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Consequences and opportunities from river breach and decant of an acidic mine pit lake

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ABSTRACT

Mining typically diverts natural water courses during operations which are then not reinstated at closure allowing an isolated pit lake to form in the open cut void. Pit lake water quality may then degrade over time.

A heavy rainfall event led a diverted river to breach a large acidic, coal mine pit lake allowing assessment of river flow-through for both lake and downstream river environments.

Lake and river water quality samples were interpreted and compared to end use value guidelines. Fresher, more alkaline and nutrient-richer river water interacted with saline and acidic pit lake water improving upper lake water quality and enabling beneficial end use opportunities.

There was no significant risk of toxicity to downstream river livestock drinking water during the period. However, water quality at all sites sampled (including a reference site) exceeded pH and Zn ecosystem protection guidelines, and some recreational and aesthetic guidelines.

River flow-through is being trialled as the most sustainable long-term closure option for this lake. Flow-through may also represent the best closure scenarios for mine pit lakes with similar socio-environmental contexts.

1. Introduction

Due to operational and regulatory practicalities, pit lakes are common mine closure legacies for many open-cut mines. Pit lakes may form in open cut mine voids extending below the water table when they subsequently fill with ground and surface waters upon cessation of dewatering operations. Where natural water courses have been diverted during operations, these original water courses are then typically not reinstated in order to minimise risk to downstream values.

Pit lake water quality is often degraded by acid and metalliferous drainage (AMD) leading to acidic water with elevated metal concentrations (Castro and Moore, 2000; McCullough, 2008). Salinity may also increase through time due to evapo-concentration processes (Niccoli, 2009; McCullough et al., 2013b). This impaired water quality may leave a significant liability at mine closure and may also reduce end use values and opportunities (McCullough and Lund, 2006). Closure guidelines increasingly require of post-mining land uses of equivalent capacity to pre-mining conditions (Jones and McCullough, 2011; Jones, 2012). Good mine closure minimises long term post-mining landform liabilities and maximises benefits to stakeholders and the environment. However, the risks presented by pit lakes are regularly neglected in mine closure planning (McCullough and Lund, 2006; McCullough et al., 2009; Vandenberg et al., 2015).

One strategy that is increasingly used to maintain or improve pit lake water quality from both salinisation and acidification is to direct river flow (often back to its original course) through pit lakes (McCullough and Schultze, 2015). River flow-through strategies can increase the range of end uses available at closure and minimise long term lake liability issues for example, so that beneficial end uses dependent upon the water quality such as irrigation, recreation and wildlife habitat can be achieved (McCullough and Lund, 2006; McCullough and Van Etten, 2011).

A number of pit lakes have now used a river flow-through as part of closure including many pit lakes of the Central German Mining District (Klemm et al., 2005; Schultze et al., 2011b); British Columbia, Canada (Pelletier et al., 2009); Tennessee, USA (South Pit Lake, Wyatt et al., 2006); Northern Territory, Australia (Enterprise Lake, Fawcett and Sinclair, 1996), and Waihi, New Zealand (Golden Cross, Ingle, 2002; Castendyk and Webster-Brown, 2006). Flow through is also proposed in closure planning for pit lakes in the

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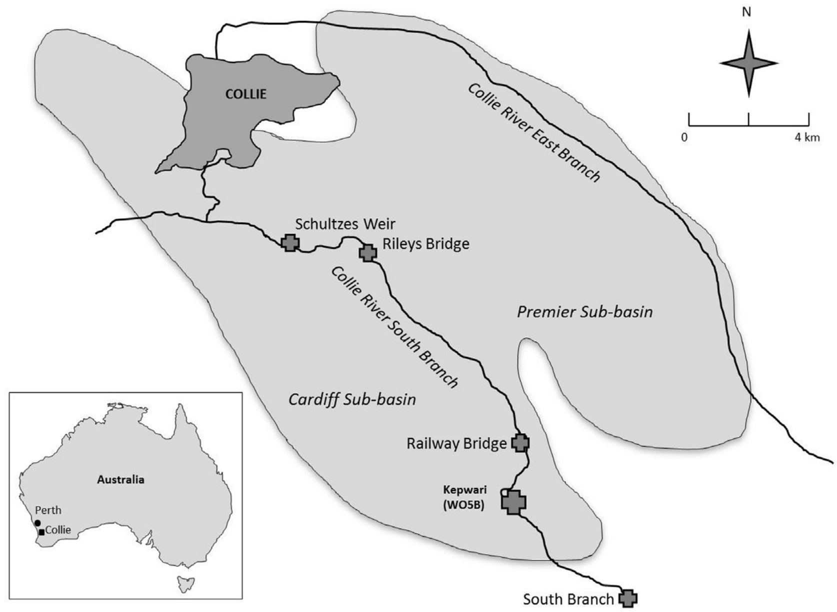

Fig. 1. Location of Lake Kepwari (large cross) in the Collie Coal Basin in south-western Australia. Water quality sampling sites above (South Branch) within (Lake Kepwari) and below (Railway and Rileys Bridges, and Schultzes Weir).

Athabasca oil sands region (CEMA, 2012), Western Australia (CEMA, 2012) and the Rhenish Mining District in Germany (Schultze et al., 2011a).

A pit lake may have positive effects on degraded rivers, such as nutrient removal, reduced suspended sediment loads and flood mitigation. Flow-through may also resolve many acidic pit lake water quality issues, such as low pH and elevated metal/metalloid concentrations. Connecting a pit lake to a river also increases the effective size of the pit lake catchment, allowing for greater inputs into the lake of nutrients, organic matter, plant propagules and biota (Lund et al., 2013).

Nonetheless, flow-through may create new liabilities associated with contamination of the river downstream with AMD from the pit lake. Risks include increased acidity, metal/metalloid, nitrate and ammonia concentrations, sediment retention, altered flow regimes, C and P nutrient and the lake acting as a barrier migrating biota. Many of these impacts are similar to those encountered after the installation of dams and weirs (McCartney et al., 2001).

This study describes river flow-through and decant of a pit lake during a flood event as an opportunity to evaluate river flow-through of an acid pit lake on pit lake and downstream river water quality. The key objectives for the current study were to determine if the AMD discharge reduced river end use values; and to ascertain how the inflow of river water altered water quality and limnology of the pit lake; in particular, if river inflow mitigated pit lake AMD. Together, the study sought to determine if river flow-through might form a long-term closure strategy for an acid pit lake.

2. Methods

2.1. Study area

The south west of Western Australia is regarded as highly bio-diverse, with eight of the ten native freshwater fish found in the south-west endemic (Morgan et al., 1998). At least five species of native freshwater fish with limited distributions are also specifically found in the study area located in the Collie region itself (Whiting et al., 2000). However, the biodiversity hotspot tag comes at a price, as these areas are listed for having the most endemic species and being the most threatened areas in the world (Myers et al., 2000; Malcolm et al., 2006) especially the aquatic ecosystems found there (Horwitz et al., 2008).

Collie is situated in an area of Mediterranean climate, with hot, dry summers (range 12–29 °C) and cool, wet winters (range 4–15 °C). Seventy-five percent of the rainfall occurs during the five months from May to September. The 100 year mean annual rainfall for the Collie Basin is 939 mm, although this has decreased to an average of 690–840 mm over the past 20 years (Lund et al., 2012). The mining of the Lake Kepwari void in south-west Australia (WO5B, Fig. 1) began with diversion of the seasonal Collie River South Branch (CRSB) away from the pit site around the western margin and ceased in 1997. During rehabilitation, reactive overburden dumps and exposed coal seams were covered with waste rock, battered and topsoil replaced, and revegetated with native plants. To reduce wall exposure and acid production, the pit void was rapid-filled by a brackish first-flush diversion from the CRSB over three winters from 2003 to 2005 (Salmon et al., 2008). The river diversion pathway was maintained around the lake.

Although river water initially raised water pH to above pH 5, lake pH subsequently declined to below pH 4 by 2011 and displayed elevated solute concentrations as a result of acidity inputs, most likely though in-catchment and in-lake acidity generation, and acidic groundwater inflow (Müller et al., 2011).

The volume of the lake is now around 32×10^6 m^3, with a maximum depth of 65 m and surface area of 103 ha. Although Lake Kepwari was proposed as a recreation resource for primary water contact activities such as swimming and water skiing (Evans and Ashton, 2000), low pH and high metal concentrations currently restrict authorised use of the lake for these purposes (Neil et al., 2009).

2.2. River breach and decant

On the 24th August 2011, a rainfall of 85.6 mm in Collie over 48 h (BOM, 2012) led to rapidly rising high flows in the CRSB of a 1:8 year magnitude (DOW, 2013) (Fig. 2). The water level in the CRSB rose, overtopping and then eroding the engineered northern dyke wall that separated the CRSB diversion from Lake Kepwari. As a result, water levels in Lake Kepwari rose from 185.1 m by 1.7 m