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Dear Josh,

LONGWALL 16 END OF PANEL REPORT AQUATIC FLORA AND FAUNA REVIEW

Introduction

South 32 - Illawarra Metallurgical Coal (South32) 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 DA1, DA2 and DA3. DA3, situated to the west of Lake Cordeaux, is currently being mined. A modification to the mine layout of DA3, approved in December 2008, allowed the mine to be expanded and Area 3 to be sub-divided into three smaller domains, DA3A, DA3B and DA3C. Mining of DA3B Longwall 17 is currently underway. Longwalls in DA3B have been extracted as follows:

- Longwall 9 commenced 9 February 2013; completed on 2 June 2014;
- Longwall 10 commenced 21 January 2014; completed 20 January 2015;
- Longwall 11 commenced 18 February 2015; completed 26 January 2016;
- Longwall 12 commenced 22 February 2016, completed 31 January 2017;
- Longwall 13 commenced 3 March 2017, completed on 19 April 2018;
- Longwall 14 commenced 22 May 2018, completed 26 February 2019;
- Longwall 15 commenced 4 April 2019, completed 22 January 2020; and
- Longwall 16 commenced 25 February, completed 4 November 2020.

Longwall 17 commenced 12 December 2020 and is currently underway. Extraction of Longwalls 18 and 19 in DA3A would follow.

Cardno NSW/ACT (Cardno) was commissioned by South32 to undertake a review of the status of aquatic flora and fauna in relation to the extraction of Longwall 16 to support the End of Panel reporting for the longwall. Cardno has been undertaking ongoing monitoring of watercourses within the DA3B mining area including the perennial Wongawilli Creek, Donalds Castle Creek and several associated first and second order tributaries (referred to hereafter as drainage lines). 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 Ecology Lab 2012) and Subsidence Management Plan (SMP) (BHPBIC 2012) for DA3B. 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 South32 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 considers the effects of extraction of Longwall 16 in DA3B and focuses on the findings of ongoing monitoring by South32. Assessment of impacts to aquatic ecology are made based on Cardno's extensive experience of undertaking monitoring and assessment of aquatic habitat and biota in the Dendrobium Mine Area . Information on Sandy Creek and drainage lines of Wongawilli Creek (WC15) and Lake Avon (LA2 and LA4A) where mining impacts were observed during extraction of Longwall 16 has been provided by South32, though these are not routinely monitored by Cardno as part of the ongoing aquatic ecology monitoring.

Any impacts to swamps and amphibians are considered by other specialist consultants.

Aquatic Ecology Management and Monitoring

The monitoring requirements recommended in the AFFA for DA3B and included in the SMP for DA3B incorporates a Before, After, Control, Impact (BACI) sampling design to monitor 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; and
- Fish abundance using backpack electrofishing and bait traps.

It was recommended that monitoring in DA3B be undertaken once every two years (Cardno Ecology Lab, 2012).

Table 1-1 summarises the monitoring that has been completed in DA3B in line with the AFFA and SMP. Baseline surveys were undertaken in DA3B in 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) and 2019 (Cardno 2020). Additional monitoring was undertaken in DA3B in 2011 to support the AFFA, including more extensive fish surveys in WC21 and during the 2014 investigations in DA3A (Cardno Ecology Lab 2015). 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 DA3B. Aquatic habitat in WC21 was also inspected visually by Cardno during 2014 following the observation of physical mining impacts within the tributary.

South32 undertake weekly monitoring of landscape and natural features in DA3B when within 400 m of the active longwall, and monthly thereafter. This includes monitoring during extraction of DA3B longwalls to identify any fracturing, pool water level reduction, changes in flow and water quality in Wongawilli Creek and its drainage lines and Lake Avon drainage lines.

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 within 400 m of a feature, such as a creek, is completed); and
- Level 3 – Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period.

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

The increase in iron straining that occurred in Sandy Creek during extraction of Longwall 16 was attributed to extraction of previous DA3A longwalls outside of the catchment of Longwall 16. Thus, they are not considered further.

Table 1-1 Monitoring undertaken for DA3B longwalls in line with the DA3B SMP Requirements and Recommendation in Cardno Ecology Lab (2012)

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	Observations of mining impacts and effects on aquatic habitat in WC21 in 2014 that were attributed to extraction of Longwalls 9 and 10, undertaken as part of DA3A monitoring fieldwork
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 2017 Cardno (2020)	May / Jun / Oct / Nov 2019	Habitat assessment, fish, macroinvertebrates, water quality

Predicted and Observed Impacts

Physical and Water Quality Mining Impacts

Details of the physical and associated water level, flow and quality triggers identified by Illawarra Metallurgical Coal Environmental Field Team (IMCEFT) (South32 2020) during extraction of Longwall 16 are provided in **Table 1-2**. One of the three rock fractures identified during extraction of Longwall 16 was attributed to this longwall. This fracture occurred upstream of Pool 34 in WC15 and was in an area where fracturing had not been identified previously. This fracture was associated with flow diversion and reduction in water level in Pool 34, which is approximately 10 m x 7 m and up to 1 m deep. Although Pool 34 was observed to be dry during the baseline period, the observed rate of recession following this fracture was the highest recorded and its recent drainage has been attributed to fracturing and flow diversion due to Longwall 16 (South32 2020). Other impacts attributed to Longwall 16 included erosion resulting in a hole the earth bank near WC15 of length of 1.8 m, width of 0.5 m and a measurable depth of 1.1 m. The other impact that occurred during extraction of Longwall 16 was iron straining in Pool 34 in LA2. This ephemeral pool is located above Longwall 16 and is approximately 2 m x 4 m and no more than a few 10s cm deep with water present following rainfall events. The iron staining is localised to this pool and does not extend downstream.

Other impacts observed during extraction of Longwall 16 were not attributed to this longwall. A further two fractures, which could result in flow diversions, observed in WC15 during extraction of Longwall 16 were in areas where fracturing had been identified previously during extraction of Longwall 14 and these were not attributed to Longwall 16.

Elevations in electrical conductivity (EC) (to 233 µS/cm, above the trigger value of 129.8 µS/cm), and reductions in pH (to pH 4, below the trigger value of pH 4.9) and dissolved oxygen (DO) (to 59.7 % saturation, below the trigger level of 69.5 % saturation) in LA4 were attributed to previous Longwalls 12 and 13. Extraction of Longwall 12 and Longwall 13 took place beneath LA4 in April 2016 and March 2017, respectively, with subsequent rock fracturing and flow diversion also observed. The LA4 catchment us not undermined by Longwall 16 and these water quality changes were not attributed to this longwall. Similarly, the increase in EC in Donalds Castle Creek during extraction of Longwall 16 (this longwall is located outside the Donalds Castle Creek catchment) was attributed to extraction of previous DA3B longwalls.

Table 1-2 Physical and water quality impacts observed by IMCEFT in the Wongawilli Creek and Donalds Castle Creek catchments during extraction of DA3B Longwall 16

Watercourse	Site / Reference	Impact Type	Identification Date	Comment
LA2	DA3B_LW16_038	Iron Staining	14/09/2020	Ironing staining present at LA2_Pool34.
WC15	DA3B_LW14_017 (Update)	Rock Fracturing & Displacement	9/09/2020	Additional rock fracturing and displacement on tributary WC15.
WC15	DA3B_LW14_019 (Update)	Rock Fracturing, Uplift & Displacement	9/09/2020	Additional rock fracturing, uplift and displacement near tributary WC15.
WC15	DA3B_LW16_030	Erosion	9/9/2020 & 31/08/2020	Localised erosion on tributary WC15.
WC15	DA3B_LW16_028	Rock Fracturing	31/08/2020	Rock fracture to rockbar/step above WC15_Pool 34.
LA4	LA4_S1	Water Quality Trigger	3/08/2020	Trigger for dissolved oxygen at LA4_S1.
LA4	LA4_S1	Water Quality Trigger	3/08/2020 & 1/09/2020	Trigger for electrical conductivity at LA4_S1.
LA4	LA4_S1	Water Quality Trigger	3/08/2020 & 1/09/2020	Trigger for pH at LA4_S1.
Donalds Castle Creek	Donalds Castle Creek (FR6) (Update)	Water Quality Trigger	20/05/2020 & 1/06/2020 & 30/06/2020	Trigger for electrical conductivity.

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 South32 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 in the AFFA (Cardno Ecology Lab 2012). These predictions were based on the maximum predicted subsidence parameters for the sections of Wongawilli Creek, Donalds Castle Creek and the tributaries that flow through the DA3B SMP Area, their predicted impacts on the physical and water chemistry characteristics of the waterways (MSEC 2011), and the assessment of potential impacts on surface water quality (Ecoengineers 2011).

The physical mining impacts resulting in fracturing and pool drainage in WC15 would be expected to be associated with some reduction in the amount aquatic habitat. At the scale of individual pools such impacts are relatively severe. These most recent observations during extraction of Longwall 16 would further contribute to the loss of aquatic habitat in WC15. By April 2020, approximately 1.2 km of WC15 (77% of its 1.6 km length) had experienced water loss and reduction in availability of aquatic habitat. Although severe at the scale of pools and drainage lines, based on the abundance of first and second order stream habitat in the local area, in isolation these impacts could be considered relatively minor in the context of the Metropolitan Catchment Special Area. Baseline data (i.e. before any mining) also indicates that this pool (and WC15) is naturally ephemeral and therefore provides relatively limited aquatic habitat compared with larger watercourses such as Wongawilli Creek. The cumulative impact to drainage lines due to extraction of longwalls in DA3B and the wider Metropolitan Catchment should however, be considered. Mapping by IMCEFT indicates that approximately 97 km, or 14 %, of the total 556 km length of watercourse habitat within the upper Avon and Cordeaux Catchments has experienced mine subsidence movements which could have resulted in loss of flow and reduction in pool water level (Cardno 2018). It is noted that a large proportion of this is expected to be ephemeral 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 connectivity for some species at times of naturally high rainfall.

The changes in water quality identified in Donalds Castle Creek at Fire Road 6 and in LA4 during extraction of Longwall 16 appear temporary and small in magnitude. Although reductions in pH and DO in LA4 were below the ANZECC Default Trigger Values (DTVs) for pH (lower DTV for pH 6.5 and DO 90 % saturation), this was also the case during the baseline period. The elevated EC recorded in LA4 did not exceed the lower DTV (350 µS/cm). Thus, significant impacts to aquatic ecology are not expected to occur. Likewise, the small area of iron staining observed in the ephemeral LA2 located directly above Longwall 16 is not expected to have resulted in a significant impact to aquatic ecology.

Table 1-3 Predicted and observed impacts to aquatic ecology associated with Longwall 16

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 16.
Fracturing of bedrock and diversion of surface flows	No significant fracturing resulting in surface water flow diversions. Minor, isolated fractures of the streambed may occur within 400 metres from the proposed Longwalls. Minor fracturing of the creek bed and subsequent diversion of flows would not have significant geochemical effects. Formation of ferruginous springs is unlikely, but could occur at the margins or upslope of swamps (Ecoengineers 2011).	No significant changes in the quantity or quality of permanent aquatic habitat due to fracturing of bedrock and diversion of surface flows.	No reductions in pool water levels and flow or changes in water quality observed by South32 during extraction of Longwall 16, and, thus no suggestion of impacts occurring to aquatic habitat and biota
Donalds Castle Creek and drainage lines (WC15, LA4, LA2)			
Ponding, flooding and scouring of stream banks due to tilt	Reversals in grade may occur along Tributary WC21, adjacent to the tailgates of Longwalls 10 and 11. These could result in small increases in the levels of ponding, flooding and scouring of stream banks in highly localised areas along the tributaries. The impacts resulting from such changes are expected to be small relative to those that occur naturally during floods.	Localised changes in habitat availability and connectivity may occur along the tributaries due to tilt, but will be difficult to detect because of the large variability in natural flows within these ephemeral systems.	No impacts observed due to tilt.
Fracturing of bedrock and diversion of surface flows	Fracturing of the bedrock is likely to occur. In ephemeral creeks with alluvial deposits, fractures are likely to be in-filled by deposits during flow events. In areas with exposed bedrock, some diversion of surface flows into underlying strata and drainage of pools may occur, particularly during low flows. It is unlikely, that this would result in a significant impact on the overall quantity or quality of water flowing from the catchment.	There is unlikely to be any significant long-term changes in the quantity, quality or connectivity of aquatic habitats. Any losses of habitat and connectivity that do occur would be minor, localised and transient.	None observed in Donalds Castle Creek during extraction of Longwall 16. Fracturing of bedrock and diversion of flows in WC15 (a drainage line of Wongawilli Creek) would have resulted in further reduction in quantity and connectivity of ephemeral aquatic habitat in this drainage line. Given the area of affected habitat (10 m x 7 m) and abundance of comparable first and second order stream habitat in the upper Avon and Cordeaux Catchments, associated impacts to aquatic biota would also be expected to be minor. The relatively minor changes in water quality that have been observed in Donalds Castle Creek and LA4 and the increase in iron straining in LA2 are not expected to have significant impacts on aquatic biota.

It is very unlikely that the threatened Macquarie perch previously identified downstream in Wongawilli Creek has been put at risk by extraction in DA3B. 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 near Longwall 16, nor were any impacts observed here during extraction of Longwall 16. 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.

It is difficult to quantify the additional impact to aquatic habitat and biota in WC15 due to extraction of Longwall 16. The physical mining impacts observed during extraction of this longwall occurred following

several other mining related impacts that occurred in DA3B during extraction of previous Longwalls 13, 14 and 15. It is probable that the additional fracturing observed in WC15, and any that was not observed, has exacerbated the existing impacts to water levels and flow.

Overall, it is difficult to link any physical mining related impact with associated impacts on aquatic habitat and biota with extraction of individual longwalls. Physical mining impacts that have occurred may be associated with individual longwalls or a cumulative effect of several longwalls. In such cases, it is unclear if 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 TARP levels to determine if these have been triggered and what management actions associated with extraction of Longwall 16 and previous longwalls may be appropriate, if any. These TARPS are applicable only to watercourses where aquatic ecology monitoring sites are located (Wongawilli Creek, Donalds Castle Creek). For Site X1 on Donalds Castle Creek, the active subsidence period ended on 24 October 2013 when Longwall 9 was more than 400 m away from this site. It is noted that the TARP triggers here relate to mining of the domain as a whole, rather than individual longwalls. Thus, the reduction in aquatic habitat observed at these sites constitute a Level 3 Trigger. Actions for a Level 3 Trigger include notification of stakeholders and the development and implementation of CMAs. It would be possible but unlikely that extraction of Longwall 16 may have affected Donalds Castle Creek. The reductions in pool water levels and aquatic habitat in Wongawilli Creek during 2018 occurred for less than 1 year and did not constitute a trigger.

Table 1-4 TARP triggers and current status in Wongawilli Creek and Donalds Castle Creek

TARP	Wongawilli Creek	Donalds Castle Creek
Level 1 – Reduction in aquatic habitat for 1 year	Not triggered	Triggered September 2014
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	Triggered 24 October 2015
Level 3 – Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period	Not triggered	Triggered During 2017 Aquatic Ecology Surveys (Cardno 2018)

Conclusion and Recommendations

Fracturing and associated flow diversions was observed in drainage line WC15 during extraction of Longwall 16. The other two fractures were additional fractures in areas previously affected by Longwall 14. In isolation, these impacts represent relatively minimal impacts to aquatic habitat and biota in these watercourses. Due to the limited aquatic habitat provided by WC15, and the abundance of drainage line habitat in the Metropolitan Special Area, the fracture and flow diversion observed represent minor impacts to aquatic ecology at the scale of the Cordeaux River and Avon River catchments. The apparent temporary and minor changes in water quality and iron staining observed drainage lines of Lake Avon (LA2 and LA4) and Donalds Castle Creek also represent relatively minimal impacts to aquatic ecology. Those in LA4 and Donalds Castle Creek were also attributed to extraction of previous longwalls. At this stage, no specific actions associated with Longwall 16 or these drainage lines are recommended. No mining impacts were observed in Wongawilli Creek during extraction of Longwall 16.

Nevertheless, extraction of Longwall 16 would have added to existing physical mining impacts, reduction in availability of aquatic habitat and assumed loss of some associated aquatic biota in WC15 and potentially other drainage lines in DA3B. However, it is difficult to quantify what proportion of the observed impacts are associated with extraction of Longwall 16 alone. It would be expected that extraction of Longwall 16 would have contributed to mining induced groundwater depressurisation in DA3B. This could result in a greater potential for and severity of any future similar reductions in pool water levels and flow in Wongawilli Creek. It is noted that previous reductions in flow observed in Wongawilli Creek have been within predictions. No TARPs have been triggered with respect to Wongawilli Creek. Level 3 triggers were in place for WC21 and Donalds Castle Creek prior to extraction of Longwall 16 and remain in place.

It is recommended that further during- and post-mining aquatic ecology monitoring is completed in DA3B in Wongawilli Creek and Donalds Castle in line with the AFFA and SMP. South32 should continue to monitor

watercourses that have been affected by extraction of Longwall 16 and previous longwalls and the findings of these will be used to assess whether TARPs will subsequently be triggered.

Yours sincerely,

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