South32 - Illawarra Metallurgical Coal

DENDROBIUM MINE

End of Panel Surface Water and Shallow Groundwater Assessment: Longwall 21 (Area 3C)

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Cover photo: Cordeaux River tributary location CR29_S1, looking upstream on 27/10/2016

QUALITY CONTROL

Process	Staff	Signature	Date
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Summary

This report summarises the observed, measured and estimated effects on hydrological features resulting from the extraction of Dendrobium Longwall 21. Longwall 21 is the first panel to be extracted from Dendrobium Area 3C. Extraction of Longwall 21 commenced on 25/4/2023 and was completed on 6/8/2023. Longwall 21 has a total length of 863 m and a width of 305 m including first workings with a maximum cutting height of 3.9 m. The depth of cover ranges between 284 m and 384 m. Rainfall during Longwall 21 extraction was well below average (29% of the average for the period). As a result, soil moisture storage has declined rapidly to 30th percentile levels in September 2023.

The Illawarra Metallurgical Coal Environmental Field Team (IMCEFT) conducts monitoring and inspections on landscape features including watercourses and swamps within Dendrobium Area 3C. This monitoring is conducted in accordance with the Dendrobium Area 3C Subsidence Management Plan (SMP) and monitoring and contingency plans contained therein. Trigger Action Response Plans (TARPs) contained in the SMP form the basis of the impact assessments in this report.

A total of 36 new ground surface impacts attributed to the extraction of Longwall 21 were recorded, of which 7 were associated with watercourses or swamps. Fracturing was noted in watercourse WC20 which flows directly over the Longwall 21 footprint. New or reactivated occurrences of iron staining were noted in or near Wongawilli Creek and in tributaries WC20 and WC24.

Surface water quality

Most watercourses, including upstream control sites show an increase in EC during 2023 corresponding with a return to dry conditions following three years of above average rainfall conditions during while stream salinity was lower. Most watercourses also show a decline in DO during 2023 which, again, is related to low flow conditions during which disconnected pools are more common.

No water quality TARPs were triggered in the review period. Anomalous water quality effects are noted in streams that have been directly mined under by previous longwalls (e.g. WC21, SC10C, LA4, Donalds Castle Creek). Those effects include transient or persistent increases in EC, increases (or decreases) in pH and increases in dissolved metal concentrations such as Fe, Mn, Al and Zn. Dissolved iron concentrations in SC10 have declined during 2023, resulting in a decrease in the extent of iron staining on the watercourse. Analysis of flow-corrected trends in water quality indicate that EC and dissolved sulfate, Fe, Mn and Zn are slightly elevated relative to baseline conditions at downstream monitoring sites DCC_FR6 and SCK_Rockbar 5. EC and dissolved sulfate and manganese are elevated compared with baseline at WC_FR6.

In September 2023, DPE received a complaint regarding iron staining in Wongawilli Creek and requested further information in relation to the occurrence. The complaint related to observations of suspended iron oxides along a similar stretch of the watercourse as was previously reported in 2021. Subsequent investigation indicates that the recurrence of suspended iron in Wongawilli Creek is related to fluctuating and increasing concentrations of iron at WC_Pool 50 associated with discharge from an adjacent iron-rich spring. A recent report into the occurrence recommended that IMC commission an independent assessment of the ecotoxic effects on aquatic flora and fauna due to elevated dissolved iron concentrations and associated iron precipitates.

A gas release was observed in Wongawilli Creek at WC_Pool 50 on 18/1/2023. The release is intermittent to continuous and emanates from the base of a sandstone step on the western side of the pool with smaller gas bubbles from the centre of the pool. An inspection carried out in September

2023 reported one light and intermittent gas release from the base of the same sandstone step. The gas emission at Pool 50 is very minor and is considered to have negligible environmental consequences.

Stream flow

There has been a delay in the provision of data for the key Reference Site (WaterNSW gauge 213200) that is used in TARP Assessments A, B and C. As such, these assessments have not been completed. Assessment D has been carried out. This has not been triggered during the Longwall 21 period.

Pool levels

Pools along Wongawilli Creek were observed to be full and flowing during the review period; no pools along Wongawilli Creek that are normally full have become dry as a result of mining. Longwall 21 did not pass directly under any Lake Cordeaux tributaries and most pools are beyond the area of mining influence. However, a number of monitored pools located on mid-to upper tributary reaches recorded no-flow or were dry during August and September 2023. Given their distance from the longwall the decline in pool levels are assumed to be related to dry conditions in 2023, contrasting with the wet conditions during the baseline for most of the pool monitoring sites. Longwall 21 passed within 400 m of Wongawilli Creek tributary WC24 and directly beneath WC20. There is no observed change in the outflow status of monitored pools on WC24 following the extraction of Longwall 21. The pool at WC20_Rockbar17 became dry following passage of Longwall 21 beneath the watercourse. Surface cracking and flow diversion are expected in watercourses that are directly mined under (MSEC, 2019).

Pools along watercourse SC10 which overlaps with the area of mining influence for the previous Longwall 19 were reassessed in this report. All monitored pools have remained full and flowing since 2020; there were no observed changes to pool outflow statis since the end of Longwall 19. A data logger in SC10_Pool 26a showed anomalous fluctuations during 2023; however, inspection of the site has found no evidence for subsidence impacts at the pool or elsewhere on the watercourse.

Swamp hydrology

All reference swamp sites recorded a decline in shallow groundwater levels and soil moisture during 2023 in response to during conditions. Performance measures for Area 3C relate to four swamps that lie outside the areas that will be directly mined beneath by Longwalls 21 to 23: Swamps 09, 144, 145 and 154. There were no observations of increases in erosion, nor changes in the structural integrity of rock bars or pools following the start of Longwall 21.

Shallow groundwater levels declined at all swamps within Area 3C during 2023 to levels below baseline. Recession rates remained consistent with those observed during the baseline. The decline in groundwater levels triggered Level 3 TARPs for all performance measure swamp sites in Area 3C. Based on the distance from the longwall and comparison with reference sites, the triggers are unlikely to be related to mining and instead reflect the wetter conditions during the baseline period for most of the swamp monitoring sites.

Average soil moisture levels declined to below baseline levels at piezometers at all soil moisture sites within the mining area of influence (Swamps 9, 144, 145), triggering Level 3 TARPs for all Area 3C sites. The declines in soil moisture reflect boarder declines across the region in response to drying conditions in 2023. As for groundwater levels, the TARP triggers are the result of dry conditions in 2023, contrasting with the wet conditions during the baseline period. Potential mining effects at Swamp 144 should be reassessed as more data become available.

1. Introduction

Illawarra Metallurgical Coal (IMC) operates the Dendrobium underground coal mine, located approximately 12 km west of Wollongong (NSW) in the Southern Coalfield. IMC is required under the conditions of mining approval to submit regular reviews of the local hydrological data, including water quantity and quality, for watercourses and water bodies above and adjacent to Dendrobium Mine.

Surface water monitoring has been undertaken by IMC since 2003. Field parameter measurements and sampling for more detailed laboratory chemical analyses were collected by the IMC Environmental Field Team (IMCEFT). Field observation sites include hydrographic gauging stations, shallow groundwater piezometers, soil moisture sensors and surface water sampling sites.

This End of Panel (EoP) assessment primarily focuses on hydrographic and water quality data for watercourses and sub catchments within the zone of mining influence of Longwall 21 in Area 3C; however, the report also provides an overview of temporal and spatial trends and cumulative effects associated with Longwall 19 and other mining areas. Data is assessed against baseline and impact criteria defined in the Trigger Action Response Plan (TARP) which forms part of the Subsidence Management Plan for Area 3C and the Swamp and Watercourse management plans contained therein.

1.1 Reporting Objectives

This EoP surface water assessment report has been prepared to form part of IMC's EoP Review which satisfies Condition 3-9 of the Approval for Dendrobium Mine (DA 60-03-2001). The EoP Review:

- reports all subsidence effects (both individual and cumulative) for the longwall panel and compares subsidence effects with predictions;
- describes in detail all subsidence impacts (both individual and cumulative) for the panel;
- discusses the environmental consequences for watercourses, swamps, water yield, water quality, aquatic ecology, terrestrial ecology, groundwater, cliffs and steep slopes; and
- compares subsidence impacts and environmental consequences with predictions.

This report provides the following assessment for the EoP Review:

- Impacts to water flow, water levels and water quality in watercourses.
- Impacts to shallow groundwater levels and soil moisture levels in mapped Coastal Upland Swamps within the mining area of influence, compared with reference swamps.

1.2 Longwall 21

Longwall mining at Dendrobium has been carried out in three designated areas: Area 1 (east of Lake Cordeaux), Area 2 (west of Lake Cordeaux), and Area 3 (between Lake Cordeaux and Lake Avon) which is divided into sub areas 3A, 3B and 3C. Mining in Area 3B was completed in May 2022, after which mining resumed in Area 3A with Longwall 19. Extraction of Longwall 21 in Area 3C commenced on 25/4/2023 and was completed on 6/8/2023. Longwall 21 has a total length of 863 m and a width of 305 m including first workings with a maximum cutting height of 3.9 m. The depth of cover ranges between 284 m and 384 m.

1.3 Feedback from agencies on previous assessment

WaterNSW and BCD provided feedback to DPIE in relation to Surface Water components of the Longwall 19 End of Panel Reporting (Letters dated 8/9/2023 [WaterNSW] and 15/9/2023 [BSD]). IMC provided a response to DPE in in November 2023. Agreed changes to reporting will be reflected in the next EOP report.

2. Surface water and groundwater management

This section outlines the network of monitoring infrastructure and sites operated by IMC at and around the Dendrobium Mine. Further details of monitoring sites and procedures are outlined in the Dendrobium Area 3C Watercourse Impact Monitoring Management and Contingency Plan .(South32, 2020a)

2.1 Surface Water Monitoring

Monitoring includes a selection of sites downstream and within the mining area, as well as sites located away from the mining area to provide control sites and act as a comparison to impact sites. Pools within streams are monitored monthly before and following mining and weekly (when site access available) during active subsidence, and in response to any observed impacts. Surface water monitoring sites fall into four categories:

- **Flow gauge sites** at which stream flow is monitored at a calibrated gauge or weir.
- **Water chemistry sites** at which samples are collected for laboratory analysis (DOC, Na, K, Ca, Mg, Filt. SO_4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si), in addition to water observations, field parameters.
- **Water field parameter sites** at which water quality field parameters are measured (pH, Electrical Conductivity (EC), temperature, Dissolved Oxygen (DO), Oxygen Reduction Potential (ORP), in addition to water observations.
- **Water observation sites** at which pool water levels and flow status are noted and photographs taken upstream and downstream.

At a subset of sites, data loggers are installed in pools to allow monitoring of pool water level and temperature at hourly intervals. The monitoring of water quality parameters provides a means of detecting and assessing the effects of streambed fracturing or induction of ferruginous springs.

Figure 1 shows the location of surface water monitoring and sampling sites in relation to the extracted and planned longwall panels. Figure 2 shows the locations of hydrographic gauging stations which extend beyond the mining lease. A full list of all stream gauge installations is included in Appendix B.

2.1.1 Stream flow monitoring

Changes and improvements to the stream flow monitoring network are summarised in Table 1. No new gauging stations were installed during the review period.

Table 1. Changes to the stream flow monitoring network during the review period

Type of change / improvement	Description of recent change	Reference / comment
New surface water gauging sites	None in Area 3A, and one in Area 3B. New sites approved, and some installed in A3C.	NDCS1 on Native Dog Creek was installed in late 2021, and is analysed here for the first time. Figure B1 (Appendix B) shows the network.
Upgrade of existing sites	None during recent EOP period	It was originally proposed that site SC10S1 would be upgraded in early 2022. This commenced but was interrupted by long period of Catchment closure, and then not progressed further due to Longwall 19 commencing.

Gauge rating curves	More gaugings taken at most sites. Rating curves updated at most sites.	Details from ALS (consultants) can be requested via IMC. Methods to estimate uncertainty in surface water flow estimation has been developed by Enviromon (consultant), and is being rolled out to all sites. See Appendix C5 for sites assessed thus far, including 4 sites now analysed in Area 3C.
Pool monitoring sites	Installation of additional water level data loggers in key pools.	Additional water level loggers installed in pools in Wongawilli Ck (more relevant to Area 3C).
Revision of assessment methods	Surface flow TARPs (Assessments A-D) not change since agreement in early 2020. IAPUM requested that old method (comparison of rainfall-runoff modelling) be re-instated.	Section 0, WIMMCP (IMC, 2020a) and Watershed HydroGeo, 2019a. Section 2.1.3. Peer-review of methods planned for early 2022.
WWL vs WWL_A correlation	No change. Enviromon analysed the common period of WWL and WWL_A records in order to allow cessation of monitoring at WWL. Due to the shorter record at WWL_A and uncertainties at WWL it is recommended to continue to rely on data from WWL until the end of Area 3A (Longwall 19), and use WWL_A thereafter.	See separate document (Enviromon, 2021).

2.1.2 Surface water flow data update

IMC's contract hydrographers, ALS, provided the most recent flow data for assessment for sites in and around Areas 3A, 3B and 3C (details in Table C1 of Appendix C). This has been augmented by flow data from sites managed by WaterNSW, specifically one of the primary reference flow gauges (O'Hares Creek at Wedderburn) and for WaterNSW's Sandy Creek gauging station (GS 2122205). The WaterNSW Sandy Creek gauging station is co-located with IMC's SCL2 gauging site, but has a longer record and, based on comments from ALS, relies on higher accuracy monitoring equipment.

This data was then assessed based on the quality of records provided before some further processing was conducted. A discussion of this assessment is provided below. As is standard, data is available to agencies on request.

2.1.3 Re-rating of flow records

ALS updates the rating curves of flow monitoring sites as new manual gaugings are taken and added to the dataset that correlates 'stage' (water level at a monitoring site) and flow at the site. In recent times, WaterNSW has granted limited access to the Special Area during wetter periods in order to improve the moderate/high flow sections of the rating curves. This has meant that historical records of estimated flow can change when a rating curve is updated.

Hydrographers ALS took over the contract for flow monitoring at Dendrobium on 11/05/2016. ALS provide the record of daily flow for each IMC site based on the latest rating curve and the historical record of stage (level) at each site. ALS do not provide re-rated data from before their contract date, i.e. before 11/05/2016.

Table 2. Stream gauges that have been re-rated in 2022-23

DATE	A3A/B GAUGES RE-RATED	OTHER GAUGES RE-RATED
June 2022	SCL2, WC21S1, DCU	DC8

It is apparent from review of previous data obtained from WaterNSW for O'Hares Creek (WaterNSW site 213200) that a similar re-rating process occurs periodically in WaterNSW data.

There are two implications of the re-rating process:

1. Estimates of flow included in previous EOP reports may be different to that reported in the current (or future) EOP report. For example, median flow for sub-catchment WWU for the period May-2016 to June-2020 was 0.068 ML/d in the EOP for Longwall 15 but was revised to 0.202 ML/d EOP for Longwall 16 due to changes to the rating curve.
2. For gauging sites that commenced operation before the contract date of ALS (11/05/2016), time-series data prior to that date need to be adjusted to account for re-rating. This pre-processing step was accomplished by comparing the 'old' (pre-ALS) flow data and the new rating curve in order to derive a flow record that is based on a consistent rating curve across the entire record.

2.1.4 Data quality assessment

An analysis of the data received from ALS was performed to assess the reliability and continuity of data collected at each flow gauge. The data quality code recorded by ALS for flow measurements was used for this purpose. A summary of these data quality codes has been provided in Table C2 of Appendix C, alongside the data quality assessment of each flow gauge.

Each daily flow recorded is the average flow determined from multiple sub-daily (typically 15-minute interval) stage measurements. The Hydstra database maintained by ALS will assign the 'worst' data quality code from any of the sub-daily records to the aggregated or averaged daily record. It is for this reason that Hydstra will sometimes assign quality code 140 ("Level below cease-to-flow") to days where there is a small, non-zero average flow.

For each flow gauge the percentage of available daily flow measurements was calculated. This value indicates the number of measurements that exist between the first date of data collection and the last available date. From this the percentage of 'suspect' data was calculated. Based on the ALS quality codes, suspect data refers to any flow data with a code that falls between 104 and 255. A summary of the data quality assessment for each flow gauge is included in Table C3 and C4 of Appendix C.

Data processing was then undertaken for flow data where entries were blank or entered as text and these could be confidently infilled. These entries were associated with the following quality codes:

- 151 ("data not yet available"): associated with comments of 'rating exceeded', commonly following high regional rainfall events;
- 161 ("poor quality data from debris affecting sensor"): occurred only at flow gauge WWU for the period 23/01/2019 to 27/02/2019;
- 205 ("data lost"): associated with comments such as 'logger dead', 'data lost';
- 255 ("no data exists"): associated with comments of 'rating exceeded', 'logger dead'.

For these entries an infilling procedure was used to estimate the flow value, if the record could be confidently estimated (e.g. flows were consistent through time and compared to other gauging stations, especially at higher flows when the "rating exceeded" flag was assigned. Flow estimates were calculated using either the average flow from the preceding and following days, or the flow recorded at another gauged sub-catchment for the same day, scaled by catchment size. The percentage of infilled data is recorded for the relevant gauges in Appendix C. The results of processing, with comparison against 'raw' data are illustrated on charts in Appendix C.

2.2 Shallow Groundwater (Swamp) Monitoring

Figure 2 shows Longwall 21 in relation to the locations of shallow groundwater monitoring sites in Areas 3A, 3B and 3C. Swamps and shallow groundwater monitoring near Longwall 21 are shown in the local scale map in Typically, these sites are piezometers approximately 1 - 3 m deep that monitor groundwater levels within the swamp deposits located around the Dendrobium area. IMC maintains a network of shallow groundwater monitoring sites at swamps within the area of mining influence (400 m), referred to as “impact” sites, as well as “reference” sites installed within swamps that are located well outside the influence of mining (currently Swamps 22, 24, 25, 33, 84, 85, 86, 87 and 88).

Figure 2 also shows swamp areas: broadly mapped by NSW Office of Environment and Heritage (OEH) and refined through site-scale mapping for IMC carried out by Biosis and Niche Environment and Heritage. Note that the TARP assessment relates only to those piezometers that are located within swamp sub-communities mapped as Banksia Thicket, Sedgeland-heath complex and Tea Tree Thicket; being listed as Costal Upland Swamp Endangered Ecological Community (EEC). Piezometers located within other areas, such as fringing Eucalypt Woodland, are excluded from the TARP assessment as per the advice from OEH (17/01/2014).

The following swamps and piezometers are located within 400 m of Longwall 21:

- Swamp 9: Piezometers 09_01 and 09_02
- Swamp 144: Piezometer 144_01
- Swamp 145: Piezometer 145_01

Shallow groundwater monitoring data are presented and discussed in Section 6.

2.3 Soil moisture monitoring

Soil moisture profiles are monitored at most swamps, with sensor arrays typically positioned near shallow piezometers (where possible). Where possible the monitoring arrays are numbered according to the corresponding piezometer (if present) with the addition of an ‘S’ prefix. At most locations, sensors are installed up to a maximum depth of 1.2 m.

Soil moisture is measured using Sentek sensors which monitor changes in the dielectric constant within a cylinder of soil extending to a radial distance of 10 cm from the access tube. Soil moisture is reported as mm water per 100 mm soil depth (or volumetric % water) at each monitored depth (Sentek, 2017). The most recent installations are equipped with automated data loggers set to record moisture levels every hour. The remaining installations are recorded manually during scheduled site visits.

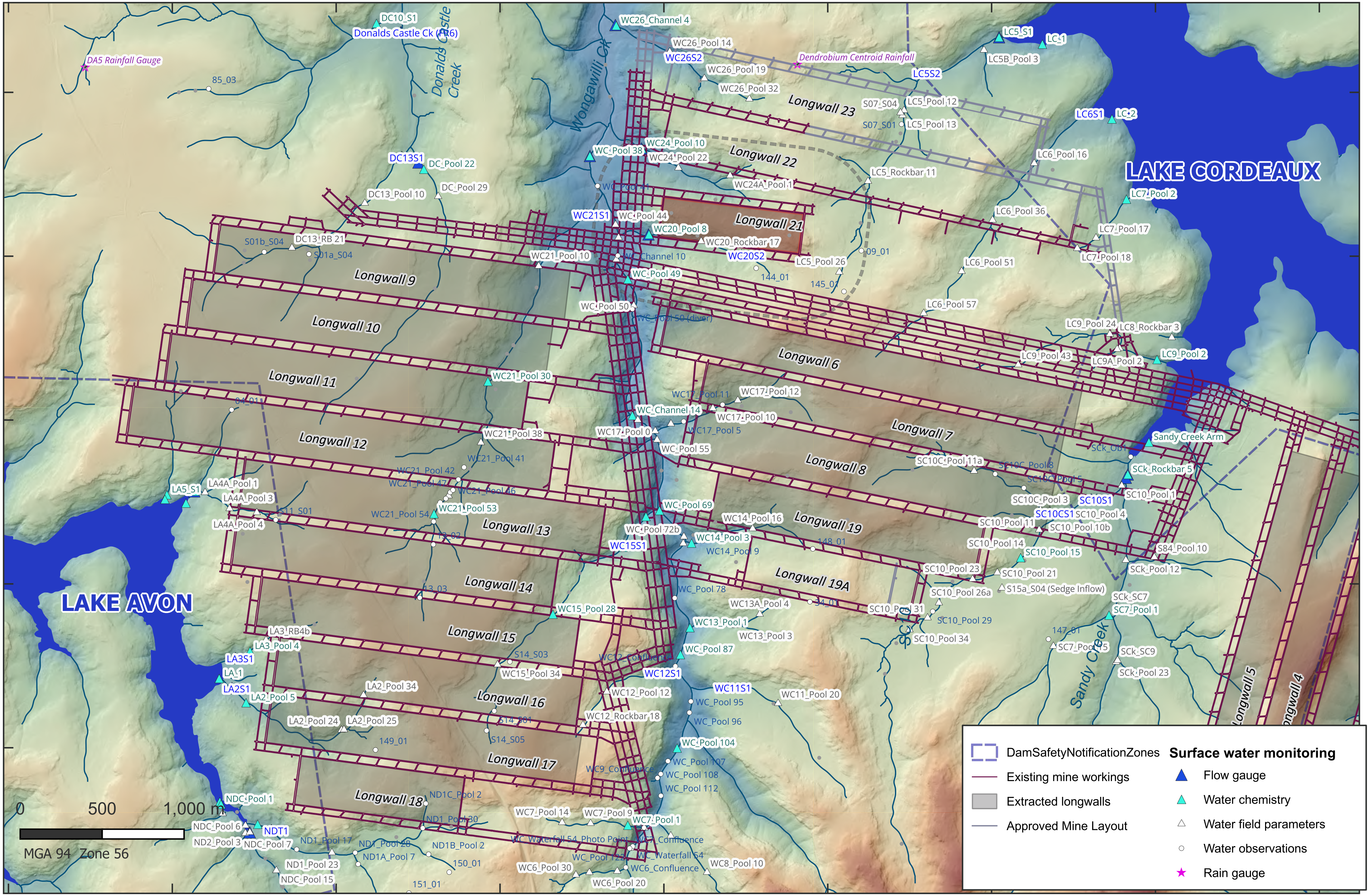
2.4 Catchments and watercourses within mining influence of Longwall 21

Dendrobium Mine is located within the catchments of the Avon and Cordeaux Rivers, which are tributaries of the Upper Nepean River. Drainage is generally to the north-northwest, towards the Nepean River, with most of the local surface runoff initially captured in Cordeaux, Avon, Nepean and Cataract lakes, before eventually flowing into the Nepean River. These lakes are reservoirs operated by WaterNSW as part of the water supply network for Sydney. Lake levels are regulated by controlled releases and overflow at the reservoir dams.

Longwall 21 is located to the north of Area 3A and is oriented roughly east-west, parallel with a ridge between Wongawilli Creek tributaries WC20 and WC24. The longwall footprint is almost entirely within the Wongawilli Creek sub-catchment, with the 400 m area of influence partly overlapping with the LC5 sub catchment. Surface watercourses and sub-catchments mined beneath by Longwall 21 are listed in Table 3.

Table 3. Surface water features within area of mining influence

Catchment / location	Approximate dates	Monitoring sites (level and chemistry)	
		Upstream	Downstream
Wongawilli Creek	Longwall 21 finished at 244 m from the main channel of Wongawilli Creek on 6/8/2023. Approximately 735 m of channel length is within 400 m of the longwall.	Sites upstream of WC_Pool 50: WWU4 is upstream of all Dendrobium operations	Sites downstream of WC_Pool 41
WC20	Longwall 21 mined directly beneath the middle reaches (325 m) of this first-order tributary to Wongawilli Creek. The entire tributary is within 245 m of the longwall.	-	All sites on WC20 within 400 m
WC24	WC24 was not directly mined beneath. However 850 m of the tributary (80%) is within 400 m of the longwall. The main channel passes within 90 m of the longwall footprint.	-	All sites on WC24 within 400m
WC19	The WC19 watercourse is outside of the area of influence of Longwall 21 and was previously mined under by Longwall 6 in early 2010. Approximately 6.4 Ha (20%) of the sub-catchment is within 400 m of longwall 21.	-	No active sites
LC5	A second-order tributary to Lake Cordeaux. The watercourse is not directly mined under by Longwall 21. Approximately 644 m (31%) of the upper reaches of the watercourse pass within 400 m of the Longwall, the closest pass being 262 m (LC5_Pool26).		All sites on LC5



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Dendrobium End of Panel Surface Water Assessment

Surface water monitoring sites

Figure 1

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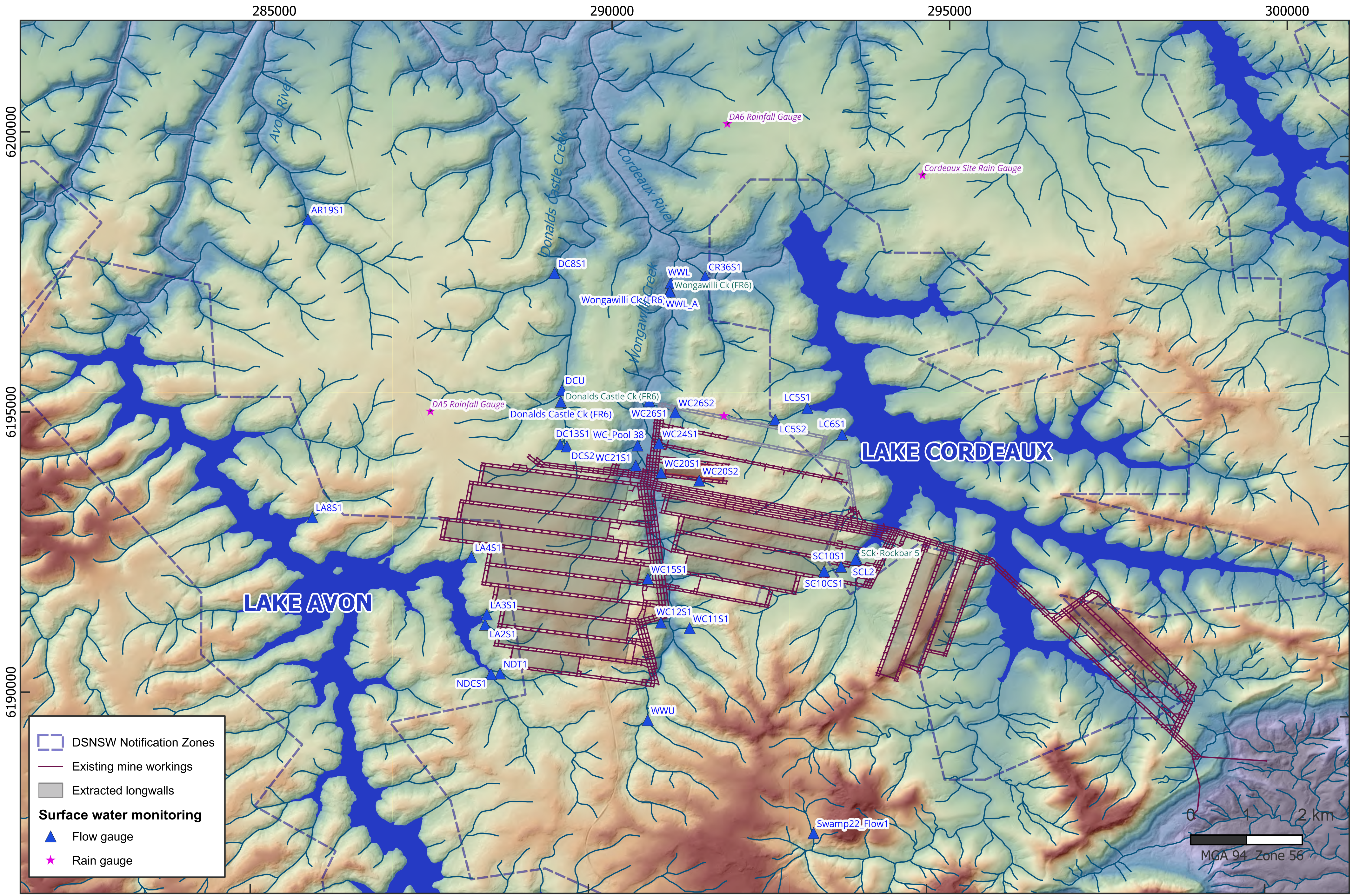

Dendrobium Mine End of Panel Surface Water Assessment

Hydrographic gauging stations

Figure 2

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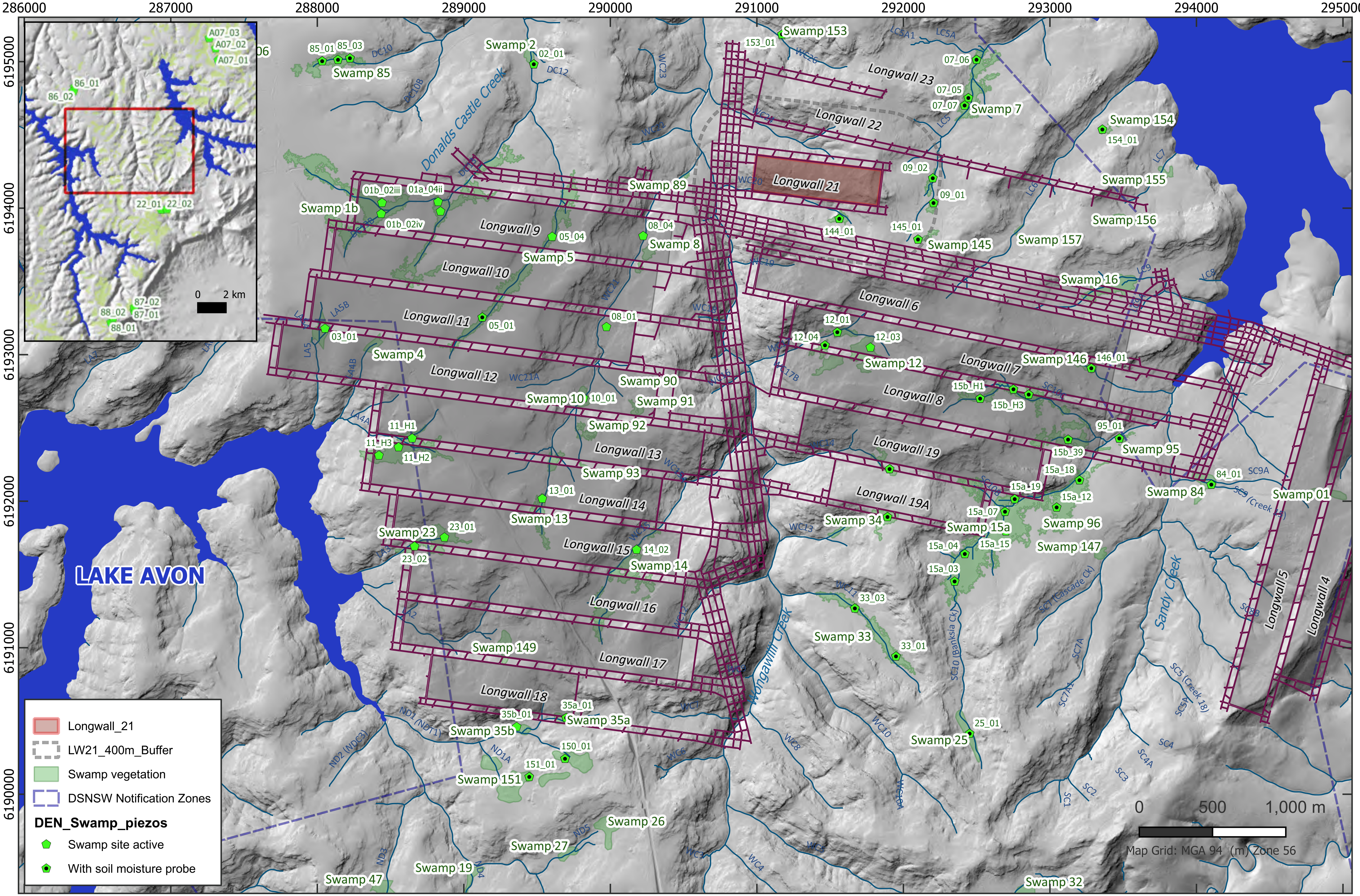

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Dendrobium Mine End of Panel Surface Water Assessment

Swamp monitoring sites

Figure 3

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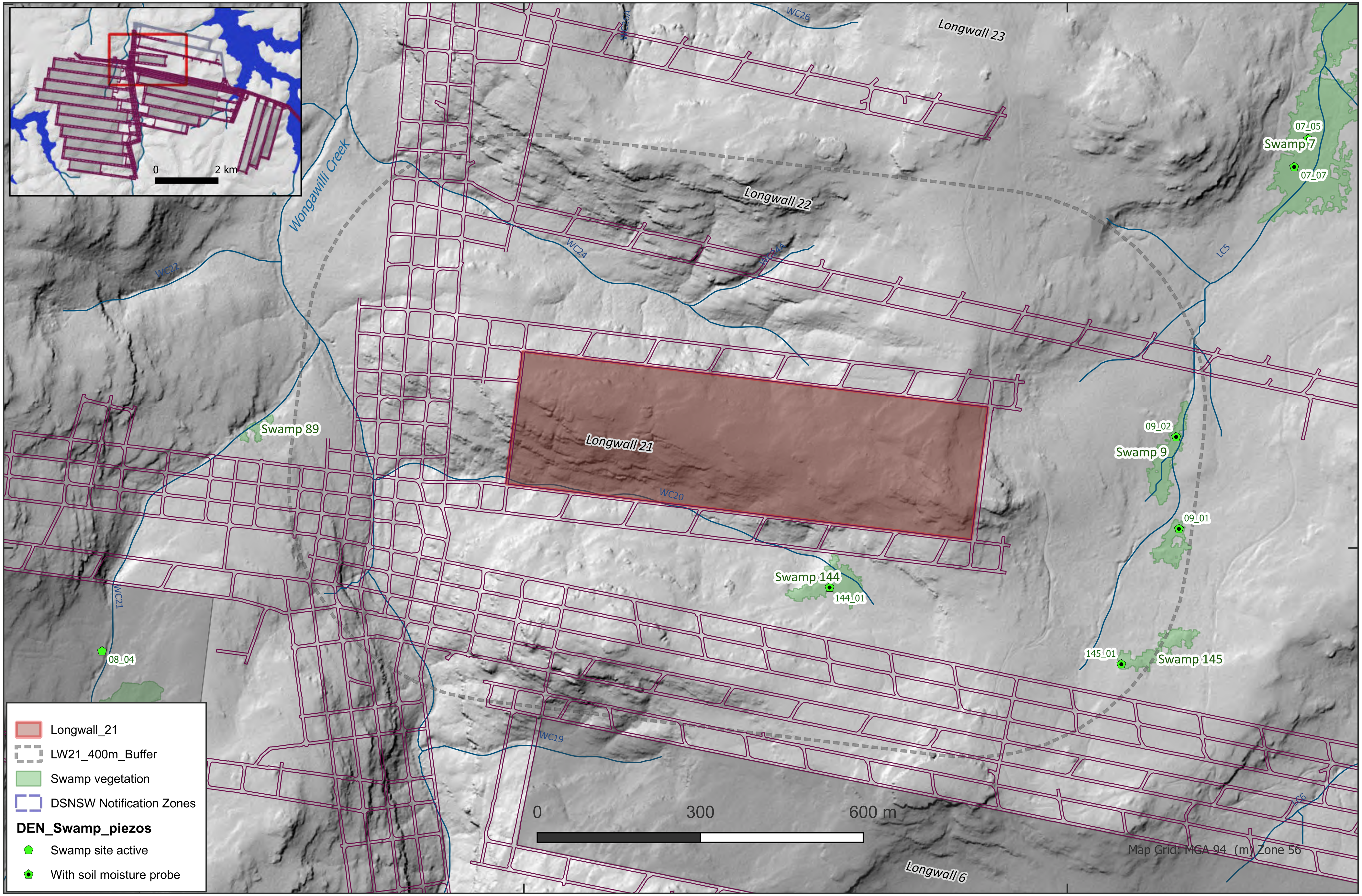

Dendrobium Mine End of Panel Surface Water Assessment

Swamp monitoring sites within 400 m of Longwall

Figure 4

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2.5 Weather conditions during the assessment period

Rainfall data is collected from several gauging stations across the mining lease. Weather observations at Dendrobium over the last 5 years are summarized in Figure 5. Potential evapotranspiration (EVT) is calculated from SILO data (DSITI, 2011) for Dendrobium, using the FAO Penman-Monteith formula (Allen et al., 1998). The average annual rainfall for Dendrobium is 1142 mm (2002 – 2022) based on data from site rainfall gauges. Rainfall events occur year-round but tend to be more frequent in the summer and early autumn months. It is common for a substantial proportion of the annual rainfall to be delivered in a small number of large rainfall events, during which significant surface water runoff and groundwater recharge is generated. Evapotranspiration varies seasonally in line with temperature and solar radiation, peaking during the summer months.

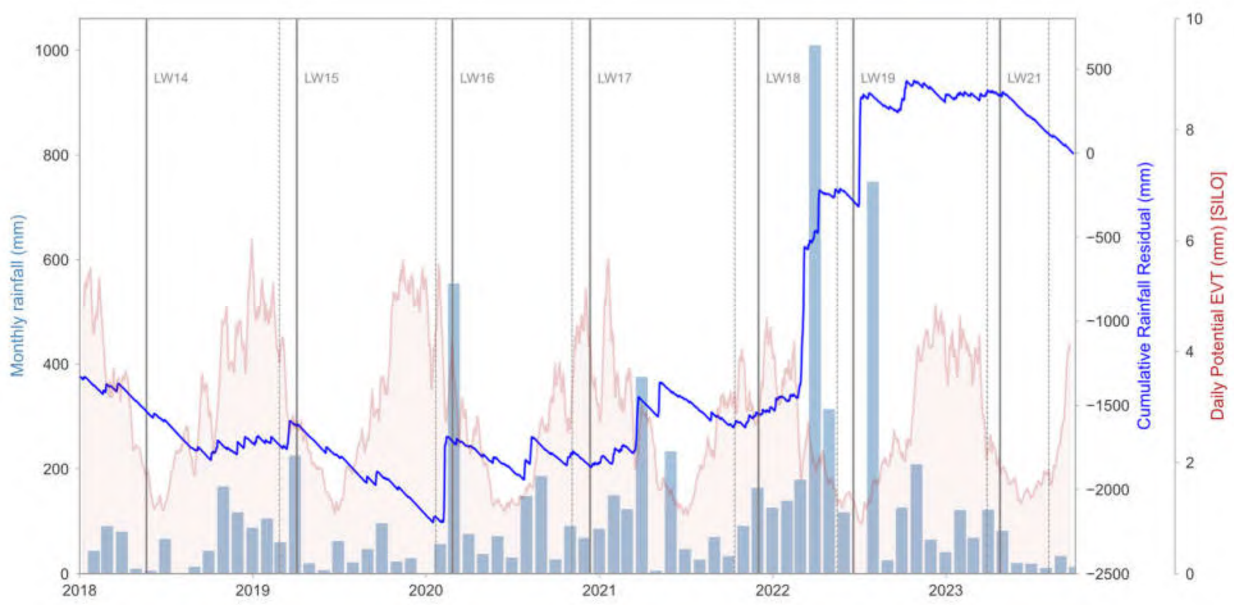


Figure 5. Rainfall and potential evapotranspiration (EVT) at Area 3 for the reporting period

Rainfall during Longwall 21 extraction was well below average, totalling 302 mm, just 29% of the average over the 104-day period. The whole of 2023 has, so far, been considerably drier than average, with 494 mm recorded at Dendrobium to 26 September 2023, which is 60 % of the average. The dry conditions in 2023 and during Longwall 21 contrast with the very wet conditions experienced during 2022 and the preceding two years.

Soil moisture levels derived from the Australian Water Resources Assessment Landscape model (AWRA-L) are through the Bureau of Meteorology (BOM) Australian Water Outlook site. A time series of estimated soil moisture storage for the Woronora Plateau in the vicinity of Dendrobium Mine is shown in Figure 6. Calculated soil moisture storage declined to record low levels during the 2017-2019 drought but was completely replenished during the 2020-2022 wet period. Drier conditions in 2023 have resulted in a sharp decline in calculated soil moisture storage to the ~30 percentile level in September 2023.

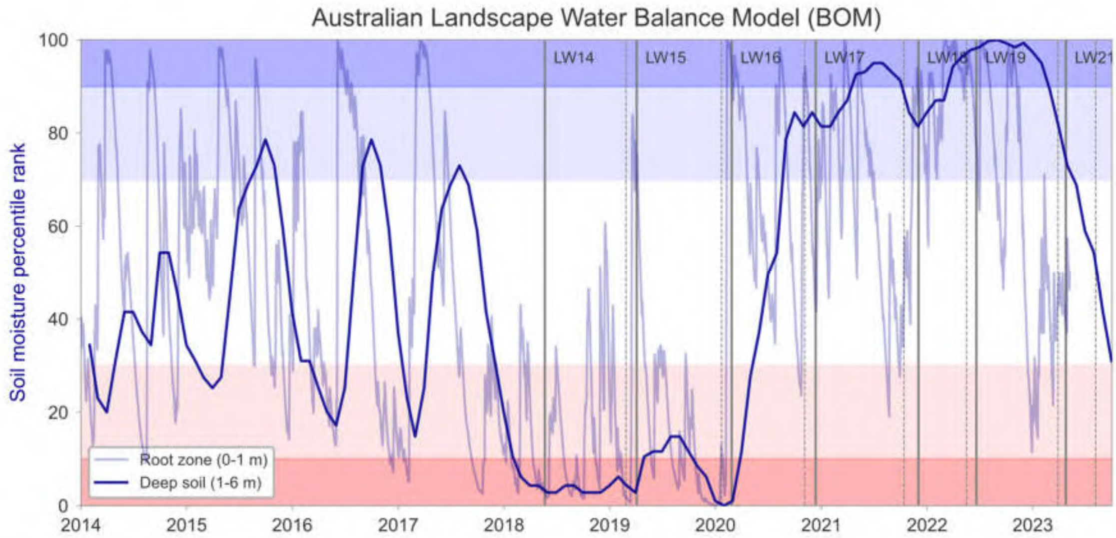


Figure 6. Calculated soil moisture from the AWRA Landscape Model

3. Longwall subsidence effects

Figure 7 presents the total subsidence predicted by MSEC (2021, 2019) above Area 3C longwalls in including Longwall 21. This shows that Wongawilli Creek and Lake Cordeaux are well outside the main area of subsidence for Longwall 21. The upper reaches of tributaries WC20 and WC24 pass within the 20mm predicted subsidence contour for Longwall 21.

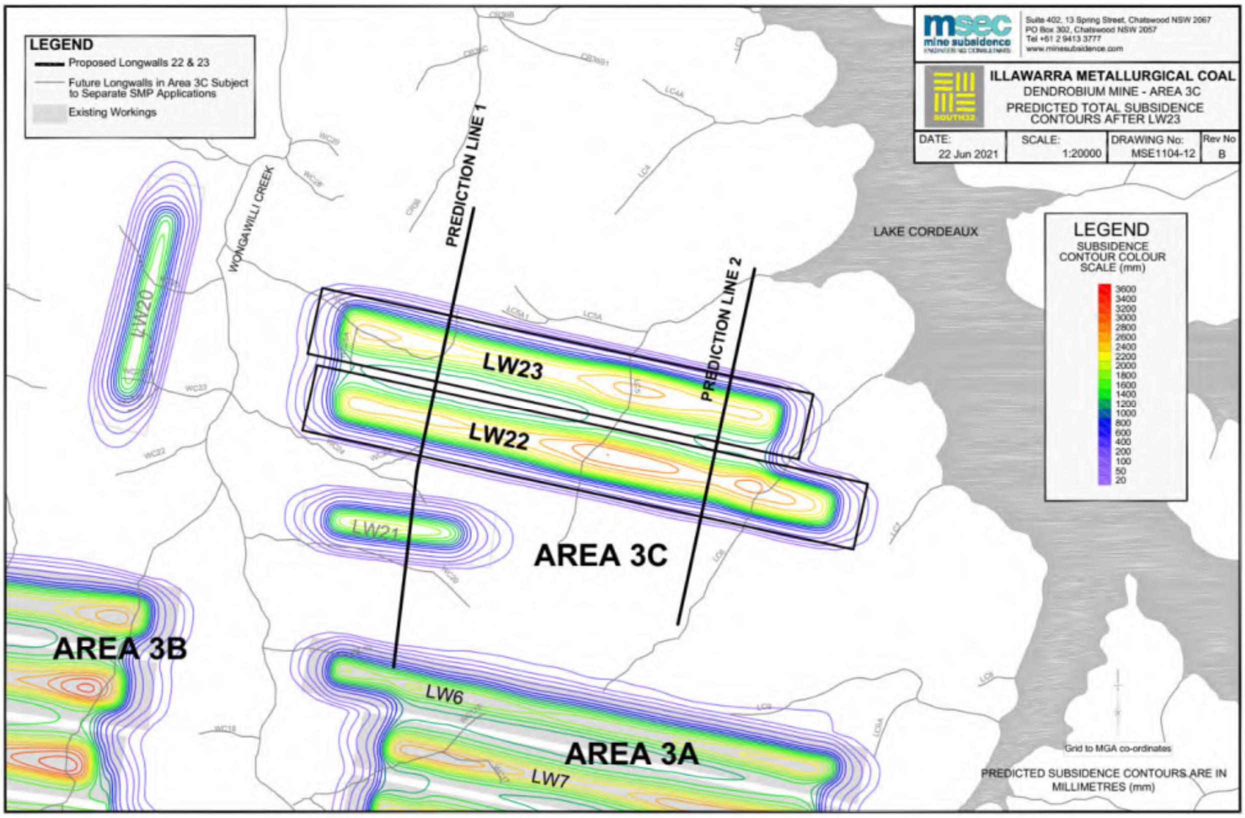


Figure 7. Predicted Subsidence above Area 3C (from MSEC, 2020)

3.1 Measured subsidence

Observed mine subsidence movements due to the extraction of Longwall 21 were reviewed by MSEC (MSEC, 2023). Mine subsidence effects were measured using the Wongawilli Creek closure lines, Sandy Creek Waterfall closure lines, Area 3C 3D monitoring points, 330 kV transmission line monitoring points, WC20 cross-line and LiDAR scans of the area. The review concluded that "*the observed surface impacts on the natural and built features due to the mining of LW21 are consistent with the MSEC assessments provided in Report No. MSEC978* (MSEC, 2019)*which supported the Extraction Plan Application for LW21*."

3.2 Observed surface impacts

Observed subsidence impacts on the landscape, including surface fracturing and iron staining are monitored by the IMCEFT and reported separately in the EoP Landscape Report (South32, 2023). A total of 36 new ground surface impacts attributed to the extraction of Longwall 21 were recorded (Figure 8). Of those, 7 were associated with watercourses or swamps and are listed in (Table 4).

Table 4. Reported subsidence impacts to stream beds during Longwall 21

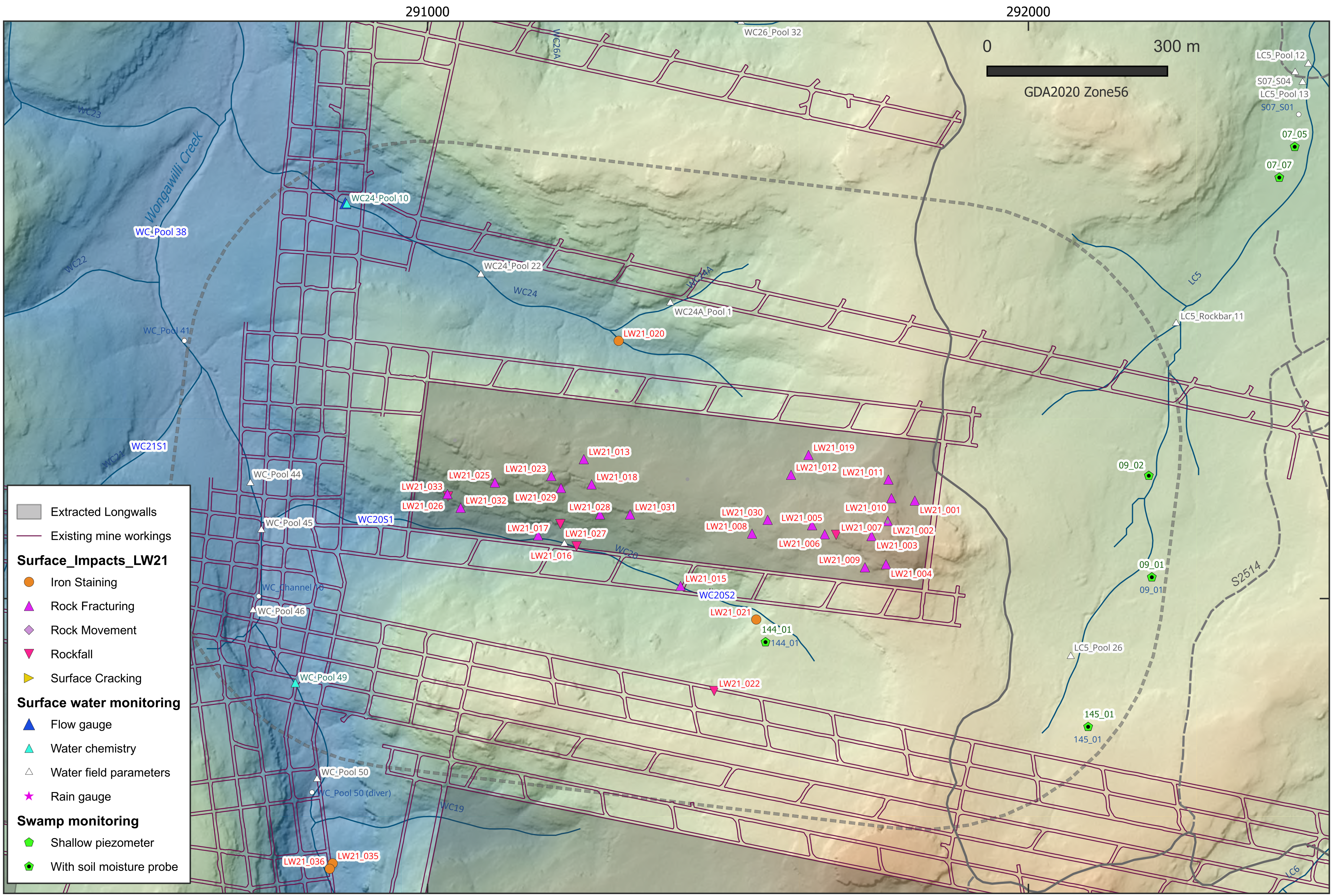
Site ID	Watercourse	Date Observed	Description	Tarp Level
LW21_015	WC20	7/11/2023	Rock fracture in WC20_Channel 8. Max length2.26 m, max width 0.02 m and max meas. depth of 0.37 m. No observable water in channel but signs of water there previously.	2
LW21_016	WC20	7/11/2023	Increase in the rockfall area was identified. The rockfall now has a length of ~7 m, a width of ~1m, a height of ~2.5 m, a total volume of ~17.5 m^3 and a ground disturbance area of ~20 m^2	1
LW21_017	WC20	7/26/2023	Impact DA3C_LW21_017 consists of rock fracturing and uplift to WC20_Rockbar 15 on tributary WC20. The fracturing has a maximum length of 2.6 m, a maximum width of 0.012 m and uplift of 0.02 m. No surface flow was present during inspection	1
LW21_020	WC24	1/8/2023	Localised iron staining was observed along a 45m stretch of dry streambed on WC24 during the latest inspection. The iron staining originates at WC24_Pool 35 and extends downstream to WC24_Rockbar 15.	1
LW21_021	WC20	1/8/2023	DA3C_LW21_021 consists of localised iron staining on the downstream basal step of Swamp 144. The iron staining originates from under a large boulder mid-way down the basal step. The iron staining is approximately 2m in length, 1m in width	1
LW21_035	Wongawilli Creek	9/10/2023	Iron staining present flowing on valley slope within proximity to Wongawilli Creek.	1
LW21_036	Wongawilli Creek	9/10/2023	Iron staining present flowing on valley slope within proximity to Wongawilli Creek.	1

In August 2023, an occurrence of suspended iron floc in Wongawilli Creek, downstream of WC_Pool 50 was reported to DPE. The occurrence is a continuation of Iron staining and suspended iron floc that was first reported in the same reach of Wongawilli Creek by IMC in August 2021 (Impact reference LW17_031). In response to a request by DPE, the IMC carried out an assessment of the extent and likely cause of the occurrence. Results of the assessment are presented in Section 4.4.1, below.

3.3 Specialist advice in relation to observed impacts.

Subsidence impacts of TARP Level 2 or above require specialist advice in relation to possible Corrective Management Actions (CMAs), reporting and/or monitoring. Advice in relation to subsidence impacts to watercourses is as follows:

- **LW21_015**: A rock fracture was recorded within WC20_Channel 8. The impact is located 37 m south of the Longwall 21 footprint. According to the subsidence assessment for Longwall 21 by MSEC (2019), it is expected that "*fracturing of bedrock would occur along the sections of the drainage lines that are located directly above the proposed LW20 and LW21. Fracturing can also occur outside the extents of the proposed longwalls, with minor and isolated fracturing occurring at distances up to approximately 400 m*". The observed fracturing is therefore within prediction. Current routine monitoring is considered adequate, and no additional actions are recommended.



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Dendrobium Mine End of Panel Surface Water Assessment

Observed surface impact sites

Figure 7

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4. Assessment of surface water quality effects

During the reporting period between the start of Longwall 21 (25/4/2023) and one month after the end of Longwall 21 (6/9/2023), monitoring was carried out at 145 surface water sites. Sites were monitored on an approximately weekly or monthly basis, as per the Watercourse Impact Monitoring Management and Contingency Plan (WIMMCP). In this section, water quality in monitored watercourses is assessed as follows:

- Performance against water quality TARP thresholds (Section 4.1)
- Overview of water quality trends and anomalies (4.2)
- Quantitative assessment of water quality trends and changes from baseline (4.3)
- Occurrences of iron staining (4.4).
- Gas emissions (4.5).
- Assessment against performance measures for watercourses (7.1).

4.1 Performance against TARP thresholds for Area 3C

Trigger values for water quality field parameters are defined in the Area 3C WIMMCP Attachment 1 (South32, 2020b). Trigger thresholds (TARPs) have been defined for three locations downstream of mining Area 3C for which there is adequate high-quality baseline information (Wongawilli Creek (at Fire Road 6 [FR6]), Donalds Castle Creek (at FR6) and Lake Cordeaux (LC5_S1). The TARPs are based on the field parameters pH, EC and DO and defined by the value three standard deviations (SD) from the baseline mean (mean plus 3SD for EC and mean minus 3SD for pH and Dissolved Oxygen). TARP levels are defined as follows:

- Level 1: One exceedance within six months
- Level 2: Two non-consecutive exceedances within six months
- Level 3: Three exceedances within six months
- Exceeding prediction: Mining results in two consecutive exceedances within 6 months.

Predicted impacts are summarised in the WIMMCP.

TARP triggers for the monitoring period are summarised in Table 5. No water quality TARPs were triggered during the review period; however, water quality TARPs remain triggered at Lake Avon tributary site LA4_S1 for EC, pH and DO as a result of impacts related to Area 3B.

Table 5. Summary of Water Quality TARPs for the monitoring period

DATE	CATCHMENT / LOCATION	PARAMETER	VALUE	TARP	TRIGGER LEVEL
-	-	-	-	-	None triggered

Assessment of surface water quality effects, including TARP triggers is presented by catchment (watercourse) in the following subsections.

In addition to the surface water TARPs, the relevant SMP approval contains performance measures related to watercourse water quality, appearance, and flow. Assessment of performance measures is presented in Section 7.1.

4.2 Overview of surface water quality

Hydrographs of stream field parameters (EC, pH and DO) are presented in Appendix A for 119 observation sites and hydrographs of dissolved sulfate, Fe, Mn, Al, Si and Zn are presented for 48 sites at which sampling, and laboratory analysis are carried out. Due to the large volume of data, water quality trends (qualitative) for the review period are summarised for representative sites and sites at which significant or noteworthy trends are apparent in Table 6. A quantitative analysis of water quality trends is presented in Section 4.3, below.

A spatial analysis of water quality data is presented in Appendix A as a series of maps that show relative concentrations for specified analytes (EC, pH, DO, Fe, Mn, Al and Zn) at each sampled site for each month during the Longwall 21 review period (March through to September 2023). In each map, the three highest values are highlighted. Examples are shown below for stream EC and pH in September 2023 in Figure 9. The maps clearly show spatial anomalies, such as elevated iron at SC10C_Pool1 and WC_Pool49, and others which are discussed below.

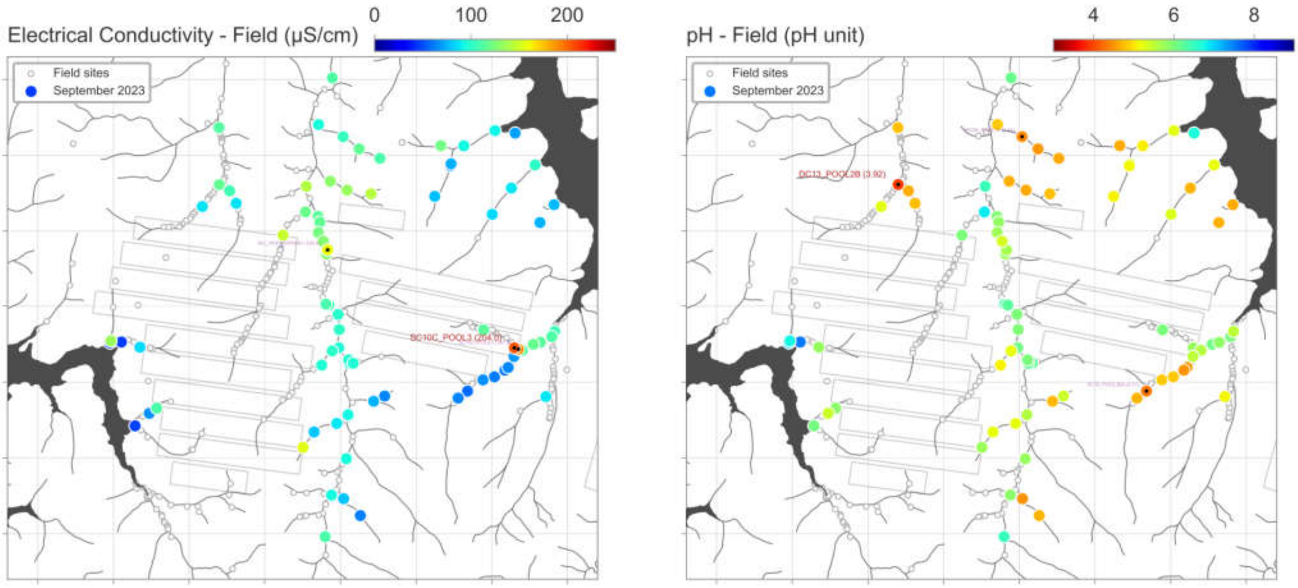

Figure 9. Example water quality maps showing stream EC and pH in September 2023

In general, stream salinity (EC) and other water quality parameters vary over periods of weeks to months and correlate with rainfall conditions. Stream EC generally decreased between 2020 and 2022 due to higher-than-average rainfall and runoff during that period. Most watercourses, including upstream control sites show an increase in EC during 2023 corresponding with a return to dry conditions. Under dry and low-flow conditions EC can increase due to evaporative concentration of salts and a higher proportion of flow derived from groundwater (baseflow). Time series of EC at the Area 3C TARP sites (Figure 10) and an upstream control site WWU4 (Figure 11) are shown below as examples. Stream EC at the downstream TARP sites continues to vary within the baseline range (and close to the baseline mean) with no apparent long-term trend.

Most watercourses also show a decline in DO during 2023 which, again, is related to low flow conditions during which disconnected pools are more common. A sharp decrease in DO is noted at some monitoring sites in Area 3C (e.g. LC5_S1, LC7_Pool2 and WC24_Pool 22). All instances except WC24_Pool22 are well outside the 400 m area of influence for Longwall 21 which is the first longwall in Area 3C. Therefore, the decrease in DO is unlikely to be mining related at those sites. The decrease in DO at WC24_Pool22 may be related to the occurrence of iron staining upstream in WC24 during Longwall 21 (Impact LW24_020, reported 1/8/2023); noting that the same sharp decline is not apparent at the downstream site WC24_Pool10.

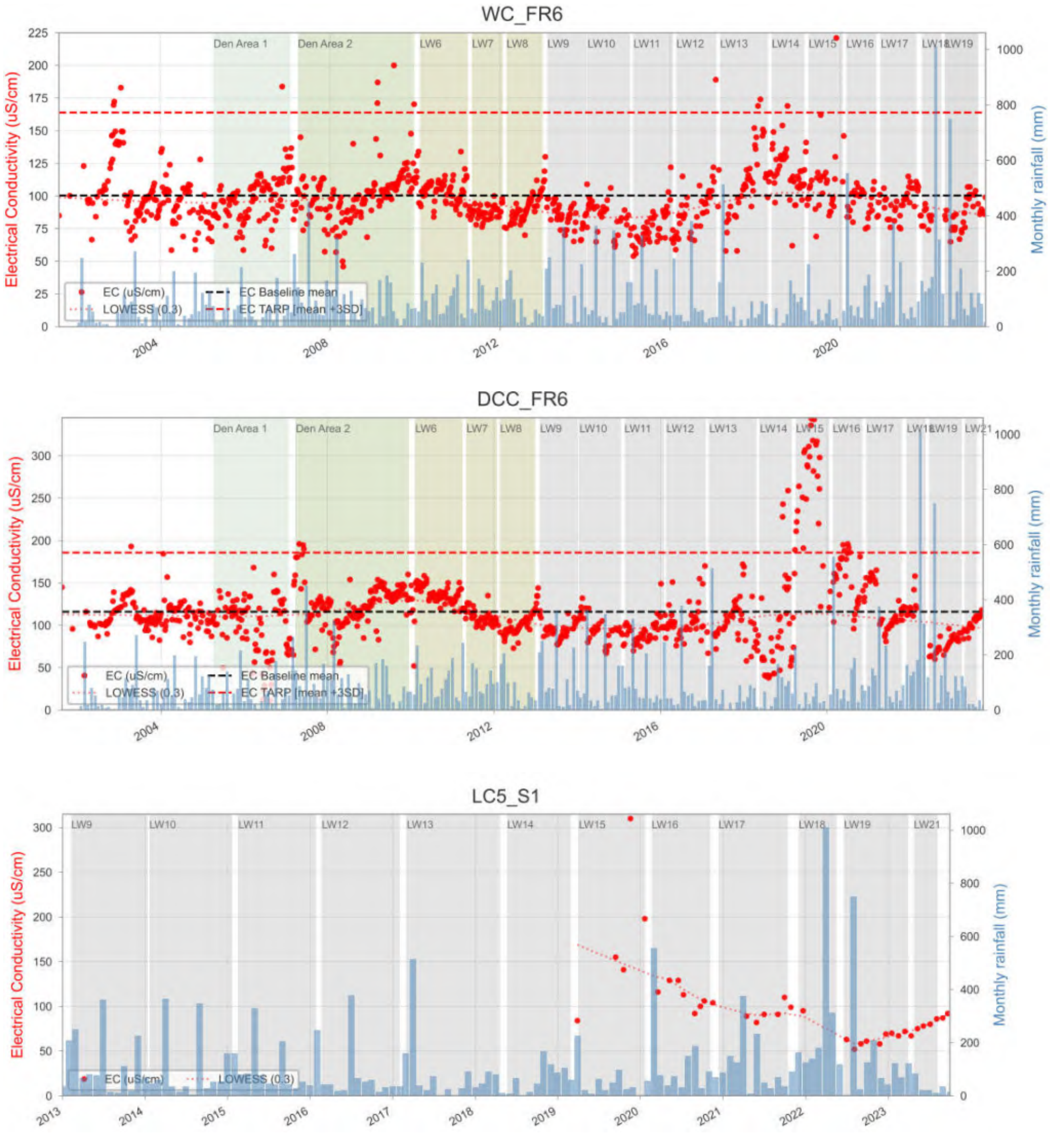

Figure 10. Time series of water Electrical Conductivity at TARP sites.

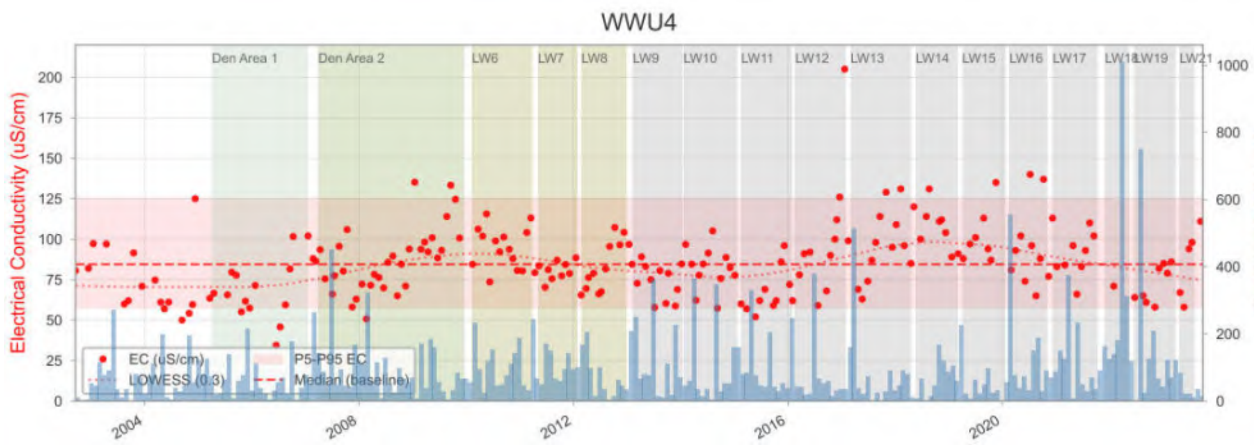

Figure 11. Time series of water Electrical Conductivity at upstream control site WWU4.

Across the other mining areas, anomalous water quality effects have been noted in streams that have been directly mined under by previous longwalls (e.g. WC21, SC10C, LA4, DCC). Those effects include transient or persistent increases in EC, increases (or decreases) in pH and increases in dissolved metal concentrations such as Fe, Mn, Al and Zn. Iron staining in creek beds is commonly associated with watercourses that have been directly mined beneath or are within the mining area of influence.

Table 6. Summary of surface water quality observations and trends

Catchment	Field parameters (EC, pH and DO)	Dissolved metals
Wongawilli Creek	**WC_FR6 TARP: None in review period** **Iron staining**: Iron staining reported between Pool 50 and RB12 in August 2021, associated with iron spring adjacent to Pool 50, and new seeps identified in Oct 2023 (LW21_035, 036). Suspended iron floc reappeared in at Pool 49 in August 2023. New iron staining observed	WC_FR6: Increasing trends in sulphate and Mn. WC_Pool38,49: Dissolved Fe, Mn remain elevated compared with baseline (See Section 4.4.1). Slight increasing trend in EC related to this.
Wongawilli Creek tributaries	WC21: Fracturing / Loss of flow upstream of Pool 5 following Longwall 10. EC and pH remain slightly elevated at Pools 5 and 10.	WC12: Increasing Fe, Mn and sulfate during 2023 WC24_Pool10: Slight increase in dissolved Fe which started prior to LW21. WC21_Pool5: Increasing Fe,Mn and SO4 since early 2020; remains elevated compared with baseline.
Donalds Castle Creek	**DCC_FR6 TARP: None in review period.** EC, DO within baseline range; pH slightly below baseline. DC13_Pool2B Decline in pH during 2023. Slight decline in pH also seen in Pool 22	DCC_FR6: Increase in Sulfate, Zn, Al and Mn after Longwall 14; Decline since 2020, but remain above baseline. Upstream sites: DC13_Pool2B and DC_Pool22; Transient increases in Fe, Mn, Al, Zn after Longwall 13; Declined to near baseline levels from 2020; slight increase in Fe at Pool 2B in 2023.
Lake Avon tributaries	LA4_S1: Fracturing / loss of flow after Longwall 13; EC slightly higher and pH, DO lower than baseline since flow returned in 2020. LA3: iron staining observed following completion of Longwall 18. EC, pH and DO within baseline range.	LA4_S1: Dissolved Fe, Mn, Al, Zn and Si remain elevated above baseline after flow returned in 2020. LA2: No adverse trends. LA3: Increase in Fe in 2023 at Pool 4.
Native Dog Creek	Native Dog Creek NDT1 (Pools 2, 23): EC, pH and DO within baseline range; no adverse trends.	ND1_Pool2: No adverse trends
Sandy Creek	SCk_Rockbar5: EC and DO within baseline range; pH slightly higher than baseline (~6.3); no adverse trends. SC10C: Pool 11A: increase in EC during 2023 to ~175 uS/cm;	SCk_Rockbar5: Increase in Fe, Mn from 2020 (to ~2.0 and 0.8 mg/L); small increase in Zn from 2016 (to ~0.05 mg/L). Fe Mn and Zn remain above baseline. SC10_Rockbar3: Increase in Fe, Mn from 2019; small increase in Zn from 2016. Concentrations declined in 2023. SC10C_Pool1: Increase in Fe, Mn, Al, Zn, Si and sulfate following Longwall 8. Declining trends since 2020. Fe and Mn remain above baseline.
Cordeaux River	No Adverse trends	CR_S1 and CR_S2: Slight increase in Fe, Mn, Al and Si from 2020-22.
Reservoirs	Lake Avon (LA5_S2): No adverse trends. Lake Cordeaux (SANDY CREEK ARM): No adverse trends **Lake Cordeaux (Sandy Creek Arm) TARP: None in review period**	Lake Avon (LA5_S2): No adverse trends. SANDY_CREEK_ARM: Small spike in concentrations of Fe and Mn associated with 2017-2019 drought. Possible increase in Fe and Al since 2020.

4.2.1 Sandy Creek

In May 2022, WaterNSW (via DPE) requested that IMC *Investigate a potential link between anomalous water quality results observed in the tributary of Banksia Ck (SC10C_Pool1) and increasing 3-year trends in sulphate and dissolved metal (manganese, zinc) concentrations at Sandy Creek (SCk_Rockbar5).* IMC carried out a longitudinal sampling survey along the affected reaches of the watercourse over a period of 6 months from September 2022 to February 2023. The results were presented in a report by HGEO (2023a).

The investigation found that All solutes generally decrease systematically with distance downstream from SC10 Pool 3 to SCk_Rockbar5. The highest iron concentrations occur in reaches of SC10C that directly overlie the previously mined Longwall 8. There are apparent step-changes in concentration corresponding with the confluence of SC10C with SC10 and the confluence of SC10 with Sandy Creek, consistent with expected dilution at those confluences.

Samples collected from SCK_Rockbar5 during 2023 have declined to within the range observed prior to mining in Area 3A (9/2/2010 – 29/12/2012). The decline at SCK_Rockbar5 reflects a decline in iron concentration at upstream sites (SC10C_Pool1, SC10_Rockbar3), although the iron concentration at SC10C_Pool1 remains above baseline levels. It is presumed that drier conditions have resulted in a decline in flow contributions from SC10C and associated iron-rich springs.

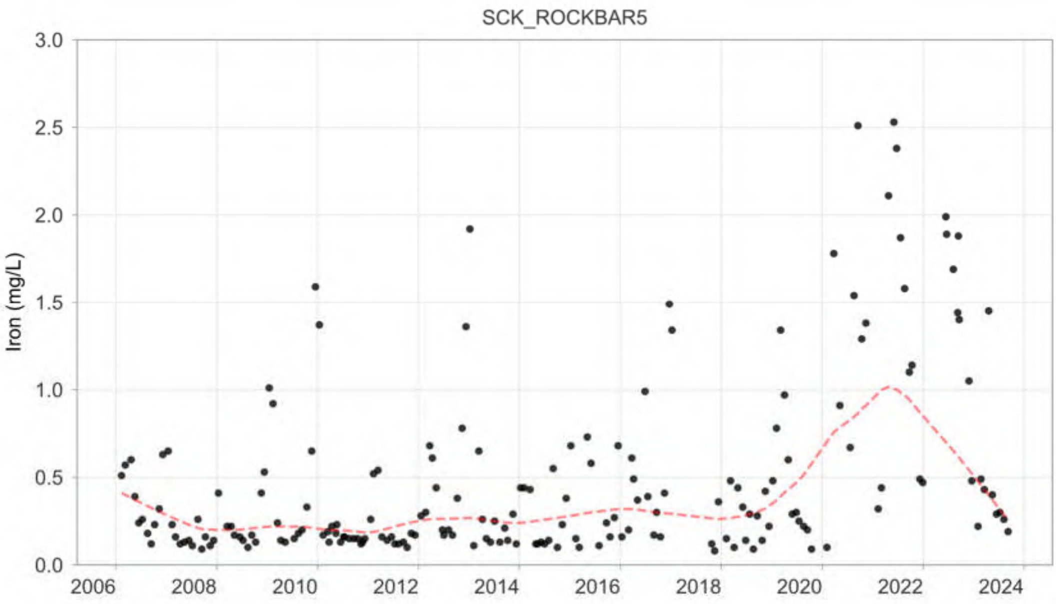

Figure 12. Dissolved iron concentration at Sandy Creek rock bar 5

4.3 Quantitative assessment of water quality trends

WaterNSW endorsed the recommendation of the Independent Advisory Panel for Underground Mining (IAPUM) that "*A method of quantifying and reporting trends in key water quality indicators (both concentrations and loads) should be trialled in addition to applying the proposed water quality TARPs.*". A methodology for trend analysis was developed by HGEO (2021a) in consultation with WaterNSW. Trend analysis is carried out as follows:

- A flow-corrected residual time series is generated for each analyte using multiple regression: stream flow and rainfall residual are used as the explanatory variables.
- For each specified review period, calculate the Mann-Kendall test statistic for significance at the 5% significance level (for ordinal trend); the Theil-Sen slope; and compare the mean concentration during the review period with the baseline period using the non-parametric Mann-Whitney U rank sum test statistic. Effect size is estimated using the rank-biserial correlation coefficient.
- Trend analysis is carried out on flow-corrected field EC, pH and DO, and flow-corrected sulphate, dissolved Fe, Mn, Al, Zn. Analysis is also carried out on non-corrected (raw) data as a comparison.
- Trend analysis is carried out for monitoring sites with associated flow gauges on the major 3rd order streams: sites WC_FR6, DCC_FR6, SCk_Rockbar5 and an appropriate control site (O'Hares Creek, or WWU4).

4.3.1 Trend analysis results

Water quality time series (flow-corrected and raw) and tabulated statistics are included in Appendix A2. A summary table, highlighting results of statistical significance is provided in Table 7. The trend analysis results reflect the qualitative assessment presented in the previous section, with the following being statistically significant:

- At WC_FR6: The median flow-corrected concentrations of sulfate and iron are also higher than that of the baseline. There are increasing trends in EC is identified in flow-corrected data, despite non-flow-corrected data showing no significant long-term trend (Figure 10). The last year of data defines an increasing trend in Al, although no trends is apparent in the raw time series. The changes were not sufficient to trigger a TARP at the site.
- At DCC_FR6: Over the past 1-year and 3-year periods, EC, sulphate, Mn, Zn and Al are elevated compared with baseline (flow-corrected); whereas pH is lower than baseline. Flow-corrected data show increasing trends for EC, Mn, and Al and a decreasing trend in pH. Again, no TARP was triggered for EC, pH nor DO for the review period.
- At SCk_Rockbar5: Mean flow-corrected EC, sulphate and dissolved metals Fe, Mn and Zn are above the baseline, contrasting with the upstream control site (WWU4) which shows no significant change. Flow-corrected pH has trended lower over three years, but remains above the baseline mean. These trends reflect contributions from tributary SC10C which was mined under by Longwall 8. No TARP was triggered for EC, pH nor DO for the review period.

At the upstream control site WWU4, the same analysis indicates no significant change in mean concentrations or value for EC, pH, DO, sulfate, Fe, Mn, Zn or Al, compared with the baseline. However, note that the timeseries plots indicate that Mn, Al and Zn define a declining trend during the baseline period, possibly due to residual effects from Elouera Mine.

Table 7. Summary of flow-corrected water quality trends (as of April 2023)

Site	Parameter	Ordinal Trend[1, 2]		Median values (Raw)			Change in mean[3] Flow-corrected		Change in mean[3] Raw data	
		1-year	3-year	Baseline	1-year	3-year	1-year	3-year	1-year	3-year
WC_FR6	EC_uS/cm	Increasing	Increasing	99	101	94	>Baseline			
	pH_field			5.8	6.6	6.2				
	DO_%			93.8	95.8	95.5				
	SO4_mg/L			4	7	5		>Baseline	>Baseline	>Baseline
	Fe_mg/L			0.16	0.08	0.14				
	Mn_mg/L			0.044	0.085	0.077		>Baseline	>Baseline	>Baseline
	Zn_mg/L			0.009	0.005	0.007				
	Al_mg/L	Increasing	Increasing	0.05	0.01	0.01				
DCC_FR6	EC_uS/cm	Increasing	Increasing	123	90	105	>Baseline	>Baseline		
	pH_field	Decreasing		5.3	4.9	4.8		<Baseline	<Baseline	<Baseline
	DO_%			88.6	95.4	94.9				
	SO4_mg/L			3	2	4	>Baseline	>Baseline		
	Fe_mg/L			0.065	0.350	0.100			>Baseline	
	Mn_mg/L		Increasing	0.041	0.083	0.083	>Baseline	>Baseline	>Baseline	>Baseline
	Zn_mg/L			0.005	0.014	0.015	>Baseline	>Baseline	>Baseline	>Baseline
	Al_mg/L	Increasing	Increasing	0.13	0.24	0.29	>Baseline	>Baseline	>Baseline	>Baseline
SCK_ROCKBAR5	EC_uS/cm			96	82	91	>Baseline	>Baseline		
	pH_field		Decreasing	5.4	6.3	6.2				
	DO_%			78.8	90.7	90.3				
	SO4_mg/L			2	8	8	>Baseline	>Baseline	>Baseline	>Baseline
	Fe_mg/L			0.20	0.45	1.29		>Baseline	>Baseline	>Baseline
	Mn_mg/L			0.046	0.306	0.368	>Baseline	>Baseline	>Baseline	>Baseline
	Zn_mg/L			0.003	0.020	0.025	>Baseline	>Baseline	>Baseline	>Baseline
	Al_mg/L				0.02	0.02	*No baseline for Al*		*No baseline for Al*	
WWU4	EC_uS/cm			88	81	83				
(control)	pH_field			5.1	6.4	6.4				
	DO_%			95.4	96.3	97.8				
	SO4_mg/L			8	8.5	5				
	Fe_mg/L			0.08	0.10	0.08				
	Mn_mg/L			0.124	0.121	0.072				
	Zn_mg/L			0.039	0.019	0.028				
	Al_mg/L		Increasing	0.06	0.02	0.03				

1. Theil-Sen slope is the median of the slopes between all pairs of x-y points in the data. It is a non parametric estimator of median slope
2. Mann-Kendal test for serial correlation: Highlighted are where there is a <5% probability of obtaining a correlation result at least as extreme due to chance
3. Mann-Whitney U test: A non parameteric rank-sum test for the difference in means between different time intervals. (95% Confidence level)

Similar trends and significant changes in mean values are apparent in both the flow-corrected and raw data. The rank-biserial correlation coefficient (r) was calculated to quantify the effect size of the observed difference in mean values between the baseline and review periods (the last one or three years). In most cases the effect size, r, was greater than 0.5 indicating a practical significance in the mean differences, based on the sample sizes.

The above results highlight that the trend analysis can produce non-intuitive results, depending on the time-period chosen. For example, the Mann-Kendall trend analysis may identify trends over (relatively short) 1-year and 3-year periods, whereas the Locally weighted regression trend (LOWESS – blue and green lines in the timeseries plots in Appendix A) defines longer-term trends that may “smooth over” short- and medium-term fluctuations. Results should therefore be interpreted with reference to both the flow-corrected and non-corrected hydrographs.

The statistical significance of the changes in concentration since the baseline does not necessarily imply environmental consequence in terms of water quality, as specified in the watercourse performance measures in the SMP approval. The observed changes, while statistically significant, were not sufficient to trigger TARPs for EC, pH nor DO during the review period. Further analysis would be required to assess environmental consequences such as the effects on aquatic ecosystems and water supply.

4.4 Iron staining

Iron staining of watercourses can occur through natural processes or as a result of mine subsidence impacts. Iron staining occurs when dissolved iron precipitates as one or more iron oxyhydroxide minerals (typically ferrihydrite, goethite and haematite) which are reddish-brown to orange-brown in colour. The term "iron staining" is often used to describe a broad range of features related to the precipitation of iron oxyhydroxides within watercourses which include:

- **Residual iron staining**. Often seen as red-brown colouration on rock surfaces within and adjacent to stream channels, rock bars and pools. Residual iron staining may persist for months or years following a period of active iron precipitation.
- **Iron floc**. Actively precipitating, or recently deposited iron oxyhydroxides; typically occurs in delicate clumps and mats on stream beds and attached to vegetation.
- **Suspended iron oxides**. Turbidity resulting in poor visibility and orange/brown colouration in the water column. This may result from active precipitation of iron oxyhydroxides, or disruption and suspension of iron floc.

Dissolved iron is generally not considered to be highly toxic to aquatic species at moderate to low concentrations. However elevated iron and associated iron precipitates may have other adverse impacts such as oxygen depletion, build-up of sediment/floc that may smother plants and habitats, and reduction in bioavailability of nutrients.

Occurrences of iron staining are logged by the IMCEFT during routine monitoring. Subsidence related iron staining typically occurs in watercourses that are directly mined under, or that are within 300 m of a mined longwall. The staining is usually caused by discharge of iron-rich groundwater (or redirected surface water) via surface fractures formed within or adjacent to watercourses. Figure 13 shows the locations of all reported instances of iron staining, with those reported during the recent longwall highlighted with larger symbols (and described in Section 3.2). Two minor iron staining occurrences on WC20 (LW21_021) and WC24 (LW21_020) are located at or within 100 m of the longwall footprint. A further two occurrences (LW21_035 and LW21_036) are located adjacent to Wongawilli Creek and ~570 m from the Longwall 21 footprint. At that distance, the latter two occurrences are unlikely to be directly related to Longwall 21 subsidence. They are located close to the previously described slope spring adjacent to Wongawilli Creek (LW17_031) which is described further below.

Photographs of the occurrences are included in the Landscape Report for Longwall 21. Notable continued occurrences (Wongawilli Creek and SC10C) are discussed further in the following subsections.

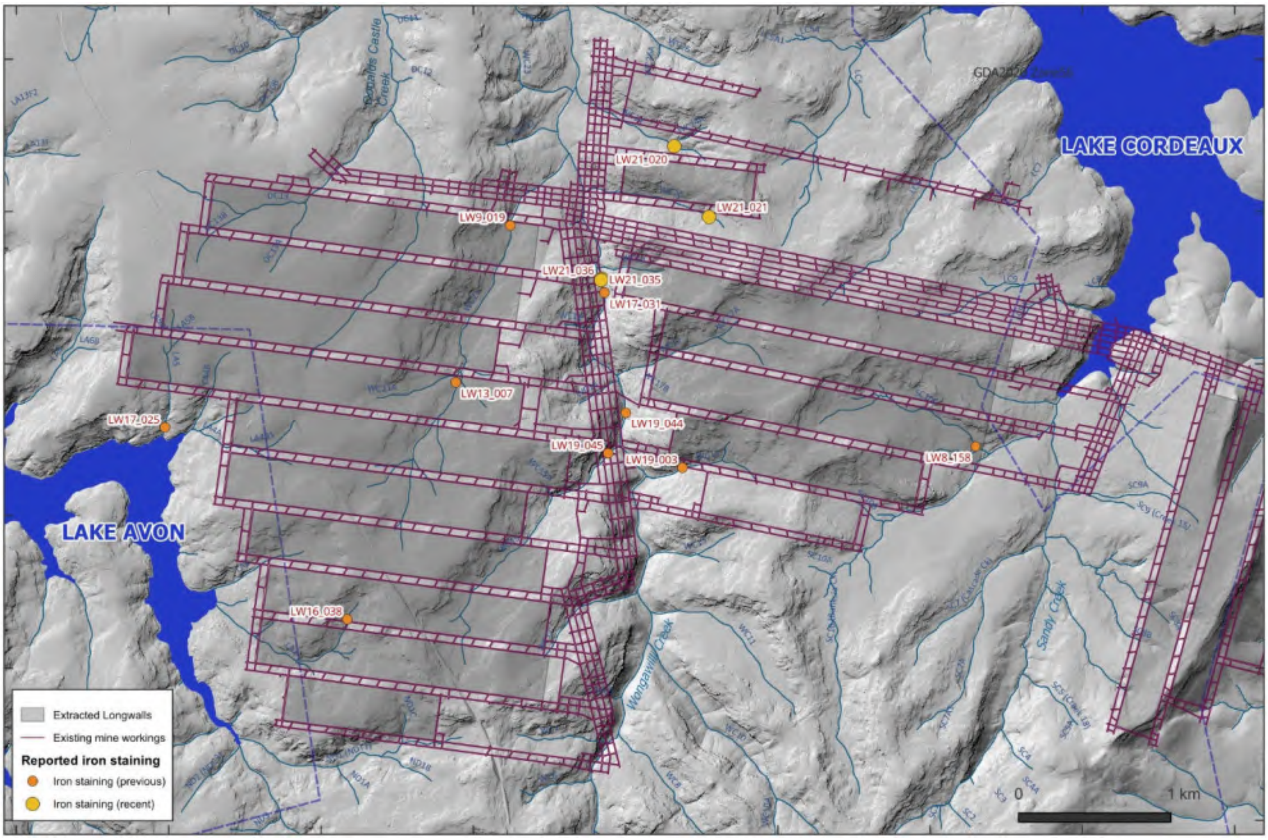

Figure 13. Reported occurrence of subsidence-related iron staining

4.4.1 Iron-staining in Wongawilli Creek (LW17_031)

In August 2021, an increase in iron staining (suspended iron floc) was observed along reaches of Wongawilli Creek adjacent to Areas 3A and 3B during routine monitoring. The observations were reported in an IMC impact report on 2/8/2021 (impact reference DA3B_LW17_031) and corresponded to a Level 3 TARP trigger. The cause if the iron staining was assessed and reported (HGEO, 2021b).

In September 2023, DPE received a complaint regarding iron staining in Wongawilli Creek and requested further information in relation to the occurrence. The complaint related to observations of suspended iron oxides along a similar stretch of the watercourse as was previously reported in 2021. In response to DPEs request, the IMC Environmental Field Team (IMCEFT) carried out field monitoring to assess the extent of the staining, in addition to routine monitoring in the catchment. Field observations are reported in the End of Panel Landscape report for Longwall 21. The cause of the recurrence of suspended iron floc in Wongawilli Creek was assessed and reported by HGEO (2023b). The main findings are as follows:

- As of September 2023, iron staining and suspended iron oxides are evident from WC_Pool 50, downstream to WC_Pool 20. The extent of iron staining has fluctuated but is less extensive in September 2023 than when it was first reported in August 2021.
- The main source of the iron is a slope spring adjacent to WC_Pool 50 with elevated concentrations of dissolved iron which flows into Wongawilli Creek. The spring reactivated in 2021 as a result of rising groundwater levels which was caused by higher-than-average rainfall between 2020 and 2022. Inspections carried out in October 2023 identified a further two iron seeps adjacent to WC_Pool 50 (Impacts LW21_035 and LW21_036).

- Episodes of suspended iron, characterised by orange coloured turbidity appear to be associated with spikes in dissolved iron concentration in WC_Pool 50. The spikes occur during periods of low rainfall when stream flow is low and there is less dilution of slope spring discharge.

- While iron staining can occur naturally from spring discharges, the extent of iron precipitation and staining is greater than that typically seen in natural springs and iron seeps. It is therefore possible that both the high flow rate and high iron concentration from the slope spring are partly due to groundwater flow through mine related fracture networks from approved mining in which there are relatively fresh reactive fracture surfaces.

- It is possible that slope spring discharges are facilitated by subsidence fracturing associate with Longwall 6 (mined between 9/2/2010 and 28/3/2011), with the impact becoming evident as the mining induced depressed groundwater repressurised and springs reactivated in 2021.

The report noted that, while iron staining and dissolved iron is generally not considered toxic to aquatic species, active iron precipitation may have other adverse impacts such as oxygen depletion, build-up of sediment/floc that may smother plants and habitats, and reduction in bioavailability of nutrients. It was recommended that IMC commission an independent assessment of the ecotoxic effects on aquatic flora and fauna due to elevated dissolved iron concentrations and associated iron precipitates in Wongawilli Creek.

4.4.2 Iron staining in Sandy Creek

Iron staining was first reported in SC10C (Pool 3) on 11 March 2013 after Longwall 8 mined beneath the watercourse (Impact reference LW8_158). The iron staining corresponds to the first detection of high dissolved Fe (13/3/2013; 15.6 mg/L) and followed two months of high rainfall. Iron staining was also observed downstream of the SC10 and SC10C confluence following the extraction of Longwall 8.

Iron staining persisted at SC10C_Pool3 through to 2020, generally localised to SC10C and SC10. Following high rainfall in 2020 the iron staining was reported by IMC as an update to impact LW8_158 (Report date 19/10/2020), extending downstream into Sandy Creek and to SCk_Rockbar5 and Sandy Creek waterfall. As of November 2023, there is evidence for residual iron staining at SCK_Rockbar5 and at Sandy Creek Waterfall; however, there is no sign of active iron precipitation, and the water appears clear and free of suspended iron floc. This is consistent with the observed decline in dissolved iron in SC10 during 2023 (Section 4.2.1).

4.5 Gas emissions at Wongawilli Creek, Pool 50

The IMCEFT reported a gas release in Wongawilli Creek at WC_Pool 50 on 18/1/2023. The release was observed originating from the base of a sandstone step on the western side of the pool. The emission was observed to be intermittent with smaller gas bubbles from the centre of the pool. Follow-up inspections were carried out on 1/2/2023 and 26/4/2023. The latest inspection was undertaken on 11/9/2023 during which one light and intermittent gas release was reported from the base of the same sandstone step. No releases were observed within the centre of pool.

A gas sample was collected on 1/2/2023 for laboratory analysis, which indicated mostly carbon dioxide and very low levels of methane. A water sample collected from WC_Pool50 on 26/4/2023 was analysed for dissolved gasses. Dissolved methane was present at a concentration of 43 µg/L and ethane was below detection (<10 µg/L). Methane occurs naturally in streams and wetlands and is produced by microbial activity during decomposition of organic matter (amongst other processes). Most methane is lost to the atmosphere, but low concentrations may be present in natural streams. It is not known to be harmful to aquatic life under natural conditions and the ANZECC Guidelines for Fresh and Marine water Quality have no Default Guideline Values (DGV) for methane.

The gas emission at Pool 50 is very minor and is considered to have negligible environmental consequences.

5. Assessment of surface water flow and pool levels

5.1 Performance Measures

Performance Measures have also been agreed and are documented in the WIMMCP. These are outlined in Table 8. The assessment of these is presented in Section 7.1.

Table 8. Area 3C Surface flow Performance Measures

DOMAIN	PERFORMANCE MEASURE	AGREED MEASURE
Areas 3A and 3B	Wongawilli Creek – minor environmental consequences	Assessment Methods C and D, to be compared against predictions made in contemporary groundwater modelling conducted to the satisfaction of the Secretary to assess whether effects that cannot be explained by natural variability "exceed prediction".
Area 3A	Sandy Creek – minor environmental consequences	Assessment Method C to be compared against predictions made in contemporary groundwater modelling conducted to the satisfaction of the Secretary to assess whether effects that cannot be explained by natural variability "exceed prediction".
Area 3A	Lake Cordeaux – negligible reduction in the quantity of surface water inflows to Lake Cordeaux	Surface water inflows calculation = [Impacts at gauged catchments (SCL2 + LC5 + LC6) + estimated impacts at ungauged but undermined catchments (e.g. LC9, LC4)] / [total inflow to LC].
Area 3B	Lake Avon – negligible reduction in the quantity of surface water inflows to Lake Avon	Surface water inflows calculation = [Impacts at gauged catchments (LA2 + LA3 + LA4 + NDT1) + estimated impacts at ungauged but undermined catchments (e.g. LA5)] / [total inflow to LA].
Areas 3A and 3B	Cordeaux River – negligible reduction in the quantity of surface water inflow to the Cordeaux River at Wongawilli Creek	Flow reduction as determined from measured flow gauging station WWL_A (or WWL, whichever gauge is being used).

5.2 Surface Water Flow TARPs

The surface water flow assessment and relevant TARPs have been developed in consultation with government agencies between 2018 and 2019 (Watershed HydroGeo, 2019). The revised TARPs form part of the Area 3C WIMMCP (South32, 2020).

This assessment of surface water flow relies on comparison against flows at Reference Sites, as recommended by the IEPMC (IEPMC, 2019, 2018). The agreed TARPs comprise 4 separate assessments (A to D), as follows:

Table 9. Surface water flow TARP assessment criteria

Assessment	Description	Measure and thresholds
A	Change in flow exceedance (percentile) behaviour compared to Reference Sites. Aims to quantify an otherwise visual or qualitative assessment of (normalised) flow behaviour compared with flow at Reference Sites.	Proportion of time with lower-than-expected flow percentile, relative to Ref Site flow percentile: Level 1: ≥ 10% Level 2: ≥ 15% Level 3: ≥ 20%
B	Relative change in the percentage of cease-to-flow days over a period, compared to that at Reference Sites. This assessment is focussed on changes that are likely to be significant to ecological values.	Change in cease-to-flow days between pre- and post-mining period at the gauge site, *beyond* that observed at the Ref Site:

Assessment	Description	Measure and thresholds
		Level 1: ≥ +5% Level 2: ≥ +10% Level 3: ≥ +20%
C	Relative change in median flow ("Q50") compared to Reference Site flows. Aims to assess change in the water resource potential of each sub-catchment. Note that the median us used rather than the average because the average flow is highly sensitive to the measurement uncertainty at high flow rates. The median is much less sensitive to the uncertainties associated with high flows.	Change in Q50 flow between pre- and post-mining period at the gauge site, *beyond* that observed at the Ref Sites: Level 1: ≥ +10% **See below. Level 2: ≥ +15% **See below. Level 3: ≥ +20%
D	Assess whether observed dry pools and 'cease-to-flow' conditions along Wongawilli Creek between WWU and WWL gauging stations are anomalous.	Two or more consecutive no-flow observations along Wongawilli Creek

See Watershed (2019) for further detail and examples of assessment methodology.

Note that for Assessment C (** in Table 9), if the assessment using reference sites does NOT trigger Level 3, then the gauge site should also be assessed against the simulated post-mining flow using a calibrated Rainfall Runoff model. In this case, the most conservative assessment prevails.

If any of these indicate an impact is likely to have occurred, then the EOP will describe the Impact as it relates to one or more of the broad hydrological behaviours, a reduction in the water resource Indicator, or an effect that could modify or impact upon the ecological values of the stream.
Assessment against surface water flow TARPs

TARP assessment D for flow conditions along Wongawilli Creek is presented in **Appendix H**. Results of the watercourse flow assessments for the Longwall 21 are presented in the following subsections.

5.3 Surface water flow assessment for Longwall 21

Note that, at the time of reporting, stream flow data for a key reference site (213200 O'Hares Creek @ Wedderburn) was not available from the WaterNSW web portal, nor through direct inquiry. Therefore Assessments A to C could not be completed as at the end of the Longwall 21 review period. The full flow assessment will be presented in the next EOP review, following completion of Longwall 19A.

5.3.1 Discussion of flow assessments A, B, C.

Assessment not possible due to lack of reference site data. Assessment deferred to the EOP Review for Longwall 19A.

5.3.2 Comparison against rainfall-runoff modelling

Assessment not possible due to lack of reference site data. Assessment deferred to the EOP Review for Longwall 19A.

5.4 Assessment D: flow reduction Wongawilli Creek

Field surveys typically make a qualitative observation of surface water flow conditions at many sites around Area 3A and 3B and Area 3C over the period of a month. The "Outflow" results of IMCEFT's surveys are plotted on the maps in **Appendix H** for each month during the period covering the extraction of Longwall 21. That appendix presents more of the details of the assessment.

As noted on the maps, observations are limited in two months during Longwall 19 (July and October-2022) due to the heavy rainfall conditions and catchment closures (Section **Error! Reference source not found.**).

While there are often “no flow” observations on the tributaries which flow into Wongawilli Creek, there are consistent observations of flow along Wongawilli Creek itself. Of the completed surveys, all months are “Not triggered”. As a result, the further calculation of Assessment D is not required.

Table 10. Assessment D for Wongawilli Creek: Longwall 21

During Longwall 21	Assessment D
May-2023, June-2023, July-2023, Aug-2023, Sep-2023	Not triggered
none	Catchment closed

Any inferred loss of flow from Assessment D is then used in assessing compliance against Performance Measures for Wongawilli Creek (Section 5.5).

5.5 Assessment against surface water flow Performance Measures

There are four agreed Performance Measures for surface water flows in the Area 3C WIMMCP.

Analysis of these could not be carried out due to the lack of data from the O’Hares Creek Reference Site.

5.6 Watercourse pool levels and outflow status

This section reviews the observed water levels and outflow status in pools that occur along watercourses that pass within the zone of influence (<400 m) of Longwall 21, and the previous Longwall 19 in Area 3A. Representative pools are monitored for water level and outflow status during each monitoring visit. Water level dataloggers are installed in key pools to supplement existing manual baseline water level measurements.

Pool outflow is summarised using “heatmap” plots showing observed flow status at each pool for monthly monitoring periods, with the passage or close approach of longwalls marked as lines. Pools are arranged from upstream (bottom of the plot) to downstream (top), a convention adopted simply because most watercourses in Area 3B flowed in a northerly direction. Observations of “no water in the pool” are overlain as “-“ symbols. Where more than one monitoring round was carried out in a month, the minimum condition was used in the figure. Grey cells represent periods during which no observations were made and usually reflects site access or extended catchment closures.

The Area 3A WIMMCP includes assessment of pool levels along Wongawilli Creek and Sandy Creek against prescribed TARP level thresholds as follows:

Level 1: Single pool on a subject Creek is observed as dry [when it is typically full].

Level 2: A single pool on a subject creek is observed as dry in consecutive monitoring events, or, two or more pools are observed as dry in a single monitoring event.

Level 3: Fracturing resulting in diversion of flow such that <10% of the pools have water levels lower than baseline period.

Exceeding Predictions: Fracturing resulting in diversion of flow such that >10% of the pools have water levels lower than baseline period.

A summary of current TARP levels is provided in Table 11. Further discussion relating to the assessment of pools is in the following subsections.

Table 11. Current TARP levels related to pools on subject creeks.

Creek	Total pools	Dry Pools*	Comments	TARP Level
Wongawilli Creek	124	0	A number of pools along Wongawilli Creek became dry during the severe 2017-2019 drought. Since 2020 all monitored, pools have returned to full and flowing status (Section 5.6.1.1)	None
Donalds Castle Creek	87	0	The third-order watercourse of Donalds Castle Creek is entirely outside the 400 m area of mining influence for Longwall 21. The upper reaches of Donalds castle Creek and DC13 were previously mined beneath by Longwalls 9 to 12 in Area 3B.	None for Area 3C

Note: * Dry pools are pools observed to be dry that are typically not dry under similar weather conditions.

5.6.1 Pools along Wongawilli Creek

Stream mapping by IMCEFT identified 124 pools along Wongawilli Creek, separated by various rock bars, channels and woody debris. Figure 14 provides an overview of outflow status for 34 monitored pools along Wongawilli Creek as a temporal heat map. Pools monitored for outflow status were observed to contain water and have observable flow during monitoring events from 2011 to late 2016. During the severe drought of 2017-2019 most pools were observed to cease to flow, and several became completely dry. Since 2020 all monitored, pools have returned to full and flowing status. There is no apparent change in pool status as a result of mining in Area 3B, Longwall 19 in Area 3A, or Longwall 21 in Area 3C.

Additional pools monitored with water level dataloggers are discussed in the following subsections.

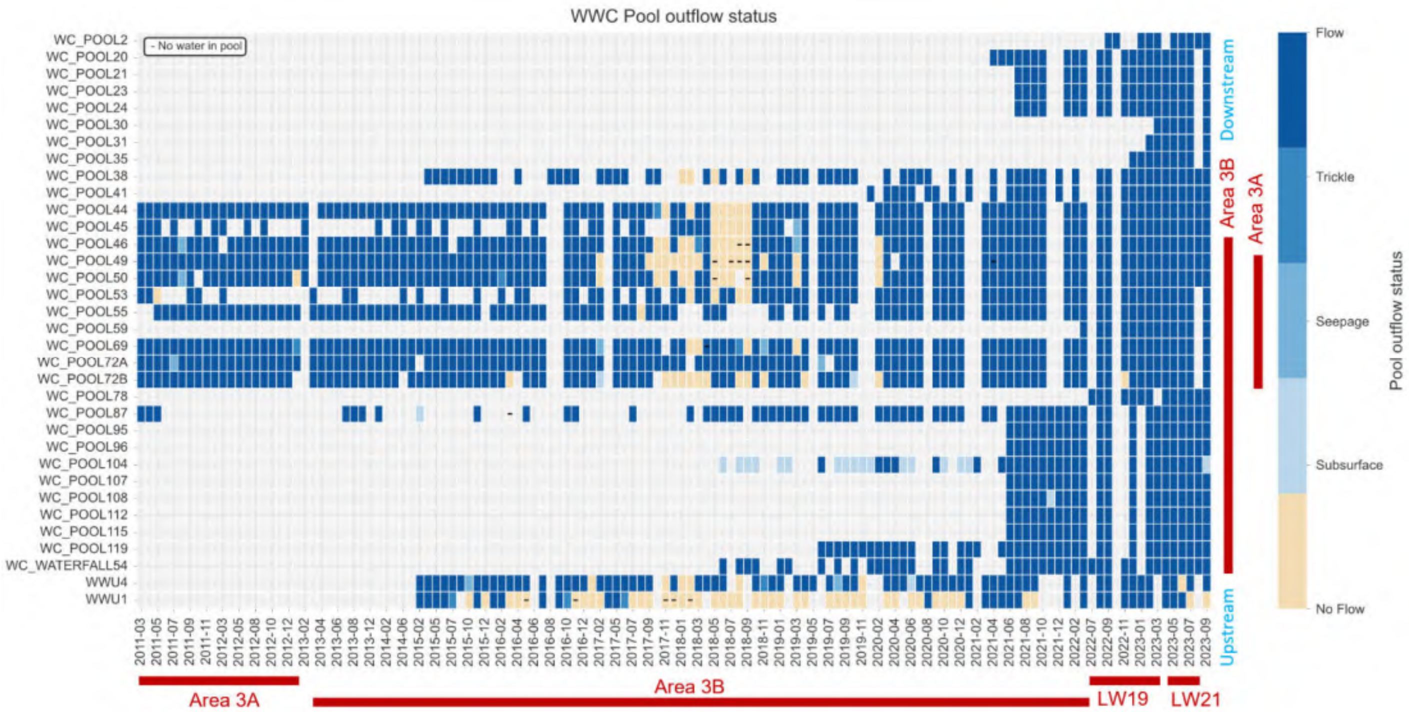

Figure 14. Flow status of pools on Wongawilli Creek

5.6.1.1 Wongawilli Creek Pool 50

WC_Pool 50 (previously Pool 43B) is located on Wongawilli Creek, 348 m east of Longwall 9 in Area 3B (extracted between 9/2/2013 and 2/6/2014) and 315 m northwest of Longwall 6 in Area 3A (9/2/2010 - 28/3/2011). Pool 50 is controlled by a rock bar. On 20/11/2017, it was noted during a site visit that water levels in Pool 50 on Wongawilli Creek were below the baseline (impact number DA3B_LW13_015, dated 28/11/2017). The observation triggered a TARP Level 3 because a previously reported fracture (first observed on 18/12/2013) is present in the sandstone forming the pool base. No significant changes to the downstream control were noted by the IMCEFT at Pool 50.

An assessment was carried out into the cause of the declining water levels in Pool 50 by Watershed (2018). The assessment concluded that the decline in pool levels was likely due to depressurisation of the underlying formations (HBSS and BGSS; Figure 16) due to mining adjacent to the creek, exacerbated by the very low rainfall and flow conditions during the 2017-2019 drought. The decline in pool levels started prior to the formation of the fracture (Figure 15) suggesting that water loss from the pool was not directly related to the formation of the fracture.

Piezometric levels in the sandstone substrate adjacent to Wongawilli Creek have recovered as mining in Area 3B has moved south and away from Pool 50 (Figure 16). Since 2021, piezometric levels in the HBSS adjacent to the pool have recovered to above the elevation of the creek bed. Water levels in Pool 50 trended higher between 2019 and 2022 in response to both higher rainfall conditions and recovering groundwater levels, peaking at ~0.1 m below pre-mining levels in 2022. Pool 50 water levels have declined slightly in early 2023 in response to drier conditions.

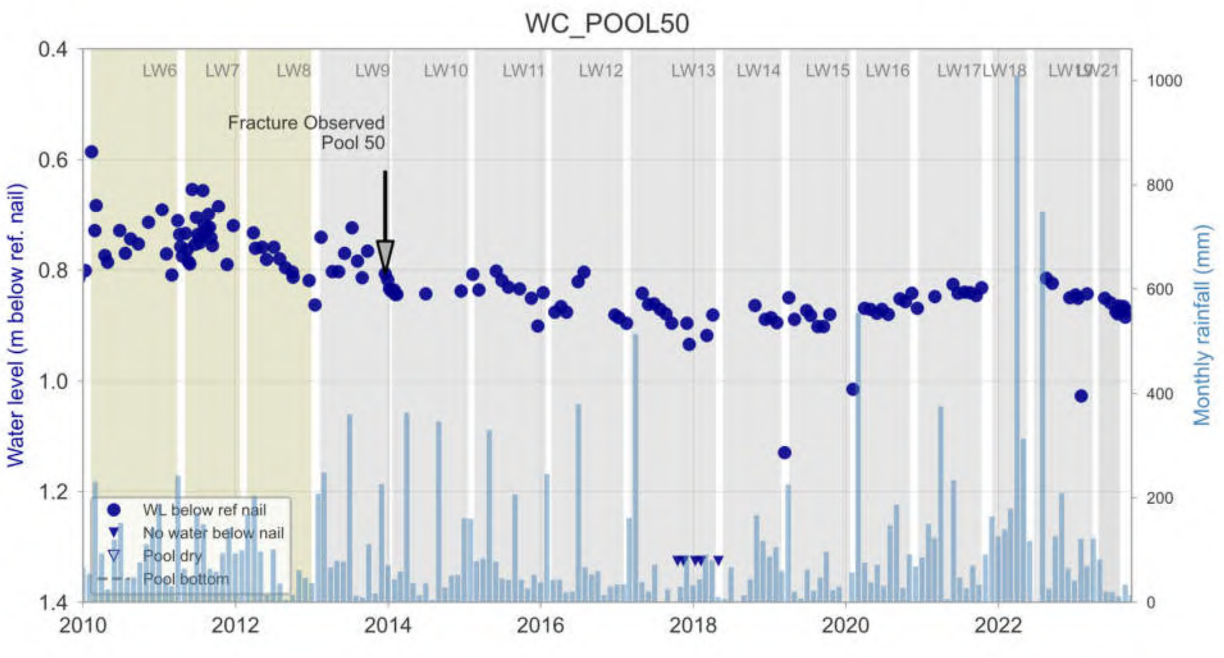

Figure 15. Time series plot of water level observations in Pool 50

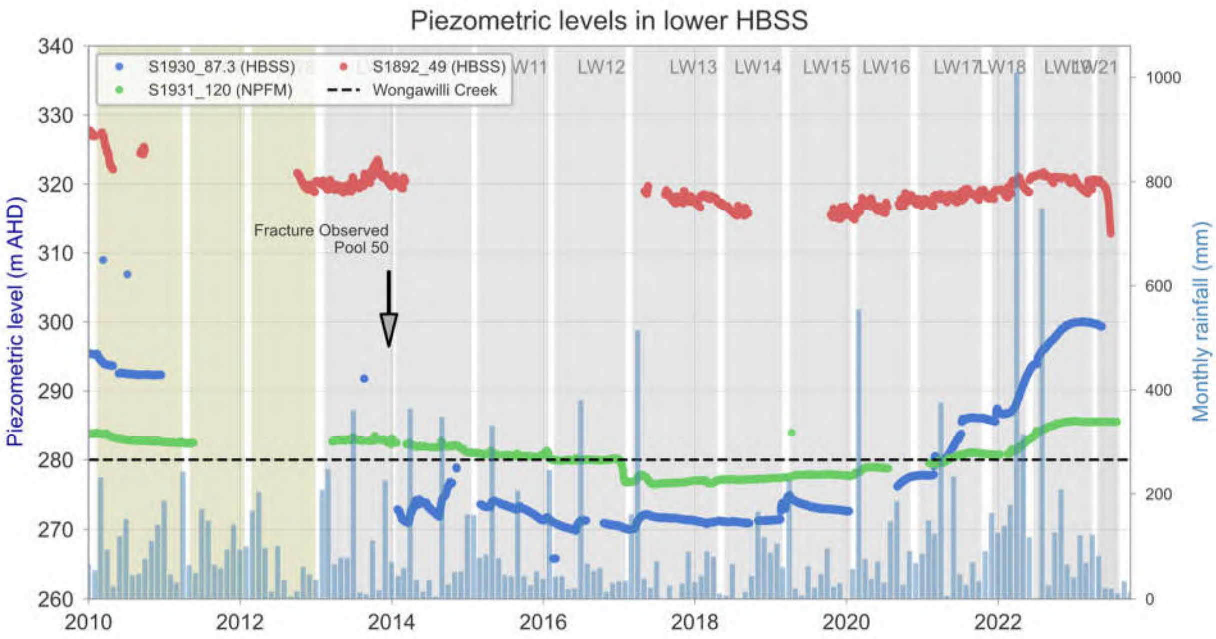

Figure 16. Groundwater hydrographs for lower HBSS adjacent to Wongawilli Creek

5.6.1.2 Pool level dataloggers in Wongawilli Creek

Pool level dataloggers are installed in 15 pools along Wongawilli Creek adjacent to Areas 3A, 3B and 3C, including the upstream site WWU. The dataloggers measure the water level at hourly intervals relative to a surveyed benchmark at the respective sites. Hydrographs for the loggers are included in Appendix F. Most of the loggers were installed after 2020 and therefore have limited baseline data, their main function being to supplement manual level measurements, which have a longer monitoring baseline, with higher frequency data.

In general, the loggers record declining levels during 2023 in response to dry conditions. Pools 45 and 49 are located within 400 m of Longwall 21 (as indicated on the hydrographs). No adverse trends related to mining are evident as of the end of the current reporting period.

5.6.2 Pools on Wongawilli Creek tributaries in Area 3C

Longwall 21 passed within 400 m of Wongawilli Creek tributary WC24 and passed directly beneath part of WC20 (Table 3). The flow status of monitored pools on both watercourses is summarised in (Figure 17). There was no significant change in the outflow status in monitored pools on WC24 following the extraction of Longwall 21. The pool at WC20_Rockbar17 became dry following passage of Longwall 21 beneath the watercourse. Surface cracking and flow diversion are expected in watercourses that are directly mined under (MSEC, 2019).

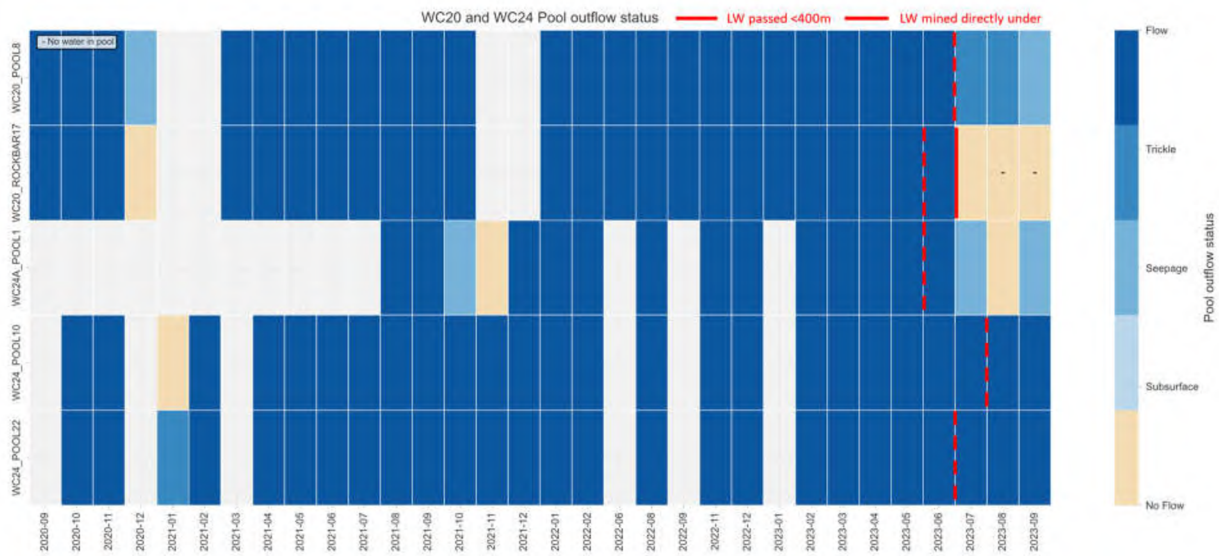

Figure 17. Flow status of pools along Wongawilli Creek tributary WC24

5.6.3 Pools on Lake Cordeaux tributaries in Area 3C

Four watercourses overlap with the mining area of influence associated with approved longwalls in Area 3C: LC5, LC6, LC7 and LC9. Longwall 21 did not pass directly under any Lake Cordeaux tributaries, however, approved Longwalls 22 and 23 will pass directly beneath LC5 and LC6, affecting pools along their middle reaches. A total of 18 major pools are monitored on a routine basis. The outflow status of monitored pools is shown as a heatmap in Figure 18. The figure shows that the majority of monitored pools recorded no-flow or were dry during August and September 2023 following Longwall 21, contrasting with baseline conditions.

It is unlikely that the occurrence of dry pools in August and September is related to mining for two reasons: Firstly, only one monitored pool on LC5 is located within the mining area of influence for Longwall 21 (LC5_Pool26). All others are located well-beyond the area of mining influence for Area 3C and other mining areas. Secondly, the baseline period for most pool sites coincides with a period of above average rainfall between 2020 and 2022 which is unrepresentative of the dry conditions experienced during 2023. The pools that remained full are those located in the lower reaches of each watercourse that are model likely to receive baseflow from groundwater discharge.

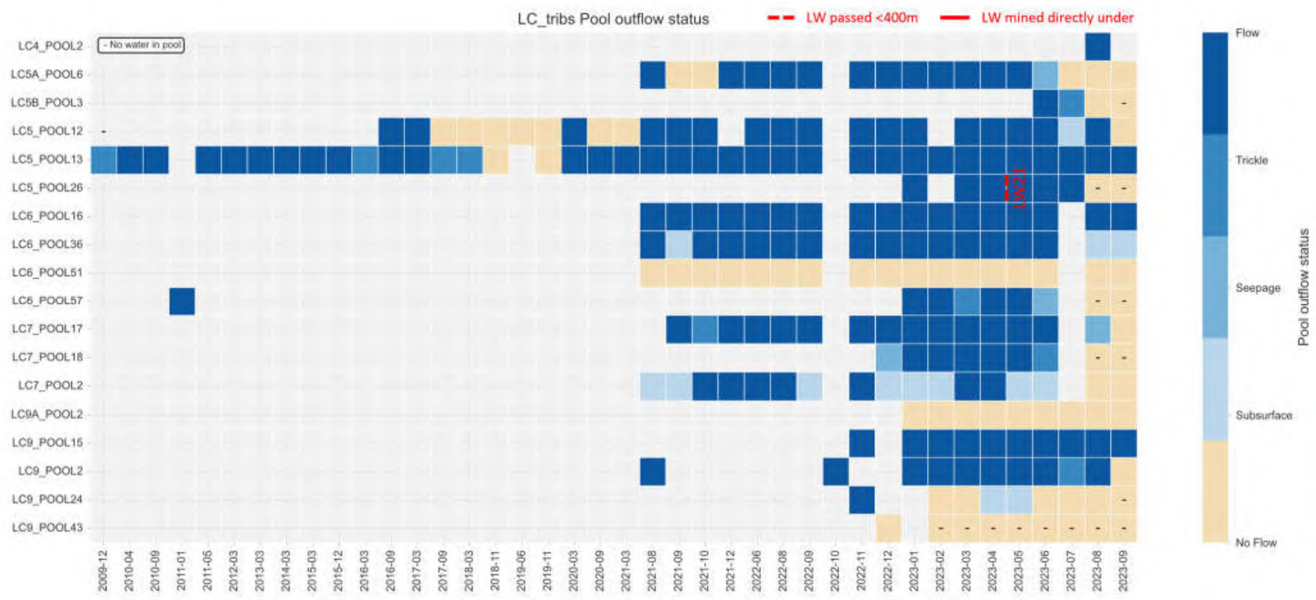

Figure 18. Flow status of pools along LC tributaries

5.6.4 Pools along tributary SC10

SC10 is a major second-order tributary to Sandy Creek which flows northward to join Sandy Creek at SCK_Pool 6. There are 39 mapped pools along the main second-order watercourse of SC10, separated by rock bars and channels. Figure 19 shows that all monitored sites except Pool 29 have remained full and flowing since 2020. As of September 2023, there are no apparent changes to outflow status following Longwall 19, nor previous mining at Area 3A.

Water level dataloggers are installed at five pools along SC10 (SC10_Pool 11, 14, 23, 26a and 29). With reference to the hydrographs in Appendix F, no anomalous water level variations are noted in Pools 11, 14 and 23 associated with Longwall 19, or following its completion. The hydrograph for Pool 26a shows erratic declines in water level and increased recession rate compared with the other three pools, from late 2023. Water levels recovered at the pool before declining in late 2023 in response to low rainfall conditions. There is insufficient baseline data at Pool 26a to determine whether the observed water level changes are related to Longwall 19.

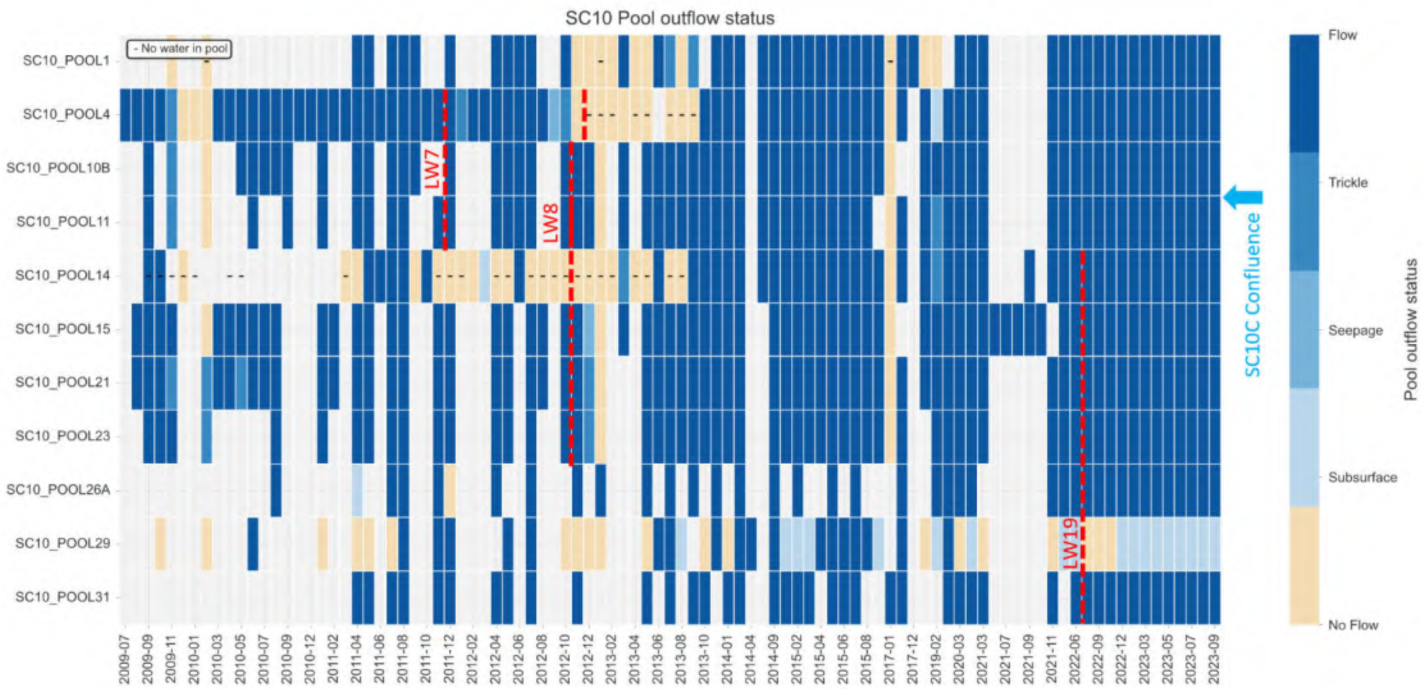

Figure 19. Flow status of pools on the SC10 watercourse

6. Assessment of swamp hydrology

The TARP for swamps in Area 3C is aligned with the performance measures defined in the SMP approval of Longwall 21 and is designed to assess performance with respect to:

a) Erosion of the surface of the swamp

b) Hydrology of the swamp

c) Size of the swamp

d) Ecosystem functionality

e) Structural integrity of controlling rock bars and permanent pools

TARP triggers are defined within the Swamp Impact Monitoring Management and Contingency Plan (SIMMCP) for Longwall 21 (2020c). Shallow groundwater levels and soil moisture levels have been identified as important indicators of hydrological and ecosystem functionality of the swamps. Performance in relation to the hydrological function of the swamps is assessed in the subsections below. Other indicators of ecosystem functionality such as swamp size and species richness are assessed in a separate special report by Niche consulting.

Performance measures for Area 3C relate to four swamps that lie outside the areas that will be directly mined beneath by Longwalls 21 to 23, as listed in Table 12:

Table 12. Swamps in Area 3C

Swamp	Area (ha)	Vegetation communities	Performance measures*	Monitoring	
				Shallow GW	Soil Moisture
Swamp 9	0.79	Banksia Thicket, Tea Tree Thicket	Yes	09_01 09_02	S09_S01 S09_S02
Swamp 144	0.54	Banksia Thicket	Yes	144_01	S144_01
Swamp 145	0.41	Banksia Thicket	Yes	145_01	S145_01
Swamp 154	0.40	Banksia Thicket	Yes	154_01	S154_01
Swamp 7	4.87	Banksia Thicket, Tea Tree Thicket	No	07_05, 07_06 07_07	S07_S05, S07_S06 S07_S07
Swamp 16	3.75	Banksia, Tea Tree Thicket, Sedgeland-Heath Complex	No	-	-
Swamp 155	0.50	Banksia Thicket	No	-	-
Swamp 156	0.71	Banksia Thicket	No	-	-
Swamp 157	0.12	Tea Tree Thicket	No	-	-

Note*: performance measures are defined for swamps outside the areas that will be directly mined beneath. Impacts at swamps that are directly mined beneath are subject to environmental offsets.

6.1 Surface erosion

The performance measure requires that there is negligible erosion of the surface of the swamp. Performance triggers relate to an observed increase in the length of gully (or other) erosion within the swamp, compared with pre-mining conditions. An increase in erosion may manifest as the activation or re-activation of a gully knickpoint within the swamp and may originate from surface cracking associated with subsidence. The TARP trigger level is dictated by the length of the erosional feature relative to the swamp size or length.

Surface impacts related to subsidence are summarised in Section 3.2. **No surface impacts, including increased erosion were identified within Area 3C swamps during the review period**.

6.2 Structural integrity of controlling rock bars and permanent pools

The performance measure requires maintenance or restoration of the structural integrity of the bedrock base of any significant permanent pool or controlling rock bar within the swamps. Performance triggers related to observations of cracking of the bedrock or controlling rock bar which results in a loss of surface water from the pool. The loss of water is assessed as the percentage decrease in water level relative to the base of the pool, compared with baseline conditions, in addition to any decrease observed at reference pools. The TARP trigger level is dictated by the percentage decrease in water level and the length of time over which the decrease occurs (as a percentage over 1 year).

Swamp 09 consists of two areas of Banksia and Tea Tree Thicket within and near the LC5 valley bottom. The watercourse crosses the northern portion of the swamp which is formed up-stream of LC5_Rockbar 13. It is assumed that rock bar 13 is a controlling rock bar for the swamp, however no permanent pools are mapped along the watercourse within the swamp. Swamps 144 is an area of banksia Thicket formed on a sandstone step in the headwaters of WC20. It has no mapped permanent pools and is not hydraulically controlled by a rock bar. Swamps 145 and 154 are areas of banksia Thicket formed on mid-slopes. Neither swamp is associated with a mapped watercourse and contain no permanent pools.

Table 13. Assessment of structural integrity of rock bars and pools within swamps

Swamp	Controlling rock bar	Permanent pools	Impacts
Swamp 09	Swamp is upstream of LC5_Rockbar13	Watercourse LC5 passes through part of the swamp; No permanent pools mapped.	None observed
Swamp 144	None	Headwater swamp to WC20 watercourse; No permanent pools mapped.	Iron staining reported on WC20, northwest of swamp (LW21_021); No other impacts.
Swamp 145	None	No permanent pools	None observed
Swamp 154	None	No permanent pools	None observed

6.3 Shallow groundwater level and recession rate

Shallow groundwater level is identified as an indicator of potential changes in ecosystem functionality of swamps. TARPS are defined in Table 14.

Table 14. Performance criteria for shallow groundwater levels

TARP Level	Criteria	Response
1	Groundwater **level** lower than baseline level at **any** monitoring site within a swamp (in comparison to reference swamps); and/or; **Rate** of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at **any** monitoring site (measured as average mm/ day during the recession curve).	Increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars
2	Groundwater **level** lower than baseline level at **50%** of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps); and/or **Rate** of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at **50%** of monitoring sites (within 400 m of mining) within the swamp.	
3	Groundwater **level** lower than baseline level at **>80%** of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps); and/or **Rate** of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at **>80%** of monitoring sites (within 400 m of mining) within the swamp.	

Groundwater level hydrographs for each shallow piezometer are presented in **Appendix D**. The hydrograph is plotted together with ground elevation and the elevation of the piezometer base, longwall timing, groundwater level recession rate (in mm/day), and the dates that longwalls pass under (if relevant) or within 400 m of a piezometer. Assessment of mining effects is based on these hydrographs.

A summary of hydrograph responses and cumulative effects at Areas 3A and 3B swamps is included in Table 17 for Impact Sites. In accordance with the definition of the TARPs, the sites within 400 m of mining *and* within the mapped swamp areas are assessed for triggers related to mining impacts.

An overview of shallow groundwater levels and cumulative effects is shown in Figure 20 and Figure 21 as the monthly median % saturation at each reference and impact swamp piezometer. The % saturation is calculated as the level of groundwater within the swamp piezometer relative to the total thickness of the sediments at that location (from base of the piezometer to the ground surface).

6.3.1 Reference swamp sites

IMC maintains shallow groundwater monitoring sites at reference swamps located well outside the mining zone of influence. Those sites provide an important comparison when assessing swamp sites closer to the mine for possible shallow groundwater impacts. Shallow groundwater at all reference sites recovered after the 2017-2019 drought as a result of higher-than-average rainfall between 2020 to 2022. Drying conditions in 2023 resulted in a decline in shallow groundwater levels in several reference swamps, with some reference swamps recording near-zero saturation in late 2023.

A review of shallow groundwater hydrographs for reference swamps in Appendix D (and evident in Figure 20) indicate two main hydrological end-member types:

1. Near-continuously saturated swamp sediments. Examples include Swamps 22 and 25 (and Swamp 7 prior to Area 3C commencement). Swamp sediments at these locations remain

saturated during periods of prolonged drought. It is assumed that at these locations, groundwater levels within the swamp are sustained by discharge from adjacent and underlying sandstone substrate (groundwater-connected swamps).

2. Intermittently saturated swamp sediments. Examples include Swamps 33, 84, 85, 86 and 88. Swamp sediments at these locations saturate, typically to the ground surface, following large rainfall events and remain saturated for several weeks to months as shallow groundwater levels recede to below the base of the swamp. The duration of saturation and rate of recession vary between locations and likely depend on the characteristics of the swamp substrate, controlling rock-bar and contributions from adjacent or up-gradient perched sandstone aquifers. It is assumed that at these locations, the swamp sediments are likely perched above the water table in the sandstone substrate.

Continuously saturated locations tend to be within deep valleys (valley-fill) where adjacent ridges rise ≥ 50 m above the swamp level. Intermittently saturated swamp locations tend to reside in shallow valleys where the adjacent ridges rise ≤ 20 m above the swamp level (typical of headwater swamps) or occur on shallow swamp sediments on sandstone slopes that receive intermittent interflow.

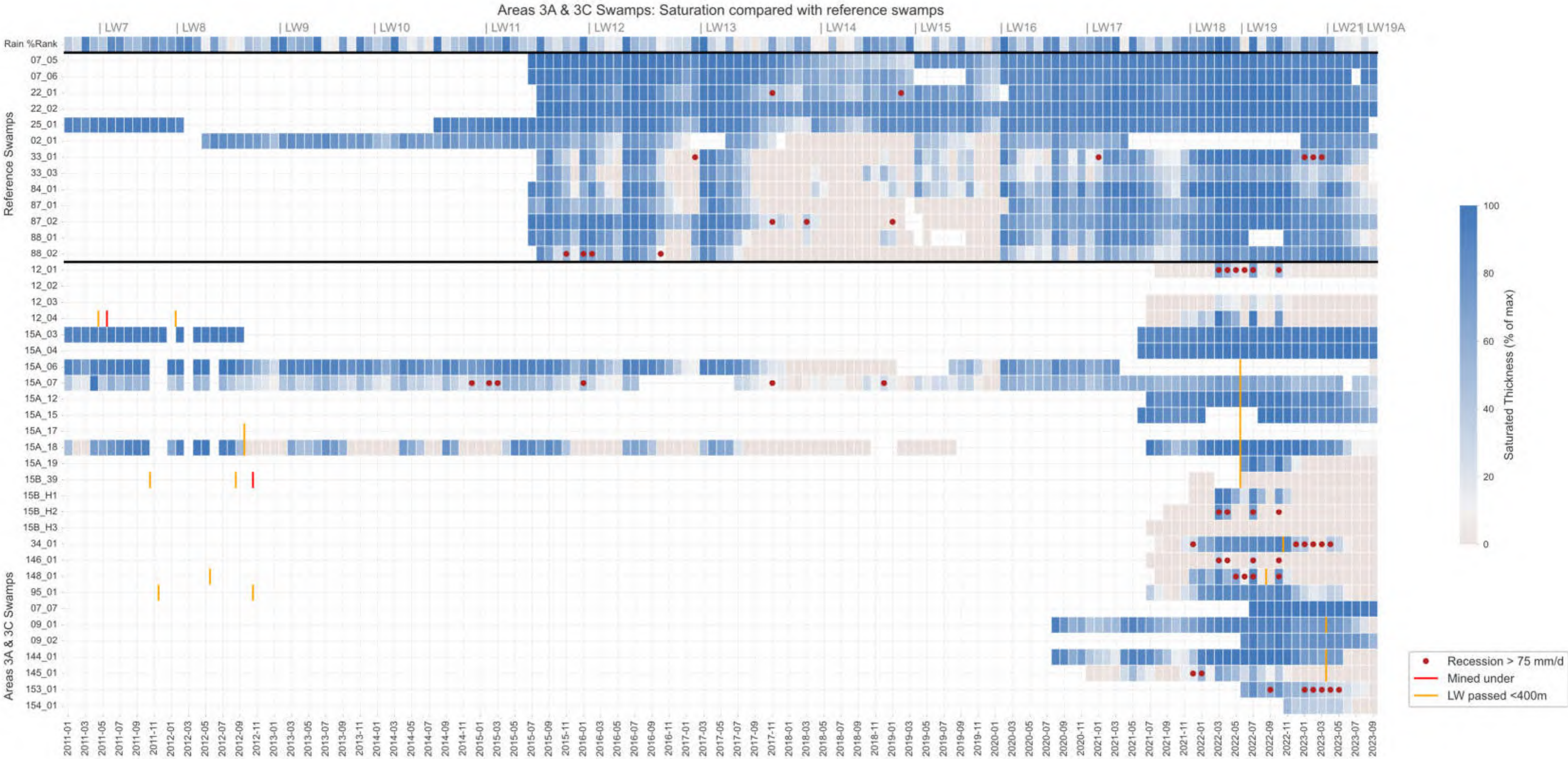

Figure 20. Overview of swamp saturation levels by month, Areas 3A and 3C

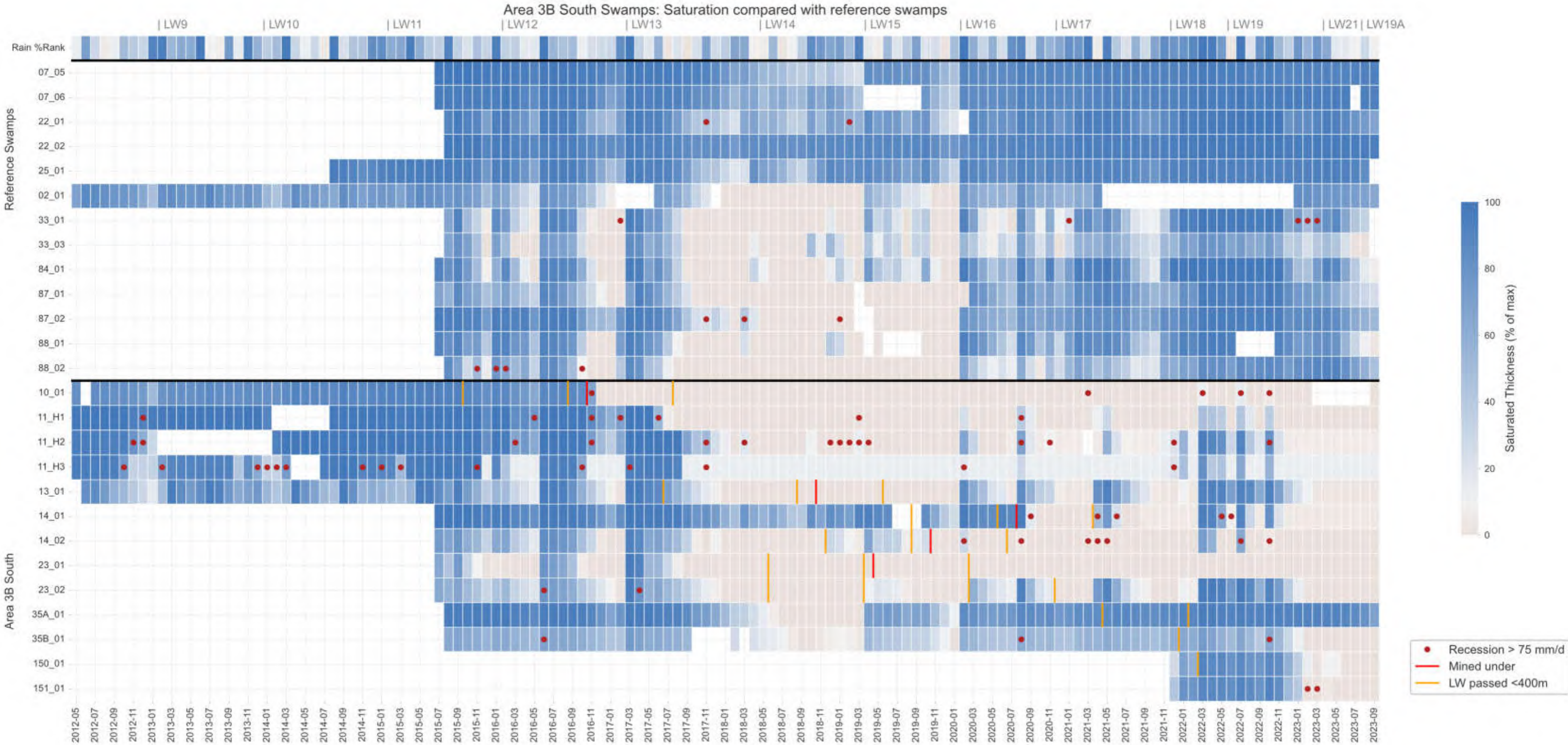

Figure 21. Overview of swamp saturation levels by month, Area 3B South

6.3.2 Impact swamps – Longwall 21

Swamps and swamp piezometers that are located within 400 m of Longwall 21 are listed in Table 15. The table summarises shallow groundwater observations with reference to the saturation heat maps in Figure 20 and Figure 21, and the shallow groundwater hydrographs presented in Appendix D. A TARP trigger level is assigned by comparing saturation levels, shallow groundwater level trends and recession rates with baseline data and reference swamps as describe in previous sections.

Table 15. Assessment of shallow groundwater levels at Area 3C swamp sites

Swamp	Piezo-meter	Closest distance (m)	Date of closest approach	Date LW passed <400 m	Observations GWL: Groundwater level RR: Recession rate	TARP trigger
09	09_01	367	25/4/2023	25/4/2023	Lowest recorded GWL in Sept 2023; No change in RR.	**Yes**
	09_02	341	25/4/2023	25/4/2023	Lowest recorded GWL in Sept 2023; No change in RR.	**Yes**
144	144_01	113	21/5/2023	25/4/2023	Longwall 6 passed within 400 m on 3/5/2010. GWL dropped below base of piezometer in July 2023; No change in RR	**Yes**
145	145_01	348	25/4/2023	25/4/2023	Longwall 6 passed within 400 m on 10/6/2010. GWL below piezometer base since April 2023; no change in RR	**Yes**

GWL = Groundwater level; RR = Groundwater level recession rate

All swamp piezometers recoded a decline in shallow groundwater level in mid to late 2023 to levels below their pre-Longwall 21 baseline. Recession rates remained consistent with those observed during the baseline. The observed declines in groundwater level relative to the baseline **technically trigger Level 3 TARPs at all Area 3C swamps within the mining area of influence of Longwall 21**.

It is unlikely that all of the observed declines in groundwater level during Longwall 21 and the associated TARP triggers are mining effects. The reasons for this interpretation are as follows:

- All swamp piezometers except for 144_01 are located more than 300 from the goaf footprint. Based on subsidence modelling and empirical data from Dendrobium, surface fracturing and impacts to shallow groundwater levels are very unlikely at that distance, although not impossible (MSEC, 2019; Watershed HydroGeo, 2021).

- Swamp piezometers located well-beyond mining influence (>400 m) such as 154_01 and 153_01 show a similar decline in groundwater level below baseline levels. Swamp 154 is located 1.5 km from Longwall 21 and 1.3 km from previously mined Longwall 6. There are no mapped lineaments or faults that could provide a potential hydraulic connection between those swamps and mined longwalls. The observed effects at those locations are therefore unrelated to mining.

- Swamp piezometers in Area 3C have a limited baseline that largely coincides with the very high rainfall period between 2020 and 2023. Reference sites have much longer baseline periods that include several dry periods including the severe drought between 2017and 2019. The TARP triggers therefore reflect drought conditions following a very wet baseline.

- At all sites, observed recession rates are similar to baseline and do not show the anomalously high recessions that are characteristic of mining impacts.

In summary, shallow groundwater levels declined to levels below baseline at all piezometers in Area 3C, triggering Level 3 TARPs. However, based on the distance from the longwall and comparison with reference sites, the declines at most sites are unlikely to be related to mining. Piezometer 144_01 is located 113 m from Longwall 21 and there is a slightly higher likelihood that the effects may be mining related at that location. Given the relatively short period of monitoring data available and dry conditions during Longwall 21, it is recommended that the swamps be re-evaluated as part of the next End of Panel assessment. Ideally the re-evaluation should be carried out over a period of average rainfall conditions.

6.3.3 Impact swamps – Longwall 19 review

As highlighted above, assessment of mining impacts associated with a recent longwall can be uncertain given the limited timeseries data available and the potentially delayed effects of mining on swamp hydrology. In this section, swamp piezometers that are located within 400 m of the previous longwall (Longwall 19) are reassessed using additional data.

Table 16. Assessment of swamp sites within Longwall 19 influence

Swamp	Piezo-meter	Closest distance (m)	Date of closest approach	Date LW passed <400 m	Observations GWL: Groundwater level RR: Recession rate	TARP trigger
12	12_04	398	12/3/2023	12/3/2023	Previously mined beneath by Longwall 7 (2/6/2011); Impacted previously	Previous
15A	15A_07	168	17/7/2022	20/6/2022	GWL and RR consistent with previous and reference sites	No
	15A_12	172	20/6/2022	20/6/2022	GWL declined below baseline (BL from 7/2023); RR consistent with previous.	**Yes**
	15A_15	298	13/7/2022	20/6/2022	GWL declined below baseline (BL from 7/2023); RR consistent with previous.	**Yes**
	15A_18	275	20/6/2022	20/6/2022	Intermittent saturation previously; no evidence for change in saturation behaviour	No
	15A_19	70	11/7/2022	20/6/2022	GWL dropped below piezo base on 31/12/2022 and has not recovered. RR elevated following LW.	**Yes**
15B	15B_H1	248	4/9/2022	19/7/2022	Previously mined beneath by Longwall 8 (21/8/2012). Impacted previously	Previous
	15B_H2	357	1/8/2022	10/7/2022	Longwall 8 passed within 10 m (24/9/2012). Impacted previously	Previous
	15B_H3	343	16/7/2022	20/6/2022	Previously mined beneath by Longwall 8 (8/10/2012). Impacted previously	Previous
	15B_39	175	20/6/2022	20/6/2022	Previously mined beneath by Longwall 8 (13/11/2012). Impacted previously	Previous
148	148_01	38	5/12/2022	24/9/2022	GWL dropped below piezo base on 20/11/2022 with no significant saturation since. RR elevated prior to	**Yes**
34	34_01	361	29/11/2022	2/11/2022	Shallow groundwater saturation behaviour and recessions similar to previous.	No

Given their proximity to Longwall 19 and the observation of elevated recession rates in addition to a decline in groundwater level, piezometers 15A_19 and 148_01 are likely related to mining effects. Declines in groundwater level at 15a_12 and 15a_15 are not accompanied by changes in recession rates and, at distances greater than 160 m from the longwall, are most likely related to drought condition in 2023.

Table 17. Summary of cumulative shallow groundwater effects and TARP status at *Impact Sites*

SWAMP	TARP SITES	RELEVANT LONGWALLS	PIEZOMETERS WITH AN OBSERVED RESPONSE			OBSERVED BEHAVIOUR	COMMENT	TARP LEVEL
			YES	UNCLEAR OR >400M	NO			
01a	6	Longwall 9, Longwall 10	01, 04, 04i, 04ii, 04iii, 04iv, 04v		02	Groundwater levels lower than baseline and recession rate greater than baseline at greater than 50% to 90% of monitoring sites	Limited baseline data for five piezometers.	Level 3
01b	5	Longwall 9	02, 02iii	02ii, 02iv	01	Groundwater levels lower than baseline and recession rate greater than baseline at greater than 50% of monitoring sites.	Limited baseline data for five piezometers	Level 2
03	1	Pillar 11/12	01			Possible increase in recession rate and apparently reduced response to rainfall after Longwall 11 passed and Longwall 12 undermined.	Rapid recession after rain during Longwall 13 supports impact at Swamp 3	Level 3
05	6	Longwall 9, Longwall 10, Longwall 11	01, 02, 03, 03ii, 04	05		Groundwater levels lower than baseline and recession rate greater than baseline at >80% of monitoring sites	Unclear if piezometer 5_05 impacted by either Longwall 11 or 12 due to limited baseline.	Level 3
08	0	Longwall 9, Longwall 10 Longwall 11	*01, 04, 02*			Groundwater levels lower than baseline and recession rate greater than baseline at a number of piezometers, not within swamp boundary.	Outside swamp boundary (Not subject to TARP)	n/a
09	2	Longwall 21	01, 02			Shallow groundwater levels dropped lower than baseline following the end o Longwall 21. ; recession rates similar to baseline.	Both piezometers within 400 m of Longwall 21.	**Level 3**
10	1	Longwall 12	01			Sharp decline in groundwater levels below base of the piezometer after Longwall 12. Level and rate of decline anomalous compared with baseline.	Mined under by Longwall 12	Level 3
11	3	Longwalls 13-14	H1, H2, H3			All three piezometers show mostly desaturated conditions following the passage of Longwall 14 with only brief periods of saturation following rainfall events.	Partially mined under by Longwall 13 and by Longwall 14	Level 3
12	3	Longwalls 6-8, 19	01, 03, 04			All three piezometers show low levels of saturation compared with reference swamps after being directly mined under by Longwall 7.	Mined under by Longwall 7	Level 3
13	1	Longwalls 13-14	01			Groundwater level below the piezometer base since early 2018; Impact apparent as of Longwall 15. Swamp re-saturated 2020-2021 but not to the same level as previously.	Partially mined under by Longwall 13 and by Longwall 14	Level 3

14	2	Longwalls 15-18	01, 02			Evidence for impact to swamp groundwater levels at 14_01 and 14_02 following Longwalls 16 and 15 respectively. Effects confirmed in post-Longwall 17 assessment. No further effects related to Longwall 18.	Partially mined under by Longwalls 15, 16 and 17	Level 3
15a	7	Longwall 8, 19	19	03, 04,	07, 12, 15, 18	Evidence for impact at 15a_19 following extraction of longwall 19.	Located 70 m from Longwall 17	Level 1
15b	4	Longwall 7,8,19	H1, H2, H3, 39			All four sites show evidence for impact; low saturation levels and high recession rates compared with reference sites. Impacts associated with Longwall 7.	Most of swamp directly mined under by Longwalls 7 and 8	Level 3
23	2	Longwalls 15-17	01, 02			Evidence for impact to swamp groundwater levels and duration of saturation at 23_01 and 23_02, following passage of Longwalls 15 and 16.	Partially mined under by Longwall 15, passed within 400 m by Longwalls 16 and 17.	Level 3
35a	1	Longwalls 17,18			01	No evidence of mining effects from Longwall 17 or 18.	Longwall 18 overlapped the northern fringes of the swamp	n/a
35b	1	Longwall 18	01			Increase in recession rate following passage of Longwall 18; Shallow groundwater levels below expected in early 2023 compared with previous and reference sites	Longwall 18 passed ~108 m from 35b_01.	Level 3
144	1	**Longwall 21**	144_01			Shallow groundwater levels and recessions consistent with previous and reference sites		**Level 3**
145	1	**Longwall 21**	145_01			Shallow groundwater levels and recessions consistent with previous and reference sites		**Level 3**
146	1	Longwall 6, 7	01			Site shows low levels of saturation and high recession rates compared with reference sites indicating impacts associated with Longwall 7, prior to installation of the piezometer.	Site directly mined under by Longwall 7 before installation.	Level 3
148		Longwall 19	01			WL dropped below piezo base on 20/11/2022 with no significant saturation since despite moderate rainfall in March 2023.	Longwall 19 passed within 38 m of 148_01	Level 3
149	0	Longwalls 17, 18			-	No shallow groundwater monitoring due to shallow soil profile. Swamp likely to be affected.	Longwall 17 passed directly beneath swamp.	n/a
150	1	Longwall 18			150-_01	Piezometer installed in 2021; Decline in groundwater levels at 150 in 2023 likely related to dry conditions in this perched swamp.	Longwall 18 passed within 281 m of Swamp 150_01.	n/a
151	1	Longwall 18		151_01		Piezometer installed in 2021	Longwall 18 passed within 436 of Swamp 151_01.	n/a

154		**Longwall 21**	154_01			Shallow groundwater levels and recessions consistent with previous and reference sites		n/a

Note: " i " in site name (e.g. 04i) indicates installation during Longwall 9 extraction. * at these swamps which are located away from active or recent mining areas the data has been logged (recorded) at the piezometer, but not collected since that time.

6.4 Soil moisture

Significant change in soil moisture characteristics compared with baseline monitoring is identified as an indicator of potential changes in ecosystem functionality of the swamps. Response trigger conditions related to soil moisture at swamp monitoring sites are listed in the SIMMCP (South32, 2020d), and reproduced in Table 18.

Table 18. TARP trigger conditions related to soil moisture at swamp monitoring sites

TARP Level	Trigger conditions	Response
1	Soil moisture level lower than baseline level at **any** monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps).	Increased intensity and frequency of vegetation monitoring and/or further investigations of subsidence impacts on bedrock base and rockbars
2	Soil moisture level lower than baseline level at **50%** of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps).	
3	Soil moisture level lower than baseline level at **>80%** of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps).	

The TARP has been assessed by comparing the average moisture content of the soil profile during the longwall assessment period against that of the baseline period. If the average soil moisture level drops below the minimum level recorded during the baseline period, a TARP is triggered. The TARP level increases according to the proportion of monitoring sites that exceed this criterion at each swamp within the area of mine influence (Table 18). This is the same approach used by the IMCEFT for regular impact reporting. The baseline period is the period of monitoring before the site is approached within 400 m by a longwall.

Soil moisture hydrographs for all active monitoring locations are presented in **Appendix E**. Assessment of soil moisture hydrographs for locations within Areas 3A, 3B and 3C areas of influence (< 400 m) are presented in Table 19.

In relation to Swamps within the zone of influence for Longwall 21, average soil moisture levels declined to below baseline levels at all soil moisture sites within the mining area of influence (Swamps 9, 144, 145) and those well outside the area of influence (Swamps 153 and 154). The **observations correspond to Level 3 TARP triggers for all performance measure swamp sites (09, 144 and 145)**. As was discussed in Section 6.3 in relation to groundwater levels, most soil moisture sensors in Area 3C were installed during the high rainfall period 2020 to 2022. A return to dry conditions in 2023 has resulted in a rapid decline in soil moisture levels to below the baseline period (Section 2.5). Therefore, the observed soil moisture declines are unlikely to be related to mining. Site S144_01, being located within 160 m of Longwall 21 may be influenced my mining and it is recommended that all sites be reassessed in the new End of Panel Review.

Swamp soil moisture sites within the mining area of influence of the previous longwall (Longwall 19) are reviewed and updated in Table 19.

Table 19. Cumulative assessment of soil moisture hydrographs in Areas 3A and 3B

Swamp	Longwall	Sensors and TARP triggers			Comment	TARP Level
		Not triggered	Triggered	Insufficient baseline or >400m		
05	9-11		S05_05, S05_01, S05_02, S05_08		All four sites show soil moisture decline below baseline after LW passed; baseline <2 y). Possible recovery at S05_S08.	3
08	9-11	S08_05			Soil moisture falls below baseline after undermining. *Not within mapped swamp boundary*.	n/a
09	21		S09_01, S09_02		Mean soil moisture dropped below baseline following LW21.	**3**
11	13,14		S11_01, 02, 05		Soil moisture at all sensors dropped to lowest levels following LW13 and LW14. Likely mining effect, exacerbated by dry conditions. Some recovery in 2021.	3
12	6,7,8,19		S12_01, S12_04		Both sites record average soil moisture below Longwall 19 baseline; noting that the sites were previously mined under and impacted by Longwall 7	3
13	13,14	S13_03	S13_01, 02,		Soil moisture at all sensors dropped to lowest levels during 2017-2019 drought. Recovery in 2020 and 2021 at S13_S03. Other sensors record lower moisture levels than baseline.	2
14	15-17		S14_01, 02		Soil moisture at S14_S01 below baseline in contrast to recovery at reference swamps 22, 85 and 86. S14_S02 shows lower moisture levels compared with baseline and reference swamps.	3
15a	19		S15a_07, 12, 15, 18, 19	S15a_03, 04,	Soil moisture in 3 out of 5 sensors within 400m dropped below baseline during review period.	**3**
15b	7,8,19		S15b_39, H1, H2, H3		Logging sensors installed after Longwall 8 passed beneath or near sites. Likely impacted.	**3**
23	15-17	S23_01 S23_02			No TARP trigger (previously Level 2). Both sensors show recovery in 2020 and 2021 with moisture levels varying within the baseline range.	-
34	19		S34_01		No TARP trigger following Longwall 19	**3**
35a	17,18	S35a_01			No TARP trigger	-
144	21		144_01		SM dropped below baseline during Longwall 21	3
145	21		145_01		SM dropped below baseline during Longwall 21	3
148	8, 19		148_01		Recoded average soil moisture below baseline from 11/2022 after the passage of Longwall 19	**3**
149	17,18	S149_01			Installed in 2021, insufficient baseline. No apparent effects	-
150	17,18		S150_01		No TARP trigger	3
151	18		S151_01		No TARP trigger	-

7. Assessment of performance measures

7.1 Assessment of performance measures for watercourses

Wongawilli Creek	Comment
Minor environmental consequences including:	
Minor fracturing	No fracturing is reported in Wongawilli Creek associated with Area 3C (Section 3.2)
Minor gas releases	Very minor gas release at WC_Pool 50 (Section 4.5)
Minor iron staining	Minor iron staining reported in WC20 and WC24; continued suspended iron in Wongawilli Creek (Section 4.4)**.
Minor impacts on water flows	Assessment not possible due to lack of reference site data. Assessment deferred to the EOP Review for Longwall 19A.
Minor impacts on water levels	No change in outflow status of monitored pools. No further change in water level at WC_Pool 50 as a result of mining in Area 3C.
Minor impacts on water quality	No water quality TARP triggers at WC_FR6. Minor detectable changes in SO4 and Mn concentrations at WC_FR6 compared with baseline (Section 4.3).
Assessment	**Performance measure met** (pending further assessment**)

Note**: Suspended iron affected Wongawilli Creek over a length of 2.8 km in September 2023 and was first reported in August 2021. Environmental consequence should be assessed in an independent investigation into the ecotoxic effects on aquatic flora and fauna (as recommended by HGEO(2023b))

7.2 Assessment of performance measures for swamps

Swamp Den09	Comment
Minor environmental consequences including:	
Negligible erosion of the surface of the swamp	No increased erosion observed (Section 6.1)
Minor changes to the hydrology of the swamp	Decline in groundwater levels and soil moisture levels; unlikely to be mining related (Section 6.3)
Minor changes to the size of the swamp	Refer to report by Niche Consulting
Minor changes in the ecosystem functionality of the swamp	Refer to report by Niche Consulting
Maintenance or restoration of the structural integrity of the bedrock base and any significant permanent pool or controlling rockbar within the swamp	No impact controlling rock bar; no permanent pools (Section 6.2)
Assessment:	**Performance measure met**

Swamp Den144	Comment
Minor environmental consequences including:	
Negligible erosion of the surface of the swamp	No increased erosion observed (Section 6.1)

Minor changes to the hydrology of the swamp	Decline in groundwater levels and soil moisture levels; potentially mining related (Section 6.3)
Minor changes to the size of the swamp	Refer to report by Niche Consulting
Minor changes in the ecosystem functionality of the swamp	Refer to report by Niche Consulting
Maintenance or restoration of the structural integrity of the bedrock base and any significant permanent pool or controlling rockbar within the swamp	No controlling rock bars or permanent pools (Section 6.2)
Assessment:	**Performance measure met, subject to reassessment of swamp groundwater levels**

Swamp Den145	Comment
Minor environmental consequences including:	
Negligible erosion of the surface of the swamp	No increased erosion observed (Section 6.1)
Minor changes to the hydrology of the swamp	Decline in groundwater levels and soil moisture levels; unlikely to be mining related (Section 6.3)
Minor changes to the size of the swamp	Refer to report by Niche Consulting
Minor changes in the ecosystem functionality of the swamp	Refer to report by Niche Consulting
Maintenance or restoration of the structural integrity of the bedrock base and any significant permanent pool or controlling rockbar within the swamp	No controlling rock bars or permanent pools (Section 6.2)
Assessment:	**Performance measure met**

8. Conclusions

Longwall 21 is the first to be extracted from Area 3C. Longwall 21 commenced on 25/4/2023 and was completed on 6/8/2023. It has a total length of 863 m and a width of 305 m including first workings with a maximum cutting height of 3.9 m. The depth of cover ranges between 284 m and 384 m. Effects and potential effects on surface water flow, water quality and shallow groundwater levels are assessed as follows:

Rainfall during Longwall 21 extraction was well below average (29% of the average for the period). As a result, soil moisture storage has declined rapidly to 30th percentile levels in September 2023.

8.1 Effects on surface water quality

Under natural conditions, stream salinity (EC) and other water quality parameters tend to vary over periods of weeks to months and correlate with rainfall conditions. Stream EC generally decreased between 2020 and 2022 due to higher-than-average rainfall and runoff during that period. Most watercourses, including upstream control sites show an increase in EC during 2023 corresponding with a return to dry conditions. Most watercourses also show a decline in DO during 2023 which, again, is related to low flow conditions during which disconnected pools are more common.

No water quality TARPs were triggered in the review period. Anomalous water quality effects are noted in streams that have been directly mined under by previous longwalls (e.g. WC21, SC10C, LA4, Donalds Castle Creek). Those effects include transient or persistent increases in EC, increases (or decreases) in pH and increases in dissolved metal concentrations such as Fe, Mn, Al and Zn. Dissolved iron concentrations in SC10 have declined during 2023, resulting in a decrease in the extent of iron staining on the watercourse. Analysis of flow-corrected trends in water quality indicate that EC and dissolved sulfate, Fe, Mn and Zn are slightly elevated relative to baseline conditions at downstream monitoring sites DCC_FR6 and SCK_Rockbar 5. EC and dissolved sulfate and manganese are elevated compared with baseline at WC_FR6.

In September 2023, DPE received a complaint regarding iron staining in Wongawilli Creek and requested further information in relation to the occurrence. The complaint related to observations of suspended iron oxides along a similar stretch of the watercourse as was previously reported in 2021. Subsequent investigation indicates that the recurrence of suspended iron in Wongawilli Creek is related to fluctuating and increasing concentrations of iron at Pool 50 associated with discharge from an adjacent iron-rich spring.

8.2 Effects on surface water flow

Surface water flow TARPs were reviewed in 2019 in consultation with relevant government agencies and based on recommendations of the IEPMC (Watershed HydroGeo, 2019a). The revised TARPs form part of the Area 3C WIMMCP and rely on comparisons against flows at Reference Sites. The TARPs comprise 4 separate assessments (A to D) aimed at assessing potential effects on catchment yield (median flow statistics) and ecological function (e.g. cease to flow days).

The results of Assessments A, B and C are normally summarised here, however due to the lack of data from the key Reference Site, Assessments A,B and C could not be carried out in the required timeframe.

Analysis of available surface water flow observation records for Wongawilli Creek did not trigger TARP Assessment D for any of the months assessed during the Longwall 21 period.

8.3 Effect on watercourse pool levels

The Area 3C WIMMCP includes performance measures related to pool levels along Wongawilli Creek and Donalds castle Creek. Donalds Castle Creek is entirely outside the mining influence for Longwall 21 and was preciously affected by mining in Area 3B. Pools along Wongawilli Creek were observed to be full and flowing during the review period; no pools along Wongawilli Creek that are normally full have become dry as a result of mining.

Longwall 21 did not pass directly under any Lake Cordeaux tributaries and most pools are beyond the area of mining influence. However, a number of monitored pools located on mid-to upper tributary reaches recorded no-flow or were dry during August and September 2023. Given their distance from the longwall the decline in pool levels are assumed to be related to dry conditions in 2023, contrasting with the wet conditions during the baseline for most of the pool monitoring sites. Longwall 21 passed within 400 m of Wongawilli Creek tributary WC24 and directly beneath WC20. There is no observed change in the outflow status of monitored pools on WC24 following the extraction of Longwall 21. The pool at WC20_Rockbar17 became dry following passage of Longwall 21 beneath the watercourse. Surface cracking and flow diversion are expected in watercourses that are directly mined under (MSEC, 2019).

Pools along watercourse SC10 which overlaps with the area of mining influence for the previous Longwall 19 were reassessed in this report. All monitored pools have remained full and flowing since 2020; there were no observed changes to pool outflow statis since the end of Longwall 19. A data logger in SC10_Pool 26a showed anomalous fluctuations during 2023; however, inspection of the site has found no evidence for subsidence impacts at the pool or elsewhere on the watercourse.

8.4 Effects on swamp hydrology

Performance measures for Area 3C relate to four swamps that lie outside the areas that will be directly mined beneath by Longwalls 21 to 23: Swamps 09, 144, 145 and 154. No increases in

erosion, nor changes in the structural integrity of rock bars or pools were observed following the start of Longwall 21.

Shallow groundwater levels declined at all swamps within Area 3C during 2023 to levels below baseline. Recession rates remained consistent with those observed during the baseline. The decline in groundwater levels triggered Level 3 TARPs for all performance measure swamp sites in Area 3C, except Swamp 154 which is beyond the 400 m zone of potential mining influence. Based on the distance from the longwall and comparison with reference sites, the triggers are unlikely to be related to mining and instead reflect the wetter conditions during the baseline period for most of the swamp monitoring sites. Similarly, average soil moisture levels declined to below baseline levels at piezometers at all soil moisture sites within the mining area of influence (Swamps 9, 144, 145), triggering Level 3 TARPs for all Area 3C sites. The declines in soil moisture reflect boarder declines across the region in response to drying conditions in 2023. As for groundwater levels, the TARP triggers are the result of dry conditions in 2023, contrasting with the wet conditions during the baseline period. Potential mining effects at Swamp 144 should be reassessed as more data become available.

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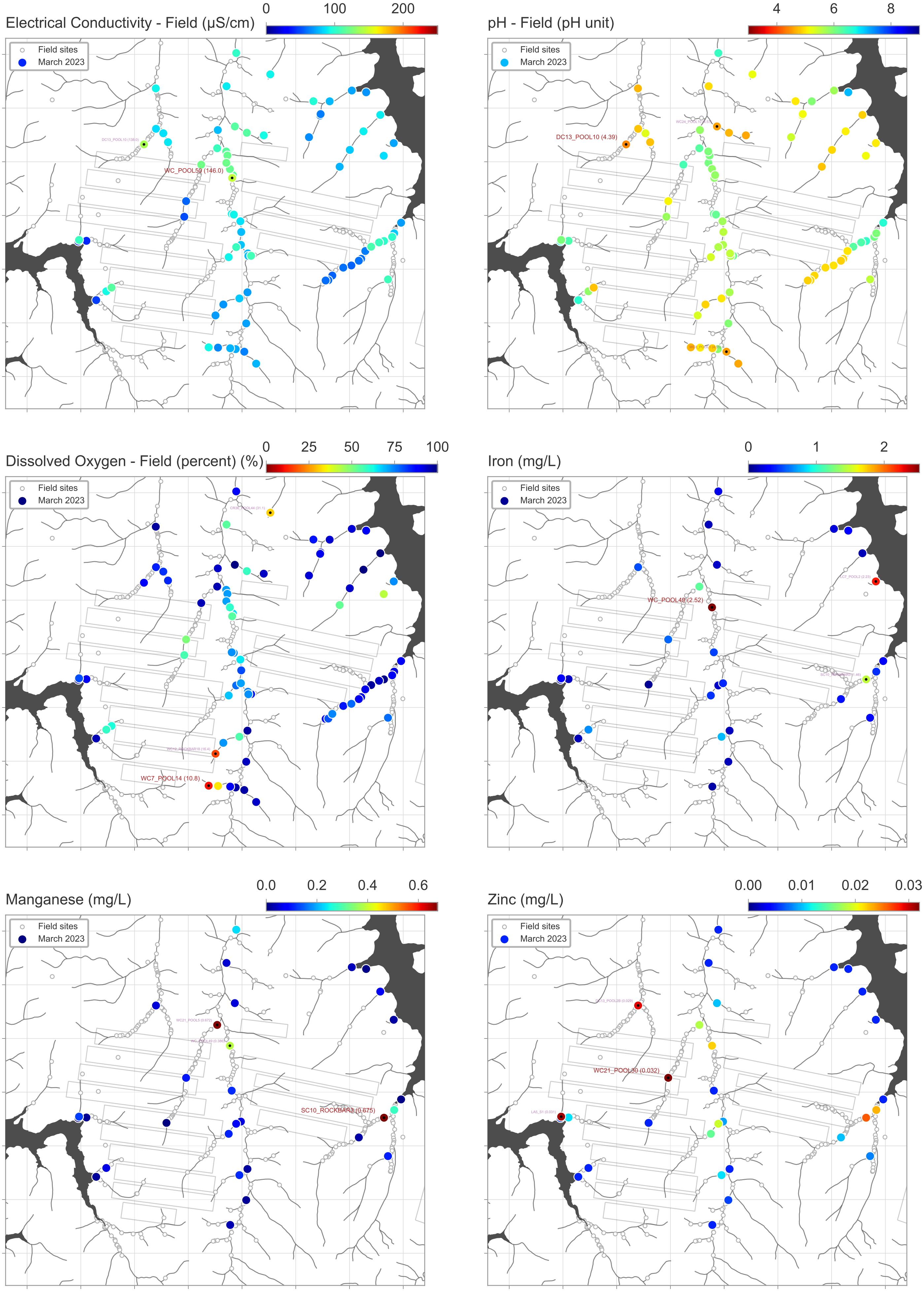
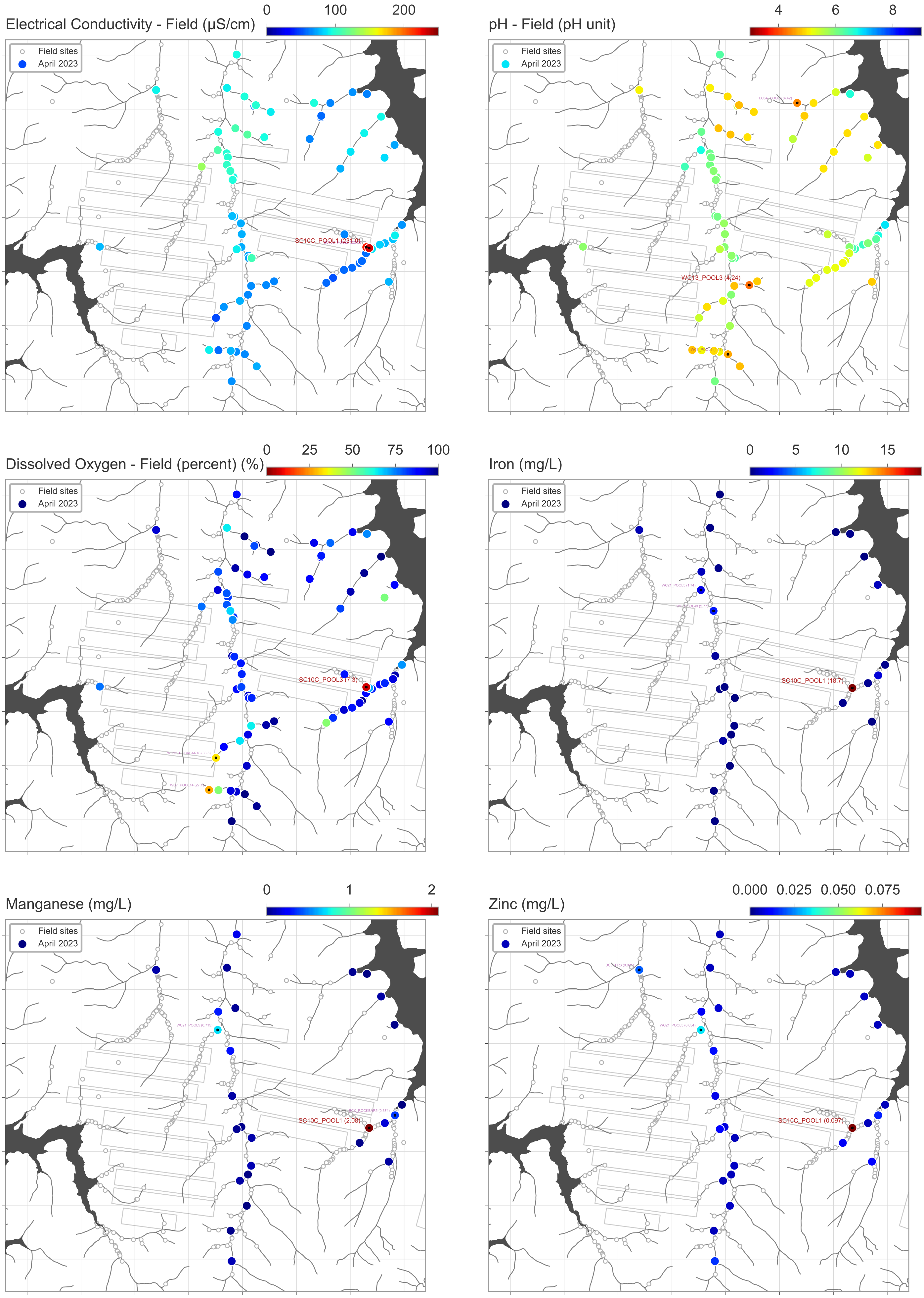
Appendix A1: Water quality hydrographs

Dendrobium stream water quality March 2023



Dendrobium stream water quality April 2023



Dendrobium stream water quality May 2023