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Josh Carlon
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Dear Josh,

RE: Review of Aquatic Flora and Fauna for Dendrobium Area 3B Longwall 12

Introduction

South32 – Illawarra Coal (South32) is extracting coal using longwall mining techniques from the Dendrobium Coal Mine, situated approximately 15 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. DA3A currently comprises Longwalls 6, 7, 8 and 19 which are situated between Wongawilli and Sandy Creeks. Longwalls 6, 7 and 8 were completed from 2010 to 2012. Mining of DA3B Longwalls 9 to 18 commenced following completion of Longwall 8 in the following sequence:

> Longwall 9 commenced 9 February 2013; completed on 2 June 2014;

> Longwall 10 commenced 21 January 2014; completed 20 January 2014;

> Longwall 11 commenced 18 February 2015; completed 26 January 2016; and

> Longwall 12 commenced 22 February 2016, completed 31 January 2017.

Extraction of DA3A Longwall 19 will follow mining in DA3B.

Cardno NSW/ACT (Cardno) was commissioned by South32 to undertake a review of aquatic flora and fauna in relation to the extraction of Longwall 12 to support the End of Panel reporting for the Longwall. Cardno has been undertaking ongoing monitoring of aquatic ecology in the watercourses within the DA3B mining area. These include the perennial Wongawilli Creek, Donalds Castle Creek and several associated tributaries. The overall objective of the monitoring is to determine whether the extent and nature of observed impacts, primarily subsidence-induced fracturing of bedrock, diversion and loss of aquatic habitat, if any, are consistent with the predictions made in the aquatic flora and fauna review (AFFA) (CEL 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 site visits undertaken by Cardno and a comparison with those predicted in the SMP; and

> Recommendations for any Corrective Management Actions (CMA) and future aquatic flora and fauna monitoring.

The review considers the effects of extraction of Longwall 12 in DA3B and focuses on the findings of ongoing monitoring by South32 and on data from aquatic ecology impact sites in Wongawilli Creek and WC21. Information on Lake Avon tributaries near the western extent of Longwall 12 has also been provided by South32, though these are not routinely monitored by Cardno as part of the ongoing aquatic ecology monitoring. Donalds Castle Creek is located some distance downstream of Longwall 12 and is not relevant to this review.

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 (CEL 2012) and included in the SMP for DA3B (BHPBIC 2012) incorporates a Before, After, Control, Impact (BACI) sampling design to monitor mine subsidence impacts on aquatic ecology with collection of at least 2 years of baseline data and ongoing during and after extraction monitoring. The following indicators of aquatic ecology are considered at impact and control sites (total of 16) within and outside the SMP area for DA3B:

> Aquatic habitat 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; and

> Fish using backpack electrofishing and bait traps.

It was recommended also that monitoring in DA3B be undertaken once every two years CEL (2012b).

Table 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, followed by the first year of during-extraction monitoring in 2013, and the second in 2015. The first survey of the second year of during-extraction monitoring was undertaken in April 2017, with further surveys planned for May, October and November 2017. Additional monitoring was also undertaken in DA3B in 2011 to support the AFFA, including more extensive fish surveys in WC21. The AFFA also includes 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 during 2014 as part of the ongoing monitoring for DA3A.

The Illawarra Coal Environmental Field Team (ICEFT) also undertake weekly monitoring of landscape and natural features in DA3B. This includes monitoring during extraction of Longwall 12 to identify any fracturing, pool water loss, changes in flow and water quality in Wongawilli Creek and its tributary WC21, Donalds Caste Creek, and Lake Avon tributaries, including LA4 and LA4B.

The SMP also 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); 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 aquatic ecology, 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.

Table 1 Monitoring undertaken for DA3B longwalls in line with the DA3B SMP Requirements and Recommendation in CEL (2012)

Baseline Monitoring		
Report	Survey Date	Sampling Component
Dendrobium Areas 3A and 3B. Aquatic Ecology Monitoring 2008 to 2013 (CEL 2014)	Mar / May / Sep Nov 2010 Apr / Jun / Sep / Oct 2011	Habitat assessment, fish, macroinvertebrates, water quality
During Extraction Monitoring		
Report	Survey Date	Sampling Component
Dendrobium Areas 3A and B. Aquatic Ecology Monitoring 2008 to 2013 (CEL 2014)	Apr / Jun / Sep / Nov 2013	Habitat assessment, fish, macroinvertebrates, water quality
Dendrobium Area 3A Aquatic Ecology Monitoring 2008 to 2014 (CEL 2015)	Throughout 2014	Visual 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 (CEL 2017)	May / Jun / Oct / Nov 2015	Habitat assessment, fish, macroinvertebrates, water quality
Expected late 2017	Apr / May / Oct / Nov 2017	Habitat assessment, fish, macroinvertebrates, water quality

Predicted and Observed Impacts to Aquatic Ecology

Details of the physical and water quality impacts identified by ICEFT (ICEFT 2017) during extraction of Longwall 12 are provided in **Table 2**. The impacts to aquatic ecology observed by ICEFT and Cardno associated with these physical and water quality impacts are described in **Table 3**, along with the impacts that were predicted to occur to aquatic ecology based on the physical and water quality impacts in the AFFA (CEL 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 and their predicted impacts on the physico-chemical characteristics of the waterways (MSEC 2011) and the assessment of potential impacts on surface water quality (Ecoengineers 2011). Finally, **Table 4** compares observations with the TARP levels to determine if these have been triggered and what management actions associated with extraction of Longwall 12 may be appropriate, if any. These TARPS are applicable only to watercourses where aquatic ecology monitoring sites are located (Wongawilli Creek and WC21)

The physical mining impacts observed in Lake Avon LA4B were associated with some reduction in the amount aquatic habitat. Based on the abundance of first and second order stream habitat in the local area these impacts are relatively minor the context of the Metropolitan Special Area Catchment. Though water quality-triggers have been recorded (dissolved oxygen in LA4 and electrical conductivity in Wongawilli

Creek), these appear to have been temporary changes. In addition, the preliminary findings of the April 2017 survey does not suggest any change to aquatic habitat, macroinvertebrates and fish in Wongawilli Creek.

During the latest aquatic ecology monitoring survey in April 2017, the only aquatic habitat at X2 in WC21 consisted of a few small and disconnected pools, likely derived from rainfall (**Plate 1a-c**). This site is above Longwall 9 and approximately 900 m downstream of Longwall 12. Fracturing was also present at the upstream section of this site. Mining-related fracturing of bedrock, flow diversions and associated reductions in pool water levels and flow were first observed in WC21 by Illawarra Coal in December 2013. Associated loss of aquatic habitat was first observed by Cardno in early 2014 (CEL 2015). By 2015, there was a complete loss of surface water base-flow at aquatic ecology monitoring site X2 (approximately 100 m long) and surface water was restricted to a few small, disconnected pools. By March 2016 the length of WC21 that had been affected by reduction in surface flow and pool water levels was 1,050 m (South32 Pers. Comm. March 2016) and by April 2017 it was approximately 1,600 m (South32 Pers. Comm. April 2016). This reduction in aquatic habitat availability and connectivity in WC21 represents a significant impact to aquatic ecology with respect to this tributary.

Table 2 Physical and water quality impacts observed by ICEFT during extraction of DA3B Longwall 12

Watercourse	Site	Impact Type	Date	Description
LA4	DA3B_LW12_005	Rock fracture	3/05/2016	Rock fracture and uplift and associated diversion of flows
LA4	DA3B_LW12_006	Water Quality	3/05/2016	Reduction in dissolved oxygen below trigger value
LA4B	DA3B_LW12_008	Rock fracture	20/05/2016	Rock fracture and uplift to rockbar, associated flow diversion expected to occur during period of flow
LA4B	DA3B_LW12_010	Rock fracture	25/05/2016	Rock fracture to sandstone channel, flow diversion evident.
WC21	DA3B_LW12_019	Rock fracture	09/11/2016	Hairline fracturing and associated uplift on WC21 Rockbar 48
Wongawilli Creek	FR6	Electrical conductivity recorded slightly above trigger value	23/01/2017	Electrical Conductivity of 189 µS/cm was recorded, above the 154.1 µS/cm trigger level.

It is difficult to quantify the additional impact to aquatic ecology that may have occurred in WC21 due to extraction of Longwall 12 as the physical mining impacts observed in WC21 during extraction of this longwall occurred following the several other mining related impacts that occurred here during extraction of previous DA3B Longwalls 9, 10 and 11. At the very least, it is possible that the additional fracturing observed in WC21, and any that was not, has exacerbated the existing impacts. The length of WC21 affected has increased between March 2016 and April 2017 suggesting that extraction of Longwall 12 has contributed to the impacts currently observed in WC21.

Nevertheless, during the latest site visit as part of the ongoing aquatic ecology monitoring in April 2017, flow was present downstream from the impacted area at aquatic ecology monitoring Site 6, located on WC21 just upstream of its confluence with Wongawilli Creek. In April 2017, water was also present upstream of Site X3 (**Plate 1d**), which is located on WC21, 80 m downstream of Longwall 12, and within the length of WC21 where water loss was observed previously by ICEFT, albeit during an extended dry period. The channel and banks at X3 consist of loose sediment and detritus, compared with the exposed bedrock and general absence of this material further downstream at X2. This material may have filled-in any

Table 3 Predicted and observed impacts to aquatic ecology associated with Longwall 12

Attribute	Predicted Physical Impacts	Predicted Impacts on Aquatic Ecology	Observed Impacts to Aquatic Ecology
Wongawilli Creek			
Ponding, flooding and scouring of stream banks	No significant change predicted.	No measurable effects on the availability and connectivity of most aquatic habitats.	None identified during observations at aquatic ecology monitoring sites on Wongawilli Creek in April 2017.
Fracturing of bedrock and diversion of surface flows	No significant fracturing of bedrock or surface water flow diversions. Minor, isolated fractures of the streambed may occur within 400 metres from the proposed Longwalls. No diversion of surface flows.	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.	None identified during observations at aquatic ecology monitoring in April 2017.
Tributaries (WC21, LA4 and LA4B)			
Ponding, flooding and scouring of stream banks	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. The diverted water is likely to re-emerge downstream, so net loss of water from the catchment is unlikely.	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 also 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.	Rock fracturing observed in WC21 during extraction of Longwall 12 has potentially exacerbated impacts (fracturing and associated reduction in the water level of pools and reductions in the quantity and connectivity of aquatic habitat) identified during extraction of previous DA3B longwalls. Due to the impacts previously observed, any additional impact associated with extraction of Longwall 12 cannot be quantified. Fracturing of bedrock and diversion of flows in Lake Avon tributaries is likely to have resulted in some minor reduction in quantity and connectivity of aquatic habitat here.

subsurface bedrock fractures (none have been observed) in this section of creek, thereby reducing the extent and / or duration of flow diversion and habitat loss that may have occurred. Thus, while there has been a significant impact to aquatic ecology at the scale of the tributary, this appears localised to the area directly adjacent to the observed physical mining impacts. TARP Level 1 has not been triggered with respect to WC21 as water was observed at Site X3 in April 2017. Furthermore, there was no evidence of any change to macroinvertebrate and fish data at the site further downstream on WC21 (Site 6) following extraction of Longwalls 9, 10 and 11 (CEL 2017), further suggesting that impacts observed in WC21 are localised to the areas directly affected by habitat loss. Monitoring of this site will continue throughout 2017 as part of the ongoing monitoring program.

Table 4 TARP levels applicable to aquatic features relevant to Longwall 12 as of May 2017

TARP	Wongawilli Creek	WC21
Level 1 – Reduction in aquatic habitat for 1 year	Not triggered	Not triggered
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);	Not triggered	Not triggered
Level 3 – Reduction in aquatic habitat for >2 years or complete loss of habitat following the active subsidence period	Not triggered	Not triggered

Conclusion and Recommendations

The fracturing of bedrock and reductions of pool water levels and flow in WC21 following the extraction of DA3B Longwalls 9, 10, 11 and 12 represents a local loss of aquatic habitat and biota. This represents a significant impact to aquatic ecology associated with this tributary. However, due to the impacts observed during extraction of Longwalls 9, 10 and 11, it is difficult to quantify what proportion of the observed impacts are associated with extraction of Longwall 12. The reach of WC21 above Longwall 12 may be less susceptible to fracturing induced flow diversions and habitat loss, due to increased amounts of loose sediment and detritus and reduced valley depth resulting in reduced valley closure movements. Nevertheless, it is likely that extraction of Longwall 12 has increased impacts to WC21, particularly as the length of creek affected by this longwall increased during extraction. At this stage, and following the April 2017 observation of water at monitoring site X3 located just downstream of Longwall 12, no TARPs have been triggered with respect to Longwall 12 as there does not appear to have been a loss in aquatic habitat here for longer than 1 year.

Due to the limited aquatic habitat provided by Lake Avon tributaries LA4 and LA4B, and the abundance of these stream types in the Metropolitan Special Access Area, the fracturing and flow diversions observed here represent a minor impact to aquatic ecology. At this stage, no specific recommendations or associated with these tributaries is required, nor are TARPS applicable to these tributaries. No TARP has been triggered with respect to Longwall12 and Wongawilli Creek and WC21.

It is recommended that further during and post mining aquatic ecology monitoring is completed in DA3B and in WC21 in line with the AFFR and SMP. South32 should continue to monitor WC21 and other watercourses that have been affected by extraction of Longwall 12 and the findings of these will be used to assess whether TARPs have been triggered with respect to Longwall 12.

Furthermore, the triggering of aquatic ecology TARPs associated with the impacts observed in WC21 and following extraction of Longwalls 9, 10 and 11 should continue to be reviewed, as these are likely to have been triggered, and management actions and CMAs may be appropriate.

Yours faithfully,

Daniel Pygas

Senior Environmental Scientist, Cardno

Plates

Plate 1: Site X2 on WC21 in a) November 2013 b) November 2015 and c) April 2017 and d) Site X3 further upstream on WC21 in April 2017

References

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