

GLENCORE

**INVESTIGATION OF COXS
RIVER SWAMP MONITORING
PROGRAM**

Groundwater Level and Quality

FINAL

June 2020

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Prepared by
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on behalf of
Baal Bone Colliery

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1.0 Introduction

1.1 Background

Baal Bone Colliery is an underground/open cut coal mine that has been in care and maintenance since September 2011. The mine is located in the Western Coalfields of NSW, approximately 125 km north-west of Sydney, 25 km north-west of Lithgow and 5 km north-east of the township of Cullen Bullen. The mine is located within both the Hawkesbury Nepean Catchment and the Central West Catchment of NSW.

During operation, the Baal Bone Colliery extracted coal from the Lithgow Seam using open cut and longwall (underground) mining techniques. Open cut mining operations ceased in 2007 and in the same year the Department of Primary Industries (DPI) approved the most recent and last extraction of coal at the mine from longwall sections LW29-LW31, as shown in **Figure 1.1**. Underground mining of the longwalls occurred during the following periods and ceased in September 2011.

- Longwall 29: 6 July 2009 – 25 April 2010
- Longwall 30: 11 June 2010 – 2 February 2011
- Longwall 31: 7 March 2011 – 3 September 2011

Longwall mining typically results in subsidence of overlying strata which can impact surface and groundwater resources. Subsidence can result in changes in catchment boundaries, cracking that increases connectivity between surface and groundwater resources and exposure of strata containing soluble species (Jacobs 2015). Following rain events, runoff can leach soluble material from strata exposed by subsidence cracks. Runoff can infiltrate through the strata, travel as baseflow into groundwater sources and cause a reduction in water quality (Jacobs 2015).

The southern sections of Longwalls LW29-31 are within the headwaters of the Coxs River, a perennial river within the Hawkesbury Nepean Catchment, and the Coxs River Swamp catchment. Coxs River Swamp is a perched alluvial groundwater and surface water source, likely the result of an aquiclude formed by the Caley Formation (BBC 2019a). The Coxs River Swamp water sources are the Coxs River which flows through the swamp, groundwater flows from swamp catchment surface infiltration and rainfall-runoff from the immediate upslope catchment, including areas overlying LW29-31 (BBC 2019b) and supports a riparian ecosystem.

1.2 Groundwater Monitoring

Groundwater in and around Coxs River Swamp has been monitored for the purpose of identifying any potential impacts associated with the mining of LW29-31. Monitoring has occurred on a monthly basis, since 2007 for groundwater level and since 2008 for groundwater quality. The monitoring network consists of six (6) monitoring bores (refer to **Figure 1.1**) which includes one background monitoring bore (BBP4). BBP4 is considered to be unimpacted by mining of LW29-31 and therefore can be used for comparison with the five potentially impacted bores (BBP1, BBP2, BBP3, BB5 and BBP6).

1.3 Previous Studies

Aurecon (2009a)

Trigger levels for water quality parameters were developed in Aurecon (2009a) using baseline water quality collected monthly between November 2009 and April 2010 (six months total). Using the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) protocols, Aurecon (2009a) developed minor and major trigger levels which considered the pre-mining 80th percentile baseline and post mining 50th percentile, as well as allowing for the effects of short-term rainfall runoff events (BBC 2019a). The parameters monitored and associated trigger values are presented in **Section 2.1**.

Aurecon (2012)

In 2011, Baal Bone Colliery noted increases in trace metals (zinc, copper and iron) in some bores upslope of the Coxs River Swamp (BBP1, BBP2 and BBP3). Baal Bone Colliery engaged Aurecon to investigate exceedances of the trigger levels and review appropriateness of the TARP trigger levels considering new data. Aurecon (2012) noted that BBP3 showed exceedances for minor and major change criteria for iron and minor change criteria exceedances for zinc. Aurecon (2012) also noted major change criteria exceedance for copper at BBP4 (background bore) and minor change criteria exceedances for pH at BBP6. The report concluded “there is no need to update the TARP trigger values”. With regard to trace metal exceedances at BBP3 and BBP4, Aurecon concluded that:

- that the zinc exceedances at BBP3 were a result of natural variability and that the largest increase corresponded with the peak in rainfall recovery
- the copper exceedances at BBP4 were seasonal and associated with a natural process where biological decay results in increasing acidity and consumption of alkalinity which provides favourable conditions for the dissolution of trace metals
- the iron exceedances at BBP3 were likely the result of the wetting of dry strata following an extended dry period and a reflection of the natural abundance of iron in the area.

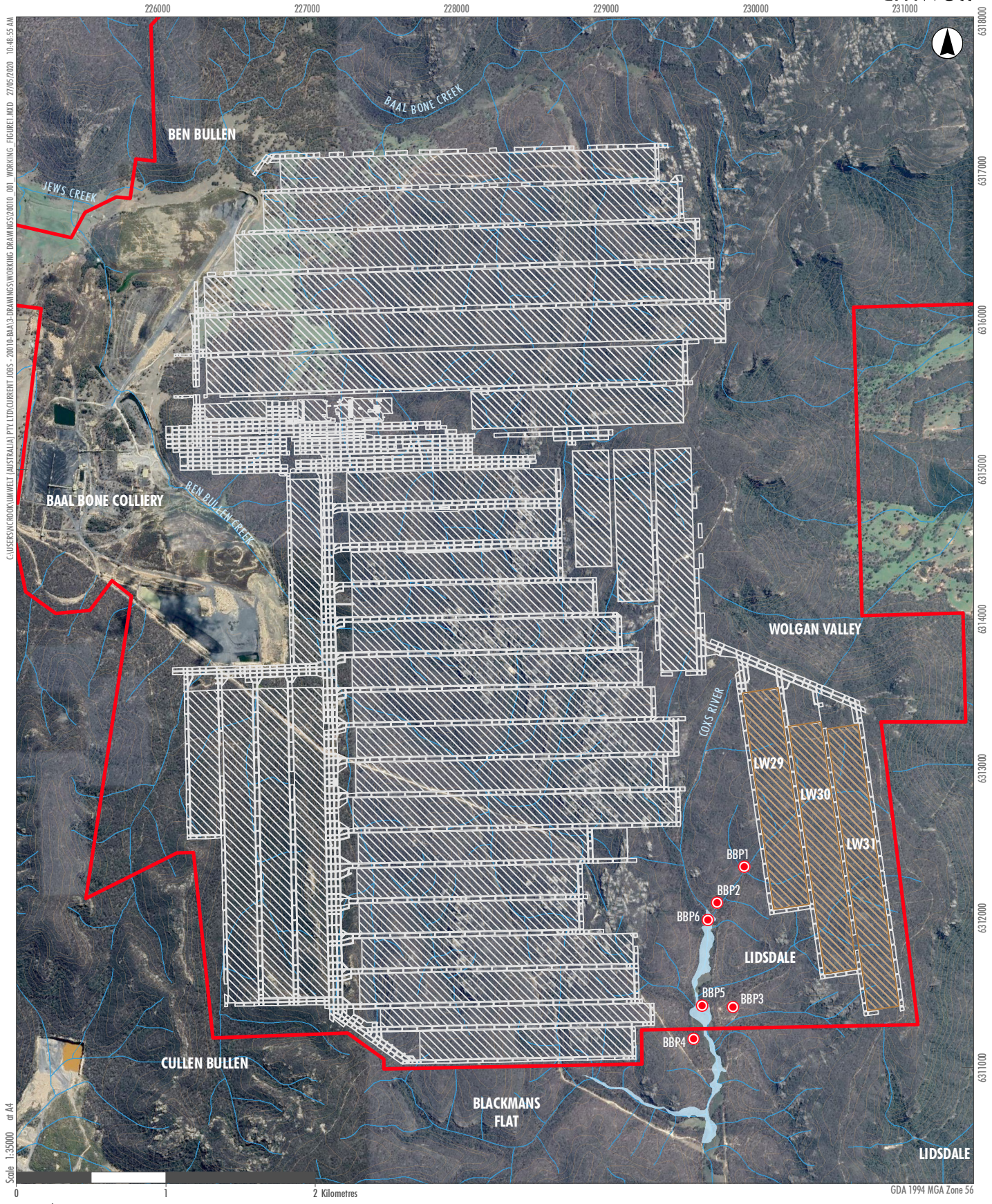
Hansen Bailey (2019)

Hansen Bailey were engaged to conduct an independent environmental audit of compliance at Baal Bone Colliery. Hansen Bailey (2019) found that ongoing exceedances of water quality trigger levels for dissolved zinc at BBP3 was a low risk non-compliance. The audit recommended that Baal Bone Colliery, “revisit the zinc trigger levels for BBP3 in consultation with DPIE for the closure stage”.

1.4 Purpose and Scope

The purpose and scope of this investigation is to assess:

1. the potential causes of elevated zinc concentrations at BBP3, including potential mine related impacts and natural processes
2. whether the existing groundwater minor and major change criteria (trigger values) should be updated
3. the benefits and need for ongoing monitoring (water quality and level) of the Cox’s River Swamp piezometer network.



- Legend**
- Baal Bone Colliery
 - Extraction
 - LW29-31
 - Workings
 - Groundwater Monitoring Locations
 - Cox River Swamp
 - Watercourses
 - Contours

FIGURE 1.1
Groundwater Monitoring Locations

Image Source: Google Earth (2020) Data source: NSW LPI (2019)

2.0 Data Analysis and Discussion

2.1 Groundwater Trigger Values

Groundwater trigger values or change criteria are presented **Table 2.1** below.

Table 2.1 Major and Minor Change Criteria

Parameter	Minor Change Criteria ^a	Major Change Criteria ^a	All Bore 80 th Percentile	BBP4 80 th Percentile
pH	4.6	4.2	5.0 ^b	5.5 ^b
Electrical conductivity ($\mu\text{S}/\text{cm}$) ^c	300	300	100	90
Copper (mg/L)	0.041	0.043	0.011	0.007
Iron (mg/L)	15.25	24.28	11	11
Zinc (mg/L)	0.143	0.175	0.098	0.074

NOTE:

^a Minor change criteria apply for ≤ 2 consecutive monthly measurements; major change criteria apply for >2 months.

^b 20th percentile for pH

^c 300 $\mu\text{S}/\text{cm}$ is from ANZECC (2000)

2.2 Groundwater Levels

Analysis of the groundwater level data with reference to BBP3 is summarised below (refer to in **Chart 1**):

- Groundwater levels at monitoring bores BBP2, BBP3 and BBP4, respond rapidly to short-term rainfall which suggests permeable soils within the Coxs River Swamp catchment and high groundwater-surface water connectivity. BBP5 and BBP6 maintain more consistent water levels due to their location within the swamp (refer to **Figure 1.1**). Prior to mining of LW29, BBP1 responded rapidly to short-term rainfall until mining impacted groundwater recharge at the bore. Mining of LW29 also impacted BBP2 groundwater recharge around the same time as BBP1, although a recovery in groundwater recharge at BBP2 is apparent from August 2010, also noted in Aurecon (2012).
- Groundwater levels across all of the monitoring bores, including BBP1, have responded to an extended period of dry conditions since January 2017, shown as the 'cumulative rainfall deficit' in **Chart 1**.
- Long-term groundwater levels across BBP2-BBP6 do not appear to have been impacted by the mining of LW29 to LW31. Post-mining groundwater levels appear consistent with pre-mining levels, i.e. groundwater levels at BBP2-BBP6 vary with climatic conditions as they did prior to mining of LW29 to LW31.

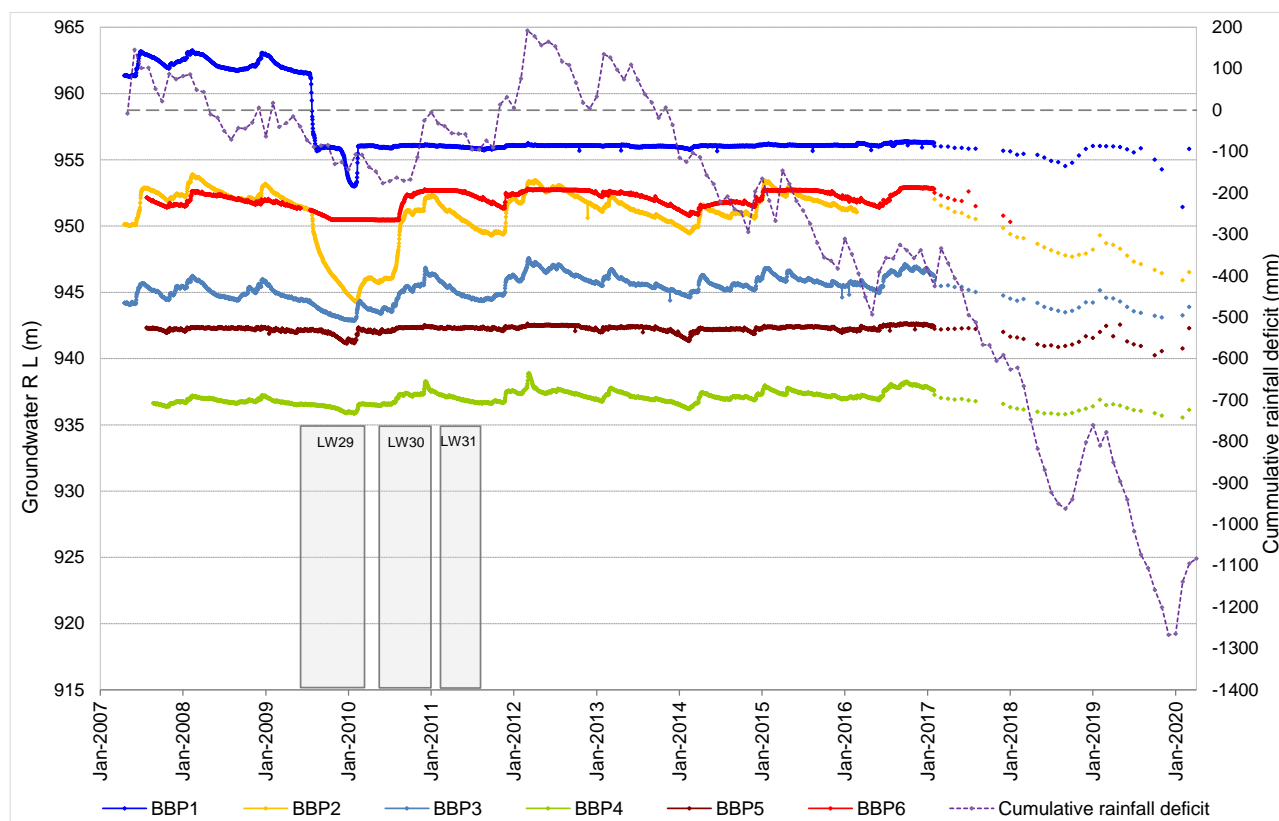


Chart 1 Coxs River Swamp groundwater levels for BBP1-BBP6 and cumulative rainfall deficit at Lithgow (Birdwood Street)

2.3 Zinc Concentrations at BBP3

The analysis of zinc concentrations at BBP3, and other trace metals investigated in Aurecon (2012), is summarised below (refer to **Chart 2**):

Since August 2012, zinc concentrations measured at BBP3 (Chart 2) were found to frequently exceed the major change criteria. Three events of significantly elevated zinc concentrations and several less significant events have occurred since monitoring commenced in 2008. Two of the three significantly elevated concentration events would classify as exceeding the major change criteria shown in , while the other events would only exceed the minor change criteria. All events are summarised below:

- A zinc concentration of 1.36 mg/L was measured on 1 September 2008 which was prior to the commencement of mining LW29 to LW31. Subsequent results fell below 0.175 mg/L and therefore the event only exceeded the minor change criteria.

NOTE – the zinc result of 1.36 mg/L was not included in the baseline data used to determine minor and major change criteria in Aurecon (2009a). No explanation is given for the exclusion of the result in Aurecon (2009a).

- Several zinc concentrations measured during mining of LW30 and LW31 and several shortly after mining exceeded the major change criteria value of 0.175 mg/L, but none of these occurred for more than two consecutive months. Therefore, these results are classified as minor change exceedances.

- A maximum zinc concentration of 1.61 mg/L was measured nearly one year after the completion of mining in LW31 on 29 August 2012. Zinc concentrations remained high for approximately one year following the initial concentration spike then gradually declined over several years. The majority of zinc results during this time exceeded the major change criteria.
- A zinc concentration of 2.05 mg/L was measured on 6 February 2019, nearly seven and a half years after mining. Subsequent results declined rapidly over the following three month period but then remained marginally above the major change criteria trigger value until February 2020.

The peak concentrations during many of these events was recorded shortly after increased rainfall following a prolonged dry period. This suggests that rainfall-runoff infiltration has mobilised zinc from dry strata within the BBP3 catchment and that a wetting and drying process could be a significant contributor to groundwater zinc concentrations.

Elevated zinc concentrations were observed to occur pre-mining, during mining and post-mining. Elevated zinc concentrations at times followed a rise in groundwater level in BBP3 (refer to **Chart 3**), which supports the rainfall-runoff observation stated above. However, groundwater level alone does not appear to be the only cause of the elevated concentrations with several rises in groundwater level not accompanied by elevated zinc concentration results. Rising and falling groundwater could support a natural wetting and drying process that also mobilises zinc contained in strata near the BBP3.

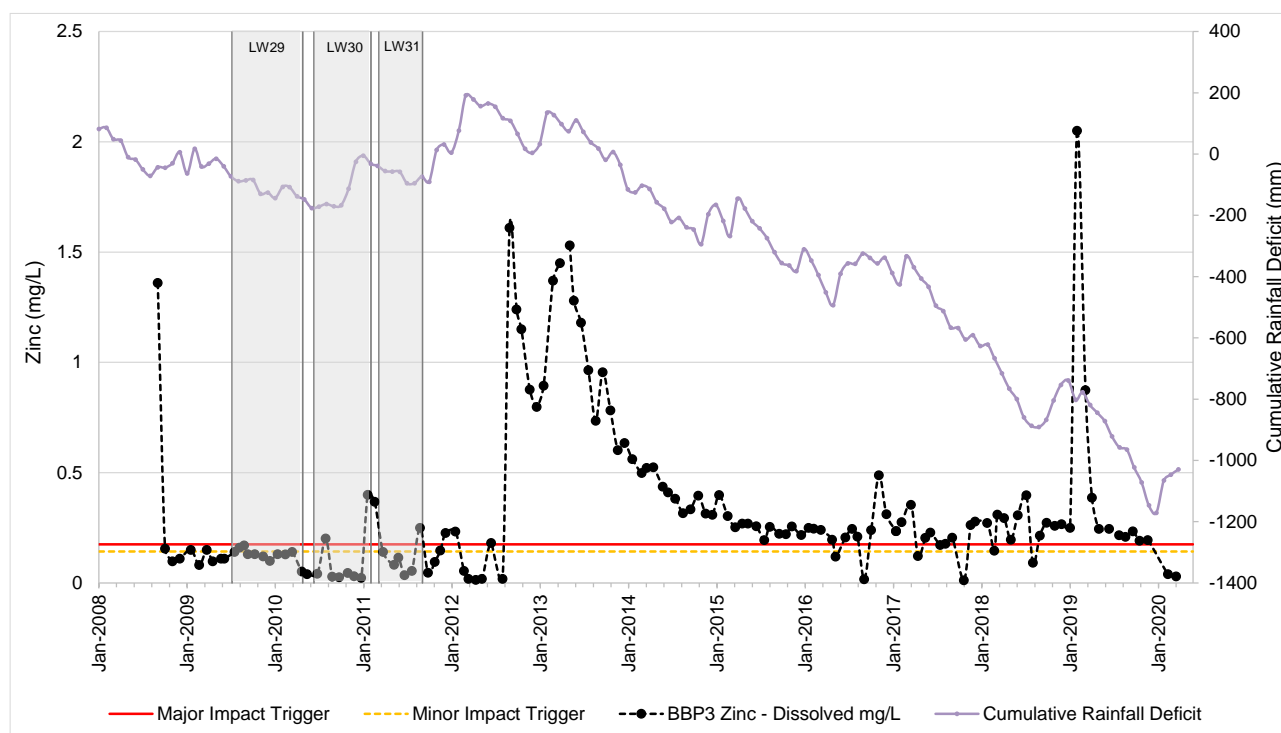


Chart 2 Dissolved zinc concentrations measured at BBP3 and cumulative rainfall deficit at Lithgow (Birdwood St)

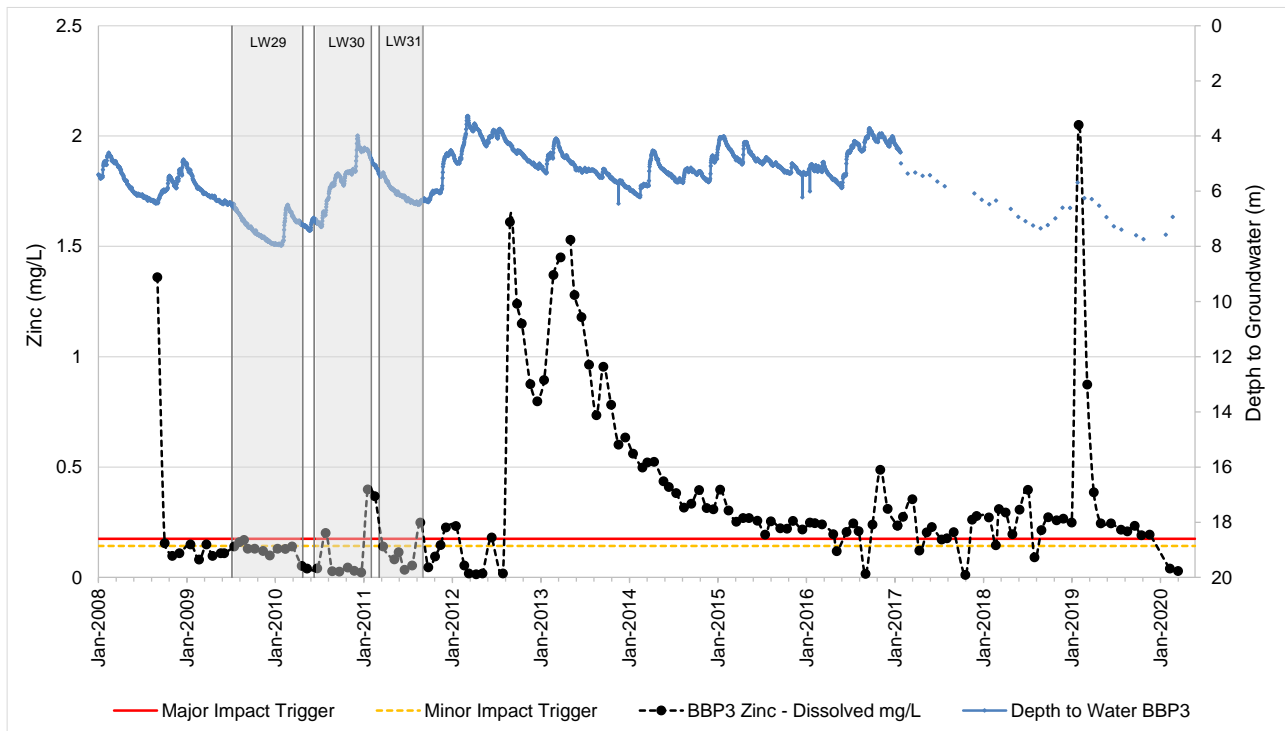


Chart 3 Dissolved zinc and depth to groundwater level measured at BBP3

The mobilisation of trace metals within catchments containing sandstone geology, following longwall mining, has been documented in *Monitoring and management of subsidence induced by longwall coal mining activity* (Jacobs 2015). This mechanism involves the fracturing of overlying sandstone strata that contains soluble metal species due to mining induced subsidence. Infiltration of rainfall-runoff through the newly exposed material dissolves and mobilises the soluble species. This may have contributed to the first major change exceedance for zinc concentration approximately one year after the completion of mining LW31. The high pre-mining zinc concentration demonstrates that the mobilisation of zinc, which is most likely to be contained in carbonate minerals in sandstone, can occur naturally. The increased fracturing and exposure of zinc bearing strata may accelerate and increase the short to medium-term impacts of this process. Observations supporting this mechanism at BBP3 are:

- LW31 footprint extends into the BBP3 catchment (refer to **Figure 1.1**). Any mining-related subsidence cracking, from the section of LW31 that extends into BBP3, might also extend further into BBP3 catchment.
- The extended period of elevated zinc concentrations following the completion of mining LW31 suggests increased exposure of zinc bearing strata to surface infiltration, which is a possible consequence of mining-related subsidence. Subsidence cracking could result in the exposure of a greater surface area of zinc bearing material to rainfall-runoff infiltration than that likely to occur by natural processes. As a result of this process, the rate of zinc dissolution, and therefore the measured zinc concentration in BBP3, may increase.

Results for iron (refer to **Chart 4**), which would be mobilised by the same mechanism described in Jacobs (2015), show that elevated concentrations coincided with the initial high concentration for zinc (September 2008) but did not coincide with the second (starting August 2012) and third (starting February 2019) increased zinc concentration events. There were elevated iron concentrations approximately one year prior to the second and third elevated concentration events, however, there appears to be no relationship between iron and major criteria zinc exceedances at BBP3.

Alkalinity (refer to **Chart 5**), which would increase with dissolution of carbonates bearing zinc, spikes at the same time iron increased prior to the second increased concentration event but does not follow the same behaviour for other events. Similar to iron, there appears to be no relationship between alkalinity and major criteria zinc exceedances at BBP3.

The consistent exceedances of the major change criteria since August 2012 corresponds to an extended period of rainfall deficit.

The two most recent zinc concentrations recorded are below the minor change criteria.

Comparing zinc, iron and alkalinity at BBP3 suggests that there are complex geochemical processes occurring across the catchment, but these do not fully support the mechanism described in Jacobs (2015).

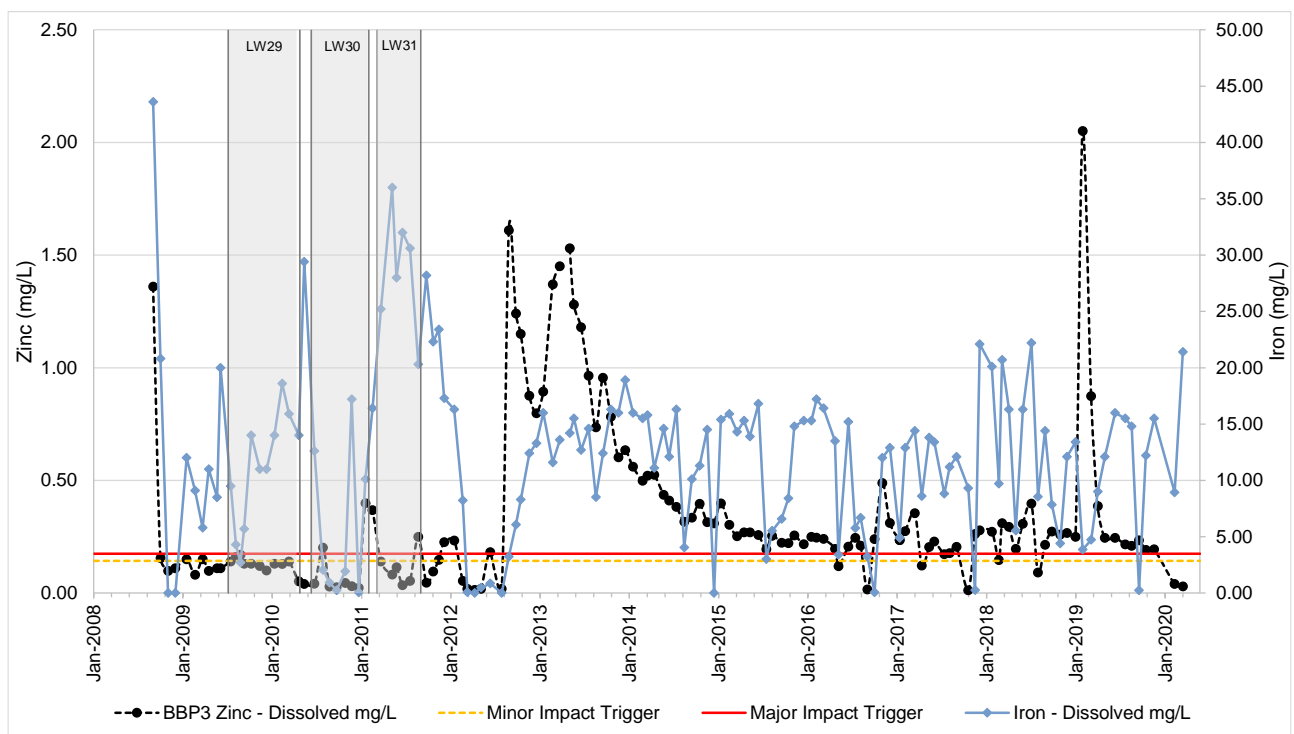


Chart 4 Dissolved zinc and dissolved iron measured at BBP3 (major and minor change criteria for zinc)

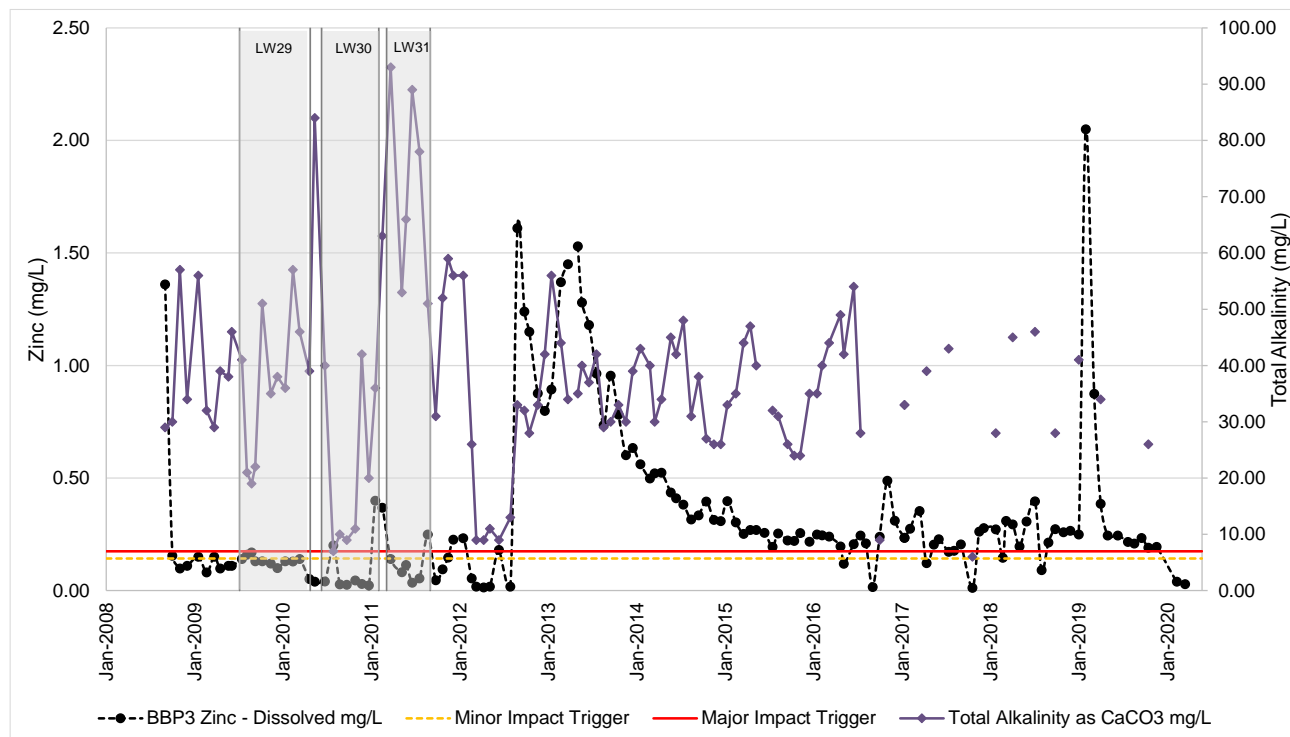


Chart 5 Dissolved zinc and total alkalinity measured at BBB3 (major and minor change criteria for zinc)

2.4 Zinc Concentrations at all Monitoring Bores

The analysis of zinc concentrations at groundwater bores BBB1-BBB6 (refer to Chart 6) is summarised below:

- Historical monitoring data for potentially mine impacted bores BBB1, BBB2, BBB5 and BBB6 demonstrates no exceedances of the major change criteria for zinc and, but two minor change exceedances for BBB2, one minor change exceedance for BBB5 (pre-mining) and two minor change exceedances for BBB6 (pre-mining). The pre-mining exceedances recorded at BBB5 and BBB6 were excluded from the baseline data set used to determine the current minor and major change criteria.
- Historical monitoring data for the background bore, BBB4, shows only two individual zinc results above the major change concentration, but these were not consecutive and therefore would be considered minor change exceedances.
- No elevated zinc concentrations were recorded for BBB5 and BBB6 (the monitoring bores within Coxs River Swamp) at the time of, or subsequent to, the recorded high zinc concentrations in BBB3 (refer to **Chart 6**). This indicates that elevated zinc concentrations recorded at BBB3 are not impacting on groundwater quality within Coxs River Swamp.
- While post-mining zinc concentrations at BBB3 are generally higher than those recorded in the pre-mining period, BBB3 has typically exhibited higher zinc concentrations than all other monitoring bores. This suggests a difference in the geochemistry of the strata within the BBB3 groundwater catchment that interacts with rainfall-runoff infiltration. Elevated zinc concentrations recorded at other bores, including the background bore BBB4, suggest that the dissolution of zinc is a natural process that is largely dependent on climatic conditions, i.e. rainfall to transport the element from zinc bearing strata.

- The prolonged period of elevated zinc concentrations following the completion of mining suggests that subsidence cracking impacted the rate of zinc mobilisation within the BBP3 groundwater catchment by exposing a larger surface area of zinc bearing strata to rainfall runoff infiltration. This would appear to have been exacerbated by a prolonged period of rainfall deficit which also seems to contribute to an increased tendency for zinc to mobilise in response to short term rainfall events. However, the most recent zinc results (February and March 2020) for BBP3, may indicate a return to pre-mining zinc concentrations.

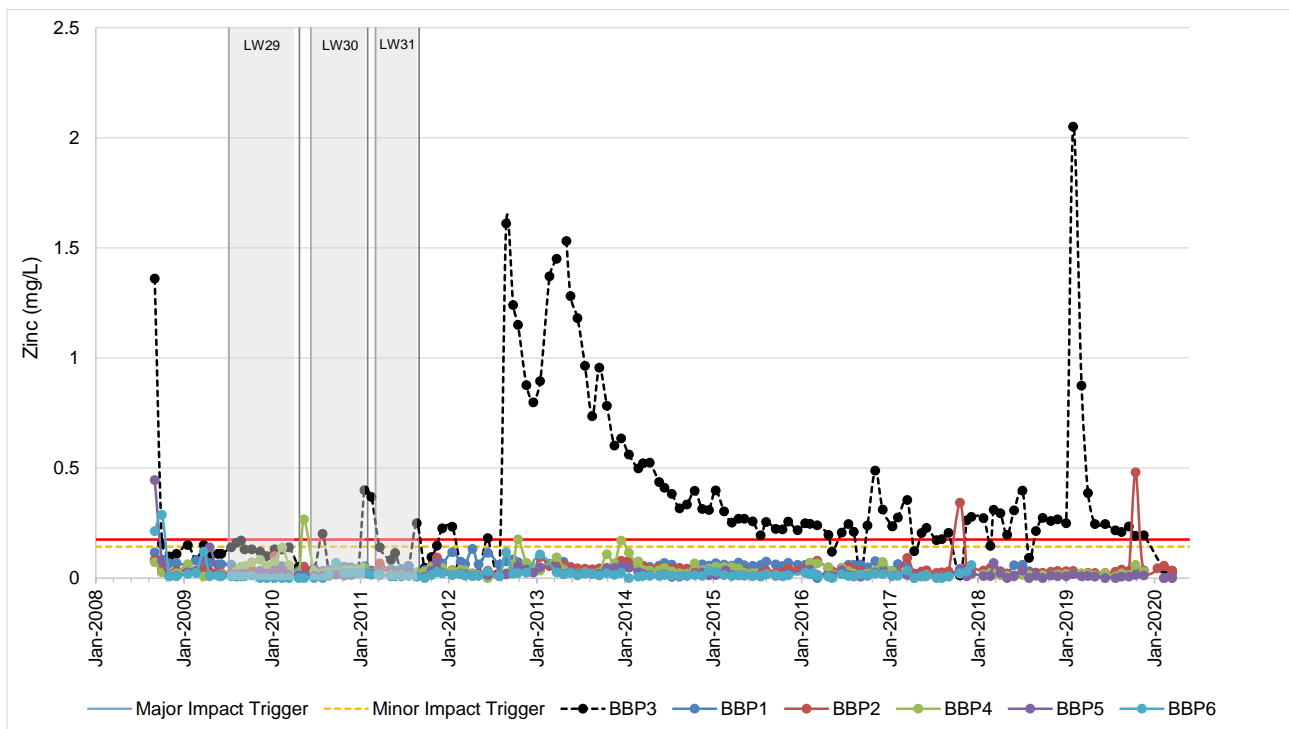


Chart 6 Dissolved zinc measured at BBP1-BBP6 with (major and minor change criteria for zinc)

3.0 Conclusion

Except for BBP1, groundwater levels in the Coxs River Swamp monitoring network do not show evidence of impacts associated with mining-related subsidence. Groundwater levels in these bores appear to be typical of a shallow groundwater source, responding to short-term rainfall and following long-term rainfall trends.

The mobilisation of trace metals and their transport of the mobilised metals to an underlying groundwater source is a naturally occurring process that may be accelerated by mining-related subsidence. Historical monitoring data for the period 2008 to present suggests that this natural process has occurred across all of the Coxs River Swamp monitoring bores, including the background bore BBP4. The data also shows that subsidence around LW31 may have accelerated this process and contributed to an extended period of elevated zinc concentrations in BBP3. However, given the ongoing period of rainfall deficit and the high pre-mining zinc concentration (recorded September 2008), the elevated zinc concentrations recorded at BBP3 cannot be definitively attributed to mine subsidence.

4.0 Recommendations

Monitoring bores BBP1, BBP2, BBP5 and BBP6 do not show evidence of groundwater quality impacts associated with mine subsidence. Rather, water quality within these bores appears to be representative of background groundwater quality and vary based on natural processes. As such, ongoing monitoring in these bores is unlikely to provide further benefit and is not recommended.

Given the consistently elevated zinc concentrations recorded at BBP3 it is recommended that water quality and level monitoring continue once every two months until at least December 2020 to confirm whether zinc concentrations return to pre-mining and pre-rainfall deficit concentrations. For reference purposes, groundwater level and water quality monitoring in the background bore, BBP4, should continue with BBP3 monitoring.

5.0 References

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