Our Ref: NE30130_R019_Rev0: DP
Contact: Dan Pygas

26 July 2023

South32 - Illawarra Metallurgical Coal

Port Kembla Coal Terminal
Port Kembla Road
Inner Harbour
PORT KEMBLA 2502
New South Wales

Stantec

Level 9 - The Forum
203 Pacific Highway
St Leonards NSW 2065
Australia

Phone +61 2 9496 7700
Fax +61 2 9496 7748

www.stantec.com

Attention: Josh Carlon

Dear Josh,

LONGWALL 19 END OF PANEL REPORT AQUATIC FLORA AND FAUNA REVIEW

Introduction

South32 - Illawarra Metallurgical Coal (IMC) extracts coal using longwall mining techniques from the Dendrobium Coal Mine, situated approximately 15 km to 20 km west of Wollongong. Consent for the mine, granted in November 2001, allows extraction from three longwall domains, known as Areas Dendrobium Area 1, Dendrobium Area 2 and Dendrobium Area 3 (DA1, DA2 and DA3). DA3, situated between Lake Cordeaux and Lake Avon, is currently being mined. A modification to the mine layout of DA3, approved in December 2008, allowed the mine to be expanded, with DA3 divided into three smaller domains, DA3A, DA3B and DA3C. Longwalls 9 to 18 in DA3B were extracted between February 2013 and May 2022. Longwall 19 is the fourth of five longwalls in DA3A and was extracted 20 June 2022 to 29 March 2023.

Stantec (formerly Cardno) was commissioned by IMC to undertake a review of the status of aquatic flora and fauna in relation to the extraction of Longwall 19 to support the End of Panel reporting. Stantec has been undertaking ongoing monitoring of watercourses within the DA3B and DA3A mining areas including the perennial Wongawilli Creek, Sandy Creek, Donalds Castle Creek and several associated first and second order ephemeral / intermittent tributaries. The overall objective of the monitoring is to determine whether the extent and nature of observed impacts, primarily subsidence-induced fracturing of bedrock, flow diversion and loss of aquatic habitat, if any, are consistent with the predictions made in the Aquatic Flora and Fauna Assessment (AFFA) (Cardno 2020a), Subsidence Management Plan (SMP) (IMC 2021a) and Watercourse Impact Monitoring, Management and Contingency Plan (IMC 2021b) for Longwall 19. This review includes:

- An overview of the management of aquatic flora and fauna including monitoring proposed and undertaken;
- Review of observed impacts to aquatic habitat, flora and fauna from IMC impact reports and a comparison with those predicted in the SMP; and,
- Recommendations for any Corrective Management Actions (CMA) and future aquatic flora and fauna monitoring.

This review focuses on any physical and water quality impacts to watercourses overlaying and within 400 m (i.e., have potential to be impacted based on previous observations of mining impacts in the Dendrobium mine area) of Longwall 19 and any associated potential impacts to aquatic habitat and biota that may have occurred during extraction of Longwall 19. These are Wongawilli Creek, Wongawilli Creek tributaries WC15, WC13, WC14 and WC17, and Sandy Creek tributaries SC10, SC10A, SC10B and SC10C. The aquatic ecology impact assessment is based on the findings of ongoing field surveys in these watercourses by the Illawarra Metallurgical Coal Environmental Field Team (IMCEFT) and on Stantec's experience of undertaking monitoring and assessment of aquatic habitat and biota in the Dendrobium Mine Area.

The potential impacts to aquatic ecology attributed to extraction of Longwall 19 are also placed in context of the cumulative impacts to aquatic ecology experienced in the Dendrobium mining area. A full assessment of impacts due to extraction of all longwalls in DA3B and DA3A will be provided in the latest biennial monitoring report (Stantec *in prep*) following completion of aquatic ecology surveys in 2023. Any impacts to swamps and amphibians are considered by other specialist consultants.

Aquatic Ecology Management and Monitoring

The monitoring requirements recommended in the AFFA and SMP for Longwall 19 incorporates a Before, After, Control, Impact (BACI) sampling design. The program monitors mine subsidence impacts on the aquatic environment with collection of at least two years of baseline data followed by monitoring during extraction, and at least two years of post-extraction monitoring. The following indicators were monitored at impact and control sites within and outside the SMP area for DA3B as a measure of aquatic health:

- Aquatic habitat condition - using a modified version of the Riparian, Channel and Environmental Inventory method (RCE) (Chessman *et al*. 1997).
- Macroinvertebrates, including threatened species of dragonfly (Adams emerald dragonfly and Sydney hawk dragonfly) - using AUSRIVAS and standardised artificial collectors.
- Limited *in-situ* water quality – using a portable probe.
- Fish abundance using backpack electrofishing and bait traps.

It was recommended that monitoring in DA3A be undertaken once every year (Cardno 2020a). Monitoring in DA3B is undertaken biennially.

Table 1-1 summarises the monitoring that has been completed in in line with the AFFA and SMP for Longwall 19. Baseline surveys were undertaken 2010 and 2011 (Cardno Ecology Lab 2011), followed by the during-extraction monitoring in 2013 (Cardno Ecology Lab 2014), 2015 (Cardno 2016), 2017 (Cardno 2018), 2019 (Cardno 2020b), 2021 (Cardno 2022c) and 2023 (Stantec *in prep*). Surveys in 2021 also provided further baseline data for Longwall 19. The AFFA also included a literature review on the physical setting, aquatic habitat, water quality, aquatic macroinvertebrates, fish, threatened species, populations and ecological communities in DA3A.

Table 1-1 Monitoring undertaken for DA3A longwalls in line with the Longwall 19 SMP Requirements and Recommendation in Cardno (2020a)

Report	Survey Date	Sampling Component
Baseline Monitoring		
Dendrobium Areas 3A and 3B. Aquatic Ecology Monitoring 2008 to 2013 (Cardno Ecology Lab 2014)	Mar / May / Sep / Nov 2010 Apr / Jun / Sep / Oct 2011	Habitat assessment, fish, macroinvertebrates, water quality
During Extraction Monitoring		
Dendrobium Areas 3A and B. Aquatic Ecology Monitoring 2008 to 2013 (Cardno Ecology Lab 2014)	Apr / Jun / Sep / Nov 2013	Habitat assessment, fish, macroinvertebrates, water quality
Dendrobium Area 3A Aquatic Ecology Monitoring 2008 to 2014 (Cardno Ecology Lab 2015)	Throughout 2014	Habitat assessment, fish, macroinvertebrates, water quality
Dendrobium Area 3B Aquatic Ecology 2010 to 2015 (Cardno 2016)	May / Jun / Oct / Nov 2015	Habitat assessment, fish, macroinvertebrates, water quality
Dendrobium Area 3B Aquatic Ecology 2010 to 2017 Cardno (2018)	Apr / May / Oct / Nov 2017	Habitat assessment, fish, macroinvertebrates, water quality
Dendrobium Area 3B Aquatic Ecology 2010 to 2019 Cardno (2020a)	May / Jun / Oct / Nov 2019	Habitat assessment, fish, macroinvertebrates, water quality
Dendrobium Area 3A and 3B Aquatic Ecology 2010 to 2021 Cardno (2022a)	Apr / May / Sep / Oct 2021	Habitat assessment, fish, macroinvertebrates, water quality
Dendrobium Area 3A and 3B Aquatic Ecology 2010 to 2023 Stantec (in prep)	Apr / May / Sep / Oct 2023	Habitat assessment, fish, macroinvertebrates, water quality

IMC undertake weekly monitoring of landscape and natural features in DA3A and DA3B when within 400 m of the active longwall, and monthly thereafter. This includes monitoring during extraction of active longwalls to identify any fracturing, pool water level reduction, changes in flow and water quality in Wongawilli Creek, Donalds Castle Creek, and their tributaries.

The SMP includes the following triggers as part of the Trigger Action Response Plans (TARPs) relating to aquatic ecology:

- Level 1 – Reduction in aquatic habitat for 1 year.
- Level 2 – Reduction in aquatic habitat for 2 years following the active subsidence period (i.e., when a longwall is within 400 m of a feature, such as a creek).
- Level 3 – Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period.

Trigger specific management actions aim to minimise any further impacts to the aquatic environment, and include requirements for further monitoring, reporting, application of corrective management actions (CMAs), such as grouting and repair of fractures, and notification of relevant stakeholders, as required.

Predicted and Observed Impacts

Physical and Water Quality Mining Impacts

Details of the mining related impacts identified in watercourses by IMCEFT (IMC 2023) during extraction of Longwall 19 are provided in **Table 1-2**. On 12 April 2023, just following completion of extraction of Longwall 19, an extension of a rock fracture previously identified on WC14 following extraction of Longwall 8 was observed. The fracture was located 3 m downstream of Longwall 19 and is a level 1 trigger described in the DA3A Watercourse Impact, Monitoring, Management and Contingency Plan.

Localised iron staining was observed in Wongawilli Creek tributary WC14 and just outside the main channel in bushland and in a step near WC15 Pool 2. A gas release was observed in Wongawilli Creek Pool 50 on 18 January 2023 and was active on 26 April 2023.

No changes to water quality were attributed to Longwall 19 (HGEO 2023). However, increases in EC, changes in pH and increases in dissolved metal concentrations such as Fe, Mn, Al and Zn continue to be observed in SC10C and related to previous extraction of Longwalls 7 and 8. Reductions in surface flow in WC15 (and other Wongawilli Creek tributaries outside of the 600 m boundary for Longwall 19) first noted during extraction of DA3B Longwalls have also continued during and following extraction of Longwall 19 (HGEO 2023). Changes to flow are not evident downstream on Wongawilli Creek (Site WWL) despite flow reductions at upstream tributaries including WC15.

Table 1-2 Mining related impacts observed in watercourses by IMCEFT during extraction of DA3A Longwall 19

Site ID	Impact Type	Watercourse	Identification	Description	Trigger Level
DA3A_LW19_003	Iron Staining	WC14	16/08/2022	In channel	2
DA3A_LW19_029	Gas Release	WC Pool 50	18/01/2023	Within pool	1
DA3A_LW19_044	Iron Staining	Hillslope of Wongawilli Creek	19/04/2023	In bushland on eastern slope of valley of Wongawilli Creek. Iron staining does not enter Wongawilli Creek.	1
DA3A_LW19_045	Iron Staining	WC15 Pool 2	26/04/2023	In step near pool	1
DA3A_LW8_003 (Update)	Rock fracture	WC14	12/04/2023	Rock fracturing with associated rockfall and fragmentation on WC1	1

Impacts on Aquatic Habitat and Biota

The assessment of impacts to aquatic habitat and biota due to the physical and water quality impacts observed by IMC and described above are summarised in **Table 1-3**. The findings are compared with the impacts to aquatic habitat and biota predicted to occur in the AFFA for Longwall 19 (Cardno 2020a). These predictions were based on the maximum predicted subsidence parameters for the sections of Wongawilli Creek and tributaries that flow through the Longwall 19 SMP Area, their predicted impacts on the physical and water chemistry characteristics of the waterways (MSEC 2020), and the assessment of potential impacts on surface water (HGEO 2020) and groundwater (SLR 2020).

Table 1-3 Predicted and observed impacts to aquatic ecology associated with Longwall 19.

Attribute	Predicted Physical Impacts	Predicted Impacts on Aquatic Ecology	Observed Impacts to Aquatic Ecology
Wongawilli Creek			
Ponding, flooding and scouring of stream banks due to tilt	No significant change predicted.	No measurable effects due to tilt.	None identified by IMCEFT during extraction of Longwall 19.
Fracturing of bedrock and diversion of surface flows	The overall likelihood of significant fracturing resulting in surface water flow diversions at the rockbars along Wongawilli Creek is 7% (based on the rate of rockbar fractures experienced in DA3B due to extraction of Longwalls 9 to 12). Minor fracturing could occur along the creek at distances up to approximately 400 m from the proposed longwall (0.9 km of watercourse length). Fracturing and flow diversions are not predicted to occur in Sandy Creek.	A total of 32 pools with length up to 160 m (total of 1,164 m of pool habitat) have been identified in this section of creek. Based on the predicted fracture rate, it would be unlikely the major rockbar would experience fracturing associated with flow diversions. In the unlikely event this did occur, the length of aquatic habitat that would be affected due to flow diversions is expected to be limited. Some reduction in the population size of aquatic biota associated with pool habitat (fish and many macroinvertebrates) would be expected. Though given the limited amount of pool habitat that would be affected, impacts to aquatic habitat and biota as a direct result of pool drainage would be relatively minor.	No reductions in pool water levels and flow or changes in water quality observed by IMC during extraction of Longwall 19, and thus no suggestion of impacts occurring to aquatic habitat and biota.
Water Quality and Availability	Groundwater modelling suggests the number of no-flow days would increase from 10 % to 28% of the time due to extraction of all DA3A, DA3B and DA3C longwalls. However, these are conservative predictions and considered highly unlikely (SLR 2020, HGEO 2020). Extraction of Longwall 19 would contribute less than 10 % of this increase. Impacts to water quality due to mining are expected to be minor in stream reaches within subsidence affected areas (HGEO 2020). Effects are likely to include slight and temporary changes in water salinity, pH and iron content with local discolouration of streambeds and rock faces by iron hydroxide.	An overall reduction in base flow and increase in the number of zero flow days would impact aquatic habitat and biota in Wongawilli Creek and Sandy Creek. Although substantial reductions in baseflow that may result in relatively severe impacts to aquatic ecology are not expected. Impacts to aquatic habitat and biota due to changes in water quality appear unlikely as only minor changes in water quality are expected.	Iron staining and the single gas release are not associated with any water quality triggers. No evidence of impacts to aquatic biota during observations in April and June 2023.
Tributaries of Wongawilli Creek and Sandy Creek			
Ponding, flooding and scouring of stream banks due to tilt	Although predicted changes in grade (3%) are larger as a proportion of the natural grade (10% to 20%), compared with that for creeks, it is unlikely that there would be large-scale adverse changes in the levels of ponding or scouring of the banks along these drainage lines due to subsidence induced tilt. It is possible that localised increased ponding could develop in some isolated locations, where the natural grades are small and where the drainage lines exit the mining area	Localised changes in habitat availability and connectivity may occur along the drainage lines due to tilt but these effects will be difficult to detect due the large variability in grade and natural flows within these ephemeral systems. The impacts resulting from the changes in surface water flows are expected to be small in comparison with those which occur during natural flooding conditions. Consequently, impacts to aquatic habitat and biota due to tilt, if any, are	No impacts observed due to tilt.

Attribute	Predicted Physical Impacts	Predicted Impacts on Aquatic Ecology	Observed Impacts to Aquatic Ecology
		expected to be minor and localised.	
Fracturing of bedrock and diversion of surface flows	Fracturing is expected to occur along the sections of the drainage lines that are located directly above the proposed Longwall 19. Fracturing can also occur outside the extents the proposed longwalls, with minor and isolated fracturing occurring at distances up to approximately 400 m. Surface water flow diversions are also likely to occur along the sections of drainage lines that are located directly above the proposed longwalls. In times of heavy rainfall, most of the runoff would flow over the fractured bedrock and soil beds and would not be diverted into the dilated strata below. In times of low flow, however, surface water flows can be diverted into the dilated strata below the beds.	Fracturing induced flow diversions in the highly ephemeral drainage lines directly above the longwalls would result in a reduction in the amount of aquatic habitat. However, smaller drainage lines such as these are limited in habitat value for aquatic biota. Flow diversions would reduce the volume and duration of flow in these ephemeral drainage lines. Approximately 0.5 km of first and second order drainage lines occur directly above Longwall 19 and a further approximate 3.0 km within the Study Area. These lengths represent a very small proportion of that present in the wider Cordeaux River Catchment. Most of these watercourses have previously been impacted by extraction of longwalls from DA3A and DA3B.	Extension of a rock fracture previously identified in WC14 following extraction of Longwall 8 was observed. Although flow diversions may occur, the natural ephemeral nature of WC14 indicates that any reduction in availability and connectivity of aquatic habitat and associated impacts to aquatic biota in WC14 would be minor.
Water quality	Impacts to water quality due to mining are expected to be minor in stream reaches within subsidence affected areas (HGEO 2020). Effects are likely to include temporary changes in water salinity, pH and iron content with local discolouration of streambeds and rock faces by iron hydroxide.	Minor impacts to water quality are unlikely to represent substantial risks to aquatic habitat and biota in drainage lines.	Iron staining in WC14 and WC15 was not associated with any water quality triggers. No impacts to water quality in drainage lines observed. Thus, no impacts to aquatic habitat and biota are expected. Iron staining previously identified in SC10C and SC10 during extraction of Longwall 8 continued during extraction of Longwall 19. However, no evidence that Longwall 19 has contributed to this iron staining and the previously reported limited impacts to aquatic ecology (Cardno 2020c).

Only relatively minor impacts were observed in watercourses following commencement of extraction of Longwall 19. These were iron staining in WC14, WC15, and in bushland adjacent to Wongawilli Creek, a gas release in WC Pool 50, and an extension of a previously identified rock fracture in WC14. No changes in water quality in watercourses were identified (HGEO 2023). Localised iron staining in WC14 and WC15 would not be associated with significant impacts to aquatic habitat and biota given these ephemeral / intermittent tributaries provide aquatic habitat of limited value and represent a very small component of the total aquatic habitat in the Dendrobium Mine area. Although flow diversions may occur due to the fracture in WC14, any reduction in availability and connectivity of aquatic habitat and associated impacts to aquatic biota in the naturally ephemeral / intermittent WC14 would also be minor. In the absence of changes in water quality in Wongawilli Creek associated with the gas release in Pool 50, and any change in aquatic habitat noted during the recent aquatic ecology surveys in Wongawilli Creek in April and June 2023, any associated impacts to aquatic ecology are expected to be negligible.

During extraction of Longwall 19, iron straining previously observed in SC10C and SC10 following extraction of Longwall 8 in 2013 has continued. This iron straining currently extends throughout SC10C and into SC10 and on occasion into Sandy Creek downstream of the SC10 confluence. During the latest aquatic ecology observations in April and June 2023 iron straining was present in SC10C (Site 13) and SC10 (Site 12) but not Sandy Creek (Site 9) (**Figure 1-2**). Associated impacts include a modification to aquatic habitat associated with iron flocculation and infilling of habitat interstices and changes in some indicators of water quality. The assessment of related impacts to aquatic ecology in SC10C (Cardno 2020c) indicated a reduction in the abundance of some aquatic macroinvertebrate taxa (including the pollution sensitive leptophlebiid mayfly), but not other taxa, suggesting impacts to aquatic ecology associated with the iron staining and flocculation are limited. Although this iron staining has persisted though extraction of Longwall

19, extraction of Longwall 19 does not appear to have contributed to its extent or associated impacts to aquatic ecology. Iron straining (nor any other impacts) has not been observed in the section of SC10 downstream of Longwall 19 and upstream of the SC10C confluence. Monitoring and assessment of iron straining in the Sandy Creek catchment and associated impacts to aquatic ecology will continue as part of the ongoing DA3 monitoring program, with further aquatic ecology surveys to be undertaken next in spring of 2023.

The cumulative impact to tributaries due to extraction of longwalls in DA3A and DA3B and the wider Metropolitan Catchment should, however, be considered. Mapping by IMCEFT indicates that approximately 40 km of the total 700 km length of watercourse habitat located directly above longwall mining. This could result in loss of flow and reduction in pool water level. It is noted that a large proportion of this is expected to be ephemeral and intermittent first and second order watercourses that provide more limited habitat for aquatic biota compared with larger and more permanent watercourses such as Wongawilli Creek. Nevertheless, these watercourses would still provide habitat and connectivity for some species at times of high rainfall. Given these tributaries are ephemeral, and thus, provide disconnected habitat irrespective of mining, any further reduction in connectivity associated with flow diversions would not be expected to result in significant impacts to aquatic habitat and biota. It is also expected that that connectivity would occur during high rainfall events. It is also likely that extraction of Longwall 19 has and will continue to contribute to groundwater depressurisation in the Dendrobium Mine. This is expected to be associated with some reduction in the amount of aquatic habitat during drought conditions.

It is very unlikely that the threatened Macquarie perch previously identified downstream in Wongawilli Creek has been put at risk by extraction of Longwall 19. Macquarie perch has been recorded in Dendrobium Area 3 in the mid to lower reaches of Wongawilli Creek, including pools just upstream and downstream of the Fire Road 6 crossing (Cardno 2018 and references therein). However, this species was not identified further upstream in Wongawilli Creek. This was despite extensive sampling here as part of this and previous surveys in Wongawilli Creek for the DA3B monitoring program. It is possible that this species is unable to pass the natural barrier in the form of a cascade / waterfall present a few hundred metres upstream of the Fire Road 6 crossing, at least not in any appreciable numbers. Macquarie perch would be very unlikely to occur in tributaries overlaying Longwall 19 due to the absence of suitable habitat otherwise provided by large permanent pools.

It is difficult to quantify the additional impact to aquatic habitat and biota in DA3A and DA3B due to extraction of individual longwalls. Physical mining impacts that have occurred can be associated with individual longwalls or a cumulative effect of several longwalls. In such cases, it is difficult to determine if aquatic ecology impacts are due to a delayed response following extraction of earlier longwalls, a cumulative effect of extracting multiple longwalls, or a combination of mining impacts with prevailing environmental conditions e.g., prolonged reduced rainfall periods.

Aquatic Ecology TARP

Table 1-4 compares observed impacts to aquatic ecology with the aquatic ecology TARP levels to determine if any have been triggered and what management actions associated with extraction of Longwall 19 and previous longwalls may be appropriate, if any. These TARPS are applicable to watercourses where aquatic ecology monitoring sites are located within 400 m of Longwall 19 (Wongawilli Creek Sites 2, 3 and X4). No aquatic ecology triggers occurred at these sites during extraction of Longwall 19.

Table 1-4 TARP triggers and current status in Wongawilli Creek relevant to Longwall 19

TARP	Wongawilli Creek
Level 1 – Reduction in aquatic habitat for 1 year	Not triggered
Level 2 – Reduction in aquatic habitat for 2 years following the active subsidence period (i.e., when a longwall within 400 m of a feature, such as a creek, is completed)	Not triggered
Level 3 – Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period	Not triggered

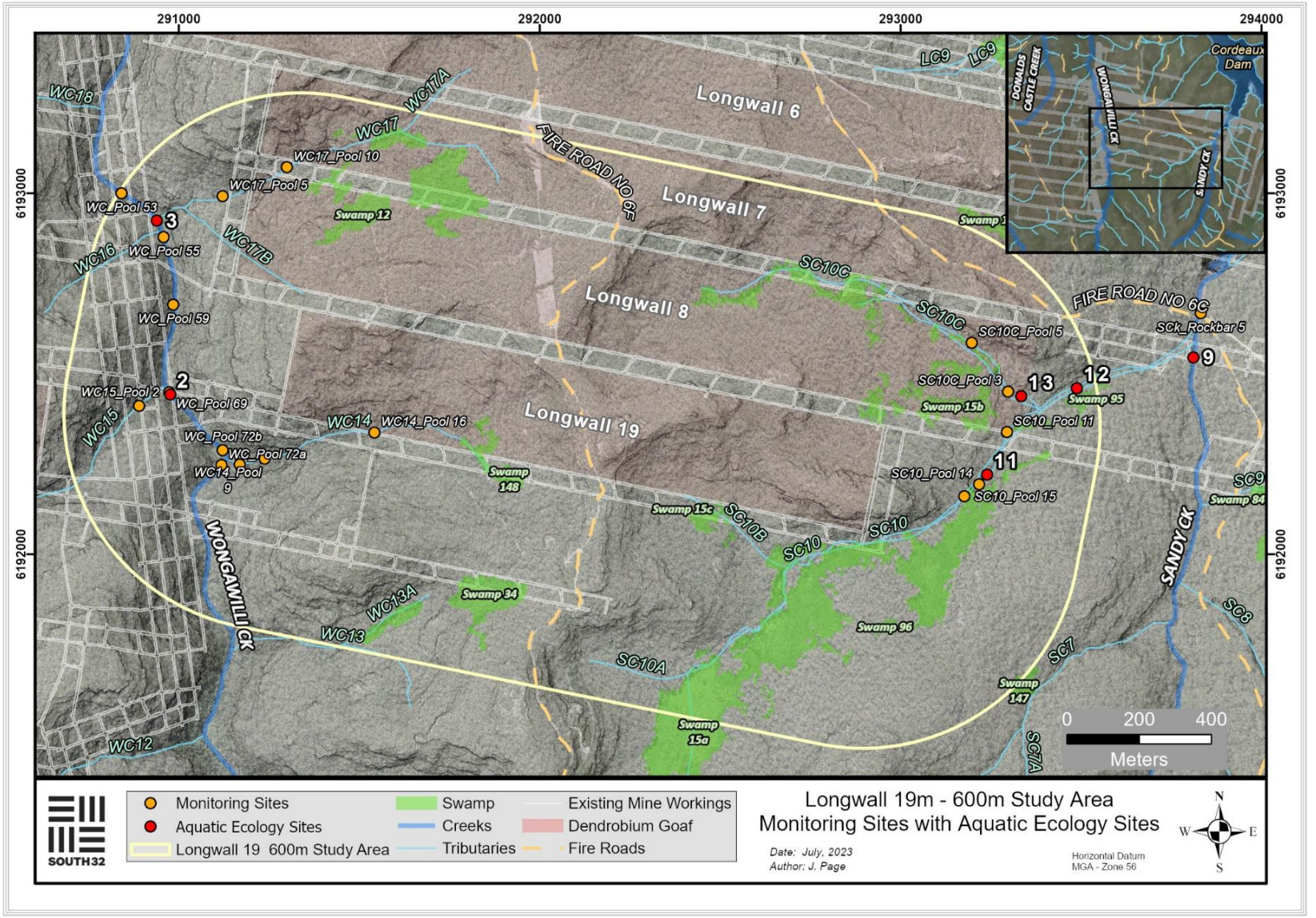

Figure 1-2 DA3A Longwalls 6 to 8 and 19, nearby watercourses and associated monitoring sites, including aquatic ecology monitoring Sites 11 to 12.

Conclusion and Recommendations

Only minor physical impacts in tributaries and no water quality impacts to watercourses in DA3A have been attributed to extraction of Longwall 19. The iron staining and gas release also represent relatively minimal impacts to aquatic habitat and biota in Wongawilli Creek and its tributaries, nor were any impacts observed to aquatic biota during surveys in April and June of 2023. At this stage, no specific actions associated with Longwall 19 are recommended.

It would be expected that extraction of Longwall 19 would have contributed to mining induced groundwater depressurisation in the Dendrobium Mine. Physical mining impacts, reduction in availability of aquatic habitat and assumed loss of some associated aquatic biota in tributaries overlying and within 400 m of Longwall 19 may also have occurred but have not yet been observed. Such impacts could result in a greater potential for and severity of any future similar reductions in pool water levels and flow in tributaries and Wongawilli Creek. It is noted that previous reductions in flow observed in Wongawilli Creek have been within predictions. No aquatic ecology TARPs have been triggered with respect to Wongawilli Creek.

It is recommended that further during- and post-mining aquatic ecology monitoring is completed in DA3A in Wongawilli Creek and tributaries in line with the AFFA and SMP for Longwall 19. IMC should continue to monitor watercourses (as required by the SMP) that have been affected by Area 3A longwalls. The findings of these will be used to assess whether TARPs will subsequently be triggered.

Yours sincerely,

Daniel Pygas

Principal – Aquatic Ecology

for Stantec

Email: Daniel.Pygas@stantec.com

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