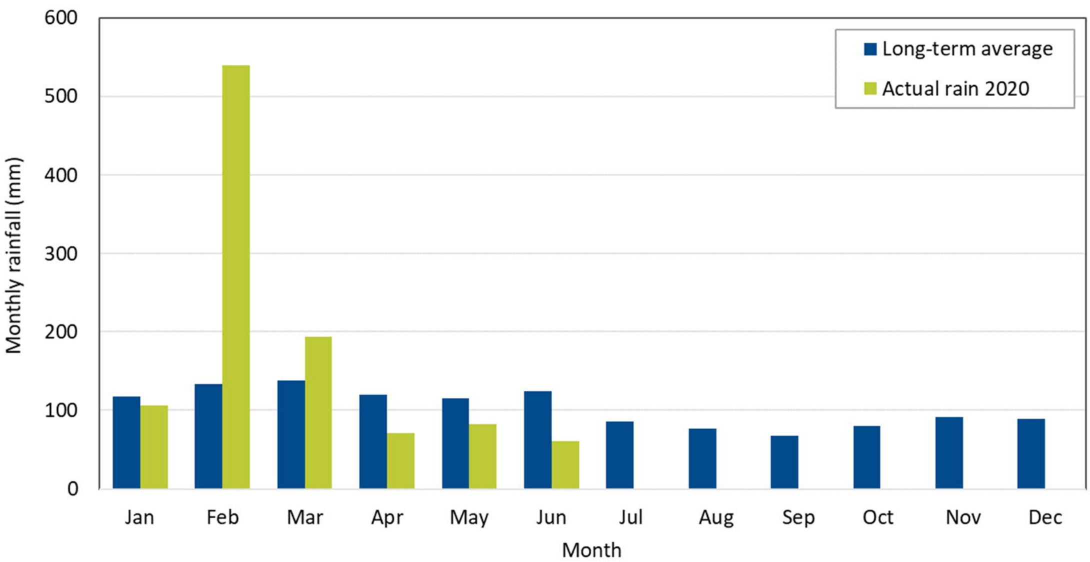


Figure 4 Comparison of average monthly rainfall with observations for 2020

2.2 Swamps

2.2.1 Sites

Groundwater monitoring of upland swamps involves the use, where practicable, of paired piezometers, one in the swamp substrate and one in underlying sandstone. This allows direct measurement of the vertical hydraulic gradient beneath the swamp. A summary of the swamp monitoring locations discussed in this report is included in Table 5. The locations of the swamps are presented in Figure 1.

Table 5 Swamp Monitoring Locations

Location ID	Underlying Mine Area	Ground Elevation (mAHD)	Approx. Depth (m)	Lithology
Swamp 20 (S20)	Longwalls 20-22	219.3	0.9	HBSS (substrate)
		219.1	4	HBSS
		219.1	10	HBSS
Swamp 25 (S25)	Longwalls 20-22	273.1	0.9	HBSS (substrate)
		272.9	10	HBSS
Swamp 101 (S101)	Control site	293.4	0.9	HBSS (substrate)
		293.4	10	HBSS
Woronora River 1 (WRSWAMP1)	Control site	321.1	0.9	HBSS (substrate)
		321.1	4	HBSS
		321.0	10	HBSS
Swamp 28 (S28)	Longwalls 23-27	247.9	1	HBSS (substrate)
		247.8	10	HBSS
Swamp 30 (S30)	Longwalls 23-27	236.2	1	HBSS (substrate)
		236.0	10	HBSS
Swamp 33 (S33)	Longwalls 23-27	241.3	1	HBSS (substrate)
		241.2	10	HBSS
Swamp 35 (S35)	Longwalls 23-27	256.0	1	HBSS (substrate)
		256.1	10	HBSS
Swamp 137 (at S137a)	Control site	271.3	1	HBSS (substrate)
		271.1	10	HBSS
Swamp 137 (at S137b)	Control site	276.6	1	HBSS (substrate)
		276.7	10	HBSS
Bee Creek Swamp	Control site	241.1	1	HBSS (substrate)
		241.3	10	HBSS
Swamp 40 (S40) – valley side swamp	Longwalls 301-303	231.9	1	HBSS (substrate)
		232.1	9.9	HBSS
Swamp 41 (S41) – valley side swamp	Longwalls 301-303	279.6	0.8	HBSS (substrate)
		279.4	9.9	HBSS
Swamp 46 (S46) – valley side swamp	Longwalls 301-303	282.6	0.7	HBSS (substrate)
		282.8	10.1	HBSS
Swamp 50 (S50) – valley side swamp	Longwall 304	266.8	0.4	HBSS (substrate)
		266.9	9.9	HBSS
Swamp 51(S51) – valley side swamp	Longwalls 301-303	274.9	0.6	HBSS (substrate)
		274.9	9.9	HBSS

Location ID	Underlying Mine Area	Ground Elevation (mAHD)	Approx. Depth (m)	Lithology
Swamp 52 (S52) – valley side swamp	Longwalls 301-303	283.8	1.1	HBSS (substrate)
		283.7	9.8	HBSS
Swamp 53 (S53) – valley side swamp	Longwalls 301-303	295.6	1.7	HBSS (substrate)
		295.5	9.9	HBSS
Swamp 71 (at 71a) – valley side swamp	Longwall 305	275.8	0.3	HBSS (substrate)
		275.8	9.9	HBSS
Swamp 72 – valley side swamp	Longwall 305	264.5	1.4	HBSS (substrate)
		264.5	10.9	HBSS

Note: HBSS – Hawkesbury Sandstone, blue shade: control sites

Paired piezometers have also been installed in Swamps 60, 62, 64, 133 and 134, which can also be used as potential reference sites during the mining of Longwalls 305-307.

2.2.2 Data quality assessment

The following observations were made in terms of data quality:

- Swamps S40, S41, S46, S50, S51, S52 and S53 sensor depths were re-measured over 19 to 22 February 2018. These revised sensor depths have been used within this assessment report.
- The data for swamps 20, 25, 30 and 35 was provided up to 17 June 2020 and for swamp 28 up to 24 June 2020 (which means there are 1-2 weeks of data missing at these swamps for the reporting period.

2.3 Groundwater

2.3.1 Sites

The current groundwater monitoring network details are presented in the WMP, and are summarised for this report in Table 6 to Table 8 below. The bore locations of selected groundwater bores are presented in Figure 5. All other bore locations are referenced in the tables.

The bores listed in Table 6 relate to monitoring near surface water features. The bores listed in Table 7 are transect bores that observe the interaction with Woronora Reservoir. The bores listed in Table 8 are water pressure monitoring sites, mostly Vibrating Wire Piezometers (VWPs), that can measure water pressure at different depths at one location. More details on the bores listed in Table 8, such as depth of each sensor and formation monitored, can be found in the WMP, Table 20.

Table 6 Summary of shallow groundwater monitoring sites (water level and quality)

Site number	Location	Easting (m)	Northing (m)	RL (mAHD)	Commencement date
SWGW1	Swamp S06	307893	6214226	343.7	12 March 2009
WRGW1	Waratah Rivulet	309886	6214360	207.8	16 February 2007
WRGW2	Waratah Rivulet	309868	6214335	207.9	16 February 2007
WRGW3	Waratah Rivulet	309629	6214072	215.0	16 February 2007
WRGW4	Waratah Rivulet	309579	6214090	217.8	16 February 2007
WRGW5	Waratah Rivulet	309393	6212890	225.4	4 April 2007
WRGW6	Waratah Rivulet	309361	6212871	226.1	4 April 2007
WRGW7	Waratah Rivulet	310717	6215382	184.2	1 September 2010
WRGW8	Waratah Rivulet	310685	6215353	184.3	1 September 2010
RTGW1A1	Tributary B	309593	6215109	222.0	23 August 2007
UTGW 1	Tributary D	309520	6214151	218.2	16 February 2007
UTGW 2	Tributary D	309097	6214012	237.6	7 March 2007
UTGW 3	Tributary D	308833	6213951	247.2	7 March 2007
FGGW1	Forest Gully	308951	6213200	232.4	8 March 2007
FGGW2	Forest Gully	308816	6213158	240.5	4 April 2007
FGGW3	Forest Gully	308682	6213113	250.4	4 April 2007
ETGW1	Eastern Tributary	312129	6215644	172.6	1 September 2010
ETGW2	Eastern Tributary	312134	6215664	172.1	1 September 2010
ETO1	Eastern Tributary	311665	6214107	228.0	30 May 2019
ETO2	Eastern Tributary	311634	6214141	217.3	30 May 2019
ETO3	Eastern Tributary	311589	6214112	221.0	30 May 2019
ETO4	Eastern Tributary	311534	6214143	216.2	30 May 2019

Table 7 Summary of transect bores

Site number	Easting (m)	Northing (m)	RL (mAHD)	Commencement date
T1	312048	6217168	174.106	07-Sep-16
T2	312092	6217209	195.118	07-Sep-16
T3	312201	6217246	225.45	07-Sep-16
T4	312280	6217296	236.306	07-Sep-16
T5	312423	6217379	258.041	07-Sep-16
T6	311447	6217375	255.87	18-Dec-17

Table 8 Summary of groundwater level/pressure monitoring sites

Site number	Location	Easting (m)	Northing (m)	RL (mAHD)	Number of sensors	Depth of sensors	Commencement date
9HGW0	Longwall 10 Goaf Hole on Fire Trail 9H	309762	6213480	274.5	8	From 35 to 300 mbgl	12 Apr 2007
9HGW1B	Fire Trail 9H west of Longwall 18	308189	6214580	351.2	8	From 52 to 386 mbgl	12 Nov 2008
9GGW1B[1]	Fire Trail 9G	310974	6214317	287.9	10	From 45 to 477 mbgl	14 Mar 2009
9GGW1-80[1]	Fire Trail 9G	310974	6214317	287.0	1	~80 mbgl	21 Nov 2013
9GGW2B	Fire Trail 9G at western end of Longwall 27	311734	6215359	240.8	10	From 55 to 474 mbgl	20 Apr 2010
9FGW1A	Fire Trail 9F west of Longwall 22A	308556	6215537	310.2	10	From 55 to 513 mbgl	19 Feb 2010
9EGW1B	Fire Trail 9E	309483	6216091	309.0	10	From 52 to 542 mbgl	1 Nov 2009
9EGW2A	Fire Trail 9E	311331	6217099	276.9	11	From 60 to 557 mbgl	28 May 2011
9EGW2-4[2]	Fire Trail 9E	311216	6216986	276.3	5	From 407 to 557 mbgl	18 Dec 2017
F6GW3A	Old Princes Hwy east of LW 301	312855	6215539	242.6	8	From 50 to 450 mbgl	17 Jun 2013
F6GW4A	Old Princes Hwy between LW303 and 304	312531	6216694	265.0	8	From 50 to 512 mbgl	17 Jun 2013
PHGW2A	Fire Trail west of Princes Highway	312322	6217752	263.0	11	From 60 to 508 mbgl	16 Mar 2011

Site number	Location	Easting (m)	Northing (m)	RL (mAHD)	Number of sensors	Depth of sensors	Commencement date
PHGW1B	Fire Trail west of Princes Highway	312281	6218335	289.8	10	From 65 to 554 mbgl	28 Jun 2010
PM01 (9DGW1B)	Fire Trail 9D	309971	6217271	283.6	10	From 52 to 548 mbgl	5 Feb 2010
PM02	Fire Trail 9D	310650	6218509	267.4	8	From 35 to 495 mbgl	23 Dec 2007
PM03	Woronora Dam Road	311664	6219773	265.0	11	From 64 to 526 mbgl	14 Feb 2011
S1997*	North Cliff	306997	6212765	370.2	11	From 24 to 512 mbgl	10 Jun 2009
302GW01[3]	Overlying Longwall 302	312952	6216553	305.1	9	from 80 to 440 mbgl	23 Nov 2017 End Date: 25 May 2018
TBS02-80[4] (pre-mining standpipe)	Overlying Longwall 302	312849	6216579	305.1	1	82.5 mbgl	1-Oct-17 End Date: 12 Jan 2018
TBS02-90 (post-mining standpipe)	Overlying Longwall 302	312843	6216580	306.5	1	90 mbgl	13 Feb 2019
TBS02-190 (post-mining standpipe)	Overlying Longwall 302	312837	6216583	305.7	1	190 mbgl	8 Feb 2019
TBS02-250[5] (pre-mining hole)	Overlying Longwall 302	312852	6216598	306.1	2	From 192 to 243 mbgl	27 Oct 2017 End Date: 22 Oct 2018
TBS02-250R (post-mining hole)	Overlying Longwall 302	312865	6216583	307.4	4	From 90 to 245 mbgl	24 Jan 2019 VWP 245 failed during grouting
TBS02A-15	Overlying Longwall 302	312837	6216577	304.2	1	15.5 mbgl	31 Oct 2017
TBS03-230[6] Pre-Mining	Overlying Longwall 303	312652	6216685	281.9	2	From 162 to 213 mbgl	22 Feb 2018 End Date: 13 Dec 2018

Site number	Location	Easting (m)	Northing (m)	RL (mAHD)	Number of sensors	Depth of sensors	Commencement date
TBS03-230R (post-mining hole)	Overlying Longwall 303	312648	6216686	281.5	4	From 162 to 265 mbgl	12 Apr 2019
TBS03-15	Overlying Longwall 303	312647	6216684	281.9	1	15.5 mgbl	23 Feb 2018

mbgl: metres below ground level

1 Multi-level piezometer site 9GGW1B was installed above Longwall 22 to monitor deep groundwater levels/pressure as part of the Longwalls 20-22 monitoring program, however this site was decommissioned due to safety risks in late 2013 prior to Longwall 22 passing the site. Metropolitan Coal replaced this site with a new bore (9GGW1-80) which monitors the groundwater level with a single piezometer at 70 m depth.

2 Multi-level piezometer site 9EGW2A experienced failure of certain lower level instrumentation. An additional hole was drilled adjacent to 9EGW2A (bore 9EGW2-4) to a depth of 557 m to install new piezometers at the same RL as the failed piezometers in December 2017.

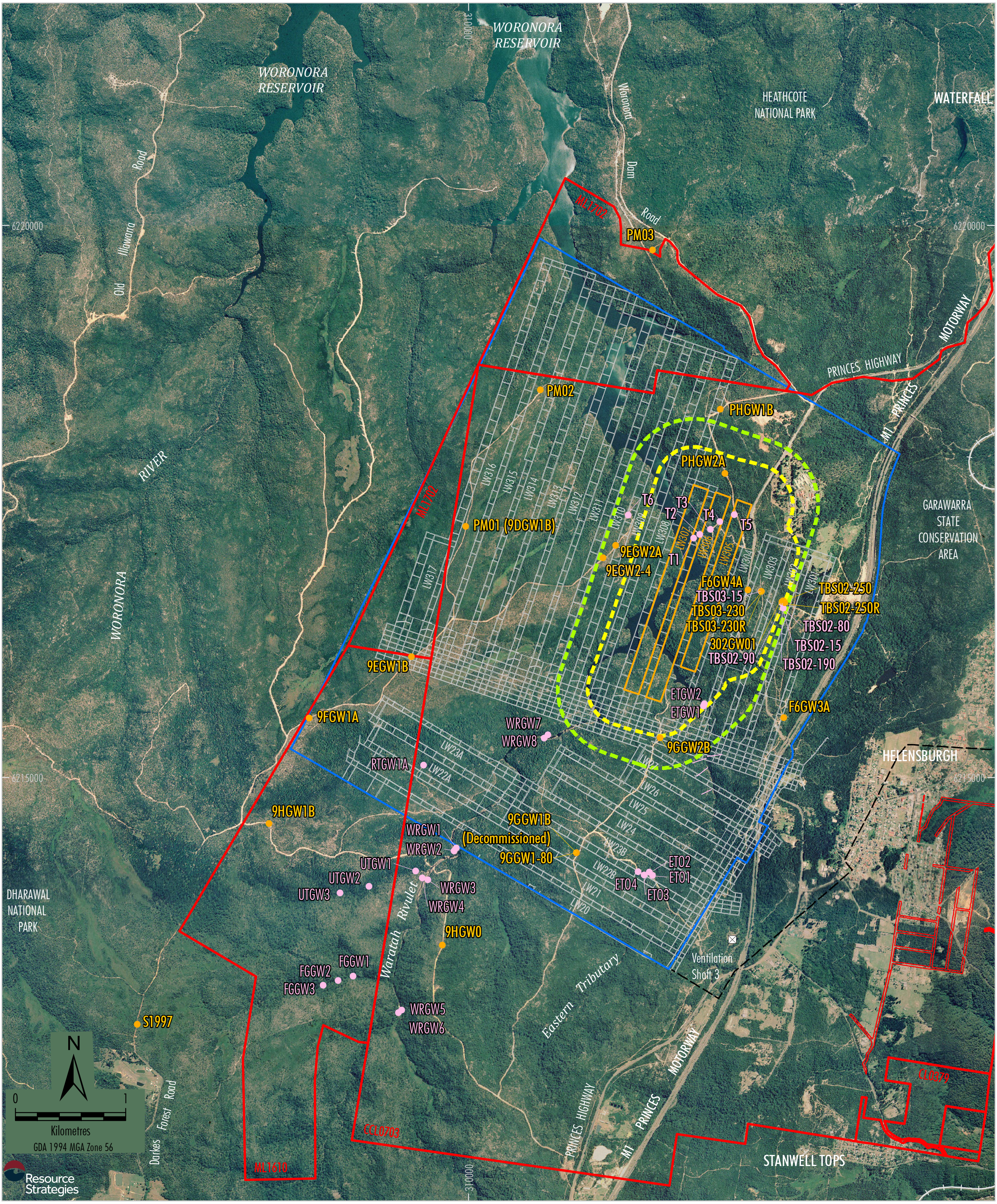
3 302GW01 piezometer site intended to be first site to safely monitor throughout the longwall extraction process with new optical fibre piezometers. Optical fibres unfortunately were severed by ground movement as Longwall 302 passed under the site.

4 TBS02-80 m hole found obstructed 12 Dec 2018, unable to clear obstruction or dip water level. Hole remediated, and replacement hole installed 13 Feb 2019 at 90 m depth.

5 TBS02-250 (pre-mining) VWP communications lost 22 Oct 2018. Hole remediated, and replacement hole installed 24 Jan 2019.

6 TBS03-230 (pre-mining) VWP communication lost as Longwall 303 passed underneath. Post mining hole (TBS03-230R) reinstated 12 April 2019.

* Data courtesy of BHP Billiton Illawarra Coal.



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 305-307 Secondary Extraction
- Longwalls 305-307 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Longwalls 305-307 Secondary Extraction
- Existing Underground Access Drive (Main Drift)
- Groundwater Level/Pressure Bore
- Groundwater Level Bore

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2019); MSEC (2019)

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Figure 5 Groundwater Level and/or Pressure Monitoring Bore Locations

2.3.2 Data quality assessment

A re-assessment of data quality has been undertaken for the VWP hydrographs and is presented in Table 9. If an issue with a VWP sensor was identified, it has been categorized as “disabled”, “unstable” or “unreliable” responses. Disabled VWPs are those that were not recording for the entire reporting period. Instability was assessed in terms of expected trends over the reporting period. Reliability was assessed by considering consistency in the variation of groundwater heads with depth. The assessment finds that 64 percent (%) of the VWP records are currently providing useful data, with 4% rated as unstable, 24% disabled and 9% considered to be unreliable.

Table 9 Qualitative Assessment of Vibrating Wire Piezometer Data Quality

Site	Number of VWPs	Number of Useful VWPs	Number of Unstable VWPs	Unstable VWPs	Number of Disabled VWPs	Disabled VWPs	Number of Unreliable VWPs	Unreliable VWPs
9HGW0	8	6	0		0		2	135, 300
9HGW1B	8	8	0		0		0	
9GGW1-80	1	1	0		0		0	
9EGW1B	8	6	0		1	542	1	233
9FGW1A	10	8	0		0		2	185, 455
9GGW2B	10	4	0		5	138, 163, 304, 340, 474	1	393
9HGW1B	8	8	0		0		0	
PM01	10	8	0		2	52, 170	0	
PM02	8	7	0		0		1	400
PM03	11	9	1	214	1	492		
PM01R	10	7	1	482	2	52, 170	0	
9EGW2	11	6	0		5	407, 454, 484, 517, 557	0	
PM03	11	7	1	214	1	492	2	189, 385
PHGW1B	10	8	1	554	0		1	432
PHGW2A	11	7	2	470, 508	0		2	365, 437
F6GW3 A	8	8	0		0		0	
F6GW4A	8	2	0		6	139, 201, 278, 362, 440, 512	0	
302GW01	9	0	0		9	80, 150, 200, 245, 340, 380, 400, 411, 440	0	
TBS02-original	2	2	0		0		0	
TBS02-redrill	4	3	0		1	245	0	
TBS03-redrill	4	0	0		4	162m, 213m, 245m, 265m	0	
Total	170	115 (67.6%)	6 (3.5%)		37 (21.8%)		12 (7.1%)	

3 Swamp monitoring results

This section presents the current and historical water level and quality results collected at the monitoring locations specified in Section 2.2.1. Discussion on the results and trends is included for each monitoring location.

Due primarily to differences in data logger software algorithms, a correction procedure was implemented in late 2016 to Longwalls 20-22 and Longwalls 23-27 upland swamp program data to ensure consistency of measurements between monitoring campaigns. Adjustments were validated against manual water depths measured over the previous year, and by ensuring consistency in both minimum and maximum water levels over the full monitoring period. As an illustration of successful validation, the swamp hydrograph charts from Figure 6 onward include examples of the manual measurements (as crosses) during the validation period, and separate elevations for sensor level and the physical bottom of the monitoring hole. Where the latter two elevations differ, the observation of a “flat-line” on a hydrograph means that the swamp is “nearly dry” rather than completely dry, at that location.

Groundwater monitoring of upland swamps involves the use, where practicable, of paired piezometers, one in the swamp substrate and one in underlying sandstone. This allows direct measurement of the vertical hydraulic gradient beneath the swamp.

3.1 Swamp Monitoring Longwalls 20-22

Monitoring of upland swamps for Longwalls 20-22 includes monitoring of the following piezometers (locations shown in Figure 1):

- Multiple piezometers (i.e. one swamp substrate piezometer to a depth of approximately 0.9 m and two sandstone piezometers to depths of approximately 4 and 10 m), located in Swamp 20 (S20) overlying Longwalls 20-22.
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 0.9 m and one sandstone piezometer to a depth of approximately 10 m), located in Swamp 25 (S25) overlying Longwalls 20-22.
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 0.9 m and one sandstone piezometer to a depth of approximately 10 m), located in control Swamp 101 (S101).
- Multiple piezometers (i.e. one swamp substrate piezometer to a depth of approximately 0.9 m and two sandstone piezometers to depths of approximately 4 and 10 m), located in control swamp Woronora River 1 (WRSWAMP1).

3.1.1 Background Trends – Control Swamp 101 and Woronora River Swamp 1

The following charts show the control swamps Swamp 101 and Woronora River Swamp 1 for the period 1 June 2008 to 30 June 2020 and indicate the commencement date for this six-monthly period (1 January to 30 June 2020).

The hydrographs at the two control swamps for Longwalls 20-22 (Swamp 101 and Woronora River Swamp 1) are shown on Figure 6 and Figure 7, respectively. Although sites are well away (1-2.5km) from mining, longwall start dates are included on Figure 6 and Figure 7 to facilitate comparison with swamp responses within the mining footprint. The rainfall residual mass curve is included as a guide to the influence of rainfall on groundwater responses, as outlined in Section 2.1.

During the second half of 2017 and continuing until September 2018, the rainfall residual mass displayed a significant declining trend due to below average rainfall; an increasing trend followed from October to December 2018 due to above average rainfall; then followed a declining trend from January to September 2019, with a small increase in response to a rainfall event in September 2019. During the current reporting period, the rainfall residual mass displayed a large increase in February with much greater than average rainfall and then followed a declining trend with below average rainfall from April to June 2020, as displayed in Figure 4.

Both Swamps 101 and Woronora River Swamp 1 show pronounced drops in swamp substrate (piezometer at 1 m depth) and sandstone (piezometer at 10 m depth) groundwater levels associated with periods of rainfall deficit.

At Swamp 101 (Figure 6), the water tables have always been separated, generally by less than 0.5 m when both piezometers are saturated, and groundwater flow direction is downwards. Both piezometer water level trends displayed correlation with the rainfall residual mass throughout the review period. Water level in the sandstone 10 m piezometer continued a declining trend seen in December 2019 and January 2020; a large water level recovery of over 4 m occurred in February 2020 in response to rainfall of 540 mm in February, the largest monthly rainfall total recorded at site during the period of record since 2006; a slight declining trend ensued from April to June 2020. Over this reporting period the shallow (1 m) swamp substrate piezometer similarly became saturated and displayed a rapid spike in water level following large rainfall in February, however the substrate did not retain the water and then remained dry (groundwater level below the sensor level) from March to June 2020.

At the Woronora River 1 swamp (Figure 7), the water level in the swamp substrate (piezometer at 1 m depth) has almost always been lower than the potentiometric level in the deepest sandstone piezometer. Normally, therefore, the swamp is being recharged by groundwater from below and possibly from the sides.

During the current reporting period at Woronora River 1 swamp all three piezometers; 1 m, 4 m and 10 m responded significantly to rainfall in February 2020, with the 1 m piezometer becoming saturated following a period of dry swamp conditions, punctuated by two very short periods of saturation, from December 2017 to January 2020, and the 4 m and 10 m piezometer water levels recovering sharply. Following this water level recovery in February 2020, the normal, pre-December 2017, groundwater conditions of upward groundwater head was re-established during the period March to June 2020.

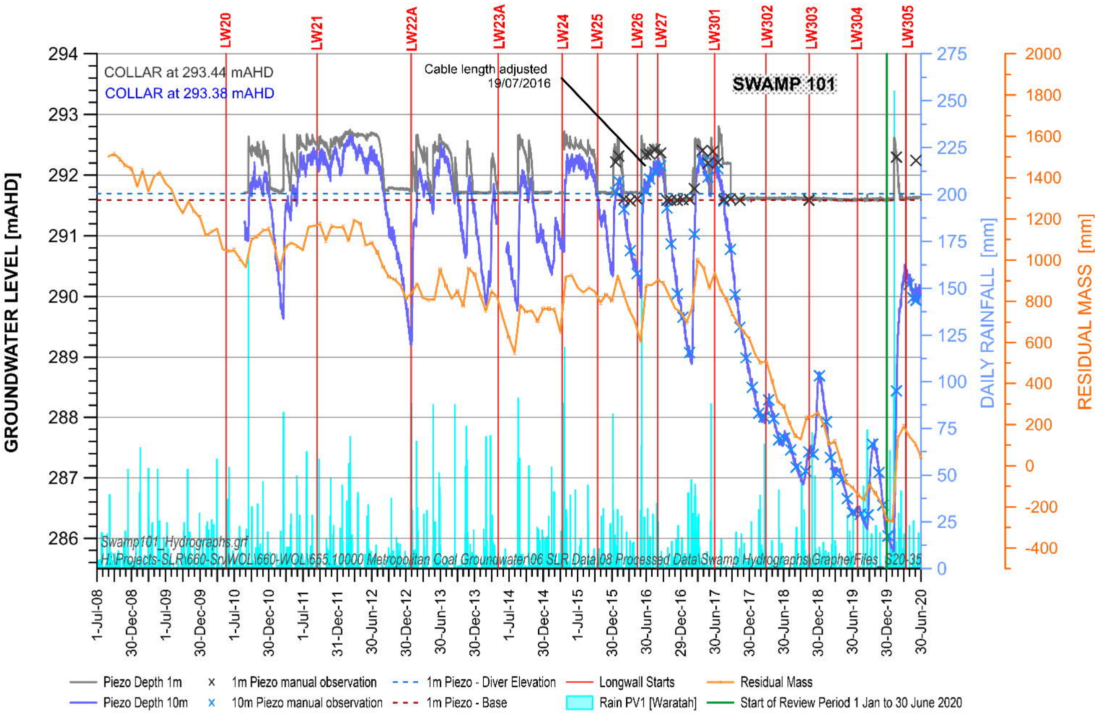


Figure 6 Groundwater Hydrographs at Control Swamp 101

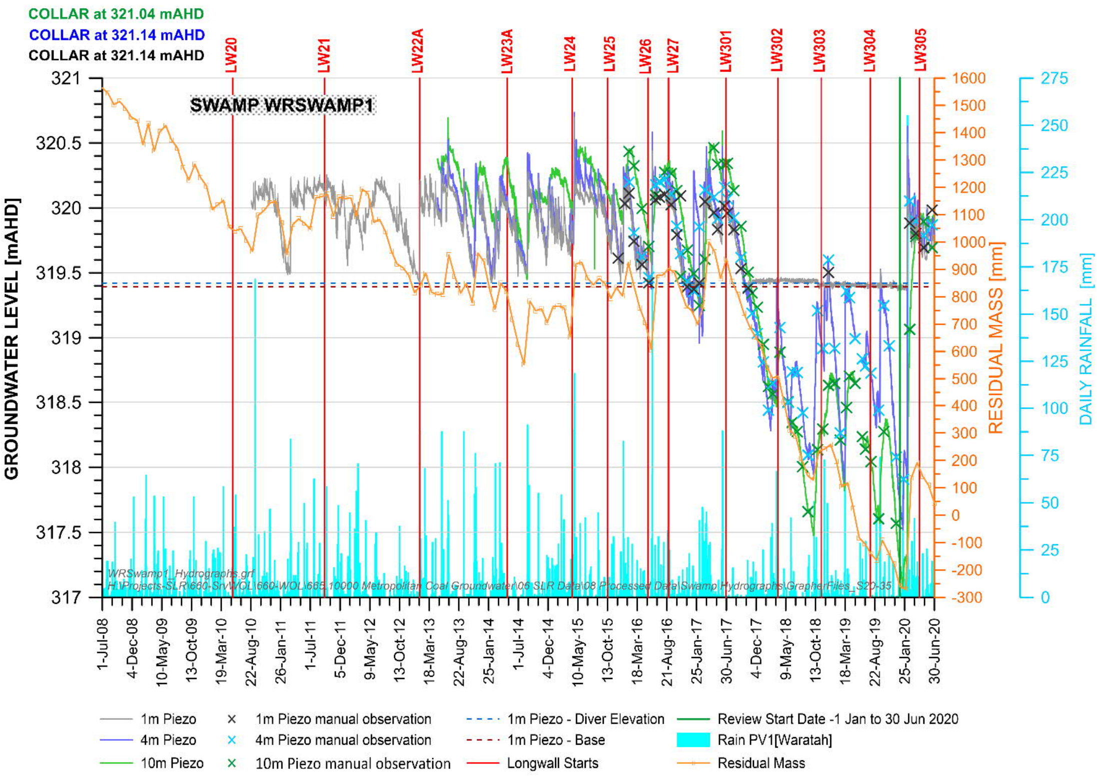


Figure 7 Groundwater Hydrographs at Woronora River 1 Control Swamp

3.1.2 Swamp 20

Hydrographic responses for Swamp 20 overlying Longwalls 20-22 are shown in Figure 8 and discussed below. During the baseline period, water appears to be infiltrating downwards to a series of perched water tables monitored by sandstone piezometers at 4 m depth and 10 m depth. The sandstone water levels (piezometers at 4 m and 10 m) remained stable from March 2011 (after a dry episode) until April 2012 when the deepest (10 m) piezometer reacted to the approach and passage of the Longwall 21 mining face, combined with lower than average rainfall. The deepest water level fluctuated by up to 1.8 m, then declined by about 8 m by September 2012. It remained around 210 mAHD, about 1 m above the bottom of the borehole, until January 2013 when water levels fluctuated up to 2.5 m in the deepest piezometer in response to a high rainfall event. From January 2014 to May 2016, groundwater levels at the 10 m piezometer remained relatively stable, ranging between 210.0 mAHD and 210.5 mAHD. Slight increases in groundwater levels were recorded following high rainfall events in March 2014 and April 2015. The 10 m piezometer groundwater level increased by approximately 2 m in response to the high rainfall in June 2016 and remained high (between 211 and 212 mAHD) until November 2017, with a small decline to approximately 210.5 mAHD from November 2016 to March 2017. From November 2017, water levels in the 10 m piezometer returned to the bottom of the hole, being mostly below sensor level. Water levels increased in response to above average rainfall from October to December 2018. Over 2019 water levels were generally below the sensor level, except following rainfall in March and in September. From September water remained relatively stable until November, after which time they declined and remained close to the base of the bore in December 2019. After the large rain event in February 2020, the water levels increased to 212 mAHD and remained at this level for the remainder of the reporting period.

The upper two piezometers (one sandstone [4 m] and one swamp substrate [1 m]) at Swamp 20 exhibited clear mining effects from August 2012 to January 2013, after which time the water levels recovered in response to heavy rain. The water levels in the swamp substrate have been fluctuating from dry to full saturation since then, in line with rainfall. Although Longwall 22B passed alongside the monitoring site in September 2013, no anomalous response is evident in the swamp substrate piezometer at that time. The swamp has changed from being permanently saturated (during the wet period of 2011) to intermittently saturated since that time. Over 2019 the 1 m piezometer groundwater level was generally below the sensor level, with the exception of September when a temporary rise in levels was recorded in response to above average rainfall. The 4 m piezometer groundwater level followed a declining trend in line with the rainfall residual mass apart from a significant increase of over 2 m in water level following above average rainfall in September 2019 and again in February 2020.

An assessment of Swamp 20 groundwater levels against those at control swamps for this reporting period is provided in Section 5.1.1.

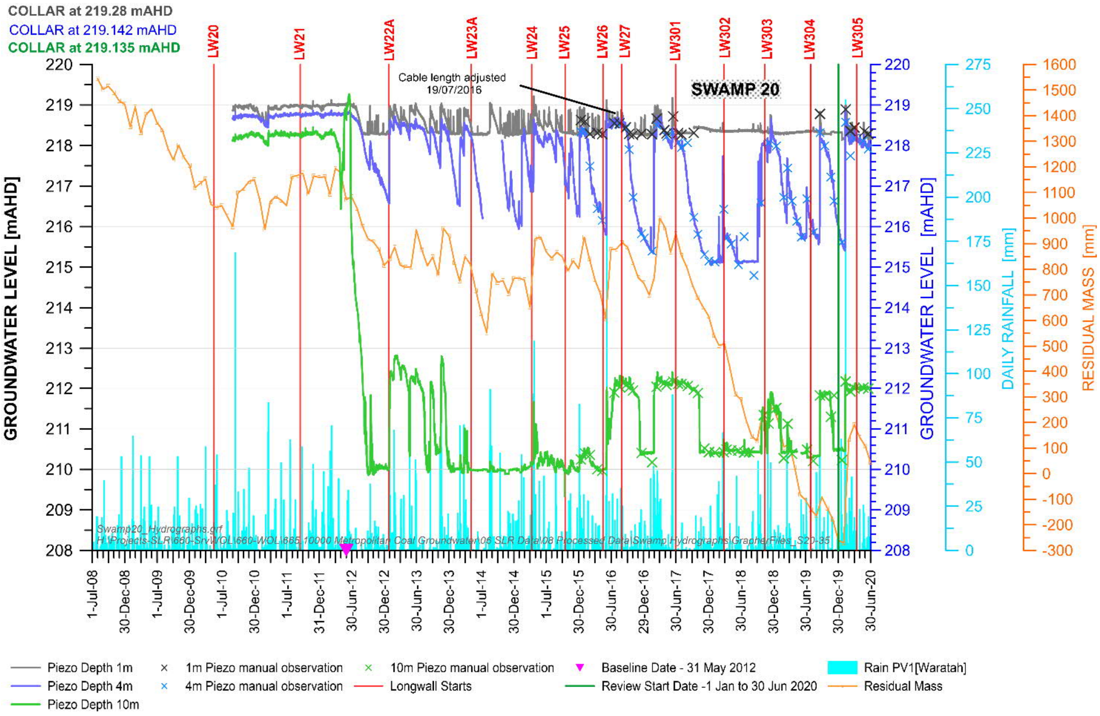


Figure 8 Groundwater Hydrographs at Swamp 20

3.1.3 Swamp 25

Hydrographic responses for Swamp 25 overlying Longwalls 20-22 are shown in Figure 9 and discussed below. Swamp 25 has always maintained a separation between swamp water levels and the water table level in sandstone at 10 m depth. Accordingly, water is likely to be infiltrating downwards from the swamp. The deeper sandstone hydrograph correlates fairly well with the rainfall trend but the swamp substrate hydrograph fluctuates within the historical bandwidth with no obvious mining effect. At the time Longwall 21 passed beneath the monitoring site (August 2012), there was a decline of about 4 m in the deeper water level and the water level in the swamp dropped to sensor level. Coincidentally, the longwall crossing occurred during a particularly dry period. In 2015 the peak groundwater level in the sandstone declined by 2-3 m despite strong rainfall events but the high rainfall in June 2016 restored the peak level to 1 m below baseline peaks. Since then, low levels suggest an ongoing mining effect to the sandstone water levels. Both the substrate and sandstone piezometers in Swamp 25 remained dry (groundwater level was below the sensor level) from September 2017 to September 2018. The substrate piezometer (1 m) was intermittently saturated from October to December 2018. The sandstone piezometer recorded a rise in levels around November to December 2018; however, the data logger was not recording during November 2018. The piezometers returned to dry conditions (water level below sensor level) over 2019. An exception to this was a short-duration saturation response in the substrate piezometer in September 2019, in response to an above average rainfall event. A delay in recharge response was observed for the 10 m piezometer, which recorded a saturation response in October 2019. Both piezometers showed some recovery after the large rain event in February 2020, however the groundwater level is lower than during the baseline period.

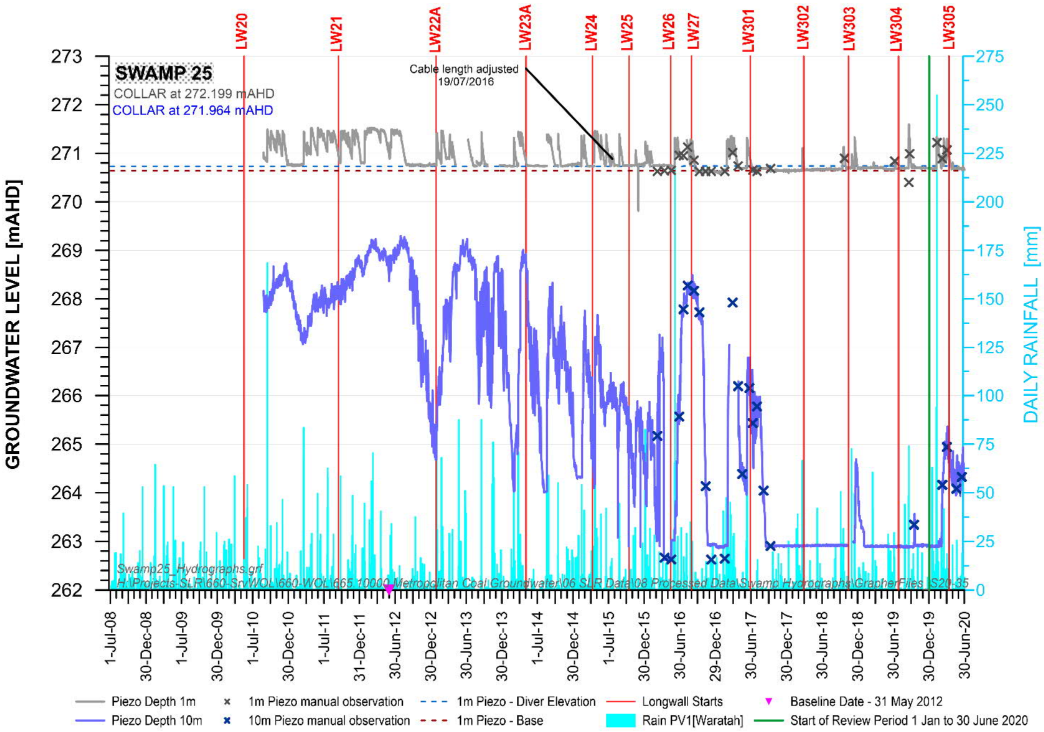


Figure 9 Groundwater Hydrographs at Swamp 25

3.2 Longwall 23 – 27

Monitoring of upland swamps for Longwalls 23-27 includes monitoring of the following piezometers; refer to Figure 1 for locations:

- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in Swamp 28 (S28) overlying Longwalls 23-27.
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in Swamp 30 (S30) overlying Longwalls 23-27.
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in Swamp 33 (S33) overlying Longwalls 23-27.
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in Swamp 35 (S35) overlying Longwalls 23-27.
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in control Swamp 137 (at S137a).
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in control Swamp 137 (at S137b).
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in control swamp Bee Creek Swamp.

As shown in Figure 1, Swamps 28 and 33 are located over Longwall 24. Swamp 30 is located to the north of Longwall 25 and to the west of Longwall 26. Swamp 35 is located between Longwalls 26 and 27, near the start of the longwalls.

In all cases, the sandstone heads are lower than the perched water levels in swamps 28, 30, 33 and 35, indicating the potential for downward flow of water. The separation between the water tables is generally 0.5 m to 2 m across the four sites. All swamps have intermittent saturation with occasional periods of dryness. Each of the swamps recorded saturation in December 2018 and September 2019, with more subdued responses in March and July 2019, that appear to coincide with rainfall events.

3.2.1 Background Trends – Control Swamps 137a, 137b and Bee Creek Swamp

The hydrographs at the three additional control swamps established for Longwalls 23-27 (Swamp 137a, Swamp 137b and Bee Creek Swamp) are shown on Figure 10 to Figure 12. All sites are well away from mining, nevertheless the longwall start dates are included on the figures to facilitate comparison with swamp responses within the mining footprint. The rainfall residual mass curve is included as a guide to the influence of rainfall on groundwater responses. Prior to September 2017 all swamp substrate sites show intermittent saturation in agreement with rainfall trends. Since then Swamps 137a and 137b, and Bee Creek, did not respond to regional rainfall events until February 2020.

At Swamps 137a (Figure 10) and 137b (Figure 11) the swamp and sandstone water tables are always separated, generally by 2-4 m, and groundwater flow direction is downwards. The two swamps have similar long periods with little or no saturation in the swamp substrate. From July 2017 to February 2018, the 10 m piezometers at both swamp sites followed a continual declining trend, concordant with the rainfall residual trend. The 10 m piezometers at both sites recorded a rise in levels in March, June and December 2018 and in March, July and September 2019, correlating with rainfall events. The swamp substrate (1 m) piezometers at both sites remained dry since September 2017. With the large rain event in February 2020, the 10 m piezometers at both swamps recovered by 2m, and the substrate piezometer showed full saturation.

At the Bee Creek Swamp (Figure 12), the swamp generally has perched water conditions. The 10 m sandstone piezometer shows groundwater levels that are typically 1.5 m higher than the swamp substrate, implying an upward gradient and upward seepage of groundwater to the swamp from the sandstone. Groundwater conditions in the sandstone were artesian during 2013-2017, varying over a narrow range (241.1 – 241.5 mAHD), with the collar reference at 241.247 mAHD, showing significant recessions only during prolonged dry periods. This is especially evident in the water levels recorded at the swamp since October 2017, with sharp decline apparent consistent with the low rainfall conditions. The direction of flow between the sandstone and the swamp substrate was reversed during most of the 2018-2019 period. The 10 m piezometer recorded a rise in levels in December 2018 and in March, July and September 2019, correlating with rainfall events. The substrate (1 m) piezometer remained dry (water level below sensor) until June 2019 while from June 2019 until December 2019 there were very minor fluctuations in groundwater level in response to rainfall. Full saturation occurred in February 2020 , and the sandstone is again recharging the swamp substrate.

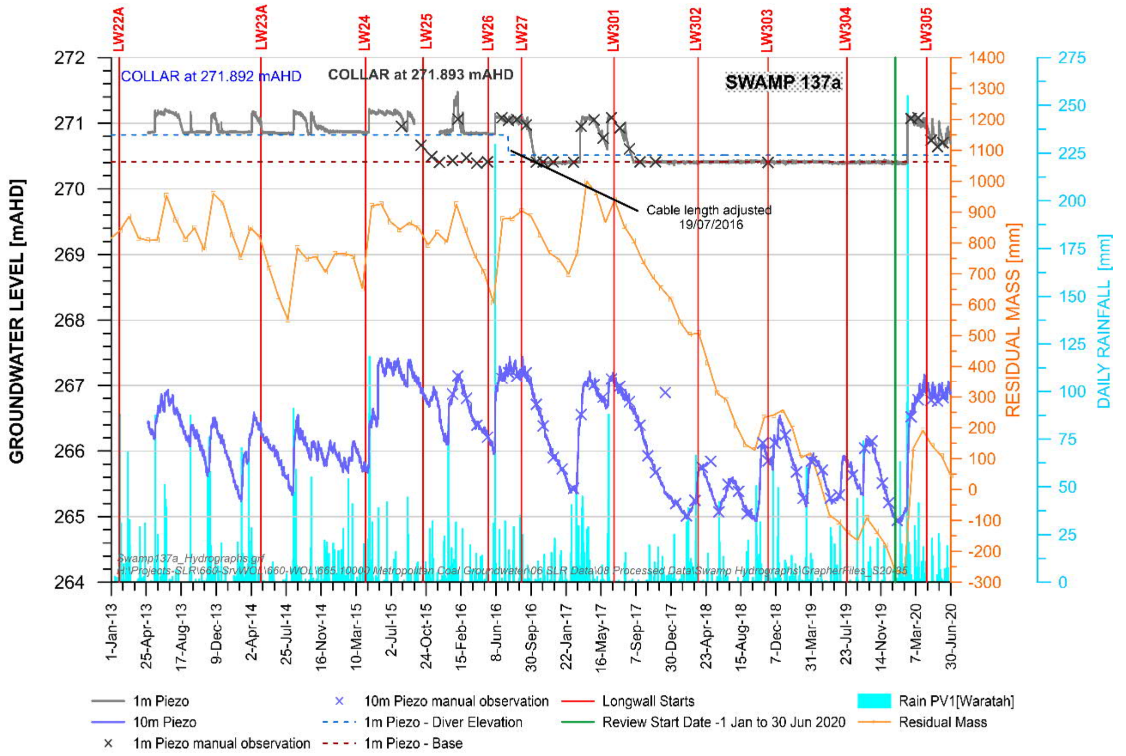


Figure 10 Groundwater Hydrographs at Control Swamp 137a

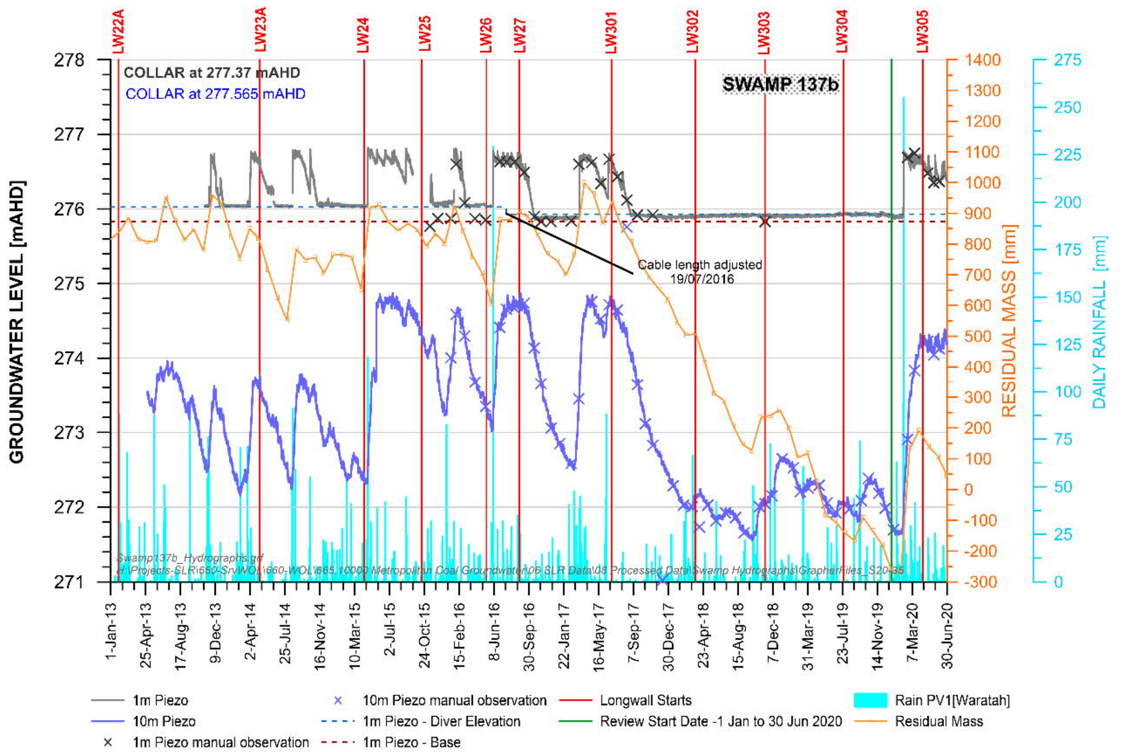


Figure 11 Groundwater Hydrographs at Control Swamp 137b

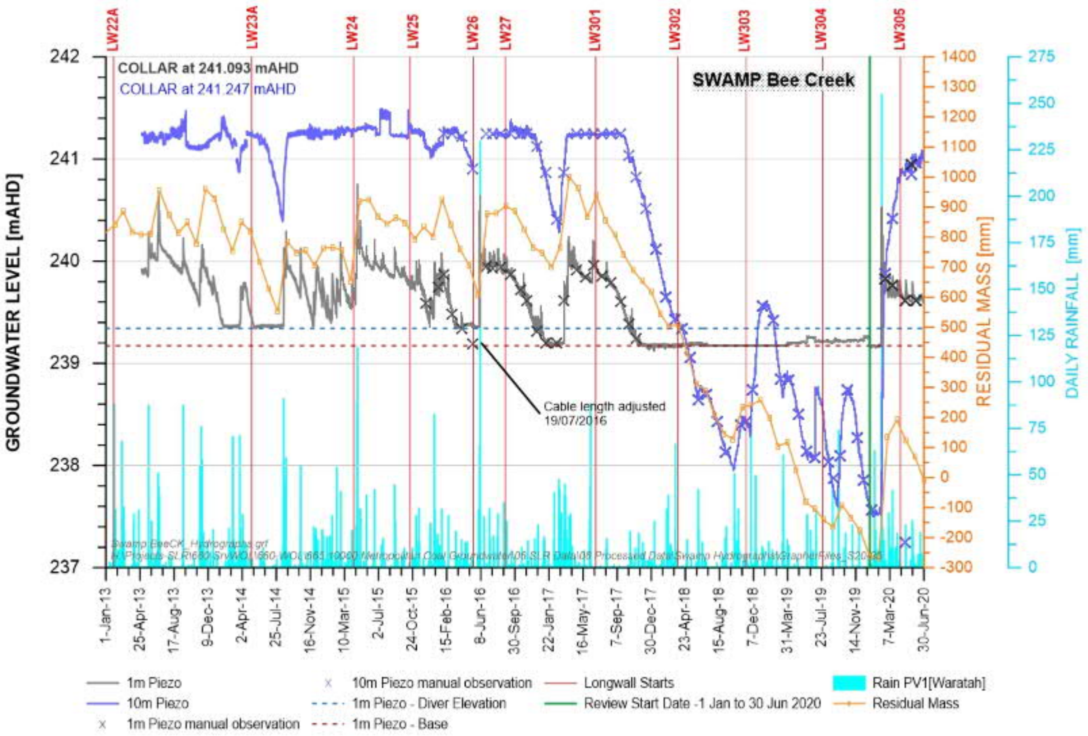


Figure 12 Groundwater Hydrographs at Bee Creek Control Swamp

3.2.2 Swamp 28

Both piezometers (shallow and deep) in Swamp 28 (Figure 13) show fluctuations in groundwater level that correlate with rainfall deficit trends prior to the passage of Longwall 24 in early May 2015, at which time the 10 m piezometer had a sharp 4 m decline followed by nearly complete recovery in June 2015. Another sharp and anomalous decline of 3.8 m occurred at the end of November 2015, coinciding with the passage of Longwall 25. In this case, the groundwater level in the 10 m piezometer did not recover, remaining at approximately 239 mAHD until the heavy rain event in June 2016. Even then, the recovery was short-lived. Both groundwater drawdown responses (May and November 2015) in the 10 m piezometer are greater than the rainfall related responses in the control swamps (< 1 m decline) and are considered to be related to mine subsidence and near-surface cracking. Since 2015 groundwater levels have remained relatively stable to slightly declining. Short duration peak levels have been recorded in response to rainfall trends, which generally declined within a month of the event. The 10 m piezometer recorded a rise in levels in December 2018 and in March, July and September 2019, correlating with rainfall events. The large rain event in February 2020 resulted in a rise of water level in both the shallow and deep piezometers. The deep piezometer water level increased after the rain event and has since decreased in line with the CRD. The shallow piezometer water level increased after the rain event and has stayed at that level since.

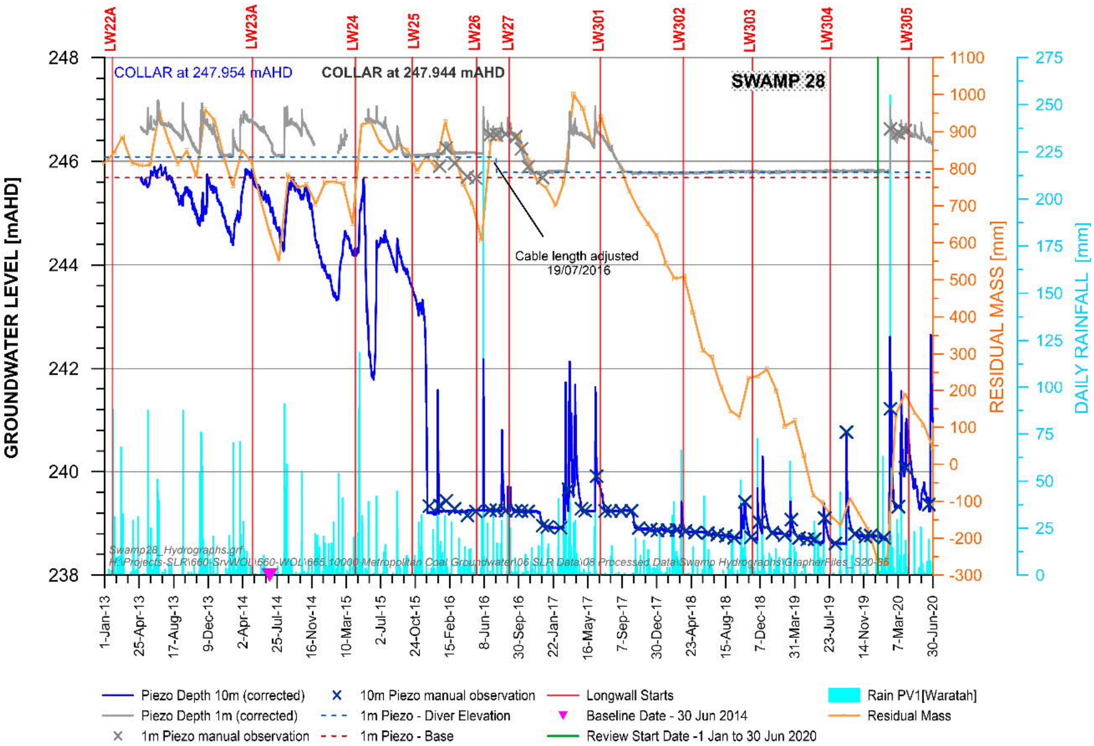


Figure 13 Groundwater Hydrographs at Swamp 28

The Swamp 28 (1 m) hydrograph is compared with the responses at the two relevant control swamps (137a and 137b)[1] in. The 1 m piezometer has been dry (groundwater level was below the sensor level) from September 2017 and remained dry (groundwater level was below the sensor level) until February 2020. The 1 m piezometers in both of the control swamps have also remained dry throughout this period. All three swamps have since increased in water level and have stayed at that level during the remainder of the reporting period.

An assessment of Swamp 28 groundwater levels, including a comparison with the relevant control swamps, during the reporting period is provided in Section 5.1.1, Figure 54.

3.2.3 Swamp 30

Hydrographic responses for Swamp 30 are shown on Figure 14. The groundwater level in the 10 m sandstone piezometer at Swamp 30 displays a probable mining effect attributable to the passage of Longwall 25. A significant magnification of amplitude in water level response with rainfall, and rapid rate of decline relative to earlier in the monitoring record is displayed and corresponds with the start of mining of Longwall 27. The water level in the substrate piezometer remained below the sensor level producing a flat line response in January and February 2017. From January 2017 to June 2018, the 10 m sandstone piezometer showed rainfall response, including in March 2018, but no recovery trend and continued declining water levels with low rainfall. The 10 m sandstone piezometer recorded a rise in groundwater levels in December 2018 and September 2019, with more subdued responses in March and July 2019, that appear to coincide with rainfall events. With the large rain event in February 2020, both the substrate and the shallow piezometer water levels recovered significantly.

1 The Bee Creek Control Swamp is not an appropriate control as groundwater flows upwards from the sandstone to the substrate.

An assessment of Swamp 30 groundwater levels, , including a comparison with the relevant control swamps, during the reporting period is provided in Section 5.1.1, Figure 58.

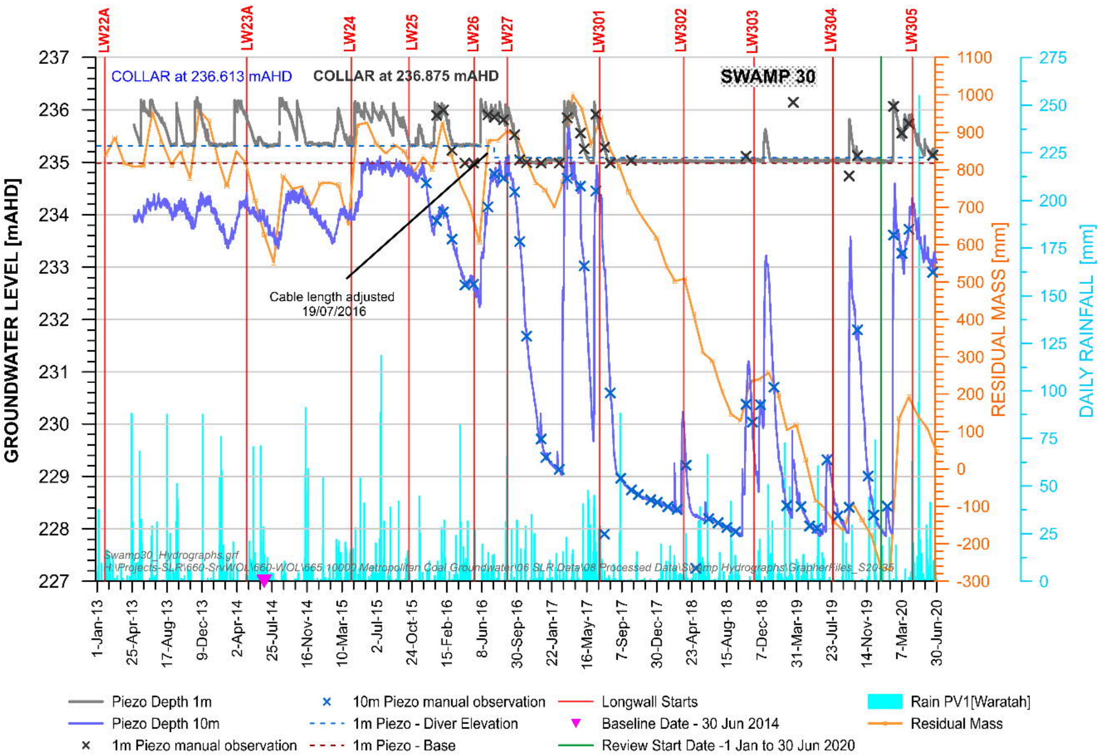


Figure 14 Groundwater Hydrographs at Swamp 30

3.2.4 Swamp 33

Hydrographic responses for Swamp 33 are shown on Figure 15. The groundwater levels in the swamp substrate were consistently more than 1 m higher than the groundwater levels in the underlying sandstone, indicating perching of the swamp groundwater. Both groundwater systems showed fluctuations that reflected the rainfall deficit trends until mid-2015. Following the high rainfall in April 2015, there was a gradual 1 m increase in groundwater levels in the sandstone accompanied by an increase of 0.8 m in the swamp substrate. From July 2015, the groundwater level in the sandstone started a steep decline of 4.6 m to December 2015. The start of the decline coincided with the passage of Longwall 24 beneath the swamp in July 2015. Another decline of approximately 3 m after high rainfall in January 2016 coincided with the passage of Longwall 25. This trend continued in 2016 and 2017; the water level trend tracked the rainfall residual and displayed a declining trend through the second six months of 2017 until January 2018 from when the water levels fell below the sensor.

These responses in the sandstone piezometer are anomalous compared with previous groundwater fluctuations and are significantly different from the modest declines seen in the control swamps. The response in the sandstone water levels at Swamp 33 is therefore likely to be a mining effect as reported in the June 2017 Six Monthly Review (HydroSimulations, 2017). The 10 m sandstone piezometer recorded a rise in groundwater levels in December 2018 and September 2019, coinciding with periods of above average rainfall. Minor rises in levels also occurred in March and July 2019 coinciding with rainfall events. The large rain event in February 2020 resulted in a more sustained recovery in the 10m piezometer for the remainder of the reporting period.

The groundwater level in the swamp substrate (1 m) piezometer at Swamp 33 has generally been reported below the sensor elevation since 2017. Exceptions to this include short periods of saturation coinciding with rainfall events. Recent events include following rain in March, October and December 2018, as well as September and October 2019. The large rain event in February 2020 resulted in a more sustained recovery in the shallow 1 m piezometer for the remainder of the reporting period.

An assessment of Swamp 33 groundwater levels during the reporting period is provided in Section 5.1.1, Figure 60.

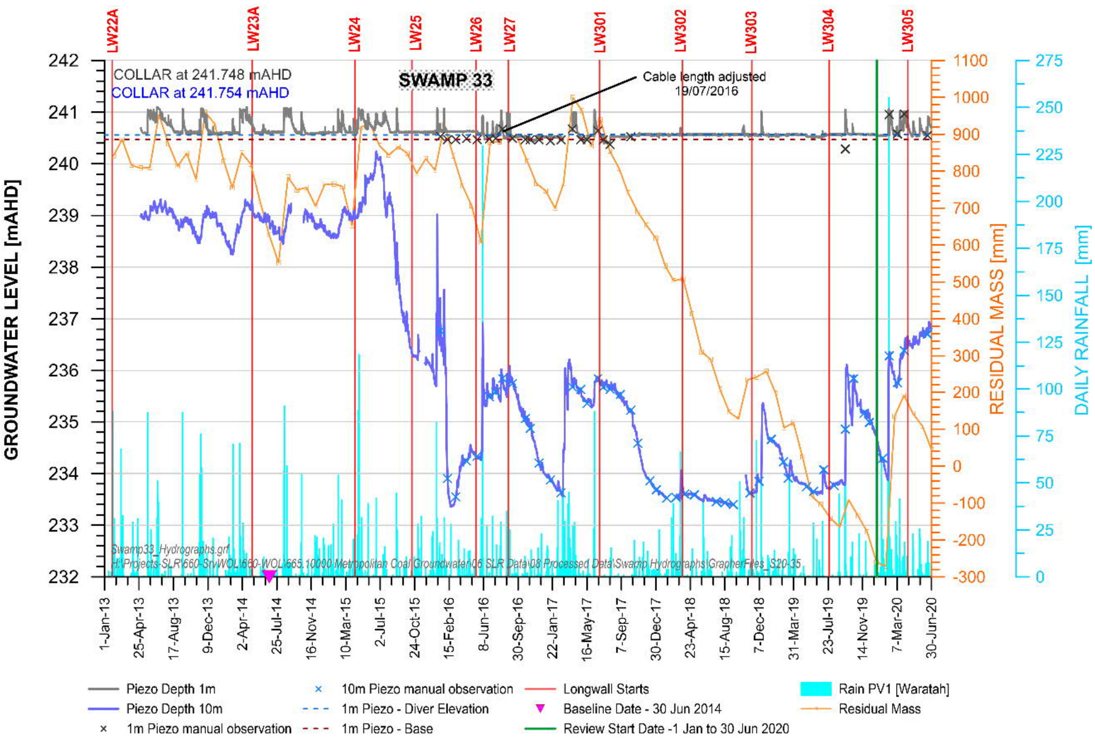


Figure 15 Groundwater Hydrographs at Swamp 33

3.2.5 Swamp 35

Hydrographic responses for Swamp 35 are shown on Figure 16. Groundwater levels in the swamp substrate are typically 1.0 to 1.5 m higher than groundwater levels in the underlying sandstone. However, in March 2017 a reversal of hydraulic gradient occurred for the first time in the monitoring record. For a short period following a significant increase in rainfall residual, the water level in the 10 m piezometer was above that of the substrate piezometer, but this has not been repeated since. Both levels are strongly correlated with each other and with the rainfall deficit trend. Longwall 25 passed within 250 m of the swamp in December 2015. There was a decrease in groundwater level in the sandstone of 1.2 m in late November – early December 2015, but this decrease also coincided with a period of low rainfall and decline of similar magnitude at control swamps.

The observed response is therefore consistent with natural responses to low rainfall rather than mining. Water levels in the sandstone and the substrate increased with the high rainfall in June 2016 and remained high through to late September 2016. Water level in the sandstone piezometer rose 2.7 m in March 2017, with rainfall, to its maximum recorded elevation of 255.6 mAHD, and then followed a declining trend with responses to rainfall events until reaching a low point in September 2018 at 252.0 mAHD. There was an increasing trend in the sandstone piezometer from October to December 2018, reaching 254.9 mAHD. The sandstone piezometer was responsive to rainfall events in September and October 2019. More subdued rises in groundwater levels were also recorded in March and July 2019 in response to rainfall events.

After the swamp substrate piezometer was saturated in March 2017, water level declined slowly until replenished by the rainfall event of 7 June 2017 and then remained dry from August 2017 to the end of September 2018, apart from a short period following rain in March 2018, and was intermittently saturated from October to December 2018, concordant with the rainfall residual mass trend. During 2019 the swamp substrate piezometer was dry during July and August, remained saturated through September and October 2019 and returned to dry conditions through November and December 2019. The large rain event in February 2020 caused both the substrate and shallow piezometer water levels to increase substantially. No mining effect is discernible at the commencement of Longwall 27 almost directly beneath the swamp.

An assessment of Swamp 35 groundwater levels during the reporting period is provided in Section 5.1.1., Figure 62.

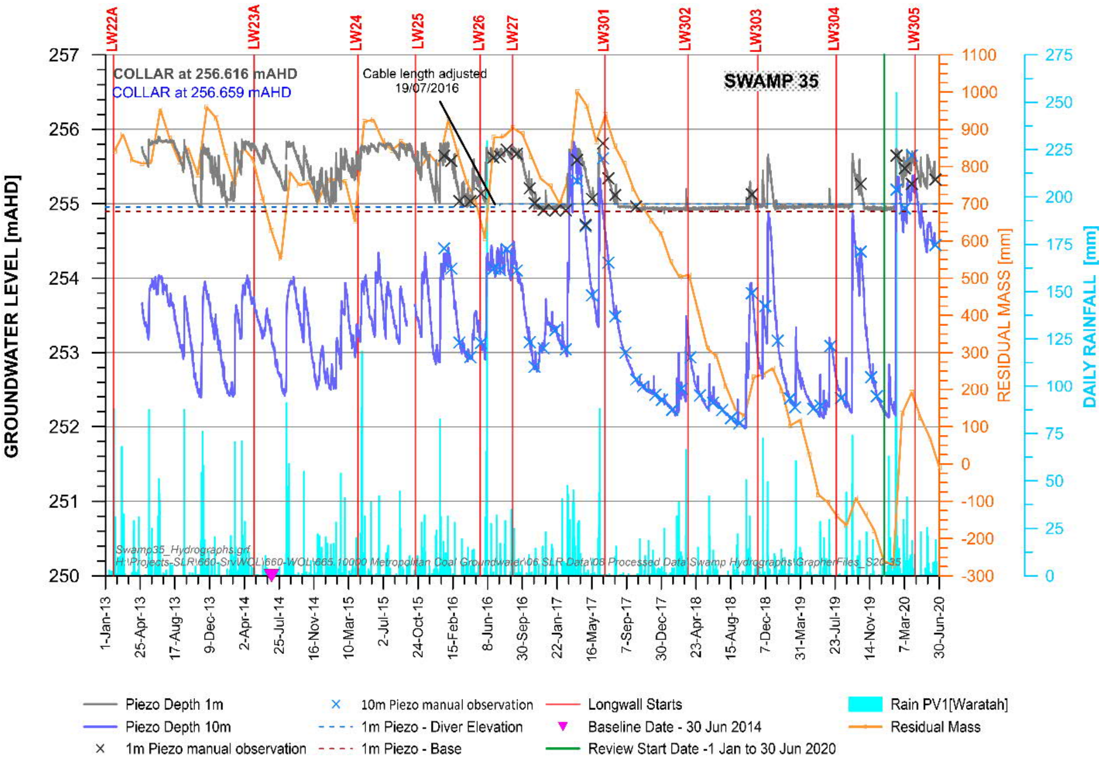


Figure 16 Groundwater Hydrographs at Swamp 35

3.3 Longwall 301-303 swamps

Groundwater monitoring of upland swamps for Longwalls 301-303 includes monitoring of the following piezometers (locations shown in Figure 1):

- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in Swamp 40 (S40).
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in Swamp 41 (S41).
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in Swamp 46 (S46).
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in Swamp 51 (S51).
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in Swamp 52 (S52).
- Paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m), located in Swamp 53 (S53).

All the swamps mapped in the Longwalls 301-304 mining area are valley side swamps (Metropolitan Coal, 2018c).

3.3.1 Swamp 40

Figure 17 shows the groundwater levels in the substrate and shallow piezometers for Swamp 40, together with the daily rainfall and CRD. The shallow piezometer generally shows a response to rainfall, and has seen a significant increase in February 2020. The substrate piezometer shows less variation over time (< 1m), and has seen some small response to the large rain event in February 2020. In general, the substrate piezometer water level is above the shallow water level, which indicates downward movement of water.

A comparison of the substrate hydrograph with the control swamps is presented in Section 5.1.2, Figure 64.

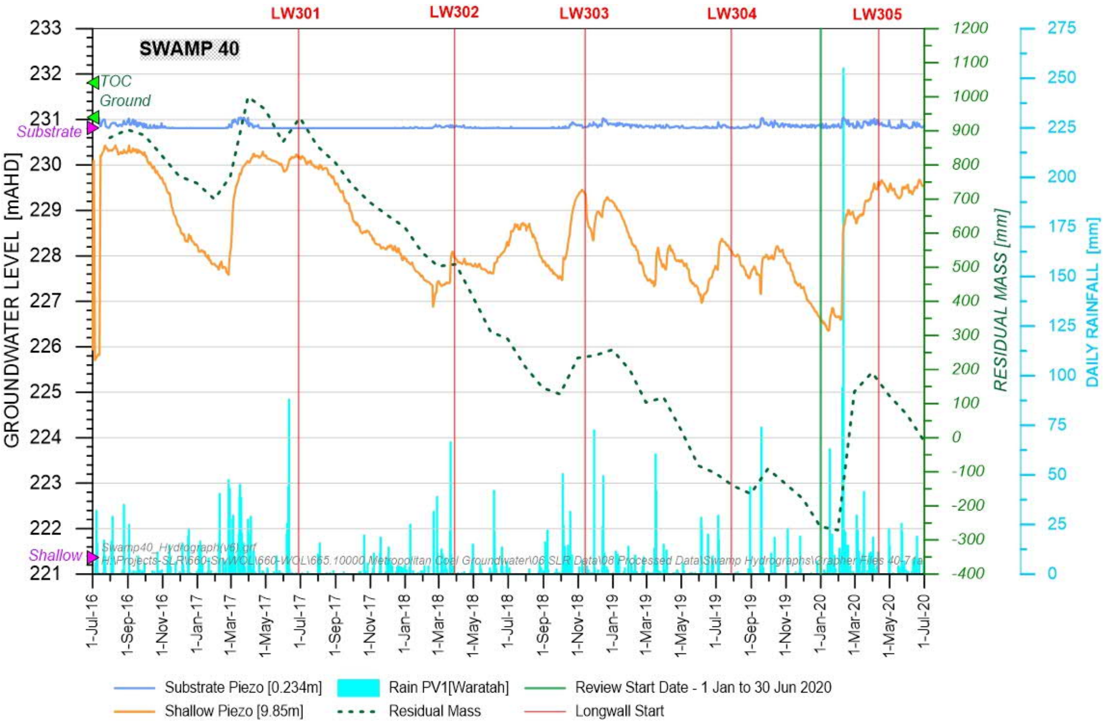


Figure 17 Groundwater Hydrographs at Swamp 40

3.3.2 Swamp 41

Figure 18 shows the groundwater levels in the substrate and shallow piezometers for Swamp 41, together with the daily rainfall and CRD. The shallow piezometer generally shows a range of about 4 m in water level and a good response to rainfall. The substrate piezometer shows less variation over time (~ 1m), and has seen some responses to rain events that broke longer periods of groundwater levels below logger levels. Since the rain event in February 2020, the water level in Swamp 41 remained high, close to full saturation. In general, the substrate piezometer water level is above the shallow water level, which indicates downward movement of water.

A comparison of the substrate hydrograph with the control swamps is presented in Section 5.1.2, Figure 66.

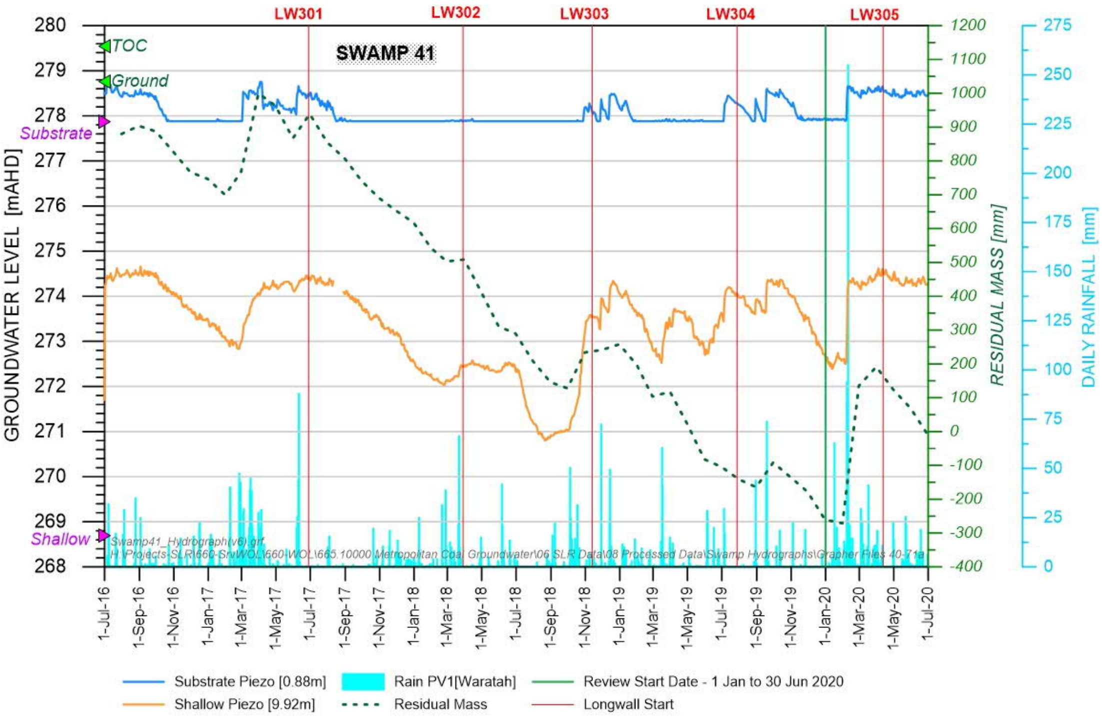


Figure 18 Groundwater Hydrographs at Swamp 41

3.3.3 Swamp 46

Figure 19 shows the groundwater levels in the substrate and shallow piezometers for Swamp 46, together with the daily rainfall and CRD. The shallow piezometer generally shows a range of about 3 m in water level, whereas the substrate piezometer shows less variation over time (~ 1m) and has seen some responses to rain events that broke longer periods of groundwater levels below logger levels. Since the rain event in February 2020, both the shallow and the substrate water levels increased and remained at that new level for the remainder of the reporting period. The substrate piezometer water level is always above the shallow water level, which indicates downward movement of water.

A comparison of the substrate hydrograph with the control swamps is presented in Section 5.1.2, Figure 68.

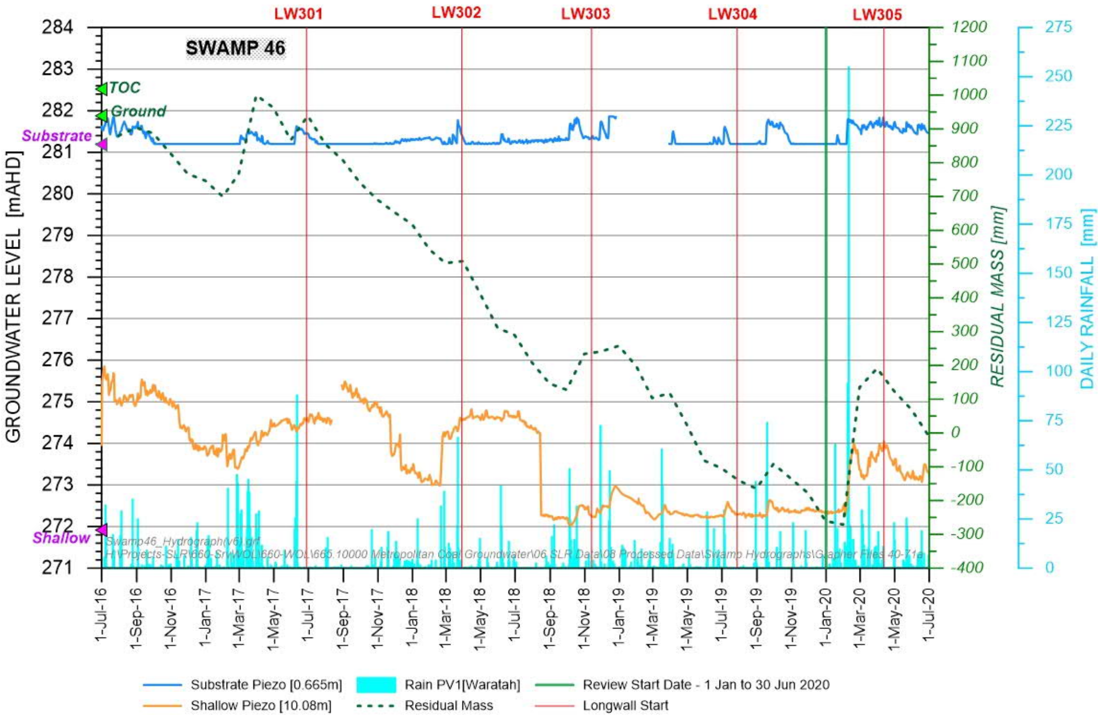


Figure 19 Groundwater Hydrographs at Swamp 46

3.3.4 Swamp 51

Figure 20 shows the groundwater levels in the substrate and shallow piezometers for Swamp 51, together with the daily rainfall and CRD. The shallow piezometer generally shows a range of about 4 m in water level and a good response to rainfall. The substrate piezometer shows less variation over time (~ 1m), and has seen some responses to rain events that broke longer periods of groundwater levels below logger levels. Since the rain event in February 2020, water in Swamp 51 remained present. In general, the substrate piezometer water level is above the shallow water level, which indicates downward movement of water.

A comparison of the substrate hydrograph with the control swamps is presented in Section 5.1.2, Figure 72.

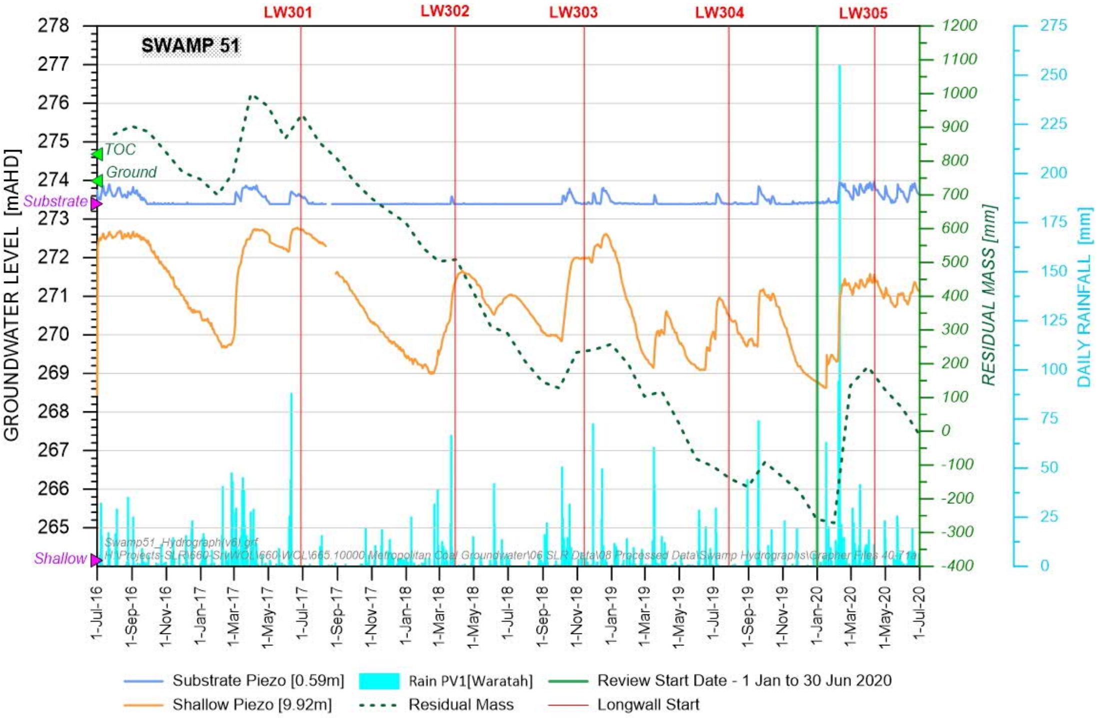


Figure 20 Groundwater Hydrographs at Swamp 51

3.3.5 Swamp 52

Figure 21 shows the groundwater levels in the substrate and shallow piezometers for Swamp 52, together with the daily rainfall and CRD. The shallow piezometer generally shows a range of about 4 m in water level and a good response to rainfall. The substrate piezometer shows less variation over time (~ 1m) and has seen some responses to rain events that broke longer periods of groundwater levels below logger level (flat lines in the plot). Since the rain event in February 2020, the water level in Swamp 52 has remained close to full saturation. In general, the substrate piezometer water level is above the shallow water level, which indicates downward movement of water. Swamp 52 (1 m piezo) was replaced on 28 August 2019.

A comparison of the substrate hydrograph with the control swamps is presented in Section 5.1.2, Figure 74.

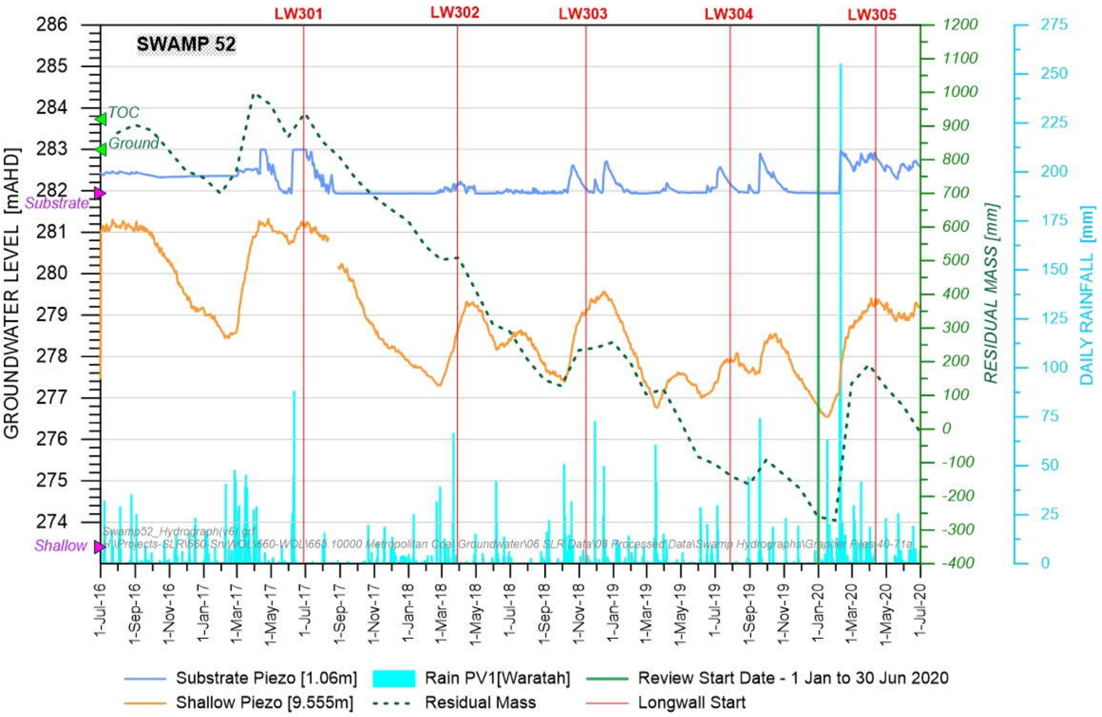


Figure 21 Groundwater Hydrographs at Swamp 52

3.3.6 Swamp 53

Figure 22 shows the groundwater levels in the substrate and shallow piezometers for Swamp 53, together with the daily rainfall and CRD. The shallow piezometer generally shows a range of about 5 m in water level and a good response to rainfall. The substrate piezometer shows less variation over time (~ 2m) and has seen some responses to rain events that broke longer periods of groundwater levels below logger level (flat lines in the plot). Since the rain event in February 2020, the water level increased and remained at that recovered level for the rest of the reporting period. Most of the time, the substrate piezometer water level is above the shallow water level, which indicates downward movement of water. However, there are periods where the water level at the shallow piezometer is above the water level in the substrate piezometer, which would indicate upward movement of water.

A comparison on the substrate hydrograph with the control swamps is presented in Section 5.1.2., Figure 76.

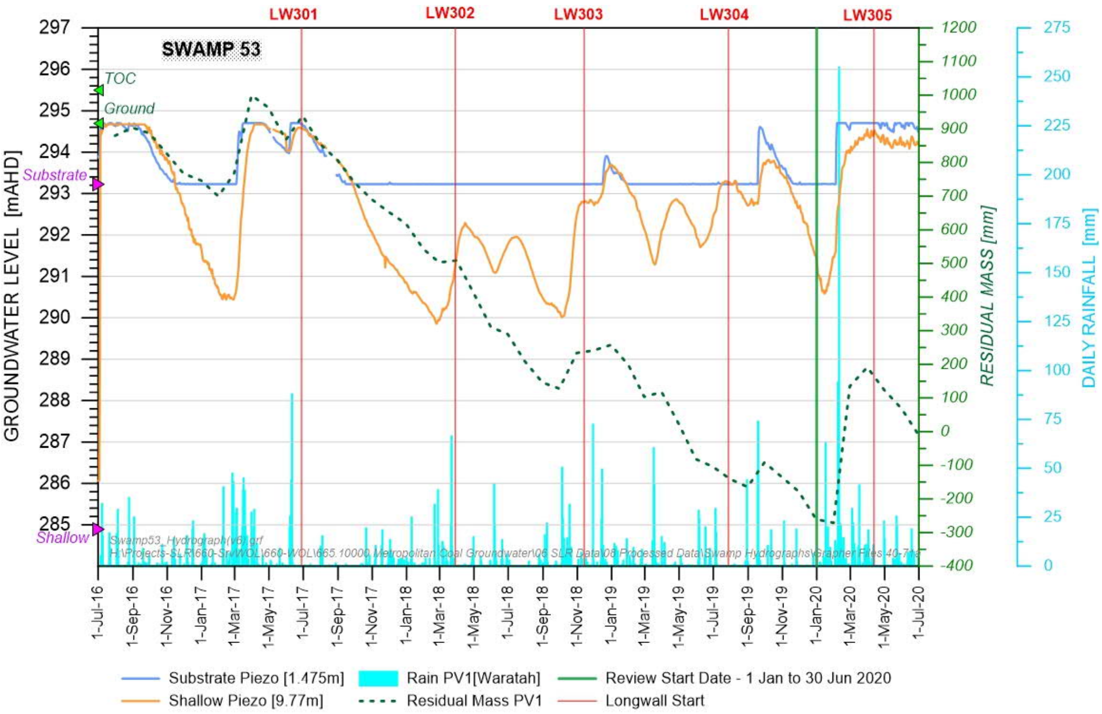


Figure 22 Groundwater Hydrographs at Swamp 53

3.4 Longwall 304 swamps

3.4.1 Swamp 50

Figure 23 shows the substrate and shallow (10 m) piezometers installed in Swamp 50. During the previous reporting period, the Swamp 50 10 m piezometer displayed a pronounced decline in water level from October 2019 continuing to the end of the reporting period 31 December 2019 coinciding with the passage of Longwall 304; this is an apparent mining affect considered to be related to mine subsidence. Since the large rain event in February 2020, some of the decline recovered; however, water levels remain approximately 3 m lower than before the passage of Longwall 304.

There is a large data gap for the substrate piezometer between February 2016 and May 2018, the substrate piezometer was replaced in May 2018. The substrate piezometer did not show any evidence of decline. The occasional flatlined water level in the plot is attributed to dry conditions. Since February 2020, the piezometer showed water levels above the minimum. A comparison of the substrate piezometer with the control swamps is presented in Section 5.1.2, Figure 70.

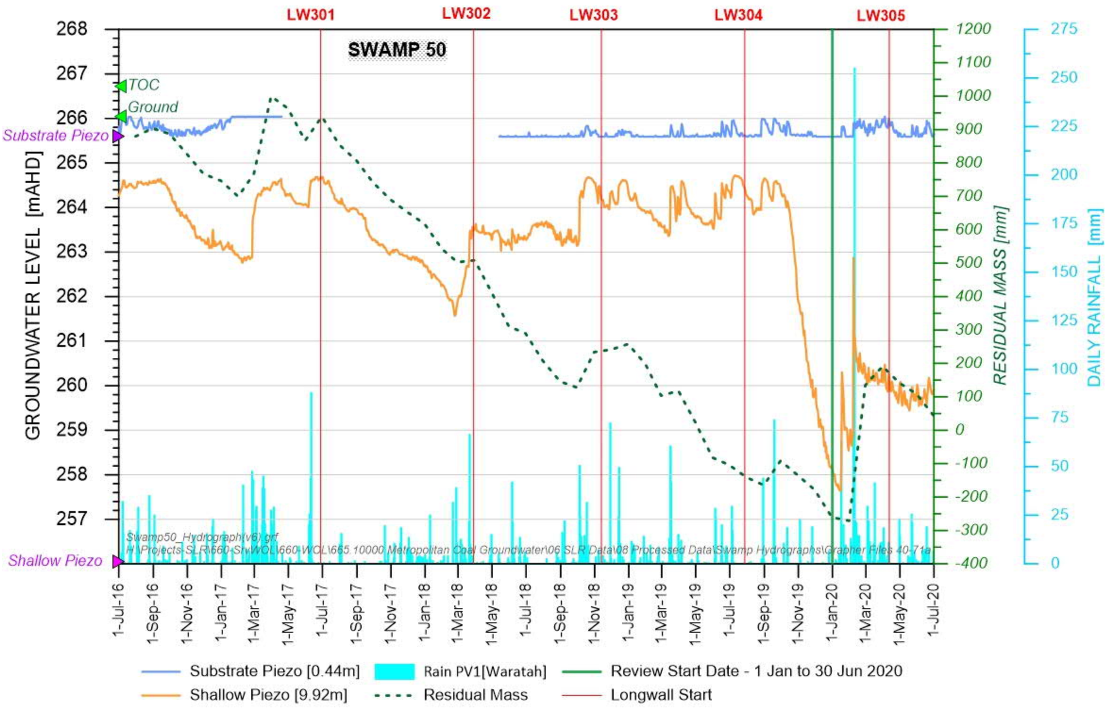


Figure 23 Groundwater Hydrographs at Swamp 50

3.5 Longwall 305-307 swamps

3.5.1 Swamp 71a

Swamp 71a has been monitored since 2016 and it is the first time that the results are reported, as this swamp is part of the Longwall 305-307 BMP requirements. Figure 24 shows the water levels for the substrate piezometer and the shallow piezometer along with the CRD. The shallow piezometer shows a water level range of approximately 2 m, with the highest water levels recorded in this reporting period (January to June 2020). The substrate piezometer flatlines at ground level during wet periods, and varies only marginally (as expected with a shallow installation depth).

A comparison between Swamp 71a and the control swamps 101, 137a and 137b is presented in Section 5.1.3, Figure 78.

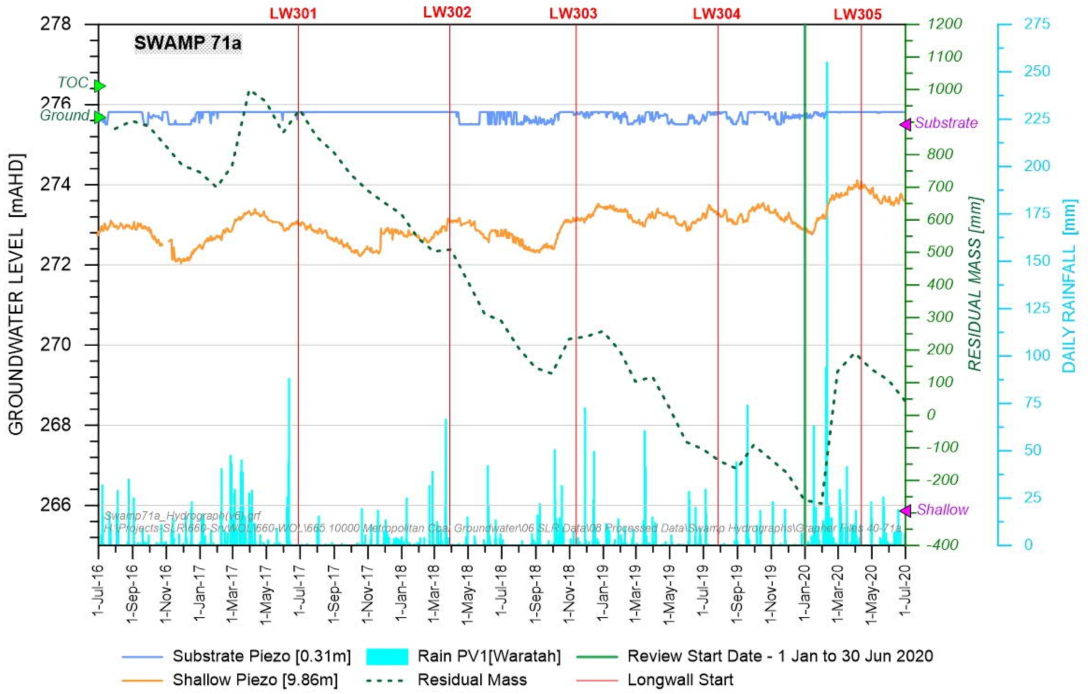


Figure 24 Groundwater Hydrographs at Swamp 71a

3.5.2 Swamp 72

Swamp 72 has been monitored since February 2019 and it is the first time that the results are reported, as this swamp is part of the Longwall 305-307 BMP requirements. Figure 25 shows the water levels for the substrate piezometer and the shallow piezometer along with the CRD. Unlike for other swamps, the shallow piezometer shows a relatively small water level range of approximately 1 m, with the highest water levels recorded in this reporting period (January to June 2020). However, the water level observations provided by a third-party seem to be limited by the ground level at the top (flatlining). The substrate piezometer shows a similar range of observation (~0.7 m).

A comparison of the substrate water level with the control swamps is presented in Figure 80. Swamp 72 showed varying water levels during a period when the control swamps water levels were below the level of the loggers (January 2019 to February 2020). With the large rain event in February 2020, the control swamp water levels recovered and the water levels in Swamp 72 showed a lesser degree of increase.

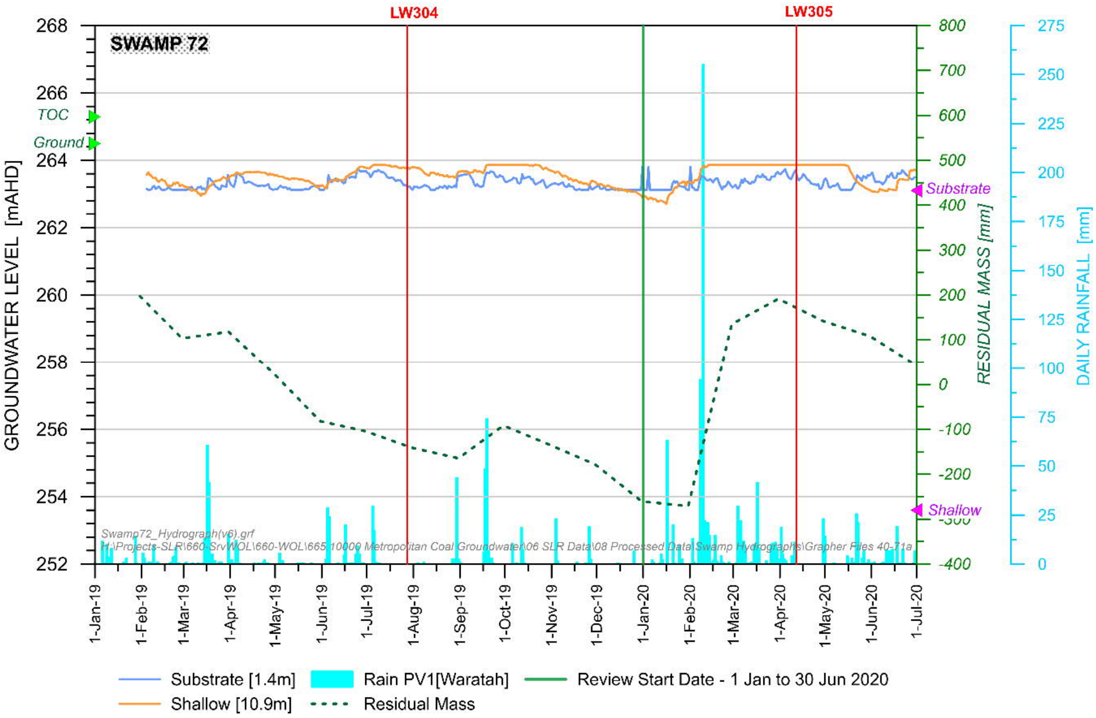


Figure 25 Groundwater Hydrographs at Swamp 72

4 Groundwater monitoring results

4.1 Shallow groundwater levels

Continuous water level monitoring of shallow groundwater levels has been conducted at sites WRGW1, WRGW2 and WRGW7 along Waratah Rivulet and sites ETGW1 and ETGW2 on the Eastern Tributary (locations are shown in Figure 5).

4.1.1 WRGW1 and WRGW2

Sites WRGW1 and WRGW2 are located on opposite banks of the Waratah Rivulet, to the immediate south of Longwall 20. The groundwater level monitoring results for sites WRGW1 and WRGW2 are shown on Figure 26 and are compared with rainfall trends and rainfall events as recorded at the Waratah Rivulet catchment PV1 pluviometer. Sites WRGW1 and WRGW2 show comparable information over the reporting period, with rapid response to rainfall events and sharp spikes associated with runoff events, indicating interaction with the Waratah Rivulet. Site WRGW1 shows a greater response to rainfall events than site WRGW2 but shows the same trends, as has been the case for the length of record. At the time of passage of the Longwall 21 mining face past the piezometer sites (March 2012), the measured groundwater levels dropped by about 1 m. As wet conditions prevailed at the time, this was not a climatic effect. This conclusion is supported by the observation that none of the other Waratah Rivulet piezometers showed a similar response at that time. The passage of Longwall 20 a year earlier had no obvious effect at sites WRGW1 or WRGW2. Since March 2012, groundwater levels recorded at sites WRGW1 and WRGW2 have fluctuated in response to seasonal rainfall variations with a seasonal (dry) minimum that is approximately 0.75 m below previous levels.

Throughout 2017, the water levels at sites WRGW1 and WRGW2 correlated closely with rainfall trends. During October-December 2017 both piezometers followed an increasing trend as the rainfall residual mass was declining (see residual mass curve on Figure 26); this can be explained as the monthly total rainfalls were less than average, meaning the residual trend remained in decline, though monthly rainfalls and individual daily rainfalls were greater than the July-September 2017 period causing some recovery. This trend was reversed from January 2018 to September 2018 with groundwater levels following the declining rainfall residual mass; apart from a spike in water level following rainfall in March 2018, greater response was recorded in WRGW2 than WRGW1. From October 2018 to December 2018, the rainfall residual mass and water levels followed an increasing trend. During January to June 2019, the water level correlated with the daily rainfall including a large spike following the March rainfall event, and generally correlated with the residual mass curve except for January and February, when following rainfall in December 2018 the water level increased while the monthly rainfall was below average. The water levels have not returned to pre-March 2012 levels. The water levels at both WRGW1 and WRGW2 sites during 2019 displayed the usual correlation with the daily rainfall with a large spike at a September 2019 rainfall event. The large rain event in February 2020 resulted in a spike in the groundwater level at both monitoring sites.

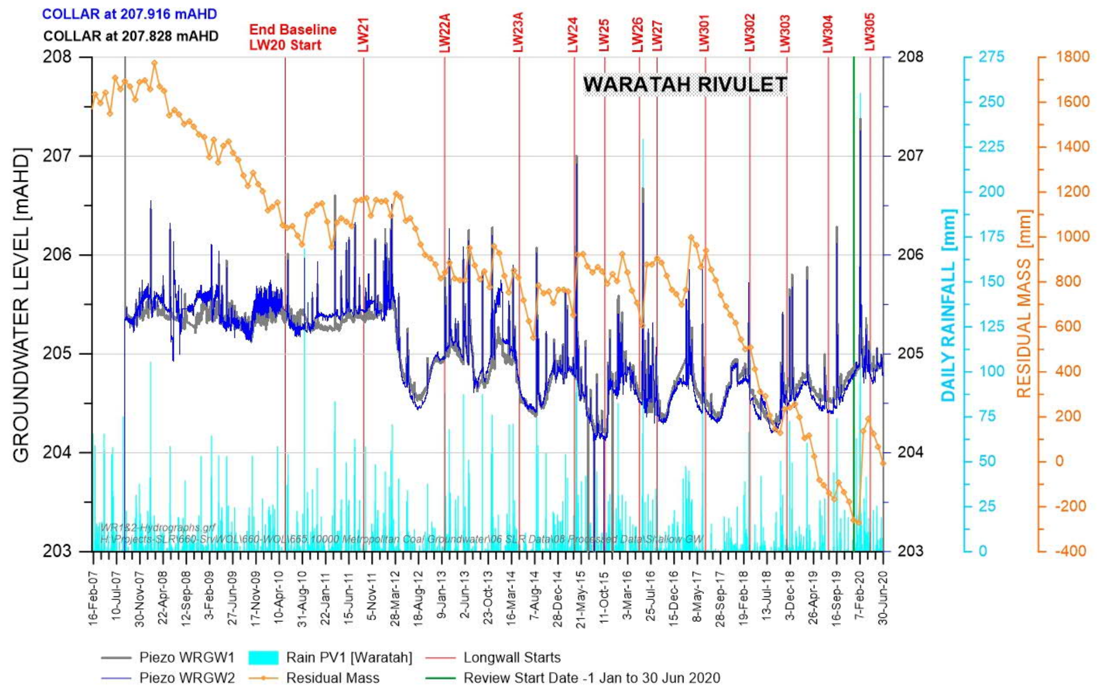


Figure 26 Shallow Groundwater Hydrographs on Waratah Rivulet at WRGW1 and WRGW2

4.1.2 WRGW7

The shallow groundwater level data available for site WRGW7 on the Waratah Rivulet (Figure 27) indicate a good correlation between the response at site WRGW7 and rainfall trend, and good evidence of stream-aquifer interaction for Waratah Rivulet flow events. Site WRGW7 is located approximately 400 m downstream of Longwall 23. Groundwater levels at site WRGW7, whilst not showing a large response to the March 2019 rainfall event, remain correlated with rainfall trends and unaffected by mining. During the current reporting period the water level maintained correlated trends with the daily rainfall and showed a significant response to the February 2020 rainfall event. Similar to the previous reporting period Site WRGW7 remained unaffected by mining.

4.1.3 ETG1 and ETG2

At the Eastern Tributary sites ETGW1 and ETGW2, which are located downstream of Longwall 27, shallow groundwater levels have previously followed the rainfall trends closely (Figure 28), and continued to show a close correlation during the reporting period. The variations at these sites are unrelated to mining. Reservoir water levels also respond to rainfall with a similar pattern. A groundwater hydraulic gradient is maintained towards the reservoir because the groundwater levels are 6-14 m higher than dynamic reservoir levels.

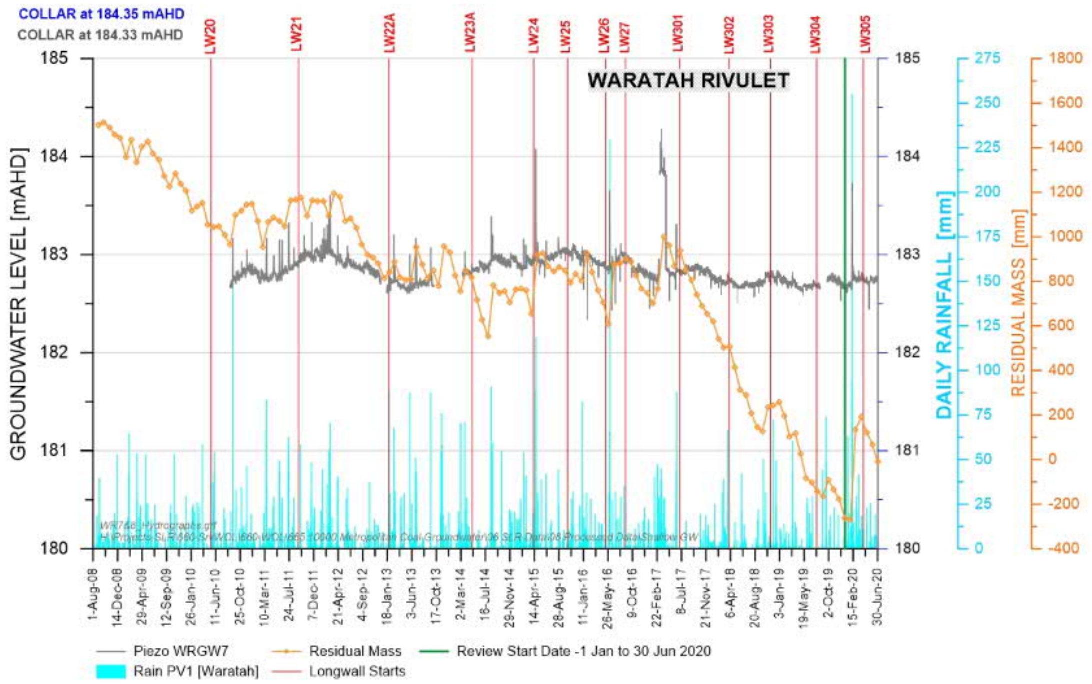


Figure 27 Shallow Groundwater Hydrograph on Waratah Rivulet at WRGW7

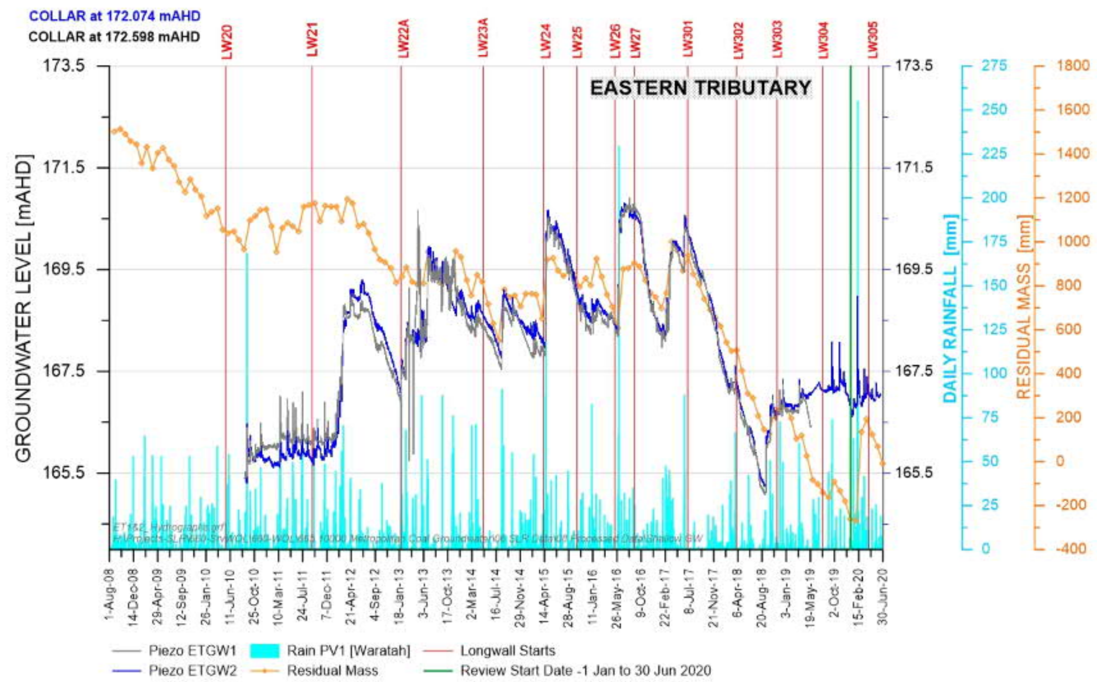


Figure 28 Shallow Groundwater Hydrographs on Eastern Tributary at ETGW1 and ETGW2

4.1.4 Transect bores

Continuous groundwater level monitoring has been conducted at an approximately east-west transect of bores (sites T1, T2, T3, T4, T5 and T6) located to the west of Longwalls 301-303, and is displayed in Figure 29.

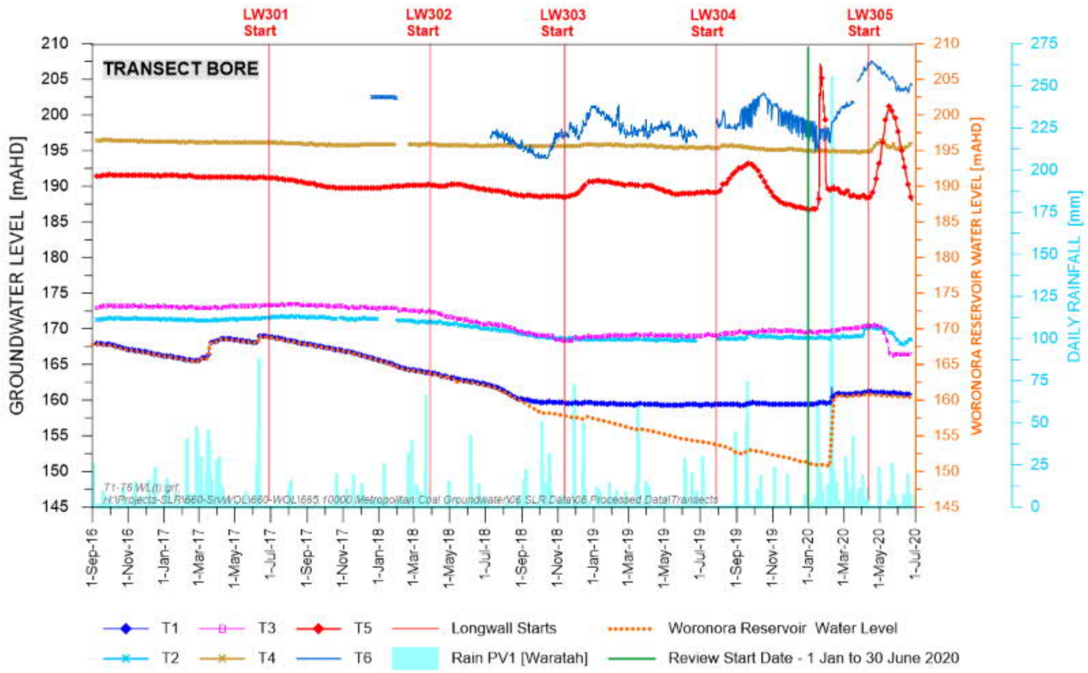


Figure 29 Groundwater Level in Bores T1 to T6

Bore T1, the nearest of the five bores to Woronora Reservoir, has almost identical water levels to those measured in the reservoir, until an old weir across the rivulet is exposed at low water levels. In that case, T1 water levels are maintained a little below the water level in the weir pool.

Bores T2 and T3 showed fairly stable water levels in line with previous observations at the start of the reporting period, with a gradual rise in T3. Water levels in both bores started decreasing in May 2020, with an abrupt drop at T3, due to the passage of the Longwall 305 mining face at that time. These water levels will need a close review in the next six-monthly assessment.

Bore T4 remains anomalous, as its head has always been higher than the head at upgradient site T5. This is unlikely to be a groundwater divide as it is not related to the topographic ridge well upgradient.

Since the last review (SLR, 2020), the water levels at T5 showed a high variability. The water level increased by 15 metres in early January 2020 and decreased in late January 2020. This spike in water level was unrelated to the large rainfall event in February 2020. Since April 2020 (after LW305 started), the water levels increased again, this time over a longer period and have again decreased. The second spike is reflected in the observations for T4, which shows a lower rise and fall at the same time. The broad rises in T5 water levels in 2019 and 2020 are compressive effects associated with the passage of Longwalls 304 and 305, respectively. Bore T5 will need further review over the next six months to confirm the cause of these water level changes

Bore T6 lies on the western side of Woronora Reservoir at a higher elevation than the eastern transect. Unlike the eastern bores, it responds readily to rainfall recharge and its dynamics closely correlate with the rainfall residual mass trend.

Assessments against the performance indicators are presented in Section 5.4.

4.2 Deep groundwater levels/Pressures

Continuous groundwater level/pressure monitoring is conducted at bores 9HGW0 (Longwall 10 Goaf Hole), 9EGW1B, 9FGW1A, 9GGW1-80, 9GGW2B, 9HGW1B, PM02, PM01, 9EGW2A, PM03, PHGW1B, PHGW2A, F6GW3 and F6GW4 (locations shown in Figure 5). The results of deep groundwater level monitoring for the reporting period are described below.

The time-series head variations and vertical head differences for these bores have been examined (Figure 30 to Figure 43), with the following outcomes:

- sites close to current mining show significant depressurisation with depth, consistent with the Project EA (Helensburgh Coal Pty Ltd, 2008); and
- sites close to old workings at Helensburgh show substantial depressurisation with depth, consistent with the Project EA.

The monitoring sites closest to Longwall 301-303 are bore F6GW4A (west of Longwall 303), bore F6GW3A (to the south of Longwall 301) and bore 9GGW2B (above 300-series mains and to the south-west of Longwall 303) (Figure 5).

Additional groundwater monitoring bores were installed in the third quarter of 2017 as a component of the Woronora Reservoir Impact Strategy including a goaf hole over Longwall 302 (302GW01). Metropolitan Coal installed five copper wire and four optical fibre piezometers in hole 302GW01 to monitor groundwater as longwall extraction progressed. Unfortunately, most of the sensor cables were severed by ground movement as Longwall 302 passed under the site.

Metropolitan Coal also installed additional bores over Longwall 302 (TBS02 80, TBS02 250 and TBS02 15) and Longwall 303 (TBS03 230 and TBS03 15). The two deep holes each have vibrating wire piezometers installed 15 m above and below the Bald Hill Claystone (192 m bgl and 243 m bgl at TBS02 250 m bgl, 162 m bgl and 213 m bgl at TBS03 230) (Figure 44). Also two standpipes at 90 m bgl and 190 m bgl were installed in February 2019 over Longwall 302; currently both are recording data (Figure 44).

The TBS02 piezometer at 192 m failed in November 2018 (following passing of Longwall 302) and the piezometer at 243 m bgl failed in January 2019 (following passing of Longwall 303). The TBS02 Replacement Bore (piezometers at 90 m bgl, 150 m bgl, 180 m bgl and 245 m bgl) was installed and commenced monitoring on 24 January 2019; three of the four piezometers are recording data. The VWP piezometer at 245 m bgl failed in February 2019. In June 2020, the original TBS02 bore was found to have resumed reporting measurements from the two sensors downhole.

The TBS03 piezometer at 213 m bgl failed in June 2018 (following passing of Longwall 302) and the piezometer at 162 m bgl depth failed in December 2018 (following passing of Longwall 303). The TBS03 Replacement bore (VWPs at 162 m bgl, 213 m bgl, 245 m bgl and 265 m bgl) was installed and commenced monitoring on 12 April 2019 (Figure 44). The VWPs at 162 m bgl and 213 m bgl failed in November 2019. The VWPs at 245 m bgl and 265 m bgl failed in September 2019 and October 2019 respectively. Currently all VWP sensors at TB03 have lost communications and there is no plan to replace this hole in future.

The original goaf hole 9HGW0 (Figure 30) showed no abnormal variation during the reporting period and continued to report steady conditions.

Figure 31 shows the water levels for site 9EGW1B. The groundwater levels remained stable until the start of the reporting period. Two of the sensors showed a change in water level during the reporting period, that is sensor 213 (BHCS) and sensor 233 m (BGSS), coinciding with smaller abrupt changes at three other sensors. The sensor at 213 m recorded a sudden drop of approximately 20 m, after which the water level stabilised. The sensor at 233 m showed an upward trend with increased variability. The reason for the abrupt responses is not known. As mining along the mains was about 2 km from the bore in early 2020, the bore is too far from active mining for the effect to be due to mining.

Figure 32 shows the groundwater levels for site 9FGW1A. All sensors showed a continuing water level record, either stable or continuing a previous declining trend. The sensor at 210 m (BGSS) showed some increasing spikes on an otherwise stable water level, which it historically has at times.

Figure 33 shows a decline in water level of about 6 m from 2009 to 2013 prior to the compulsory decommissioning of bore 9GGW1B before Longwall 22B mining passed beneath the site. The substituted standpipe 9GGW1-70 has had far more dynamic fluctuations in water level, but has now settled to a stable water level with a range of about 5 m.

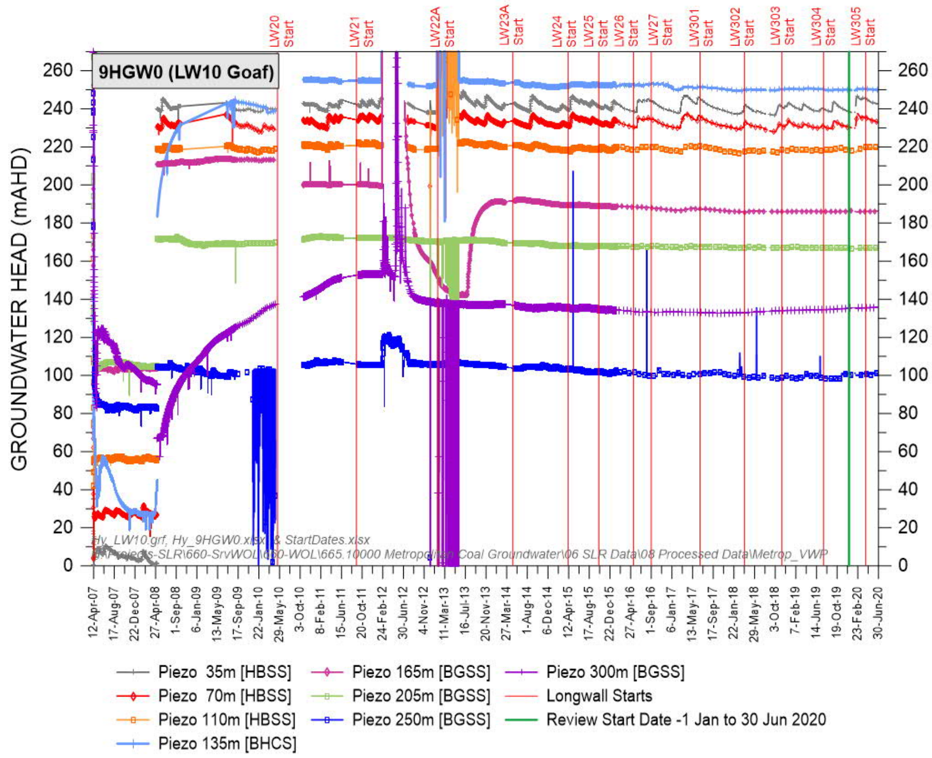


Figure 30 Time Variations in Potentiometric Heads at 9HGW0

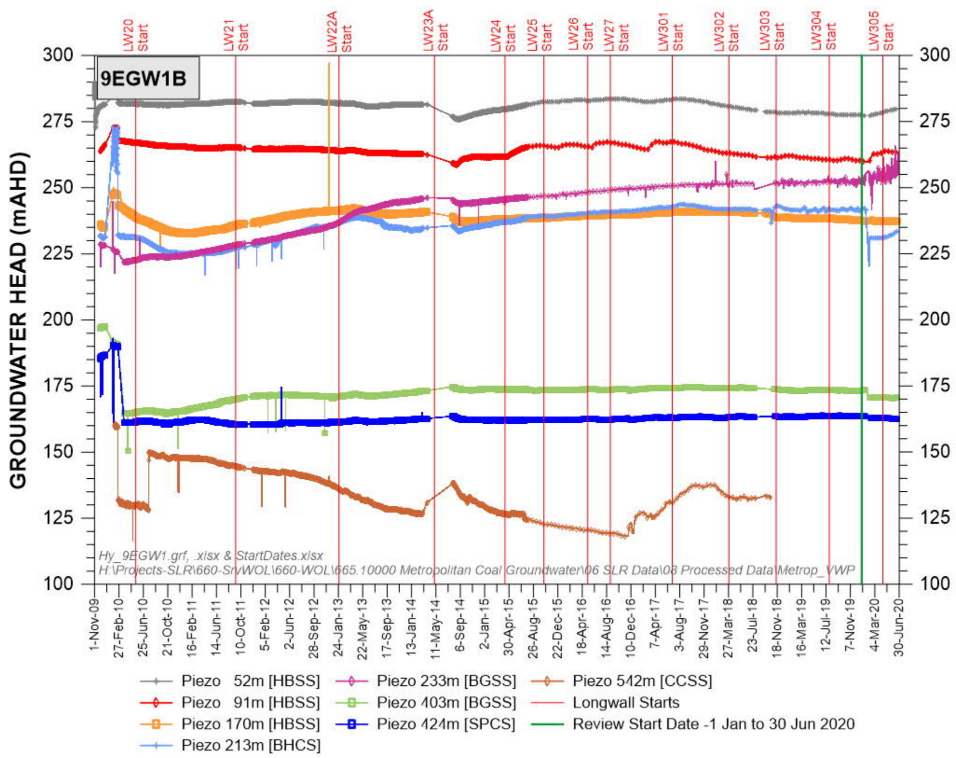


Figure 31 Time Variations in Potentiometric Heads at 9EGW1B

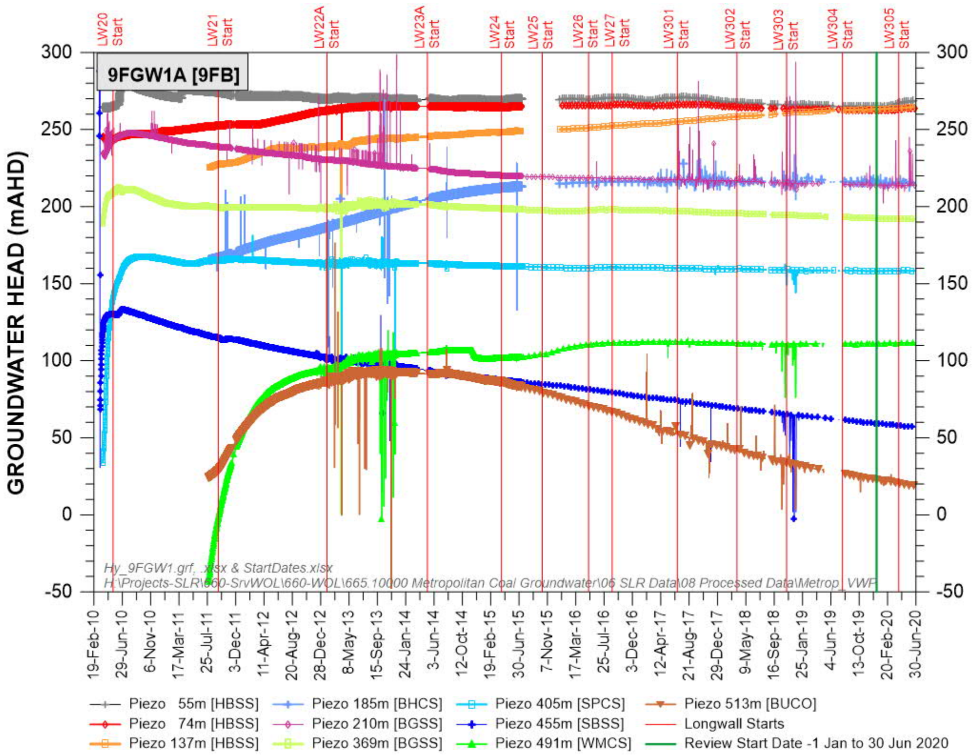


Figure 32 Time Variations in Potentiometric Heads at 9FGW1A

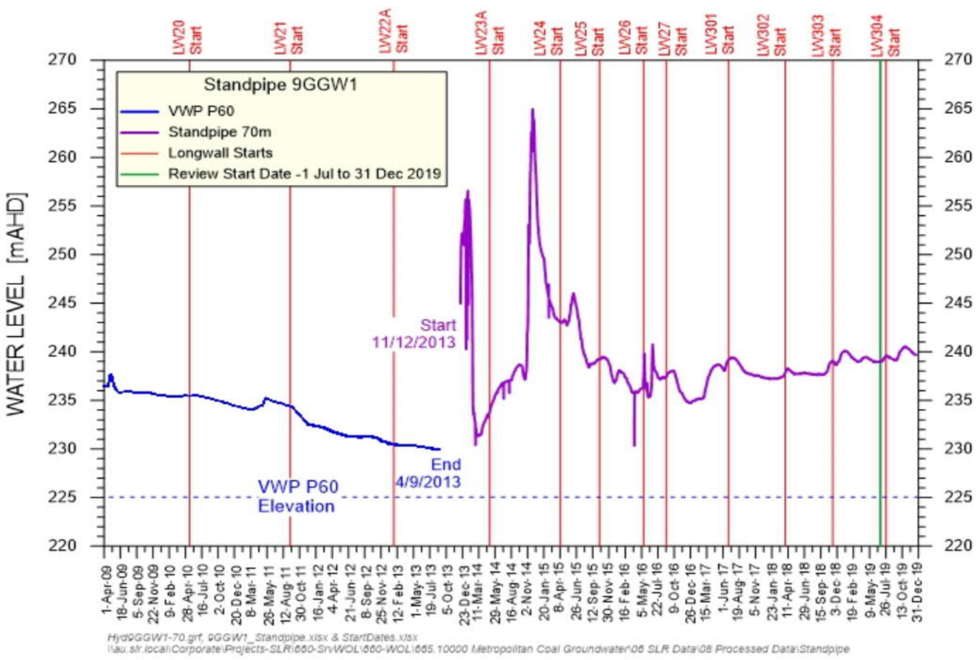


Figure 33 Time Variations in Water Table at Standpipe 9GGW1-70 and Decommissioned Vibrating Wire Piezometer 9GGW1-60

The time-series record for bore 9GGW2B is shown on Figure 34. As the hydrographs show inconsistent head variations with depth, some of the piezometers are unreliable. During the passage of Longwall 24 (>600 m away), minor drawdowns were observed in the Bulli Coal Seam and the Scarborough Sandstone, but other sensors exhibited no effect or a rise in head. The passage of Longwall 25 (>400 m away) caused distinct drawdowns in the Scarborough Sandstone, Wombarra Claystone, Stanwell Park Claystone and upper Bulgo Sandstone. Characteristic arcuate segments between cusps associated with subsequent longwall crossings are evident in the Scarborough Sandstone, Wombarra Claystone and Stanwell Park Claystone, but not in the Bulli Coal Seam. The lower Bulgo Sandstone shows rising head arcuate segments for Longwall 26 and Longwall 27 crossings, due to compression at that level. Sympathetic drawdowns are also exhibited in the three Hawkesbury Sandstone piezometers at the times of the Longwall 26 and Longwall 27 crossings. The 138 m bgl, 163 m bgl, 304 m bgl and 474 m bgl deep vibrating wire piezometers have not recorded data since the end of 2016. The 340 m bgl deep vibrating wire piezometer has not recorded data since June 2017. The upper, mid and lower Hawkesbury Sandstone piezometers (55 m bgl, 80 m bgl and 106 m bgl) remained stable during the reporting period.

The water levels for sites 9HGW1B, PM02, PM01R, 9EGW2A, PM03 and PHGW1B (Figure 35 to Figure 40) show a continuing water level record, either stable or continuing a previous declining trend. The sensor at 218m (PM01R (BHCS), Figure 37) showed a slight increase of water level in the reporting period. The sensor at 214 m (PM03 (BGSS), Figure 39) showed increased variability in water levels. A connection failure prevented upload of data for sensors in PHGW1B in 2016 (Figure 40). Sensors have now been reinstated.

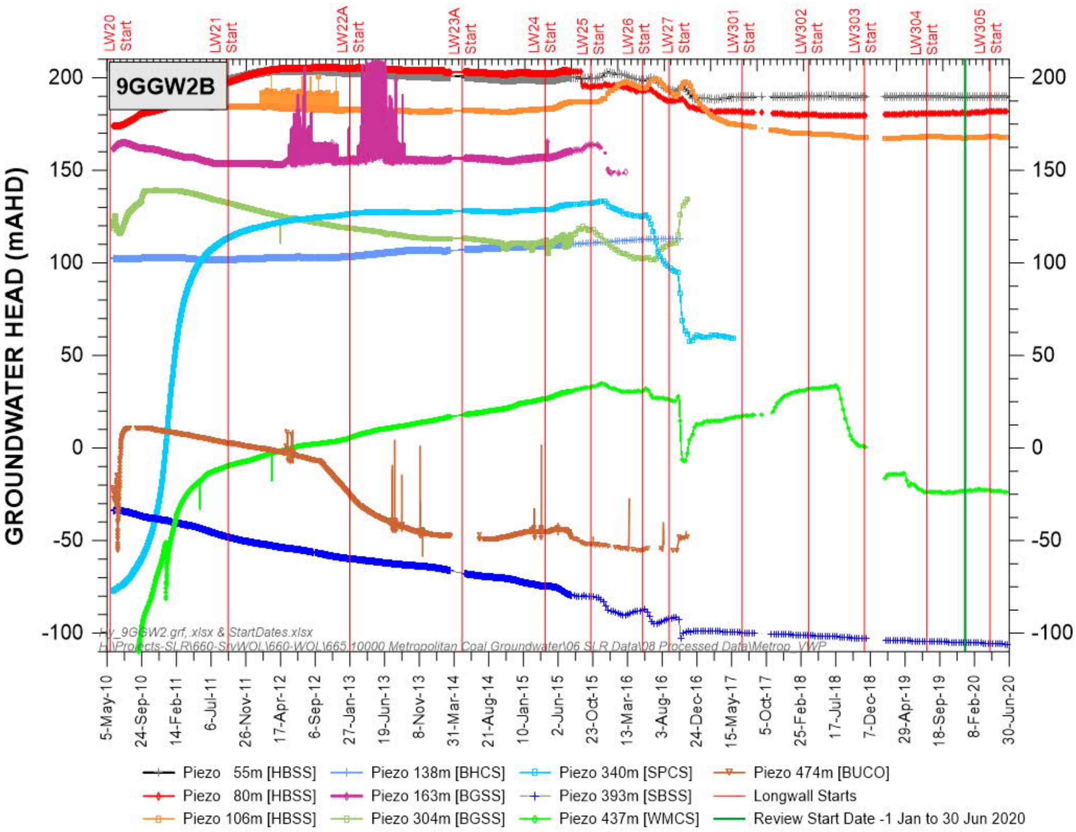


Figure 34 Time Variations in Potentiometric Heads at 9GGW2B

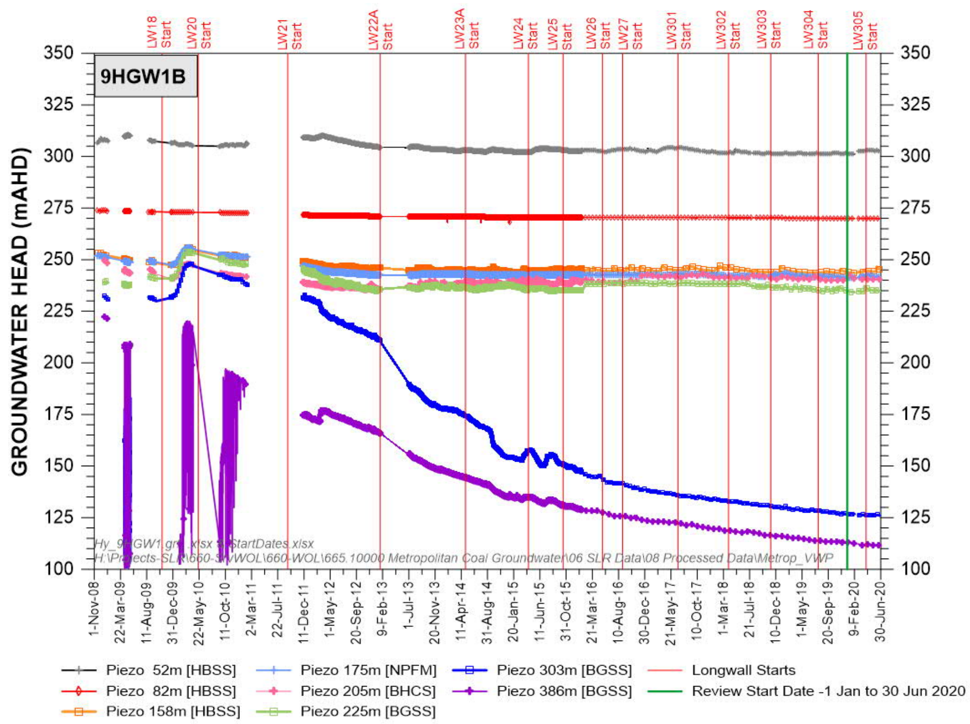


Figure 35 Time Variations in Potentiometric Heads at 9HGW1B

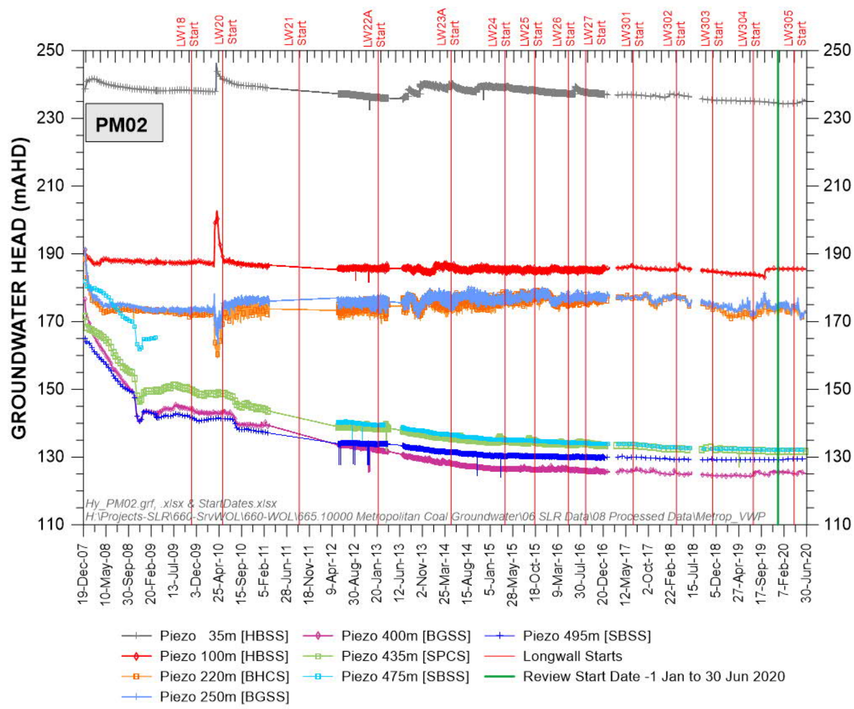


Figure 36 Time Variations in Potentiometric Heads at PM02

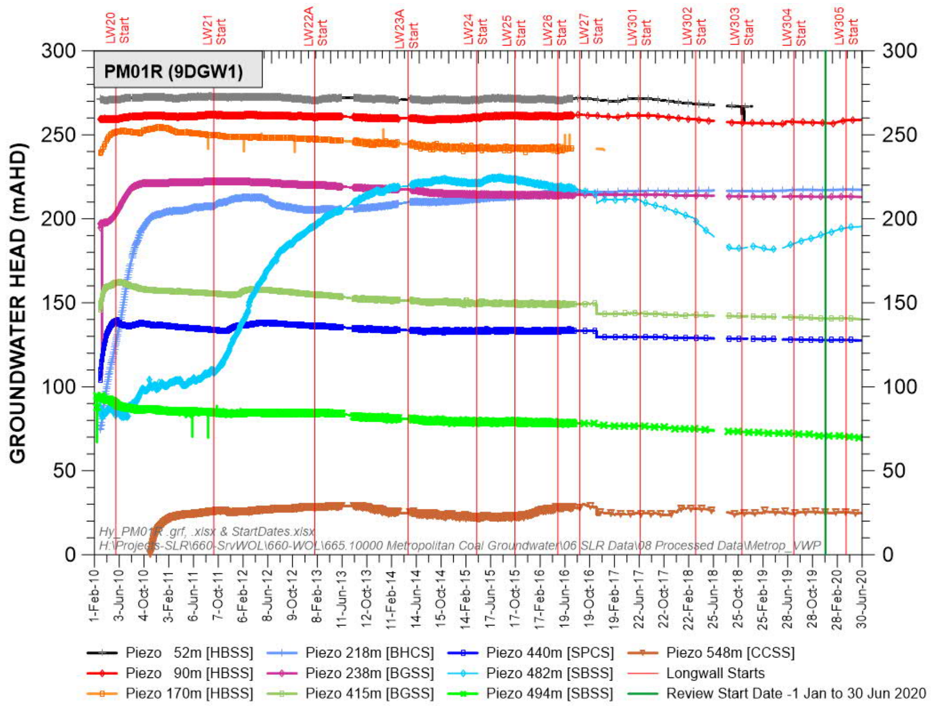


Figure 37 Time Variations in Potentiometric Heads at PM01R

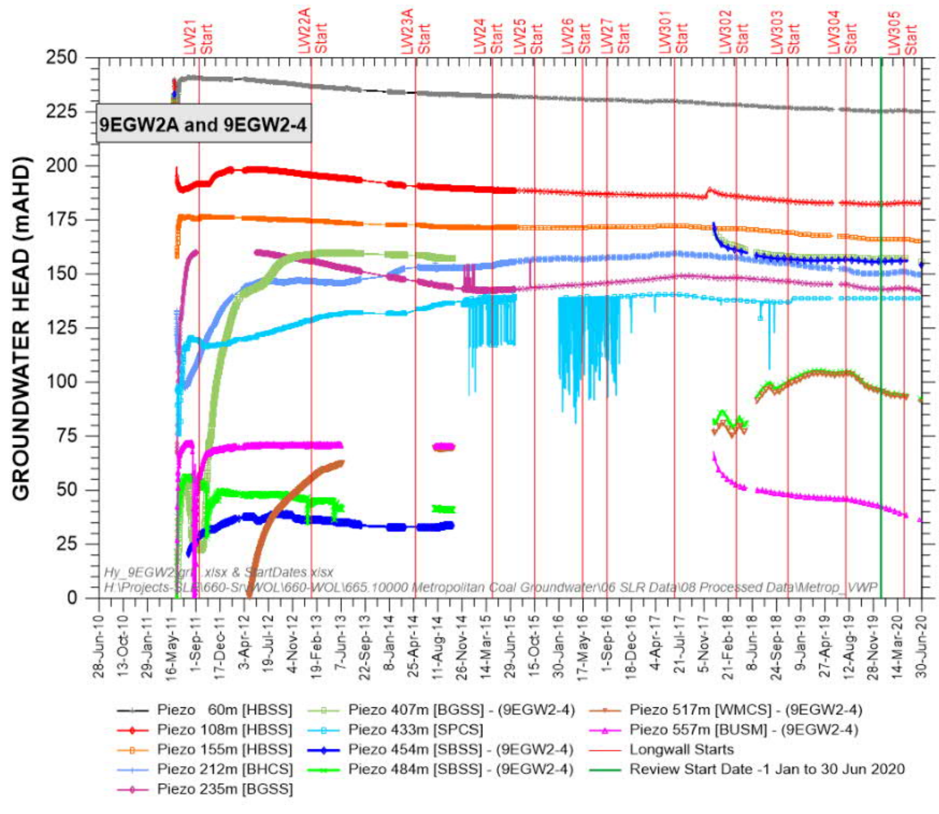


Figure 38 Time Variations in Potentiometric Heads at 9EGW2A and 9EGW2-4

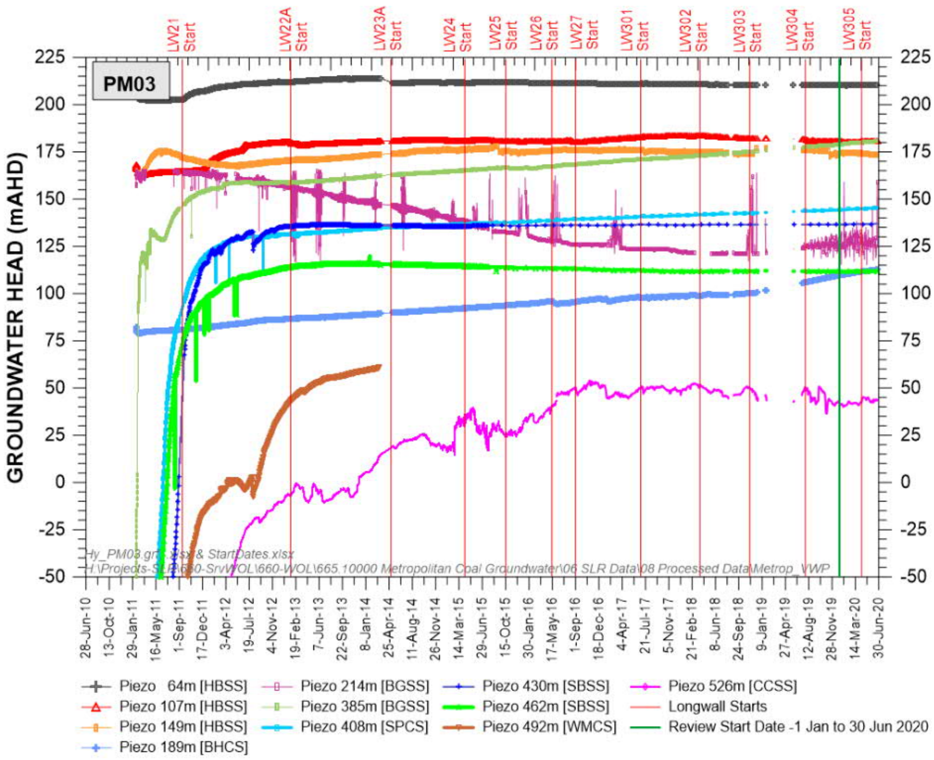


Figure 39 Time Variations in Potentiometric Heads at PM03

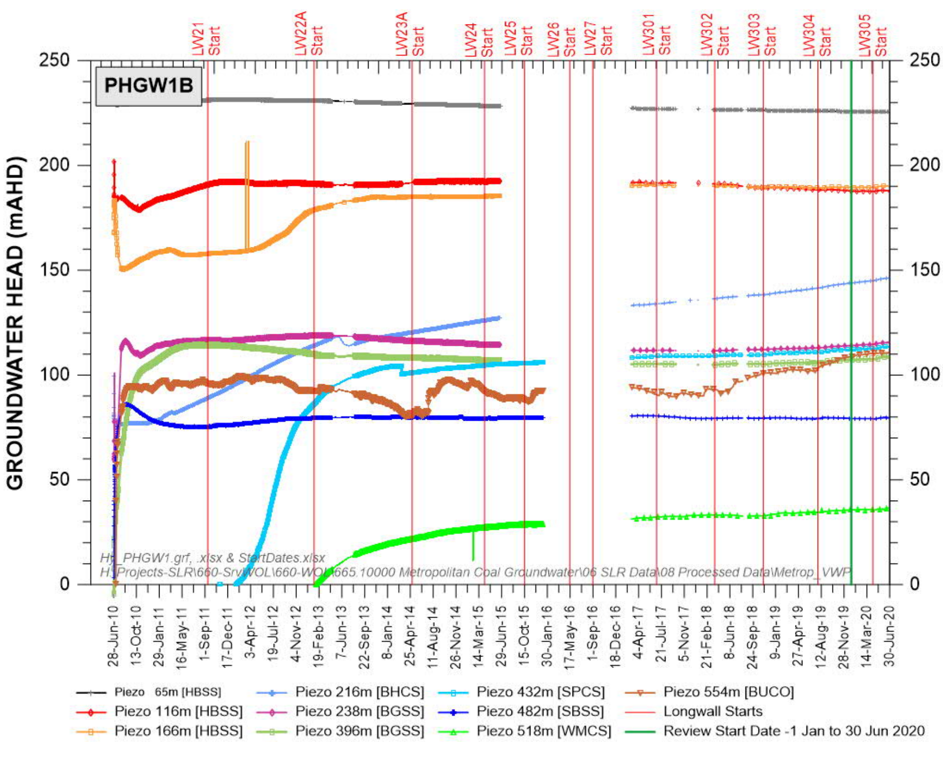


Figure 40 Time Variations in Potentiometric Heads at PHGW1B

Figure 41 shows the groundwater levels at site PHGW2A. At the start of the reporting period, all piezometers showed no trend (except Piezo 470, which showed a decrease). With the start of Longwall 305, all piezometers showed a sudden increase, more pronounced with depth. This is likely a compression effect from mining Longwall 305, similar to the effects observed at bore T5 about 400 m to the south-east. Note that a connection failure prevented upload of data for sensors in PHGW2A in 2016. Sensors have now been reinstated.

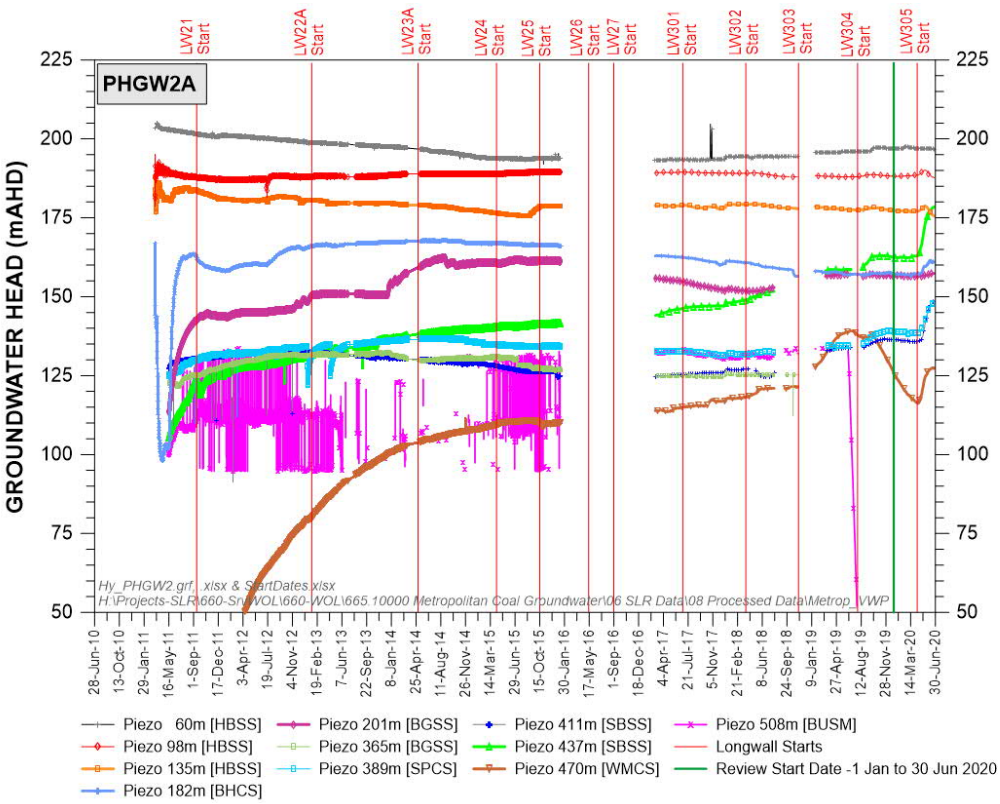


Figure 41 Time Variations in Potentiometric Heads at PHGW2A

Bore F6GW3A (Figure 42) is located adjacent to Longwall 301 about 150 m beyond its southern end, and at about 800 m from Longwall 27. Significant depressurisation has occurred from historical workings to the east at about 500 m distance. The 450 m bgl deep piezometer at the base of the Coal Cliff Sandstone displays significant depressurisation continuing from the mining of the first heading in the 300 mains in November 2013. The rise in pressure in the 380 m bgl piezometer, noted in the previous reporting periods as potentially related to compression from the adjacent LW302 beginning in March 2018, continued at a slight rate during the current reporting period. However, communications lost due to the vandalised aerial cable for four VWPs at 220 m bgl, 308 m bgl, 380 m bgl and 450 m bgl on 22 September 2019. The cables have since been re-instated and the full eight sensors are displayed and show stable water levels during this reporting period, with the exception of Piezo 220 and 308, which show a slight decrease and Piezo 308, which shows a slight increase in water levels.

Bore F6GW4A overlies Longwall 303; the time-series record for bore F6GW4A is shown in Figure 43. This bore is two panel widths from Longwall 301 and one panel width from Longwall 302. The respective mining faces came closest to the bore in late-September 2017 and late-May 2018, at which times distinct features are evident on all hydrographs. The passage of Longwall 301 caused mild responses, generally short-term increases in head, while the passage of Longwall 302 caused sharp cusp-like features on the Hawkesbury Sandstone hydrographs, sustained rises in the upper and mid Bulgo Sandstone, and strong declines in the three deepest piezometers. In January 2019, F6GW4A was undermined by Longwall 303 causing the depressurisation and disabling of the six lower sensors (139 m bgl, 201 m bgl, 278 m, 362 m bgl, 440 m bgl and 512 m bgl). The upper and mid Hawkesbury Sandstone piezometers (50 m bgl and 90 m bgl) also displayed a lowering of groundwater head following the passage of Longwall 303; however they showed no significant decline after the passage of Longwall 304 and 305 during this reporting period. Assessment of these piezometers against the performance indicator is given in Section 2.3.2.

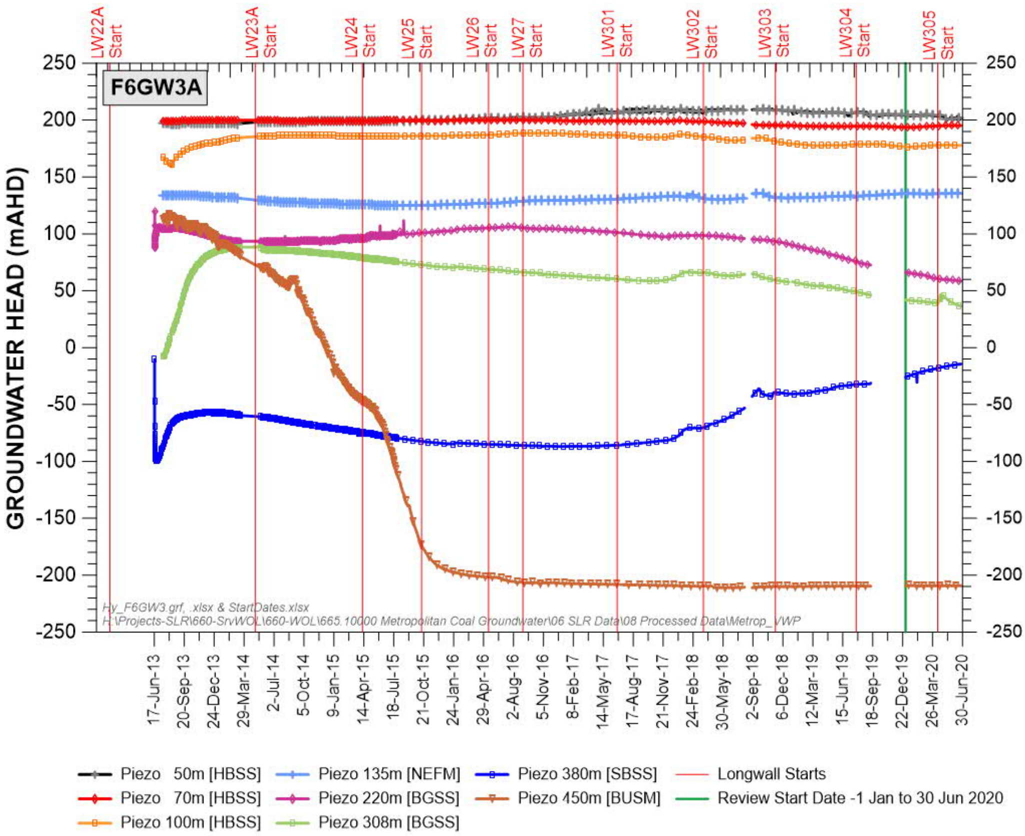


Figure 42 Time Variations in Potentiometric Heads at F6GW3A

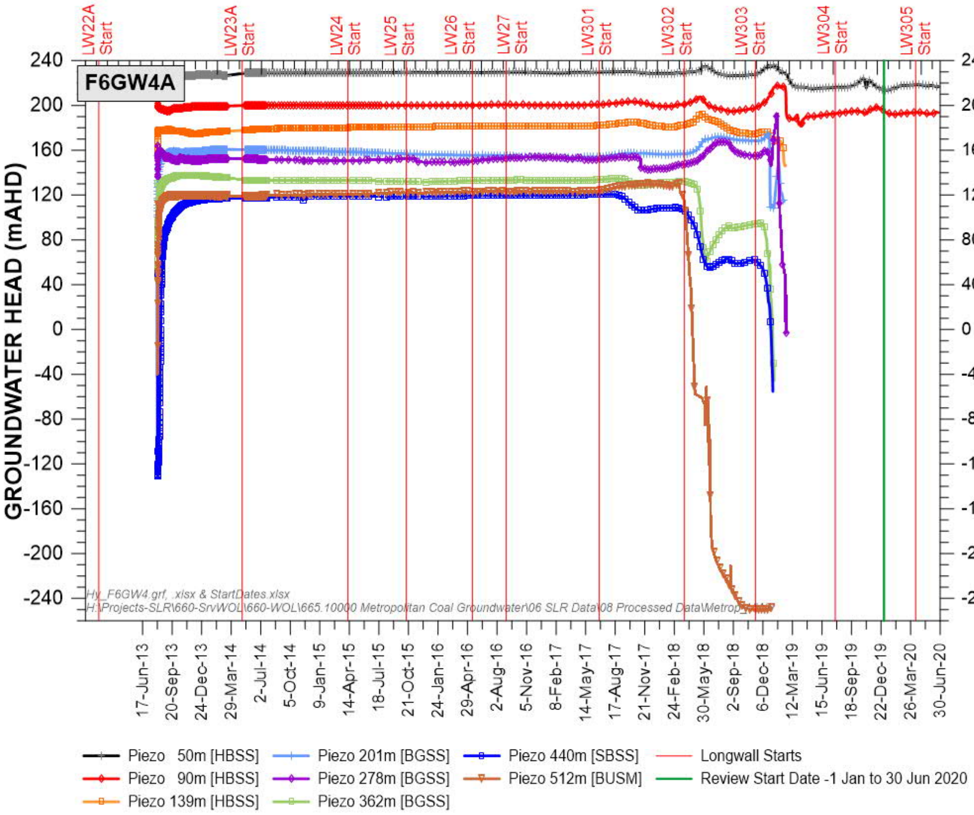


Figure 43 Time Variations in Potentiometric Heads at F6GW4A

The time-series record for the monitoring bores 302GW01, TBS02 and TBS03 is shown in Figure 44. Groundwater pressures were first recorded at bore 302GW01 in November 2017 when the mining face was 450 m to the south in the adjacent Longwall 301, heading away from 302GW01. During the extraction of Longwall 302, the heads in 302GW01 commenced rising in all but the shallowest piezometer (at 80 m) when the mining face was about 300 m from the bore. The rises of 10-60 m are expected to be due to dynamic compression of the rock matrix as the mining face approached the bore. About a week before the mining face passed beneath the bore on 25 May 2018, the groundwater heads declined substantially, except for the shallowest piezometer at 80 m depth. About a week after the crossing, eight of the nine sensors ceased to function. The active vibrating wire piezometer (VWP) at 80 m below ground level lost communication at the end of July 2019. It is probable that the sensor cables sheared off at the shear planes identified by the TBS02 inclinometer surveys. However, the two corresponding sensors in bore TBS02, 20 m away, survived the crossing and continued to record meaningful data. The observed drawdowns were about 80 m at the base of the Hawkesbury Sandstone and about 140 m at the top of the Bulgo Sandstone to June 2018. The water levels of the remaining active sensors showed no trends during the reporting period.

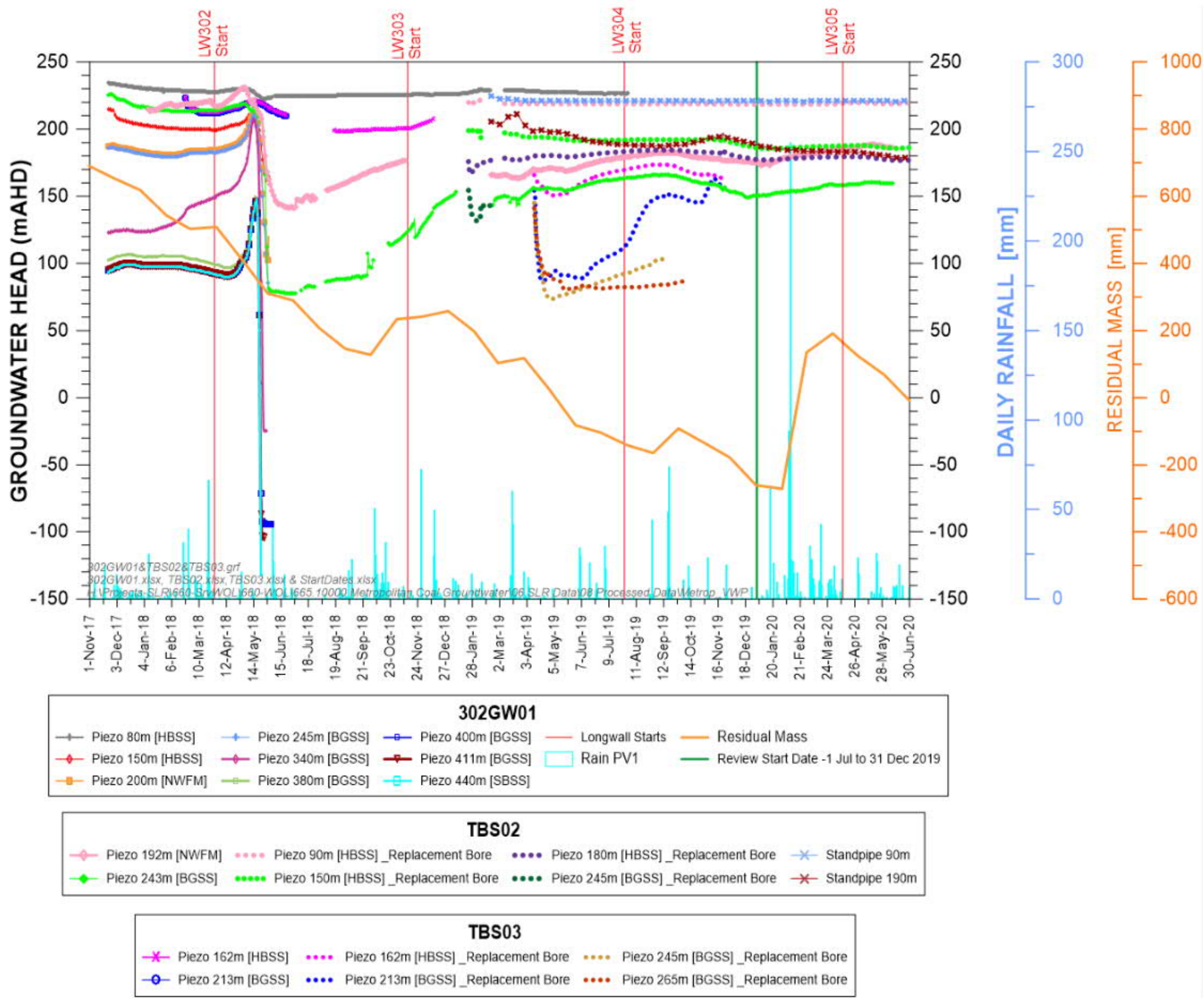


Figure 44 Time Variations in Potentiometric Heads at 302GW01, TBS02 and TBS03

4.3 Groundwater Quality

Shallow groundwater is sampled for water quality analysis monthly at sites WRGW1, WRGW2 and WRGW7 along the Waratah Rivulet and at sites ETGW1 and ETGW2 on the Eastern Tributary.

Water quality parameters sampled include EC, pH, Eh, Ca, Mg, Na, K, Cl, SO_4, HCO_3, Ba, Sr, Mn, Fe, Zn, Co and Al. The samples collected for the analysis of metals have been field filtered.

4.3.1 WRGW1 to WRGW7

Monitoring results for Fe, Mn and pH levels at sites WRGW1, WRGW2 and WRGW7 are provided on Figure 45 to Figure 47. Site WRGW4 was sheared in 2011 and has subsequently not been sampled. Monitoring results for sites WRGW3 to WRGW6 are also shown on Figure 45 to Figure 47 to show trends over the length of the Waratah Rivulet. Rainfall events since 2007, as recorded at the Waratah Rivulet catchment PV1 pluviometer, provide context for the substantial fluctuations in parameters; however, there is no obvious relationship with rainfall.

The key observations at the Waratah Rivulet groundwater quality monitoring sites (WRGW1 to WRGW7) are:

- Iron (Fe) concentrations are usually in the 1-10 milligrams per litre (mg/L) range, with the exception of sites WRGW1 and WRGW2 which peaked at 14 mg/L in earlier years (2010-2011). Fe concentrations in groundwater at WRGW1 and WRGW2 have decreased since 2011. During the reporting period concentrations increased at both bores and remained below 11 mg/L (Figure 45). Fe concentrations in groundwater at site WRGW7 fluctuated up and down during the current reporting period. Further upstream at WRGW3, Fe was variable and ranged from 5.8 mg/L to 7.8 mg/L in the July to December 2019 reporting period. During current reporting period Fe recorded between 4.7 mg/L to 7.5 mg/L.
- Manganese (Mn) concentrations are typically less than 1 mg/L (Figure 46). Higher concentrations of Mn were reported for WRGW3 in June 2015 (3.36 mg/L), September 2015 (1.47 mg/L), March 2017 (1.31 mg/L) and April 2017 (1.65 mg/L) and for WRGW6 in April 2017 (1.77 mg/L). In the previous reporting period, all sites remained below 1 mg/L, which was also observed during the current reporting period, with the exception of one observation of 1.11 mg/L at WRGW3 in April 2020. Mn concentrations at WRGW3 have followed a slight increasing trend since 2007.
- Monitoring prior to 2014 showed an apparent increase in Fe and Mn concentrations with distance downstream from WRGW5 and WRGE6 to WRGW1 and WRGW2 and then a decrease (relative to sites WRGW1 and WRGW2) with distance downstream to WRGW7. The overall decrease in Fe and Mn concentrations in groundwater at the downstream sites make this spatial trend less apparent since 2014.
- Groundwater is generally acidic with pH usually between pH 5.5 and 7.0. Occasional occurrences in excess of pH 9 and less than pH 5 in prior reporting periods are unsustained outliers. The pH at all sites remained within the historical range during the reporting period (Figure 47).
- Aluminium (Al) was below the detection limit (< 0.1 mg/L) in all WRGW1 to WRGW7 samples in the reporting period; except for two readings of 0.1 mg/L in March and April 2020 at bore WRGW3.

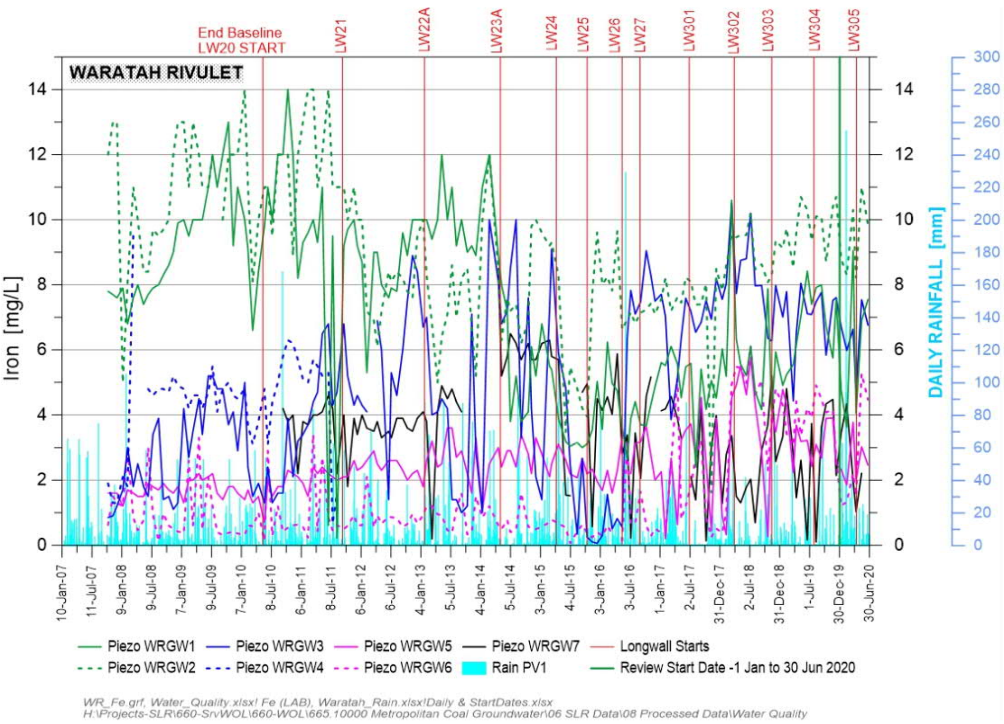


Figure 45 Iron Concentrations at WRGW1 to WRGW7

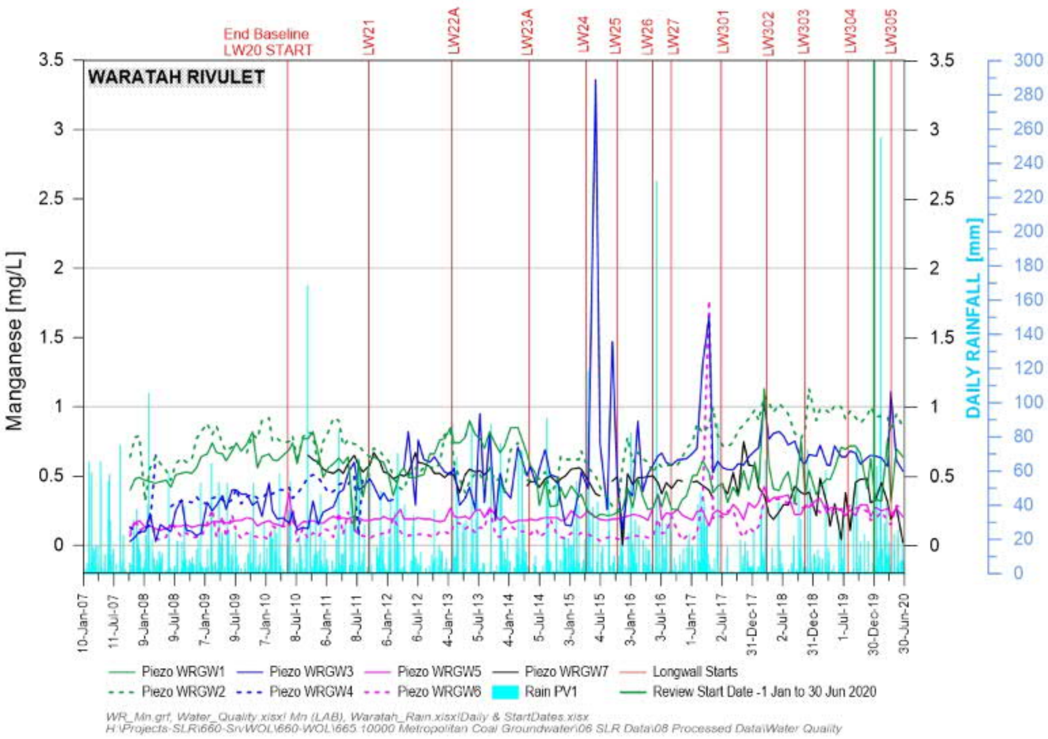


Figure 46 Manganese Concentrations at WRGW1 to WRGW7

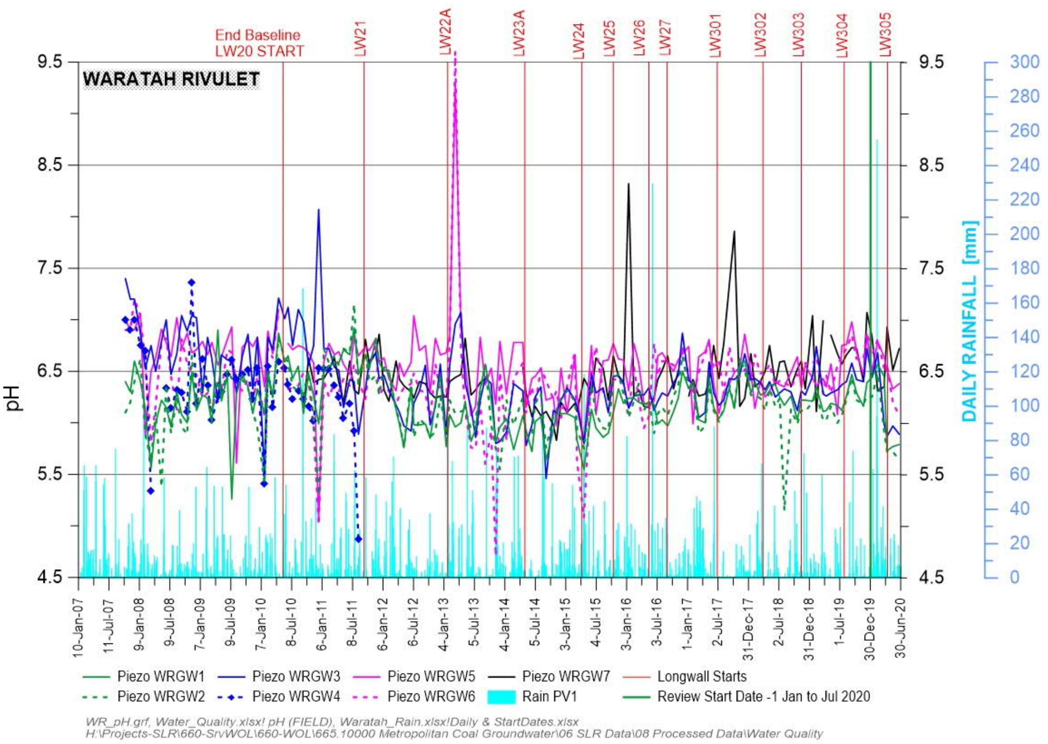


Figure 47 pH Levels at WRGW1 to WRGW7

4.3.2 ETGW1 and ETGW2

Groundwater quality at the two Eastern Tributary sites (ETGW1, ETGW2) is shown on Figure 48 to Figure 50 for Fe, Mn and pH, respectively. Rainfall events since 2008, as recorded at the Waratah Rivulet catchment PV1 pluviometer, provide context for the fluctuations in parameters; however, there is no obvious relationship with rainfall. Bore ETGW1 was unable to be sampled for groundwater quality from January to March 2017. Further, ETGW1 was sheared in July 2017 and has subsequently not been sampled.

The key observations at the groundwater quality monitoring sites ETGW1 and ETGW2 are:

- High iron concentrations with an increasing trend, and larger variability than recorded in the period 2010–2015, persisted until July 2017 when the concentration decreased. During 2019, ETGW2 displayed a variable trend and recorded the maximum recorded concentration of 21.8 mg/L in October 2019 and the historical minimum of 0.4 mg/L in March 2019 (Figure 48). Variable ranges of Fe concentrations are continued to be noticed in this reporting period with a lowest value of 1.9 mg/L and highest value of 19.8 mg/L.
- The manganese concentrations are shown on Figure 49. The concentrations in samples collected continue to be consistently higher than the historically recorded manganese concentrations at ETGW2. Up to 2017 ETGW2 recorded manganese concentrations below 0.6 mg/L, but these have increased to a range of 0.6 to 1 mg/L since then. During the current reporting period manganese concentrations were recorded between 0.74 mg/L and 0.97 mg/L.
- Aluminium was below 0.01 mg/L in all ETGW2 samples during the reporting period.
- The groundwater is generally acidic, ranging between pH 5.5 and pH 6.5 for most of the monitoring record (since 2010). At ETGW2, pH remained between 5.8 and 6.4 during the reporting period (Figure 50).

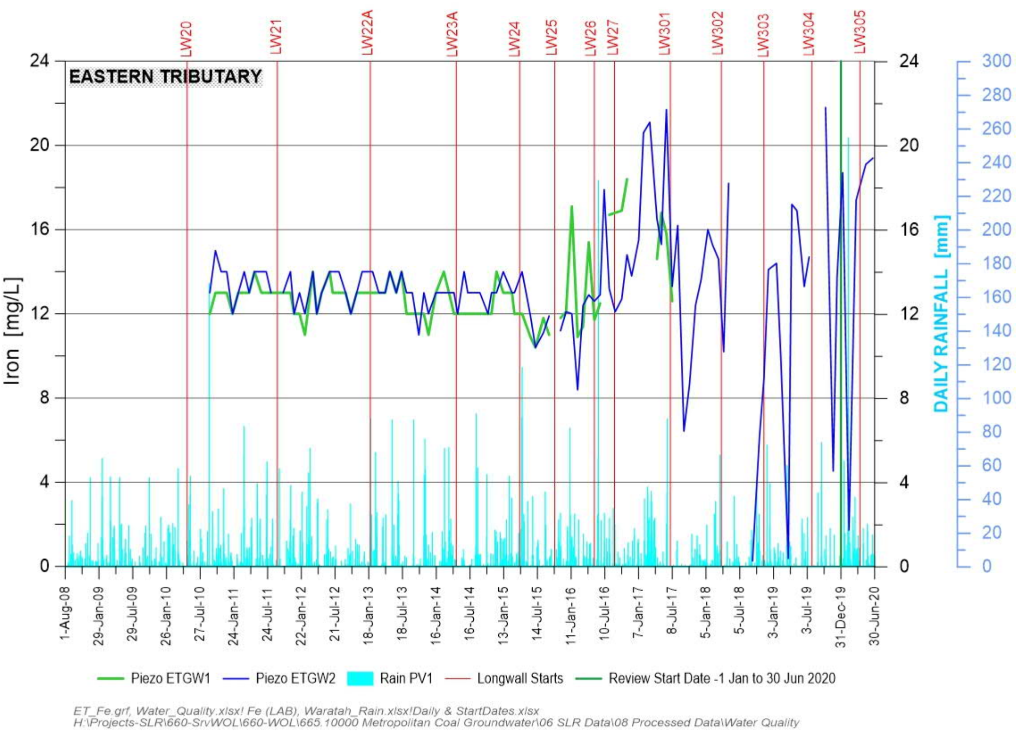


Figure 48 Iron Concentrations at ETGW1 and ETGW2

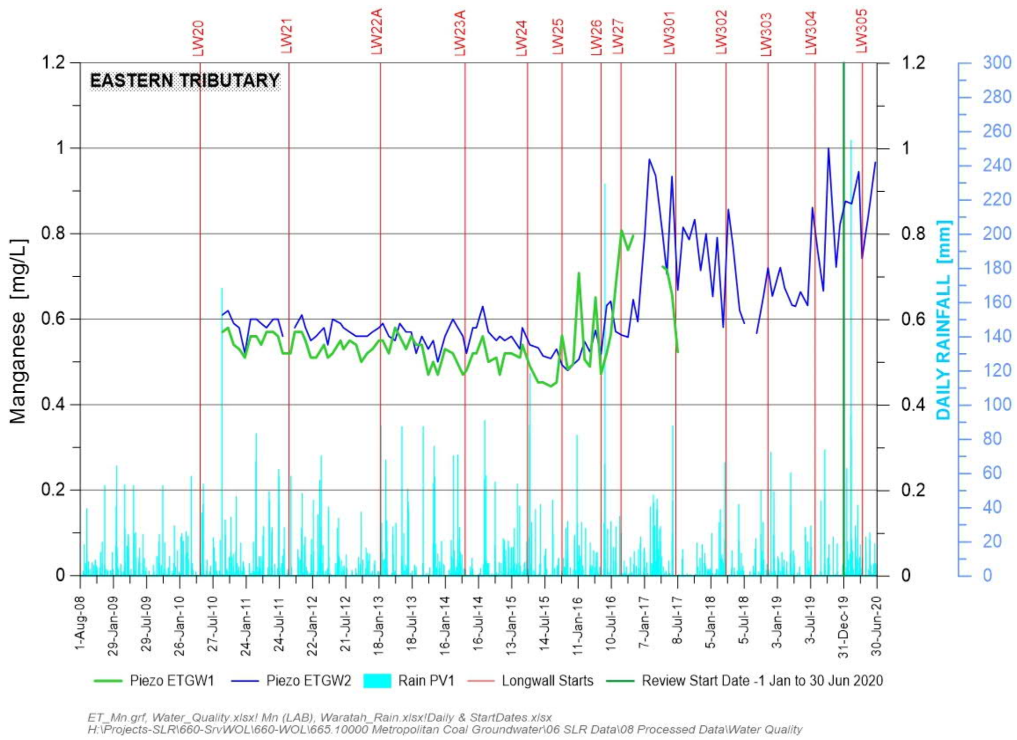


Figure 49 Manganese Concentrations at ETGW1 and ETGW2

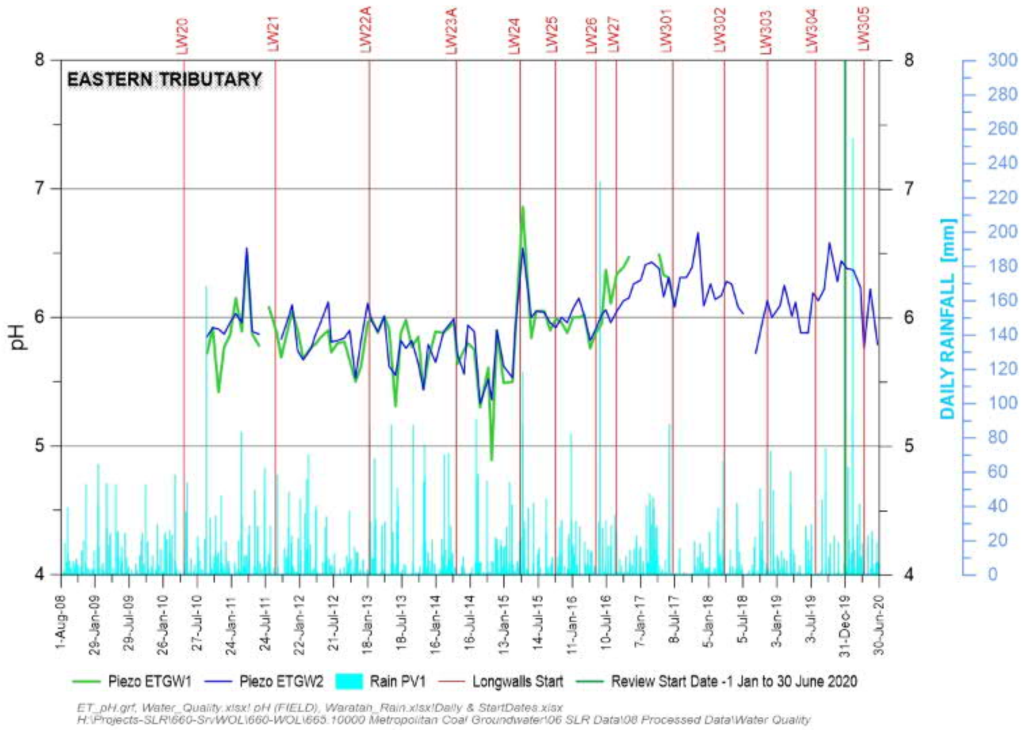


Figure 50 pH Levels at ETGW1 and ETGW2

5 Assessment of environmental performance

5.1 Upland Swamps Groundwater Levels

The upland swamp groundwater performance indicator in the BMP uses the swamp substrate piezometers listed in Section 2.2.1 to assess swamp groundwater levels.

Analysis against Upland Swamp Groundwater Performance Indicator

Surface cracking within upland swamps resulting from mine subsidence is not expected to result in measurable changes to swamp groundwater levels when compared to control swamps or seasonal variations in water levels experienced by upland swamps prior to mining.

5.1.1 Longwalls 20-27 Swamps

As described in Section 3.1 and Section 3.2, the upland swamp groundwater performance indicator has been exceeded at Swamp 20 since 2012 and at Swamp 28 since 2016. In accordance with the BMP, swamp water levels at Swamp 20 and Swamp 28 are analysed on a six-monthly basis and assessments against the performance measure are conducted annually.

The performance assessment during the reporting period for Swamp 20 is illustrated on Figure 51. The 2σ bandwidth for the baseline period (to 31 May 2012) is narrow at 0.5 m. Only rare exceedances of the -2σ limit occurred prior to this date. During the last quarter of 2012, the swamp substrate changed character from being permanently saturated to being periodically saturated and now the groundwater levels regularly drop below the -2σ limit. This change appears to have coincided with the passage of Longwall 21 past the site in April 2012. The water levels have fluctuated since then between the top and bottom of the hole. The passing of Longwall 22B alongside the monitoring site (September 2013) seems to have had no additional effect. Similarly, no obvious effect was observed for the closest approach of Longwall 23B (September 2014), Longwall 24 (April 2015), Longwall 25 (September 2015) or Longwall 26 (May 2016). There was a small adjustment to the diver cable length on 19 July 2016. The substrate piezometer remained below the -2σ limit for most of the January to June 2017 period apart from two short periods following rainfall events in March and June. The substrate piezometer remained dry, below the -2σ limit, from July 2017 to November 2018. During December 2018 the substrate piezometer became saturated, following rainfall, but did not reach the -2σ limit. During 2019 period the 1 m substrate piezometer was dry apart from a short period of saturation with rainfall in September 2019. After the large rain event in February 2020, the substrate piezometer returned into the +/-2σ range, however water levels decreased below the -2σ level shortly after the rain event.

Comparison is made on Figure 52 between the 1 m piezometers at Swamp 20 and the control swamp WRSWAMP1, and with rainfall residual mass. There is a very strong correlation with rainfall trend at both sites. As the rate of decline in the two piezometers is similar between 2013 and 2016, but different in 2012, it is likely that Longwall 21 caused a mining effect at Swamp 20, but Longwalls 22-27 and Longwalls 301-303 have not exacerbated the effect. In 2018 and 2019, both swamps reported water levels at the base of the substrate datalogger for the full period apart from the short period of saturation recorded in Swamp 20 in September 2019. Both swamps increased in water level after the large rain event in February 2020; however, Swamp 20 decreased shortly after whereas the WRSWAMP1 water levels remained at near-saturated levels.

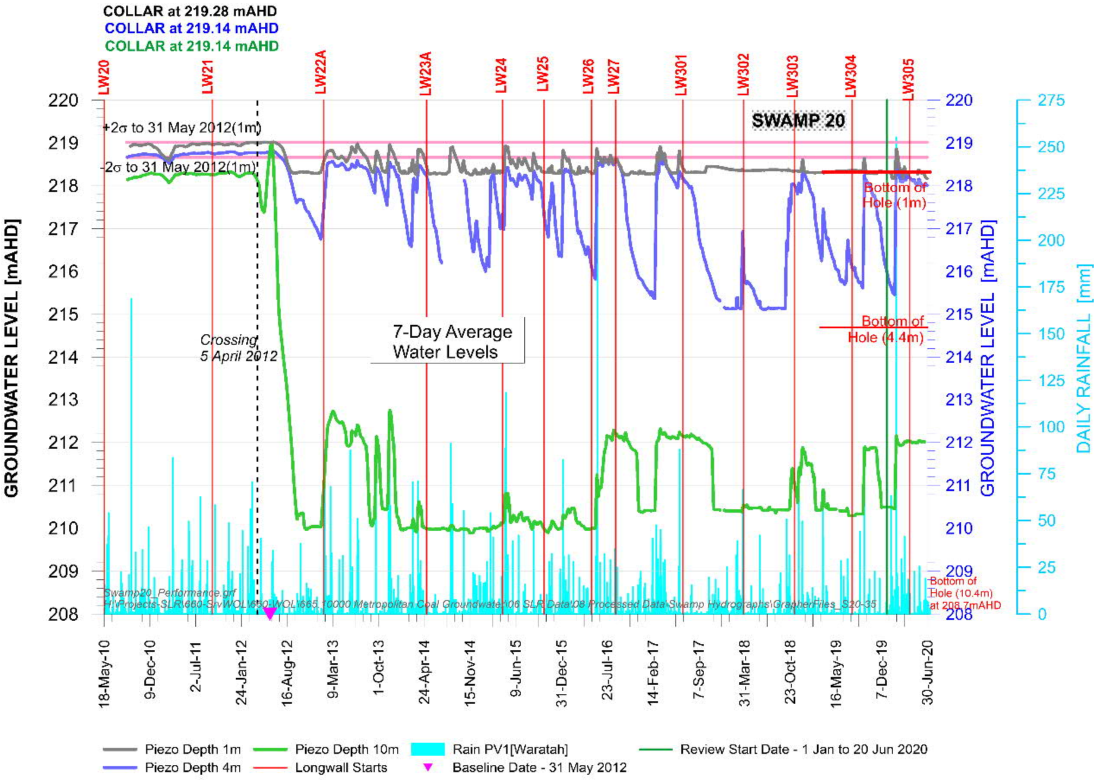


Figure 51 Seven Day Average Water Levels at Swamp 20

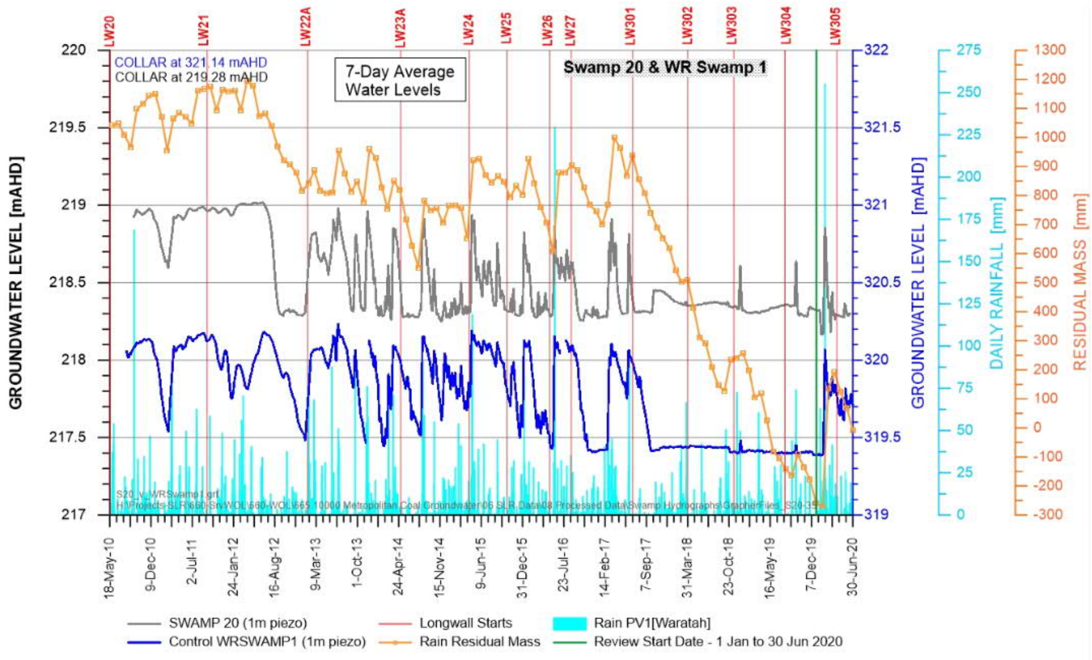


Figure 52 Comparison of Piezometer Responses at Swamp 20 and Woronora River 1 Control Swamp

The face of Longwall 24 passed Swamp 28 during April/May 2015, and the swamp was passed by Longwall 25 in November 2015. The performance assessment for Swamp 28 is illustrated on Figure 53. The 2σ bandwidth for the Swamp 28 swamp substrate piezometer is about 0.9 m which is restrained by the recurrent dry episodes in 2013 and the first half of 2014, and the sensor setting at that time. The water table in the substrate piezometer during 2016 and 2017 correlates well with the rainfall trends (Figure 13 in Section 3.2.2), despite the sharp declines in groundwater level observed in the sandstone (10 m) piezometer following the passage of Longwalls 24 and 25. During the second half of 2016, water levels in the swamp substrate exceeded the -2σ limit but only in response to adjustment of the diver cable length on 19 July 2016. This should not be construed as a mining effect. However, compared to the water levels prior to 2016, the amplitude of the substrate water level response was incomplete in the January-June 2016 reporting period and this continued to be observed during the second half of 2016, with only partial recovery of swamp substrate groundwater levels. Accordingly, it was determined that a mining effect had occurred in early 2016, but not at the time when mining passed directly beneath the swamp. For the first two months of 2017, readings in the swamp substrate piezometer continued to be dry, below sensor level since November 2016. Between March and June 2017, the substrate piezometer displayed a response to increased rainfall residual similar to that of the control swamps, and the upper height of saturation had almost returned to normal. The substrate piezometer at Swamp 28 returned to dry conditions from September 2017, remaining so until the end of December 2019, as did the two control swamp piezometers. With the large rain in February 2020, the water level in both the substrate and the shallow piezometer recovered. The substrate piezometer indicated saturated conditions until the end of the reporting period. The sandstone (shallow) piezometer has receded slightly after the rain event.

This has not changed the previous interpretation that Swamp 28 is considered to have had an impact from mining of Longwall 25, although no effect occurred on the substrate when Longwall 24 passed directly underneath the monitoring site.

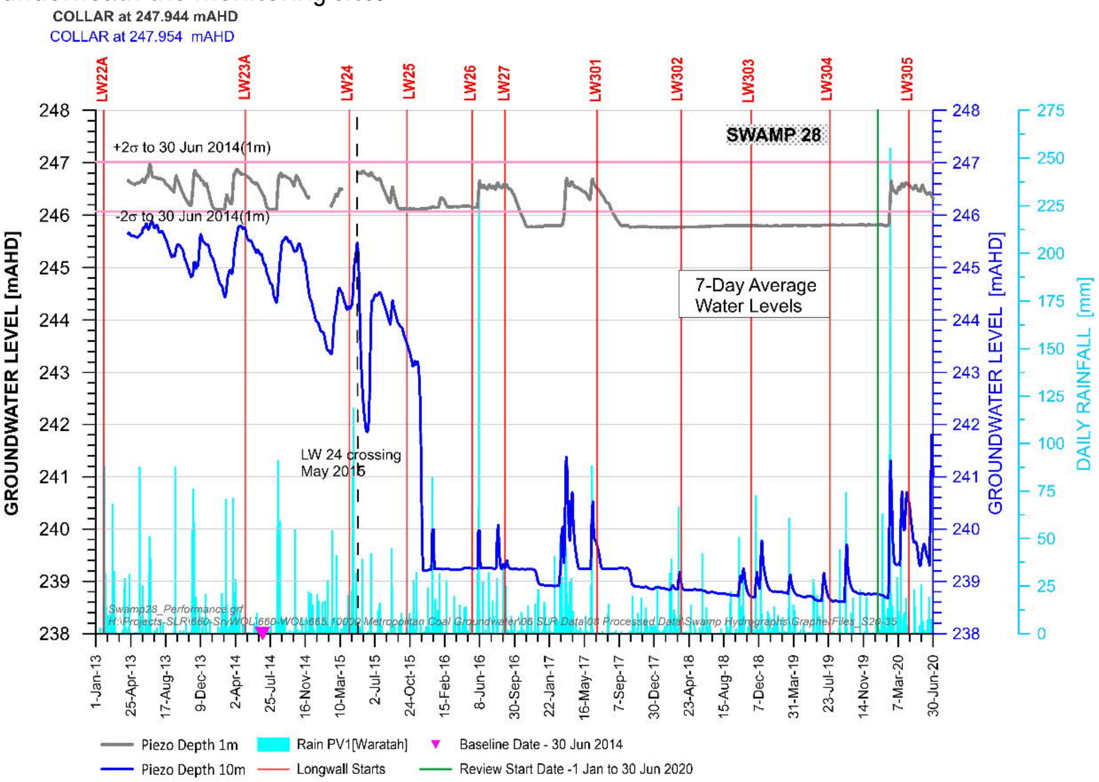


Figure 53 Seven Day Average Water Levels at Swamp 28

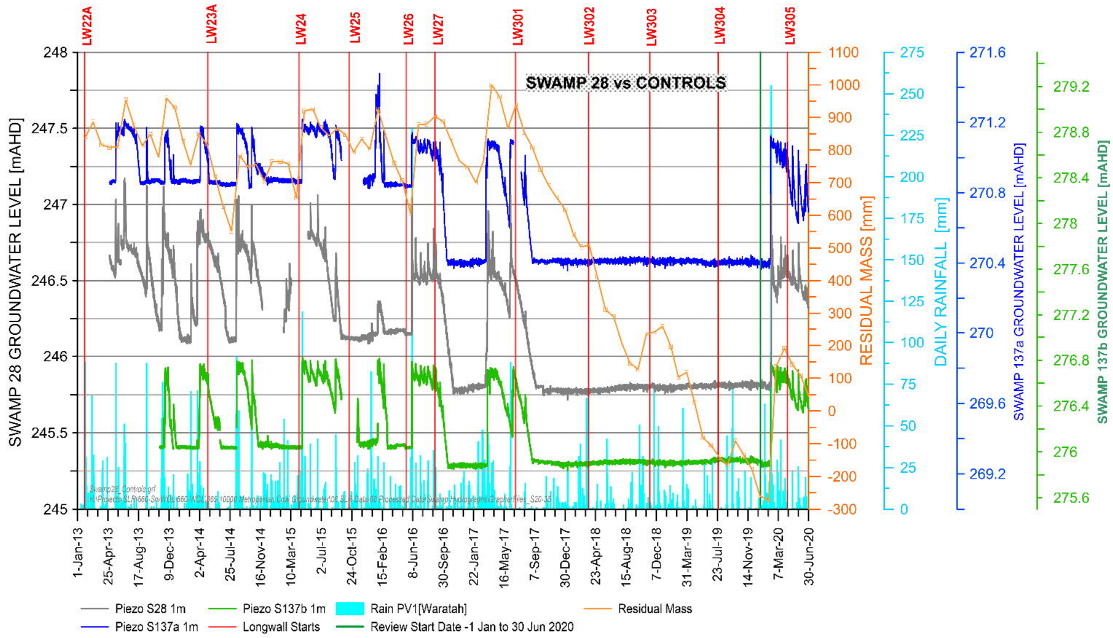


Figure 54 Groundwater Hydrographs at Swamp 28 and Two Control Swamps (137a and 137b)

For Swamps 25, 30 and 33, data analysis is undertaken to assess whether the seven-day moving average is within the 5th percentile established for the swamp's full length of record, and whether the seven-day moving average for Swamp 35 is within two standard deviations below the mean established for the swamp's full length of record[2]. In July 2016, Metropolitan Coal lowered the piezometer sensors in swamp substrate holes so that all sensors are consistently 100 mm above the bottom of the hole. The lowering of the piezometer cable lengths in most holes has made the baseline bandwidths no longer applicable, as the baseline period included apparently "dry" measurements that were in fact unable to record saturation levels between the position of the sensor and the bottom of the hole. Measurements taken since July 2016, during dry conditions, are expected to lie beneath the 5th percentile or -2σ standard deviation levels for the Longwalls 20-27 swamps. This gives an "exceedance" of the 5th percentile or -2σ levels that could be due to instrumental changes coupled with dry weather, rather than necessarily due to mining. Semi-quantitative comparisons with control swamps and rainfall record have been undertaken when such "exceedances" have occurred to assess whether the dry swamp conditions are natural. Semi-quantitative analysis includes examination of the rate of recession from high to low water levels and analysis of rates of recovery from low to high water levels, compared to control swamps.

2 The 'full length of record' relates to the groundwater swamp substrate dataset for Longwalls 20-22 swamps to 31 May 2012, and for Longwalls 23-27 swamps to 30 June 2014.

The seven-day average groundwater levels at Swamp 25 are illustrated on Figure 55. The swamp substrate (1 m) piezometer indicates ongoing intermittent saturation. The 5th/95th percentile bandwidth shows that the lower percentile coincides with the minimum recorded levels prior to the adjustment of diver cable length on 19 July 2016. There is an apparent departure from the 5th percentile in September 2016 which continued to February 2017, due only to the adjustment of diver cable length, but this should not be regarded as an exceedance of the performance indicator for Swamp 25 as the same departure happens at the control swamp as well (Figure 56). This is also shown by the substrate piezometer being dry from July 2017 to December 2018, with the exception of short periods of saturation in response to rainfall in March, October and December 2018. During 2019 the substrate piezometer remained dry throughout, the only exception being for the September 2019 rainfall event, when the substrate piezometer shows a response to rainfall. The substrate piezometer responded to the large rainfall event in February 2020 and the water levels remained within the 5th/95th percentile bandwidth until May 2020.

The deeper (10 m) piezometer at Swamp 25 recorded sharp declines in groundwater level at the time Longwalls 21 and 22B passed. Coincidentally, rainfall was low during both periods and therefore these sharp declines are potentially due to rainfall conditions. However, overall there is a declining trend in groundwater levels in the 10 m piezometer from August 2012 to June 2017, despite a general rainfall surplus trend in that time, indicating a mining effect in the sandstone beneath Swamp 25. The 10 m piezometer at Swamp 25 remained dry from September 2017 to October 2018 and became saturated from November to December 2018, declining during January and February 2019 to remain dry for the remainder of the year. As reported previously, it is likely that groundwater levels in the sandstone beneath the swamp have been affected by mining. Prior to March 2018, control Swamp 101 appeared to retain water for a greater proportion of time than Swamp 25 did following mining. This behaviour was apparent until early 2018, with Swamp 25 only recording intermittent saturation in response to rainfall in comparison to the prolonged retention and more gradual decline in water levels at Swamp 101.

During the current reporting period, the substrate (1 m) piezometer at Control Swamp 101 recorded dry levels with exception of a spike in February 2020. The substrate (1 m) piezometer at Swamp 25 also recorded a response to that rain event. Semi-quantitative comparison with the control swamp and rainfall records (Appendix A) do not show a definitive mining effect and the dry conditions are regarded as a natural response to reduced rainfall over this period (Level 2 of the Trigger Action Response Plan for upland swamp groundwater monitoring BMP).

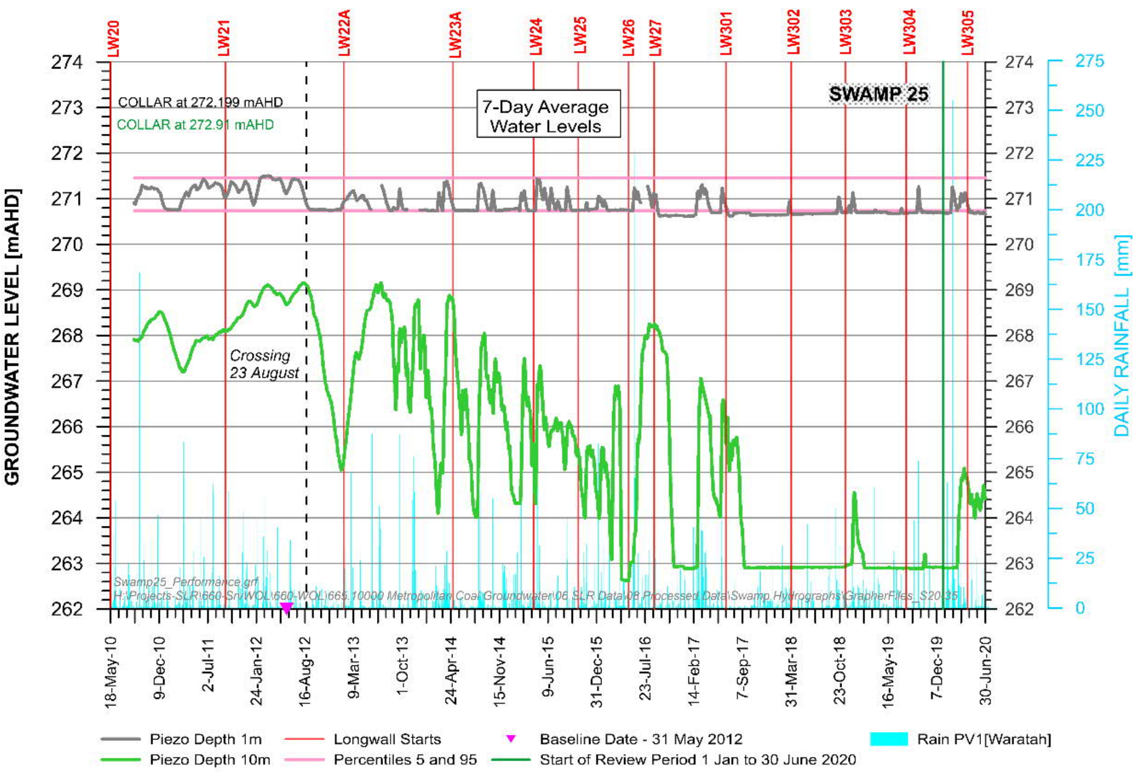


Figure 55 Seven Day Average Water Levels at Swamp 25

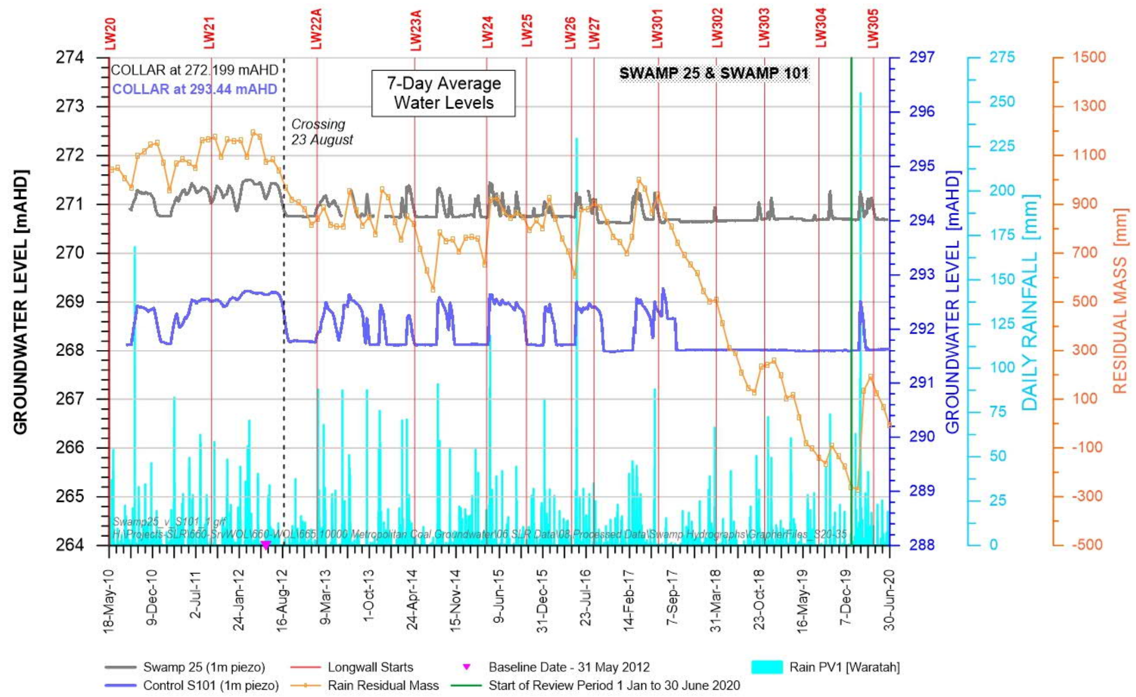


Figure 56 Comparison of Piezometer Responses at Swamp 25 and Control Swamp 101

The 5th/95th percentile bandwidth for the Swamp 30 substrate piezometer is 0.8 m (Figure 57). The minimum value of the seven-day average of substrate water levels always remained within the 5th/95th percentiles prior to the adjustment of the diver cable length on 19 July 2016, after which it has often fallen below the 5th percentile as a result of the adjustment.

The Swamp 30 (1 m) hydrograph is compared with the responses at the two relevant control swamps (137a and 137b) in Figure 58. During the reporting period both Swamp 30 and the two control swamps started unsaturated and all recovered to saturated conditions after the large rain event. Swamp 30 is assessed as being at Level 2 trigger level (Trigger Action Response Plan for upland swamp groundwater monitoring in the BMP).

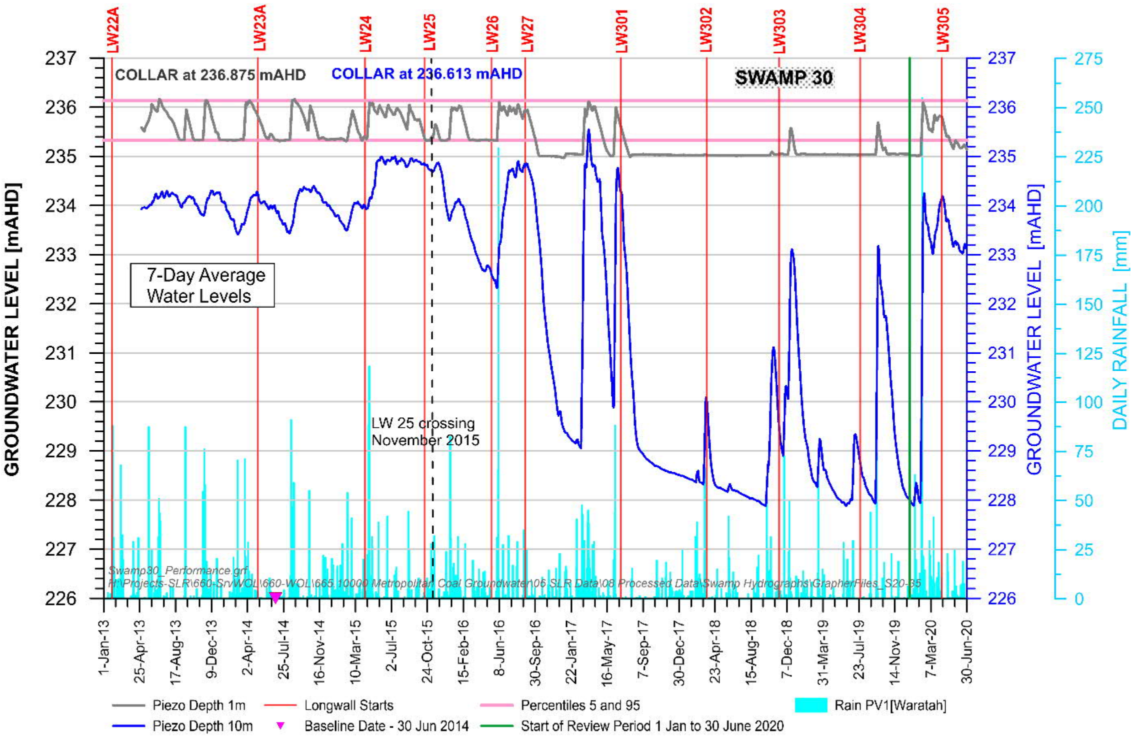


Figure 57 Seven Day Average Water Levels at Swamp 30

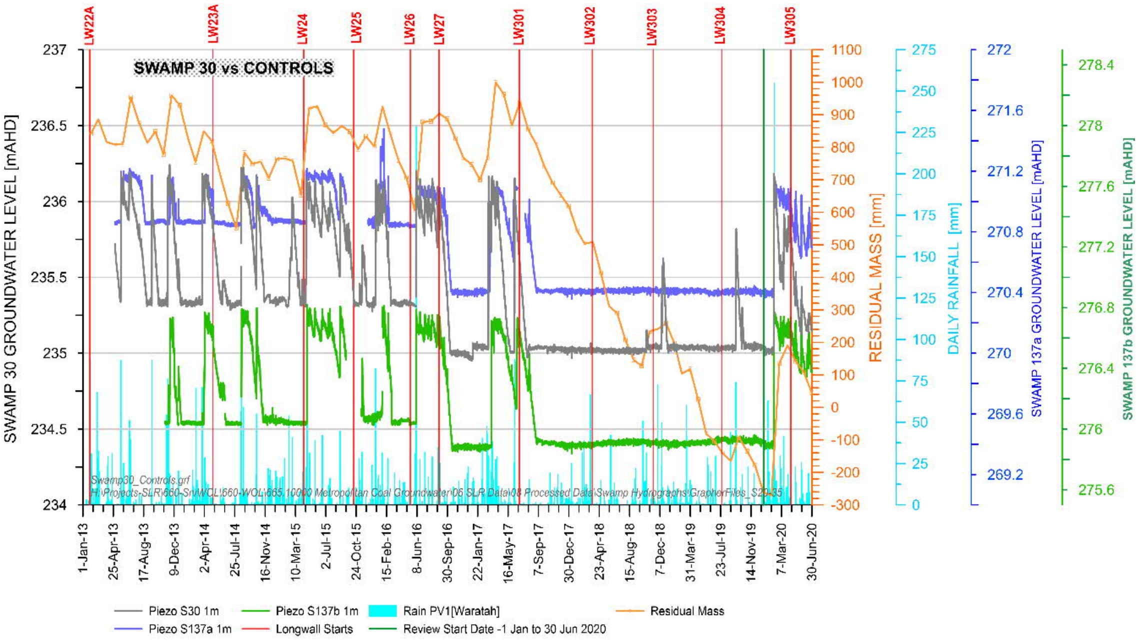


Figure 58 Groundwater Hydrographs at Swamp 30 and Two Control Swamps (137a and 137b)

The Swamp 33 seven-day average substrate water levels are illustrated on Figure 59. It has a bandwidth of 0.4 m and substrate water levels remained above the 5th percentile until the diver cable length was adjusted on 19 July 2016. The water levels in the substrate (1 m) piezometer have maintained a steady position over time with occasional wetting periods occurring that match well with rainfall inputs. There is no evidence of a mining effect corresponding to the passing of Longwall 23B (January 2015), Longwall 24 (July 2015), Longwall 25 (February 2016), Longwall 26 (July 2016) or Longwall 27 (November 2016). Swamp water levels rose in accordance with rainfall events, in March and June 2017.

The groundwater level in the swamp substrate remained below the lower limit from July 2017 to September 2018, in line with continuing declining rainfall residual mass trend, and became saturated for two short periods in October and December 2018, following rainfall. During 2019, the swamp substrate piezometer remained dry throughout, apart from responding to the rainfall event in September 2019. During this reporting period, the substrate piezometer was saturated most of time. The behaviour is not significantly different from past behaviour when considered with the rainfall residual, and the apparent exceedance in the past is due to lowering of the sensor level rather than a mining effect. The strong correlation between different sites in terms of the timing and amplitudes of groundwater responses indicates that a mining effect is unlikely on the substrate at Swamp 33. As there is a local rain effect in February-March 2015 at Swamp 33 that is not evident at the control sites, exact agreement with control sites cannot be expected.

Swamp 33 is assessed as being at Level 1 trigger level (Trigger Action Response Plan for upland swamp groundwater monitoring in the BMP)

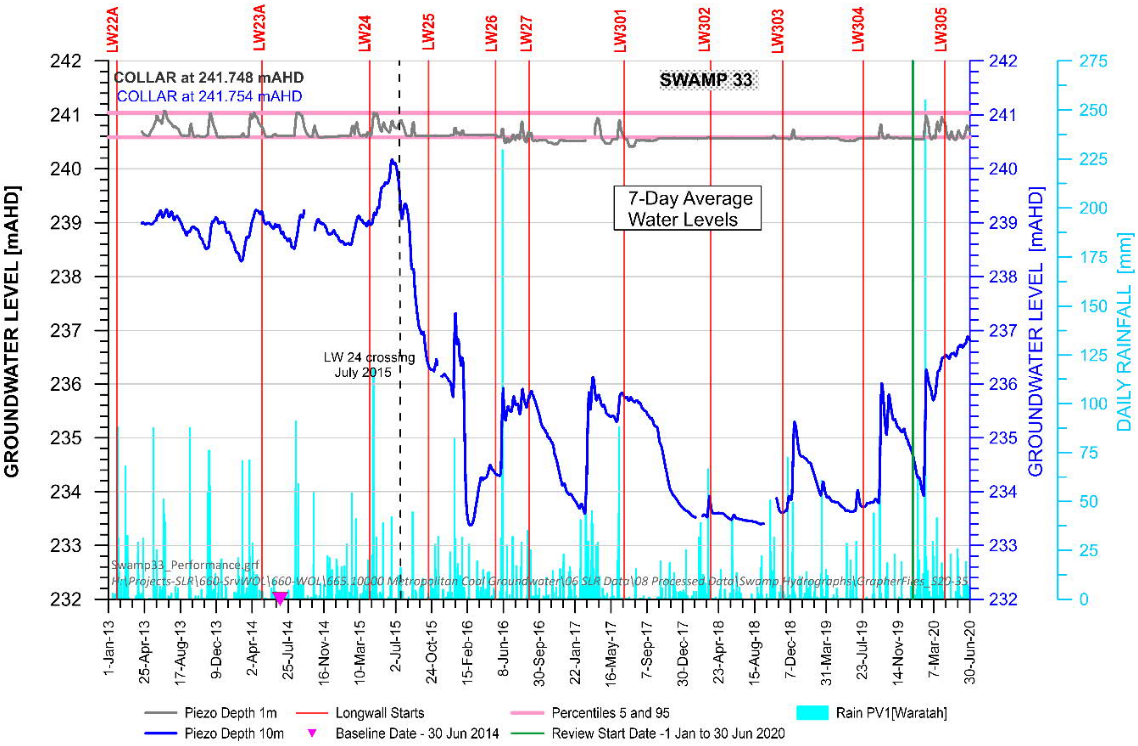


Figure 59 Seven Day Average Water Levels at Swamp 33

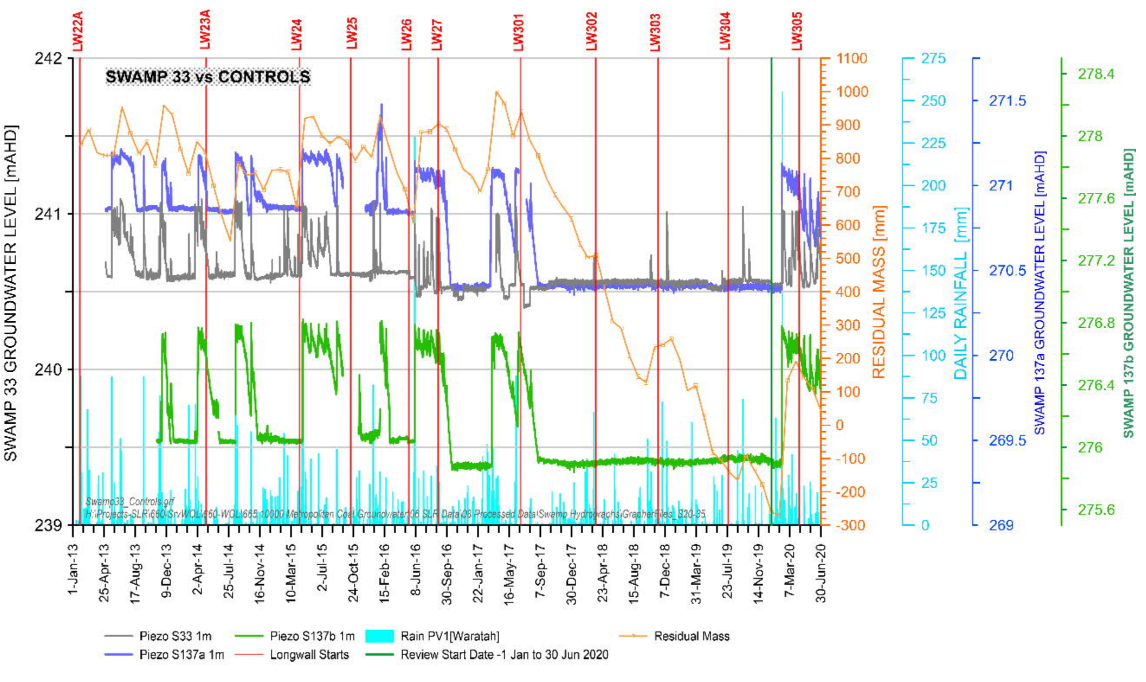


Figure 60 Groundwater Hydrographs at Swamp 33 and Two Controls (137a and 137b)

The performance assessment for Swamp 35 is illustrated on Figure 61. The 2σ bandwidth limit is about 1 m. As the diver cable length was adjusted on 19 July 2016, the lower limit reflects the old diver level. During 2017 the water level was recorded below the lower bandwidth, the piezometer being dry, from January to March 2017 and September 2017 to September 2018 and intermittently saturated from October to December 2018. During 2019, dry levels persisted in the swamp substrate piezometer. After the large rain event in February 2020, the swamp substrate became saturated again and remained saturated for the remainder of the reporting period. As with other swamps overlying Longwalls 23-27, groundwater levels correlate well with the rainfall trend (Figure 62). This monitoring site is about 250 m from Longwall 25 and less than 50 m from the closest approach of Longwall 26 which occurred in May 2016. There is no evidence of a mining effect from the commencement of Longwall 27 in September 2016, although the distance of separation is only a few metres laterally.

The performance indicator has not been exceeded for Swamp 35, despite the minor apparent exceedance due to lowering of the sensor. The significant amplitude response to rainfall in the Swamp 35 sandstone (10 m) piezometer during March and June 2017, more closely reflecting groundwater level in the substrate piezometer, may indicate an increased connectivity between the swamp and underlying sandstone. There appears to be a new source of water at 10 m depth, either vertical or lateral. However, there is no evidence of any reduced capacity in the swamp substrate. Water levels in both piezometers began declining after July 2017 in response to reduced rainfall with the 1 m piezometer becoming dry and remaining so since September 2017, apart from October to December 2018. Water levels in the 10 m piezometer do not plateau at the base of the datalogger but continue to decline from July 2017 to September 2018. Rainfall in March and June 2018 led to a brief recovery of water levels; however, after these rainfall events, water levels began to drop immediately. The sandstone piezometer water level again responded strongly to rainfall in October and December 2018, March and September 2019 and February 2020. Swamp 35 is assessed as being at Level 2 trigger level (Trigger Action Response Plan for upland swamp groundwater monitoring in the BMP).

In summary, the performance indicator for upland swamp groundwater levels should not be regarded as having been exceeded for Swamps 25, 30, 33 or 35 when lowering of the sensor is taken into account. There is no evidence for mining effects on the swamp substrate groundwater levels at this time for these swamp sites (refer to Appendix A for semi-quantitative analysis).

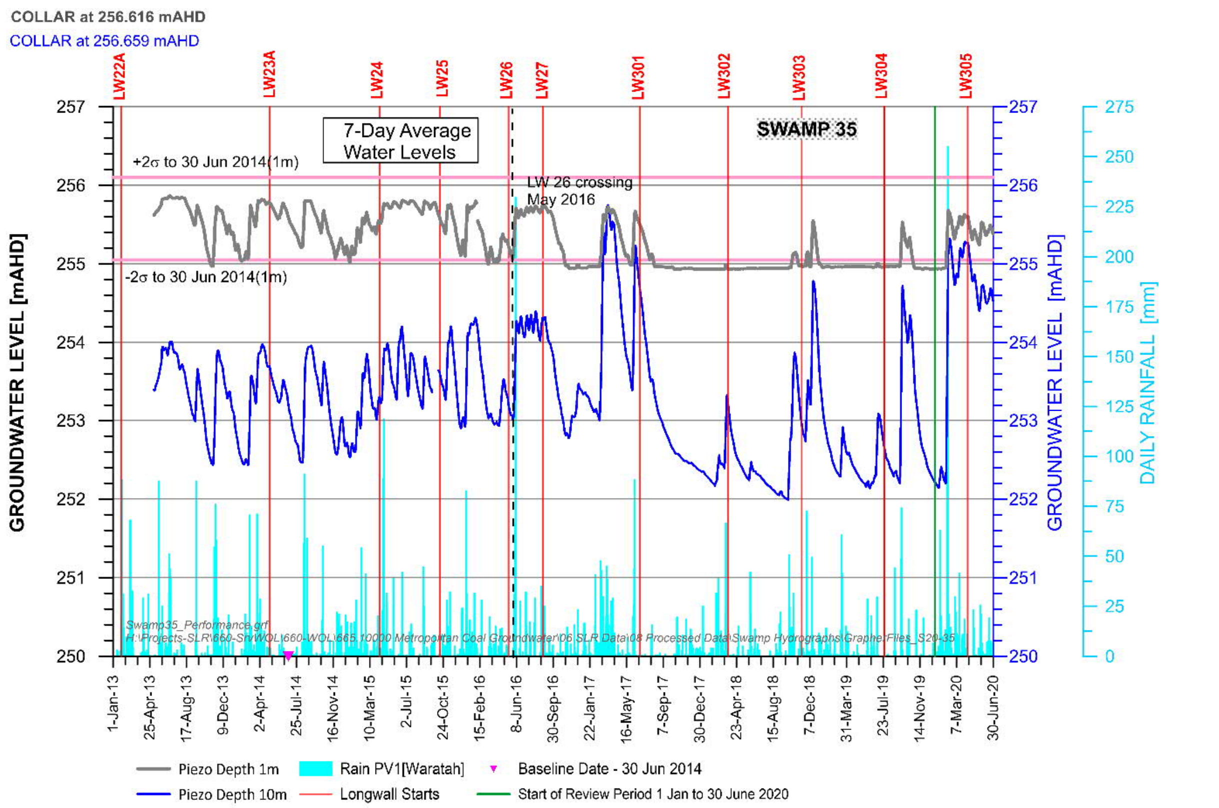


Figure 61 Seven Day Average Water Levels at Swamp 35

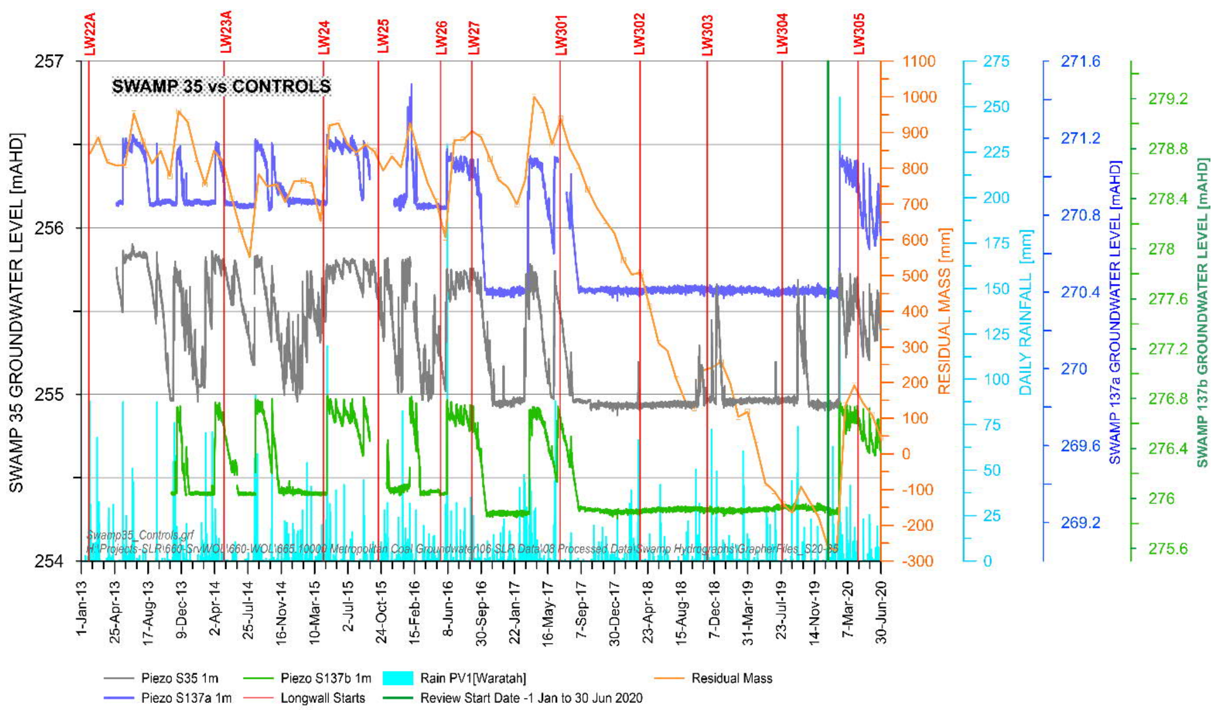


Figure 62 Groundwater Hydrographs at Swamp 35 and Two Control Swamps (137a and 137b)

5.1.2 Longwalls 301-304 Swamps

The seven-day average recorded water levels for both the sandstone and swamp substrate piezometers for swamp sites S40, S41, S46, S50, S51, S52 and S53 as well as swamp substrate piezometers in comparison to control swamps 101, 137a and 137b are displayed in Figure 63 to Figure 76.

As sensors were removed for the period 16 August 2017 to 28 August 2017 during WaterNSW hazard reduction burns, the data for this period are not displayed in the figures. Sensor depths were re-measured during the period 19 February 2018 to 22 February 2018 and the water levels recorded prior to this period were adjusted. This has resulted in changes to the measured minimum water level recorded to 30 June 2017 for Swamps 40 and 41. The Longwalls 301-303 Biodiversity Management Plan minimum levels will need to be updated to indicate the minimum water level recorded to 30 June 2017 was 230.38 mAHD for Swamp 40, 277.71 mAHD for Swamp 41, 280.64 mAHD for Swamp 46, 273.18 mAHD for Swamp 51, 281.73 mAHD for Swamp 52 and 293.0 mAHD for Swamp 53. As noted in section 3.3.1, data has been filtered to remain within the ground elevation and sensor elevation at each site, to normalise the data prior to the February 2018 sensor level adjustments to remain within that range.

Longwall 301 passed by Swamp 46 in November 2017 and Swamp 41 in December 2017. As rainfall residual mass was declining at that time, no mining effect is evident in the swamp substrate or the sandstone (10 m) piezometer at the time of passing. Longwall 302 passed by Swamp 53 in May 2018, Swamp 46 in June 2018 and Swamps 40 and 41 in July 2018. Longwall 303 passed by Swamp 51, Swamp 52 and Swamp 53 in November 2018, Swamp 46 in January 2019, Swamp 41 (one panel width away) in February 2019 and Swamp 40 in March 2019. Longwall 304 commenced in July 2019 and ended in January 2020. Longwall 305 started in April 2020. Refer to Table 2 for a list of longwalls and swamp passing distances and times.

All swamp hydrographs show strong consistency and correlation with the responses at the control swamps, except for apparently anomalous data at S52 prior to April 2017 (Figure 76).

Data analysis for the reporting period indicates the seven-day moving average for Swamps 41 and 53 was at or above the minimum established for the swamp's full length of record[3]. Refer to Table 10 for a summary of trigger levels and observed minima during the reporting period.

Swamps 40, 41, 46, 51, 52 and 53 are assessed as being at Level 1 trigger level (Trigger Action Response Plan for upland swamp groundwater monitoring in the BMP).

During the previous reporting period (June-December 2019), the Swamp 50 10 m piezometer displayed a pronounced decline in water level from October 2019 continuing to the end of December 2019 coinciding with the passage of Longwall 304; this is an apparent mining affect considered to be related to mine subsidence.

The Swamp 50 performance indicator relates to the substrate piezometer and not the shallow sandstone (10 m) piezometer. The seven-day moving average for Swamp 50 was at the minimum established for the swamp's full length of record, below sensor level, during the reporting period. Swamp 50 is assessed as being at Level 2 trigger level (Trigger Action Response Plan for upland swamp groundwater monitoring in the Longwalls 304 Biodiversity Management Plan).

3 The 'full length of record' relates to the groundwater swamp substrate dataset for Longwalls 301-303 swamps to 30 June 2017.

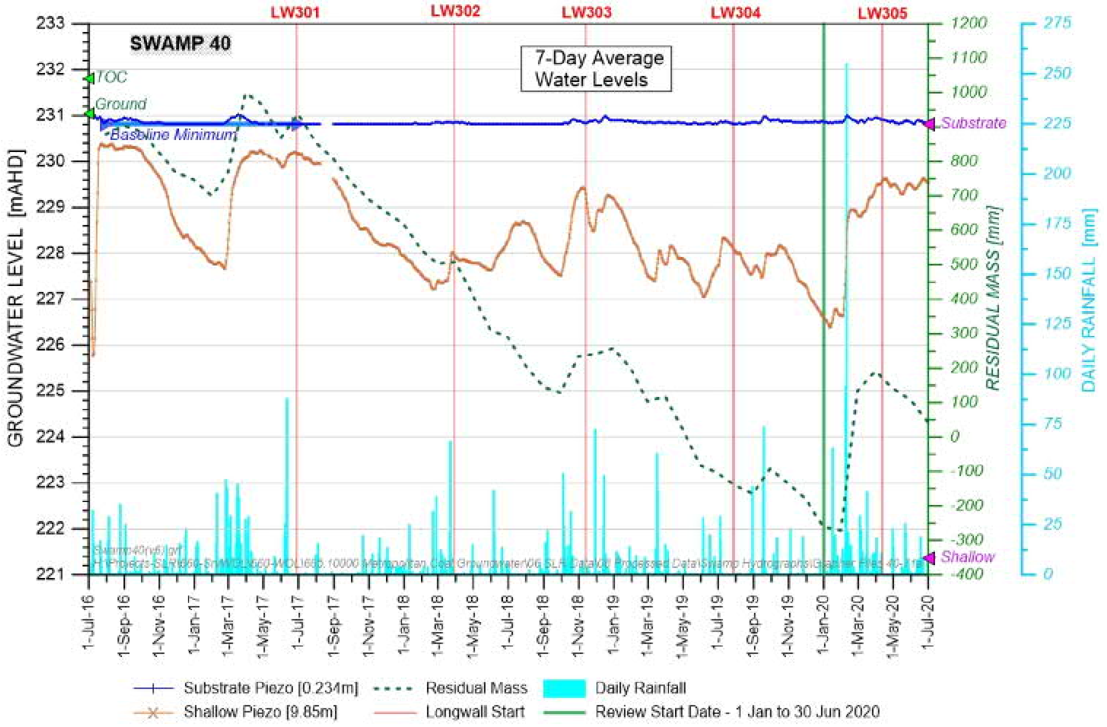


Figure 63 Seven Day Moving Average at Swamp 40

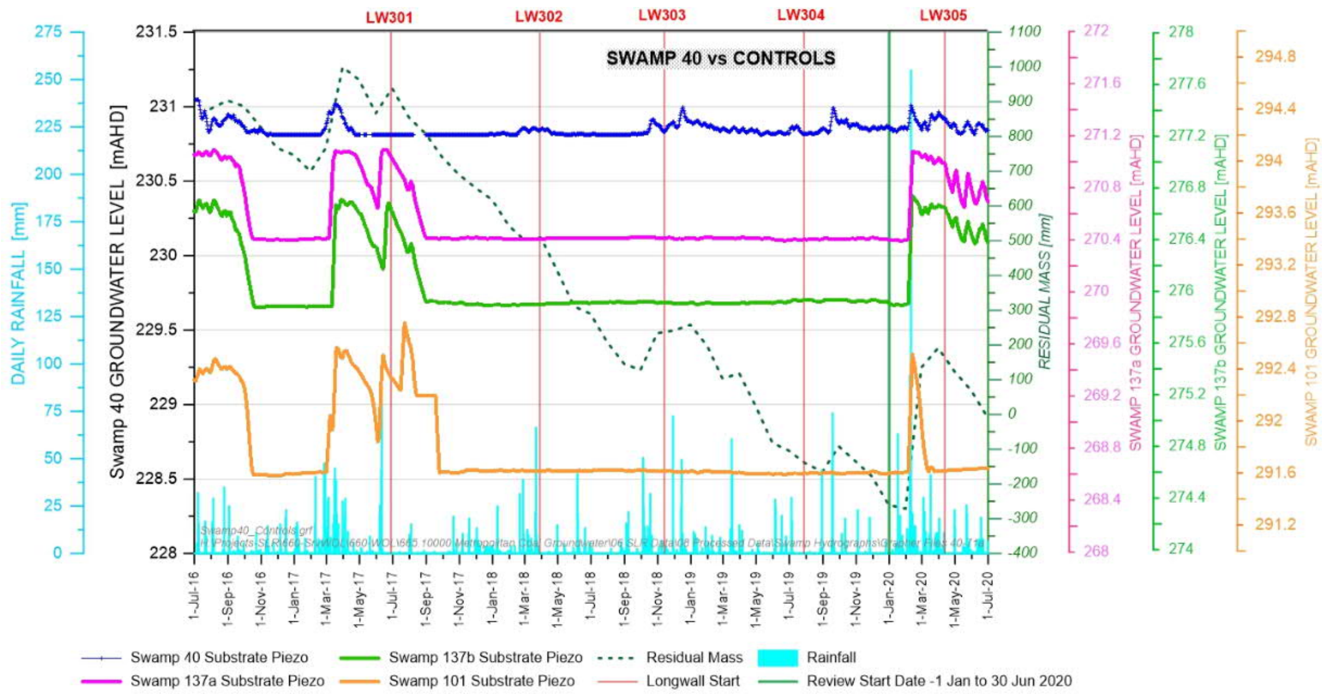


Figure 64 Substrate Groundwater Hydrographs at Swamp 40 and Three Control Swamps

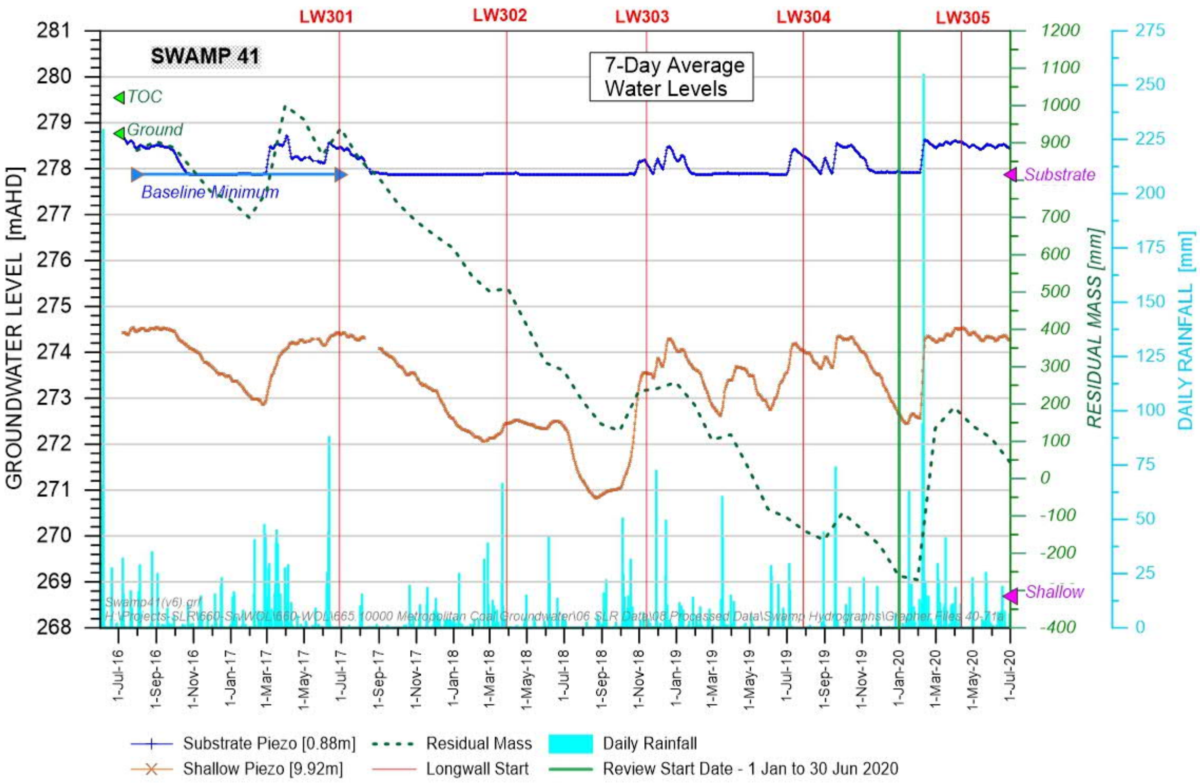


Figure 65 Seven Day Moving Average at Swamp 41

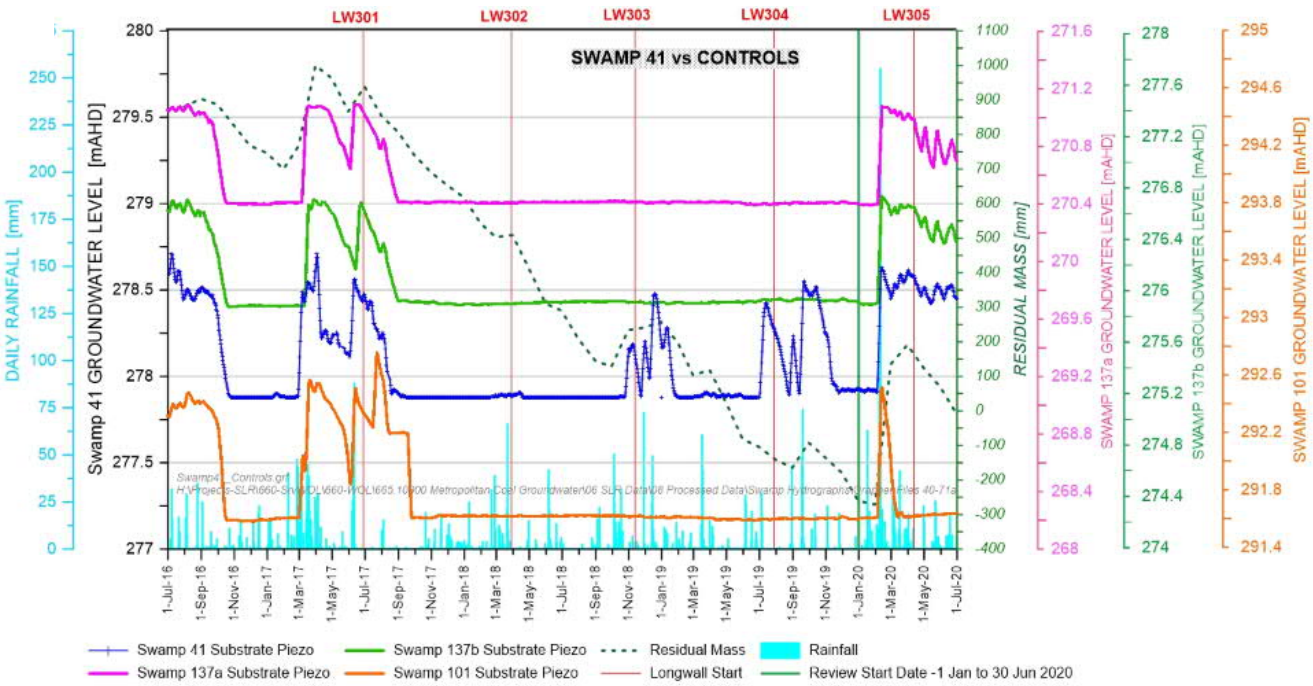


Figure 66 Substrate Groundwater Hydrographs at Swamp 41 and Three Control Swamps

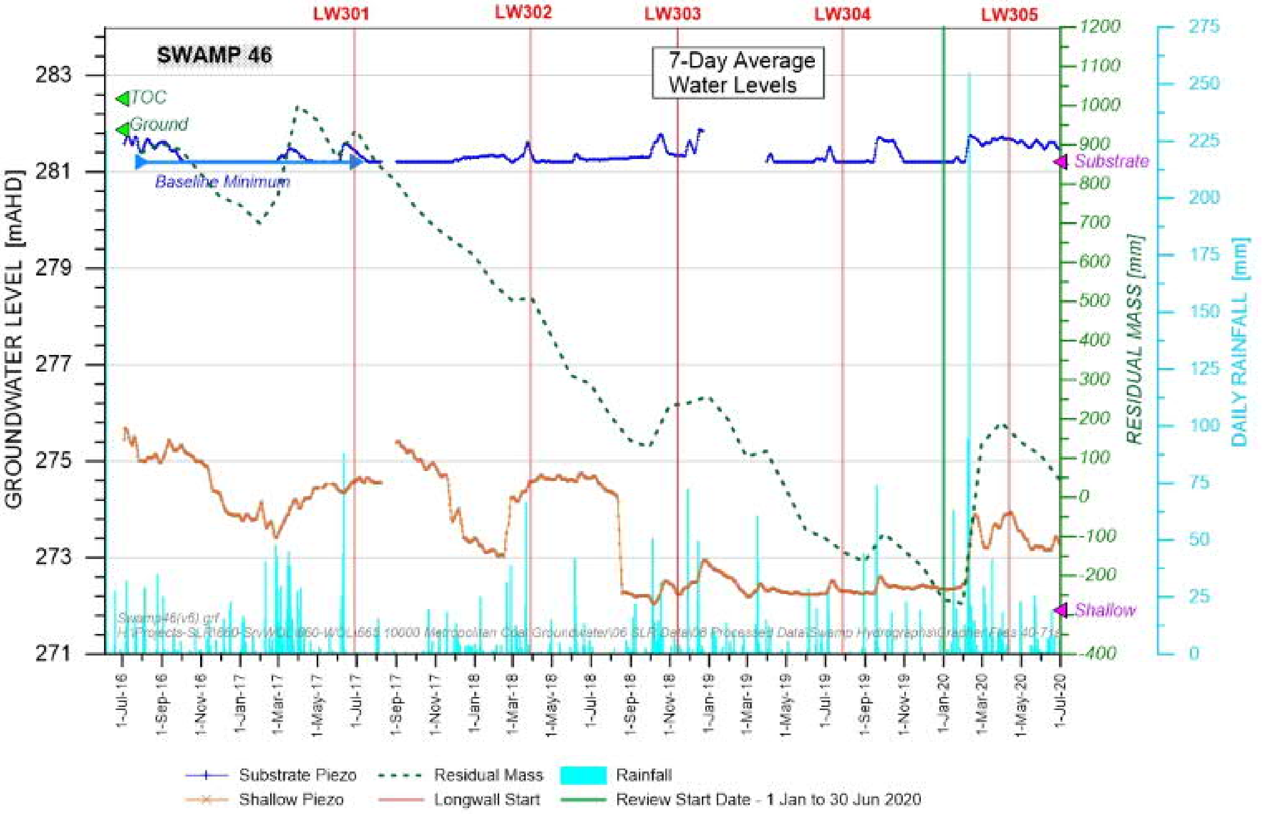


Figure 67 Seven Day Moving Average at Swamp 46

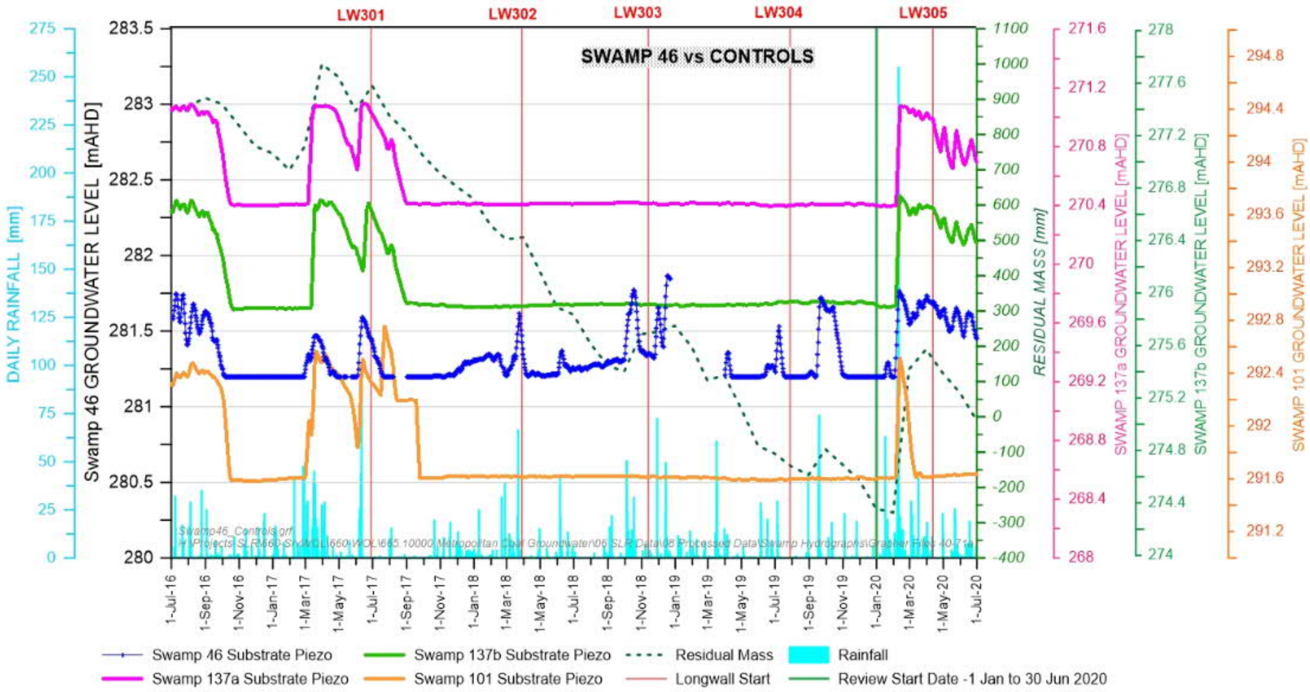


Figure 68 Substrate Groundwater Hydrographs at Swamp 46 and Three Control Swamps

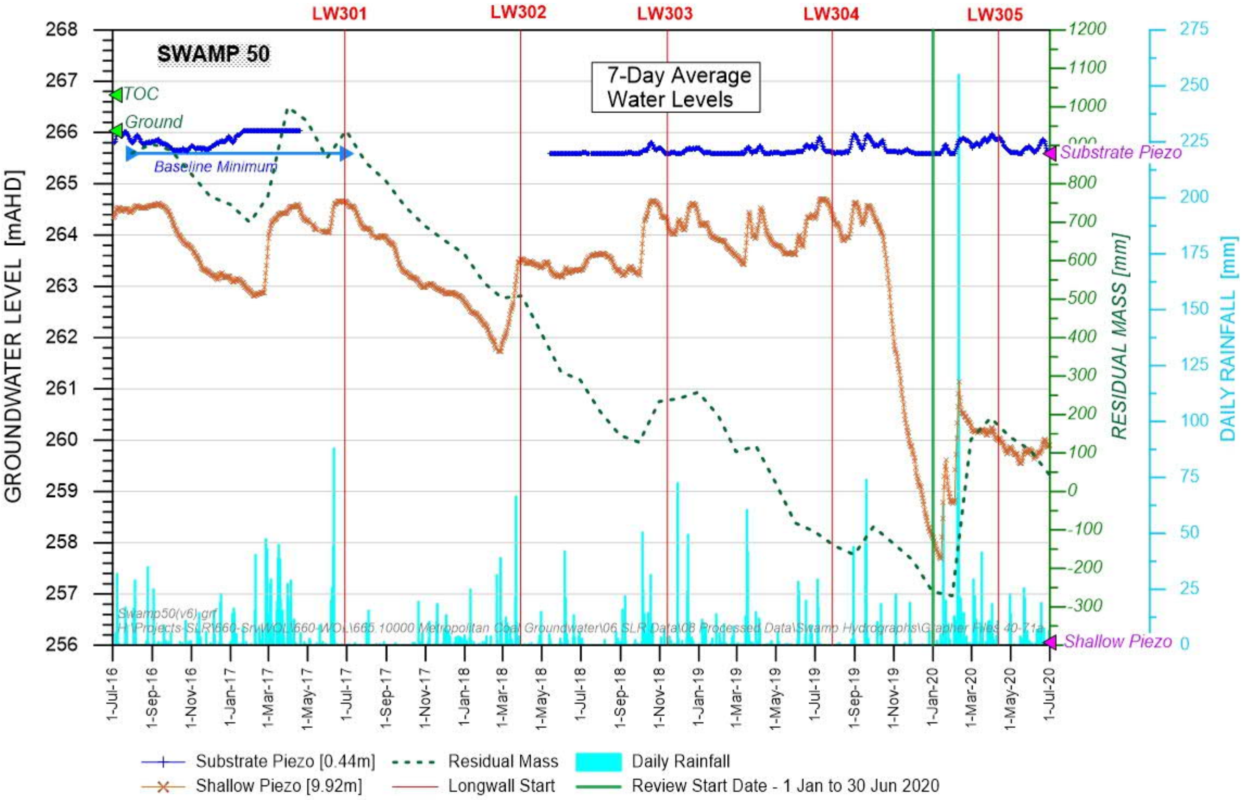


Figure 69 Seven Day Moving Average at Swamp 50

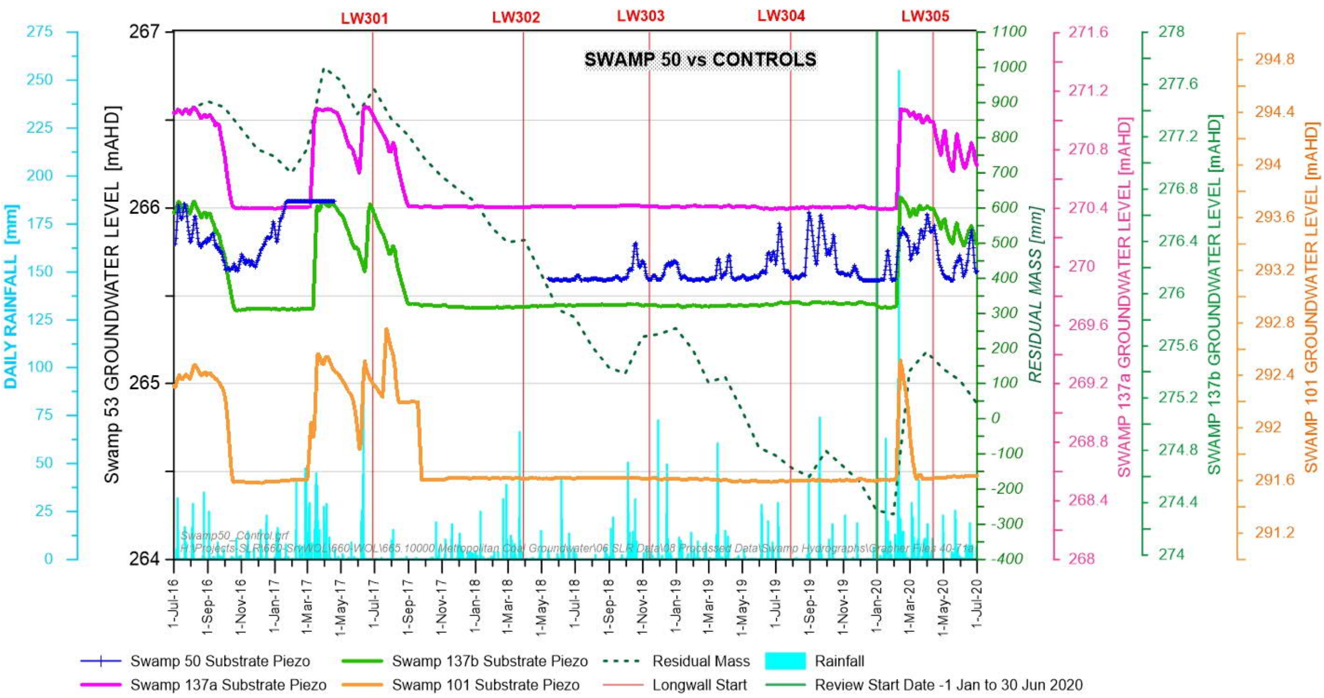


Figure 70 Substrate Groundwater Hydrographs at Swamp 50 and Three Control Swamps

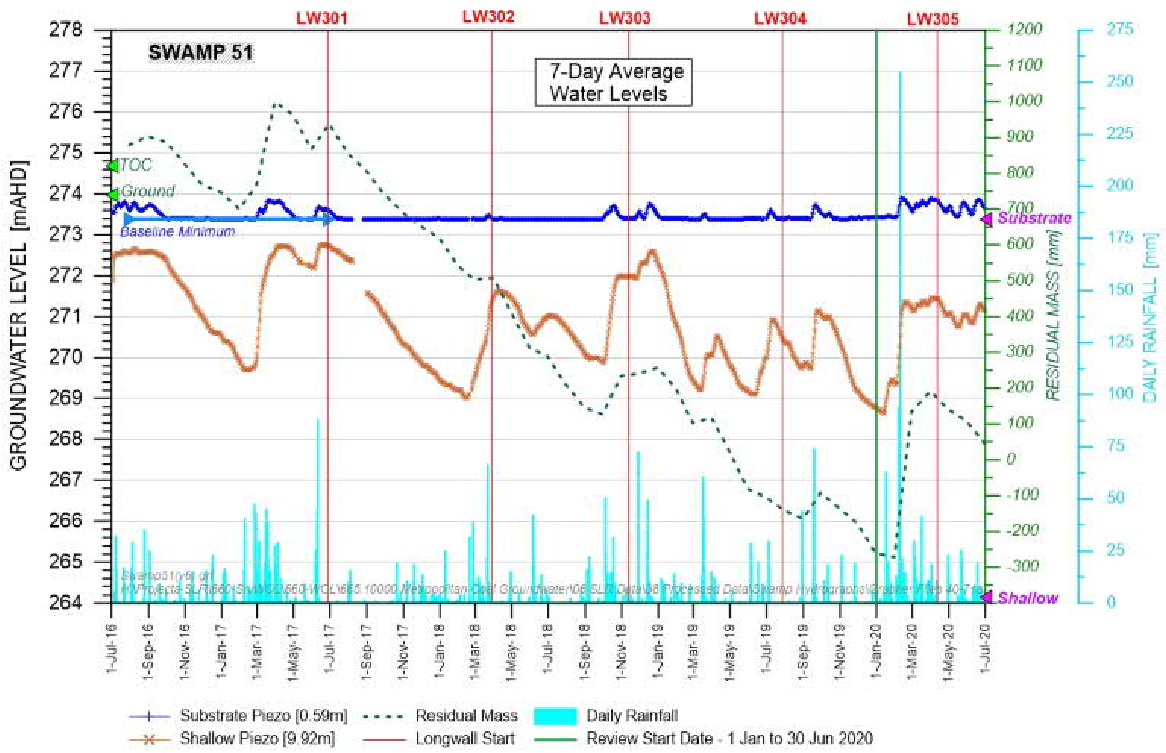


Figure 71 Seven Day Moving Average at Swamp 51

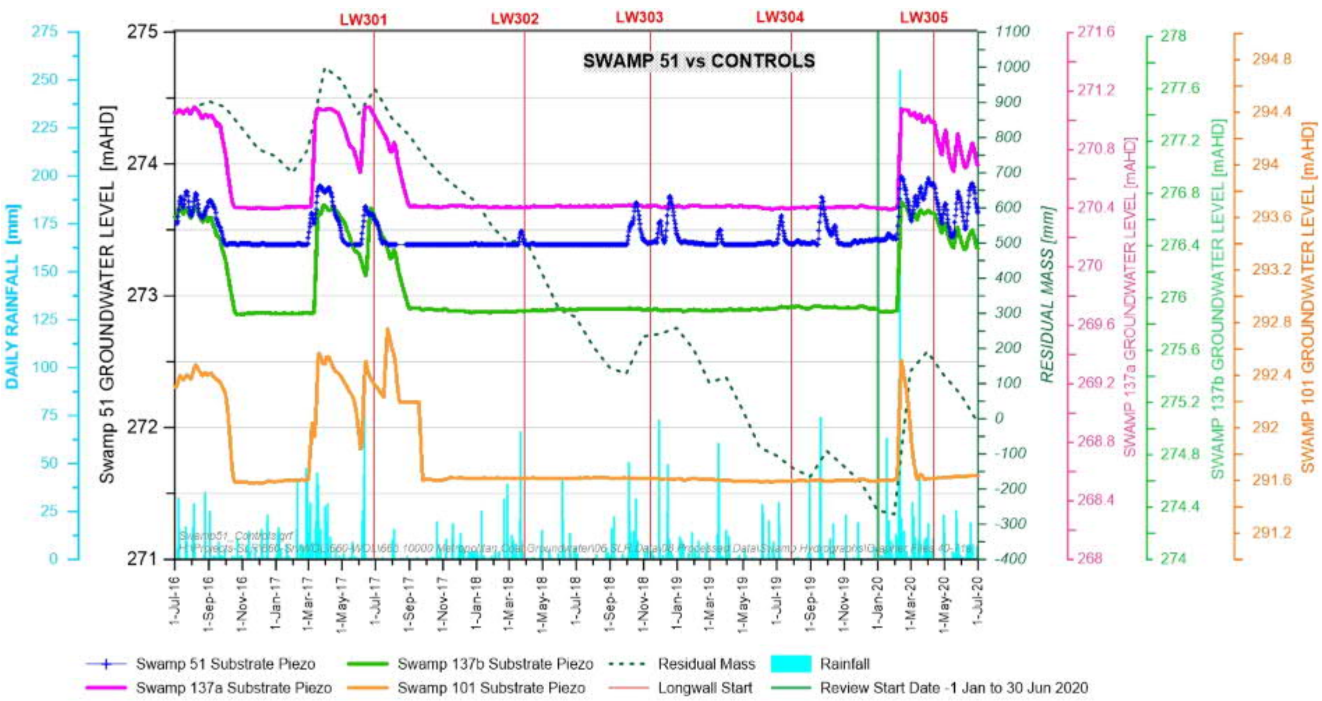


Figure 72 Substrate Groundwater Hydrographs at Swamp 51 and Three Control Swamps

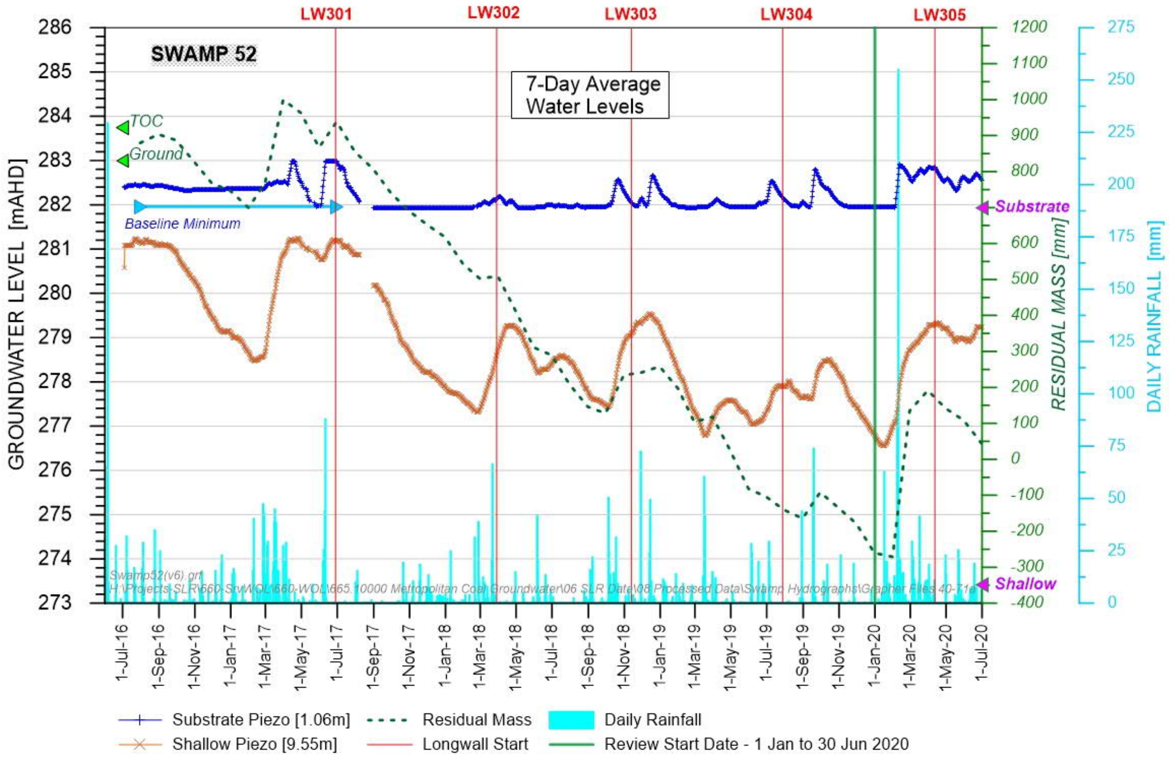


Figure 73 Seven Day Moving Average at Swamp 52

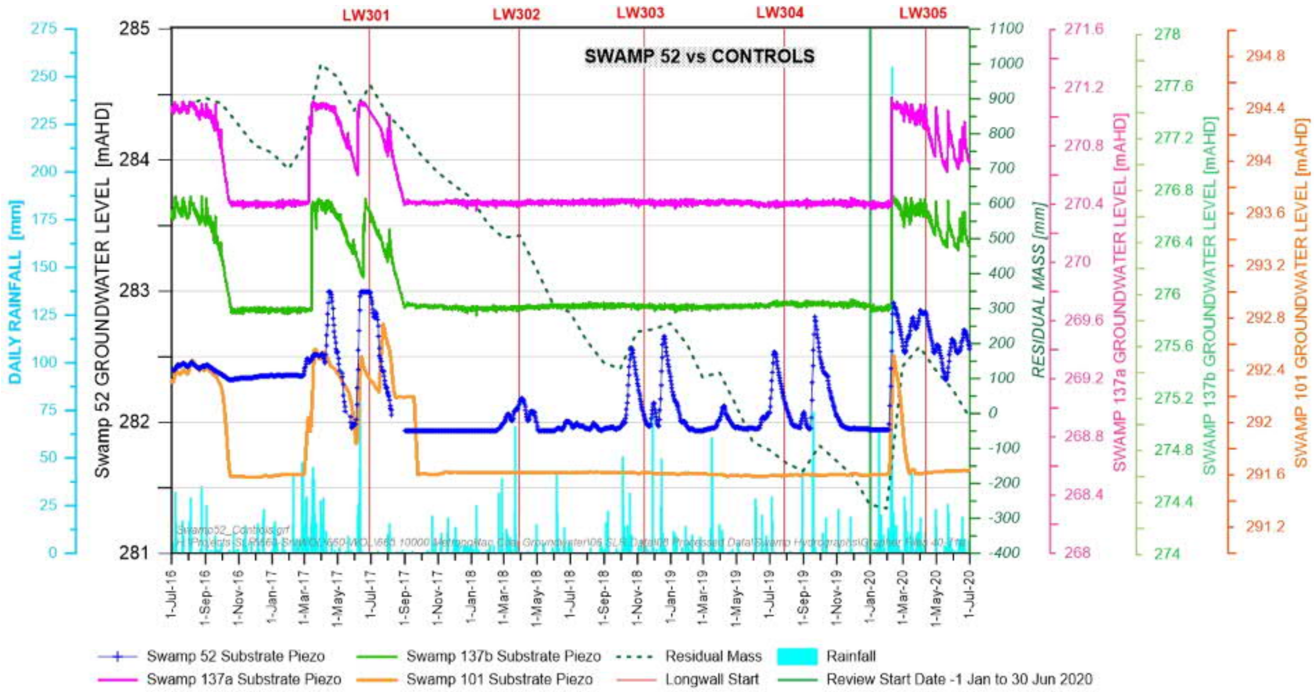


Figure 74 Substrate Groundwater Hydrographs at Swamp 52 and Three Control Swamps

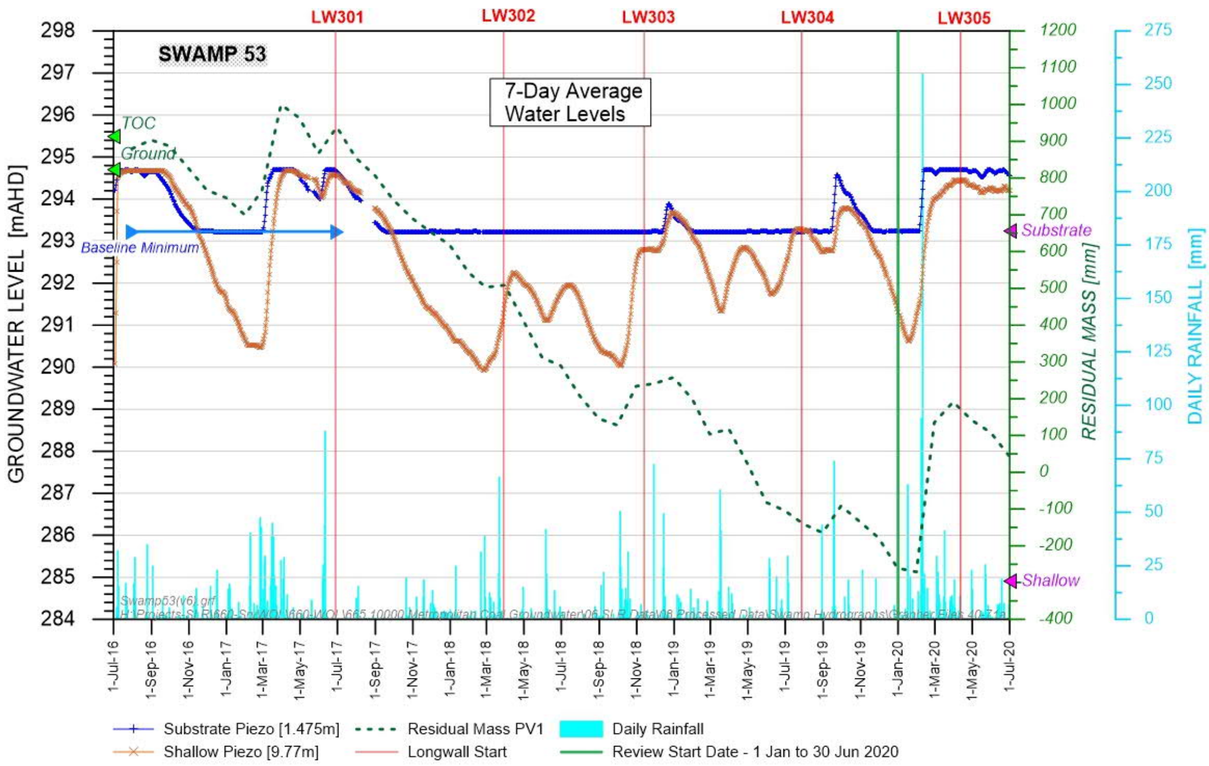


Figure 75 Seven Day Moving Average at Swamp 53

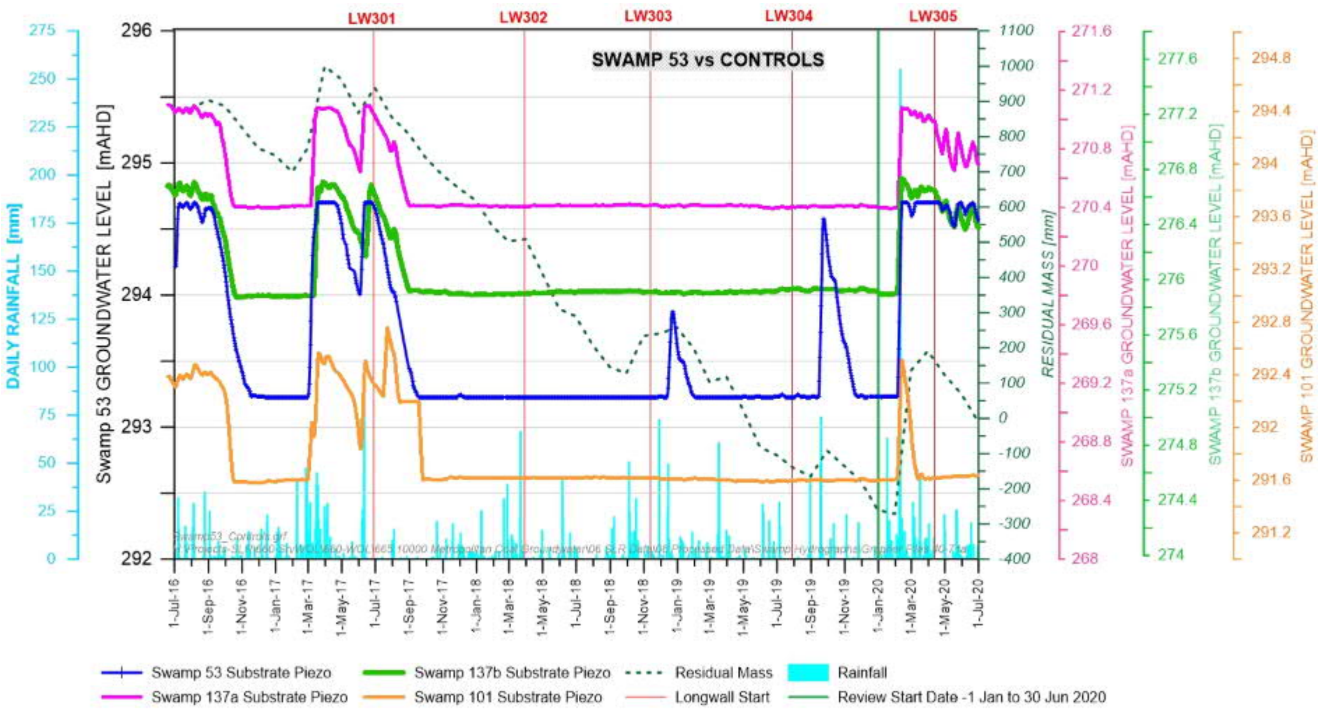


Figure 76 Substrate Groundwater Hydrographs at Swamp 53 and Three Control Swamps

5.1.3 Longwall 305-307 Swamps

Mining of Longwall 305 commenced on 12 April 2020. The end of the baseline period for swamps S71a and S72 was set to the end of the previous month, i.e. 31 March 2020.

The seven-day average recorded water levels for both the sandstone and swamp substrate piezometers for swamp sites S71a and S72 as well as swamp substrate piezometers in comparison to control swamps 101, 137a and 137b are displayed in Figure 77 to Figure 80.

The visual comparison for Swamp 71a with the control swamps shows that Swamp 71a remains unaffected by mining. The control swamps show longer periods of dryness during dry climatic conditions.

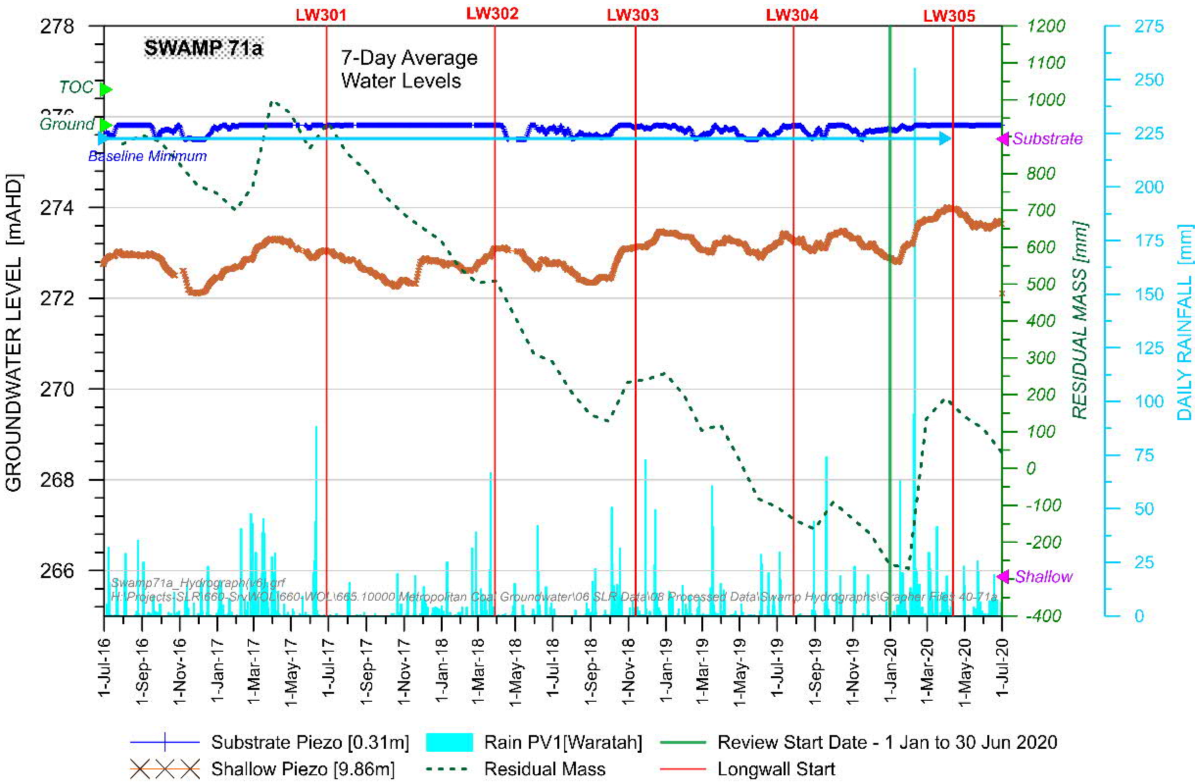


Figure 77 Seven Day Moving Average at Swamp 71a

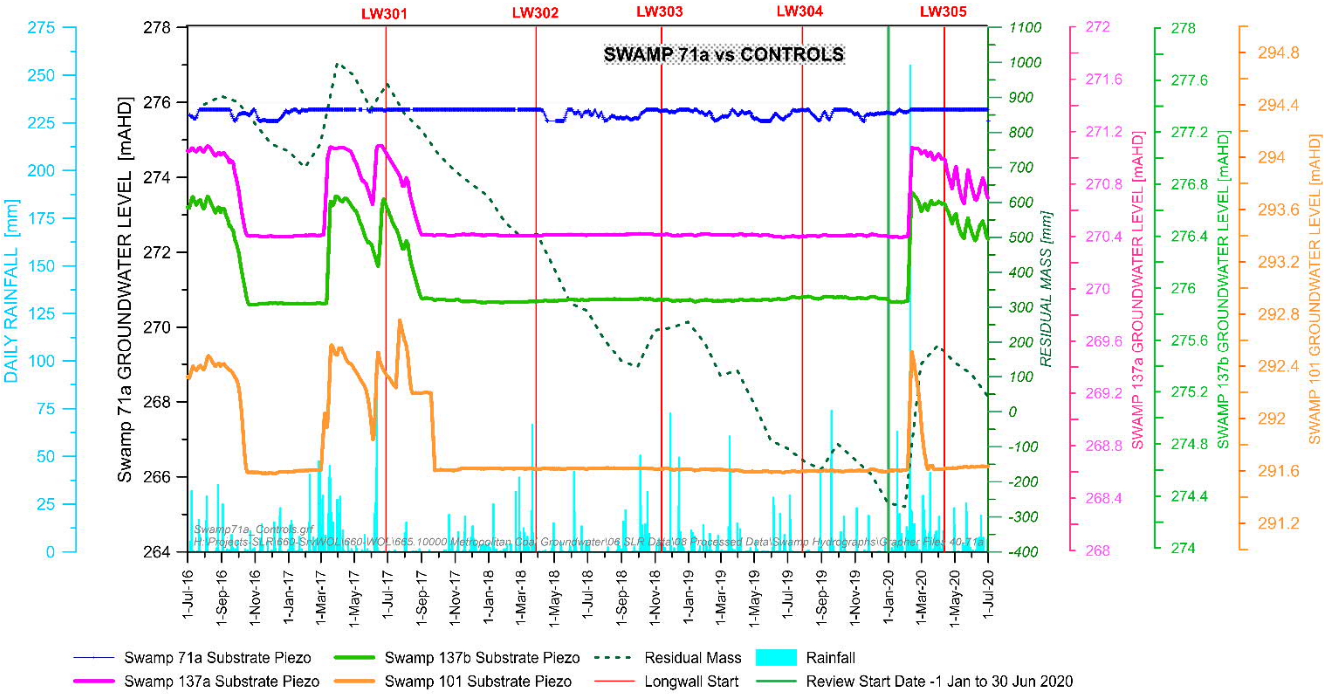


Figure 78 Groundwater Hydrographs at Swamp 71a and Control Swamps

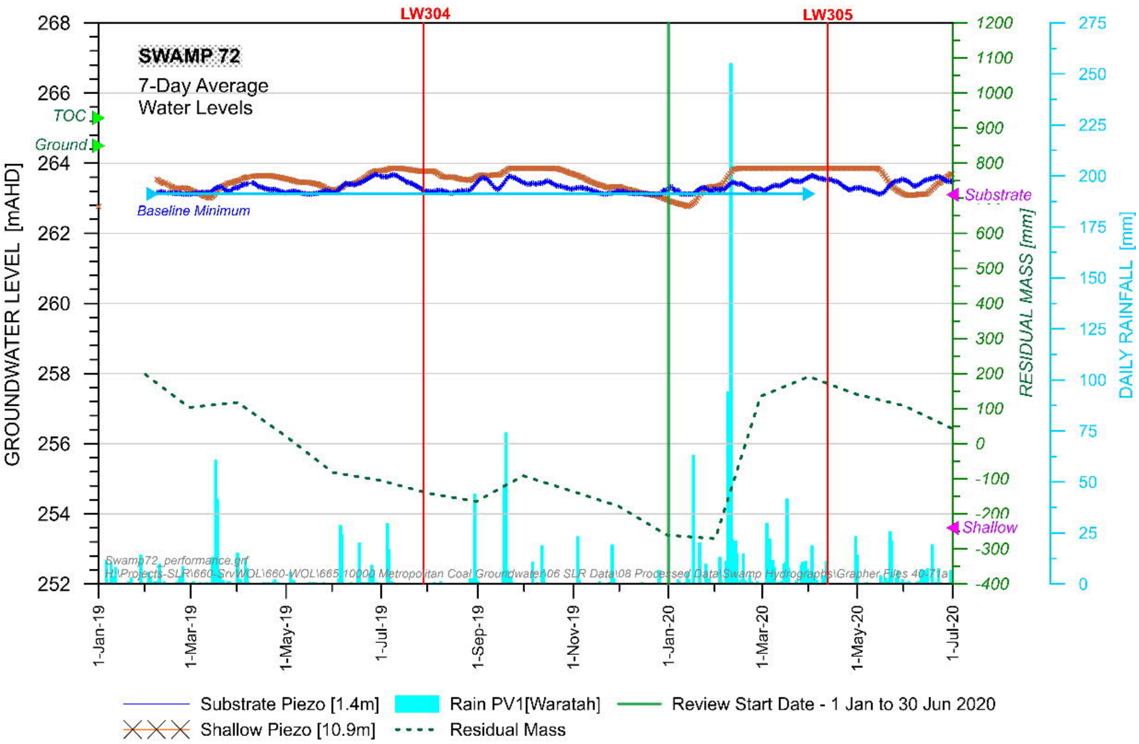


Figure 79 Seven Day Moving Average at Swamp 72

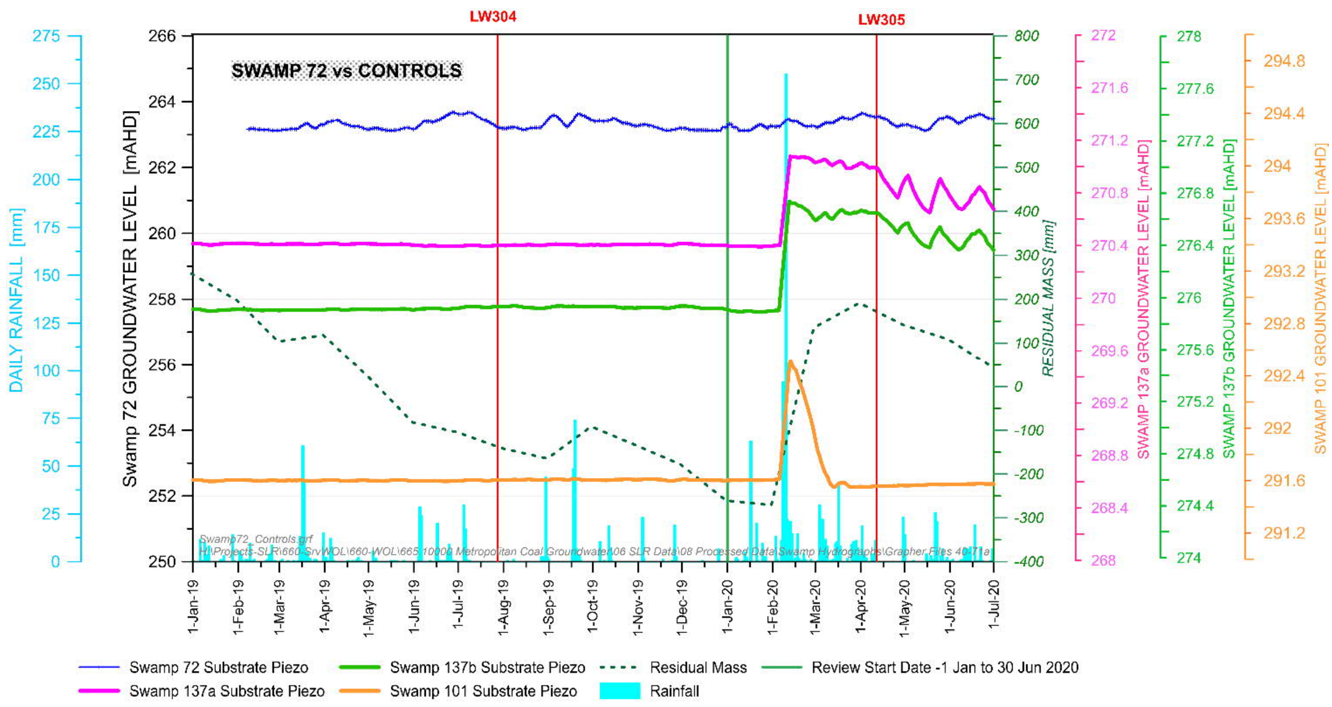


Figure 80 Groundwater Hydrographs at Swamp 72 and Control Swamps

5.1.4 Summary of upland swamp assessment

Table 10 provides a summary of the TARP assessment against the BMP trigger levels. The minimum of the substrate piezometer recordings are compared against the trigger levels listed in the current BMP. If the minimum of the substrate water levels is above the trigger level, otherwise the level is Level 2. In this instance, the semi-quantitative method (Appendix A) was applied and all swamps were considered to be not impacted by mining as the control swamps and swamps showed similar recession and recovery characteristics.

Table 10 Upland swamp TARP assessment against trigger levels

Swamp	BMP trigger level (mAHD)	Minimum of reporting period (mAHD)	TARP Level
20	NA (previously deemed impacted)	218.14	NA
25	270.7	270.67	Level 2
28	NA (previously deemed impacted)	245.78	NA
30	235.3	234.99	Level 2
33	240.5	240.52	Level 1
35	255.0	254.9	Level 2
40	230.38	230.81	Level 1
41	277.71	277.88	Level 1

Swamp	BMP trigger level (mAHD)	Minimum of reporting period (mAHD)	TARP Level
46	280.64	281.20	Level 1
51	273.18	273.40	Level 1
52	281.73	281.94	Level 1
53	293.0	293.23	Level 1
50	265.59	265.59	Level 2
71a*	275.51	275.79	Level 1
72*	263.12	263.12	Level 1

* Baseline period was set at 31 March 2020, as LW 305 started on 12 April 2020.

5.2 Assessment of vertical potentiometric head profiles

Vertical potentiometric head profiles at Bores 9GGW2B and F6GW3A have been used to assess connective cracking between the surface and the mine during the reporting period in accordance with the WMP.

Analysis against Performance Indicators

Performance Indicators: Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore 9GGW2B does not occur.

Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore F6GW3A does not occur.

The performance indicators are considered to have been exceeded if the measured potentiometric head profile is inconsistent in shape or lies significantly to the left of the predicted high-inflow model curve.

Bore 9GGW2B is located above the 300-series mains. The vertical head profiles for 9GGW2B measured up to the end of the reporting period are shown on Figure 81 and compared with simulated profiles at the end of Longwall 304. The low heads in the Bald Hill Claystone and Scarborough Sandstone are expected to be anomalous and no regional model could ever replicate such departures from normal. As Table 9 notes one unreliable VWP and five disabled VWPs, past measurements must be relied on to indicate profile shape. The measured/inferred head profile at site 9GGW2B at 30 June 2020 is similar to those of the previous periods and is consistent in shape with the simulated vertical gradient for the groundwater model. The potentiometric head at the 437 m piezometer in Wombarra Claystone is displaying a decreasing trend. The model predicts a pressure head in the Bulli Coal seam that is lower than observed, meaning that the model is overestimating the expected impact at the coal seam depth at this site.

The potentiometric head profiles for bore F6GW3A shown on Figure 82. The trend of the most recent head profile on 30 June 2020 matches well with previous head profiles, apart from the decline of groundwater head in the Bulgo Sandstone and the rising of head in the Scarborough Sandstone from the previous head profile on 31 December 2019. Both the piezometers in the Bulgo Sandstone show head drops from the previous profile which are about 14 m and 9 m in the middle and lower Bulgo Sandstone respectively. The model consistently overestimates the head in all strata from the Bald Hill Claystone downwards, but the shape of the profile agrees very well with what has been measured. The deviation between modelled and observed profiles is not a deterioration in model performance but an inherent weakness in the calibrated model at this location. Much effort was expended during the most recent re-calibration of the model in August 2020 but better agreement could not be attained. As measurements from July 2014 to June 2020 show that the vetical head profiles have not moved significantly to the left over that period of time, the monitored response at F6GW3A is fairly stable with only minor ongoing reduction in heads due to expansion of 300-series mining.

Table 9 notes that all VWPs at bore F6GW3A are considered reliable. In the previous reporting period communications were lost from the lower four VWPs at 220 m, 308 m, 380 m and 450 m on 22 September 2019. However, new aerial cable has been installed and continued recording data.

Bore 9GGW2B and bore F6GW3A are assessed as being at Level 2 trigger level (Trigger Action Response Plan for no connective cracking between the surface and the mine and negligible leakage from Woronora Reservoir) during the reporting period. The performance indicators have not been exceeded during the reporting period because the measured potentiometric head profiles are consistent in shape and do not lie significantly to the left of the predicted model curve. The sensor observation in the Bulgo Sandstone for bore F6GW3A has moved to the left of the curve over time (Figure 82. However, all other sensors above the Bulgo Sandstone have not changed position, which resulted in the interpretation that no surface cracking is occurring at this location.

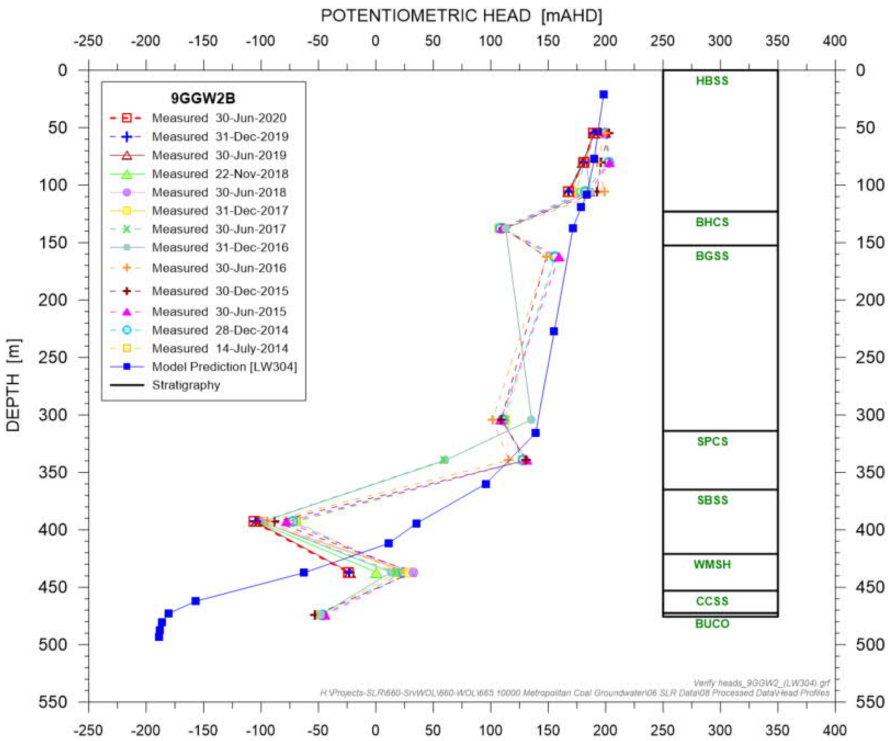


Figure 81 Measured and Simulated Potentiometric Head Profiles at Indicator Site 9GGW2B

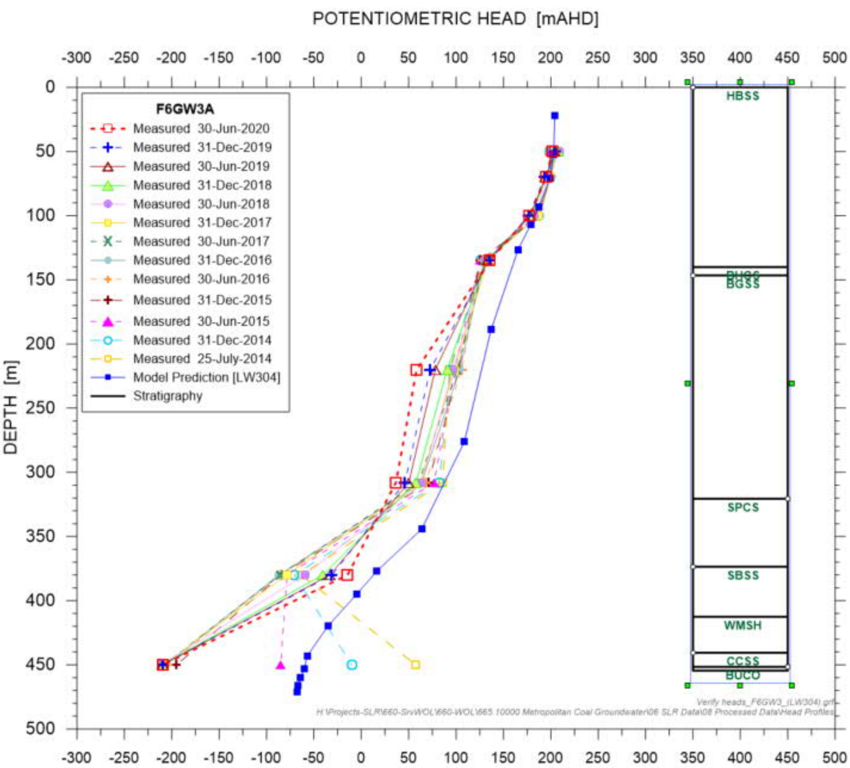


Figure 82 Measured and Simulated Potentiometric Head Profiles at Indicator Site F6GW3A

5.3 Assessment of the gradient to the Woronora Reservoir

The groundwater head of Bores PHGW2A, F6GW4A, 9GGW2B, 9EGW2A and PM02 are compared to the full supply level of the Woronora Reservoir to assess reductions in hydraulic gradient from the bores to the Woronora Reservoir in accordance with the WMP.

Analysis against Performance Indicators

Performance Indicators:

The hydraulic gradient to the Woronora Reservoir at full supply level from Bore PHGW2A is reduced by no more than 40% from that measured to 30 June 2017.

The groundwater head of Bore F6GW4A is greater than 10 m above the Woronora Reservoir full supply level.

The hydraulic gradient to the Woronora Reservoir at full supply level from Bore 9GGW2B is reduced by no more than 40% from that measured to 30 June 2017.

The hydraulic gradient to the Woronora Reservoir at full supply level from Bore 9EGW2A is reduced by no more than 40% from that measured to 30 June 2017.

The hydraulic gradient to the Woronora Reservoir at full supply level from Bore PM02 is reduced by no more than 40% from that measured to 30 June 2017.

The performance measures were selected conservatively as a warning system. A decrease of 40% in gradient is a conservative early warning for a change of gradient from the reservoir to the groundwater. Even at 40% less gradient, the Woronora Reservoir is receiving water from the groundwater and not losing water into the groundwater.

The groundwater levels in the mid Hawkesbury Sandstone piezometers at sitesPHGW2A, F6GW4A, 9GGW2B, 9EGW2A and PM02 are presented on Figure 83 to Figure 87 and are compared to the relevant trigger levels in the Trigger Action Response Plan for no connective cracking between the surface and the mine and negligible leakage from Woronora Reservoir.

The highest trigger level recorded during the reporting period, at bores F6GW4 and 9EGW2A was the Level 2 trigger level, while PHGW2, PM02 and 9GGW2B reached the Level 1 (Figure 83 to Figure 87).

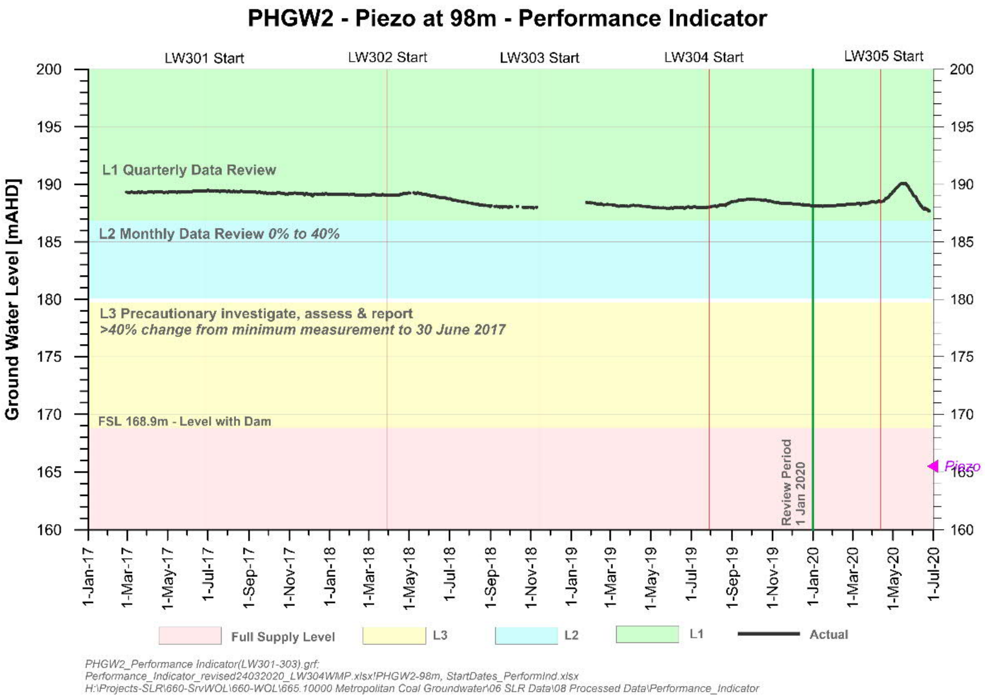


Figure 83 Mid Hawkesbury Sandstone Groundwater Levels at PHGW2 since 1 January 2017

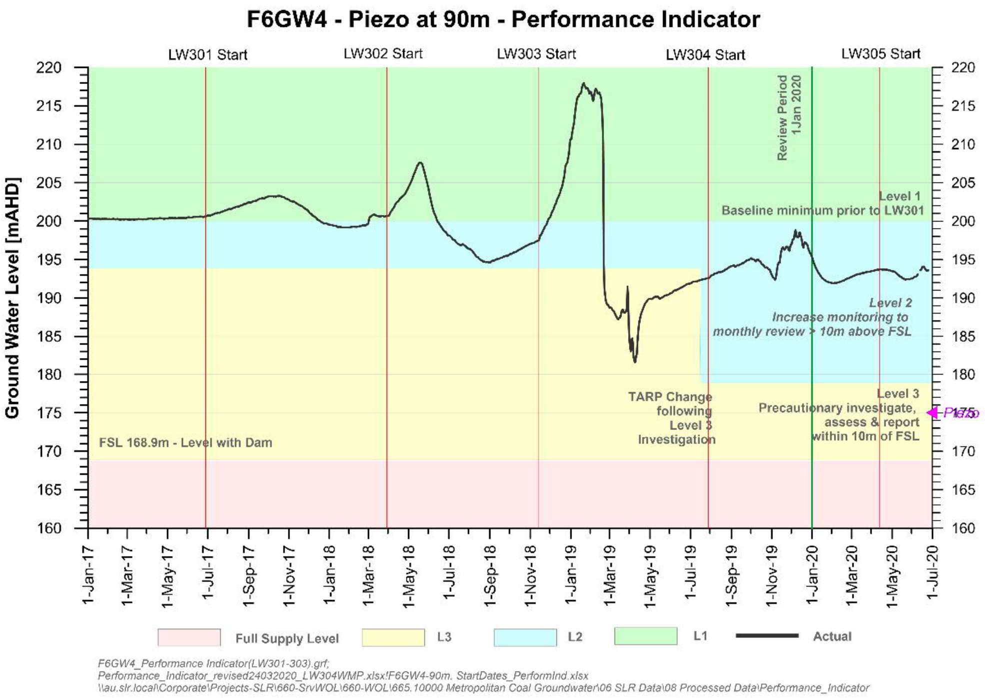


Figure 84 Mid Hawkesbury Sandstone Groundwater Levels at Bore F6GW4A since 1 January 2017

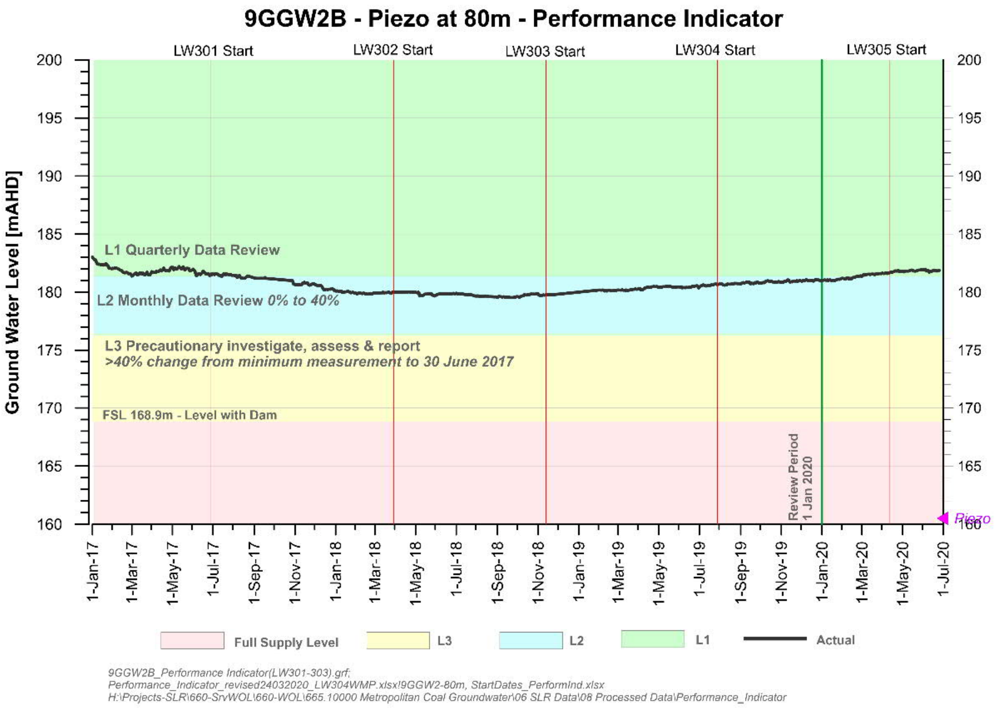


Figure 85 Mid Hawkesbury Sandstone Groundwater Levels at 9GGW2B since 1 January 2017

The observed rise in pressure at bore 9EGW2A in November 2017 is a result of drilling for the adjacent 9EGW2-4 replacement hole. Since December 2017 9EGW2A has displayed a declining trend (Figure 86). During the current reporting period the pressure was fairly stable showing a slight rising in the middle of the reporting period. The performance level remains at Level 2. An exceedance of the Longwalls 301-303 Water Management Plan Level 3 trigger and performance indicator was identified for bore 9EGW2A in March 2019 and an assessment against the subsidence impact performance measure "Negligible leakage from the Woronora Reservoir" was undertaken (SLR, 2019a). The assessment concluded that the performance measure had not been exceeded and recommended the trigger levels be revised in the Longwall 304 Water Management Plan to allow for climatic conditions. During the reporting period the water levels in 9EGW2A stabilised and rose a little while the Woronora Reservoir water level increased significantly over a short period of time due to the large rainfall event in mid February 2020 (more than 440 mm of rain recorded over a week).

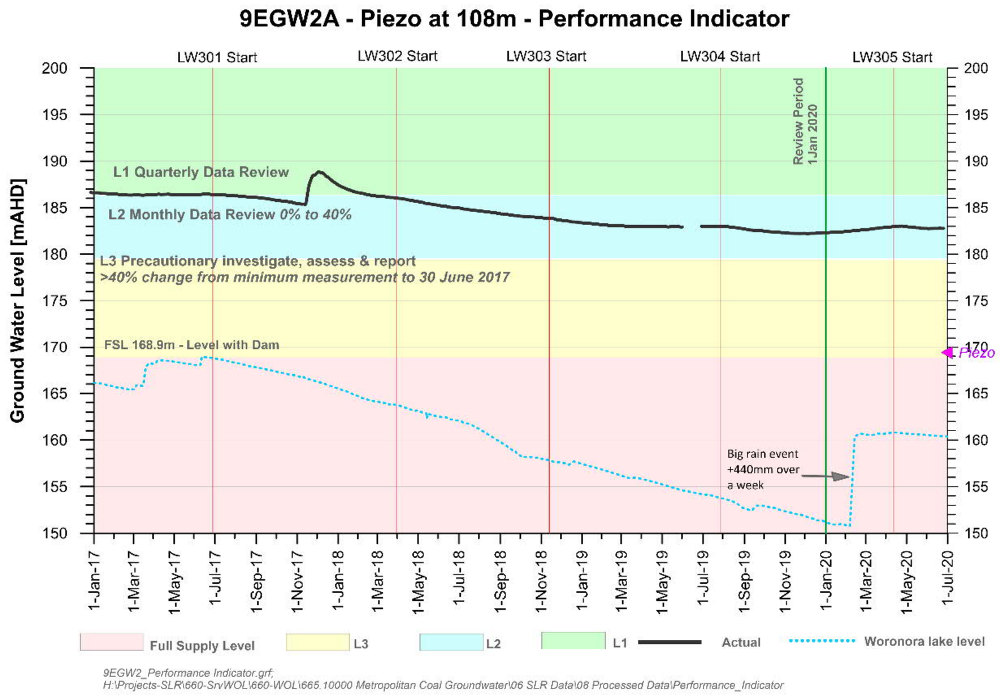


Figure 86 Mid Hawkesbury Sandstone Groundwater Levels at 9EGW2A since 1 January 2017

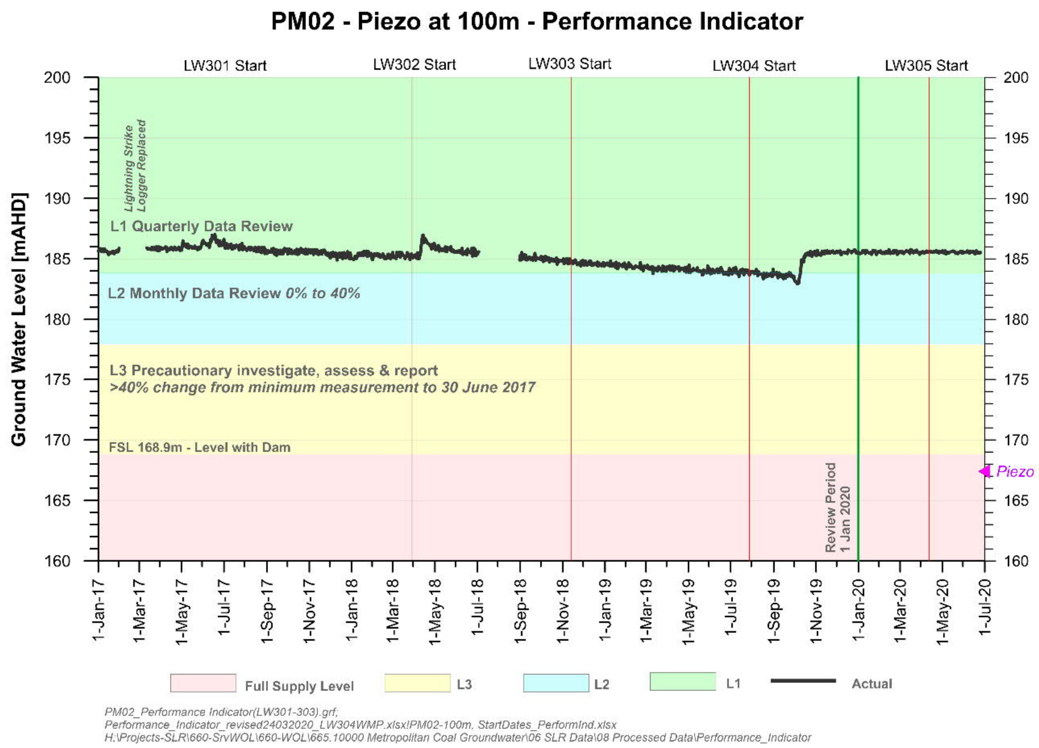


Figure 87 Mid Hawkesbury Sandstone Groundwater Levels at PM02 since 1 January 2017

5.4 Assessment of transect water level gradients

The hydraulic gradient at transect bores T3 and T5 has been assessed against the performance indicators below in accordance with the WMP.

Analysis against Performance Indicators

Performance Indicators:

> The hydraulic gradient to the Woronora Reservoir from transect bore T2 is reduced by no more than 10% from that measured on 30 June 2017.
>
> The hydraulic gradient to the Woronora Reservoir from transect bore T3 is reduced by no more than 10% from that measured on 30 June 2017.
>
> The hydraulic gradient from transect bore T5 to bore T3 is reduced by no more than 10% from that measured on 30 June 2017.

The hydraulic gradient from transect bore T2 to the Woronora Reservoir Level (WRL) over the reporting period is presented on Figure 88 and is compared to the relevant trigger level in the Trigger Action Response Plan for no connective cracking between the surface and the mine and negligible leakage from Woronora Reservoir. The performance can be classified in Level 1 during the entire reporting period.

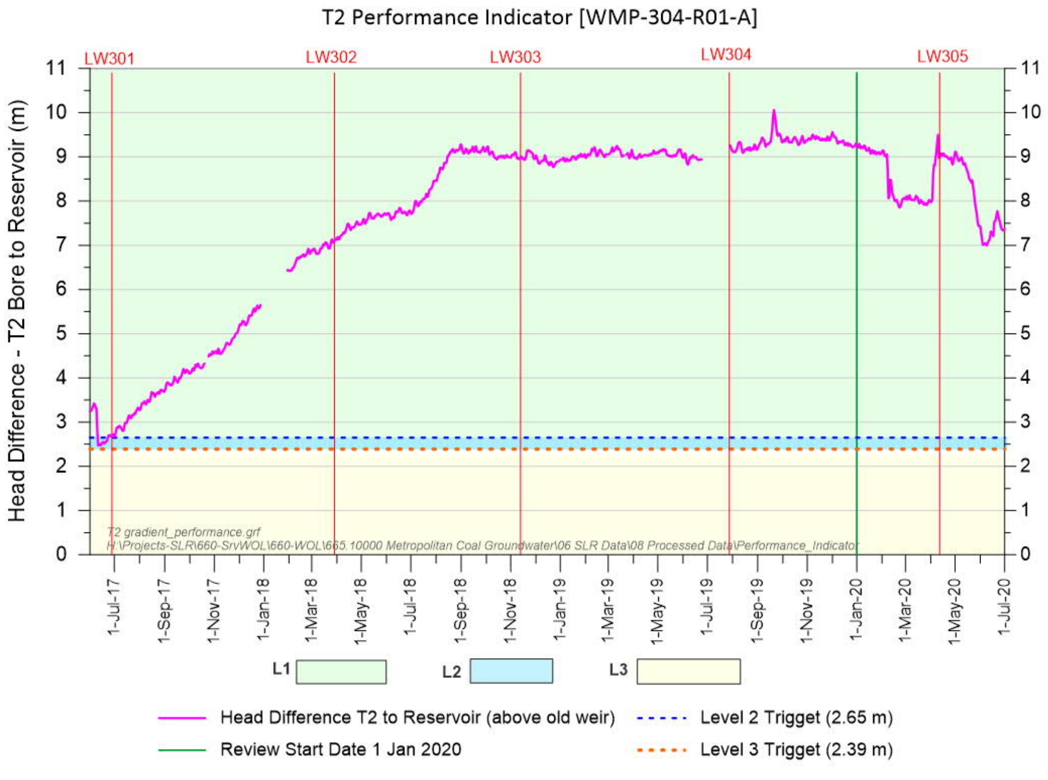


Figure 88 Hydraulic Gradient measured from bore T2 to WRL

The hydraulic gradient from transect bore T3 to the Woronora Reservoir Level (WRL) over the reporting period is presented on Figure 89 and is compared to the relevant trigger level in the Trigger Action Response Plan for no connective cracking between the surface and the mine and negligible leakage from Woronora Reservoir. The performance can be classified in Level 1 during the entire reporting period.

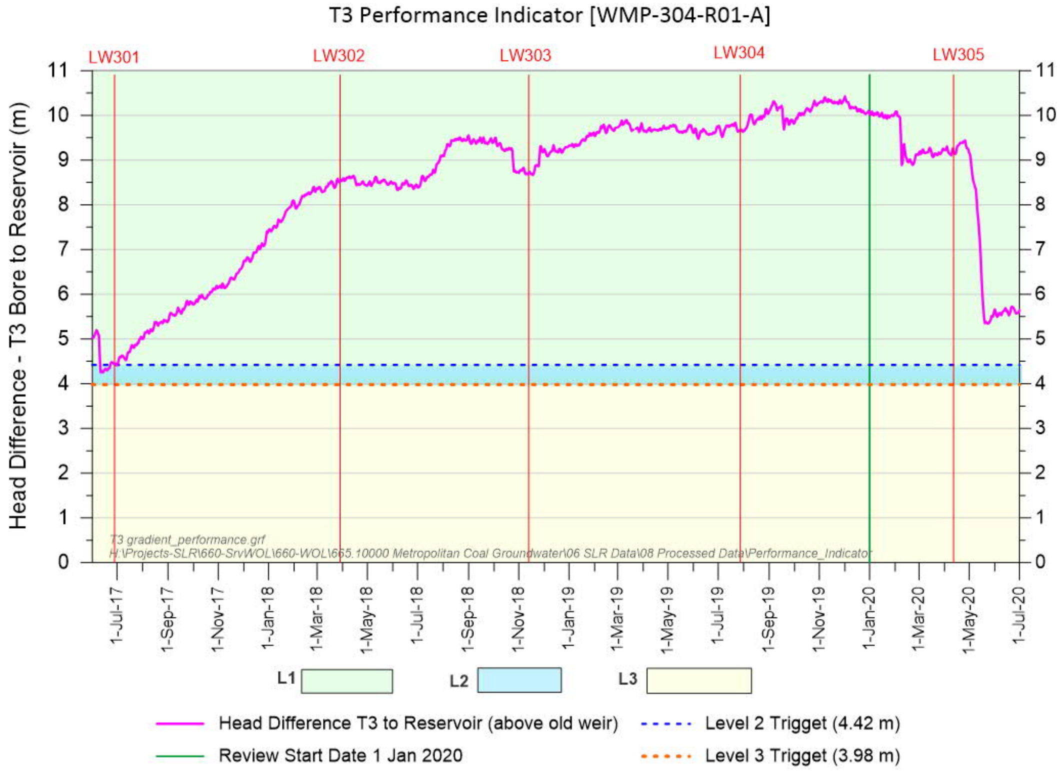


Figure 89 Hydraulic Gradient measured from bore T3 to WRL

The hydraulic gradient from transect bore T5 to transect bore T3 over the reporting period is presented on Figure 90 and is compared to the relevant trigger level in the Trigger Action Response Plan for no connective cracking between the surface and the mine and negligible leakage from Woronora Reservoir.

The hydraulic gradient displayed on Figure 90 shows that the gradient indicator started at Level 2 trigger (blue area) at the start of the reporting period. Coupled with compressive effects, the big rain event in February 2020 contributed to an increase in the gradient into the Level 1 area (green), where it remained for the end of the reporting period, with some variation. The gradient subsequently decreased, and rose back again in late April 2020. This performance indicator is at the Level 1 trigger level at the end of the reporting period. As stated in Section 4.1.4, both bores T5 and T3 require close monitoring, due to the unusual observations, which could have an impact on the gradient in the future.

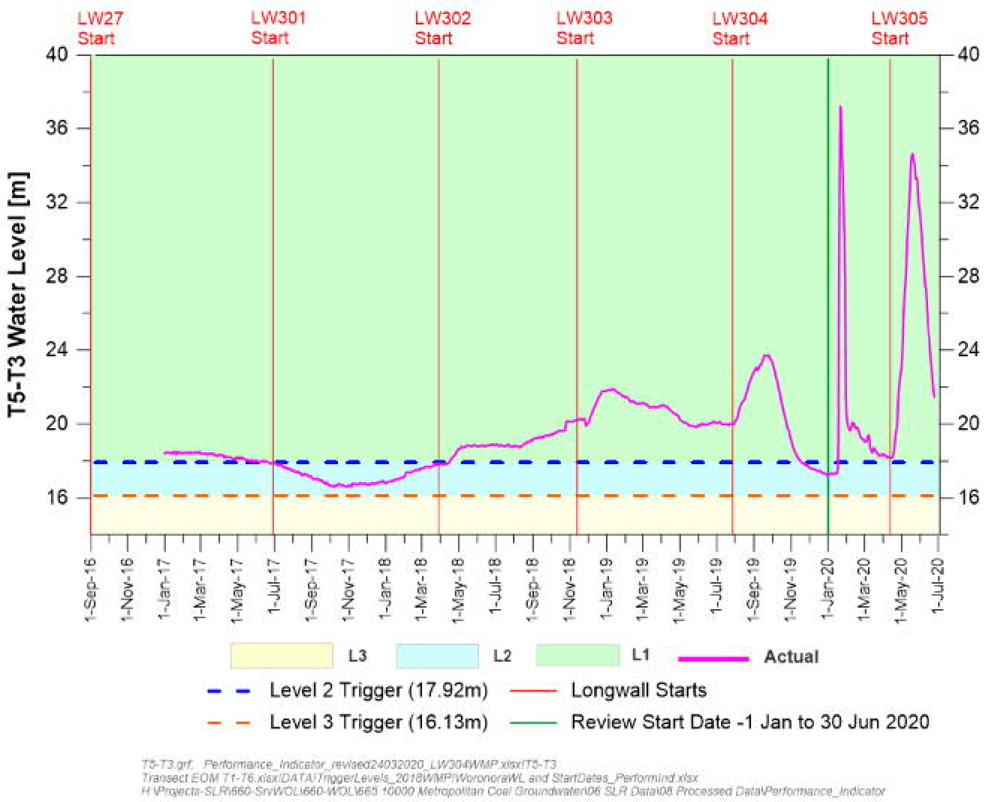


Figure 90 Hydraulic Gradient measured from bore T5 to bore T3

5.5 Summary of performance assessment

The subsidence impact performance indicators and performance measures in Table 11 were developed to address the predictions of subsidence impacts and environmental consequences on groundwater included in the Project EA and Metropolitan Coal Extraction Plans. Assessments against the subsidence impact performance indicators and performance measures have been conducted for the reporting period (1 January to 30 June 2020).

Table 11 highlights the Level of each requirement and lists the actions arising from the respective level that the WMP/BMP prescribe.

Table 11 Summary of Groundwater Environmental Performance Assessment

Performance Measure	Performance Indicator	Monitoring Site(s) being Assessed	Parameters	Highest Significance Level/Trigger Recorded in the Reporting Period		Comment	Subsidence Impact Performance Indicator Exceeded?	Subsidence Impact Performance Measure Exceeded?
Negligible impact on Threatened Species, Populations, or Ecological Communities	Surface cracking within upland swamps resulting from mine subsidence is not expected to result in measurable changes to swamp groundwater levels when compared to control swamps or seasonal variations in water levels experienced by upland swamps prior to mining[1]	Swamp 20 Swamp 28	Swamp substrate groundwater levels	N/A	N/A	Previously assessed as being impacted by mine subsidence	Yes	To be assessed annually by relevant specialists
		Swamp 25 Swamp 30 Swamp 35 Swamp 50		Level 2	Data analysis of swamp substrate water levels indicates: - the seven day moving average for Swamps 25 and 30 is below the 5th percentile established for the swamp's full length of record; - the seven day moving average for Swamp 35 lie outside two standard deviations below the mean established for the swamp's full length of record; - The seven-day moving average for Swamp 50 is below the baseline minimum, and - semi-quantitative comparisons with control swamps and rainfall record indicates that dry swamp conditions are natural.	Quarterly data analysis required	No	No

Performance Measure	Performance Indicator	Monitoring Site(s) being Assessed	Parameters	Highest Significance Level/Trigger Recorded in the Reporting Period		Comment	Subsidence Impact Performance Indicator Exceeded?	Subsidence Impact Performance Measure Exceeded?
Negligible impact on Threatened Species, Populations, or Ecological Communities (cont.)	Surface cracking within upland swamps resulting from mine subsidence is not expected to result in measurable changes to swamp groundwater levels when compared to control swamps or seasonal variations in water levels experienced by upland swamps prior to mining[1]	Swamp 33 Swamp 40 Swamp 41 Swamp 46 Swamp 51 Swamp 52 Swamp 53 Swamp 71a Swamp 72	Swamp substrate groundwater levels	Level 1		Continue Monitoring Six-monthly reporting	No	No

[1] This performance indicator has been exceeded at Swamp 20 since 2012 and at Swamp 28 since 2016. Swamp water levels at Swamp 20 and Swamp 28 will continue to be analysed on a six-monthly basis and assessments against the performance measure will be conducted annually.

Table 11 Summary of Groundwater Environmental Performance Assessment (Continued)

Performance Measure	Performance Indicator	Monitoring Site(s) being Assessed	Parameters	Highest Significance Level/Trigger Recorded in the Reporting Period		Comment	Subsidence Impact Performance Indicator Exceeded?	Subsidence Impact Performance Measure Exceeded?
No connective cracking between the surface and the mine	Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore 9GGW2B does not occur.	Bore 9GGW2B	Groundwater pressures/ levels	Level 2		Quarterly data analysis required	No	No
	Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore F6GW3A does not occur.	Bore F6GW3A	Groundwater pressures/ levels	Level 2		Quarterly data analysis required	No	No
No connective cracking between the surface and the mine. Negligible leakage from the Woronora Reservoir.	The hydraulic gradient to the Woronora Reservoir at full supply level from Bore PHGW2A is reduced by no more than 40% from that measured to 30 June 2017.	Bore PHGW2A (97.5 m)	Groundwater pressures/ levels	Level 1	PHGW2A >= 186.92 m AHD	Continue monitoring Six-monthly reporting	No	No
	The groundwater head of Bore F6GW4A is greater than 10 m above the Woronora Reservoir full supply level	Bore F6GW4A (90.0 m)	Groundwater pressures/ levels	Level 2	F6GW4A4 < 199.92 m AHD and > 178.90 m AHD	Monthly data analysis required Six-monthly reporting	No	No
Negligible leakage from the Woronora Reservoir.	The hydraulic gradient to the Woronora Reservoir at full supply level from Bore 9GGW2B is reduced by no more than 40% from that measured to 30 June 2017.	Bore 9GGW2B (80.3 m)	Groundwater pressures/ levels	Level 1	9GGW2B >= 181.38 m AHD	Continue monitoring Six-monthly reporting	No	No

Performance Measure	Performance Indicator	Monitoring Site(s) being Assessed	Parameters	Highest Significance Level/Trigger Recorded in the Reporting Period		Comment	Subsidence Impact Performance Indicator Exceeded?	Subsidence Impact Performance Measure Exceeded?
	The hydraulic gradient to the Woronora Reservoir at full supply level from Bore 9EGW2A is reduced by no more than 40% from that measured to 30 June 2017.	Bore 9EGW2A (107.5 m)	Groundwater pressures/ levels	Level 2	9EGW2A < 186.32 m AHD and > 179.35 m AHD	Monthly data analysis required Six-monthly reporting	No	No
Negligible leakage from the Woronora Reservoir (cont.)	The hydraulic gradient to the Woronora Reservoir at full supply level from Bore PM02 is reduced by no more than 40% from that measured to 30 June 2017.	Bore PM02 (100 m)	Groundwater pressures/ levels	Level 1	PM02 >= 183.86 m AHD	Continue monitoring Six-monthly reporting	No	No
	The hydraulic gradient to the Woronora Reservoir from transect bore T2 is reduced by no more than 10% from that measured on 30 June 2017.	T2	Groundwater levels	Level 1	T2-WRL >= 2.65 m	Continue monitoring Six-monthly reporting	No	No
	The hydraulic gradient to the Woronora Reservoir from transect bore T3 is reduced by no more than 10% from that measured on 30 June 2017	T3	Groundwater levels	Level 1	T3-WRL >= 4.42 m	Continue monitoring Six-monthly reporting	No	No
	The hydraulic gradient from transect bore T5 to bore T3 is reduced by no more than 10% from that measured on 30 June 2017	Bores T3 and T5	Groundwater levels	Level 1	T5-T3 >= 17.92 m Note: the six-months reporting period started out with Level 2, however, since mid-January, Level 1 has been achieved consistently.	Continue monitoring	No	No

6 References

HydroSimulations, 2018. A quantitative methodology for assessing changes in swamp hydrology, Letter report, dated 15/03/2018.

Golders, 2020. LW305-309 Upland Swamp Piezometer, Bore installation reports

Peabody, 2019a. Metropolitan Coal Longwalls 304 Water Management, April 2019

Peabody, 2019b. Metropolitan Coal Longwalls 304 Biodiversity Management, April 2019

Peabody, 2020a. Metropolitan Coal Longwalls 305-307 Water Management, ME-TSE-MNP-0078, 16 March 2020

Peabody, 2020b. Metropolitan Coal Longwalls 305-307 Extraction Plan, EP-R01-B, 30 January 2020

Peabody, 2020c. Metropolitan Coal Longwalls 305-307 Biodiversity Management, ME-TSE-MNP-0080, 16 March 2020

APPENDIX A

SWAMP semi-quantitative analysis

A-1 Summary of methodology

The methodology was described in a letter (HydroSimulations, 2018) in detail. This section gives a brief summary of how the Recession/Recovery semi-quantitative methodology works and how it interpreted.

Initially, a pre-processing step is performed on all data. Firstly, short-term fluctuations in the data, "noise", are suppressed by finding the seven-day average water level from the range of daily data. This allows for changes and trends in the data to become clearer.

These seven-day average water levels are used to calculate a normalised weekly average of water level above the base of the piezometer (water level minimum), in turn providing an indication of the relative saturated thickness. Normalised values are calculated to be within a range of 0 and 1. The equation used to normalise the data is as follows:

$$n = \frac{\mathrm{WL} - \mathrm{WL}_{\mathrm{min}}}{\mathrm{WL}_{\mathrm{max}} - \mathrm{WL}_{\mathrm{min}}}$$

where: n is the normalised output (dimensionless), WL is any seven-day average water level from the data (m), and WL_{min} and WL_{max} are the minimum and maximum water levels for the specified data range (m), respectively. Normalising the data in this way allows data from different swamps to be meaningfully comparable while also accounting for occasional changes in piezometer elevation.

The recession-recovery method compares the change in gradient of rising and receding swamp water levels over time. It is plotted as a cumulative frequency distribution to highlight the gradient trends for a given period. Gradients of water level change are calculated using the normalised water levels, as calculated above. This involves finding the difference between normalised water levels (n_a and n_b) over a time period as per the equation:

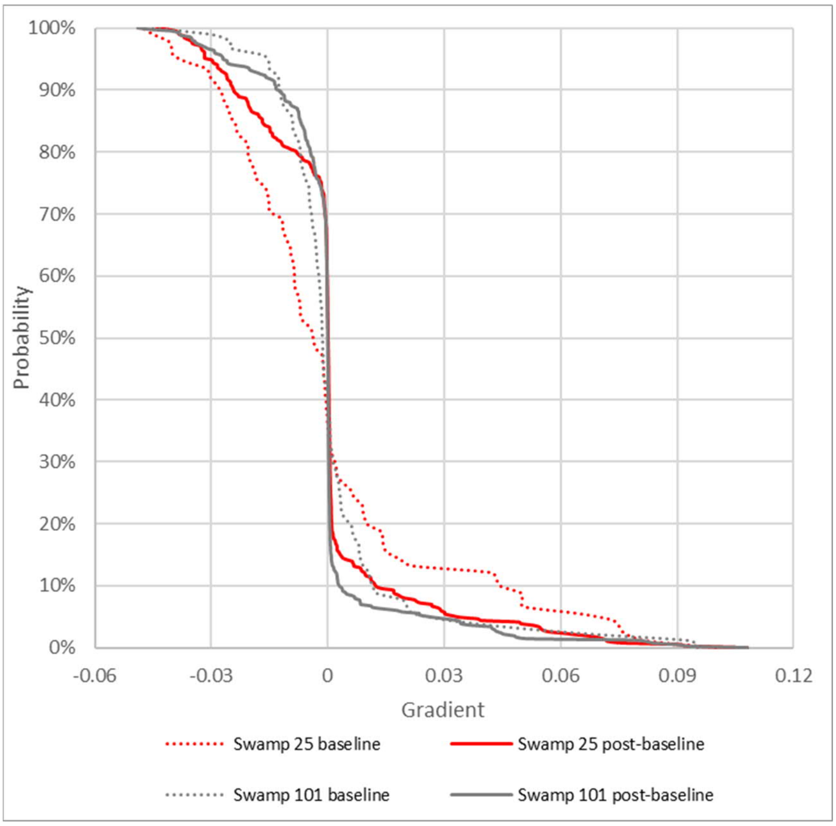
$$Gradient = \frac{n_b - n_a}{\Delta t}$$

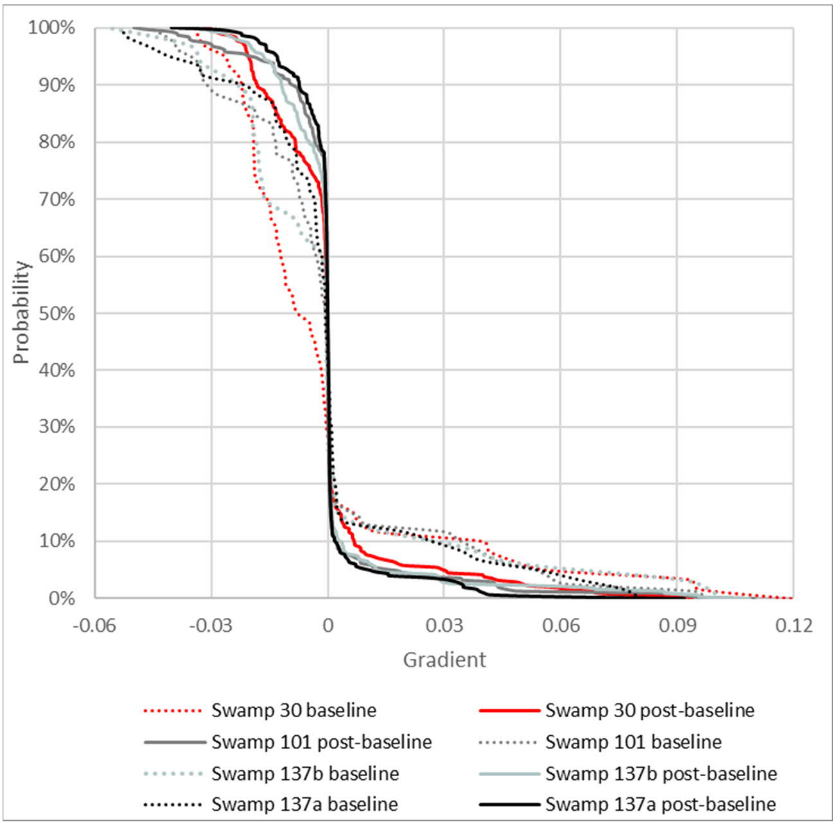
The time period (t) is usually seven days, if the data set is complete. For data gaps, the time period would be adjusted accordingly. The unit of the gradient is 1/day (note: this is a correction from HydroSimulations, 2018).

From these gradients, recession events are isolated by separating all those values less than zero. The method also provides information on rates of recovery during wet periods, using only positive gradient values. Both gradients of recovery and gradients of recession are then plotted on a cumulative frequency distribution (CFD) plot. There are a number of ways the CFD plot can be interpreted, as it is dependent on the change relative to the control swamp and baseline period. It is assumed that both the control swamp and monitored swamp would have experienced the same regional climate and therefore would show similar trends in response to increased or decreased water levels as a result of changes in precipitation. There are three scenarios:

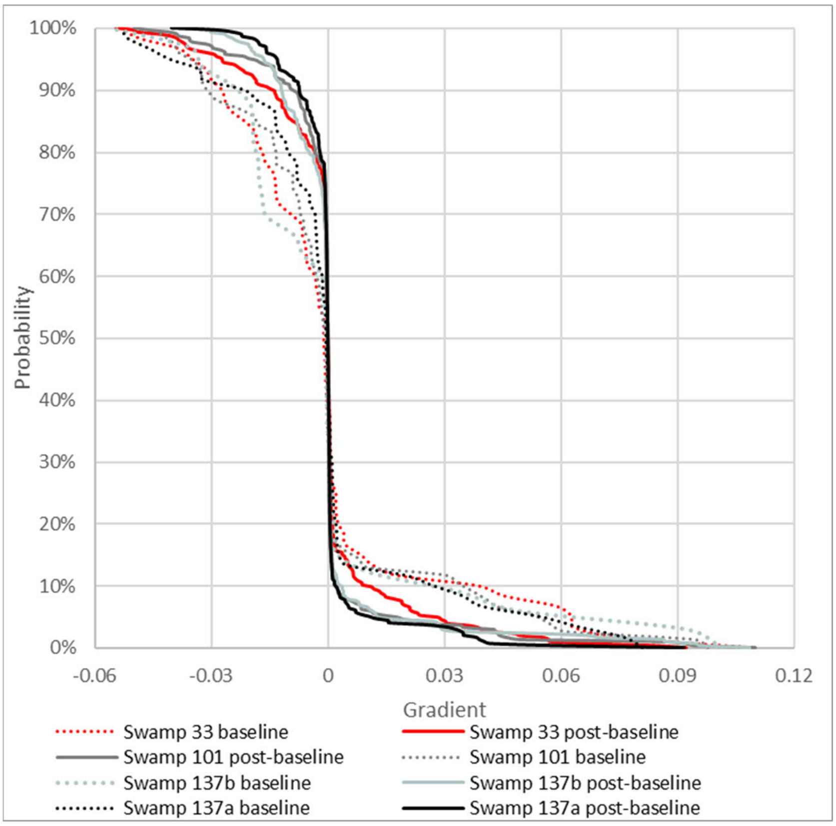
1. If the CFD curves for both baseline and post-baseline periods at the control and monitored swamps are similar, it can be assumed that changes in gradient are predominantly a result of climatic changes.
2. Post-baseline conditions that reflect more intense changes in water level: Compared to the gradient distributions in the baseline, the post-baseline is characterised by steeper rises and falls of water level with decreased stability as evidenced by the reduction in gradients around or at zero. Such a regime may be attributed to increased connectivity beneath the swamp substrate which has allowed enhanced drainage following a precipitation event.
3. The post-baseline gradient distribution has changed from one with high rates of water level fluctuation to one where relatively little change is occurring. A higher proportion of gradients at or near zero characterises the distribution of gradients in the post-baseline. In this case, the swamp substrate is less responsive to drying or wetting events post-baseline.

A-2 Results

SWAMP 25	Assessment
	Note that for Swamp 25, only one control swamp (101) is available, as the other two control swamps (137a and 137b) started recording after the Swamp 26 baseline period. Swamp 25 (and to a lesser degree Swamp 101) show the behaviour that can be attributed to less change (higher proportion of zero gradients post baseline). Swamp 25 not impacted.

SWAMP 30	Assessment
	Swamp 30 and to the control swamps show the behaviour that can be attributed to less change (higher proportion of zero gradients post baseline). Swamp 30 not impacted.

SWAMP 33

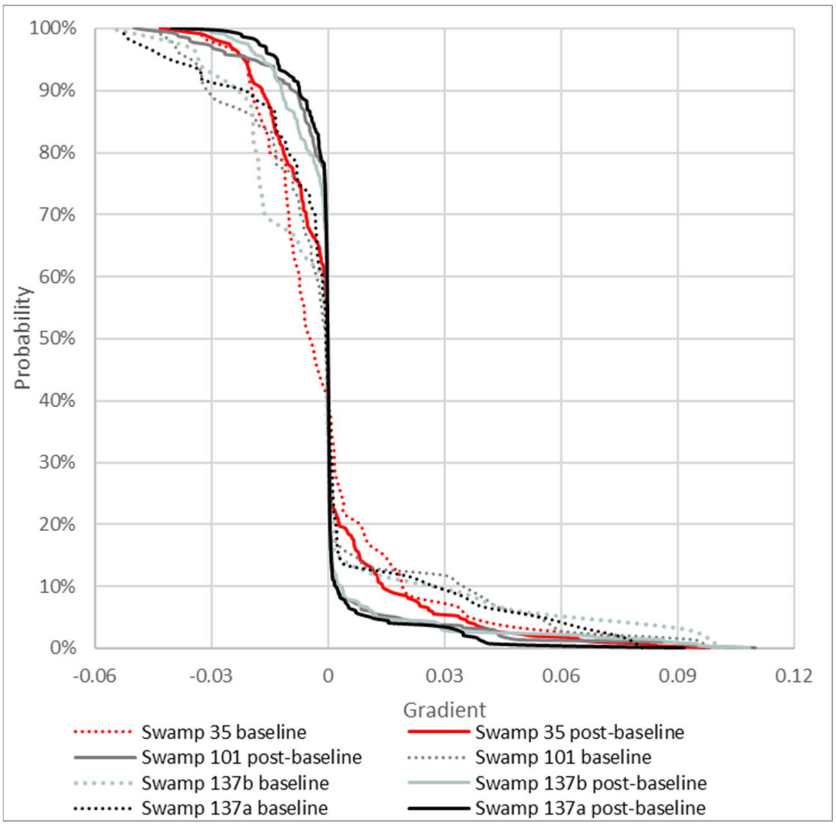


Assessment

Swamp 33 and the control swamps show the behaviour that can be attributed to less change (higher proportion of zero gradients post baseline).

Swamp 33 not impacted.

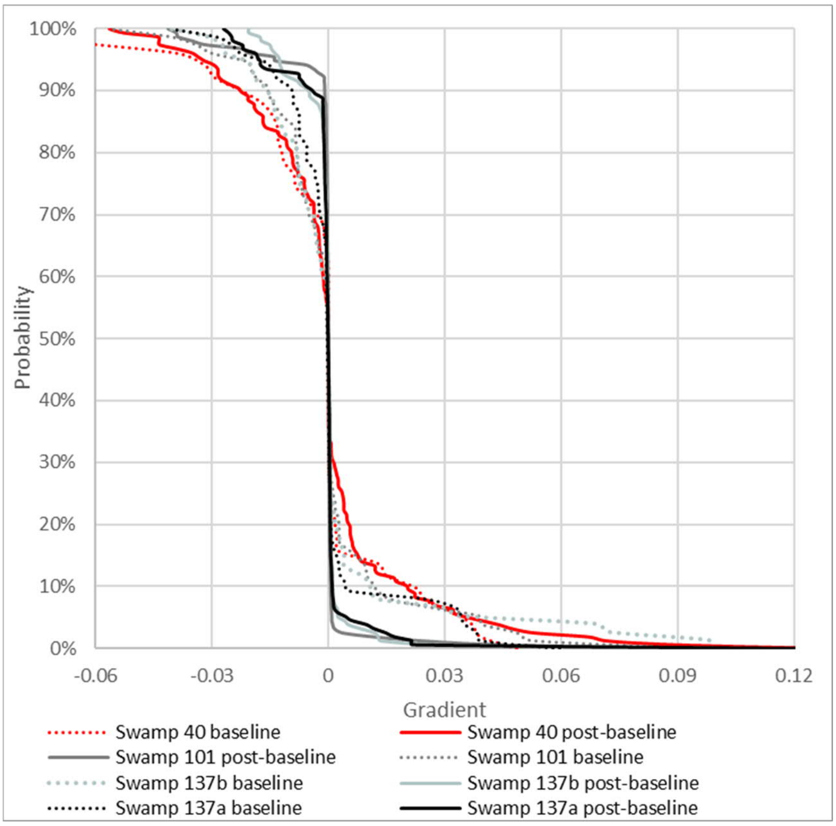
SWAMP 35

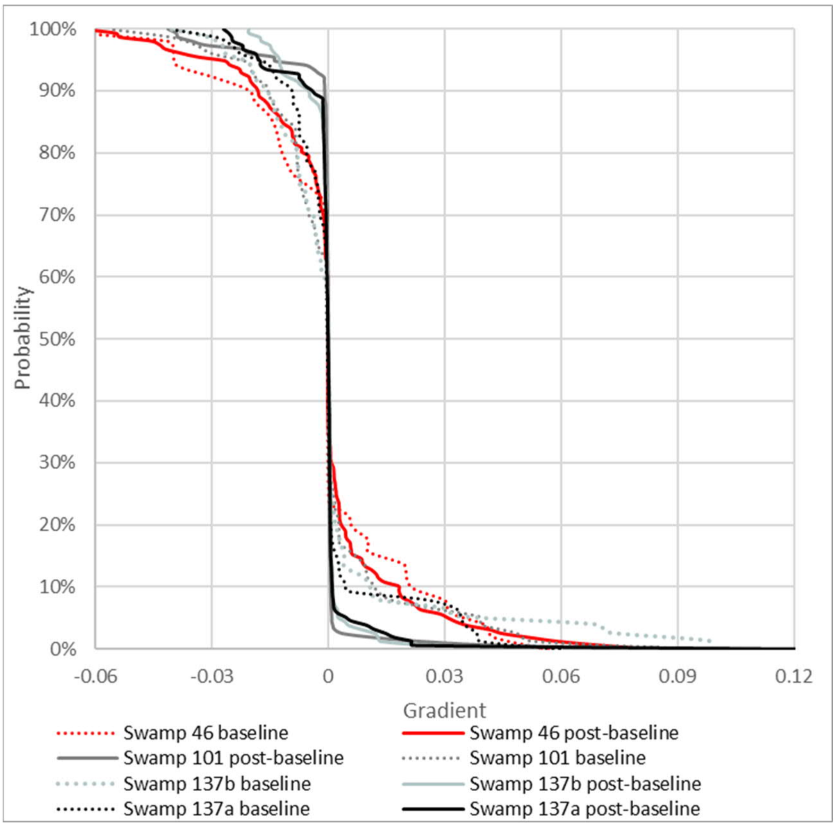


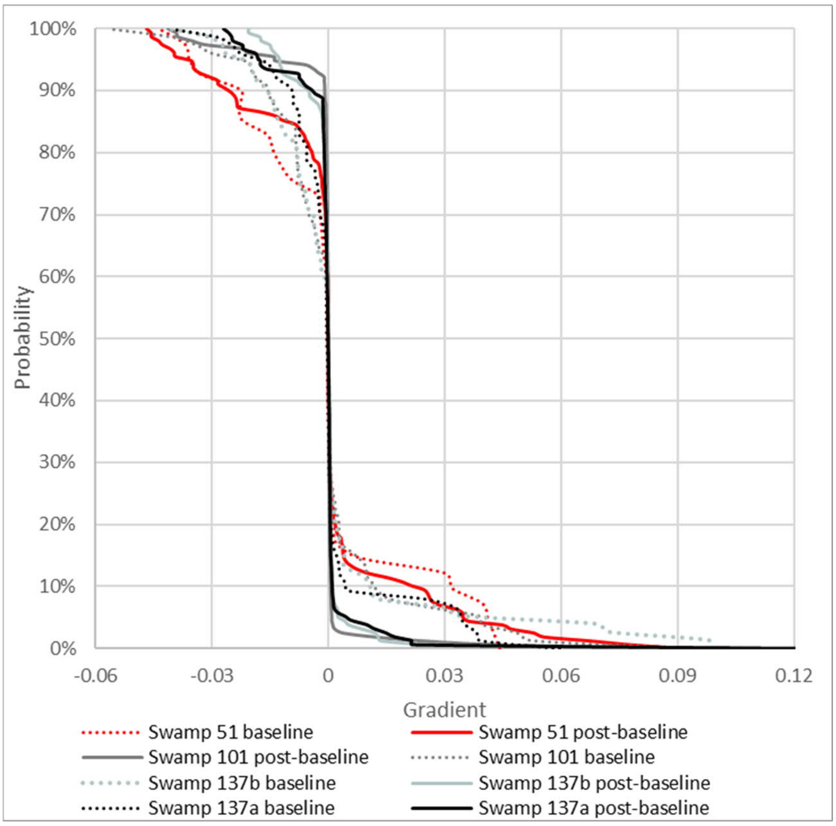
Assessment

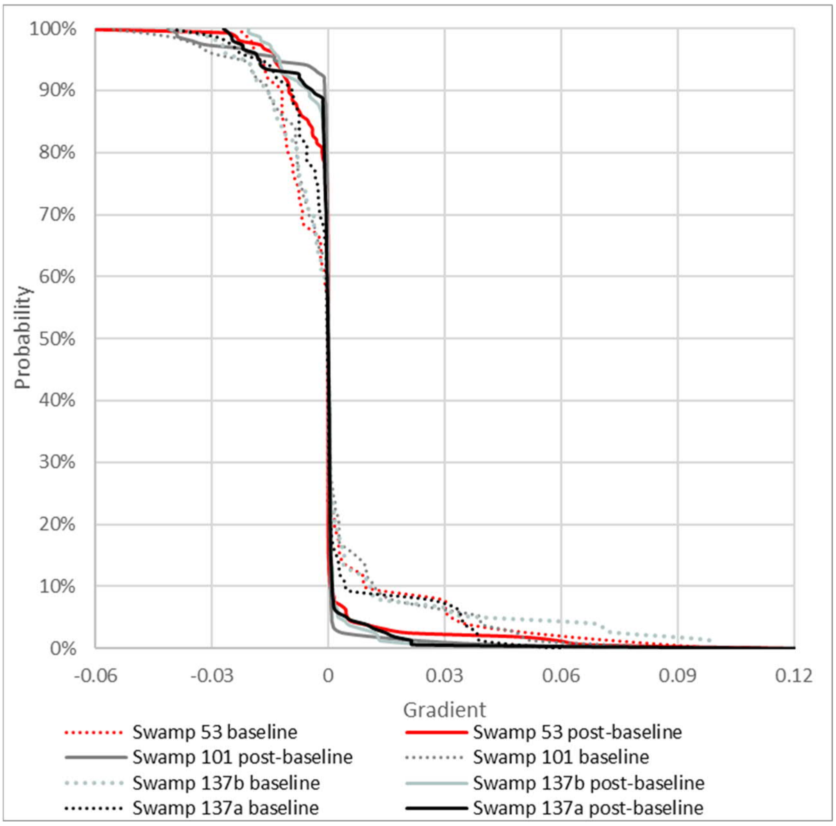
The baseline and post-baseline curves for Swamp 35 are plotting very close to each other, indicating little change between baseline and post-baseline. The control swamps show the behaviour that can be attributed to less change (higher proportion of zero gradients post baseline).

Swamp 35 not impacted.

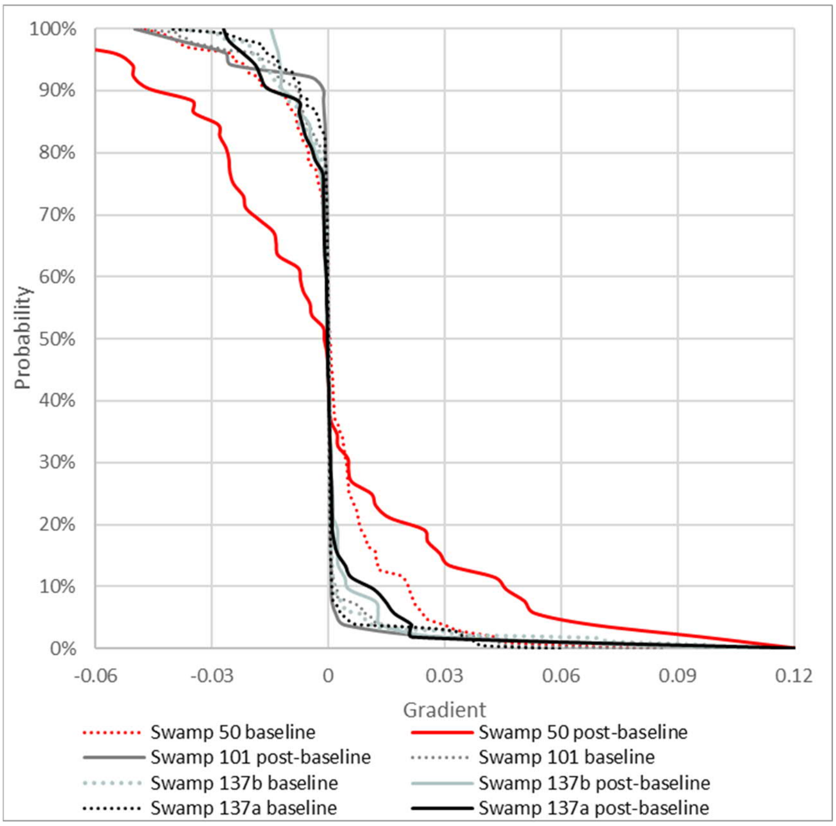
SWAMP 40	Assessment
	The baseline and post-baseline curves for Swamp 40 are plotting very close to each other, indicating little change between baseline and post-baseline. The control swamps show the behaviour that can be attributed to less change (higher proportion of zero gradients post baseline). Swamp 40 not impacted.

SWAMP 46	Assessment
	The baseline and post-baseline curves for Swamp 46 are plotting very close to each other, indicating little change between baseline and post-baseline. The control swamps show the behaviour that can be attributed to less change (higher proportion of zero gradients post baseline). Swamp 46 not impacted

<table>
<tr><th>SWAMP 51</th><th>Assessment</th></tr>
<tr><td>
</td><td>Swamp 51 and the control swamps show the behaviour that can be attributed to less change (higher proportion of zero gradients post baseline).
Swamp 51 not impacted.</td></tr>
</table>

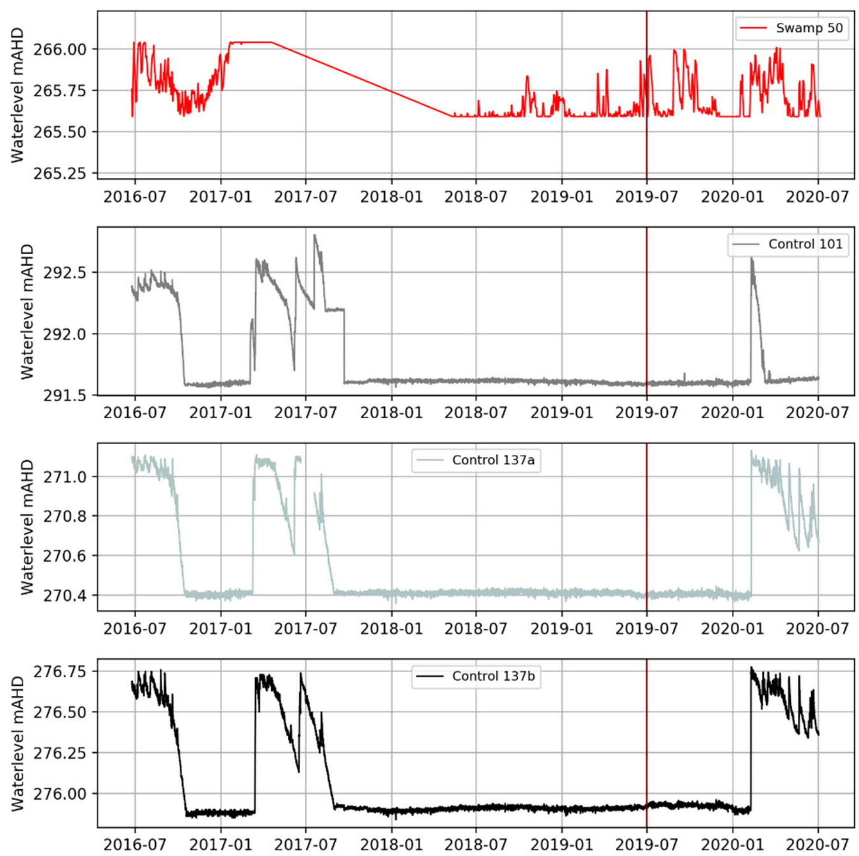
<table>
<tr><th>SWAMP 51</th><th>Assessment</th></tr>
<tr><td>
</td><td>Swamp 53 and the control swamps show the behaviour that can be attributed to less change (higher proportion of zero gradients post baseline).
Swamp 53 not impacted.</td></tr>
</table>

SWAMP 50



The control swamps show the behaviour that can be attributed to less change (higher proportion of zero gradients post baseline).

Swamp 50 shows the behaviour that is attributed to the higher changes and potential impact.

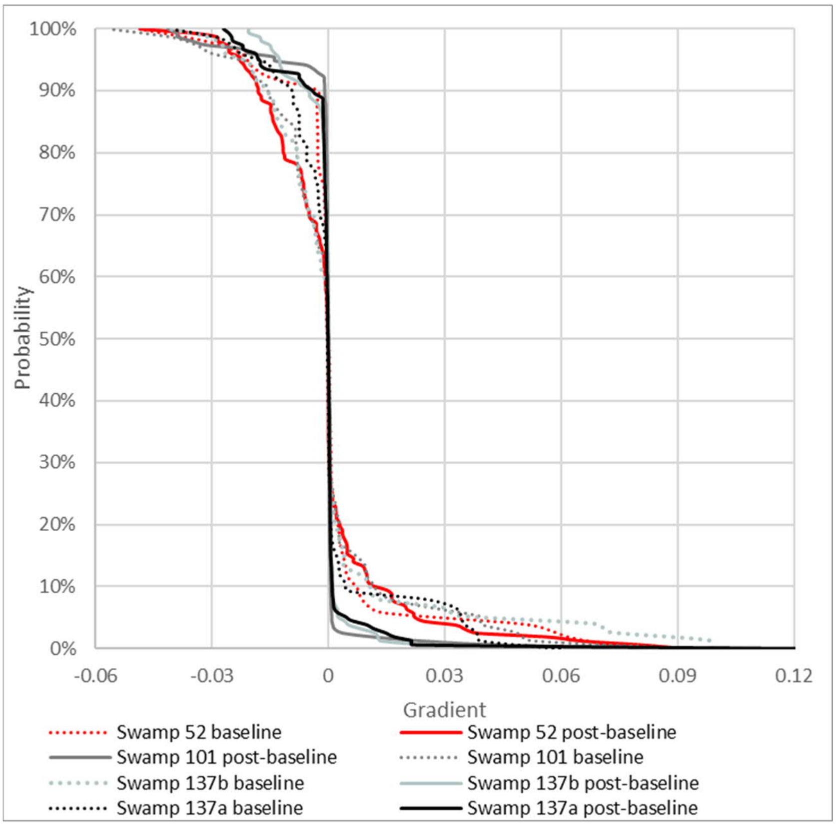


However, the hydrogrpahs for Swamp 50 and the control swamps show that the methodology might not be applicable for this swamp, as Swamp 50 had a large data gap between January 2017 and May 2018, which coincided with a wet period, and subsequently this recession/recovery data was lost for the analysis.

Furtherr, the hydrogrpahs show that Swamp 50 responded to rainfall in 2018 and 2019, where the control swamps remained dry.

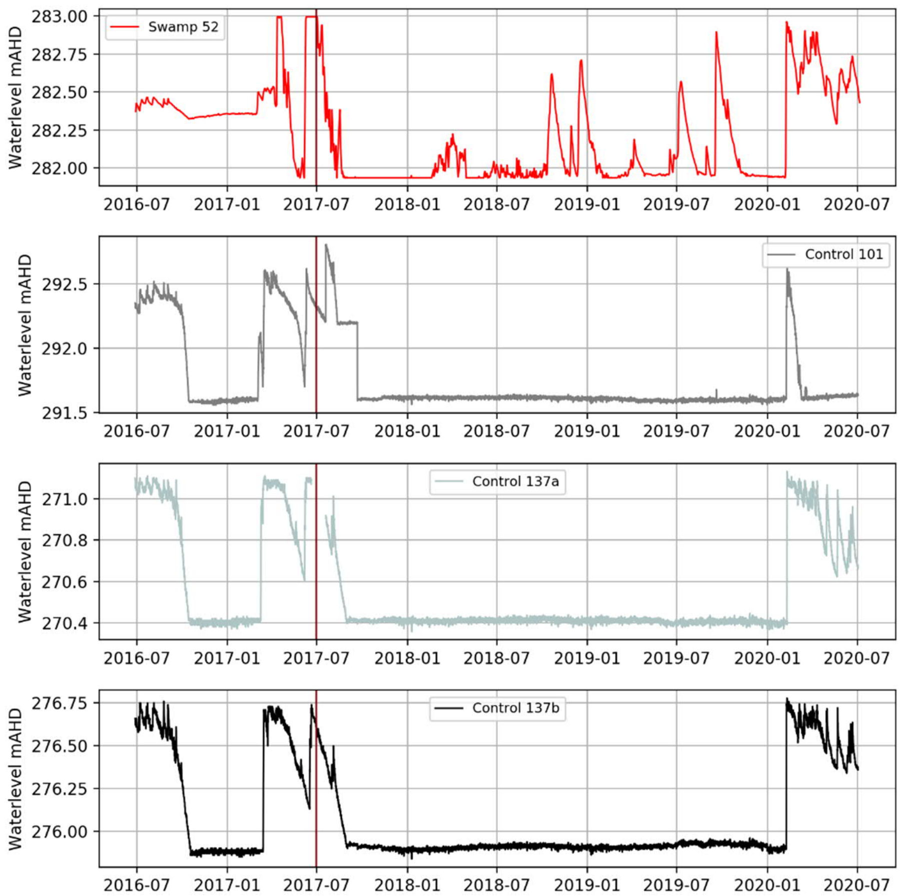
Swamp 50 not impacted.

SWAMP 52



The control swamps show the behaviour that can be attributed to less change (higher proportion of zero gradients post baseline).

Swamp 52 shows the behaviour that is attributed to the higher changes and potential impact.



However, the hydrogrpahs for Swamp 52 and the control swamps show that the methodology might not be appliccable for this swamp, as Swamp 52 shows responses to rainfall in 2018 and 2019, where the control swamps remained dry.

Swamp 52 not impacted.

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