Independent Monitor ENVIRONMENTAL PERFORMANCE ANNUAL REPORT 2017-2018

McARTHUR RIVER MINE

SEPTEMBER 2018
Report No. 01164F_1_v2

NORTHERN TERRITORY GOVERNMENT

ERIAS GROUP

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Report to the Minister for Primary Industry and Resources
Department of Primary Industry and Resources

McArthur River Mine

Independent Monitor
Environmental Performance Annual Report
2017-2018

September 2018
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Document	Date	Compiled by	Checked by	Authorised by
01164F_1_v1	07/08/2018	MLC	DAB	DAB
01164F_1_v2	19/09/2018	MLC	DAB	DAB

Executive Summary

This is the fifth environmental performance report prepared by ERIAS Group since being appointed as the Independent Monitor (IM) in December 2013. The IM has prepared this report following review of monitoring data and various environmental assessments and similar documents, and a site inspection. The period covered by this report is October 2016 to March 2018. The review period has been increased by six months at the initiative of DPIR and MRM to reduce the timeframe between the end of the operating year and the IM publicly releasing its report. The IM strongly endorses this change and the importance of reporting on the environmental performance of the operation in a timely manner. The change in reporting timeframes has placed additional time restrictions on MRM and its specialists to complete annual monitoring reports. The IM commends MRM on its support to ensure that the IM’s report on environmental performance is relevant to stakeholders.

At the time of being appointed as the IM in December 2013, MRM advised government of significant changes in the geochemical classification of waste rock at the mine site. The McArthur River Mine deposit includes some of the most highly pyritic materials observed by the IM, and mine waste geochemistry (and its implications) remains the most significant environmental issue for the site. In addition to acid, metalliferous and saline drainage (AMD) issues, some mine materials have spontaneous combustion potential where there is abundant fine-grained pyrite and organic carbon.

Since understanding that the geochemistry of the waste rock was substantially different to its previous interpretation, MRM has made considerable progress in regard to understanding the AMD potential and leaching kinetics of mine materials (including waste rock, tailings, open cut walls/void and stockpiles) in recent years. This, together with more thorough definition of surface and groundwater AMD transport pathways, has enabled development of better and more defensible geochemical modelling and prediction of potential short- and long-term impacts. McArthur River Mining's proposed AMD management strategies have evolved over the last five years with this increasing knowledge, and the IM also notes that improved waste management and placement has reduced the occurrence of spontaneous combustion.

While the change in comprehension of the geochemistry of the waste rock was significant and resulted in extensive investigations over the last five years, the IM has also observed ongoing improvements in other areas of environmental performance at the site. These include:

- Management of water on the TSF.
- Construction and quality assurance/quality control at both the TSF and NOEF.
- Design and construction of the NOEF (including movement to lining runoff dams using high density polyethylene (HDPE)).
- Data collection and management of the site's water balance.

- Increased knowledge of the mechanisms impacting erosion of the McArthur River diversion channel.
- Implementation of measures to reduce movement of contaminated water and sediment at Barney Creek haul road bridge.
- Increased number of monitoring sites (e.g., surface water, groundwater, aquatic, marine) and, more importantly, a more rigorous analysis of this data to guide the implementation of mitigation strategies.

The continuous improvement in data collection, analysis and reporting is evident in the executive summary of the 2017-2018 OPR, where this describes MRM's key environmental objectives and a tiered management approach that takes into account preventative management (e.g., on-site water management), on-site performance identification (e.g., on-site artificial surface water quality, groundwater quality and natural surface water quality monitoring), off-site performance identification (e.g., downstream water quality monitoring), and performance confirmation (e.g., aquatic biota monitoring). The IM endorses this approach and notes that it reflects an integrated view of environmental management in relation to the environmental objectives – an approach that was not evident five years ago.

Planning for closure of the McArthur River Mine has been central to the numerous investigations that have been undertaken over the past five years. These investigations culminated in the Draft Overburden Management Project Environmental Impact Statement (OMP EIS) and Supplementary Environmental Impact Statement (SEIS). At the time of preparing this report, the findings of the Draft OMP EIS and OMP SEIS were being assessed by the Northern Territory government. It is clearly evident from the investigations that have been completed and subsequent development of closure strategies, and from discussions with MRM personnel on site, that planning and preparing for closure of the mine in the future is central to the operation of the mine.

Issues that the IM has identified during the review of the 2017-2018 operating year include the following, some of which have also been discussed in previous IM reports:

- The hydraulic assessment of potential erosion risk for the McArthur River diversion channel identified a number of measures used to determine erosion risk that are substantially above those recommended in relevant guidelines for diversion design. Substantial erosion is already occurring along sections of the diversion and recent risk ratings have indicated that further work is required to address this erosion risk.

  The potential for an avulsion[1] upstream above the McArthur River diversion channel should be noted as a substantial risk with potential impacts to diversion stability and the integrity of the mine levee wall. If this occurs it is likely that movement of the channel will occur reasonably rapidly with the channel likely to migrate into the old McArthur River channel. Impact to the mine levee wall is likely, potentially in the medium term and almost certainly in

[1] An avulsion is the rapid abandonment of a river channel and the formation of a new river channel.

the long term unless action is taken to address this risk. Not addressing this issue will also impact on any high flow off-take structure used in potential mine closure scenarios.

Should the avulsion occur, erosion will be ongoing and very difficult (and expensive) to mitigate. Proactive mitigation measures (mitigating erosion to halt the avulsion) are strongly recommended (pending an options investigation) as it will be far easier to stop the avulsion than to address its impacts.

- McArthur River Mining is devoting increased attention on the effects of the operation in terms of mine-derived loads reporting to McArthur River and the various sources that contribute to these loads. The existing (preliminary) information suggests that mine-derived loads for some contaminants is significant compared to background loads, and the next steps are for MRM to fully quantify these loads and changes over time, and determine the associated environmental risks, particularly in terms of downstream impacts within the context of the relevant environmental values.
- Declining groundwater quality near the SPROD, especially at bore GW95S where Zn concentrations of up to 59 mg/L were recorded, exceeded the Australian livestock drinking water trigger value of 20 mg/L. The source of the contamination has not been identified but most likely relates to ongoing seepage from the SPROD. The IM notes that MRM plans to install a synthetic liner at the dam, which should improve the nearby groundwater quality, although this will need to be confirmed with ongoing monitoring.

Some of the improvements noted by the IM in its review are:

- Continued improvement in results from monitoring of freshwater biota at McArthur River Mine, including no exceedances of the MPC of 0.5 mg/kg for Pb in muscle or liver of commonly consumed finfish species. Declining levels of contamination in environmental indicator species (including from SW19) are likely due to controls implemented by MRM (such as the installation of sediment sumps at SW19 and a berm along the eastern side of the haul road).
- Continued development of the acoustic monitoring program of migratory species (freshwater sawfish and barramundi) and the first data download and analysis of fish movements within the McArthur River and diversion channel.
- Developing and implementing an air quality management plan, and associated trigger action response plans (TARP), for the mine site and Bing Bong Loading Facility.
- Refining the seagrass monitoring program in 2016, with seagrass sampling sites modified within Sector 3 to address historical issues caused by a moving sandbar.
- Refining monitoring sites for the Annual Marine Monitoring Program in 2017, with sites around Sir Edward Pellew Islands discontinued and instead additional sites to the east of the Bing Bong Loading Facility added to better understand sources of contaminants in the study area.
- Initiating community engagement projects including the common edible species survey and a report that addresses traditional plants and their uses in the McArthur River area.

- Planting 84,000 tube stock in 2017 (which is reportedly twice the previous maximum number planted) with approximately 96% grown in the onsite nursery.
- Successfully retaining many of the grasses that were planted even after a significant wet season event in January 2018.
- Successfully eradicating weed infestations of neem tree at Bing Bong Loading Facility and devil's claw at the McArthur River floodplain with no plants identified during inspections in 2017.
- Completing construction and commissioning of the WPROD.
- Using alluvium advection barriers to reduce oxygen ingress into non-benign wastes.
- Identifying new resources of clay and alluvium material in the pit and borrow areas for construction of the NOEF.
- Improved handling and placement of clays that has significantly reduced the number of compaction tests not meeting the specification.
- Additional drilling of monitoring bores into the NOEF to improve understanding of temperature and gas transport processes in the dump.
- Updated geochemical modelling of the NOEF using an alternate approach to the previous DumpSim modelling as an independent check of findings.
- Improved block modelling, materials tracking and checks.
- Preferential construction of advection control layers on older, end-tipped dump areas of the NOEF.
- Initiating surface sampling and water extraction testing of deposited tailings (in the TSF), which confirm the lack of significant acid generation from oxidising tailings.
- Commissioning a new SCADA (supervisory control and data acquisition) network for monitoring and reporting of site water management operations in real time (e.g., pond water levels and water transfers).
- Substantially improving water management TARP tables.
- Successfully managing the high rainfall of January 2018 with no uncontrolled releases from any PROD or the TSF.
- Discharging a high volume (2,656 ML) of water in the 2017/18 wet season via controlled off-site releases to reduce the volume of water stored on the mine site. This was a substantial

increase on the 859 ML for the previous 2016/17 wet season and the 97 ML in the previous operational period[2].

- Improving groundwater monitoring at the McArthur River Mine and Bing Bong Loading Facility by installing new monitoring bores and equipping selected bores with loggers.

The IM has also reviewed DPIR's performance in regulating the McArthur River Mine. During the 2017-2018 operational period, the DPIR continued a series of field inspections that were aimed at:

- Informing the assessment by DPIR mining officers of the 2013-2015 MMP and amendments.
- Providing an update to management on the status of operations and assessing compliance with DPIR conditional approvals.

Following most of these site inspections, a detailed inspection report was compiled by DPIR, which discussed the objectives of the site visit, observations and findings, and included supporting photographs. During the reporting period, the IM noted an improvement with the DPIR inspection reports. The IM has previously recommended that inspection reports adopt a consistent approach to including recommendations and required actions. While the structure of reports from earlier in the reporting period differs from those later on, the inclusion of the recommendations section was a useful addition to reports from March 2017 onwards and the addition of the 'actions' within the 'observations' section in the February 2018 report was another positive inclusion which more clearly identify items for MRM to address.

In the last IM report it was noted that since commencing in the role as IM, a number of specific recommendations to improve the performance of DPIR have been made by the IM. Progress on implementing these recommendations had been slow. The IM recognises that DPIR has completed a number of recommendations during the reporting period and has commenced work on all outstanding recommendations.

[2] While the IM agrees with the principle of reducing the volume of stored water on site, appropriate consideration needs to be given to the consequent increased loads being discharged and the implications with respect to protecting downstream environmental values.

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1. Introduction

1.1 Role of the Independent Monitor

ERIAS Group Pty Ltd (ERIAS Group) commenced the role of Independent Monitor (IM) in 2014 following appointment by the Department of Mines and Energy (DME; now the Department of Primary Industry and Resources[1] (DPIR)) in December 2013. ERIAS Group's scope of work is to provide an independent monitoring assessment of the environmental performance of the McArthur River Mine (Figure 1.1). The scope of the project includes the mine (Figure 1.2) and Bing Bong Loading Facility (Figure 1.3). The main role of the IM is to assess the environmental performance of the McArthur River Mine by reviewing and reporting on environmental assessments and monitoring activities undertaken by McArthur River Mining Pty Ltd (MRM), and environmental assessments and audits undertaken by DPIR, with respect to the environmental performance of the mine and Bing Bong Loading Facility.

The imperative for the IM is outlined in the MRM mining authorisation (0059-01 and 0059-02[2]), where clauses 49 and 50 (independent monitoring assessment conditions) state that:

> 49. The purpose of these conditions is to establish and set out the operational requirements for an independent monitoring assessment of the environmental performance of the mine.
>
> 50. The Department will engage an Independent Monitor to undertake the independent monitoring assessment.

1.2 Scope of the Assessment

Clause 52 (a) of the independent monitoring assessment conditions states that the IM is required to monitor the environmental performance of the mine[3] by reviewing:

(i) environmental assessments and monitoring activities undertaken by the Operator; and

(ii) environmental assessments and audits undertaken by the Department.

Issues relating to mine safety, social issues, personnel matters, administration matters or governance arrangements resulting from the operation of the mine in the McArthur River region will not be included in the assessment.

This assessment of environmental performance addresses the period from October 2016 to March 2018 (inclusive)[4] and is referred to as the 2017-2018 operational period[5]. This operational period is six months longer than normal and has been extended for this year to reduce the timeframe from the completion of the operational year through to the reporting of environmental performance to stakeholders. In future years the operational year will cover the period from April to the following March.

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[1] During the 2016 operational year, the Department of Mines and Energy changed its name to the Department of Primary Industry and Resources. Throughout this report, reference has been made to Department of Primary Industry and Resources (DPIR) for consistency.
[2] On 29 November 2017, MRM was issued with a Variation of Authorisation.
[3] Includes Bing Bong Loading Facility.
[4] Note that monitoring data has been assessed primarily for the period of July 2016 to March 2018.
[5] The term operational period is interchanged with operational year, reporting period and review period throughout this report.

PROJECT LOCATION

McArthur River Mine Project

FIGURE 1.1

McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 1.2

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BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 1.3

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The scope of the assessment included the following:

- An inception meeting with MRM personnel at the mine site.
- Reviewing environmental assessments, monitoring activities and reviews undertaken by both MRM and DPIR.
- Undertaking a site visit and discussions with MRM personnel and MRM consultants.
- Undertaking a joint risk assessment workshop to promote a shared understanding of the risks. Participants included:
  - MRM personnel.
  - MRM consultants.
  - DPIR personnel.
- Reviewing relevant research required to inform monitoring activities.
- Discussions with DPIR personnel regarding progress on completion of recommendations from the last IM report.
- Updating the risk assessment and gap analysis for the 2017 operational period, taking into consideration the discussions from the joint risk review.
- Preparing a report for the Minister for Primary Industry and Resources concerning the environmental performance of the MRM operation (by both the operator and regulator).
- Preparing and distributing a community report to the Borroloola community and other key stakeholders concerning the environmental performance of the MRM operation. This includes a community presentation.
- Developing and maintaining a website for the display of the report, the response reports from the operator and regulator, community report and other relevant information.

1.3 Objectives of the Assessment

The objectives of the IM assessment are to:

- Document the review of environmental performance.
- Report on progress from the previous IM assessment.
- Identify any urgent issues that require investigation and reporting.
- Identify areas of MRM's and DPIR's environmental performance that require improvement and recommend actions to address these deficiencies.
- Acknowledge areas of MRM and DPIR environmental performance that are done well.

1.4 Report Structure

This report comprises the following:

- Executive Summary – provides a summary of how the assessment was undertaken and the key findings.
- Chapter 1 Introduction (this chapter) – provides definition around the scope of the assessment.
- Chapter 2 Background – provides general context for the assessment.
- Chapter 3 Method – outlines the approach to the review of environmental performance.
- Chapter 4 Results – presents results by technical discipline, e.g., geochemistry, and highlights key risks, controls, incidents and non-compliance, progress since the previous IM assessment, successes and new recommendations. Assessment of MRM and DPIR performance is described separately.
- Chapter 5 Summary of Recommendations – provides a summary of new and ongoing recommendations.
- Chapter 6 Conclusions – presents an overview of the environmental performance of the McArthur River Mine since the previous assessment and highlights the main areas of concern.
- Chapter 7 Limitations – identifies the limitations of the assessment.
- Chapter 8 Definitions – provides definitions for less commonly used terms.

The details of the bibliographic references used in the report are provided at the end of each section, as applicable.

Supporting information such as the updated risk assessment and gap analysis are appended to the report.

2. Background

2.1 Statutory Requirements

The need for the IM environmental assessment is set out in the mining authorisation (see Section 1.1) that is issued by the Mining Compliance Group of DPIR under the Northern Territory *Mining Management Act* (MM Act).

The MM Act is the main piece of legislation that governs mining operations in the Northern Territory. Pursuant to the act, a mining management plan (MMP) must be prepared that details the particulars of the management systems to address environmental issues. Operators are obliged to comply, and manage their operations in accordance, with the approved MMP. The currently approved MMP is the 2013-2015 MMP (see Section 3.2) that was approved by DPIR in December 2015. A number of amendments to the MMP have been approved since that date.

During the review period, three waste discharge licences (WDL 174-09, WDL 174-10 and WDL 237) were issued under the *Water Act* that applied to the discharge of wastewater into the McArthur River and at the Bing Bong Loading Facility. It is an offence under the *Water Act* if the holder of the waste discharge licence contravenes, or fails to comply with, the conditions of the licence.

The McArthur River Mine is also operated with reference to other legislation, agreements, standards and codes of practice, some of which are:

- *Aboriginal Sacred Sites Act* (NT) and *Aboriginal and Torres Strait Islander Act 2005* (Cwlth).
- *Environmental Assessment Act* (NT).
- *Heritage Act* (NT).
- *Mineral Titles Act* (NT).
- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
- *Waste Management and Pollution Control Act* (NT).
- Other relevant codes and standards (e.g., National Water Quality Management Strategy, National Health and Medical Research Council, Enduring Value Framework (Minerals Council of Australia), national environment performance measures).

2.2 Project Status

Mining at McArthur River Mine commenced in 1995 with underground operations and converted to open pit mining in 2007. In 2012, MRM submitted an environmental impact statement for the Phase 3 Development Project which involved expanding the operation to increase throughput of the processing plant from 2.5 million tonnes per annum (Mtpa), producing 360,000 dry metric tonnes per annum (dmtpa) of zinc-lead concentrate, to 5.5 Mtpa to produce approximately 800,000 dmtpa of zinc-lead concentrate. The Phase 3 Development Project also increased the mine life by an additional nine years to 2036. Construction and commissioning of the Phase 3 Development Project was completed in 2014.

In December 2013, MRM staff advised government that, following further testwork, the geochemical classification of the waste rock had changed. New categories for classification of the waste rock were introduced and in particular categories for waste rock which have the potential to generate saline/neutral metalliferous drainage. A notice of intent was submitted to the Environment Protection Authority (EPA) in June 2014 by MRM. The EPA, in its statement of reasons issued in July 2014, determined that an environmental impact statement was required to assess the environmental impacts associated with the change in geochemical classification of waste rock. The terms of reference for the Overburden Management Project EIS (OMP EIS) were finalised in September 2014. In March 2017, MRM submitted the Draft OMP EIS (MRM, 2017) to the EPA. Following an eight-week public consultation period, the EPA collated public comments and provided these to MRM. McArthur River Mining prepared a Supplementary EIS (SEIS) (MRM, 2018) responding to comments on the Draft OMP EIS and providing an update on changes to the project following the submission of the Draft OMP EIS. At the time of preparation of this report the EPA was continuing its assessment of the project.

Ore from the zinc/lead/silver deposit is extracted and processed to produce a high-grade concentrates. Waste associated with mining and processing is stored in the northern overburden emplacement facility (NOEF), western overburden emplacement facility (WOEF), southern overburden emplacement facility (SOEF) and tailings storage facility (TSF) (which comprises two cells and an adjacent water management dam). Three watercourse diversions have been required to facilitate the operation resulting in the construction of three diversion channels: McArthur River diversion channel, Barney Creek diversion channel and Little Barney Creek diversion channel. Surprise Creek is the other catchment within the mine development area (see Figure 1.2).

The concentrate is transported from the mine to Bing Bong Loading Facility by road along the Carpentaria Highway. The concentrate is stored at the loading facility in a concentrate storage shed from where it is loaded onto the MV Aburri bulk carrier and barged to waiting ships in a transfer (trans-shipment) zone in the Gulf of Carpentaria. Concentrate is offloaded via a boom that feeds the material onto conveyor belts that discharge into the hold of the ship. A swing basin and channel allow the MV Aburri to move between Bing Bong Loading Facility and waiting ships; these facilities require regular maintenance dredging with the spoil stored in onshore dredge spoil ponds (see Figure 1.3).

Surface water at the mine site is managed via a series of ponds and dams that manage process water, pit water (including dewatering) and runoff. Similarly, surface runoff from the facilities at Bing Bong Loading Facility is managed via three ponds and a pond drain. The main features of these systems are described in Table 2.1 with key components shown in Figures 1.2 and 1.3.

Table 2.1 – Surface Water Management Ponds/Dams

Pond/Dam	Description of Water Stored
Mine Site	
Anti-pollution pond (APP)	Contaminated water[1] from the old run of mine (ROM) area, laydown areas, process water, and water from the concentrator runoff pond (CRP) and TSF
Concentrator runoff pond (CRP)	Contaminated water from the processing area, process water
Van Duncan's dam (VDD)	Mine water, runoff from the new ROM area and overflow from the process water circuit (CRP overflow)
Pete's pond (PP)	Mine water from underground workings and pit
Pete's pond 2 (P2)	Clean intercepted groundwater
Old McArthur River Channel	Water storage prior to discharge to McArthur River
Eastern levee storage (ELS)	Mine water from underground workings and pit (the ELS was removed as a water storage during the 2015 operating year)
Lake Archer (LA)	Not currently part of the water circuit and contains lead concentrate
Subaru sump	Intercepts water before it enters the pit
Barney Creek northwest silt trap	Silt trap on northern side of Barney Creek haul road crossing
Barney Creek southeast silt trap	Silt trap on southern side of Barney Creek haul road crossing
NOEF southern perimeter sediment dam (SPSD)	Runoff from OEF (waste rock) (contaminated)
NOEF southern perimeter runoff dam (SPROD)	Runoff from NOEF (contaminated)
NOEF southeast perimeter runoff dam (SEPROD)	Runoff from southeast area of NOEF (contaminated)
NOEF western perimeter runoff dam (WPROD) - under construction	Runoff from western area of NOEF (contaminated)
NOEF eastern perimeter runoff dam (EPROD) - proposed	Runoff from eastern area of NOEF (contaminated)
NOEF east drain sump	Sump collection of drainage line east of the NOEF NAF area
Central west A sump	Runoff from northern NOEF (contaminated)
Central west C sediment trap (CWCST)	Surface runoff (and sediment) from north of the NOEF
East sediment trap (EST)	Surface runoff (and sediment) from northeast of the NOEF
South west sediment trap (SWST)	Surface runoff (and sediment) from southwest of the NOEF
NOEF southeast levee 1	Storage behind bund wall northeast of SEPROD
NOEF east borrow pit 1 (NOEF EBP1)	Runoff from cleared areas
NOEF east borrow pit 2 (NOEF EBP2)	Runoff from cleared areas
NOEF EPROD borrow pit	Runoff from cleared areas
NOEF west D sump (WDS)	Seepage from NOEF
Tailings Storage Facility	
Cell 2	Contaminated process water

Table 2.1 – Surface Water Management Ponds/Dams (cont'd)

Pond/Dam	Description of Water Stored
Tailings Storage Facility (cont'd)	
TSF Cell 1 sump A (TSF C1SA)	Runoff from TSF Cell 1 (potentially contaminated)
TSF Cell 1 sump B (TSF C1SB)	Runoff from TSF Cell 1 (potentially contaminated)
TSF Mini Dam (located within the WMD)	Water from TSF Cell 1 west and east sumps
Water management dam (WMD)	Contingency storage with ability to receive water from Pond 2
TSF borrow pit 1	Runoff from cleared areas
TSF borrow pit 2	Runoff from cleared areas
Bing Bong Loading Facility	
Bing Bong surface runoff pond 1	Contaminated runoff from sumps, washdown and infrastructure areas
Bing Bong surface runoff pond 2	Water from Bing Bong surface runoff pond 1
Bing Bong surface runoff pond 3	Water from Bing Bong surface runoff pond 1
Dredge spoil pond drain	Water from dredge spoil

1. May contain contaminants such as heavy metals, hydrocarbons, and mill reagents.

2.3 Previous Independent Monitor Reviews

The first IM review of MRM's environmental performance was for the period October 2006 to September 2007, also known as the 2007 operational period. Subsequent reviews have been completed for the operational periods of 2008, 2009, 2010, 2011, 2012 and 2013 (as a combined/ two-year report), 2014, 2015 and 2016. The key findings of each review are provided in Table 2.2.

Table 2.2 – Overview of Previous IM Reviews

Review Year	Key Findings/Recommendations	Environmental Performance Over Time
2007	♦ Improved monitoring, technical review and interpretation of all water monitoring data around the mine, in particular the assessment of seepage from the TSF into Surprise Creek ♦ Improved management and subsequent reduction of fugitive dust emissions at the Bing Bong Loading Facility ♦ Improved dust management practices, particularly at the TSF ♦ Improved management and rehabilitation of the Bing Bong Loading Facility dredge spoil ponds ♦ Adjustments to analytical suites for the surface water and groundwater monitoring programs	♦ High level of procedural conformance with statutory commitments and conditions
2008	Significant issues: ♦ Tailings leachate migration from TSF Cell 1 into Surprise Creek ♦ Saline leachate from the Bing Bong Loading Facility dredge spoil ponds affecting vegetation surrounding the spoil ponds	♦ Some improvements since the 2007 review

Table 2.2 – Overview of Previous IM Reviews (cont'd)

Review Year	Key Findings/Recommendations	Environmental Performance Over Time
2008 (cont'd)	Less urgent, but still significant issues: ♦ Fugitive dust emissions at the Bing Bong Loading Facility ♦ Weed management along the river diversion channels and around the mine site	
2009	♦ Excess water storage in TSF Cell 2, which poses a significant risk of overtopping and embankment failure due to the TSF spillways being under-designed for a flood event ♦ Seepage migration from the TSF to Surprise Creek and the hazard classification of tailings in Cell 1 and Cell 2 ♦ Fugitive dust emissions from the mine site ROM (run of mine) pad/ore crushing area at the mine site ♦ Fugitive dust emissions from the Bing Bong Loading Facility concentrate storage shed ♦ Detail of reporting and quality of data analysis for the dust, soil and sediments monitoring program and inclusion of long-term trends and base studies ♦ Weed management along the river diversion channels and the mine site ♦ Structural integrity of the Bing Bong Loading Facility dredge spoil ponds ♦ Testing of the TSF Cell 1 clay cap to ensure it meets design specifications	♦ A number of issues identified in the previous reviews addressed; however, there were a number of ongoing, and additional, issues
2010	♦ Adverse impacts of seepage from the TSF detected in Surprise Creek ♦ Dust from operations at the ROM pad and crushing plant, and also historically from the TSF expressed in stream sediments in both Barney and Surprise creeks ♦ Volume of water stored in Cell 2 of the TSF remains a concern as there is an extreme risk of embankment failure or overtopping of the spillway ♦ Visual method for classification of non–acid-forming (NAF)/PAF waste rock of concern as there is the potential for misclassification ♦ Progress of acidification of the tailings and delineation of the treatment options ♦ Generation of fugitive dust emissions from the ROM pad and crushing plant, and, to a lesser extent, the Bing Bong Loading Facility concentrate storage shed ♦ Structural integrity of the Bing Bong Loading Facility dredge spoil ponds ♦ Slow progress of revegetation on the McArthur River diversion channel ♦ Inadequacy of reporting for many routine monitoring programs	♦ Many improvements were noted through the review and the following monitoring programs were considered to be generally adequate: – Flora and fauna monitoring both at the mine site and at Bing Bong Loading Facility – Surface water monitoring – Fluvial sediment monitoring – Structural monitoring of the river diversion channels

Table 2.2 – Overview of Previous IM Reviews (cont'd)

Review Year	Key Findings/Recommendations	Environmental Performance Over Time
2011	♦ The volume of water stored in Cell 2 of the TSF ♦ Delineation of seepage at the TSF, and its effect on Surprise Creek ♦ Progress of acidification of the tailings and delineation of the treatment options ♦ Identification and management of PAF rock waste at the NOEF ♦ Progress of revegetation on the McArthur River diversion channel, particularly along downstream sections	♦ Environmental performance had improved over the past five years of monitoring, most notably around: – The level and detail of reporting presented within the 2011-2012 MMP and water management plan – Dust mitigation and monitoring at the mine site – Ongoing rehabilitation of the McArthur River diversion channel
2012 & 2013	♦ Significant changes to the classification of overburden advised by MRM following additional testing of waste rock resulting in revisions to the proposed closure concepts and implications for the management of water ♦ Concentration of lead in fish at SW19 (monitoring point adjacent to Barney Creek haul road bridge located on the mine site) identified lead concentrations above the maximum permitted in Food Standards Australia and New Zealand (2009) ♦ Volume of water stored on the surface of TSF Cell 2 identified as a concern ♦ Quality control during the construction of TSF Cell 2, Stage 2, found to be inadequate ♦ Quality control for construction of compacted clay liners at the NOEF may not be in accordance with design specifications with potential impacts on assumed performance ♦ Erosion of up to 2 m has occurred in the past four years along sections of the McArthur River diversion channel ♦ DPIR to improve the timeliness of issuing audit reports ♦ DPIR to implement a system for tracking MRM's progress to complete IM review recommendations ♦ Commitments made by MRM in MMPs to be specific and measureable	♦ McArthur River Mining has undertaken significant work to improve its understanding of the geochemical properties of the waste rock. This key issue requires extensive work to understand the implications of the changes in geochemical classification of waste rock. Other improvements include: – Continued addition of large woody debris in the McArthur River diversion channel – Construction of interim clay cover over PAF material on the NOEF – Development of interim cover design for TSF Cell 1 – Extension of geopolymer cut-off wall along entire length of eastern embankment of the TSF – Ongoing improvements to minimise fugitive dust emissions
2014	♦ Current estimates are that 9% of all waste rock is benign and therefore suitable for use as the outer layer of the cover. The actual material balance is unknown pending the outcome of the current cover design investigations ♦ Procedures for the quality testing of compacted clay liners, and the response by MRM when quality testing fails, is not being consistently applied, and the procedures were found to be unclear in some circumstances ♦ Examination and assessment of incidents relating to the TSF has raised some new concerns with the IM, specifically with regard to:	♦ The operation of the TSF had been significantly improved ♦ Improvements bring TSF operation largely into line with the Phase 3 EIS commitments ♦ Modifications to the design and operation of TSF Cell 2 to reduce seepage impacts and geotechnical risks ♦ Development of a successful system to control material that had spontaneously combusted ♦ Finalisation of the waste rock

Table 2.2 – Overview of Previous IM Reviews (cont'd)

Review Year	Key Findings/Recommendations	Environmental Performance Over Time
2014 (cont'd)	– Efficacy of inspections – Accuracy of monthly operating and infrastructure reports – Efficacy of annual reviews – Flood capacity of TSF Cell 1 ♦ Contaminated water runoff, sediment and/or dust are entering the environment surrounding the Barney Creek haul road bridge ♦ Review of the 2013-2018 MMP and 2013-2015 MMP evolved in a very complex and protracted way as a result of the MMPs being referred to the EPA and a number of requests for additional information, and submission by MRM of MMP amendments to ensure that the mine could continue to operate while MMPs were being assessed	classification criteria ♦ Installation of additional groundwater monitoring bores around the NOEF ♦ Placement of significant quantities of large woody debris in the McArthur River diversion channel ♦ Expansion of the aquatic biota monitoring program ♦ Installing and upgrading sediment traps at the Barney Creek haul road bridge ♦ Instrumentation of ponds and pipelines and development of a computer program which provides real time information on volume of water stored on site
2015	♦ Continued progress towards better defining the geochemical properties of, and risks associated with, mine materials ♦ In the 2012-2013 IM report, a recommendation was made that 'Mine-derived loads of contaminants reporting to the McArthur River should be reported on an annual basis, within the context of background loads in the river. Limited progress has been made on this issue and the IM's view is that, until load estimates (and load balances) are available, possible downstream impacts associated with the mine potentially remain unknown to some degree and quantification and targeting of mine-associated sources remains poorly defined ♦ Improvements in environmental incident reporting are required with exceedances of guideline values not being reported as an incident ♦ Work continued on rehabilitation of the McArthur River diversion channel; however, much remains to be done. As recommended in previous IM reports a revegetation plan is required outlining a schedule for completing the rehabilitation against which performance can be measured	♦ Improvements in operational management to better control currently identified geochemical issues and impacts ♦ Continued effective TSF pond management with evidence of subaerial tailings beach being maintained ♦ Retention of extensive amounts of large woody debris installed in the downstream end of the McArthur River diversion channel ♦ Extension of a number of monitoring programs, e.g., marine and aquatic ecology, to include additional sites ♦ Installation of nine piezometers and survey marks around the perimeter of the Bing Bong Loading Facility dredge spoil ponds embankment ♦ DPIR commenced regular site inspections to assist in informing DPIR regarding the assessment of the 2013-2015 MMP ♦ DPIR requested that MRM appoint an Independent Certifying Engineer and Independent Tailings Review Board
2016	♦ The source of declining groundwater quality south of SEPROD should be identified and mitigation measures implemented ♦ Further investigation is required of the elevated piezometric levels within the TSF Cell 2 embankment to determine implications for future TSF management	♦ Completion of geotechnical testing and investigations to further understand the geochemical properties of overburden and tailings ♦ Completion of a number of studies to address information gaps in NOEF, WOEF and SOEF composition, cover

Table 2.2 – Overview of Previous IM Reviews (cont'd)

Review Year	Key Findings/Recommendations	Environmental Performance Over Time
2016 (cont'd)	♦ Fully quantify mine-derived loads in surface water within the context of background loads and determine the associated environmental risks, particularly in terms of downstream impacts ♦ IM supported the recommendations by Hydrobiology (2016) and in particular: – Revision of the existing hydraulic model to incorporate the present-day topography – An options assessment, supported by the revised hydraulic modelling, into mitigation options for the avulsion – The options assessment should investigate and consider the extent of the bedrock bar at the downstream extent of Djirrinmini Waterhole ♦ Rehabilitation of the McArthur River diversion channel remains a concern, with very little change observed since the last IM visit despite the planting of tens of thousands of seedlings in recent years. The IM has recommended in previous reports that the revegetation strategy requires review	design modelling and assessment of groundwater modelling ♦ Construction of a 35-m-wide MS-NAF halo zone around the west, south and east side of the older West Stage of the NOEF to help control convection/advection into PAF materials in this older zone ♦ Continued effective management of the TSF pond size and cyclic deposition of tailings ♦ Completion of geomorphological assessment of the McArthur River diversion channel ♦ Declining levels of contamination in biota at SW19 likely due to controls implemented by MRM ♦ Conducting a community survey of fish consumption patterns

2.4 Stakeholders

The assessment of the environmental performance of the MRM operation is of interest to the following audience (Table 2.3). These people and groups are the McArthur River Mine's stakeholders.

Some of these stakeholders, e.g., DPIR and MRM employees, were involved in the assessment (Chapter 3), while others are interested in the outcomes (e.g., other government agencies, environment groups, other interested parties).

Table 2.3 – Stakeholders

Government	Non-government
Minister for Primary Industry and Resources	McArthur River Mining (MRM)
Department of Primary Industry and Resources (DPIR)	Traditional owners of the Borroloola region
Minister for Environment and Natural Resources	Local indigenous organisations
Minister for Infrastructure, Planning and Logistics	Wider community of Borroloola and surrounds
Department of Environment and Natural Resources (DENR)	Environment groups
Department of Infrastructure, Planning and Logistics	Other interested parties
Department of Tourism and Culture	
Northern Territory Environment Protection Authority	
Department of Health	

Table 2.3 – Stakeholders (cont'd)

Government	Non-government
Other Northern Territory Government agencies	
Roper Gulf Regional Council	
Commonwealth Government agencies, e.g., Department of the Environment and Energy	

The IM maintains a website that provides:

- An overview of the role and activities of the IM.
- Access to current and previous annual IM reports, operator and regulator response reports, community reports and other relevant information prepared, or used, by the IM in assessing environmental performance.
- Links to other relevant websites.

This website allows stakeholders to access information associated with the annual assessment of performance. Information will also be disseminated to local community stakeholders via a separate community report and presentation.

The website can be accessed at: www.mrmindependentmonitor.com.au.

2.5 References

Hydrobiology. 2016. Geomorphological Assessment: McArthur River and Barney Creek Diversions. Final Report, MRM1601_R_1_v2-0, December 2016. Prepared by Hydrobiology Pty Ltd for McArthur River Mining, Winnellie, NT.

MRM. 2017. Overburden Management Project Draft Environmental Impact Statement. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2018. Overburden Management Project Supplementary Environmental Impact Statement. McArthur River Mining Pty Ltd, Winnellie, NT.

3. Method

3.1 Review Team

The IM is led by ERIAS Group and supported by a team that brings together the experience and skills required to fulfil the role (see sections 1.1 and 1.2). The roles of the IM team members are outlined in Table 3.1.

Table 3.1 – IM Team

Name	Company	Technical Expertise for the Assessment
David Browne	ERIAS Group	Team leader; environmental risk and management; closure planning
Michael Jones	ERIAS Group	Natural surface water, artificial surface water and marine water quality
Michelle Clark	ERIAS Group	Dust, soils, fluvial and marine sediment quality
Scott Breschkin	ERIAS Group	Aquatic ecology; marine ecology (including the annual marine monitoring program and seagrass monitoring)
Mick Cheetham	Water Technology	Diversion channel hydraulics
Richard Walton	Hydro Scientia	Site water balance and management; surface hydrology
Gareth Swarbrick	Pells Sullivan Meynink	Geotechnical; TSF, OEF and Bing Bong Loading Facility dredge spoil ponds
Rob Garnham	Groundwater Resource Management	Groundwater modelling and monitoring
Warwick Stewart	Environmental Geochemistry International	Geochemistry; TSF and NOEF cover design strategies
Bill Low	Low Ecological Services	Terrestrial flora and fauna
Nicola Hanrahan	Low Ecological Services	Terrestrial flora and fauna
Derek Mascarenhas	Cambium Group	Website design and maintenance; graphic and report/ presentation production support

3.2 Assessment Framework

The IM team adopted the same assessment framework as that used last year and reviewed environmental performance within MRM's mining lease numbers 1121, 1122, 1123, 1124, 1125 and 1126, and downstream along the McArthur River to the coast and beyond within the Sir Edward Pellew Group of Islands (see Figure 1.1) in terms of:

- Key risks (Section 3.5).
- Controls:
  - Previously reported controls.
  - New controls – implemented and planned.

- Review of environmental performance:
  - Incidents.
  - Non-compliances.
  - Progress and new issues.
- Successes.

With the exception of key risks, each of these is discussed below. Deficiencies in any of the above translate to either an ongoing or new recommendation.

In general, performance has been assessed in terms of the:

- Mining management plan, which is the principal document required under the MM Act that describes how the mine will be operated and the controls that will be implemented to manage and monitor environmental risks (see Section 2.1). The currently approved MMP is the Sustainable Development Mining Management Plan 2013-2015, Volumes 1 and 2 (MRM, 2015a, 2015b), 3 March 2015, which was approved by the Minister in December 2015. Subsequent to the preparation of the MMP, MRM has submitted a number of MMP amendments to DPIR for approval.
- 2016-2017 operational performance report. The report covers monitoring activities over the period 1 June 2016 to 31 May 2017 (MRM, 2017).
- 2017-2018 operational performance report. The report covers monitoring activities over the period of 1 June 2017 to 31 March 2018 (MRM, 2018).
- Relevant criteria, guidelines and standards, e.g., Australian and New Zealand guidelines for fresh and marine water quality (ANZECC/ARMCANZ, 2000), Australian National Committee on Large Dams guidelines (ANCOLD, 2012).
- Leading practice, in the context of the key risks identified in the risk assessment (Section 3.5).

3.2.1 Controls

The IM team has identified the existing controls that MRM has implemented to manage and monitor environmental risks. New controls that have been included during the operating year or are planned to be implemented have also been identified. These are summarised for each technical area and assessed for adequacy.

3.2.2 Review of Environmental Performance

Review of environmental performance was assessed in three areas as described below.

1. Incidents and non-compliance

Incidents are defined by MRM as (MRM, pers. com., 22 August 2018):

Any event that causes, or has the potential to cause, damage or loss. These include, but are not limited to, events impacting on people, business, property, environment, stakeholders and/or the community. Environmental near miss risks are not recorded in the GCP database (unless they are HPRIs).

Incidents are managed according to the MRM's incident management procedure and ranked based on severity (actual or potential in the case of a near miss) as per Table 3.2.

Table 3.2 – Incident Severity Ranking

Category	Description	Environmental Impact
Cat 1	Negligible	♦ Near source and confined ♦ No lasting environmental damage or effect (typically < day) ♦ Requires minor or no remediation
Cat 2	Minor	♦ Near source ♦ Short-term impact (typically < week) ♦ Requires minor remediation
Cat 3	Moderate	♦ Medium-term (<2 years) impact (typically within a year) ♦ Requires moderate remediation
Cat 4	Major	♦ Long-term (2 to 10 years) impact ♦ Requires significant remediation
Cat 5	Catastrophic	♦ Unconfined and widespread ♦ Environmental damage or effect (permanent; >10 years) ♦ Requires major remediation

Over the 18-month period covered by this report there were 28 environmental incidents reported to DPIR. The IM has reviewed the incident register and the 28 incidents broadly fall into the following categories:

- Concentrate spillage – 1 incident.
- Water related – 11 incidents.
- NOEF smokers – 1 incident.
- Hydrocarbons – 15 incidents.

The water-related incidents varied from seepage from dams to overflow of runoff sumps, while the hydrocarbon incidents almost entirely consisted of spills as a result of leaks from hydraulic hoses.

Compliance was assessed in two areas:

- Compliance with the waste discharge licences that specify trigger values that must not be exceeded for two authorised compliance points (SW11 and BBDDP – dredge spoil drain).
- Compliance with relevant criteria, standards and guidelines.

Issues of compliance are discussed in each discipline section.

2. Progress and new issues

The recommendations from the previous (2017) IM review were reviewed and progress assessed. Those recommendations that have not been closed out are discussed in each of the technical areas and documented in the review of the previous IM recommendations.

New issues are those in addition to an incident or non-compliance or an ongoing issue from a previous IM review. They may relate to an information gap (Section 3.6) or be risks (Section 3.5) that are not addressed in existing controls (Section 3.2.1).

3. Successes

The assessment of environmental performance identifies areas of improvement, e.g., closing out an ongoing IM recommendation, and where it can be demonstrated that an environmental value, e.g., environment protection objective or beneficial use declaration (as defined in the waste discharge licence (see Section 2.1)) has been protected by meeting, where relevant, a criterion, guideline or standard.

3.3 Document Review

The IM was provided with a number of documents and other files and commenced its document review prior to the site inspection. Following the site inspection, additional documents were requested as a result of discussions with MRM and DPIR personnel and during the process of preparing this report. Overall, some 1,169 files were provided by MRM with another 320 files being provided by DPIR.

3.4 Site Inspection

The IM team that visited the site consisted of David Browne, Michael Jones, Rob Garnham, Richard Walton, Warwick Stewart, Gareth Swarbrick, Michelle Clark, Scott Breschkin and Nicola Hanrahan. The site visit was conducted on 14 and 15 May 2018 and included both the McArthur River Mine and Bing Bong Loading Facility. The purpose of the site visit (inspection) was to:

- Visit the mine site and project infrastructure, including the TSF, NOEF, SOEF, water storage ponds, river diversion channels, concentrate storage and handling facility at Bing Bong Loading Facility (including dredge spoil ponds), and monitoring sites.
- Gather information from discussions with MRM personnel and, in particular, progress with completion of recommendations from the 2017 IM report and work that is either in progress or is being planned.
- Present preliminary outcomes of the review at a close out meeting with MRM at the end of the site visit.

On 17 May 2018, David Browne and Michelle Clark met with DPIR to discuss the following:

- Progress with completion of IM recommendations from the 2016 operating year.
- Observations from the site visit.

3.5 Risk Assessment

3.5.1 Objective

Each year the IM is required to undertake a risk assessment to assess environmental risks associated with the MRM operation. The objectives of the risk assessment are to:

- Identify environmental risks.
- Evaluate whether environmental monitoring and assessment practices undertaken by MRM are adequate and appropriate to mitigate the risk of potential environmental impacts.
- Determine if MRM is addressing the risks identified by the IM and if actions are appropriate.

3.5.2 Method

During the annual kick off meeting, MRM expressed concern to the IM that the number of risks and level of risk had not been declining despite the significant advances that MRM has made in recent years to understand risks and develop mitigation strategies. A joint risk assessment workshop involving the IM, MRM staff, MRM specialist consultants and DPIR was held with the session facilitated by Peter Standish from Operational Risk Mentoring. While a formal risk assessment was not undertaken, the workshop provided a forum for the IM, MRM and DPIR to discuss each risk, the controls in place and the basis for its ranking. An outcome from the workshop was a series of points for the IM to consider when undertaking its review of the risk register. Subsequently, the process used in reviewing the risk register included the following:

- Updated information regarding the description of the risk where additional information is known.
- Updated controls that have been implemented to manage the risk.
- Consideration of the points raised in the risk workshop.
- Review of the consequence and likelihood rating.
- Comment as to whether additional controls are required.

This updated the previous risk assessment (completed in 2017) and therefore used the same method. This method is in accordance with ISO 31000:2009 – Risk Management Principals and Guidelines (SA/SNZ, 2009), and is based on the following definitions and matrices (Tables 3.3 to 3.6).

It should be noted that the risk matrix used by the IM has remained unchanged for the past 10 years. While this has ensured a consistent approach, the IM believes that it is an opportune time to review the risk matrix and in particular the consequence, likelihood and risk rating definitions. In particular, areas where the risk process could be improved include:

- Likelihood to include consideration of the closure timeframes.
- Consequence to include consideration of the financial impact.

Table 3.3 – Consequence Definitions

Consequence		Definition
1	Catastrophic	Severe environmental impact. Local species destruction and likely long recovery period. Extensive clean up involving external resources. Impact on regional scale
2	Major	Major environmental impact. Considerable clean up effort using site and external resources. Impact may extend beyond lease boundaries
3	Moderate	Moderate environmental impact. Clean up by site staff and/or contractors. Impact confined within lease boundaries. Or, minor impact off site; however, no irreversible damage
4	Minor	Low environmental impact. Rapid clean up by site staff and/or contractors. Impact controlled to area currently impacted by operations
5	Insignificant	No or very low environmental impact. Impact confined to small area. Site impact only

Table 3.4 – Likelihood Definitions

Likelihood		Definition
1	Certain	Expected to occur frequently at this operation
2	Likely	Expected to occur occasionally at this operation
3	Possible	Has occurred, or could occur, for this or a comparable operation
4	Unlikely	Known to occur in the global industry, but unlikely
5	Improbable	Not known to occur in the global industry, but plausible

Table 3.5 – Risk Matrix

Consequence		Likelihood				
		1	2	3	4	5
		Certain	Likely	Possible	Unlikely	Improbable
1	Catastrophic					
2	Major					
3	Moderate					
4	Minor					
5	Insignificant					

Table 3.6 – Risk Rating Definitions

Risk Rating	Definition
E	Extreme. Immediate intervention required to eliminate or reduce risk at a senior management/government level
H	High. It is essential to eliminate or reduce risk to a lower level by the introduction of monitoring and assessment measures implemented by senior management
M	Moderate. Corrective action required, and monitoring and assessment responsibilities must be delegated
L	Low. Corrective action should be implemented where practicable, and risk should be managed by routine monitoring and assessment procedures

3.6 Gap Analysis

In the 2012-2013 and 2014 IM reports, ERIAS Group adopted the gap analysis used in previous IM reviews, where a gap was defined as (EES, 2012):

> a discrepancy between the monitoring program that is taking place, and the monitoring program that should be taking place if MRM's environmental performance is to be maintained at industry best practice standards.

In undertaking the 2015 review, it was recognised that gaps in modelling can be equally important as those relating to monitoring programs. The gap analysis register was reviewed and each team member identified monitoring, modelling and/or assessment gaps in their field of expertise based on three questions:

1. Is monitoring and/or modelling undertaken in accordance with associated potential risk?
2. Is monitoring sufficient in design (frequency, type, location), and/or is modelling supported by sufficiently validated inputs/assumptions, in order to address and mitigate potential risk?
3. Is monitoring and/or modelling data/output information assessed, interpreted and managed to track risk alteration and evaluate the need for improved risk mitigation?

Gaps were categorised into three groups (Table 3.7).

Table 3.7 – Gap Categories

Category	Description
1	Monitoring and/or modelling to mitigate potential associated environmental risk is not undertaken
2	Monitoring and/or modelling is undertaken, but monitoring is not sufficient in design (that is, frequency, location, type and so on), or the inputs to/assumptions of modelling are not validated, such that results are insufficient to identify or quantify potential environmental risks
3	Monitoring and/or modelling is undertaken and is appropriate, however data/output information is not adequately assessed, interpreted or managed to appropriately mitigate potential environmental risks

A total of 87 gaps were identified:

- 20 Category 1 gaps.
- 41 Category 2 gaps.
- 26 Category 3 gaps.

These gaps will be discussed within each technical area of the report and in the most relevant section, i.e., existing controls, new issues or non-compliance.

3.7 Review of DPIR's Monitoring

The IM conducted a review of DPIR in regulating the environmental performance of MRM under the MM Act and regulations. This included review of:

- The DPIR's assessment of the MMP and MMP amendments.

- Site inspection reports.
- Correspondence.
- Independent Monitor recommendations tracking.
- Previous IM recommendations regarding DPIR performance.

It should also be noted that no DPIR audits were undertaken during the 2017-2018 operating period.

3.8 References

ANCOLD. 2012. Guidelines on Tailings Dams – Planning, Design, Construction, Operation and Closure. May. Australian National Committee on Large Dams Incorporated. Hobart, Tasmania.

ANZECC/ARMCANZ. 2000. Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT.

EES. 2012. Independent Monitor Audit of the McArthur River Mine for the 2011 Operational Period. Report to the Minister for Mines and Energy. 1 October 2012. Version 1. Prepared by Environmental Earth Sciences for the Department of Mines and Energy, Darwin, NT.

ERIAS Group. 2017. Independent Monitor. EIS Review Report. McArthur River Mine Overburden Management Project EIS Review. Report No. 01164E_1_v2. May 2017. Report prepared by ERIAS Group and submitted to the Northern Territory Environment Protection Authority, Darwin, NT.

MRM. 2015a. Sustainable Development Mining Management Plan 2013-2015, Volume 1. 3rd March 2015. Reference Number GEN-HSE-PLN-6040-0003, Issue Number: 7, Revision Number: 0. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015b. Interim Mining Management Plan 2013-2015, Volume 2: Environmental Monitoring Report. January 2015. Reference Number GEN-HSE-PLN-6040-003, Issue Number: 7, Revision Number: 1. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2017. 2017 Operational Performance Report, 1 June 2016 to 31 May 2017 Reference Number MRMDPI1711A, Issue Number: 1, Revision Number: 0. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2018. 2017-2018 Operational Performance Report, 1 June 2017 to 31 March 2018. Reference Number MRMDPI1860, Issue Number: 1, Revision Number: 0. McArthur River Mining Pty Ltd, Winnellie, NT.

SA/SNZ. 2009. AS/NZS ISO 31000:2009. Risk Management – Principles and Guidelines. Originated as AS/NZS 4360:1995. Third edition. Revised and redesignated as AS/NZS ISO 31000:2009. Standards Australia/Standards New Zealand, Canberra, ACT.

Personal Communications

MRM. Email. 22 August 2018.

4. Results

4.1 Approach and Risk Assessment Outcomes

The IM has reviewed and updated the risk register presented in the previous IM report (for the 2016 operational period). The updated risk register is based on the following actions:

- All risks were reviewed to determine if they remain current; those that were no longer pertinent were deleted.
- Where relevant, risks that remain current have been updated to reflect changes since the register was last compiled, including consideration of the feedback from the risk assessment workshop with MRM and DPIR.
- New risks as a result of the IM's document review and site inspection have been included.

The updated risk register is provided in Appendix 1, with the number of risks identified by the IM decreasing from 74 to 69. Table 4.1 presents for a summary of the risks from both the current and previous four risk assessments undertaken by the IM. A number of risks that had previously been separated relating to failure of the NOEF cover have been grouped as a single risk in this year's assessment. The grouping of these risks was considered appropriate as the Northern Territory government was completing its assessment of the Draft OMP EIS and OMP SEIS at the time of report preparation. Until the outcome of this process is known, potential failure modes cannot be described accurately and consequently an all-encompassing risk was used rather than referring to specific individual risks.

Table 4.1 – Comparison of Risk Assessment Results

Risk Rating	2014 IM Risk Assessment	2015 IM Risk Assessment	2016 IM Risk Assessment	2017 IM Risk Assessment	2018 IM Risk Assessment
Extreme	1	2	2	3	2
High	31	25	24	27	13
Moderate	29	38	40	35	41
Low	7	12	9	9	13
Total	**68**	**78***	**75**	**74**	**69**

* It was not possible to subscribe a risk rating to the remaining 1 risk as this item relates to closure objectives and criteria.

Risks identified in the 2018 review of the risk register that are considered by the IM to be key risks include:

- Potential failure of the TSF cover as a result of erosion or slumping leading to embankment failure, leading to the exposure of highly pyritic tailings to oxidation and infiltration. The main consequence of this event is acid, metalliferous and/or saline drainage (AMD) impacts on groundwater quality, and terrestrial and aquatic ecosystems.
- Active avulsion upstream resulting in McArthur River changing course and reverting to the old channel, thereby causing erosion and failure of the mine levee wall. This could result in

discharge of potentially contaminated water from the pit to Barney Creek and/or McArthur River, as well as substantial volumes of sediment reporting to McArthur River, with adverse impacts on aquatic and terrestrial ecosystems.

- Seepage of contaminated water from water storages impacting groundwater quality and aquatic and terrestrial ecosystems where this poor quality groundwater discharges to creeks/rivers.
- Seepage of contaminated water from the pit lake to the groundwater environment following closure impacting groundwater quality and aquatic and terrestrial ecosystems where this poor quality groundwater discharges to creeks/rivers or to the surface.
- Calculation of closure costs based on the closure mitigation strategies outlined in the currently approved (but out-dated) closure plan prepared in 2012 leading to inadequate funding for closure and post closure activities.
- Closure strategies for the NOEF failing due to inadequate design/implementation resulting in saline and metalliferous neutral drainage and localised acid drainage impacts in perpetuity on groundwater, terrestrial and aquatic ecosystems.
- Seepage from the NOEF impacting on groundwater quality, and aquatic and terrestrial ecosystems where this poor quality groundwater discharges to creeks or the surface.
- Slow revegetation of the McArthur River diversion channel due to high flow rates causing erosion and removal of vegetation resulting in unstable channel banks and reduced riparian habitat.

Further discussion on risks identified by the IM is outlined in Sections 4.2 to 4.13.

A comprehensive review of the risk register will be required following the Northern Territory government's assessment of the Draft OMP EIS and OMP SEIS. A number of risks may no longer be applicable as a result of new strategies that MRM have proposed in the Draft OMP EIS, e.g., failure of the TSF cover will no longer be relevant if the strategy to relocate tailings to the open pit is accepted.

4.2 Mine Site Water Balance

4.2.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of mine site water balance, and is based upon:

- Review of various reports prepared by MRM and its consultants, with particular reference to the following:
  - The 2013-2015 MMP (MRM, 2015).
  - Operational performance reports for 2016-2017 (MRM, 2017) ('OPR 2016-2017') and 2017-2018 (MRM, 2018) ('OPR 2017-2018').
  - Site water balances for the McArthur River Mine and Bing Bong Loading Facility, for 2015-2016 (WRM, 2015), 2016-2017 (WRM, 2016) and 2017-2018 (WRM, 2018a).
  - Water balance modelling in support of the 2017/18 TARP (WRM, 2018b).
  - Overburden Management Project Draft EIS ('Draft OMP EIS') (MET Serve, 2017).
- Review of various MRM forms and similar documents such as incident notification letters, and correspondence between MRM, regulators and third parties.
- Aerial and other photographs of the mine site provided by MRM.
- Review of other documents such as DPIR field inspection reports.
- A mine site inspection undertaken on 14 and 15 May 2018.

4.2.2 Key Risks

The risk of the site water balance not performing as predicted is the delivery via rainfall, surface runoff and/or pumping of a greater volume of water to one or more storages than estimated. It may not be possible to transfer this additional water to other ponds in a timely manner. This, in turn, may lead to uncontrolled off-site releases of contaminated water. The key risks to the mine site water balance as described in the risk register (Appendix 1) are:

- Errors in the water balance model parameter estimation. There is considerable interaction between water balance model parameters, that is, it is possible to obtain a match between modelled and observed water levels in ponds with a range of different parameter sets. The potential issue is that while the model may appear to provide a reasonable estimate of the water balance under the current mine site conditions, it may be a poor predictor of the water balance under changed mine site conditions (e.g., increased catchment areas, changes in runoff parameters, clay capping of NOEF). These errors may result in the delivery of a greater volume of water to one or more storages than estimated by the modelling.
- The site water management system does not adequately allow for contingencies. While the current site water balance modelling shows that the probability of uncontrolled off-site releases is within the design criterion (less than 5%), a key assumption is that model inputs

are correct and that the system performs as modelled. There is inherent uncertainty in the model predictions due to factors such as:

– Mine site layout/operations being different to those adopted in the model (e.g., delays in the construction of ponds or the water treatment plant, changes to mill throughput).

– Errors in the water balance model parameterisation.

– Uncertainty in model parameters (e.g., evaporation and seepage estimates).

– Unforeseen/unpredicted changes in the mine water balance (e.g., the failure to commission WPROD by the 2016/17 wet season, the additional contaminated water in the NOEF SPROD as at mid-2017).

– Failure of pumps and/or pipes during critical periods (e.g., during heavy rainfall).

- Changes in mine site runoff/seepage water quality. There is a risk that the mine site runoff and seepage water quality (collected in ponds on site) may become substantially worse than currently estimated. This is because the large volumes of PAF waste rock may result in a reduction in runoff/seepage pH with a concomitant increase in dissolved metal concentrations. Poorer quality site water would require (without water treatment) greater dilution for controlled off-site releases. This may reduce the volume of water that can be released off site, which in turn may lead to greater volumes of water in one or more on-site storages than estimated by the modelling. This could lead to an increase in uncontrolled off-site releases.

4.2.3 Controls

4.2.3.1 Previously Reported Controls

The existing controls employed by MRM to reduce risk in the mine site water balance management are:

- Annual revision of the water balance model to incorporate changes in the site layout and additional monitoring data.

- Modelling the mine site water balance prior to the wet season (using current water levels at that time) to assess the probability of controlled and uncontrolled releases, and water ponding in the pit. This modelling was used to develop Trigger Action Response Plans (TARPs) which defined management actions to rainfall and changes in pond water levels during the forthcoming wet season.

- Continual investment in quality equipment for monitoring and reporting of site water balance parameters (e.g., pond water levels and water transfers). This greatly assists in the parameterisation of the water balance model which, in turn, reduces model prediction uncertainty.

- Continual investment in additional storages in response to changes in the mine site layout.

4.2.3.2 New Controls – Implemented and Planned

The following controls have been implemented during the reporting period:

- Installation of additional monitoring equipment to measure pond water level and water transfer between ponds (ongoing).
- Improved water balance modelling reporting (ongoing).
- The installation of pipes to allow bi-directional water transfers between NOEF SPROD, NOEF SEPROD, NOEF WPROD and OP PP.
- Incorporating manual valve change logs (in the pipe network) into the digital records.
- The commissioning of the West Perimeter Runoff Dam (NOEF WPROD).
- Lime treatment of water in the NOEF SPROD, NOEF SEPROD and NOEF SPSD.
- The commissioning of a new SCADA network for monitoring and reporting of site water management operations in real time (e.g., pond water levels and water transfers).
- Substantial improvement in the water management TARP tables.
- Incorporation of the water management TARP tables into the SCADA reports.
- Reduction in poor quality runoff entering Barney Creek near Barney Creek haul road bridge through the commissioning of the MIA Sump and modification of the NW Sump, SW Sump and SE Sump to convert them from sediment ponds (where runoff flows through the pond to Barney Creek) to interception sumps (where runoff is pumped to another storage and there are no outflows to Barney Creek).

The following controls are planned for the next 12 months:

- Lining of the NOEF SPROD to reduce seepage.
- Installation of additional monitoring equipment to measure pond water level and water transfer between ponds. This is an ongoing commitment by MRM.
- Ongoing development and implementation of the SCADA network, including monitoring, data management and reporting components.
- Commissioning of the water treatment plant.
- Continuing lime treatment of water in the NOEF SPROD and NOEF SEPROD.
- Evaporation measurements/investigations of the NOEF PRODs and TSF Cell 2.

4.2.4 Review of Environmental Performance

4.2.4.1 Incidents and Non-compliances

Incidents

The following incidents affecting the site water balance occurred during the 2017-2018 operational period (note that the implications of these incidents on surface water quality are discussed in Section 4.3):

- 25 January 2017: TSF Cell 1 western sump overflowed to the TSF Cell 4 borrow pit. There were no off-site releases.
- 19 February 2017: TSF Cell 1 eastern sump overflowed. Water flowed off site towards the Carpentaria Highway where it mixed with other runoff beside the highway. There was extensive local flooding in Surprise and Barney Creeks at the time of the incident and it was not possible to determine the fate of the overflow water past a culvert under the Carpentaria Highway (near TSF Cell 1).
- 26 September 2017: An uncontrolled release of mine affected water to land as a result of a damaged pipeline from Central West Alpha Sump. Water ponded on and infiltrated into the Central West footprint. The contaminated soil was removed and deposited within the NOEF PAF cell. No off-site releases occurred.
- 28 October 2017: A small volume of seepage was observed in Little Barney Creek. MRM considered the water was seepage from the TSF WMD. The water was contained in Little Barney Creek; which was not flowing.
- Heavy rainfall occurred on site between 20 and 27 January 2018. The 24-hour total (to 9 am 25 January) was 196.4 mm. This was a 5% (1 in 20) AEP rainfall and the highest 24-hour January rainfall on record (in 50 years of records). The seven-day total was 537.8 mm. This was a 1% (1 in 100) AEP rainfall. Three water balance related incidents occurred during this period:
    - 24 January 2018: TSF Cell 1 western and eastern sumps overflowed to the adjacent borrow pits. There were no off-site releases.
    - 24 January 2018: The Central West Alpha Sump (CWAS) overflowed; the overflow water consisted of NOEF seepage and surface runoff. The CWAS overflow was captured by the Central West C Sediment Trap (CWCST), which in turn overflowed to the receiving environment.
    - 24 January 2018: Runoff from the NOEF West D area breached a bund and flowed into a clean water drain. This water in turn reported to Surprise Creek.

Non-compliances

The following non-compliances affecting the site water balance occurred during the operational period:

- Condition 13 of WDL 174-09 authorises wastewater to be discharged from South-East Levee 1 (SEL1) discharge point that is ‘rain water collecting inside the South Eastern Levee and separated from all contaminated seepages’. Between 20 and 26 January 2017, the CWAS was being dewatered to Pete’s Pond via the Eastern Drain Sump (EDS). Water was also being discharged off-site via the SEL1 discharge point. A routine inspection by dewatering staff identified that EDS water was seeping into SEL1 via the bund separating the two storages (the SE bund). This represented a non-compliance with WDL 174-09 (although it was concluded that no associated exceedance of trigger values occurred at SW11) and off-site releases were ceased immediately. A waste discharge licence (WDL237) was subsequently issued for the period 21 March 2017 to 31 May 2017 to allow CWAS water to be actively discharged.

4.2.4.2 Progress and New Issues

Controls

New SCADA Network

A new SCADA network for monitoring and reporting site water management operations in real time (e.g., pond water levels and water transfers) was commissioned in late 2017. The implementation of the system included installation of high quality monitoring equipment and the engagement of a consultant systems analyst. The SCADA system is currently incorporated into the site water management as follows:

- Senior staff responsible for site water management are provided with a daily report on the system status, including TARP levels.
- Technical staff responsible for implementing water management decisions (e.g., starting/ stopping pumps, repairing equipment) use the on-line displays to confirm whether the system is operating as expected (e.g., pumps are on/off).

The new SCADA system replaces a spreadsheet based site water inventory tracking tool implemented during the 2015 operational period but discontinued during the 2016 operational period. During the site visit for the current operational period MRM advised the following:

- The new system is substantially superior to the previous spreadsheet based system.
- The new system has become integral to the site surface water management.
- The key surface water management successes during the 2017-2018 operational period would not have been possible without the new system (e.g., high volumes of controlled off-site releases, successful management of the high rainfall in January 2018 without any uncontrolled releases from any PROD or the TSF).
- There is an ongoing commitment to maintain and further develop the system; with specific enhancements planned for the next operational period (e.g., additional monitoring equipment, additional reporting options, incorporation of water quality data)

The IM considers the new SCADA system, in particular its embedding into site surface water management and embracement by MRM management, a substantial improvement in site surface water management.

Trigger Action Response Plan (TARP) Modelling

There has been a substantial improvement in the TARP reporting and action plan tables (WRM, 2018b). McArthur River Mining advised that the new TARP tables are now fundamental in the site water management and assisted in the successful management of the high rainfall in January 2018; without any uncontrolled releases from any PROD or the TSF. The IM commends the TARP improvements and incorporation into site surface water management.

Planned Controls not Implemented

The following controls planned for the 2017-2018 operational period were not implemented/ achieved:

- Commissioning the water treatment plant.
- Combining the NOEF SPROD and NOEF SPSD.
- Lining the NOEF SPROD to reduce seepage.
- Setting up weather stations (i.e., to measure rainfall and evaporation) on selected ponds.
- Lining the eastern levee storage (ELS) to reduce seepage.
- Evaporation measurements/investigations of the NOEF PRODs and TSF Cell 2.

Documentation and Reporting

Annual Water Balance Modelling

The quality of reporting in the water balance modelling reports has continued to improve. In particular, the tabulation of key monitoring and modelling data/results has provided additional clarity to the document. This has allowed for easier identification of data and modelling gaps/errors. For example, clearer reporting has allowed identification of which ponds and pumps are monitored and the probability of uncontrolled releases from different ponds.

Given the improvements in clarity, understanding and error checking that tabulation of data and results provides, additional changes are recommended. In general, it is recommended that more tables be used and the readability of some tables be improved. Table 4.2 lists specific comments on the 2017-2018 annual water balance report (WRM, 2018a) to assist in the preparation of future water balance reports which the IM believes will assist in improving environmental performance. Similar recommendations to those in Table 4.2 were made in the 2016 operational period IM report; only limited progress has been made in adopting the recommendations.

Table 4.2 – Specific Recommendations to Improve Water Balance Model Reporting

WRM (2018a) Reference	Recommendation
Section 9.10 Limitations and associated uncertainties	The key limitations and uncertainties need to be summarised in a table for ease of reference/checking (in addition to what is already provided in the section text). Additional information required in the table includes: ♦ An assessment of how the assumption impacts the water balance modelling ♦ Action proposed and timeframe to remove each assumption/reduce each uncertainty ♦ A priority/ranking for each action
Section 12 Recommendations for additional monitoring and investigations	The key recommendations need to be summarised in a table for ease of reference/checking (in addition to what is already provided in the section text). Additional information required in the table includes: ♦ An assessment of how the assumption impacts the water balance modelling ♦ Action proposed and timeframe to remove each assumption/reduce each uncertainty ♦ A priority/ranking for each action

2017-2018 Operational Performance Report

There are errors and inconsistencies in the 2017-2018 OPR which provide a misrepresentation of the status of on-site water management. Table 4.3 shows a number of examples of these errors and inconsistencies.

Table 4.3 – Examples of Errors and Inconsistencies in the 2017-2018 OPR

2017-2018 OPR Reference (MRM, 2018)	IM Comment
Section 4.3.3 Mine Site Water Balance Results – 2017-2018: p144: The risk of uncontrolled release from TSF C1SA and TSF C1SB to the WMD is 2% and 1% AEP, respectively:	This is incorrect. TSF C1SA and TSF C1SB do not spill to the WMD
Section 4.3.3 Mine Site Water Balance Results – 2017-2018: p144: The risk of an uncontrolled offsite release from the WMD is less than 1% AEP	This is incorrect. The TSF WMD has a 39% (1 in 2.5) AEP flood immunity (WRM, 2017b). Therefore, the risk of an uncontrolled off-site release is also approximately 39%
Section 4.11 Reconciliation of Water Management Commitments and Actions: p191: The installation of flow meters on all major water transfers has been completed	This is incorrect and contradicts the 2017-2018 Water Balance Report (WRM, 2018a). In particular, Section 12 of WRM (2018a) contains a list of pipes that do not have flow meters (and a recommendation to fit meters to these pipes) including: ♦ Pete's Pond (OP PP) to Water Treatment Plant (OP WTP) ♦ Pete's Pond (OP PP) to the Open Pit (OP UG&OP) ♦ Water treatment plant (OP WTP) to the Concentrate Mill (Mill) ♦ Water treatment plant (OP WTP) to Pond 2 (OP P2); An assessment of how the assumption impacts the water balance modelling

Figure 4.1 shows a chart presented in the 2017-2018 OPR as an example of the predictive ability of the water balance model (a similar chart is also presented in the 2016-2017 OPR). The commentary in the 2017-18 water balance report (WRM, 2018a) describes how the

almost perfect fit is due to the groundwater inflows being derived (by difference) from the measured pumped outflows and the UG&OP stage storage curve. That is, the calculated groundwater inflow is the integration of ground water inflow and any error in inflow/outflow errors. Therefore, groundwater inflow acts as a 'fudge factor' with the model fit always being almost prefect. The results shown in Figure 4.1 are a weak test of model performance and a misrepresentation of the models accuracy. The 2017-2018 water balance report (WRM, 2018a) provides numerous additional charts that that show poorer fits between the modelled and observed data. These additional charts are more representative of model performance. It is recommended that Figure 4.1 (or figures derived with similar data) not be used in future OPRs.

Water Balance Sensitivity Testing

Annual Review

A key concern of the IM is the resilience of the water management system. That is, while the current site water balance modelling shows that the probability of uncontrolled off-site releases is within the design criterion (less than 5% probability of uncontrolled release), the key modelling assumption is that model inputs are correct and the system performs as modelled. Sensitivity tests were undertaken in the 2015-2016 (WRM, 2015), 2016-2017 (WRM, 2016) and 2017-2018 (WRM, 2018a) annual water balance reports. A number of the tests showed a large relative increase but a low absolute increase in the probability of spill of some ponds. For example the 2017-2018 water balance report showed a 5% increase in rainfall changed the risk of spill from the NOEF WPROD from 3% to 5% (a 67% increase).

Given the ongoing changes to the mine site layout and operation, sensitivity testing needs to be continued for future annual site water balance modelling.

Tailings Storage Facility

TSF Cell 1 Runoff

Tailings storage facility Cell 1 currently has a temporary capping. The cap is damaged in some places, resulting in contamination of the surface runoff. While ad-hoc minor repairs to the capping are made, no substantial changes to the cap have been undertaken. The Draft OMP EIS proposes to combine TSF Cell 1 and Cell 2. If the Cells are combined, the problem of poor quality runoff from TSF Cell 1 will be addressed. However, the strategies proposed in the Draft OMP EIS are not currently approved.

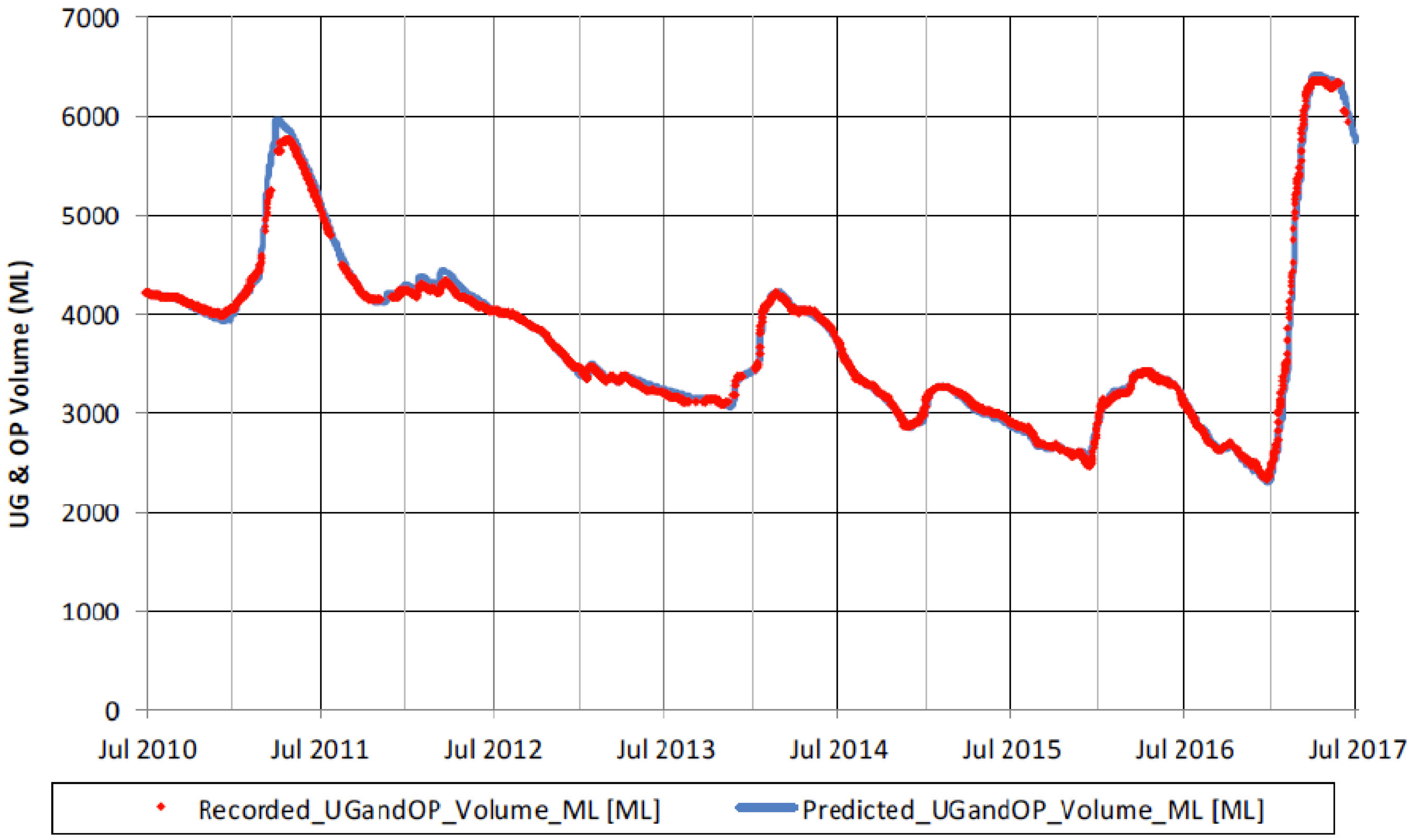
TSF Cell 1 Sumps

There were a number of incidents during the reporting period where the TSF Cell 1 east and west sumps overflowed into the adjacent borrow pits. The use of diesel pumps for the sumps was a factor in most overflows as these pumps require manual starting; which resulted in a delayed start to pumping. No change to the sumps and/or pumps has been taken to prevent further sump overflows. The Draft OMP EIS proposes to combine TSF Cell 1 and Cell 2. If the Cells are

RECORDED VS. PREDICTED WATER STORED IN THE OPEN PIT AND UNDERGROUND (COMBINED) FOR 2010 TO 2017

McArthur River Mine Project

FIGURE 4.1



Source: MRM, 2018.

combined, the sumps will be removed and TSF water will spill via the current Cell 2 spillway into the mini dam. However, the strategies proposed in the Draft OMP EIS are not currently approved.

New TSF WMD Waste Discharge Point

MRM has undertaken modelling to assess the benefit of a new waste discharge point from the TSF WMD to the adjacent Little Barney Creek (WRM, 2017a). The assessment considered dilution rates at SW11 as well as flow rates in Barney Creek. This was because there are periods where there is sufficient McArthur River flow at SW11 to satisfy the waste discharge licence dilution criteria but negligible flow in Barney Creek. Discharge into Barney Creek during these periods could result in local water quality impacts in the creek.

Barney Creek flows can be affected by backwater from high McArthur River flows. Under these conditions, any releases from the TSF WMD to Barney Creek may pond in Barney Creek; rather than be flushed through the system. The ecological impact of this ponded water is unknown. The modelling did not include this backwater effect in its release rules. That is, it was assumed that contaminates flowed freely downstream after release.

It is recommended that the ecological impact of releasing contaminates into the slow-flowing backwater in Barney Creek be considered. If necessary, the release modelling needs to incorporate the backwater periods into the contaminate release rules.

TSF Cell 2 Spills to the TSF Mini Dam

The TSF Cell 2 spillway has been moved so that uncontrolled releases enter the TSF Mini Dam; rather than the TSF WMD. It is understood that the bund separating the mini dam and the WMD is semi permeable. Therefore, any water discharged from TSF Cell 2 to the TSF Mini Dam is likely to enter the TSF WMD and lower quality of the water stored there. Given that the TSF WMD holds water ready for off-site release, deterioration of the quality of this water may prevent or delay the release of the water. This may have an impact upon the mine sites overall risk of uncontrolled releases.

While the risk of TSF Cell 2 spills to the TSF Mini Dam has been modelled, the impact (on the site water balance) of contaminating water stored in the TSF WMD, thereby making it unsuitable for off-site release has not been assessed. This issue of TSF Cell 2 water contaminating the WMD has been identified in previous IM reports but is yet to be satisfactorily addressed.

Flood Immunity of the TSF WMD

The TSF WMD has a 39% (1 in 2.5) annual exceedance probability (AEP) flood immunity. (WRM, 2017b). This is substantially lower than the recommended flood immunity of 1% (1 in 100) AEP (WRM, 2017b). Notwithstanding this, MRM advise that the WMD wall has not been overtopped by flood water in the last five years, despite a number of wet seasons with above average rainfall. This raises questions about the accuracy of the flood magnitude estimation adjacent to the TSF WMD. Further considerations for the TSF WMD flood immunity are:

- The TSF WMD currently stores water ready for controlled off-site release. It is unclear whether 1% AEP flood immunity is necessary as any mixing of TSF WMD water with flood waters may not necessarily result in environmental harm.

- The OMP Draft EIS proposes to reconfigure the TSF WMD into a much larger process water dam (TSF PWD). It is unclear what quality water will be stored in the TSF PWD. It is recommended that the required flood immunity of the TSF WMD wall be assessed against current and future operations and the wall be modified as required.

Lime Treatment of Water in the NOEF SPROD and NOEF SEPROD

Lime treatment of water in the NOEF SPROD and NOEF SEPROD was undertaken during the operational period. Treated water was pumped to the TSF WMD via Pond 2 for off-site discharge. Water quality sampling was undertaken in the PRODs, Pete's Pond and the WMD throughout the entire process to ensure water quality standards were met.

The water treatment process will result in a layer of poor quality water at the bottom of the PROD water columns. Over time, with further lime treatment, this water will deteriorate in quality and the thickness of the layer of poor quality water will increase. It is understood that MRM currently has no plans for this poor quality water. At some future time it will likely be necessary to de-sludge the PRODs. It is recommended that a plan is developed for this de-sludging.

Accurate Quantification of Water Balance Processes

Estimation of Model Predictive Uncertainty – Model Results

The water balance model currently estimates the site water balance behaviour for the coming wet season based upon the planned mine site layout. There is usually a difference (sometimes substantial) between the planned and actual mine site layouts (e.g., PRODs and/or water treatment plant not commissioned). This difference in layout is to be expected however it produces an inherent model predictive uncertainty which is unlikely to change in the future. To put it another way, the wet season planning is based upon a different mine site layout to that which is actually present during the wet season. This raises questions as to whether there is sufficient spare capacity in the water management system to accommodate the uncertainty in mine site layout and how well the model predicts the water balance.

A readily available way to quantify predictive uncertainty of the water balance model is to compare the predications (published in the previous year's water balance report, with no re-calibration) against the 'actual' site water balance for same period (based upon re-calibrated model results in the current year's report). For example, the 2015-2016 water balance predictions from the 2015-2016 report (WRM, 2015) compared with the 'actual' 2015-2016 recalibrated site water balance from the 2016-2017 report (WRM, 2016). It is important that there are no changes or recalibration of the previous year's prediction (i.e., no updating of rainfall or groundwater inflow estimates with measured data). Given that there are four rainfall scenarios modelled each year, the comparison (of actual results) should be made against the (previous years) scenario which most closely matches the actual annual rainfall total.

The comparison between predicted and actual water balance should be undertaken against a range of metrics (e.g., total inflow/outflow, evaporation, seepage, and change in water inventory). This may indicate a greater uncertainty in some system elements, which may help prioritisation of site water management and water balance model development. Further, comparison of the uncertainty analyses across years may show a (hopefully reducing) trend over time or a change in trend (e.g., with the addition of new storages or changes to mine-site layout). This trend analysis would be useful in any risk assessment. Undertaking the uncertainty analysis is a simple task. All the data is available and minimal (if any) additional modelling is required.

Estimation of Model Predictive Uncertainty – Model Parameters

It appears there may be less change in water balance model parameters between the 2017-2018 operational period than between previous years. If so, this indicates a reduction in model parameter uncertainty. However, a comparison of parameters between years has not been undertaken. It is recommended such a comparison be undertaken as a measure of reduction in parameter uncertainty over time.

Simultaneous Calibration of Multiple Parameters

The problem of simultaneous calibration of multiple parameters in the water balance modelling was identified in the 2012-2013, 2014, 2015 and 2016 operational period IM reports (ERIAS Group, 2014; 2015; 2016 and 2017). The best (if not only) way to remove the correlation between parameter estimates is to measure parameters independently. Then, over time, the uncertainty in parameter estimation is reduced. McArthur River Mining is gradually isolating individual elements of the water balance by:

- Continually increasing the amount of surface water monitoring undertaken at the mine site.
- Undertaking targeted short-term runoff, evaporation and seepage trials.

The IM acknowledges MRM's commitment and this year's successes. Notwithstanding this, there remains substantial uncertainty in the water balance modelling and the isolation of key elements will be a multi-year task. Simultaneous calibration of multiple parameters is a fundamental limitation to surface water management on site and warrants continual attention.

Evaporation Fan and Sprinkler Performance

There is substantial uncertainty in the fan and sprinkler evaporation estimates. This issue has been ongoing since the 2012-2013 operational period IM report. There has been no reduction in the evaporation estimate uncertainty for these devices since that time.

Groundwater Inflow Rates

The water balance modelling report acknowledges that there is substantial uncertainty in the groundwater inflow estimation. This uncertainty has been ongoing since the 2012-2013 operational period IM report (ERIAS Group, 2014). It is noted that MRM has commissioned studies (in progress) aiming to reduce this uncertainty. Despite this, the uncertainty in the groundwater inflow rate remains.

Pond Seepage

Seepage is difficult to measure directly and is usually calculated by difference from known, or more easily estimated, processes. This means that seepage can end up as an error term, where it is used to compensate for uncertainty in the estimation of other water balance components, i.e., it suffers from the problem of 'simultaneous calibration of multiple parameters', described previously in this section. Pond evaporation and seepage are almost perfectly correlated. This means that any under/over estimation of evaporation is compensated for by an equal over/under seepage estimate; and the water budget balances. Given that annual pond evaporation and seepage each represent about 25% (about 50% in total) of outflows in the annual site water balance, this uncertainty needs to be reduced.

This uncertainty in seepage estimates has been ongoing since the 2012-2013 operational period IM report (ERIAS Group, 2014), with minimal reduction in seepage uncertainty since then. Notwithstanding this, uncertainty in pond inflows/outflows is incrementally reducing (through additional monitoring). It is anticipated that the inclusion of WPROD monitoring data into the annual water balance model review will provide a large reduction in seepage and evaporation uncertainty. This is because WPROD has a CCL and HDPE liner and should have negligible seepage. This removes one large uncertainty from the WPROD water balance and the evaporation loss should be better defined. The assessment of the WPROD water balance behaviour during the 2017/18 wet season will be undertaken by MRM during the 2019 operational period.

Runoff Trials

Soil infiltration and runoff trials are currently in place (with more planned) for the NOEF and the SOEF (e.g., SMI, 2016a, b). The IM commends MRM for undertaking such trials. However, accurate measurement of surface runoff is notoriously more difficult than it appears. In particular, surface runoff measurements do not necessarily scale between small and large catchments. This is because:

- Small-scale trials do not accommodate the hydraulic heterogeneity across a larger catchment.
- Different physical processes dominate at different scales, e.g., generally speaking, the relative impact of preferential flow paths on hydraulic behaviour tends to increase with catchment area.

The application of the trial results to the site water balance modelling requires caution. If not done well, the monitoring could introduce more errors into the water balance model than currently exist. The IM recommends that MRM consider the cost-benefit of the runoff trials.

Evaporation Trials

There are plans to undertake evaporation trials on the mine site (CSIRO, undated). The proposed trials appear to involve placing floating evaporation measurement equipment on one or more of the PRODs. This is a good way to estimate evaporation from a small waterbody, however the IM questions the cost-benefit of such a trial. The best measure of pond evaporation on the mine site remains the change in water level over time, without (or accounting for) other factors influencing the pond water level. That is, the pond acts as an evaporation pan. Up until now it has not been possible to isolate ponds from all factors influencing water level due to operational constraints and/or seepage uncertainty. It is anticipated that data from the lined WPROD will greatly assist in reducing pond evaporation uncertainty in the next revision of the mine site water balance model.

The water balance model applies spatially averaged daily evaporation estimates to the ponds; in order to use consistent data (1900 to the present) for long-term simulations and model calibration. It is most likely that a better (site-specific) pond evaporation estimate will be different to the spatially averaged estimates and a pond evaporation factor will need to be applied to the spatially averaged data for modelling. This is most likely irrespective of how the site-specific evaporation measurements are derived.

The key issue is the cost of the evaporation trials. It is likely that the uncertainty in evaporation will be reduced through the water balance modelling over the next few years as more fully lined ponds are commissioned (e.g., WPROD, EPROD, and SPROD). Therefore, there may be water management measures that present a higher cost-benefit than the trials. The IM recommends that MRM consider the cost-benefit of the evaporation trials.

Evaporation Fan and Sprinkler Efficacy

The water balance modelling shows that the evaporation fans and sprinklers provide only a small percentage of the total water losses/outflows from the mine site. For example, the total estimated water outflows/losses for 2016/17 (WRM, 2018a) was 7,921 ML. Of this, fans comprised 293 ML (3.6%) and sprinklers 45 ML (0.57%). In addition, there is substantial uncertainty in the fan and sprinkler evaporation estimates.

Given the cost in time and money to operate/maintain the fans and sprinklers (for a small reduction in the volume of water stored on-site) MRM should undertake a cost-benefit assessment of the fan/sprinkler operation to determine whether other water management measures represent a better uses of resources (e.g., additional monitoring, additional pumps/ pipes).

January 2018 Rainfall

Heavy rainfall occurred on site between 20 and 27 January 2018. The period was noteworthy because:

- There were no uncontrolled releases from any PROD or the TSF.
- There were no substantial equipment failures (e.g., pumps, monitoring equipment).

These are noteworthy achievements since the mine site started the 2017/18 wet season with most ponds near maximum operating level. MRM put the successful management of the heavy rainfall down to the new SCADA system, new TARP tables as well as the investment in very high quality monitoring equipment. The identification of the high quality equipment is noteworthy as it is the IM's experience from other mine sites/surface water monitoring networks that equipment failures (pumps and monitoring) commonly occur during heavy rain; usually due to electrical problems.

The January 2018 rainfall was a severe test of the site water management. The successful control of the January rain helps to provide confidence in the site water management. Further, the reasons behind the success (investment in quality systems and people) reflect a strong commitment from MRM towards surface water management at the mine. McArthur River Mining considers that the controlled off site release of large volumes of water during the wet season would not have been possible without the new SCADA system. The IM acknowledges and commends MRM's performance.

The assessment of the impact of the January 2018 rainfall on the site water balance will be undertaken by MRM during the 2019 operational period.

A full assessment of the January 2018 rainfall will be undertaken as part of the 2018/19 water balance modelling (due December 2018) and reviewed in the 2019 operational year IM report.

Improvements Between the 2012 and 2017-2018 Operational Periods

Notwithstanding the need for continual improvement of the water balance model, a cursory assessment of the modelling results and mine site water management since the 2012-2013 operational periods IM report (ERIAS Group, 2014) indicates that, in general, the model is providing a better representation of mine site water behaviour than six years ago. For example:

- There have been no uncontrolled off-site releases from any PROD or the TSF since the 2013-14 operational period.
- With the exception of the CWAS overflowing during the heavy rainfall around 24 January 2018, there has been adequate pump capacity to transfer water from the ponds to the UG&OP in a timely manner so that ponds do not overflow since the start of the current IM reviews (the 2012-2013 operational period).
- The actual site water balance for the 2015-2016 operational period (from the 2016-2017 water balance report: WRM, 2016) is generally similar to that predicted in the 2015-2016 water balance report (WRM, 2015) for a similar rainfall total.
- The high rainfall of January 2018 was managed without any uncontrolled off site releases from any PROD or the TSF.

The IM acknowledge and commend this ongoing improvement.

McArthur River Mining's performance against previous IM review recommendations relating to mine site water balance is outlined in Table 4.4.

Table 4.4 – Mine Site Water Balance Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
Documentation and reporting – MMP reporting	♦ The MMP should provide the broad goals and objectives for mine water management (i.e., MRM's vision). For example: – A list of mine site water management commitments – A statement of intent to continually improve water balance monitoring and reporting – A statement of intent to manage the risk of water in the base of the pit – A list of the current limitations in the mine site water balance, ranked by impact on the water balance – An outline of the proposed mine expansion during the MMP and the site water management changes that may be required (e.g., additional levees, ponds and/or pumps)	Completed Adequate reconciliation of environmental commitments and actions in the operational performance report 2017 (MRM, 2017)

Table 4.4 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Documentation and reporting – MMP reporting (cont'd)	– A prioritised list of options that may be considered to improve mine site water management. This should include commentary on each option (e.g., ease of implementation) and a feasibility-level cost/benefit analysis	
Documentation and reporting – reporting in the main body of the MMP	♦ The water management gap analysis should be reconfigured to provide: – Specific and measureable actions – Estimated commencement and completion times – An 'effectiveness ranking' (say 1 to 5) of the impact the task will have on the site water balance – A 'priority ranking' (say 1 to 5) for completing the task. This will most likely be based upon the results of a cost/benefit analysis ♦ The gap analysis should be updated regularly (say every 6 or 12 months) and produced as a separate document, outside of the MMP	Ongoing
Documentation and reporting – TARP report	The TARP would be greatly improved by the following: ♦ Substantially reducing the reporting on model structure to include only the changes to the site water management network from the assumptions adopted in the annual water balance report ♦ Ensuring the modelling includes the most up-to-date changes in the water balance network; including those proposed for the wet season ♦ Simplifying the TARP action plan tables ♦ Using the rules embedded in the water balance model to develop the TARP recommendations	Completed
Documentation and reporting – water balance model reporting	♦ It is recommended that more tables are used to improve clarity, understanding and error checking ♦ Sensitivity analysis results should be consolidated in one section of the water balance modelling report	Ongoing Improved. Some modification to tables still recommended to aid clarity
Documentation and reporting – MMP and water balance modelling reporting	The following improvements in reporting are required: ♦ The MMP should provide the broad goals and objectives for mine water management (i.e., MRM's vision). For example: – A list of mine site water management commitments – A statement of intent to continually improve water balance monitoring and reporting – A statement of intent to manage the risk of water in the base of the pit – A list of the current limitations in the mine site water balance, ranked by impact on the water balance	Ongoing

Table 4.4 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Documentation and reporting – MMP and water balance modelling reporting (cont'd)	– An outline of the proposed mine expansion during the MMP and the site water management changes that may be required (e.g., additional levees, ponds and/or pumps) – A prioritised list of options that may be considered to improve mine site water management. This should include commentary on each option (e.g., ease of implementation) and a feasibility-level cost/benefit analysis ♦ There should be consistency between on-site water management practice, the MMP and water balance modelling reporting. The water balance modelling reporting needs to demonstrate ongoing model refinement, increased process understanding and a reduction in model parameter/calibration uncertainty	
Documentation and reporting	Increased detail is required in the reporting of the following items: ♦ The rainfall-runoff model calibration, in particular regarding how calibration was undertaken and how parameters were adjusted ♦ The water balance model calibration, in particular regarding how calibration was undertaken and how parameters were adjusted ♦ The monitoring of water balance components, in particular what is monitored, the frequency of monitoring and the accuracy of the measurement ♦ How the monitoring data is used in the water balance modelling ♦ A summary table of water balance storages, inflows and outflows needs to be included in the water balance modelling reports ♦ How the tailings storage facilities are included in the site water balance ♦ How the TSF Cell 1 surface runoff is treated in the water balance model	Completed
Water balance sensitivity analysis/scenario testing	Changes in climate ♦ The possible impact of climate change on the site water balance needs to be addressed ♦ The impact of climate change was modelled in the 2016-2017 mine site water balance report (WRM, 2016) by increasing the model rainfall depths by 5%. This resulted in an additional 4% to 5% of 'rainfall runoff'. This result is of some concern because, in general, the change in runoff is greater than the change in rainfall (sometimes substantially). The model result tends to indicate that there may be something wrong with the rainfall-runoff model. The veracity of the rainfall-runoff model needs to be checked	Completed

Table 4.4 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Water balance sensitivity analysis/scenario testing (cont'd)	Changes in water chemistry ♦ The water balance needs to assess the risks posed by possible deterioration in site runoff and seepage water quality ♦ The 2015/16 water balance modelling report (WRM, 2015) undertook this analysis by changing the controlled release dilution rate from 1 part mine water to 15 parts McArthur River water (1:15) to 1:50. It was found the changes had negligible impact upon the overall site water balance. It is unknown why a 1:50 dilution ratio was chosen. The adopted change in site water quality needs to be justified with: – Current water quality monitoring data and/or predictions (e.g., pond water quality estimates, TSF/NOEF seepage estimates) – Input from professionals with expertise in geochemistry Runoff ♦ The 2016/17 site water balance report (WRM, 2016) showed the NOEF SEPROD and NOEF WPROD were highly sensitivity to increases in runoff. This high sensitivity of changes to runoff volumes needs to be considered in all future water balance modelling Annual Review ♦ The following sensitivity analyses need to be undertaken (as a minimum) in all future annual site water balance studies: – Pump or pipe failure – Deterioration in mine site water quality – Climate change impacts (increased rainfall) – Increased runoff	Ongoing
Water balance scenario testing	Modelling of multiple years: ♦ Assessment of multiple years with the same site configuration should be considered to manage the risk of high starting pond water levels (following two or more consecutive wet years)	Ongoing
Water balance sensitivity testing	Pump or pipe failure: ♦ An assessment of the impact of pump or pipe failure should be undertaken	Completed
Site water balance database	At the time of the 2015 operational period IM site inspection (May 2016), MRM was collating monitored pond water levels and pumping rates in a database, in real time. This allowed for easy and rapid assessment of the status of the site water balance, as well as the analysis of historical data to identify trends and ongoing problems. This database is no longer used and has been replaced with a number of manually updated spreadsheets. This database should be reinstated	Completed New SCADA system commissioned

Table 4.4 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Accurate quantification of water balance model uncertainty	Model predictive uncertainty should be quantified. A readily available way to undertake this is to compare the predications (published in the previous year's water balance report) against the 'actual' site water balance for same period (based upon re-calibrated model results in the current year's report). This will greatly assist MRM in risk management	Ongoing
Incorporation of water balance model results into on-ground mine site water management	A cursory assessment of the modelling results and mine site water management since the 2012-2013 operational periods IM report (ERIAS Group, 2014) indicates that, in general, the model is providing a reasonable representation of mine site water behaviour. Unfortunately, it does not appear that MRM is taking full advantage of the model's capabilities. The two areas where the water balance model could be better utilised are risk management and options analysis	Completed The IM review for the 2017-2018 operational period showed substantial improvement in this area
Water storage ponds and tailings storage facilities	The risk of spills from the TSF Mini Dam to the WMD, thereby making it unsuitable for off-site release, needs to be assessed	Ongoing From 2017 the TSF Cell 2 spills to the TSF Mini Dam
	The MRM intent of improving TSF Cell 1 runoff quality is not reflected in current management of the cell's clay capping. This needs to be resolved	Ongoing No or limited maintenance is undertaken on the clay cap
	TSF Cell 1 surface runoff is collected in sumps and then pumped to the TSF Mini Dam	Completed TSF Cell 1 runoff collected in the TSF Cell 1 sumps is now transferred to the CRP
Risk management of the site water balance	Use of the UG&OP for water storage: ♦ McArthur River Mining needs to provide a medium- to long-term plan which resolves the conflict between mine operations and using the UG&OP as a water storage	Completed
Accurate quantification of water balance processes	Surface water monitoring at Bing Bong Loading Facility needs to be resumed	Completed
Water storage ponds and tailings storage facilities	More comprehensive reporting of TSF Cell 1 water management design and operation is required	Completed
	The risk and impact of TSF Cell 2 spills contaminating water stored in the WMD, and thereby making it unsuitable for off-site release, needs to be assessed	Ongoing From 2017 the TSF Cell 2 spills to the TSF Mini Dam
Risk management of the site water balance	Variation in rainfall: ♦ McArthur River Mining needs to develop the surface water management system to the point where there is sufficient capacity that variation in rainfall between years (and sequences of consecutive wet/dry years) is treated as business as usual and not something abnormal	Ongoing The 2017-2018 operational period is the first time during the engagement of the current IM (commencing with the 2012-2013 operational period) where MRM appear to be comfortable with the water management

Table 4.4 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Risk management of the site water balance (cont'd)		status on site; as opposed to displaying concern with the status and confusion on how to improve the situation. This improvement is commended by the IM. However, this current MRM comfort level has been displayed for one operational period only. A minimum of three consecutive years of treating the surface water management as business as usual is required before this item will be addressed
Accurate quantification of water balance processes	The uncertainty in model parameter estimation requires reduction. While this is implicit in all aspects of the water balance monitoring and modelling, high priority areas that need addressing are: ♦ The amount of simultaneous calibration of multiple parameters needs to be reduced ♦ Evaporation fan/sprinkler/fountain performance needs to be accurately quantified ♦ Groundwater inflow rates need more accurate estimation ♦ Seepage rates and runoff rates need more accurate estimation ♦ A strategy needs to be developed to reduce predictive uncertainty over time	Ongoing ♦ Incremental improvement has been made in most areas ♦ Given the large degree of uncertainty and the fact that improvement can only be made incrementally each year, this recommendation is ongoing
NOEF expansion flood study	McArthur River Mining needs to review the most recent flood study and flood and compare impacts to those provided in the Phase 3 EIS to: ♦ Determine if the off-site flood impacts have increased ♦ Demonstrate that the current flood level estimates against the NOEF batters do not compromise the MRM commitment to place all PAF material above the 1% annual exceedance probability (AEP) flood level	Ongoing The Draft OMP EIS addresses this. If the strategies proposed in the Draft OMP EIS are adopted then this action will be complete
Runoff modelling of the new clay capping on the NOEF	The method of incorporating the new clay capping into the 2014-2015 water balance modelling (WRM, 2014) does not provide confidence that the impact of the clay capping on the water balance has been adequately accounted for. The method of modelling the clay capping needs revision	Completed
Changes in climate	The possible impact of climate change on the site water balance needs to be addressed	Ongoing
Changes in water chemistry	The water balance needs to assess the risks posed by possible deterioration in site runoff and seepage water quality	Ongoing

Table 4.4 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Monitoring	Studies need to be undertaken to quantify the performance of evaporation fans, sprinklers and fountains. Targeted monitoring of selected ponds needs to be undertaken to reduce the number of processes that need to be estimated by difference in the water balance model	Ongoing Limited progress has been made
Mine site water balance model calibration	The uncertainty in model parameter estimation requires reduction. While this is implicit in all aspects of the water balance monitoring and modelling, high priority areas that need addressing are: ♦ The groundwater inflow rate ♦ Seepage estimates ♦ Additional sensitivity analysis (which needs to be undertaken in the water balance modelling) While the reduction in uncertainty is implicit in most of the recommendations, the key requirement here is that the reporting quantifies how the uncertainty is reduced in each successive year	Ongoing
Evaporation data	The evaporation data adopted in the water balance model uses long-term evaporation averages prior to 1970. The effect of this on the water balance model results needs checking	Completed
Modelling of multiple years	Assessment of multiple years with the same site configuration should be considered to manage the risk of high starting pond water levels (following two or more consecutive wet years)	Ongoing
TSF	A review of available capacity to store tailings, process water and rainfall runoff while maintaining sufficient freeboard, also taking into account the initiative to increase evaporation by using a larger part of the WMD. A review of the water balance including detailed water balance modelling should be carried out	Completed
TSF Cell 2	Following a water balance review, excess water to be removed from the facility	Completed

4.2.4.3 Successes

The successes of MRM's site water management over the reporting period include the following:

- Additional monitoring equipment has been installed (flow meters and pond water level sensors).
- An improvement in the sensitivity analyses undertaken as part of the site water balance modelling.
- An improvement in the water balance modelling reporting.
- The commissioning of a new SCADA network for monitoring and reporting of site water management operations in real time (e.g., pond water levels and water transfers).

- Substantial improvement in the water management TARP tables.
- Incorporation of the water management TARP tables into the SCADA reports.
- Successful management of the high rainfall of January 2018 with no uncontrolled releases from any PROD or the TSF.
- A high volume of controlled off-site releases to reduce the volume of water stored on site. (2,656 ML (WRM, 2018c)). This was a substantial increase on the 859 ML for the previous 2016-2017 operational period (MRM, 2017).

4.2.5 Conclusion

The 2017-2018 operational period has seen continual improvement in the site water balance in the following two areas:

- Installation of additional monitoring equipment to measure pond water level and water transfer between ponds.
- Water balance model reporting and scenario testing.

The commissioning of the new SCADA network, together with the improved TARP tables, and the incorporation of both items into daily operations have produced a step change improvement in mine site water management. During the 2017/18 wet season, the adoption of these systems resulted in the controlled off-site release of 2,656 ML water as well as the successful management of the high rainfall of January 2018. It is unlikely that either would have been achieved without these systems.

There has been substantial improvement in the performance of the site water balance model since the 2012 operational period. The modelling tends to indicate that model predictions (one year ahead) are a reasonable representation of the actual water budget on site. Notwithstanding this, there remains uncertainty in the water balance modelling and the isolation of correlated parameters will be a multi-year task. Continual ongoing improvement of the water balance modelling is required, in particular in the reduction of parameter uncertainty.

An additional assessment that can be readily undertaken with the current information is the quantification of overall model predictive uncertainty. The results of such an assessment can be used for risk management and prioritisation of site water management and water balance model development.

Ongoing and new IM recommendations related to mine site water balance issues are provided in Table 4.5.

Table 4.5 – New and Ongoing Mine Site Water Balance Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Documentation and reporting	Water balance model reporting: ♦ It is recommended that more tables are used to improve clarity, understanding and error checking	Medium

Table 4.5 – New and Ongoing Mine Site Water Balance Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Water balance sensitivity analysis	Changes in water chemistry: ♦ The 2015/16 water balance modelling report (WRM, 2015) undertook this analysis by changing the controlled release dilution rate from 1 part mine water to 15 parts McArthur River water (1:15) to 1:50. It was found the changes had negligible impact upon the overall site water balance. It is unknown why a 1:50 dilution ratio was chosen. The adopted change in site water quality needs to be justified with: – Current water quality monitoring data and/or predictions (e.g., pond water quality estimates, TSF/NOEF seepage estimates) – Input from professionals with expertise in geochemistry Runoff: ♦ The 2016/17 and 2017/18 site water balance reports (WRM, 2016, 2018a) showed the NOEF SEPROD and NOEF WPROD were highly sensitivity to increases in runoff. This high sensitivity of changes to runoff volumes needs to be considered in all future water balance modelling	Medium
Water storage ponds and tailings storage facilities	♦ While the risk of TSF Cell 2 spills to the TSF Mini Dam has been modelled, the impact (on the site water balance) of contaminating water stored in the WMD, thereby making it unsuitable for off-site release, should be assessed ♦ The MRM intent of improving TSF Cell 1 runoff quality is not reflected in current management of the cell's clay capping. This should be resolved	Medium
	The resilience of the site water management system to unforeseen changes: ♦ While the current site water balance modelling shows that the probability of uncontrolled off-site releases is within the design criterion (less than 5%), the key modelling assumption is that model inputs are correct and the system performs as modelled. There is no allowance for unforeseen changes to the water balance estimates (i.e., mine operations being different to those adopted in the model). McArthur River Mining needs to develop the surface water management system to the point where there is sufficient resilience to accommodate uncertainty in model estimates Variation in rainfall: ♦ McArthur River Mining needs to develop the surface water management system to the point where there is sufficient capacity that variation in rainfall between years (and sequences of consecutive wet/dry years) is treated as business as usual and not something abnormal	Medium
Accurate quantification of water balance model uncertainty	Model predictive uncertainty should be quantified. A readily available way to undertake this is to compare the predications (published in the previous year's water balance report) against the 'actual' site water balance for same period (based upon re-calibrated model results in the current year's report). This will greatly assist MRM in risk management	Medium

Table 4.5 – New and Ongoing Mine Site Water Balance Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Accurate quantification of water balance processes	Model parameter uncertainty: ♦ The uncertainty in model parameter estimation requires reduction. While this is implicit in all aspects of the water balance monitoring and modelling, high priority areas that should be addressed are: – The amount of simultaneous calibration of multiple parameters should be reduced – Evaporation fan/sprinkler/fountain performance should be accurately quantified – Groundwater inflow rates need more accurate estimation – Seepage rates and runoff rates need more accurate estimation	Medium
New Items		
Documentation and reporting	2017-2018 OPR: ♦ The numerous errors and inconsistencies within the OPR should be corrected to improve accuracy of representation of the status of on-site water management ♦ Water balance model calibration charts that misrepresent the models predictive ability should not be used in the OPR	Medium
Water storage ponds and tailings storage facilities	♦ It is recommended that a plan is developed for de-sludging the NOEF PRODs used for lime treatment ♦ A new waste discharge point from the TSF WMD to the adjacent Barney Creek is proposed. The ecological impact of these releases when Barney Creek flow is affected by backwater from high McArthur River flows needs to be considered ♦ The TSF Cell 1 east and west sumps overflows into the adjacent borrow pits. Changes to the sumps and/or pumps are required to prevent further sump overflows ♦ The TSF WMD currently has only a 39% (1 in 2.5) AEP flood immunity. It is recommended that the TSF WMD wall be modified to provide 1% AEP flood immunity	Medium
Accurate quantification of water balance model uncertainty	It is recommended that a comparison of model water balance parameters from year to year be undertaken as a measure of reduction in parameter uncertainty over time	Medium

4.2.6 References

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WRM. 2018c. Memo. Surface water flow volumes and analyte loads in the McArthur River, Barney Creek, Surprise Creek, Bull Creek, Emu Creek and MRM releases during the 2017 dry season 2016/17 wet season. From J. Orth to C. Dobson. 15 June 2018. Prepared by WRM Water and Environment for McArthur River Mining Pty Ltd, Winnellie, NT.

4.3 Surface Water Quality Management

4.3.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of surface water quality, and is based on review of:

- Observations and discussions with MRM personnel and selected MRM consultants during the site inspection, including presentations concerning specific matters such as water quality and the dilution calculator.
- Various reports prepared by MRM and its consultants, with particular reference to the operational performance report (OPR) for 1 June 2016 to 31 May 2017 (MRM, 2017a) and 1 June 2017 to 31 March 2018 (MRM, 2018a), mining management plan (MRM, 2015a), groundwater, surface water and fluvial sediment monitoring report for 2016-2017 (ELA, 2017), surface water monitoring report for 2017-2018 (KCB, 2018), WDL 174-09 and 174-10 monitoring report for 2016-2017 (MRM, 2017b), and WDL 237 licence report (MRM, 2017c).
- Excel files provided by MRM that contain:
  - Collated laboratory and in situ water quality data for the operational period and historical data, including DGT data.
  - McArthur River level and flow.
  - Water monitoring schedule.
  - Environment reporting matrix.
  - Compliance register.
  - Environment incident register.
  - Status of 2017 IM recommendations.
- Laboratory documents such as sample receipt notification and chemical analysis reports (including quality control data).
- Various MRM forms and similar documents such as chain of custody forms, internal water quality review memos and incident notification letters, and correspondence between MRM and other parties.
- Aerial and other photographs of the MRM mine site.
- Other documents such as MRM's waste discharge licence (WDL) and DPIR site inspection reports.

4.3.2 Key Risks

The key risks to surface water quality, as described in the risk assessment (Appendix 1), are summarised below for each of the mine site (and surrounds) and Bing Bong Loading Facility (and surrounds), and remain as described in last year's IM report.

Mine Site and Surrounds

The nature of the mine and processing plant at the McArthur River Mine is such that a number of risks are inherently associated with the operation. While some of these are relatively minor, the following key risks have been recognised:

- Poor quality seepage and surface runoff, primarily from areas such as the TSF and NOEF (which contain tailings and waste rock respectively), may result in poor water quality in McArthur River tributaries such as Surprise Creek and Barney Creek, as well as McArthur River itself. The water quality variables of most concern are pH, salts (e.g., sulfates) and trace metals (e.g., Pb, Zn, As, Cd and Cu). Poor water quality can result in loss of aquatic flora/fauna (including benthic biota) and bioaccumulation of metals with consequent human health or animal health implications should this biota be consumed, and can also adversely impact on other relevant environmental values. This type of risk also includes impacts such as those that might be associated with:

  - Tailings storage facility embankment failure (in which case the tailings solids themselves would also present a significant hazard) and/or the TSF overtopping.
  - Neutral or saline leachates from waste rock.
  - Saline seepage from areas such as the ELS potentially reporting directly to McArthur River (and further discussion about MRM's current hypothesis concerning the role of the ELS is provided in Section 4.5.3.2).
  - Poor quality surface runoff from waste rock that has been used for construction around the site but, given the revised geochemical classification, should not have been used for such purposes.

  Changes in the conductivity (EC) in McArthur River, which may be due to the influence of the Cooley deposits and oxidising pyritic shale that is intercepted by the McArthur River diversion channel (and/or the ELS), also requires ongoing consideration.

- Poor quality surface runoff due to soil contamination from depositional dust generated by mining and processing operations, primarily from the TSF, ROM pad and crushing circuit, and direct dust deposition itself, may cause poor water quality (pH, salts, trace metals) in Surprise Creek, Barney Creek and, again, McArthur River. As noted above, this can have adverse impacts on aquatic flora/fauna and, potentially, human health or animal health via bioaccumulation.

It has also been noted by MRM that process water itself if not properly contained poses an environmental hazard due primarily to elevated concentrations of SO_4, other major ions, trace metals (e.g., Pb and Zn), and process additives (MRM, 2015a).

Key closure-related risks concerns the final pit lake water quality and the potential for poor quality water to reach nearby watercourses, with adverse impacts as noted above, and the potential for active avulsion upstream resulting in McArthur River flow reverting to the old channel causing erosion and failure of the mine levee wall, again with possible downstream impacts. These are discussed further in Section 4.4 and Section 4.8, respectively. A related long-term concern is the potential for poor quality drainage from OEFs and the TSF due to factors such as failure of the cover(s) (should closure involve placing a cover on the TSF rather than transferring the tailings to the pit, with the latter being MRM's preferred, but yet to be approved, approach) and/or mistaken classification (and hence management) of waste rock, with adverse effects on surface water quality.

Bing Bong Loading Facility and Surrounds

With respect to surface (including marine) water quality, risks associated with the Bing Bong Loading Facility remain fewer in number than those at the mine site. However, some of these continue to warrant discussion, including:

- Poor quality surface runoff due to contamination from depositional dust generated by unloading and loading operations (and other material management procedures) causing poor water quality with respect to trace metals (e.g., Pb and Zn) in onshore drainages and the nearshore environment. This can have adverse impacts on aquatic and marine flora/fauna and, potentially, human health or animal health via bioaccumulation.

- Concentrate spillages or direct dust deposition during MV Aburri barge loading or trans-shipment directly affecting coastal or marine water quality, with consequent adverse impacts as described above.

As was the case in the previous reporting period, the risk associated with the release of dredge spoil due to embankment failure, with consequent adverse impacts on aquatic and marine flora/ fauna and, potentially, human health or animal health via bioaccumulation, was minimised during the reporting period due to the lack of dredging activities.

4.3.3 Controls

4.3.3.1 Previously Reported Controls

Mine Site and Surrounds

In terms of the main sources of contaminants that can affect surface water quality on the mine site and surrounds, existing controls are discussed in the relevant sections of this report that address:

- Geochemical classification of mine materials, materials management and monitoring, and design, construction and operation of the TSF and NOEF, all of which act as controls in relation to seepage and surface runoff from these facilities and other project components.

- Materials management and generation of contaminated dust.

Within the surface water management system itself, existing controls are best summarised in the 2017-2018 OPR (MRM, 2018a), where key elements include:

- Classifying mine water into six water classes, as follows (and noting that MRM refines the classification system as required to maintain relevance to MRM's operations and the WDL):
  - Class 1 – diverted water. This is typically sourced from upstream catchments that are unaffected by mining. Wherever practical, this water is diverted away from mining activities without impacting its quality.
  - Class 2 – surface water. This is typically sourced from cleared areas and benign stockpile areas. This runoff requires treatment through a sediment management structure prior to release either passively through the structure or via dewatering.
  - Class 3 – treated water. This is permeate from the water treatment plant (WTP) (which is discussed further in the next section).
  - Class 4 – managed release water. This is typically sourced from surface runoff from cleared areas with some exposed/capped non-benign material and/or treated mine water. The IM notes that the previous OPR (MRM, 2017a) refers only to exposed/ capped non–acid-forming (NAF) material, i.e., the definition of Class 4 water has been broadened in the 2017-2018 OPR. While the IM supports this in principle in terms of maximising the volumes of water that can be discharged, the question previously posed by the IM as to balancing this with the impacts associated with increased mine-derived loads has yet to be addressed (and this is further discussed later in this section). This water typically has SO_4 and/or metal concentrations that are elevated relative to trigger values specified in the WDL, and is further sub-divided into three sub-classes, i.e., a (best quality), b (good quality) or c (medium quality). End uses of this water include managed releases to McArthur River from authorised discharge points in accordance with the WDL.
  - Class 5 – poor quality (mine) water. This is typically affected by seepage from the TSF and NOEF, runoff from areas with exposed non-benign material, and/or underground void water. This water class is generally contained within the mine water management system.
  - Class 6 – process water. This is typically used within the mill and TSF as well as other process streams, and also includes seepage from ore stockpiles and brine from the WTP. This water class is contained within the mine water management system.
- The ongoing use of this classification scheme should assist MRM with surface water management, given that it represents an increasing focus on water quality rather than source.
- Establishing the following operational objectives (MRM, 2018a):

  - Manage surface water such that environmental values and ecosystems are maintained downstream of MRM's mining leases[1].
  - Maintain separation between water of varying qualities.
  - Provide a reliable source of water for mining and mill processing while minimising raw water consumption by maximising reuse of mine water.
  - Manage the operational risk of open pit inundation to ensure an uninterrupted ore supply to the mill.
  - Operate in accordance with the requirements of the current MMP and WDL conditions.
  - Ensure that there is no material change in flood immunity or erosion potential on the Carpentaria Highway, mine levee wall or key infrastructure without mitigation strategies[2].
- Achieving these objectives by implementing measures (which have been refined compared with those described previously) such as:
  - Minimising water inputs:
    - Diverting up-catchment (clean) waters around the mine.
    - Collecting poorer quality water on-site and reuse in the processing mill and dust suppression to minimise raw water consumption.
  - Optimising water outputs:
    - Maximising evaporation losses through the use of sprinklers, fans and irrigation, and operating storages at their optimum levels.
    - Optimising the discharge of suitable waters and permeate in accordance with the WDL.
  - Effective operational management:
    - Using sediment control structures to manage sediment in runoff waters.
    - Maintaining separation of process and mine water from other better quality water, including the separation of runoff from benign and non-benign catchments.
    - Minimising surface disturbance of new areas and progressively rehabilitating previously disturbed areas to limit the storage of water on-site.
    - Designing and operating the TSF to limit tailings oxidation and seepage.

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[1] The IM notes that this specific objective differs from that in the 2016 OPR (MRM, 2016a), i.e., 'Protect the integrity of local and regional surface water resources within and downstream of the mine lease boundary'. The IM supports the specific reference to 'environmental values' in the revised objective but notes that appropriate environmental values should also be established and protected upstream of SW11, as discussed later in this section.
[2] The IM notes that this is additional to the objectives in the previous OPR, and endorses its inclusion.

- Designing and operating the water storages and pumping infrastructure to mitigate the risk of uncontrolled overflows.

Of particular note is the inclusion in the executive summary of the 2017-2018 OPR (MRM, 2018a) of text that describes MRM's key environmental objectives and a tiered management approach that takes into account preventative management (e.g., on-site water management), on-site performance identification (e.g., on-site artificial surface water quality, groundwater quality and natural surface water quality monitoring), off-site performance identification (e.g., downstream water quality monitoring), and performance confirmation (e.g., aquatic biota monitoring). The IM endorses this approach and notes that it reflects an integrated view of environmental management in relation to the environmental objectives. The IM also notes that the first of the four key objectives refers to protecting downstream beneficial uses and environmental values, while the second refers to facilitating the development of ecosystems and their functions along the McArthur River and Barney Creek diversion channels.

Of further note is the summary of the specialist reviews relating to the protection of downstream beneficial uses and environmental values, which is also presented in the 2017-2018 OPR executive summary (MRM, 2018a). While the specialists concluded that this particular environmental objective was being achieved, the IM notes that the issue of mine-derived loads is yet to be satisfactorily addressed. It is important to note that the IM is not of the view that loads *per se* are necessarily problematic. The issue is that mine-derived loads of some stressors may be significant in relation to background loads and the potential impacts associated with these increased loads have not been assessed, and determination of key sources of mine-derived loads will also allow mitigation measures to be appropriately focussed. The IM also notes that WDL 174-10 requires MRM to assess mine-derived load estimates and balances reporting to McArthur River, as well as proposing mine-derived contaminant loads that protect the receiving environment, and that this work is currently in progress.

For the purposes of this report, and consistent with previous IM reports, performance of the surface water management system in terms of water quality is assessed largely by reference to the WDL conditions, the OPRs (MRM, 2017a; 2018a) and, where appropriate, the 2013-2015 MMP (MRM, 2015a), although additional levels of assessment are discussed herein where relevant. The effectiveness of the management and mitigation strategies has been determined by the monitoring program results presented in the relevant surface water monitoring reports (ELA, 2017; KCB, 2018) and the WDL monitoring report (MRM, 2017b), supplemented by review of the data provided by MRM in separate spreadsheets.

During the IM reporting period (i.e., 1 October 2016 to 31 March 2018), MRM operated under the following WDLs:

- WDL 174-08 (expired October 2016).
- WDL 174-09 (valid from October 2016 to April 2017).
- WDL 237 (valid from March to May 2017).
- WDL 174-10 (valid from April 2017 to April 2019).

The expiry date for WDL 174-08 was notionally 30 September 2016, although WDL 174-09 didn't become effective until 28 October 2016, i.e., at the end of the first month of the current IM reporting period. Discharge points for each WDL are summarised in Table 4.6 and shown in Figure 4.2.

Table 4.6 – Waste Discharge Licence Authorised Discharge Points

Authorised Discharge Points	Description
WDL 174-08 and WDL 174-09	
Mine Levee Discharge Point(s) (MLDP) (Mine levee pumping outlets)	Discharges through the MLDP include: ♦ Rain water collecting in the old McArthur River Channel (NC1A) inside the mine levee ♦ Groundwater from dewatering bores around the main pit collected in and then discharged from Pond 2 (P2) ♦ Water from the water management dam (WMD) Waters discharged at the MLDP are pumped over the mine levee wall and flow into the Old McArthur River channel upstream of the McArthur River and Glyde River confluence
South-east Levee 1 Discharge Point (SEL1 DP)	Rain water collecting inside SEL and separated from all contaminated seepages. Discharges are pumped via the pipeline to Barney Creek and then flow into McArthur River. Discharge can only occur when flow as measured in McArthur River at the downstream gauging station is in excess of 20 m^3/s
Dredge Spoil Drain (BBDDP)	The BBDDP is located on tidal mudflats to the east of the loading facility and within a tidal area. The drain is constructed around the external boundary of the dredge spoil cells to intercept saline water and extends about 400 m from the final cell At the BBDDP passive releases flow across the intertidal flats to the Gulf of Carpentaria via the Bing Bong navigation channel
WDL 174-10	
Mine Levee Discharge Point(s) (MLDP) (Mine levee pumping outlets)	As for WDL 174-08 and WDL 174-09, with an additional discharge through the MLDP being specified: ♦ Treated water from the WTP that will be stored in P2 prior to discharge from the MLDP ♦ Other sources, which can be stored and discharged via infrastructure associated with OP NC1A, OP P2 and the TSF WMD, including mine-affected treated water*
SEL1 DP	As for WDL 174-08 and WDL 174-09
Dredge Spoil Drain (BBDDP)	As for WDL 174-08 and WDL 174-09, with additional specification that the drain receives overflow from: ♦ The final dredge spoil emplacement area cell when in operation ♦ Saline water from the perimeter drain which surrounds the dredge spoil emplacement area
WDL 237	
SEL1 DP	Water from the Central West Alpha Sump is pumped to the SEL1 DP for discharge to McArthur River via Barney Creek
Central West Charlie Sediment Trap (CWCST)	Water from the Central West Alpha Sump is pumped to the CWCST for discharge. This sediment overflows to an unnamed tributary to the north of the NOEF and on to Emu Creek before flowing into McArthur River

* KCB (2018) notes that 'wording in the WDL that specifies that discharges ‘include’ certain waters at the MLDP means it does not specifically preclude other sources'.

WASTE DISCHARGE LICENCE AUTHORISED DISCHARGE POINTS

McArthur River Mine Project

FIGURE 4.2

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Surface water management incidents, e.g., discharges in contravention of the site's WDL, are discussed in Section 4.3.4.1. Other areas where MRM could fail to comply with surface water management requirements, examples of which are provided in MRM (2015a), include the following:

- Breach in integrity of hoses or pipes.
- Overflows or spills.

Should an incident occur, specific corrective actions range from spill clean ups through to modifying the operating strategies for the surface water management system, and providing other rectification measures as appropriate.

An important feature of MRM's controls at the mine site with respect to water discharges continues to be the completion of a mixing and dilution calculation prior to all discharges using a release (dilution) calculator, where this is based on measured water quality and flow rates.

This allows MRM to calculate theoretical concentrations at the McArthur River point of compliance, i.e., SW11, which can then be compared with the trigger values specified in the WDL. The spreadsheet is a mass balance calculation that takes no account of changes in metal speciation after discharge, assumes complete mixing, and includes a 25% safety factor. Input data includes river levels and flows, pumping capabilities, and water quality at SW11 and potential discharge sources relating to WDL trigger values. While a simple approach, this is likely to be an effective management tool. A requirement of WDL 174-10 is that sampling is undertaken at discharge points and when authorised discharges are expected to reach SW11, and MRM has advised that the results are informally compared by visually comparing the laboratory outputs with the calculated results. The IM recommends that this validation is explicitly and formally recorded.

A key aspect of MRM's management plan, as referred to above, is an environmental monitoring system. The stated aims and objectives of the natural surface water monitoring program are similar to those in previous years and include the following (ELA, 2017; KCB, 2018):

- Characterise water quality at monitoring sites upstream and downstream of mine operations.
- Assess potential impacts of the mine operations on the receiving environment.
- Assess the measured water quality against site-specific trigger values to verify compliance.
- Identify potential sources of contamination measured at water monitoring sites.
- Assess the efficacy of controls implemented by MRM to prevent contamination of receiving waters downstream of the site in McArthur River.

This monitoring program includes sampling sites located upstream and downstream of the mine with both in situ and laboratory (NATA-accredited or similar) analyses being undertaken, and is complemented by an artificial surface water monitoring program which has the following objectives (ELA, 2017; KCB, 2018):

- Identify potential contamination in water to determine risk and appropriate management options.
- Identify suitable water storage options, and whether off-site discharge is a viable disposal option.
- Track environmental performance and provide data for contamination source investigations.

Although these objectives differ from those provided previously, the IM notes that they are based on an earlier MRM document and are relevant to the program.

Notwithstanding the above, the IM notes that the executive summary in ELA (2017) reports the surface water objectives as being to:

- Minimise the discharge of mine affected (or 'contaminated') surface water to the surrounding environment.
- Comply with the WDL under the provisions of the NT Water Act.

While the first of these is laudable, the IM notes that this may not be consistent with the more appropriate objective of maintaining environmental values (as described earlier), where this might best be achieved by maximising the volumes of water discharged by MRM, some of which could be mine-affected, while still protecting the downstream values. It is also worth noting that the predicted surface water impacts in that executive summary include increase sulfate loads to Barney Creek diversion, but no mention is made of increased loads of other variables such as Pb or Zn (and this is discussed later). The IM further notes that this objective is not included in the subsequent surface water monitoring report, i.e., KCB (2018), and that MRM reported maximising the discharge of suitable water in the 2017/18 wet season in accordance with WDL 174-10 (MRM, 2018b) via treatment of contaminated water and improved discharge management.

As has been noted in previous IM reports, MRM devotes considerable effort to this monitoring program. Key elements of the program include (ELA, 2017; KCB, 2018):

- Natural surface waters (NSW) – this includes 32 sites (Figure 4.3), including SW11 that is used to determine compliance with MRM's WDL. McArthur River, Barney Creek, Surprise Creek, Emu Creek, Bull Creek (recently added) and Glyde River monitoring sites are sampled generally weekly, but only if flow is evident at the specific sampling sites. More frequent sampling at a number of sites in the McArthur River and Barney Creek occurred as a result of the WDL's 'upon discharge' monitoring requirements. Site SW08 on the downstream McArthur River is located at the Burketown Causeway at Borroloola (about 40 km downstream from the mine site) and is sampled on a monthly basis, as is Site SW32 (recently added) that is located about 6 km upstream of the Burketown Causeway and has been included to avoid the effects of tidal influences and the Borroloola sewerage works.
- Artificial surface water (ASW) – ELA (2017) reported that there are 62 ASW sites within the mine's monitoring program, with 31 sites being discussed therein. However, the subsequent surface water monitoring report (KCB, 2018) refers to 47 ASW sites, with 29 being selected for inclusion in the monitoring report (as shown in Figure 4.4) and the raw data for the

NATURAL SURFACE WATER MONITORING SITES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.3

Source: KCB, 2016.

ARTIFICIAL SURFACE WATER MONITORING SITES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.4

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remaining sites provided to the regulator on a quarterly basis. Sampling is either weekly or monthly basis. Reasons as to why the two reports refer to a different number of ASW sites, why the number of ASW sites was reduced, why data for only selected sites is presented in the report, and what the data for the other sites shows were not provided by MRM.

- Determination of the following (although not all parameters were determined at all sites, and frequency of determination also varied):
  - General chemistry, major anions and cations, nutrients, and filtered metals, with selected samples also being analysed for total metals and TPH/BTEXN (total petroleum hydrocarbons/ benzene, toluene, ethylbenzene, total xylenes and naphthalene).
  - In situ EC, pH, ORP (oxidation-reduction potential), temperature, turbidity and dissolved oxygen.
  - Filtered ferrous iron, total acidity (only for the NOEF ASW sites).

The IM notes an apparent inconsistency between the parameters listed in ELA (2017) and KCB (2018), and also when compared with the Excel file 'MRM Environmental Monitoring Schedule 2017-18 I001 Rev 9.xlsx'. Examples are parameters such as total N, total P, total (unfiltered) metals, and metals such as Ag, Sb and Tl being included in KCB (2018) and the spreadsheet for natural surface waters but not referred to in ELA (2017). The IM recognises that the analytical program was expanded in July 2016 to include additional parameters as recommended in Ecometrix (2016) and suggests that the rationale for such changes be appropriately documented in the surface water monitoring reports. Similarly, full ICP-MS scans are included for selected sites in the spreadsheet but are not indicated as being undertaken for surface waters in either ELA (2017) or KCB (2018), although MRM has subsequently advised that multi-element scans were undertaken on samples from SW11 and SW06 in February 2018. The IM also notes that data for some, but not all, of these additional parameters is included in the Excel spreadsheet 'MRM Raw SW and ASW Data.xlsx'. This apparent inconsistency between the monitoring schedule, collated data and interpretative reports raises questions concerning the implementation of the agreed sampling program and extent to which the various aspects of the surface water program are integrated.

Bing Bong Loading Facility and Surrounds

In terms of sources of contaminants that can affect surface water quality at Bing Bong Loading Facility and surrounds, existing controls relating to generation of contaminated dust (primarily when concentrate is loaded onto the MV Aburri transport barge and when trans-shipment occurs) are discussed in Section 4.13.

As noted in previous IM reports, advice from MRM is that the general surface water management objectives that apply to Bing Bong Loading Facility are compliance with the WDL and protection of the receiving environment. Surface water management at Bing Bong Loading Facility involves primarily (Figure 4.5):

- A surface runoff pond (BB SRP1) that collects runoff from the industrial area around the Bing Bong Loading Facility, shed roof water, return water from the truck wash, and MV Aburri washdown and rainfall capture.

SURFACE WATER MONITORING SITES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.5

Source: WRM, 2016.

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- Two overflow ponds (BB SRP2 and BB SRP3) that collect water pumped from SRP1.

A dredge spoil emplacement area (DSEA) (also referred to as 'dredge spoil ponds') is located immediately next to the Bing Bong Loading Facility. This area consists of five ponds, where decant from settled dredge spoil passes sequentially through the ponds to allow solids to settle and is then discharged via the perimeter dredge spoil drain to the tidal mud flats east of the Bing Bong Loading Facility area (see Figure 4.5). No dredging was undertaken in the swing basin or navigation channel over the October 2016 to March 2018 reporting period and hence no active releases occurred from the dredge spoil settlement ponds to the receiving environment during this period.

Measures to minimise impacts on water and sediment quality at the Bing Bong Loading Facility include:

- Using road trains that are fitted with protective covers to transport the bulk concentrate to the facility, and offloading the concentrate within the fully covered concentrate storage shed.
- Ensuring that all runoff from the concentrate shed and the hardstand areas around the loading facility is captured within BB SRP1 and disposed of primarily via sprinkler and pond evaporation (with excess water being pumped to the other two ponds).
- Intercepting seepage in a perimeter drain around dredge spoil ponds and directing this water away from vegetated areas and towards the discharge point (BBDDP) in the nearshore environment.
- Loading the concentrate onto the MV Aburri via a covered conveyor system.

As with the mine site, MRM devotes considerable effort to surface water monitoring at Bing Bong Loading Facility and in the surrounding marine environment. As described in ELA (2017), the 2016-17 program at Bing Bong Loading Facility consisted of sampling from the following (see Figure 4.5):

- Three artificial surface water sites (BBSRP1 to BBSRP3), i.e., the three runoff ponds. Sampling and observations are on a monthly basis.
- Five surface water sites (DSD01 to DSD04, BBDDP), i.e., four sites along the dredge spoil perimeter drain (DSD) plus BBDDP, which is the authorised discharge point specified in the WDL. Sampling of the DSD sites is weekly when dredging, with sampling at BBDDP occurring on a monthly basis.

The program in 2017-18 consisted of (KCB, 2018):

- The same three ASW sites, i.e., BBSRP1 to BBSRP3, with sampling and observations still being on a monthly basis.
- Only one natural surface water (NSW) site, i.e., BBDDP, with sampling also still occurring on a monthly basis.

No explanation was provided as to why the DSD01 to DSD04 sites were excluded, although the Excel file 'MRM Environmental Monitoring Schedule 2017-18 I001 Rev 9.xlsx' refers to sampling from these sites only when dredging and no dredging occurred in the review period. The IM further notes that such a sampling frequency would not pick up elevated levels of contaminants that might occur at these sites after dredging (although this is not applicable to the review period).

In addition, and as in previous years, a series of specialist projects addressed seawater quality (using DGTs), as well as nearshore sediment quality, seagrass surveys and trans-shipment area sediment quality (including Pb isotope ratios). Marine water samples were also collected from 21 sites in the vicinity of the Bing Bong Loading Facility and both east and west of that facility, as well as throughout the Sir Edward Pellew Group of Islands (SEPI), in December 2016 and from 20 sites in December 2017 as part of the annual marine monitoring program (which also included sediment and biota samples). Apart from DGTs, which are discussed below, these various components of the monitoring program are addressed elsewhere in this report.

DGT samplers were deployed at eight sites (Figure 4.6) for the 2016 – 2017 monitoring period (31 July 2016 to 7 June 2017). Of these eight sites, six were existing monitoring locations while two were new, i.e., DGT7 – a coastal site southwest of West Island, and DGT8 – in the transhipment area. Deployments were undertaken on a monthly basis, with each deployment typically being for four or six days. Subsequent analysis of the retrieved DGTs was for DGT-labile Zn, Pb, Cd, Co, Cu, Ni, Mn and Fe, as well as Pb isotope ratios. The results for the metal concentrations were assessed in terms of ANZECC/ARMCANZ (2000) guideline values for marine waters (95% level of protection and 99% level of protection). Data obtained for deployments up to and including February 2018 has also been included in the assessment presented herein to address the IM reporting period of 1 October 2016 to 31 March 2018, although reporting by MRM's consultant extended only to May 2017 (Tsang, 2017).

4.3.3.2 New Controls – Implemented and Planned

Water Classification

Further to the use of the revised water classification system for the mine site as described in the preceding section, the system has been further refined to maintain relevance to MRM's operations and the WDL. As described in the 2016-2017 OPR (MRM, 2017a), changes for the 2017-18 reporting period (noting that the 2016-2017 OPR was for the period 1 June 2016 to 31 May 2017) included:

- Adding a minimum McArthur River flow trigger value for Class 3 and Class 4a water.
- Reducing the indicative McArthur River flow trigger value for Class 4b water from 20 m^3/s to 10 m^3/s.

The revised classification system is shown in Table 4.7. The IM notes the complexity of MRM's water management system at the mine site and recommends that the rules for classification and release be further clarified for stakeholders' consideration, using mechanisms such as a decision tree or similar and with a specific emphasis on Class 4 water.

DGT MONITORING SITES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.6

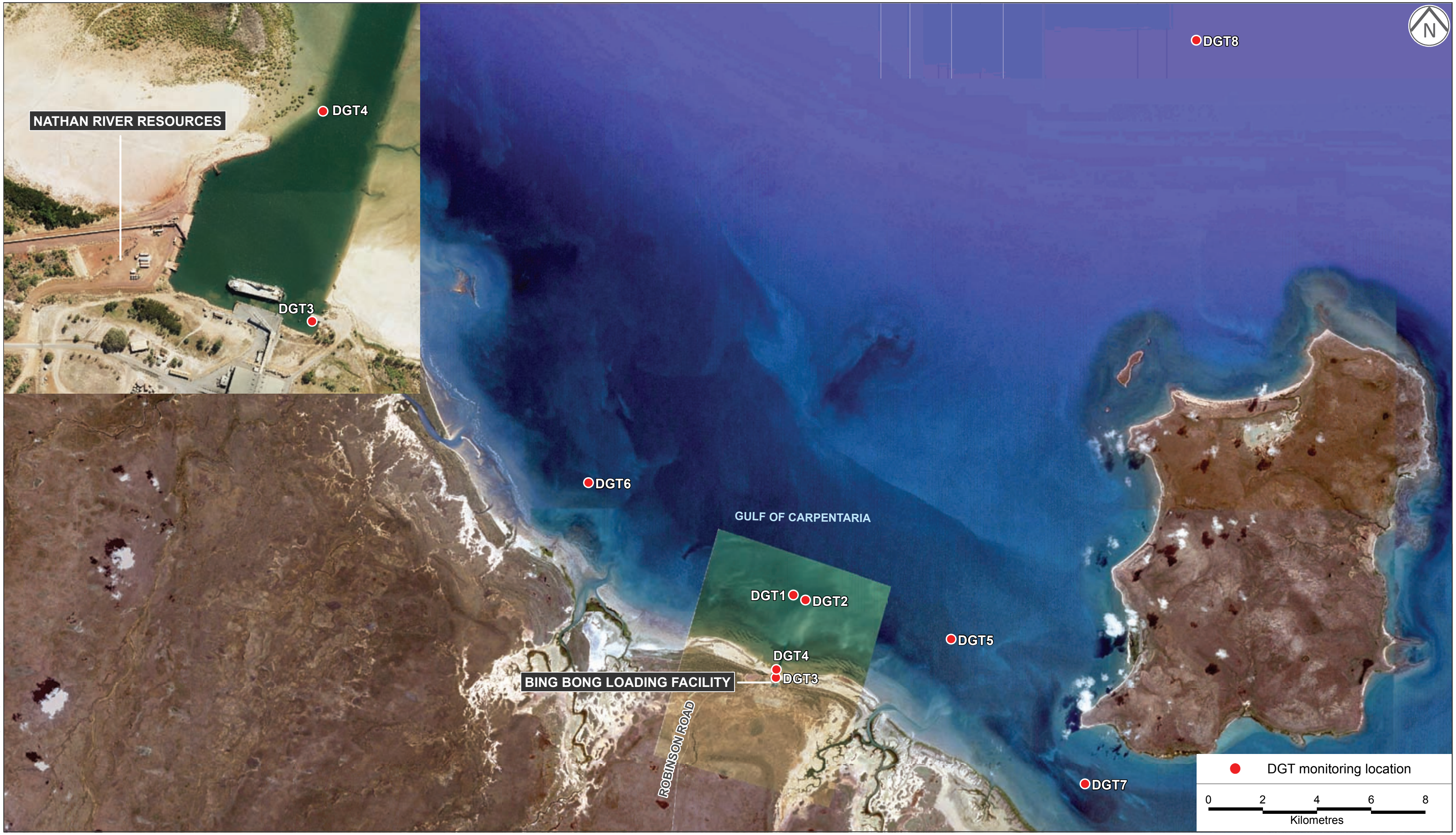


Table 4.7 – MRM Water Quality Classification from the 2017-18 OPR (MRM, 2018a)

Class	Class Description	Typical Sources	Water Quality – Number of Times Above WDL Trigger Values*		Typical Limiting CoCs	Minimum River Flow Trigger at Downstream Gauging Station (SW11)
			SO_4 and EC	All Other CoCs		
1	Diverted water	See Section 4.3.3.1	<1	<1	Nil	Unrestricted (*'N/A' in the 2016-2017 OPR*)
2	Surface water	See Section 4.3.3.1	<1	<1	Sediment	Unrestricted (*'N/A' in the 2016-2017 OPR*)
3	Treated water	See Section 4.3.3.1	<1	<1	Nil	1 m^3/s (86.4 ML/d) and 10x the managed release rate at SW11#
4	Managed release water:					
♦ 4a	Best quality	See Section 4.3.3.1	1 to 3	1 to 4	SO_4/EC, Al, NO_3, Zn, Cd	1 m^3/s (86.4 ML/d) and 10x the managed release rate at SW11#
♦ 4b	Good quality	See Section 4.3.3.1	3 to 5	4 to 20	SO_4/EC, Al, NO_3, Zn, Cd	1 m^3/s (86.4 ML/d) and 10x the managed release rate at SW11# (*10 m^3/s at SW11 in the 2016-2017 OPR*)
♦ 4c	Medium quality	See Section 4.3.3.1	5 to 25 (*'5 to 10' in the 2017 OPR*)	20 to 50	SO_4/EC, Zn, Cd	1 m^3/s (86.4 ML/d) and 10x the managed release rate at SW11# (*20 m^3/s at SW11 in the 2016-2017 OPR*)
5	Poor quality water	See Section 4.3.3.1)	25 to 30 (*'10 to 30' in the 2017 OPR*)	50 to 1,000	SO_4/EC, NO_3, Zn, Cd	N/A†
6	Process water	See Section 4.3.3.1	>30	>1,000	Metals, pH	N/A

Source: Adapted from MRM (2018a).
* The number of times of exceedance shown is based on the limiting Concentration of Concern (CoC). Concentrations of other contaminants may be lower compared with the WDL trigger values.
# Indicative only.
† Clarification is required as to whether a minimum trigger flow applies to Class 5 water since MRM (2018a) indicates elsewhere that this can be subject to managed release (and this is also discussed elsewhere in this section).

The IM encourages MRM to further explore the possibility of maximising the volume of Class 4 water that is discharged to McArthur River, thereby minimising the volume of water stored on site and facilitating water management (and reducing the McArthur River flow trigger values is a step along the path to achieving this, as is MRM's plan to have an additional contingency discharge point at CWCST in the WDL renewal (MRM, 2018d)). However, the caveat in last year's IM report remains applicable, i.e., this should be undertaken with due consideration of mine-derived loads and the need to maintain downstream water quality such that overall impacts on the environmental values associated with the river system remain protected.

A volume of 858.69 ML was discharged over the 2016/17 wet season (ELA, 2017), compared with 97.37 ML in the 2015/16 wet season. The corresponding value for the 2017/18 wet season was 2,656 ML (WRM, 2018c), despite less rainfall in the latter wet season than occurred in the previous wet season. However, significant rainfall occurred in late January 2018. During that month, the mine site received 627.4 mm of rainfall, including 537.8 mm for the 7-day period from 0900 hours on 20 January to 0900 hours on 27 January 2018 (MRM, 2018c). This included the highest January daily rainfall ever recorded at the MRM airport, which occurred on 25 January 2018, with a 24-hour total of 196.4 mm. The downstream gauging station on McArthur River at SW11 recorded a peak height of 17 m and peak flow of 1970 m^3/s before communications ceased on 26 January 2018. The upstream gauging station on McArthur River recorded a peak flow of 2480 m^3/s on 27 January 2018 (MRM, 2018c).

Daily dilution ratios of pumped water discharges, i.e., managed releases, to flows in McArthur River are reported in WRM (2018a). These ratios ranged from 32 to 90,958 (median 657) for the 2016/17 wet season and 24 to 4,081 (median 83) for the 2017/18 wet season. The higher values reflect conditions of high natural flow in the river, where the managed release rate was limited by pumping capacity rather than dilution capacity, whereas the lower values reflect low flows in the river and the need to meet dilution or flow trigger requirements in the WDL. These results demonstrate that the potential for increased discharge exists, notwithstanding the requirement to meet WDL requirements and taking into account the need to consider the effects that increased mine-derived loads may have on downstream environmental values.

Water Treatment Plant

As noted in last year's IM report, a major item of infrastructure in relation to water management at the mine site is a water treatment plant (WTP) to treat poorer quality mine-affected water (Class 5 and/or 6) to help manage the volume of stored process water. The plant will involve coarse filtration, oxidation and precipitate media filtration, and membrane filtration, as pre-treatment followed by reverse osmosis (RO) and pH correction. End uses for the permeate are proposed to include (MRM, 2018a):

- Managed releases to McArthur River during times of natural river flow.
- Storage within the managed release water circuit during times of no/low natural flows in McArthur River.
- Dilution of Class 5 water for managed release.
- Mine water demands (such as raw water supply to the mill and dust suppression).

Water is planned to be treated to Class 2 standard (MRM, 2017a). Feed water to the treatment plant will be sourced from Pete's Pond (PP), which stores water that is primarily sourced from the underground void below the open pit, at a nominal feed rate of 6.0 ML/d (increasing to 12 ML/D in the future if required). Permeate will be generated at a nominal rate of about 4.4 ML/d and waste (predominantly reverse osmosis brine) at a rate of 1.6 ML/d. Filter backwash and brine will be sent to a waste holding tank before being transferred to the tailings within the mill water circuit (Class 6) and transferred to TSF Cell 2. Brine may be temporarily discharged to the open pit during the commissioning phase.

The forecast start date given in MRM (2017a) was August/September 2017. However, MRM (2018a) reports that the WTP is planned to be operational over the 2018-2019 period, and the latest information from MRM (MRM, pers. com., 31 July 2018) is that the WTP is currently undergoing wet commissioning.

Site-specific Investigations

A number of site-specific water quality investigations were reported in the previous IM report, such as storm event runoff water quality from the NOEF SEPROD catchment and from the TSF C1SA and TSF C1SB catchments, a well as potential changes to void (underground) water quality due to transfers from TSF Cell 2. No similar investigations were reported for the current period, although updates in relation to specific actions/recommendations concerning surface water quality are provided in MRM (2018a) and these are discussed below.

Information/Knowledge Gaps

A reconciliation of key water-related knowledge gaps that were detailed in the 2016-2015 MMP was presented in the 2016 OPR (MRM, 2016a), and those directly relating to surface water quality as given in the previous IM report are shown in Table 4.8, together with their current status. A similar section is not contained in subsequent OPRs although they do contain a reconciliation of environmental commitments and actions, and these are also shown in Table 4.8 for surface water quality-related matters.

Table 4.8 –Surface Water Quality-related Knowledge Gaps Identified by MRM

Knowledge Gap (2016 OPR)/Action or Recommendation (2017-18 OPR)	Previous MRM Completion Date (2016 OPR)	Current Status (2017-18 OPR)
TARPs (trigger action response plans) for surface water quality	Q4 2016	Completed The WDL documents the procedure for response in the event of an SSTV exceedance. This includes action(s) that have or will be undertaken to mitigate any environmental harm arising from the exceedance. MRM uses compliance grids in the environmental database (an example of which has been reviewed by the IM) to identify when SSTV exceedances occur. Additionally, a weekly internal water quality report is produced outlining any trends in water quality and any SSTV exceedances requiring investigation/action
Mine-derived loads in surface water	Q3 2017	See later discussion
Waste discharge monitoring (accurately measure all waste discharge events to the receiving environment)	Q4 2016	Ongoing More than 16 digital flow meters have reportedly been installed on the water management system, although a number of pipes do not have flow meters (see Table 4.3). In addition, MRM has engaged Hydro Engineering and Consulting Pty Ltd to undertake a low flow measurement strategy for the mine
Interaction of OP ELS and diversion	No date	Pressure transducers are located in various bores around the ELS to help investigate shallow seepage originating from the ELS. Additional pressure transducers were installed in monitoring wells around the ELS during the 2016-17 reporting period

Table 4.8 –Surface Water Quality-related Knowledge Gaps Identified by MRM (cont'd)

Knowledge Gap (2016 OPR)/Action or Recommendation (2017-18 OPR)	Previous MRM Completion Date (2016 OPR)	Current Status (2017-18 OPR)
Interaction of OP ELS and diversion (cont'd)		Discussion concerning MRM's current hypothesis of the role of the ELS is provided in Section 4.5
Dredge Spoil Emplacement Area LOM (life of mine) Plan	Q4 2017	See later discussion
Continuous surface water quality monitoring	Q4 2016	See later discussion
Transhipment water quality	Q3 2016	See later discussion
Water management system monitoring and automation	2018	Completed MRM has implemented a system utilising EM flow meters, telemetry skids, SCADA and a real-time user interface to monitor pumped flows into and out of major water storages on site
Various improvements to the DGT monitoring program	na	Update of the marine metal concentrations monitoring program will be undertaken in Q3 2018
Water treatment trials	na	Completed Trials were completed with the Virtual Curtain and Bauxsol proprietary products. Neither product proved to be viable for large-scale water treatment at MRM. Hydrated lime has proven to be the most effective and suitable treatment, with alkaline water quality being produced and removal rates of up to 99% for filtered Zn
Review the McArthur River SSTVs in WDL 174-10	na	To be completed prior to the renewal of the WDL in April 2019. The review will: ♦ Consider alternative locations to apply SSTVs ♦ Assess upstream and downstream water quality using data from the last three years ♦ Assess the difference between upstream and downstream water quality and the SSTVs ♦ Assess the difference between upstream and downstream water quality and ANZECC/ARMCANZ (2000) Guidelines ♦ Include and assess mine-derived loads ♦ Propose revised SSTVs and load limits for the WDL
Water management plan for the mine site and Bing Bong Loading Facility	na	Currently in preparation

The IM commends the programs that MRM has implemented to address the gaps and recommendations. The IM also notes that a number of these address deficiencies discussed in previous IM reports, and urges that MRM continues to implement an investigations program that appropriately reflects IM findings and recommendations. The IM also recommends that MRM's future reporting (e.g., the next OPR) presents both the completion dates as presented in MRM (2018a) and revised completion dates if warranted, together with supporting explanations concerning the revised dates. Clarification of the relationship between the actions/ recommendations in MRM (2017a) and MRM (2018a) and the knowledge gaps in MRM (2016), and consistency in reporting, would also be useful.

Other Controls

Other new controls that have been implemented or planned in relation to matters such as the TSF, OEFs and open pit and which can influence the extent of adverse impacts on surface water quality are discussed in the relevant sections.

General Comment

The IM considers that the existing surface water controls at the McArthur River Mine and Bing Bong Loading Facility are generally adequate. However, some deficiencies are still evident in some aspects of the monitoring program, e.g., determination of mine-derived metal loads within the context of natural loads and assessment of the implications with respect to relevant environmental values, as noted in previous IM reports and discussed further in Section 4.3.4.2 (although the IM notes that considerable progress has been made and that further quantification of loads is required as a condition in WDL 174-10).

4.3.4 Review of Environmental Performance

4.3.4.1 Incidents and Non-compliances

Mine Site and Surrounds

McArthur River Mining's WDLs applicable to the reporting period (WDL 174-08, WDL 174-09, WDL 174-10 and WDL 237) specify values for a range of water quality triggers (SSTVs) for SW11 that are largely based on, or derived from, the ANZECC/ARMCANZ (2000) guidelines for 95% protection of species in freshwater systems. Some water quality results at this site exceeded the SSTVs in the 1 October 2016 to 31 March 2018 monitoring period, with these exceedances primarily involving:

- Elevated concentrations of filterable Al, mainly in the wet season (12 occurrences in the period from November 2016 to March 2017 and 9 occurrences in the period from November 2017 to March 2018). As in previous years, these values were attributed to upstream inputs rather than to mining-related activity, with 'other chemical changes taking place in the water across the McArthur River catchment' also being raised as a possible causal agent by KCB (2018) (although this statement contributes little to the understanding of relevant processes). One exceedance of filterable Fe at SW11 (in November 2017) was reported. This is also consistent with historical data, although it is relatively minor (370 μg/L) compared with the SSTV (300 μg/L). The IM agrees that the elevated levels of filterable Al and, to a lesser extent, filterable Fe at SW11 are likely to be due to factors other than mine-related activities.

- Dissolved oxygen levels that were primarily lower than the WDL trigger levels, although some values also exceeded the trigger values. These results are consistent with historical data and KCB (2018) notes that DO values for all sites along McArthur River remained approximately constant. The IM supports the conclusion that DO values are unlikely to be related to mine activities.

- Elevated EC values at the end of the 2017 dry season. The EC trigger value was exceeded four times over the period from 1 October 2016 to 31 March 2018 (Figure 4.7A) – all in October and November 2017. KCB (2018) notes that the end-of-dry-season EC peaks were considerably higher in 2013, 2015 and 2016, although Figure 4.7A shows that this is particularly evident in 2013 and 2015. As noted in the previous IM report, KCB (2016) referred to the possibility that surface water passing the previously-reported exposed zones of mineralisation along the McArthur River diversion channel could be responsible for the increased EC in the river, in addition to groundwater inputs. In relation to the current reporting period, ELA (2017) refers to the elevated EC being due to groundwater passing through these natural zones of mineralisation adjacent to the diversion channel and accumulating higher loads of TDS. The mineralisation includes beds of pyritic shale and structures associated with the Cooley I Pb and Cooley II Cu mineral prospects. In relation to this same area, KCB (2018) suggests that the influence of this mineralised zone on river water quality has decreased, probably due to the removal of the head in the ELS, although they still contended that the EC exceedances were likely to be related to 'groundwater expression at various locations of the stream segments'. Nevertheless, Figure 4.8A shows that an increase in EC values is still evident between SW15 and SW16, with median values increasing from 566 μS/cm to 717 μS/cm, and the step change in EC between these two sites is attributed to these areas of natural mineralisation in three of the four non-compliance notifications prepared by MRM and submitted to NT DENR (and the IM agrees that the exceedances are likely to result in negligible impact, as stated by MRM). The IM continues to recommend the inclusion of the ELS in source load calculations and further definition of the relative influence of water passing through mineralised zones, with subsequent identification of mitigation measures commensurate with the risk posed by these changes in EC.

- The in situ pH at SW11 on two separate occasions was 8.52 and 8.53 which, although marginally outside the SSTV range of 6.0 to 8.5, is the same as the upper SSTV value when two significant places are used (as in the WDL). A pH value of 8.65 was reported on 22 May 2017 and MRM attributed this to a combination of natural pH variation and the inherent inaccuracy of the field probes. The IM agrees that these are plausible explanations for the non-compliance and also agrees with MRM's position that no environmental harm would be expected.

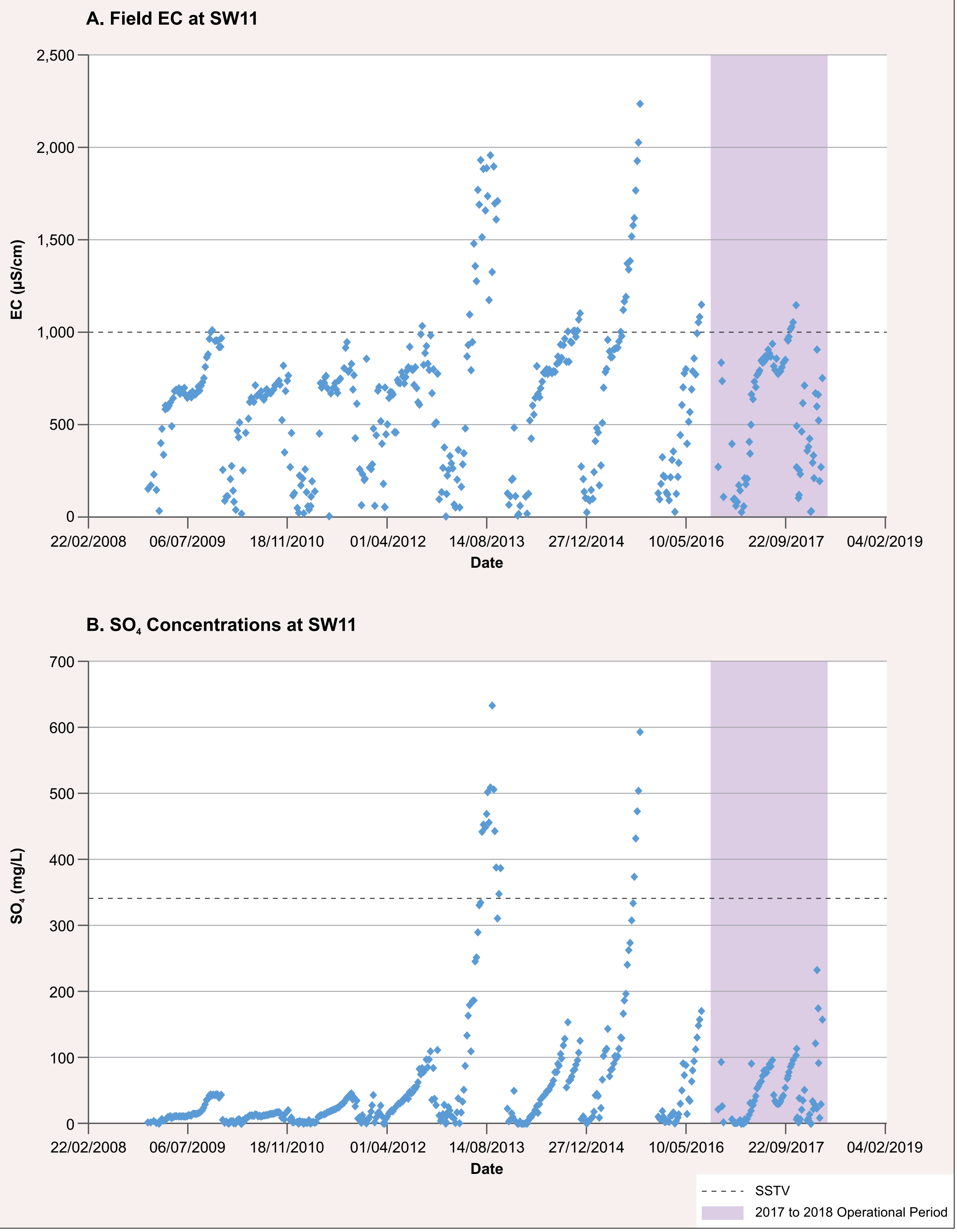
- Elevated concentrations of NO_3 occurred on two occasions in November 2017 and January 2018, where the values were 1,380 μg/L and 2,940 μg/L, respectively, compared with the WDL value of 700 μg/L. Examination of data both before and after these spikes shows that they were not part of either increasing or decreasing trends. Possible reasons for these exceedances that have been proposed previously include increased surface runoff from mine-affected areas of the Barney Creek and Surprise Creek catchments, and domestic cattle activities along McArthur River (KCB, 2016). However, KCB (2018) proposes that the Glyde River is major contributing factor to these non-compliances, and the IM agrees that the available data is consistent with this hypothesis, particularly for the November 2017 event.

The results for SO_4 concentrations at SW11 are shown in Figure 4.7B for the period from December 2008 to March 2018, which encompasses the IM reporting period of 1 October 2016 to 31 March 2018 (as shown in the figure). The SSTV for SO_4 at SW11 of 341 mg/L was not

EC LEVELS AND SO_4 CONCENTRATIONS AT SW11

McArthur River Mine Project

FIGURE 4.7

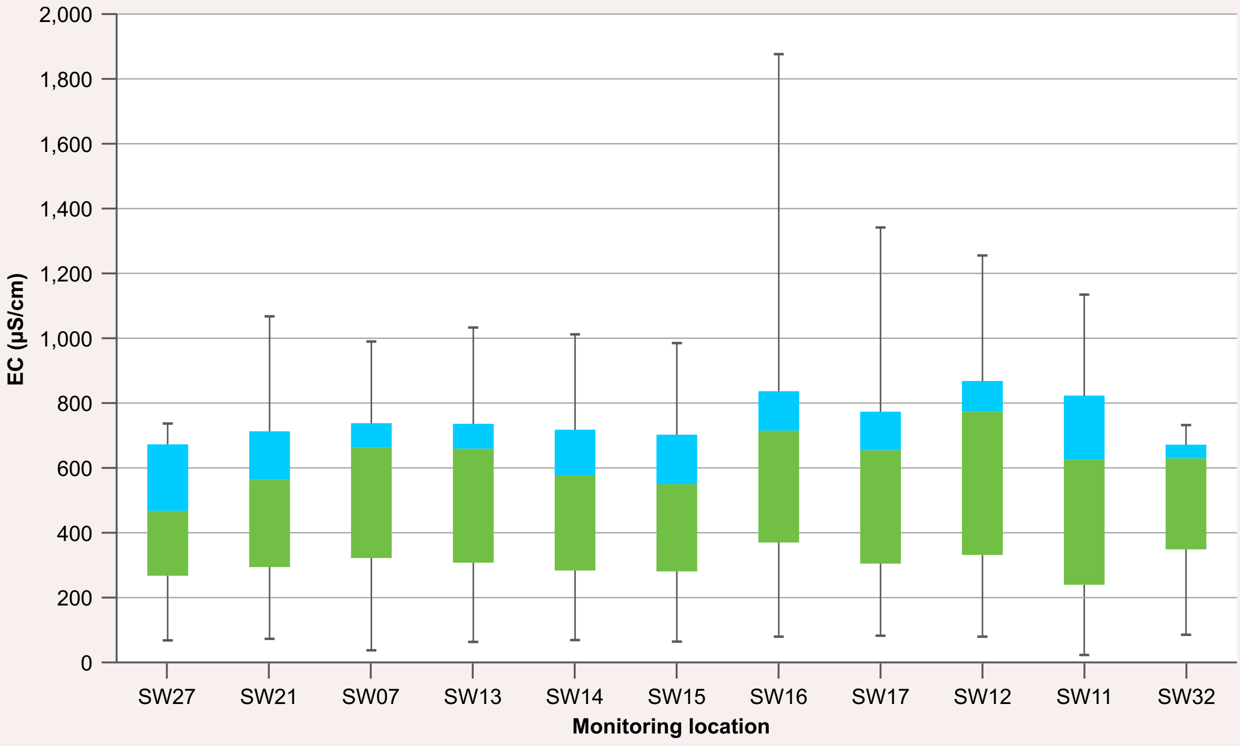


BOX PLOTS OF EC LEVELS AND SO_4 CONCENTRATIONS IN McARTHUR RIVER FOR THE PERIOD OCTOBER 2016 TO MARCH 2018

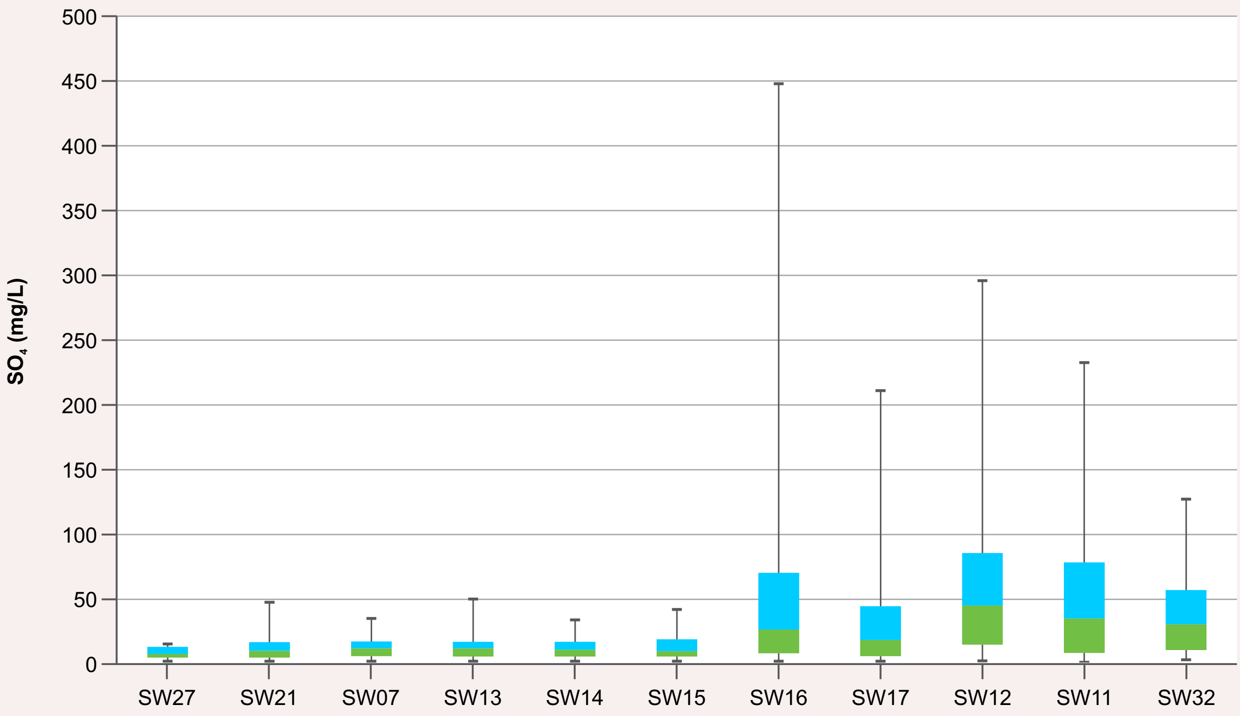
McArthur River Mine Project

FIGURE 4.8

A. Box Plot of EC for McArthur River October 2016 to March 2018



B. Box Plot of SO_4 for McArthur River October 2016 to March 2018



The box plot shows maximum, 75th percentile, median (50th percentile), 25th percentile and minimum values.

exceeded during the IM reporting period, with the maximum value being 233 mg/L on 26 February 2018. The elevated levels in both the 2016 and 2017 dry seasons are generally consistent with historical trends, with key factors being reduced flows in McArthur River as the dry season progresses, Barney Creek dewatering, and SO_4 inputs from the McArthur River diversion channel. Data supporting the latter is shown in Figure 4.8B for the reporting period, although the relative contributions of groundwater seepage versus surface water passing through mineralised rock is not known.

A further point to note is that MRM again implemented the use of a pump in Barney Creek at the haul road bridge (SW19) to remove creek water that was high in SO_4 and TDS. This action was initiated in the 2014 dry season in an effort to avoid a repeat of elevated SO_4 levels at SW11 that were observed in the 2013 dry season (and was the focus of previous IM reports), and was repeated in the 2015 dry season. The influence of this dewatering on water quality at SW11 was not specifically addressed in ELA (2017) or KCB (2018), although the latter noted that rapid decreases in SO_4 were evident at SW19 and SW20 in Barney Creek due to this pump-back (while concentrations at SW18 that is located upstream of the pump continued to rise). The dewatering pump was operated intermittently between 17 July 2017 and 12 January 2018, with the estimated volume of mine-affected base flow recovered being 100 ML in the 2017 dry season and 14 ML in the 2017/18 wet season.

From the perspective of additional incidents that could have direct adverse impacts on surface water quality at the mine site and surrounds, the file 'Incident Register Nov 2016 to Mar 2018.xlxs' provided by MRM lists some 28 environmental incidents, with additional detail for those incidents being described in the 2016-2017 OPR (MRM, 2017a) and 2017-2018 OPR (MRM, 2018a). Most of these relate to matters such as minor leaks or spills, overflows from sumps and sediment traps (e.g., CWCST), or similar. The IM has no reason to disagree with MRM's findings or the actions taken and/or required.

Avoiding all incidents at an operation such as MRM's is not feasible. The IM is reliant on MRM's incident reporting to form a view as to MRM's performance in this regard and encourages MRM to demonstrate continued diligence in both minimising the occurrence and impact of such incidents, and reporting of these incidents.

Significant gully erosion near the walking track leading to NOEF SEL1 DP was observed during the 2017 IM site visit and reported in the previous IM report. McArthur River Mining has advised that a formal hazard report was submitted and mitigation works are scheduled to be completed during the 2018 dry season.

As addressed in previous IM reports, the potential for hydrocarbons originating from the May 2011 diesel leak (approximately 28,000 L) to contaminate local drainage lines and affect downstream water quality warrants discussion. The updates presented in MRM (2017a) and MRM (2018a) indicate that, as was previously reported, there is no risk to Barney Creek or McArthur River since groundwater from the impacted area is inferred to discharge into the underground workings during both wet and dry seasons. This is further discussed in the groundwater section (Section 4.5).

From a surface water quality perspective, the IM recommends that MRM continues to implement relevant recommendations contained in KCB (2016), where these include (and the IM acknowledges that progress has been made in relation to some of these):

- Further investigation of the McArthur River diversion channel and a mitigation plan to address the source of contaminants from the exposed mineralisation.
- Investigation into the high levels of filtered Mn in Barney Creek.
- Better understanding of groundwater contributions to different reaches of the respective creeks.
- Increased flow monitoring along the creeks to better quantify zones of increased loading.
- Investigations into blast residue impact on NO_3 contributions.

The IM also notes that the recommendation in a previous surface water monitoring report (MRM, 2015b) concerning mitigation of elevated concentrations of metals and major ions in Surprise and Barney creeks, with a view to preventing the need for dry season dewatering of Barney Creek, has not been carried across to the latest surface water monitoring report. The IM considers that this should still be undertaken by MRM, since the results would support further assessment in relation to establishing appropriate environmental values that should be protected in these creeks and the McArthur River diversion channel upstream of SW11 (as well as preventing the need for dry season dewatering). As noted in last year's IM report, it is apparent that stakeholders do not share uniform views concerning protection of these watercourses. This is demonstrated by DPIR's response to an overflow from TSF Cell 1 Eastern Sump which resulted in potentially contaminated water being discharged to the Carpentaria Highway culvert, where the following was noted in Waggitt (2017):

> There appears to be a reliance on water quality at the 'compliance point' SW11 for assessment of this incident. Given that the runoff from this facility has the potential to impact Surprise Creek, Barney Creek and the McArthur River upstream of SWII it is not considered appropriate to solely rely on this location for assessment of impact.

In addition to compliance specifically with the WDL and incidents that could impact on surface water quality, the OPRs contain a list of commitments and actions. As described in the 2017-2018 OPR (MRM, 2018a), this list is sourced from the following documents:

- 2013-2015 MMP (MRM, 2015a).
- Previous OPRs.
- Recommendations from specialists.

The IM recommends that the source documents also include MMP information requests, amendments and conditional approvals.

A small number of these commitments relate directly to surface water quality, e.g., revising specific aspects of the DGT monitoring program and implementing real time in situ monitoring at SW11, although a considerable number also relate to aspects of the operation that indirectly affect surface water quality, e.g., investigate the geochemical characteristics of the dredge spoil. The status of the relevant commitments is presented throughout this section.

Bing Bong Loading Facility and Surrounds

No dredging was carried out in the swing basin or navigation channel during the reporting period, hence no dredge spoil was deposited into the emplacement facility and no active releases occurred from the dredge spoil settlement ponds to the receiving environment. All runoff from the concentrate shed and the hardstand areas around the loading facility was captured within the three runoff ponds and disposed of via sprinkler and pond evaporation. At the authorised discharge point (BBDDP), passive released water flows across the intertidal flats to the Gulf of Carpentaria via the Bing Bong navigation channel. Exceedances of the SSTV are summarised in Table 4.9. It should be noted that these results have been taken from the Excel spreadsheet provided by MRM, and these differ in a small number of instances from the data provided in ELA (2017) and KCB (2018). The IM therefore recommends that additional effort is devoted to reconciling data in the raw data spreadsheet/database with that reported in the OPR appendices.

Table 4.9 – SSTV Exceedances at BBDDP for the Period 1 October 2016 to 31 March 2018

Date of Sample	Field pH	Al (f) (µg/L)	As (f) (µg/L)	Cu (f) (µg/L)	Mn (f) (µg/L)	Hg (f) (µg/L)	Zn (f) (µg/L)
SSTV	8.0 to 8.4	0.5	2.3	1.3	80	0.4	15
09/01/2017	7.69	62.6	4.5	--	--	--	750
23/02/2017	7.48	88.3	2.5	3.04	90.5	*	35.5
25/03/2017	7.39	18.7	4	--	372	*	--
23/04/2017	--	4	2.75	--	--	--	--
02/05/2017	--	11.5	--	--	--	--	17.3
22/01/2018	7.8	6.4	--	--	--	--	--
10/02/2018	N/A	No data	No data	No data	No data	No data	No data

Source: 'MRM Raw SW and ASW Data.xlsx' provided by MRM.
* Reported as <0.8 µg/L.

The SSTV exceedances up to and including May 2017 were attributed to increased seepage from the DSEA into the perimeter drain (ELA, 2017), as has been the case with previous exceedances. However, no explanation was proposed in KCB (2018) for the more recent exceedances, with that document simply noting that the trigger levels may be too low since the groundwater quality, on average, exceeds the SSTVs. The IM agrees that the risk posed to the receiving environment was minor. However, these results are indicative of a potential issue that could be problematic in the future and the IM continues to recommend that this matter be addressed prior to future placement of dredge spoil in the DSEA.

No incidents (other than non-compliance with the WDL) that could have direct adverse impacts on surface water quality at Bing Bong Loading Facility and surrounds were reported by MRM. Although occurring some 30 km from the facility, a collision of a road train carrying concentrate with a bull resulted in the two trailers overturning on 14 December 2016. The incident did not apparently occur near any significant drainage lines and the concentrate was retained via bunds and recovered, hence surface water quality implications are likely to be negligible.

No complaints directly concerning surface water quality were reported by MRM.

4.3.4.2 Progress and New Issues

Water quality monitoring data has been discussed in other sections in terms of successes and non-compliances.

McArthur River Mining's performance against previous IM review recommendations relating to surface water quality management is outlined in Table 4.10, excluding those that have been flagged in earlier IM reports as being completed or superseded.

Table 4.10 – Surface Water Quality Management Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
Water Management	Seepage through the DSEA embankments should be addressed prior to future placement of dredge spoil in the ponds. This should also include characterisation of spoil currently contained within the DSEA	Ongoing The 2017-2018 OPR (MRM, 2018a) notes that developing a LOM plan for the DSEA, and investigation of the geochemical characteristics of the dredge spoil, is scheduled to be undertaken in 2019 (although the file '2017 IM Recommendations.xlsx' notes that this action will be completed prior to the next dredging campaign is to be confirmed)
	The possibility of maximising the volumes of Class 4 water that are discharged to McArthur River, thereby minimising the volumes of water stored on site and facilitating water management on site, should be explored. This would need to be undertaken with due consideration of mine-derived loads and the need to maintain downstream water quality such that overall impacts on the environmental values associated with the river system remain protected	Partially completed Increased volumes were discharged in the 2017/18 wet season in accordance with WDL 174-10 but consideration of mine-derived loads within this context of greater discharge volumes is yet to be completed. The IM expects this to be part of MRM's response to WDL 174-10 requirements
	Rules for release of Class 4 water (and water classification in general) at the mine site should be clearly described using mechanisms such as a decision tree or similar	Partially completed Further clarification of rules for release would be useful for stakeholders
	Specific surface water quality management objectives should be formalised for Bing Bong Loading Facility and incorporated into relevant MRM documents	Partially completed Formal objectives are included in ELA (2017) but these are not carried through into KCB (2018)
	Additional information about the use of water quality monitoring data from the ASW program should be provided for IM review, i.e., this additional information should describe how the ASW data is used on a day-to day or week-to-week basis	Completed Weekly internal WDL memos provide by MRM for review demonstrate the use of this data for determining water class and management options
NOEF and TSF/ surface water monitoring program	Given the ongoing issues associated with the NOEF and TSF: ♦ The surface water monitoring program should be reviewed on an ongoing basis to ensure that	Partially completed MRM has advised that, although a formal procedure does not exist, the program is reviewed annually by

Table 4.10 – Surface Water Quality Management Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
NOEF and TSF/ surface water monitoring program (cont'd)	sufficient early warning is provided concerning potential impacts on water quality from NOEF and TSF leachates and runoff (or other potential failures of these infrastructure components) ♦ This should include implementing a formal procedure whereby the review process, outcomes and required actions are documented and available for IM review	MRM personnel and specialist consultants with updates made as required. MRM has further advised (in file '2017 IM Recommendations.xlsx') that the proposed water management plan will include a review process and will address this recommendation
McArthur River/SW11/ other surface water sites	Environmental values to be protected in Barney Creek, Surprise Creek and McArthur River diversion channel should be determined in conjunction with relevant stakeholders, with the outcomes being used to direct measures to mitigate mine-derived elevated metal and major ion concentrations upstream of SW11	No progress KCB (2018) includes a discussion of environmental values for receiving waters downstream of MRM. From information in file '2017 IM Recommendations.xlsx', it appears that MRM's proposed water management plan will partially address this but the extent to which the recommendation will be fully implemented is not clear
	Mitigation of elevated concentrations of metals and major ions in Surprise and Barney Creek should be explored by MRM, with a view to preventing the need for dry season dewatering of Barney Creek	Partially completed Design of an interception trench between TSF Cell 1 and Surprise Creek was proposed in the Draft OMP EIS. The extent to which this will prevent the need for dewatering at SW19, or the status of other possible mechanisms that could be implemented, is not known
	The hypothesised (by MRM) reduced influence of the McArthur River diversion channel on EC and SO_4 levels at SW11 due to a wetter preceding wet season should be re-visited when assessing the 2016-2017 water quality data	Completed The 2017-2018 OPR and KCB (2018) includes discussion about EC and SO_4 levels at SW11 in the reporting period
	The origin of elevated filterable Al and Fe at SW11 should be further investigated so that the uncertainties associated with the current explanations can be minimised	Partially completed The role of Glyde River inputs requires confirmation
	A risk assessment should be undertaken concerning: ♦ Possible implications associated with elevated SO_4 concentrations and EC levels at SW11 (and sites within the ML that are next to or downstream of MRM facilities) exceeding the respective SSTVs ♦ Likely causes ♦ If MRM operations are found to be a major contributing factor, mitigation measures commensurate with the level of risk	Partially completed The IM remains of the view that an integrated assessment that draws together previous findings and other factors such as additional relevant monitoring data (including duration of elevated SO_4 levels) and the science underlying the derivation of the 341 mg/L SSTV, and takes into account confounding factors such as fauna concentration due to receding water levels, is required to address the broader risk posed by SO_4 (and EC) levels. Given the relatively low values at SW11 in the

Table 4.10 – Surface Water Quality Management Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
McArthur River/SW11/ other surface water sites (cont'd)		reporting period, this should be linked to protection of the agreed environmental values upstream of SW11 and the relevant conditions in WDL 174-10, e.g., review of SSTVs
Monitoring	The recommendations in KCB (2016) should be fully implemented	Ongoing The file '2017 IM Recommendations.xlsx' notes that all recommendations in that report are being progressed, with scopes currently being developed for the Mn and NO_3 studies
	Real-time in situ monitoring at SW11 should be implemented with the issues observed during the 2015/16 wet season (i.e., burial of the probe) being appropriately addressed	Ongoing The 2017-2018 OPR notes that a multiprobe sonde system installed at SW11 was inundated and damaged in the January 2018 floods. A similar system with greater flood immunity is to be installed for the 2018/19 wet season (although the IM acknowledges the associated challenges)
	Continued focus should be placed on QA/QC as part of the water sampling program, including: ♦ Elevated trip blank Zn and Al levels ♦ Occasional poor precision for DGT analyses ♦ Potential contamination issues associated with operating an environmental laboratory on a mine site	Ongoing There has been some progress in this area but some scatter was reported in KCB (2018) in relation to Cu, Pb and Zn blanks, with values for the latter sometimes exceeding 10 µg/L. Review of the raw data spreadsheet also shows occasional elevated blank values for metals such as Al. Continued effort is still required Occasional poor precision for the DGTs remains an issue that requires continued attention (notwithstanding the introduction of DGT triplicates
	Alternative labeling of natural surface water sampling sites when the corresponding control sites are not flowing should be investigated; these sites are not artificial and should not be labeled as such	Completed
	Additional effort should be devoted to the following in relation to mine-derived loads of contaminants: ♦ Contaminant load estimates should be determined, where these reflect both natural and mine-associated sources (including but not limited to the TSF, OEFs, ELS, run-off dams and open pit) reporting to Surprise Creek, Barney Creek (and diversion channel), Emu	Partially completed See text below table

Table 4.10 – Surface Water Quality Management Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Monitoring (cont'd)	Creek, and McArthur River (and diversion channel). Glyde River should also be included in these estimates (although this is a lower priority) ♦ Load calculations (and load balances) should take into account current and predicted natural and mine-derived loads, and seasonal variation ♦ The need to sample over specific flood events in McArthur River, Barney, Surprise and Emu creeks (and Glyde River) to complement the weekly sampling program and obtain robust load estimates should be considered ♦ Using the results from the above, mine-associated sources should be ranked in terms of contributions of contaminants to McArthur River at SW11 and further downstream, and used to prioritise management and mitigation actions	
	Results of the release calculator should be validated by concurrent water quality measurements at SW11	Partially completed MRM has indicated in file '2017 IM Recommendations.xlsx' that the results for sampling at SW11 once the discharge arrives are 'informally compared'; this should be explicitly and formally recorded
	Elemental scans should be reinstated at selected surface water monitoring sites (preferably during high flows)	Completed Although not reported in either ELA (2017) or KCB (2018), MRM has advised that multi-element scans were undertaken in February 2018 at SW11 and SW06. The IM also notes that undertaking such scans was included in 'MRM Monitoring Schedule 2017-18 I001 Rev 9.xlsx'. MRM (in file '2017 IM Recommendations.xlsx') notes that this has been added to the monitoring program
	The feasibility of deploying DGTs to monitor seawater quality in the trans-shipment area during transfer of the concentrate should be determined	Completed McArthur River Mining has collected DGT data at a site in the trans-shipment area as part of a 12-month investigation in 2016-17, i.e., DGT8. A number of deployments were lost due to poor weather. Results indicated that MRM product was being introduced into the marine environment at this location, although the influence was minor, with all concentrations measured well below the relevant ANZECC/ ARMCANZ (2000) guidelines. The site was discontinued in the 2017-18 monitoring period

Table 4.10 – Surface Water Quality Management Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
TSS loads	An assessment that validates (or otherwise) MRM's assertion about the low risk associated with mine-derived TSS is required. This assessment should also address TSS from the operations at the Bing Bong Loading Facility	Partially completed See text below table
General data interpretation and reporting	All relevant water quality data (in situ and laboratory) should be collated on a yearly basis in a format that is readily accessible and able to be interrogated (e.g., a single Excel spreadsheet or similar); this should include a reconciliation of all actual versus proposed/committed sampling events	Partially completed KCB (2018) notes that 'A reconciliation of proposed versus actual sampling events is included in Appendix II'. However, that appendix seems to describe the sampling program without reconciling what was proposed with what was actually sampled. A simple reconciliation of what was proposed to be sampled versus what was actually sampled for the entire surface water sampling program is still required
	Further interpretation and analysis of data should be presented in the MMPs, including further detail about water quality changes with river/stream flow and mine-derived influences	Partially completed Completion of this recommendation will be achieved when loads are presented and appropriately discussed, as recommended elsewhere
	Comparison of metal and metalloid results with ANZECC/ARMCANZ (2000) values should include the 95th percentile value as well as median values	No progress
	Descriptions of spills and/or leaks in the OPR should include volumes and fate of the material, i.e., where it ended up	Completed
	Consideration should be given to examining changes in DGT-labile metal concentrations that may have occurred since the program commenced	Completed
	Future MRM reporting about the investigations program to address information gaps should include the original and revised (if necessary) completion dates, with supporting explanations concerning the revised dates	Partially completed The 2017-2018 OPR contains dates and histories for some, but not all, investigations
Erosion	Gully erosion near the walking track leading to NOEF SEL1 DP should be addressed prior to the next wet season. Similarly, the potential for erosion at the actual pipe outlet should also be evaluated and addressed as required	Mitigation works are scheduled to be completed during the 2018 dry season

While additional comment to that provided in the table is not required for most matters, an exception concerns the recommendation to determine mine-derived loads of contaminants reporting to the McArthur River. This has been a high priority recommendation in the last three IM reports, and it is pleasing to note that MRM has made considerable progress. The rationale underlying the need to determine loads was flagged in last year's IM report. Similarly, identification of the need to determine contaminant loads in earlier reports commissioned by MRM, e.g., RGC (2015), MRM (2015b) and Ecometrix (2017), was also flagged in that document. In addition, the current waste discharge licence (WDL 174-10) contains a number of requirements relating to loads. These include the need for MRM to assess mine-described loads and balances reporting to McArthur River, propose mine-derived contaminant loads that sufficiently protect the receiving environment, and describe infrastructure capabilities and plans to enable assessment of contaminant loads.

Progress continues to be made in this area, with WRM (2017) reporting loads for an increased number of contaminants in the 2016/17 wet season relative to those reported in KCB (2016) for the 2014/15 wet season. The results indicate that MRM activities at the mine site are responsible for at least 50% of the total load of each contaminant at SW06 (Barney Creek). Given the significantly higher loads naturally transported in McArthur River, the relative mine-derived contributions are smaller such that only mine-derived filterable Pb, filterable Mn, SO_4 and NO_3 are at least 20% of the total loads in the river. Of possibly greater significance is that the mine-derived loads are eight times the upstream (background) load for SO_4 and twice the upstream load for filterable Mn.

Although the 2016/17 wet season load estimates for McArthur River exclude inputs downstream of SW21, the results demonstrate the importance of load calculations and the need to adopt an approach that reflects the entire mine site and the upstream catchment. This is further demonstrated in WRM (2018c), which reports mine-derived loads relative to total McArthur River loads upstream of SW12 for the 2017 dry season and 2017/18 wet season[3]. Key results are shown in Table 4.11, which is derived from WRM (2018c), with mine-derived loads that are equal to or greater than 20% of the total loads being in red. Mine-derived loads for total (unfiltered) metals were not reported and these would provide better estimates of total loads.

Table 4.11 – Estimated Mine-derived Loads for the 2017/18 Wet Season Upstream of SW12*

	Cd (f)	Pb (f)	Mn (f)	Hg (f)	Zn (f)	SO_4	NO_3	TDS
Total load upstream of the mine ('pre-mine')	21	121	2,131	21	496	1,834	225,019	89,973
Mine-derived load at SW12 (McArthur River d/s mine)	2	8	4,719	0	3,380	14,885	132,205	30,019
Mine-derived load as % of total load	9	6	221	0	682	812	52	33

* All values are reported as kg apart from SO_4 and TDS where the values are in tonnes.
Note 1: Load estimates and % contribution of mine-derived loads are sourced from WRM (2018c).
Note 2: (f) = filtered.

[3] Clarification is required as to whether the load calculations presented in WRM (2018c) include inputs from CWCST and SWST twice, i.e., as point source inputs and again as part of the loads determined at SW19 and SW26.

Key findings can be summarised as follows (and the IM appreciates the associated uncertainties as described in WRM (2018c) and the preliminary nature of the load calculations):

- Mine-derived loads in the wet season are orders of magnitude greater than those in the dry season, e.g., 14,885 t in the wet season compared with 381 t of SO_4 in the dry season.
- Mine-derived increases in loads for the 2017/18 wet season are generally less than 25%, exceptions being filtered Mn (221%), filtered Zn (682%), SO_4 (812%), NO_3 (52%) and TDS (33%), i.e., mine-derived filtered Mn, Zn and SO_4 loads are twice, seven times and eight times the background loads in McArthur River.
- Significant increases in loads are primarily due to managed releases from the Mine Levee Discharge Point, e.g., 9,060 t SO_4 from MLDP compared with a total contribution of 697 t from other discharge points. A notable exception is NO_3, where 6,749 kg is from the MLDP and 5,849 kg is from CWCST.

The IM's view therefore remains that, until load estimates (and load balances) are available for all key variables, filtered and unfiltered, possible downstream impacts associated with the mine potentially remain unknown to some degree, and quantification and targeting of mine-associated sources remains poorly defined. The IM strongly endorses the focus on loads that is reflected in WDL 174-10, and MRM has advised that the WDL requirements will be completed prior to renewal of the licence in April 2019. These load estimates should reflect relevant natural and mine-associated sources reporting to Surprise Creek, Barney Creek (and diversion channel), Emu Creek and McArthur River (and diversion channel), and take into account the following:

- Background, current mine-derived and predicted mine-derived loads.
- Filtered and unfiltered metals.
- Groundwater (e.g., seepage from various mine facilities) versus surface water inputs (e.g., discharges from MLDP).
- Seasonal variation (including loads that are transported during flood events).

Loads from Glyde River should also be estimated (although this is a lower priority).

Considerable progress has also been made in relation to evaluating suspended sediment from MRM's operations. The assessment provided in KCB (2018) reported that there seems to be no discernable difference in TSS values at SW11, SW12 and SW21. The load calculations presented in WRM (2017) indicate a mine-derived load for the 2016/17 wet season of 1,668 t in Barney Creek at SW06 compared with a load of 96,841 t for McArthur River at SW21. Load calculations in WRM (2018c) indicate a mine-derived TSS load in the 2017/18 wet season of 1,286 t at SW12 compared with upstream load of 73,425 t, i.e., only a 2% increase. Corresponding values for the dry season are 9 t compared with 61 t, i.e., a 15% increase. The IM agrees that these results suggest that TSS is unlikely to be a major contaminant of concern but recommends that TSS loads from the mine site reporting to both Barney Creek and McArthur River, including over flood events, continue to be estimated on a seasonal basis. This assessment should also include TSS from the operations at the Bing Bong Loading Facility reporting to surface (including coastal) waters.

4.3.4.3 Successes

Mine Site and Surrounds

From a broader water quality perspective, and consistent with the approach used in previous IM reports, evaluation of success from a surface water quality perspective is based primarily on the following rationale:

- The beneficial uses that have been declared for the McArthur River Area are aquatic ecosystem protection, recreational water quality and aesthetics (as referred to in the WDL), while those for the McArthur River Catchment Area are environment, cultural and riparian (also referred to in the WDL). The IM notes that KCB (2018) refers to the relevant environmental values for receiving waters downstream of the mine being aquatic ecosystems, primary industries, recreation and aesthetics, and cultural and spiritual values, and these are consistent with the WDL beneficial uses.
- Notwithstanding other factors such as habitat and stream flow, the water quality required to be achieved at SW11 by the WDL will ensure the protection of these beneficial uses downstream of this site.
- Where considered useful, further analysis of the data is undertaken in relation to trigger values from ANZECC/ARMCANZ (2000) where the latter differ from the WDL trigger values.

This approach acknowledges that some deterioration of water quality upstream of the compliance point at SW11, both in McArthur River and tributaries such as Surprise Creek and the Barney Creek diversion channel, is expected due to the proximity of the watercourses to the mine. Data from the IM reporting period shows that, as in previous years, mine-affected areas had a negative influence on the surface water quality of Surprise and Barney creeks, especially in terms of SO_4-driven increases in EC, with levels increasing during the dry season months when rainfall and flows are reduced. The monitoring data shows that the high SO_4 levels have their source in the mine waste-affected areas of the catchment. Given these impacts, the IM remains of the view that that stakeholders should agree on the environmental values that require protection upstream of SW11 but within mining-affected areas, and establish appropriate water quality objectives that reflect these values and take into account the requirements of the NT EPA's guidelines for mixing zones (NTEPA, 2013), e.g., the need to ensure that unacceptable impacts on flora and fauna do not occur, as determined by a risk assessment, and that fish migration is not adversely affected.

As was previously the case, the WDLs that applied during the monitoring period state that water quality at SW11 and BBDDP 'must not exceed the trigger values specified' in the licence[4], i.e., the WDL specifies a maximum value (or, in the case of pH and DO, both maximum and minimum values). This is conservative compared with the approach described in ANZECC/ARMCANZ (2000), whereby for physical and chemical stressors such as pH, DO or nutrients, the median

[4] WDL237, which was a short-term licence to allow discharge from Central West Alpha Sump in the 2016/17 wet season, uses similar, but not identical, words. Trigger values at SW11 are as for the other WDLs.

concentration of samples from a test site (i.e., not the maximum value) should be compared with the 80th percentile value from a reference site or, if reference site data do not exist, the relevant guideline value published in ANZECC/ARMCANZ (2000). Similarly, the recommended approach for toxicants is to compare the 95th percentile value (i.e., again, not the maximum value) with the default guideline values. Use of ANZECC/ARMCANZ (2000) guidelines as regulatory requirements is therefore a conservative implementation of these values. ANZECC/ARMCANZ (2000) also notes that 'these Guidelines should not be used as mandatory standards', and that exceedance of a trigger value (using the statistical approach described above) should result in further action such as:

- Incorporating additional information or undertaking further site-specific investigation to determine if the chemical poses a real risk to the environment.
- Initiating management action or remediation (on the basis that the trigger value can be applied directly to the site in question).

Notwithstanding the shortcomings described above, the results from the monitoring program demonstrate a relatively high level of success in terms of compliance with WDL discharge requirements, as summarised in Table 4.12. A significant number of controlled discharges were undertaken during the reporting period, considerably more than in previous years. Discharge dates, volumes and other relevant information are shown in Table 4.13.

Table 4.12 – Comparison of MRM Monitoring Data for SW11 with WDL Requirements

WDL 174-08, WDL 174-09, WDL 174-10 and WDL237[1]			MRM Monitoring Data (SW11)[2]
Parameter	**Units**	**Site-specific Trigger Value (SSTV) for SW11**	**Oct 2016 – Mar 2018[3] (Minimum – Maximum)**
pH (in situ)	pH units	6.0 – 8.5	6.19 – **8.65**
EC (in situ)	µS/cm	1,000	23 – **1,147**
DO (in situ)	% saturation	85 – 120	**45** – **147**
Al (filtered 0.45 µm[4])	µg/L	55	1.3 – **341**
As (filtered 0.45 µm)	µg/L	24	0.15 – 3.5
Cd (filtered 0.45 µm)	µg/L	1.73	All values <0.02
Cu (filtered 0.45 µm)	µg/L	10.97	0.15 – 3.65
Fe (filtered 0.45 µm)	µg/L	300	2 – **370**
Pb (filtered 0.45 µm)	µg/L	16.6	<0.01 – 0.64
Mn (filtered 0.45 µm)	µg/L	1,900	0.59 – 109
Hg (filtered 0.45 µm)	µg/L	0.6	<0.02 – 0.04
Ni (filtered 0.45 µm)	µg/L	11	0.21 – 2.02
Zn (filtered 0.45 µm)	µg/L	62.68	<0.1 – 23.6
TPH fraction C6-C9 (filtered 0.45 µm)	µg/L	N/A	N/A
Benzene (filtered 0.45 µm)	µg/L	950	All values <1

Table 4.12 – Comparison of MRM Monitoring Data for SW11 with WDL Requirements (cont'd)

WDL 174-08, WDL 174-09, WDL 174-10 and WDL237[1]			MRM Monitoring Data (SW11)[2]
Parameter	Units	Site-specific Trigger Value (SSTV) for SW11	Oct 2016 – Mar 2018[3] (Minimum – Maximum)
TPH fraction C10-C14 (filtered 0.45 μm)	μg/L	600	<50 – 320
C15-C28 (filtered 0.45 μm)			
C29-C36 (filtered 0.45 μm)			
SO_4 (filtered 0.45 μm)	mg/L	341	0.3 – 233
NO_3 (filtered 0.45 μm)	μg/L	700	<20 – **2,940**

1. WDL174-08 was applicable until 27 October 2016, after which WDL 174-09 was applicable until 27 April 2017, followed by WDL-10, with WDL 237 being applicable from 21 March 2017 to 31 May 2017; the SSTVs remained the same.
2. Ranges of values were extracted from spreadsheets provided by MRM.
3. Values in bold lie outside the relevant SSTV.
4. Early versions of the WDL actually refer to 'Total and filtered (0.45 μg/l)' for metals and metalloids, although WDL 174 - 10 and WDL237 refer only to 'Filtered (0.45 μg/l)'.

Table 4.13 – Discharges During the 2017-2018 Reporting Period

Date	Site ID	Discharge Volume (ML) (ML)[1]	Comment
2016/17 Wet Season			
30 to 31 Dec 2016	P2	23.55	Under WDL 174-09
31 Dec 2016	SEL1	0.64	Under WDL 174-09
20 to 26 Jan 2017	SEL1	36.97	Under WDL 174-09
9 to 11 Feb 2017	P2	41.04	Under WDL 174-09
11 to 13 Feb 2017	NC1A	28.15	Under WDL 174-09
20 to 25 Feb 2017	NC1A	51.63	Under WDL 174-09
21 to 23 Feb 2017	WMD	58.90	Under WDL 174-09
21 to 22 Feb 2017	P2	15.11	Under WDL 174-09
24 to 27 Feb 2017	WMD	88.49	Under WDL 174-09
28 Feb to 2 Mar 2017	WMD	43.13	Under WDL 174-09
6 to 15 Mar 2017	WMD	231.01	Under WDL 174-09
10 to 11 Mar 2017	NC1A	6.05	Under WDL 174-09
17 to 22 Mar 2017	WMD	119.72	Under WDL 174-09
24 to 27 Mar 2017	WMD	78.16	Under WDL 174-09
1 Apr 2017	SEL1	1.30	Under WDL237
2 to 3 Apr 2017	SEL1	15.04	Under WDL237
3 to 7 Apr 2017	SEL1	19.80	Under WDL237
TOTAL		858.69	
2017/18 Wet Season			
15 to 16 Nov 2017	WMD	20.36	Under WDL 174-10
27 Nov 2017	P2	4.62	Under WDL 174-10
28 Nov 2017	P2	8.79	Under WDL 174-10
24 Jan to 1 Feb 2018	P2	175.64	Under WDL 174-10

Table 4.13 – Discharges During the 2017-2018 Reporting Period (cont'd)

Date	Site ID	Discharge Volume (ML) (ML)[1]	Comment
2017/18 Wet Season (cont'd)			
24 Jan to 1 Feb 2018	WMD	191.56	Under WDL 174-10
24 Jan to 1 Feb 2018	NC1A (L1)	57.13	Under WDL 174-10
25 to 30 Jan 2018	NC1A (L2)	36.20	Under WDL 174-10
1 to 13 Feb 2018	P2	398.12	Under WDL 174-10
1 Feb to 1 Mar 2018	WMD	728.19	Under WDL 174-10
1 Feb 2018	NC1A	2.82	Under WDL 174-10
6 to 20 Feb 2018	SEL1	92.91	Under WDL 174-10
9 to 10 Feb 2018	NC1A-2	16.50	Under WDL 174-10
17 to 20 Feb 2018	SEL1-2	13.85	Under WDL 174-10
25 Feb to 1 Mar 2018	P2	116.28	Under WDL 174-10
25 Feb to 1 Mar 2018	SEL1	20.68	Under WDL 174-10
25 Feb to 1 Mar 2018	SEL1-2	20.04	Under WDL 174-10
1 Mar to 1 Apr 2018	P2	468.98	Under WDL 174-10
1 to 2 Mar 2018	SEL1	9.93	Under WDL 174-10
1 Mar 2018	SEL1-2	2.15	Under WDL 174-10
1 to 9 Mar 2018	WMD	212.80	Under WDL 174-10
5 Mar 2018	SEL1-2	2.17	Under WDL 174-10
11 to 13 Mar 2018	SEL1	9.90	Under WDL 174-10
TOTAL		2609.62	

Based on the surface water monitoring reports relevant to the reporting period (ELA, 2017; KCB, 2018) and IM review of the raw data spreadsheet provided by MRM, it is apparent that most of the results showed water quality at SW11 that complied with the WDL SSTVs. Points that are particularly worth noting are:

- All benzene and almost all TPH results were less than the respective detection limits and SSTVs, the exceptions being seven samples where TPH values were above the detection limits but still well below the trigger value.
- Nitrate values were similarly generally less than the WDL SSTV of 700 μg/L, with a small number (two) of exceptions being reported (as discussed previously).
- Most EC results at SW11 were less than the 1,000 μS/cm SSTV, with the average value being 550 μS/cm. Only four EC results from this site were above the trigger value, and these were obtained well into the dry season. This has been further discussed in terms of non-compliance (Section 4.3.4.1).
- Individual DO values at SW11 ranged from 45 to 147% saturation compared with the trigger values of 85 to 120%, with the average value over the reporting period being 88%. Dissolved oxygen levels at all sites along McArthur River, including the upstream control sites, routinely

fall outside the range of trigger values, with no long-term discernible trends (as previously discussed).

- In relation to metals and metalloids:
  - All results for filtered metals and metalloids other than Al, Fe, Cu and Zn (i.e., As, Cd, Pb, Mn, Ni, Hg) were below both the WDL SSTVs and the ANZECC/ARMCANZ (2000) 95% level of protection guideline values.
  - The SSTV for Al of 55 μg/L (which is also the ANZECC/ARMCANZ (2000) 95% level of protection guidelines value) was exceeded at SW11 a number of times over the reporting period. However, this is consistent with previous years (see 'Incidents and Non-compliances') and the IM notes that this not likely to be due to MRM activities. The matter has been discussed by MRM with government regulators in the past.
  - The concentration of total filtered (soluble) Fe at SW11 exceeded the trigger value of 300 μg/L once over the reporting period. As was the case with Al, this is consistent with previous years (see 'Incidents and Non-compliances') and the IM notes that this not likely to be due to MRM activities.
  - The results for filtered Cu were all less than the WDL SSTV (10.97 μg/L) and generally less than the ANZECC/ARMCANZ (2000) 95% level of protection guidelines value (1.4 μg/L). However, 11 values exceeded 1.4 μg/L, although the corresponding total Cu values for two of these samples were less than the filtered values, which suggests that the filtered Cu concentrations were incorrect for these samples. The maximum filterable for the remaining 9 samples Cu was 3.65 μg/L, which is only 33% of the SSTV.
- When evaluated against hardness modified trigger values (HMTVs) calculated using the hardness of each sample from SW11, ELA (2017) reported six exceedances, with two of these being for Cu in January and February 2017 and four being for Zn, also in January and February 2017 (and two of these were for the same sampling event as the Cu exceedances). Examination of the raw data provided by MRM suggests that a further exceedance occurred for Cu in November 2016 (measured filterable Cu of 3.65 μg/L compared with a HMTV of 1.88 μg/L). The IM agrees with ELA (2017) that these exceedance levels pose only a very minor risk to the receiving environment. The IM also notes that no discussion of HMTVs is included in KCB (2018), but further assessment of the data by the IM for the period 1 June 2017 to 31 March 2018 indicates that no exceedances occurred.

With respect to SO_4, and as noted in previous IM reports, elevated concentrations of this ion at SW11 in the latter part of the dry season have been a potential concern in the earlier years of the current IM's tenure. However, as shown in Figure 4.7B, these concentrations of concern were not evident in the current IM reporting period. From a 'success' perspective, MRM's implementation of management measures such as a dewatering pump in the downstream section of Barney Creek diversion channel near SW19 are noteworthy. Although SO_4 from the McArthur River diversion channel remains potentially problematic (as discussed above), water quality improved at SW16 and SW17 in the 2016 and 2017 dry seasons compared with the previous dry season (WRM, 2018b).

With respect to the artificial surface water monitoring program, the monitoring data reported by MRM, together with the internal weekly reports, indicates that the program provides a suitable basis to meet its objectives, i.e., to determine risk and management options, identify if off-site discharge is viable, and provide data for contamination source investigations (KCB, 2018).

The QA/QC data for surface water monitoring indicates that continued effort is required to address Zn and, to a lesser extent, Al blank values (as was noted in last year's IM report). The water quality data presented in the spreadsheet shows that blank values for Zn are routinely reported to be 1 to 2 μg/L (and sometimes substantially higher), which are similar to the actual values reported for samples (where the range at SW11 is <0.1 to 23.6 μg/L, with an average of 5.6 μg/L). Continued effort is also needed to address the sometimes poor precision obtained from analysing duplicate samples.

The overall conclusion is that the mining and processing operation has had relatively low impacts on downstream surface waters during the reporting period as determined by assessment of contaminant concentrations and general water quality variables (primarily at SW11). It should also be noted that the magnitude of the impact in terms of key water quality variables such as SO_4 and EC at this site seems to have improved in recent years. However, areas for improvement remain, e.g., in terms of managing the impacts that occur upstream of SW11 in Barney Creek, Surprise Creek and McArthur River diversion channel. A potentially significant risk also continues to be posed to future surface water quality due to the issues associated with acid, saline and/or metalliferous drainage from the NOEF and TSF, particularly after closure (and this is addressed elsewhere in this report). The impact of the mine in terms of loads of contaminants (as opposed to concentrations) is yet to be determined by MRM.

It should also be noted that no uncontrolled release occurred from any of MRM's major water storages during the high rainfall, event that occurred in January 2018 (highest daily January rainfall on record, 627 mm total for the month, approximately a 100 year ARI for the 7-day storm duration) (MRM, 2018b).

Bing Bong Loading Facility and Surrounds

Analogous to the approach described above for the mine site and surrounds, evaluation of success at Bing Bong Loading Facility is based on the following rationale:

- The beneficial uses that are applicable to the coastal waters of, and surrounding, the Bing Bong Loading Facility are aquatic (marine) ecosystem protection, recreational water quality and aesthetics.
- The water quality required to be achieved in these waters is as defined by ANZECC/ ARMCANZ (2000) toxicant trigger values for 95% level of protection of marine species or otherwise sourced from ANZECC/ARMCANZ (2000).

Although the WDL specifies application of ANZECC/ARMCANZ (2000) trigger values to BBDDP (see Figure 4.5) as a statutory compliance point, this effectively means that ambient water quality guideline values are applied to the discharge from the dredge settling ponds. Evaluation of data from the swing basin and navigation channel is more likely to provide an indication of environmental performance in terms of the protection of these beneficial uses. This approach has therefore been adopted in this report (which is consistent with the approach adopted by MRM and previous IM reports).

It should also be noted that no dredging in the Bing Bong Loading Facility area or entrance channel occurred in the reporting period.

Formal reporting of the results from the DGT monitoring program occurred via Tsang (2017), which includes data for deployment of the samplers in the period from 31 July 2016 to 17 May 2017. Data for subsequent deployments, i.e., from 1 June 2017 to 26 February 2018, was available only from spreadsheets provided by MRM, i.e., 'Replicate DGT metals & PbIR_2017-18.xlsx' and 'Mean DGT metals & PbIR_all years.xlsx', with a summary of the results being presented in the 2017-2018 OPR. The IM understands that a report addressing the 2017-2018 results is currently in preparation.

The results indicate a high level of success in terms of being less than the SSTVs specified in the WDL, as summarised in Table 4.14.

Table 4.14 – Comparison of MRM DGT Monitoring Data for Bing Bong Loading Facility with WDL Requirements

WDL 174-08, WDL 174-09 and WDL 174-10			ANZECC/ARMCANZ (2000) 95% (99%)[3]	MRM Monitoring Data[1]
Parameter	Units	Site-specific Trigger Value (SSTV) for BBDDP[2]		Oct 2016 – Feb 2018[4,5]
Cd	µg/L	5.5	5.5 (0.7)	0.003 – 0.037
Cu	µg/L	1.3	1.3 (0.3)	0.050 – 0.552
Co	µg/L	N/A	1.0 (0.005)	0.007 – 0.070
Mn	µg/L	80	ID	0.44 – 21.8
Ni	µg/L	70	70 (7)	0.050 – 0.772
Pb	µg/L	4.4	4.4 (2.2)	0.003 – 0.533
Zn	µg/L	15	15 (7)	0.050 – 12.0

1. Values for ranges were extracted from the spreadsheet 'Mean DGT metals & PbIR_all years.xlsx' provided by MRM.
2. Early versions of the WDL actually refer to 'Total and filtered (0.45 µg/l)' for metals and metalloids, although WDL 174 - 10 refers only to 'Filtered (0.45 µg/l)'.
3. Underlined values are recommended by ANZECC/ARMCANZ (2000) for slightly to moderately disturbed systems; values in brackets are aimed at 99% level of protection rather than 95%.
4. Values in **bold** lie outside the relevant SSTV.

Tsang (2017) reported that, during the 2016-2017 monitoring period, the concentrations of DGT-labile Zn, Pb, Co, Cu, Cd and Ni at the monitoring sites within the swing basin, i.e., DGT3 and DGT4, typically complied with their respective ANZECC/ARMCANZ (2000) guideline values for a slightly to moderately disturbed marine system (where this classification is appropriate for the swing basin). Examination of Table 4.14 shows this means that the values were also below the SSTVs. This was also the case for the results for June 2017 to February 2018 (which were not included in Tsang (2017) and hence were evaluated separately by the IM).

Tsang (2017) further reported that concentrations of DGT-labile Zn and Pb at these sites were also typically below their respective ANZECC/ARMCANZ (2000) guideline values for 99% protection and were therefore comparable to pristine environments. This was also the case for most DGT-labile Cu concentrations in the swing basin. For the period June 2017 to February

2018, six Cu values (out of 17) and two Zn values (out of 17) exceeded the 99% protection guideline (but were still less than the 95% protection guideline value).

The DGT-labile Zn, Pb, Cd, Co, Cu and Ni concentrations at monitoring sites outside the swing basin, i.e., DGT1, DGT2, DGT5, DGT6 and DGT7, and in the trans-shipment area, i.e., DGT8, were less than their ANZECC/ARMCANZ (2000) 95% protection levels (as were results for June 2017 to February 2018[5]). Concentrations of DGT-labile Zn, Pb, Cd and Ni were also below their ANZECC/ARMCANZ (2000) 99% protection levels, as was generally the case for DGT-labile Cu, and the data for June 2017 to February 2018 generally reflected these findings.

General comments relating to the results are as follows (and these are based on both the discussion in Tsang (2017) and IM review of the data for the period June 2017 to February 2018):

- Relatively higher concentrations of DGT-labile Mn at DGT3 and DGT4, particularly the former, were probably due to resuspended sediment during mooring and manoeuvring of barges and exposure of the samplers to sediment porewater.
- The average concentrations of DGT-labile Zn and Pb were generally higher at the swing basin monitoring sites (DGT3, DGT4), particularly DGT3, than the other sites. This is consistent with DGT3 being the closest monitoring location to Bing Bong Loading Facility and hence subject to influences associated with barge mooring and manoeuvring, and the consequent resuspension of bottom sediments.
- Results for Pb isotope ratios at some sites indicated that concentrate-derived Pb (and possibly other metals) had dispersed from the Bing Bong Loading Facility into the surrounding marine environment. However, the DGT-labile Pb concentrations at all monitoring sites were typically below relevant ANZECC/ARMCANZ (2000) protection levels and therefore are not expected to adversely impact the marine environment. Tsang (2017) also offers an alternative (but considered less likely) reason for the elevated Pb 208/206 values at coastal sites, this being that natural weathering and erosion of Pb orebodies other than that being mined by MRM may be the cause.
- Although elevated Pb 208/206 ratios (indicative of concentrate-derived Pb) were measured at the trans-shipment site, the DGT-labile Pb concentration remained below the 99% protection level by one order of magnitude (maximum DGT-labile Pb concentration measured was 0.65 µg/L). Concentrations of DGT-labile Zn, Cd, Ni and (most) Cu were also below the 99% trigger values applicable to pristine environments.

In addition to the low levels of metals obtained at all sites, an ongoing success is the continued implementation of the DGT method instead of grab water samples for marine monitoring. The IM endorses this approach and also notes the ongoing refinement of the method, e.g., use of HDPE DGT holders rather than stainless steel and the consequent reduced contamination by Ni (Tsang, 2017), and the introduction of field blanks. However, the IM also notes that the continued poor reproducibility of some results, as shown by imprecise duplicate concentrations on some occasions. Tsang (2017) notes that '(W)hile some samples appeared to be contaminated in the

[5] This excludes DGT8, since monitoring at this site was not continued in 2017/18.

sampling process, the overall data quality was high'. This is despite a number of issues associated with the DGTs, including:

- Vandalism/theft.
- Improper handling of the DGT units.
- Biofouling of the DGT units.
- Application to a limited number of metals/metalloids.

The IM recommends further development of the use of DGTs to improve the precision of the data.

As with monitoring at the mine, the objective of the artificial surface water monitoring program at Bing Bong Loading Facility is primarily to assess the level of contamination and consequent management options, as well as risk to the receiving environment in relation to the dredge spoil drain. Given that there was no dredging, no active discharge occurred from the ponds and hence monitoring of the compliance point BBDDP was infrequent. Monitoring data for BBDDP and the dredge spoil drain has been discussed previously.

It is apparent that MRM continues to act on recommendations from previous IM reports concerning the need to improve DGT monitoring QA/QC procedures, although additional effort to further address occasional poor precision and the issues listed above is still required.

The overall conclusion remains unchanged from last year's IM report, i.e., the mining and processing operation had relatively low impacts on adjacent coastal waters during the reporting period, although areas for improvement remain.

4.3.5 Conclusion

McArthur River Mining continues to devote considerable effort to water management at both the mine site and Bing Bong Loading Facility. Surface water quality monitoring data up to March 2018 indicates that adverse impacts on downstream surface waters due to the mine are currently limited, although some effects are noticeable in watercourses within the mine lease boundaries (and this is not unexpected). Compliance with WDL SSTVs at SW11 has improved, particularly in relation to EC and SO_4. Data from the DGT monitoring program suggests that adverse impacts on coastal waters near Bing Bong similarly remain limited.

The IM also notes that MRM is devoting increased attention on the effects of the operation in terms of mine-derived loads reporting to McArthur River and the various sources that contribute to these loads, as has been advocated in a number of recent IM reports and is now required by various conditions in WDL 174-10. The existing information suggests that mine-derived loads for some contaminants is significant, and the next steps are to fully quantify these loads and changes over time, and to determine the associated environmental risks, particularly in terms of downstream impacts within the context of the relevant environmental values.

In addition to the above findings, a major concern of the IM continues to relate to mine closure and the potential impacts on downstream water quality (including contaminant loads), given the issues associated with the NOEF, TSF and pit lake in terms of post-closure acid, saline and/or metalliferous drainage. This concern is detailed in ERIAS Group (2017) and focuses on the need for MRM to consider what happens if the PAF waste encapsulation and NOEF cover are not as effective as envisaged in the modelling, and adaptive management is also not effective, i.e., the consequent downstream impacts that might occur in such a scenario. The potential for downstream water quality impacts resulting from active avulsion upstream in McArthur River is also a possible concern.

Ongoing (including those recommendations that have been modified on the basis of additional information) and new IM recommendations related to surface water issues are provided in Table 4.15. New recommendations are low priority and relate to clarifications about the monitoring program.

Table 4.15 – New and Ongoing Surface Water Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
NOEF and TSF/ surface water monitoring program	Given the ongoing issues associated with the NOEF and TSF, a formal procedure is required whereby the review process for the surface water monitoring program, outcomes and required actions are documented (preferably in the proposed water management plan) and available for IM review	Medium
McArthur River/ SW11/other surface water sites	Environmental values to be protected in Barney Creek, Surprise Creek and McArthur River diversion should be determined in conjunction with relevant stakeholders, with the outcomes being used to direct measures to mitigate mine-derived elevated metal and major ion concentrations upstream of SW11	High
	A risk assessment should be undertaken concerning: ♦ Possible implications associated with elevated SO_4 concentrations and EC levels at sites within the ML that are next to or downstream of MRM facilities, e.g., McArthur River diversion channel, Surprise Creek and Barney Creek diversion channel, within the context of the environmental values that require protection and the relevant conditions in WDL 174-10 ♦ Likely causes (including groundwater inputs, surface water inputs and interaction of surface water with exposed mineralised areas) ♦ If MRM operations or activities are found to be a significant contributing factor, mitigation measures commensurate with the level of risk	High
	Mitigation of elevated concentrations of metals and major ions in Surprise and Barney Creek and the implementation of mechanisms additional to an interception trench between TSF Cell 1 and Surprise Creek should continue to be explored by MRM, with a view to preventing the need for dry season dewatering of Barney Creek and within the context of the environmental values upstream of SW11 that require protection	High
	The hypothesised (by MRM) role of Glyde River elevated on filterable Al and Fe at SW11 should be confirmed	Low
	MRM should continue to determine changes in mine-derived TSS loads over time, taking into flood events. This assessment should also address TSS from the operations at the Bing Bong Loading Facility	Medium
Monitoring	Real-time in situ monitoring at SW11 should be implemented with the issues observed during previous wet season (e.g., burial of the probe, damage due to inundation) being appropriately addressed	High

Table 4.15 – New and Ongoing Surface Water Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Monitoring (cont'd)	Continued focus should be placed on QA/QC as part of the water sampling program, including: ♦ Elevated trip blank Zn and Al levels ♦ Occasional poor precision for DGT analyses ♦ Potential contamination issues associated with operating an environmental laboratory on a mine site	Medium
	Additional effort should be devoted to the following in relation to mine-derived loads of contaminants*: ♦ Contaminant load estimates should be determined, where these reflect both natural and mine-associated sources (including but not limited to the TSF, OEFs, ELS (including definition of the relative influence of ELS seepage versus inputs from mineralises areas), run-off dams and open pit) reporting to Surprise Creek, Barney Creek (and diversion channel), Emu Creek, and McArthur River (and diversion channel). Glyde River should also be included in these estimates (although this is a lower priority) ♦ Load calculations (and load balances) should take into account current and predicted natural and mine-derived loads, filtered and unfiltered metals, groundwater (e.g., seepage from various mine facilities) versus surface water inputs (e.g., discharges from MLDP), and seasonal variation ♦ The need to sample over specific flood events in McArthur River, Barney Creek, Surprise Creek and Emu Creek (and Glyde River) to complement the weekly sampling program and obtain robust load estimates should be considered, as should other measures to address the uncertainties identified in WRM (2018c) ♦ Using the results from the above, mine-associated sources should be ranked in terms of contributions of contaminants to McArthur River at SW11 and further downstream, and used to prioritise management and mitigation actions	High
	Validation of the release calculator results should be explicitly and formally recorded	Low
	The recommendations in KCB (2016) should be fully implemented	High
Water management system	Specific surface water quality management objectives for the artificial surface water monitoring program should be formalised for Bing Bong Loading Facility and incorporated into relevant MRM documents, e.g., the proposed water management plan	Low
	Seepage through the DSEA embankments should be addressed prior to future placement of dredge spoil in the ponds. This should also include characterisation of spoil currently contained within the DSEA	High
	Maximising the volumes of Class 4 water that are discharged to McArthur River, thereby minimising the volumes of water stored on site and facilitating water management on site, should be undertaken with due consideration of mine-derived loads and the need to maintain downstream water quality such that overall impacts on the environmental values associated with the river system remain protected	High

Table 4.15 – New and Ongoing Surface Water Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Water management system (cont'd)	Further clarification of: ♦ Rules for release of Class 4 water, e.g., how the minimum McArthur River flow triggers are used, using mechanisms such as a decision tree or similar should be provided ♦ The status of class 5 water in relation to managed release and minimum river flow trigger values	Low
General data interpretation and reporting	A reconciliation of all actual versus proposed surface water sampling events should be completed annually and included in the surface water monitoring reports (where this addresses both natural and artificial surface waters)	Medium
General data interpretation and reporting (cont'd)	Comparison of metal and metalloid results with ANZECC/ARMCANZ (2000) values should include the 95th percentile values as well as median values for all surface water monitoring sites	Medium
	Future MRM reporting about progress in relation to (i) investigations to address information gaps, and (ii) meeting other commitments (e.g., those contained elsewhere in the OPR) in relation to surface water quality should include the original and revised (if necessary) completion dates, with supporting explanations concerning the revised dates Clarification should also be provided in relation to the actions/ recommendations in the 2016-2017 OPR and 2017-2018 OPR, and the knowledge gaps in the previous OPR Source documents in relation to MRM commitments should include MMP information requests, amendment and conditional approvals	Medium
Erosion	The proposed mitigation measures to address gully erosion near the walking track leading to NOEF SEL1 DP should be implemented prior to the 2018/19 wet season. Similarly, the potential for erosion at the actual pipe outlet should also be evaluated and addressed as required	Medium
New Items		
General data interpretation and reporting	Clarification should be provided in the next surface water monitoring report as to: ♦ The total number of ASW sites, why data for only some of these are reported, and how the data for the remaining sites is used ♦ Discrepancies between the monitoring schedule, collated data and interpretative reports ♦ The status of DSD01 to DSD04 sites within MRM's monitoring program	Low

* The IM acknowledges that WDL 174-10 requires MRM to address a number of load-related matters, including some of the recommendations contained herein.

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4.4 Diversion Channel Hydraulics Management

4.4.1 Introduction

This section addresses MRM's performance during the operational period with regards to management of diversion channel hydraulics, and is based on review of:

- Site photographs from the site visit.
- Aerial and other photographs of the mine site provided by MRM.
- Mine levee wall inspection notes and photographs.
- 2017 Operational Performance Report (MRM, 2017).
- 2017-2018 Operational Performance Report (MRM, 2018).
- Hydraulic assessment of potential fluvial erosion risk for the McArthur River and Barney Creek diversion channels (WRM, 2018a).
- Hydraulic assessment of potential fluvial erosion risk for the Barney Creek diversion channel considering no concurrent McArthur River flooding (WRM, 2018b).
- McArthur River Mine levee wall assessment (Mining One, 2018).
- Geomorphological assessment of the McArthur River and Barney Creek diversion channels (Hydrobiology, 2016).
- Other documents such as the previous mine levee wall assessment by Mining One (2016).

4.4.2 Key Risks

The key risks to diversion channel hydraulics as described in the risk assessment (Appendix 1) are:

- Flooding within the open pit in a rarer than 0.2% AEP flood event, resulting in cessation of mining activities and generation of large quantities of poor quality water (mine wall built to protect the mine site from 0.2% AEP flood event).
- Active avulsion upstream directing McArthur River flow into the old river channel causing erosion at the toe of the mine levee wall, potentially leading to failure of the mine levee wall. Hydrobiology (2016) report identified an active channel avulsion upstream of McArthur River diversion channel offtake, with potential impacts to the diversion stability and integrity of mine levee wall. The hydraulic assessment of potential fluvial erosion risk conducted by WRM (2018a), supports this eventuality.
- Erosion along an unplanned overland flow path from the old McArthur River channel into the diversion channel, potentially leading to severe erosion and substantial sediment input into the diversion. This will become more of a problem when the avulsion occurs upstream.

- Rainfall runoff erosion of the mine levee wall potentially impacting integrity in the long term (Mining One, 2016; 2018).
- Unstable and unprotected stream and gully confluences to the McArthur River diversion channel. Potential impacts to offsite stream health through deepening and widening with increased sediment supply to the McArthur River.
- Ongoing erosion in the McArthur River diversion channel, with potentially detrimental effects on rehabilitation efforts and on water quality (higher sediment loads), with subsequent impacts on aquatic ecology.
- Severe gully erosion on and adjacent to Surprise Creek. This is likely due to bed level lowering on Surprise Creek, concentration of flow to the creek or a combination of the two. Continuation of the gullying will bring it close to the south west corner of SPROD.
- Potential for lateral migration of Surprise Creek adjacent to the TSF impacting on TSF stability. Lateral migration of a waterway involves the erosion of an outside bend and deposition on the inside bend resulting and a gradual planform shift in the river channel (channel moves laterally across the valley floor). This has the potential to impact the stability of the TSF at this location.

4.4.3 Controls

4.4.3.1 Previously Reported Controls

McArthur River Mining has a range of existing control measures to address the key risks listed in Section 4.4.2. These are provided in Table 4.16.

Table 4.16 – Existing Controls to Address Diversion Channel Hydraulics Risks

Risk	Current Control
Flooding within the mine pit	♦ Early Flood Warning System Procedure
Erosion along an unplanned flow path between the old McArthur River channel and the diversion channel	♦ After erosion experienced in the 2009/10 wet season, rock armouring works were conducted in 2010 ♦ Inspections are still being carried out according to personal communication with MRM staff. However, these inspections are not documented. Whereas the flow path armouring appears to be stable, it should be inspected after each wet season and the inspection notes recorded
Ongoing erosion in McArthur River diversion channel	♦ Ongoing revegetation efforts ♦ Rock armouring in parts (some failed due to inappropriate rock sizing and high energy hydraulic forces) ♦ There is no evidence of informal assessment of aerial laser survey (ALS) topography and aerial photographs being actioned in the 2015, 2016 or 2017 reporting period. This is therefore no longer considered a control. It is, however, noted that the geomorphic assessment covers the 2016 period ♦ Revegetation operations are ongoing but limited in success rate (although more tube stock were planted than previously) ♦ Placement of large woody debris (LWD) has decreased, reportedly due to reduced availability

Table 4.16 – Existing Controls to Address Diversion Channel Hydraulics Risks (cont'd)

Risk	Current Control
Integrity of mine level wall	♦ Independent inspection carried out by Mining One Consultants in October 2016 ♦ Regular inspections are now being carried out and documented (2018)
Sourcing of appropriate materials	♦ Systematic planning for sourcing of LWD timber has been conducted with timber sources identified up to 2027. Far less wood added in the 2017-2018 operational period

4.4.3.2 New Controls – Implemented and Planned

The following new controls were implemented in the 2017-2018 operational period:

Implemented Controls

- Ongoing erosion in McArthur River diversion channel:
  - Ongoing revegetation efforts (very low success rate, although a larger number of tube stock were planted compared to previous years).
  - Large woody debris (LWD) placement operations are ongoing, albeit at a reduced rate.
- Integrity of mine level wall:
  - Independent inspection undertaken (Mining One, 2016).
  - Regular inspections being carried and documented (Mining One, 2018).
  - Both inspection reports, recommend rock armouring a section of the mine levee wall.
- Some recommendations from the geomorphic assessment of the McArthur River and Barney Creek diversion (Hydrobiology, 2016) have been undertaken, including:
  - Independent inspection undertaken (Mining One, 2016).
  - Revision of the existing hydraulic model to incorporate the present-day topography (WRM, 2018a; 2018b).

Planned Controls

- A geomorphic assessment of the McArthur River and Barney Creek diversion channels was undertaken by Hydrobiology (2016). It is understood that recommendations from this report are still being considered, including:
  - An options assessment, supported by the revised hydraulic modelling, into mitigation options for the avulsion.
  - The options assessment should investigate and consider the extent of the bedrock bar at the downstream extent of Djirrinmini Waterhole.
  - Monitoring activities on the McArthur River diversion channel, Barney Creek diversion channel and Surprise Creek.

- An independent inspection of the mine levee wall was undertaken by Mining One (2016). It is understood that recommendations from this report are still being considered, including:
  - Placing rock fill over a section of the mine levee wall.
  - Documentation and photographs of the future remediation works.

4.4.4 Review of Environmental Performance

4.4.4.1 Incidents and Non-compliances

Incidents

The IM has not identified any incidents in the 2017-2018 operational period relating to diversion channel hydraulics.

Non-compliances

The IM has not identified any non-compliances in the 2017-2018 operational period relating to diversion channel hydraulics.

4.4.4.2 Progress and New Issues

Progress has been made in several areas on previous IM recommendations. Progress includes works planned and works undertaken on diversion assessment and mine levee wall integrity.

Progress

An independent inspection of the mine levee wall was undertaken in 2016 (Mining One, 2016). Regular inspections are now being carried and documented (Mining One, 2018). The inspections have noted no current threat to the integrity of the mine levee wall, the recent inspection noted that until preventative measures are taken, heavy rain will continue to erode the embankment and possibly cause instability in the long term. The inspection report recommended placing rock fill over the area, as did the previous report. There is no indication that this has occurred.

In response to an IM recommendation, a geomorphological assessment of the McArthur River and Barney Creek diversion channels was commissioned by MRM in 2016 (Hydrobiology, 2016). This investigation identified several key risks pertaining to the diversion channels, Surprise Creek and the integrity of the mine levee wall. These risks and associated recommendations are detailed in the report. Key recommendations identified in the Hydrobiology (2016) report are listed below along with a statement of the observed progress.

- *The stability of the McArthur River diversion channel offtake:* An active channel avulsion (wholesale shift in channel position), immediately upstream of McArthur River diversion channel offtake was identified with potential impacts to the diversion stability and integrity of the mine levee wall. Should the channel realign itself to the path of the avulsion, it will be directly aligned with the old McArthur River channel. This will direct water during high flow events directly down the old channel and towards the mine levee wall. The report recommends:
  - A revision of the previous hydraulic model, incorporating the present-day topography. This has been conducted by WRM (2018a). Additionally, a scenario was run showing

the effect of the high flow through the Barney Creek Diversion with no corresponding flow (no downstream backwater effect) in the McArthur River (WRM, 2018b). The investigation into the diversion channel hydraulics was recommended in the last IM Report (ERIAS Group, 2017) and as such, its completion addresses that recommendation. However, the investigation has confirmed the previously suspected issue regarding the avulsion upstream of the diversion and raised some new concerns, discussed below.

  - An options assessment, supported by the revised hydraulic modelling, into mitigation options for the avulsion. Not yet undertaken.

- *McArthur River diversion channel instabilities:* Aggradation and erosion continue to occur at various locations along the McArthur River diversion channel. The report notes that these are likely to affect compliance and relinquishment and recommends that options to address these instabilities are investigated.

  - Revegetation operations have been carried out on the McArthur River diversion channel, although it is noted that the strike rate for planted vegetation in some areas is very low. The low strike rate would imply that the methodology should be revisited and amended as required. It is understood that a rehabilitation management plan is being developed which will identify appropriate vegetation, soil remediation and landform slopes for rehabilitation of the diversion.

  - Plans for diversion stability improvements were discussed with MRM staff during the 2016 site visit. The gorge section represents a substantial constriction on flows with the base width and top of bank width substantially narrower than up and downstream sections. This results in high flow velocities in this section as water is forced through the constriction. Plans were being discussed to counter this effect including potentially battering the banks back at this location to reduce the constriction; however, there does not appear to have been any progress on this matter in the 2017-2018 operational period. The IM understands that MRM has engaged specialist consultants to carry out a preliminary options assessment for the McArthur River diversion channel instabilities, although this is yet to be completed (MRM, pers. com., 22 August 2018).

  - It is recommended that these plans will take into account the revised hydraulic modelling.

- *Lateral movement of Surprise Creek near the TSF:* Surprise Creek near the TSF appears to be vertically stable due to the presence of bedrock; however, lateral migration of the channel is occurring. The report identifies this as a potential risk to the stability of the TSF as the channel moves towards it. Even if the measures proposed in the Draft OMP EIS are approved (moving the tailings to the pit), the TSF is to remain where it is in the short to medium term. The report therefore recommends that the area is monitored annually and following high flows and reassessed as required.

  - This recommendation has not been actioned within the reporting period. It is also noted with concern that this recommendation is omitted from the recommendations that MRM state they will undertake (MRM, 2017: p121).

  - However, the IM understands that MRM's new channel erosion monitoring procedure commenced in April 2018 (which is not within the reporting period) and includes a number of sites along Surprise Creek that will be monitored for the purpose of lateral migration (MRM, pers. com., 22 August 2018). The IM has not reviewed this monitoring procedure.

- *Surprise Creek channel instabilities:* The report identifies some other areas of channel instabilities on Surprise Creek. One site was visited during the 2017 IM site visit. Severe gully erosion was identified on the left bank of Surprise Creek near the southwest corner of SPROD (as described in the 2016 IM Report for the 2016 operational period (ERIAS Group, 2017)). The gullying is likely due to bed level lowering on Surprise Creek, concentration of flow to the creek or a combination of the two. These gullies extend up to 150 m and, where observed, were up to 2 m deep. They are likely to continue eroding in the future unless mitigated, with potential effects on mining infrastructure in the short and long term.

  - The IM did not sight any documents indicating that this recommendation had been actioned. It is also noted with concern that this recommendation is omitted from the recommendations that MRM state they will undertake (MRM, 2017: p121).

  - However, MRM has subsequently indicated that rehabilitation works for areas north of Surprise Creek that are experiencing gully erosion are likely to be completed in late 2018 (MRM, pers. com., 22 August 2018).

- *Monitoring of Surprise Creek and the McArthur River and Barney Creek diversion channels:* Monitoring gaps similar to those identified in previous IM reports were noted in the Hydrobiology (2016) report. None of the following recommendations made in the report have been actioned:

  - Cross-sectional survey at several locations to obtain bathymetric information currently unavailable from LiDAR data.

  - Expanding annual LiDAR coverage to include the area covered by the 2011 LiDAR for effective comparison.

  - Regular (two-yearly) diversion channel assessments to establish the predicted changes to the diversion and its likely condition at and after closure, taking into consideration the proposed works.

  - Establishing geomorphic monitoring locations to be regularly assessed by MRM personnel, based on methods outlined by ACARP (2002).

Placement of LWD appears to have decreased in the 2017 operation period. It appears to have been replaced with Small Woody Debris (SWD) placement which, while potentially offering temporary aquatic habitat, will play no role in slowing base flow or reducing erosion. The reduction of the LWD placement program is confusing given that systematic planning for sourcing of LWD timber had been conducted in 2016 with timber sources identified up until 2027. Large woody debris placement offers several benefits to the diversion channel including increased hydraulic roughness (slower base flows), local bedload deposition and storage (increase geomorphic complexity), and aquatic habitat. The SWD program will only offer the latter benefit and even then, only between large flows, when it will be washed away. The LWD program was a significant improvement and its reduction is a concern, particularly given the plans put forward in 2016. It is noted in the 2017-2018 OPR (MRM, 2018), that 12 loads were placed in 2017; however, this is significantly less than in the previous years (74 in 2016 and 124 in 2014). The IM was informed that LWD loads decreased in number due to reduced availability from clearing works associated with mining operations (MRM, pers. com., 22 August 2018). It is therefore recommended that the LWD sourcing plan is regularly revisited to ensure that availability is maintained. The IM also notes that MRM has indicated that a new method of LWD emplacement is being trialled (although the IM has not sighted any information concerning the success of these trials).

No plans have been sighted during the current review for the sourcing of rock for channel stabilisation; however, it is apparent that plans for rock placement are limited to gully stabilisation and localised bank erosion. Potential sources of 'clean' rock for these activities should be identified.

New Issues

The hydraulic assessment of potential fluvial erosion risk for the McArthur River and Barney Creek diversion channels including revised hydraulic modelling (WRM, 2018a; 2018b) sheds light on flow behaviour throughout the diversion. For a 2-year ARI flood flows exceed 3.5 m/s in a number of locations, with stream powers of over 300 Nm/s and bed shear stresses of over 70 Nm^2. These values are extremely high particularly for a 2-year ARI event. The 5-year ARI appears to be the worst case of the modelled scenarios (1, 2, 5, 10, 20-year ARI). Overbank flow reduces velocities and associated stream power for the 10 and 20-year ARI event. The predicted shear stresses for the 2 and 5-year events are more than enough to entrain and transport sand and gravel. Continued bed and bank erosion is also expected under these hydraulic conditions. ACARP (2002) recommend values for shear stress, velocity and stream power for river diversions and these are shown in Table 4.17 with the predicted values for the McArthur River diversion channel shown for comparison.

Table 4.17 – Diversion Channel Hydraulics for 2-Year ARI Compared to ACARP (2002) Recommendations for 2-Year ARI

Stream Type	Stream Power (Wm^2)	Velocity (m/s)	Shear Stress (N/m^2)
Incised River (similar to most of the McArthur River diversion channel)			
ACARP Recommended	20 - 60	1.0 - 1.5	<40
McArthur River diversion channel	150 - 300	3.0 - 3.5	>70
Bedrock Controlled (gorge section of the McArthur River diversion channel)			
ACARP Recommended	50 - 110	1.3 - 1.8	<55
McArthur River diversion channel	100 - 150	2.5 - 3.0	60 - 70

Peak shear stresses, velocities and stream power predicted within the diversion in the most recent hydraulic model are substantially above those recommended in the ACARP (2002) guidelines for diversion design. It is important to note that the values recommended by ACARP assume a vegetated channel. Typical permissible shear stresses for exposed (unvegetated) soils (such as those in the McArthur River diversion channel) are even lower (6-12 N/m^2, as per Kilgore and Cotton, 2005). The shear stresses predicted by the model for the McArthur River diversion channel are well above the recommended values and are more than sufficient to erode, entraining and transport sediment. Substantial erosion is already occurring along a majority of the diversion and it is no surprise that the erosion risk for unvegetated surface material along many sections of the channel is high or extreme (as identified in WRM, (2018a; 2018b)), given the hydraulic conditions predicted in the revised modelling. The fact that such high energy is experienced within the channel explains why erosion is so wide spread. It is particularly noticeable on the bank toe along much of the McArthur River diversion channel, indicating a likely trajectory of channel widening in areas that have not yet reached bedrock.

Importantly this modelling supports the notion of active channel avulsion immediately upstream of the McArthur River diversion channel offtake. In almost all the modelled scenarios (except the 1-year ARI), the hydraulics are such that erosion is expected along the identified avulsion path. The hydraulic modelling by WRM (2018a) was part of an erosion risk study using two methods of calculating erosion risk. Both sets of results confirm that erosion is likely along the identified avulsion path (as shown in Figure 4.9).

The potential for avulsion at this location should be noted as a substantial risk with potential impacts to diversion stability and the integrity of the mine levee wall. Once the avulsion occurs, the likely channel response is meander extension (lateral movement) of the new downstream apex, which will lie almost exactly at the offtake (see Figure 4.9). This may result in significant adjustment of the channel (diversion) at this location. During this planform adjustment, substantial quantities of sediment (hundreds of thousands of cubic metres) will be liberated through scour of the banks, floodplain, mine levee wall, and potentially the SOEF. This sediment will be transported through the diversion and into the McArthur River.

The channel is already attempting to short circuit itself (red line in Figure 4.9). Once this occurs it is likely that planform movement of the channel will occur reasonably rapidly with the channel likely to migrate into the old McArthur River channel (see Figure 4.9). Impact to the mine levee wall is likely, potentially in the medium-term and almost certainly in the long-term. Not addressing this issue will also impact on any high flow offtake structure used in potential mine closure scenarios.

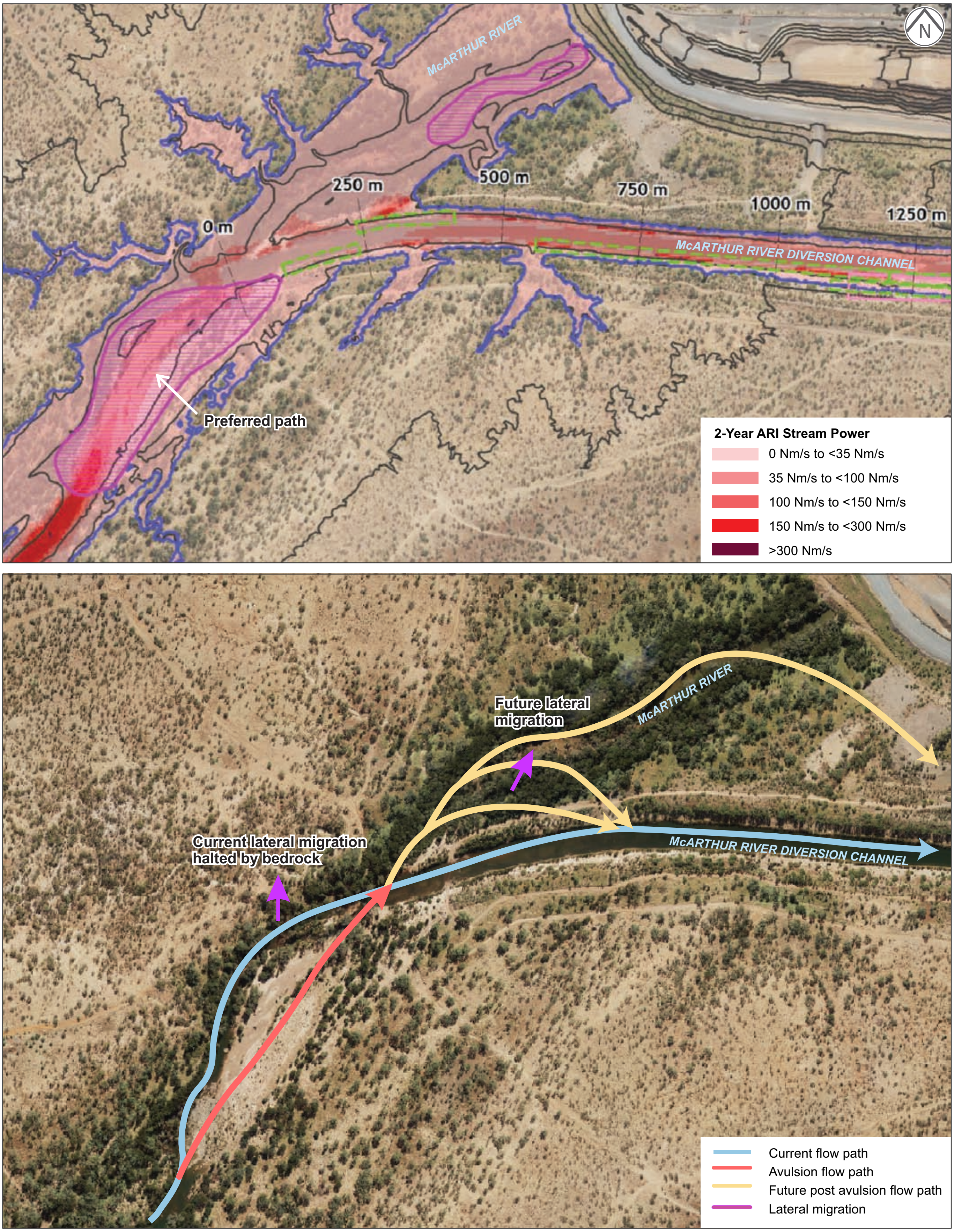
Once the avulsion has occurred, erosion will be ongoing and very difficult (and expensive) to mitigate. It is also likely that channel migration in response to this avulsion will impact on the mine levee wall (particularly when considering the post mine closure time frame). Proactive mitigation measures (mitigating erosion to halt the avulsion) are strongly recommended (pending an options investigation), as it will be far easier to stop the avulsion than to deal with the impacts of the avulsion. The IM understands that MRM plans to undertake an options assessment of the avulsion in 2019 (MRM, pers. com., 22 August 2018).

McArthur River Mining's performance against previous IM review recommendations relating to diversion channel hydraulics is outlined in Table 4.18.

McARTHUR RIVER DIVERSION CHANNEL OFFTAKE – EROSION RISK AND LIKELY FUTURE CHANNEL TRAJECTORY

McArthur River Mine Project

FIGURE 4.9



Source: WRM, 2018a.

Table 4.18 – Diversion Channel Hydraulics Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
Stability of the McArthur River diversion channel offtake	It is recommended that the recommendation from the Hydrobiology (2016) report are adopted, including: ♦ Revision of the existing hydraulic model to incorporate the present-day topography (advised as currently being undertaken) ♦ An options assessment, supported by the revised hydraulic modelling, into mitigation options for the avulsion ♦ The options assessment should investigate and consider the extent of the bedrock bar at the downstream extent of Djirrinmini Waterhole	♦ Hydraulic Modelling completed ♦ Options assessment has yet to be undertaken
McArthur River diversion channel instabilities	It is recommended that options to address the McArthur River diversion channel instabilities be investigated, as described in the Hydrobiology (2016) report	♦ The IM understands that MRM has engaged specialist consultants to carry out a preliminary options assessment for the McArthur River diversion channel instabilities, although this is yet to be completed ♦ Should consider the revised hydraulic model
Barney Creek diversion channel instabilities	It is recommended that the Barney Creek diversion channel be included in regular inspections and that consideration be given to filling the old channel for mine closure as described in the Hydrobiology (2016) report	♦ The IM understands that MRM's new channel erosion monitoring procedure commenced in April 2018 (which is not within the reporting period) and includes a number of sites along the Barney Creek diversion channel for the purpose of erosion monitoring. The IM has not reviewed this procedure
Lateral movement Surprise Creek near the TSF	It is recommended that Surprise Creek near the TSF should be monitored annually and following high flows and reassessed as require, as described in the Hydrobiology (2016) report	♦ The IM understands that MRM's new channel erosion monitoring procedure commenced in April 2018 (which is not within the reporting period) and includes a number of sites along Surprise Creek for the purpose of erosion monitoring. The IM has not reviewed this procedure
Surprise Creek channel instabilities	It is recommended that the areas of instability on Surprise Creek be investigated and an options assessment conducted on mitigating the ongoing gully erosion	♦ The IM understands that MRM plans to complete rehabilitation works for areas north of Surprise Creek that are experiencing gully erosion in late 2018

Table 4.18 – Diversion Channel Hydraulics Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Monitoring gaps	The following recommendations are made as described in the Hydrobiology (2016) report: ♦ Cross-sectional survey at several locations to obtain bathymetric information currently unavailable from LiDAR data ♦ Expanding annual LiDAR coverage to include the covered by the 2011 LiDAR for effective comparison ♦ Regular (2-yearly) diversion assessments to establish a trajectory for the diversion ♦ Establishing geomorphic monitoring locations to be regularly assessed by MRM personnel, based on methods outlined by Hardie and Lucas (2002)	♦ No indication that any of these have been conducted
Integrity of the mine levee wall	It is recommended that the mine levee wall be assessed by a qualified geotechnical engineer, particularly at the sites identified in Figure 4.7 (of the 2014 IM report). While runoff is predicted to be minor, it is recommended that these sites be repaired to ensure stability. It is also recommended that MRM produces a plan for revegetation, stabilisation and monitoring to ensure that the levee remains intact after mine closure	♦ Independent inspection undertaken (Mining One, 2016). No issue found with levee integrity; however, erosion protection of a section of the levee was recommended ♦ The Mining One (2018) inspection also recommended rock ♦ Geomorphic assessment undertaken in 2016 (Hydrobiology, 2016). Issues associated with an avulsion upstream of the diversion identified. A mitigation options analysis was recommended
Sourcing materials	Given the need for additional LWD in the diversion channels and the potential requirement for additional rock armouring (both on the diversion channels and the mine levee wall), it is recommended that future sources for these materials be investigated	♦ Systematic planning for sourcing of LWD timber has been conducted with timber sources identified up until 2027 ♦ No plans were sighted for the sourcing of rock for channel stabilisation or mine levee wall protection ♦ Large woody debris was added in the 2017-2018 operational period
Erosion at toe of mine levee wall	Erosion at the toe of the mine levee wall appears to be due to local runoff rather than fluvial erosion from flood events; however, it may pose a threat to long-term stability. It is recommended that the erosion be assessed by a qualified geomorphologist (included in the scope of the planned assessment)	Completed Geomorphic assessment undertaken in 2016 (Hydrobiology, 2016). Issues associated with an avulsion upstream of the diversion identified. A mitigation options analysis was recommended

Table 4.18 – Diversion Channel Hydraulics Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Overland flow path	The rock protection of the overland flow path appears to be adequate at present; however, it is recommended that the rock protection be inspected after each wet season to ensure its stability. This site should be included in the detailed geomorphic assessment	Completed Not identified as a risk in the Hydrobiology (2016) report. Inspections are being carried out annually but not reported on
Geomorphology	A full geomorphic condition assessment and erosion mitigation study of both diversion channels is recommended as follows: ♦ The study should utilise on ground inspection in addition to recent and future ALS ♦ The study should be carried out for both the Barney Creek and McArthur River diversion channels with priority on McArthur River diversion channel ♦ The study should include the watercourses for at least 1 km upstream and downstream of the diversion channels ♦ The study should aim to identify areas of erosion and deposition, and the current geomorphic processes causing erosion, and to quantify the degree and rate of erosion along the entire reach ♦ The study should draw upon the revised hydraulic modelling and the Review of the 'As-Designed' and 'As-Constructed' McArthur River and Barney Creek diversion channels ♦ Locations of channel constriction and/or high flow velocities should be prioritised, along with areas that have undergone erosion ♦ The study should consider previous attempts at erosion control, including revegetation attempts ♦ This study should then be used to assess the methods of erosion control that can be used and prioritise areas for corrective works	Completed The Hydrobiology (2016) report identified several key risks pertaining to the diversion channels, Surprise Creek and the integrity of the mine levee wall. These risks and associated recommendations are detailed in the report. Key recommendations from the report are included in Table 4.19

4.4.4.3 Successes

Completion of the hydraulic assessment of potential fluvial erosion risk for the McArthur River and Barney Creek diversion channels (WRM, 2018a) is a good step forward and has given weight to the risk of avulsion at the offtake and potential impacts to the integrity of the mine levee wall. This should be considered in the options assessment to mitigate the avulsion or its impacts.

4.4.5 Conclusion

The completion of the hydraulic assessment of potential fluvial erosion risk for the McArthur River and Barney Creek diversion channels (WRM, 2018a) is a great step forward. These investigations were recommended in the Geomorphic Assessment (Hydrobiology, 2016) and the last IM Report (ERIAS Group, 2017), as such, their completion addresses those recommendations. However, the analysis supports the potential for erosion of the mine levee wall at the McArthur River offtake as identified in the Hydrobiology (2016) report. This is a serious risk with potentially catastrophic consequences. Even if the avulsion doesn't immediately impact on the mine wall the potential for considerable volumes of sediment to be liberated to the McArthur River is of great concern. Lateral migration of the channel will always be a concern (particularly when considering post-mine-closure timeframes) and preventing an avulsion in this scenario is likely to be far easier and less expensive than dealing with the impacts of the avulsion. An options assessment to mitigate the avulsion or its impacts is considered a priority for investigation for the next reporting period.

Additionally the fluvial erosion risk for the McArthur River and Barney Creek diversion channels (WRM, 2018a), confirms the severe hydraulic conditions within the diversion that are observed from the wide spread erosion and degradation of the McArthur River diversion channel.

The lateral migration of Surprise Creek is also a concern and should be monitored. It is understood that the OMP EIS proposes to relocate all tailings to the pit at closure. Should the OMP EIS be approved, tailings will continue to be placed within the existing TSF until 2037 with removal over the following decade. The TSF is to be removed at closure and the tailings pumped to the pit. Even still, there are still many years before the TSF is completely removed. Surprise Creek should therefore be monitored regularly, particularly after large rainfall events. The IM understands that MRM's new channel erosion monitoring procedure commenced in April 2018 (which is not within the reporting period) and includes a number of sites along Surprise Creek that will be monitored for the purpose of lateral migration. The IM has not reviewed this procedure.

Ongoing and new IM recommendations related to diversion channel hydraulics issues are provided in Table 4.19.

Table 4.19 – New and Ongoing Diversion Channel Hydraulics Recommendations

Subject	Recommendation	Priority
Erosion	Ongoing monitoring of diversion channel and bank erosion should continue using ALS complemented by photograph monitoring and visual inspection. An annual report on observed erosion should then be completed. This should be undertaken every year to ensure an accurate record of erosion along the diversion channels. This can be done based on methods outlined by Hardie and Lucas (2002) as described by Hydrobiology (2016)	Medium
Integrity of the mine levee wall	Two independent inspection reports by Mining One (2016; 2018) have recommended erosion protection of a section of the mine levee wall. It is recommended that this is undertaken to reduce the likelihood of erosion impacting on the integrity of the levee	High
Sourcing materials	Given the need for rock armouring (both on the diversion channels and the levee wall), it is recommended that future sources for rock be investigated	High
Overland flow path	The rock protection of the overland flow path appears to be adequate at present; however, it is recommended that the rock protection be inspected after each wet season to ensure its stability	Low
Stability of the McArthur River diversion channel offtake	The Fluvial Erosion Study and Hydraulic Modelling both support the future occurrence of an avulsion with potential significant impacts to the mine levee wall. It is recommended that the recommendation from the Hydrobiology (2016) report are adopted, including: ♦ An options assessment, supported by the revised hydraulic modelling, into mitigation options for the avulsion ♦ The options assessment should investigate and consider the extent of the bedrock bar at the downstream extent of Djirrinmini Waterhole	High

Table 4.19 – New and Ongoing Diversion Channel Hydraulics Recommendations (cont'd)

Subject	Recommendation	Priority
McArthur River diversion channel instabilities	It is recommended that options to address the McArthur River diversion channel instabilities be investigated, as described in the Hydrobiology (2016) report	Medium
Barney Creek diversion channel instabilities	It is recommended that the Barney Creek diversion channel be included in regular inspections and that consideration be given to filling the old channel for mine closure as described in the Hydrobiology (2016) report	Low
Lateral movement Surprise Creek near the TSF	It is recommended that Surprise Creek near the TSF should be monitored annually and following high flows and reassessed as require, as described in the Hydrobiology (2016) report	Medium
Surprise Creek channel instabilities	It is recommended that the areas of instability on Surprise Creek be investigated and an options assessment conducted on mitigating the ongoing gully erosion	Medium
Large woody debris	It is recommended that the LWD sourcing plan is regularly revisited to ensure that availability is maintained	Medium
Monitoring gaps	The following recommendations are made as described in the Hydrobiology (2016) report: ♦ Cross-sectional survey at several locations to obtain bathymetric information currently unavailable from LiDAR data ♦ Expanding annual LiDAR coverage to include the covered by the 2011 LiDAR for effective comparison ♦ Regular (2-yearly) diversion assessments to establish a trajectory for the diversion ♦ Establishing geomorphic monitoring locations to be regularly assessed by MRM personnel, based on methods outlined by Hardie and Lucas (2002)	Medium

4.4.6 References

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WRM. 2018b. Hydraulic assessment of potential fluvial erosion risk for the Barney Creek Diversions considering no concurrent McArthur River flooding. Memorandum Dated 13 March 2018. Prepared by WRM Water and Environment for McArthur River Mining Pty Ltd.

Personal Communications

MRM. Email. 22 August 2018.

4.5 Groundwater Management

4.5.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of groundwater and is based on review of:

- Observations and discussions with MRM personnel during the site inspection.
- Various reports, memoranda and correspondence prepared by MRM and its consultants, which include:
  - The approved current mining management plan volumes 1 and 2 (MRM, 2015a; 2015b).
  - The 2016-2017 operational performance report (OPR) (MRM, 2017a).
  - The 2017-2018 OPR (MRM, 2018a).
  - The updated groundwater impact assessment for the Overburden Management Project Supplementary Environmental Impact Statement (OMP SEIS) (KCB 2017a).
  - Reports summarising the results of geological and hydrogeological field investigations carried out in 2016 and 2017 (KCB, 2018a; Logan, 2017b and 2018).
  - Reports, letters and memoranda relating to the 2011 diesel spill, including quarterly reports to DPIR (MRM, 2017b; 2017c; 2017d; 2018b), and annual reports for 2016-2017 and 2017-2018 provided as appendices in the corresponding operational performance reports.
  - Reports prepared for MRM following instruction from DPIR for an independent investigation into the harmful or possible harmful effects upon the environment from the NOEF.
  - Other reports and documents relating to the McArthur River Mine, TSF, OEFs, perimeter runoff dams, pit and underground, and the Bing Bong Loading Facility.
- Various Excel workbooks provided by MRM that contain collated water quality data for 2016 to 2018 (MRM, 2018c; 2018d), and water monitoring and monitoring bore schedules for 2016 to 2018 (MRM, 2018e).
- Various MRM forms and similar documents such as survey results, incident notification letters, and correspondence between MRM, regulators and third parties.
- Aerial and other photographs of the mine site provided by MRM.

4.5.2 Key Risks

The key risks to groundwater management, as described in the risk assessment (Appendix 1), are associated with both the operation phase of mining and the post-mining closure phase and remain essentially the same as described in last year's IM report.

The key risks for the operational phase are:

- Oxidation of ore, overburden and concentrate that will result in acid, saline and/or metalliferous drainage which, if released to the groundwater system, will impact on groundwater quality and terrestrial ecosystems and aquatic ecosystems where groundwater discharges to creeks/rivers or to the surface, as follows:
  - Ore and overburden in the open pit.
  - Overburden and low-grade ore at the OEFs.
  - Ore and concentrate at the ore crushing and processing plant.
  - Concentrate at the Bing Bong Loading Facility.
- Poor quality seepage from the TSF impacting groundwater quality and terrestrial ecosystems and aquatic ecosystems where groundwater discharges to creeks/rivers or to the surface.
- Poor quality seepage from water storages, including the perimeter runoff dams and the dams and ponds used to manage dirty and contaminated water, impacting groundwater quality and terrestrial ecosystems and aquatic ecosystems where groundwater discharges to creeks/rivers or to the surface.
- Spills/leaks from stored chemicals and hydrocarbons resulting in seepage of chemicals and/or hydrocarbons to groundwater, impacting groundwater quality and terrestrial ecosystems and aquatic ecosystems where groundwater discharges to creeks/rivers or to the surface.
- Drawdown from mine dewatering and water supply activities impacting the groundwater resource in terms of both water supply and quality (due to mixing of different quality groundwater), lowering of groundwater levels in heritage areas (Djirrinmini Waterhole) or in areas associated with groundwater-dependant ecosystems (GDEs), and interactions between groundwater and surface water.
- Poor quality seepage from the dredge spoil ponds at Bing Bong Loading Facility impacting groundwater quality and terrestrial ecosystems and aquatic ecosystems where groundwater discharges to creeks/rivers or to the surface.

For the post-mining phase after closure the key risks are:

- Poor quality seepage from the pit lake reporting to the groundwater system after mine closure, impacting groundwater quality and terrestrial ecosystems and aquatic ecosystems where groundwater discharges to creeks/rivers or to the surface.
- Failure of the cover on the OEFs resulting in acid, saline and/or metalliferous drainage which, if released to the groundwater system, will impact on groundwater quality and terrestrial ecosystems and aquatic ecosystems where groundwater discharges to creeks/rivers or to the surface.

- Failure of the cover on the TSF resulting in poor quality seepage which, if released to the groundwater system, will impact on groundwater quality and terrestrial ecosystems and aquatic ecosystems where groundwater discharges to creeks/rivers or to the surface. The IM notes that MRM is currently seeking regulatory approval under the Draft Overburden Management Project Environmental Impact Statement (OMP EIS) to relocate the tailings to the pit at the completion of mining. If this option is sanctioned then the risk of cover failure post-closure will be eliminated.

4.5.3 Controls

4.5.3.1 Previously Reported Controls

McArthur River Mining has developed a variety of control measures to assist in managing groundwater-related risks, including:

- Measures to identify and assess existing and future impacts, and investigate mitigation options (e.g., groundwater monitoring and review of monitoring data, adoption of groundwater quality trigger values, geophysical surveys, development of conceptual and numerical hydrogeological models, water balance modelling of the perimeter runoff dams, EC profiling of rivers and creeks, and pit lake modelling).

- Measures to mitigate current or predicted impacts (e.g., installation of seepage recovery systems, installation of low permeability barriers to restrict groundwater flows, lining of storages used to manage contaminated water, minimisation of the TSF decant pond, and the ongoing remediation of a diesel spill near the mine's power station).

Most of the controls were adopted prior to the current reporting period and are summarised in this section; where appropriate, controls that were described in last year's IM report are also included. New control measures and the results of recently completed studies are discussed in Section 4.5.3.2.

Groundwater Monitoring

McArthur River Mining puts considerable effort into collecting groundwater monitoring data at the McArthur River Mine and Bing Bong Loading Facility. The data provides a cornerstone in the understanding of the associated groundwater environments and is seen as being critical to:

- Identifying impacts from MRM's activities.

- Developing conceptual understanding of groundwater processes.

- Increasing the reliability of numerical models, through calibration.

A description of MRM's monitoring program is presented below.

Manual groundwater level and groundwater quality monitoring data is collected by MRM at both the McArthur River Mine and Bing Bong Loading Facility. In addition, a number of bores at both sites are equipped with data loggers. These record high frequency groundwater water level or groundwater level and EC readings.

A summary of the monitoring bores is provided in Table 4.20.

Table 4.20 – Monitoring Bore Summary

Facility	Number of Monitoring Bores
TSF (including Cells 1 and 2, the WMD and tailings pipeline corridor, but excluding the TSF embankment piezometers)	89
TSF embankment piezometers	12
NOEF (includes the SPROD, SEPROD, WPROD and Emu Creek)	88
Processing Plant (excluding the diesel spill area)	6
McArthur River Mine pit	31
Djirrinimini Waterhole	6
Bing Bong Loading Facility	27
Diesel spill area	27
McArthur River Mine bores equipped with data loggers (some of which are also included above)	92
Bing Bong Loading Facility bore equipped with data loggers (some of which are also included above)	16

Groundwater monitoring data is assessed annually either as part of the MMP or for the OPR. The assessment comprises both groundwater levels and quality for the monitoring bores.

McArthur River Mining also has reporting commitments relating to the 2011 diesel spill near the old power plant. These include quarterly progress reports on the site remediation effort, an annual report reviewing the results from the previous 12 months and recommendations for development of the site remediation plan. The IM notes that MRM has written to DPIR on a number of occasions requesting a reduction in the frequency of the sampling and reporting for the diesel spill remediation.

McArthur River Mining's groundwater monitoring schedule is summarised in Table 4.21 and the monitoring bore locations are shown in Figures 4.10 (TSF area), 4.11 (NOEF area), 4.12 (processing plant, pit and Djirrinmini Waterhole area), 4.13 (Bing Bong Loading Facility), 4.14 (vicinity of the 2011 diesel spill), 4.15 (logger-equipped monitoring bores at the McArthur River Mine) and 4.16 (logger-equipped bores at the Bing Bong Loading Facility).

Table 4.21 – Groundwater Monitoring Schedule Summary

Location	Parameters	Frequency
TSF	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 3 (pH, EC, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, alkalinity, NO_3, NH_3, alkalinity, ionic balance; filtered Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg)	Quarterly (20 bores), biannually (56 bores), annually (13 bores)
	Organics Suite 1 (TPH and BTEXN)	Biannually (4 bores)
TSF embankment	SWL	Weekly (12 piezometers)

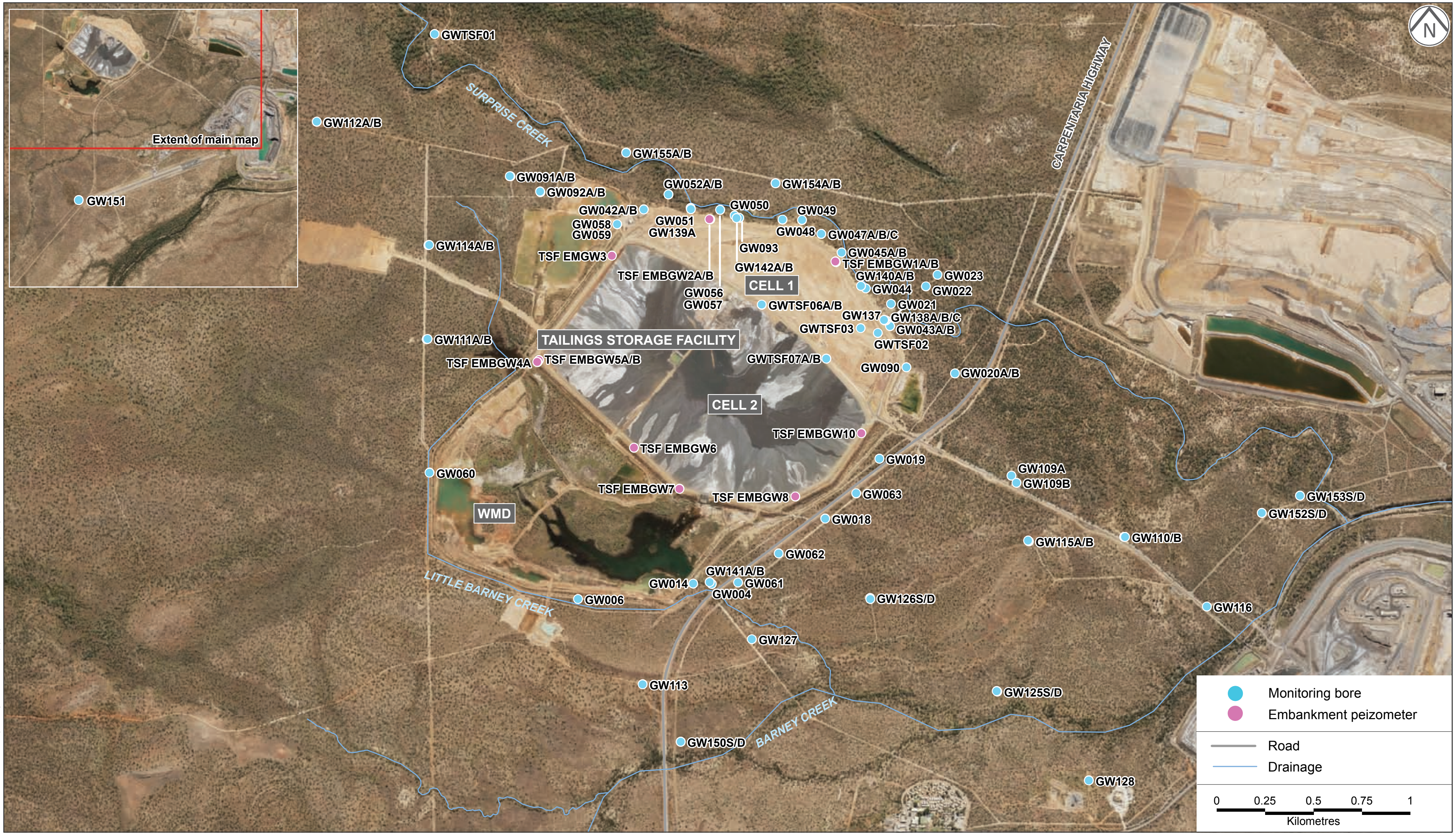
Table 4.21 – Groundwater Monitoring Schedule Summary (cont'd)

Location	Parameters	Frequency
NOEF	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 3 (pH, EC, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, alkalinity, NO_3, NH_3, alkalinity, ionic balance; filtered Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg)	Quarterly (83 bores), biannually (5 bores)
Plant area	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 3 (pH, EC, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, alkalinity, NO_3, NH_3, alkalinity, ionic balance; filtered Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg)	Quarterly (all bores)
	Organics Suite 1 (TPH and BTEXN)	Biannually (all bores)
Pit	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 3 (pH, EC, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, alkalinity, NO_3, NH_3, alkalinity, ionic balance; filtered Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg)	Quarterly (13 bores), biannually (8 bores), annually (10 bores)
Djirrinmini Waterhole	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 3 (pH, EC, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, alkalinity, NO_3, NH_3, alkalinity, ionic balance; filtered Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg)	Annually (6 bores)
Bing Bong Loading Facility	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 3 (pH, EC, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, alkalinity, NO_3, NH_3, alkalinity, ionic balance; filtered Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg)	Biannually (13 bores)
	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL); & Laboratory Suite 3 (pH, EC, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, alkalinity, NO_3, NH_3, alkalinity, ionic balance; filtered Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg) & organics Suite 1 (TPH and BTEXN)	Biannually (4 bores)
Bing Bong Loading Facility dredge pond embankment	SWL	Biannually (5 bores) before, during and after dredging operations
	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 3 (pH, EC, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, alkalinity, NO_3, NH_3, alkalinity, ionic balance; filtered Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg)	Biannually (5 bores) before, during and after dredging operations
Diesel spill area	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 9 (pH, EC, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, Br, alkalinity, ionic balance, filtered Fe^{2+}, TPH and BTEXN, sulfide)	Quarterly (all bores). Only required when bores do not contain measurable LNAPL
	Field Suite 6 (water/diesel interface)	Monthly during the dry season (all bores)

GROUNDWATER MONITORING BORES - TSF

McArthur River Mine Project

FIGURE 4.10



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GROUNDWATER MONITORING BORES - NOEF

McArthur River Mine Project

FIGURE 4.11

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GROUNDWATER MONITORING BORES - McARTHUR RIVER MINE PIT, PROCESSING PLANT AND DJIRRINMINI WATERHOLE

McArthur River Mine Project

FIGURE 4.12

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GROUNDWATER MONITORING BORES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.13

ERIAS Group | 01164F_1_F4-13_v2

GROUNDWATER MONITORING BORES - VICINITY OF 2011 DIESEL SPILL

McArthur River Mine Project

FIGURE 4.14

ERIAS Group | 01164F_1_F4-14_v2

MONITORING BORES WITH LOGGERS - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.15

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MONITORING BORES WITH LOGGERS - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.16

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Groundwater trigger values and trend analysis of key analytes have been used by MRM's groundwater consultants at the McArthur River Mine and at the Bing Bong Loading Facility to help identify impacts on groundwater quality. The trigger values are based upon the water quality limits for livestock in ANZECC/ARMCANZ (2000) guidelines. Where undertaken, the trend analysis has been carried out using the Mann-Kendall test.

Surface Geophysical Surveys

Surface geophysical surveys have been conducted on a number of occasions since 2003 to help identify areas affected by seepage. The areas surveyed comprised the TSF, TSF Cell 3 WMD, previously proposed TSF Cell 4, SPROD, SEPROD and the proposed EPROD. The most recent surveys were completed during 2016 around the TSF and NOEF.

A review of the program by MRM suggests that the surveys highlight areas of relatively high conductivity (i.e., compared to the background level), which may be linked to elevated salinity and contaminated groundwater as a result of the operations.

Information provided for the current review period shows MRM has undertaken a review and re-interpretation of earlier non-groundwater related geophysical surveys to try and characterise hydrogeological conditions at the McArthur River Mine (Section 4.5.3.2).

Development of Conceptual Geological and Hydrogeological Models

Considerable effort has been made to further develop geological and hydrogeological models for the mine site. Model development has commonly been carried out in conjunction with field studies to collect baseline information on the locations and geometry of hydrogeological units and their hydraulic properties (e.g., hydraulic conductivity and aquifer storage characteristics). This work is ongoing, but earlier investigations have included studies for the Phase 3 EIS (URS, 2012), and preliminary studies carried out by KCB in 2015 (KCB, 2015) and for the Draft OMP EIS (KCB, 2017b).

The conceptual models form the basis of subsequent groundwater flow modelling, which are discussed further in the following section and in Section 4.5.3.2.

Groundwater Flow Modelling

A number of numerical groundwater flow models have previously been developed for the mine site. The earlier models were generally used to investigate specific groundwater concerns, e.g., two-dimensional (2-D) modelling to assess pit inflows from McArthur River (Golder, 2004) and seepage modelling of the TSF (URS, 2006; Golder, 2011).

More recently, numerical modelling has moved towards site-wide assessments of groundwater conditions. This was initiated by URS (2012) as part of the Phase 3 EIS. URS's site-wide model was further developed by RPS (RPS, 2012; 2013), and then by KCB (2017a and 2017b). The latter included contaminant transport and was used to assess impacts from the TSF and NOEF on the groundwater and surface water environments for the Draft OMP EIS. The site-wide numerical model was supported by more detailed modelling of the TSF area (KCB, 2017b), which was also used to assess options for installation of a seepage recovery trench between TSF Cell 1 and Surprise Creek.

The evolution of the site-wide numerical model has continued during the current review period as part of studies for the OMP SEIS (KCB, 2017a), which is discussed in Section 4.5.3.2.

Pit Lake Modelling

Numerical modelling has been undertaken during the Phase 3 EIS and more recently for the Draft OMP EIS to assess the condition of the pit lake after mine closure (Section 4.5.3.2). The results of the Phase 3 EIS modelling, which was conducted by URS (URS, 2012) using outputs from their 3-D groundwater model, are considered preliminary at best, given the level of hydrogeological and geochemical understanding at the time.

Further water balance studies were completed by KCB for the Draft OMP EIS (KCB, 2017a) and by TWS (TWS, 2016), also for the Draft OMP EIS.

The IM notes that MRM's preferred option for the final pit void, as outlined in the Draft OMP EIS and OMP SEIS, is based on a flow-through system. This allows for the diversion of a proportion of McArthur River flow through the flooded pit during normal seasonal flood events, with the McArthur River diversion channel maintained as the primary flow path. McArthur River Mining expects that the seasonal dilution of the pit lake will prevent unacceptable deterioration of the near surface lake water quality. The assessment of the long-term pit lake and lake water quality is discussed below (Section 4.5.3.2).

Low Permeability Barriers

Geopolymer barriers have been used at the mine site to provide a low permeability wall within the superficial deposits and weathered bedrock. Barriers have been installed around TSF Cell 1 and along the eastern boundary of TSF Cell 2 and TSF Cell 3 WMD to reduce groundwater flows away from these facilities. Attempts were also made to limit inflows of uncontaminated groundwater into the pit by installing barriers across the southern limb of a palaeochannel and at discrete groundwater inflow points along the southern edge of the pit where the palaeochannel is thought to provide a conduit to McArthur River.

There is some uncertainty regarding the effectiveness of the existing geopolymer barriers. Assessments reported in KCB (2015) identified a broad seepage front north of Cell 1 and groundwater flows in the deeper fractured bedrock that may pass underneath the existing barrier network. This interpretation is supported by the groundwater levels measured upstream and downstream of the TSF Cell 1 barrier, which show negligible head differences across the barrier.

Locations of the geopolymer barriers are shown in Figure 4.17.

Lining of Water Storages

A number of storages are operated by MRM to manage release water, poor quality water and process water, i.e., Classes 4, 5 and 6. These storages are lined to limit seepage losses. The design and construction method for storage liners has improved over recent years resulting in a significant reduction in seepage rates.

Appropriate lining of storages is considered to be one of the most effective controls for limiting impacts on the groundwater environment from mining and processing activities. The IM notes that MRM is continuing with a program of lining all dams, sumps and drains using a geosynthetic liner.

TAILINGS STORAGE FACILITY GEOPOLYMER BARRIER AND TRENCH LOCATION PLAN

McArthur River Mine Project

FIGURE 4.17

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Diesel Spill Remediation

Hydrocarbon spills have been recorded at the McArthur River Mine operations on three occasions, the most recent being in 2011 when 28,000 L of diesel was released from the fuel storage near the old power station.

Since the 2011 spill, MRM has been engaged in remediation of the affected area. This work has included installation of 25 monitoring bores and a product recovery system, implementation of a comprehensive monitoring program, and assessment and reporting of results both quarterly and annually.

4.5.3.2 New Controls – Implemented and Planned

A number of studies were concluded during the review period, some being associated with the OMP SEIS, and a number of planned controls assessed. The recent studies and planned controls include:

- Collation and review of historical geochemical datasets.
- Collation, processing and review of recent and historical geophysical and drill hole data.
- Geological/hydrogeological field investigations carried out in 2016 and 2017.
- An independent review by the NOEF Independent Review Board (NIRB) of potential impacts from the NOEF and remedial options.
- Further development of the site-wide conceptual and numerical groundwater flow models, completed as part of the OMP SEIS.
- Further development of the pit lake water and solute balance model, completed as part of the OMP SEIS.
- Improvements to the site monitoring infrastructure.
- Assessment of seepage impacts from the ELS.
- Ongoing investigations at the site of the 2011 diesel spill near the power station.

Collation and Review of Historic Geochemical Datasets

A detailed review of the available historical geochemical datasets for the McArthur River Mine was undertaken by Ross Logan and Associates (Logan, 2017a) to identify areas of mineralisation outside the mining area, which could explain anomalous high SO_4 concentrations in groundwater. The datasets comprised stream sediment, soil and bedrock auger sampling at various prospects in the vicinity of the McArthur River Mine, mostly collected between 1955 and 1994.

Unfortunately, the review was unable to provide reliable information on the location of mineralised areas that might be associated with high concentrations of SO_4 in the monitoring bores located east of the TSF or near Emu Creek north of the NOEF, because of the following:

- The presence of transported soils over much of the mine area which limited the reliability of the results of the soil sampling and auger drilling programs.

- The soil sampling and auger drilling programs were carried out before the advent of Global Positioning Systems (GPS) and the position of the sample sites are not always reliable.
- Steam sediments, that are by definition transported, only providing general information on areas that might be affected by mineralisation.
- Sample collection and analyses were not subject to rigorous QAQC protocols.

The review did identify anomalous Pb and Zn concentrations in stream sediment samples draining south of the TSF along Barney Creek and Little Barney Creek, along the Emu Fault and northwest of the McArthur River Mine.

The IM notes that a number of the studies carried out by MRM and their consultants (including the OMP SEIS) assume that anomalous water quality results away from areas associated with mining and processing activities are the result of natural mineralisation. In particular, this applies to the area between the TSF and the pit, where high salinities and SO_4 concentrations have been consistently recorded and a transported soil cover identified. It is recommended that further work be carried out to confirm this assumption, given that the alternative is likely to relate to seepage from the TSF.

Collation, Processing and Review of Geological and Geophysical Datasets

A study involving the collation, processing/reprocessing and review of historic and recent geological and geophysical datasets was carried out in 2016 by Ross Logan and Associates (Logan, 2017b; 2018) in conjunction with a review of the results from earlier drilling programs. The aims of the study included identification and characterisation of faults, and identification of permeable zones and hydrogeological drilling targets. The geophysical datasets included the following:

- 1975 and 2004 seismic refraction survey across the then proposed McArthur River diversion channel.
- 1992 QUESTEM airborne electro-magnetic survey.
- 1995 helicopter magnetics survey.
- 2000 and 2001 MIMDAS IP resistivity surveys.
- 2003 Hummingbird Frequency Domain Electromagnetic survey.
- 2016 ground-based resistivity surveys around the TSF and NOEF.

The study identified a number of significant faults and fault zones that could affect the hydrogeology of the McArthur River Mine, which are described in Table 4.22 and shown in Figure 4.18 (apart from the Myrtle Fault which is still being assessed).

Table 4.22 – Summary of McArthur River Mine Faults

Fault/Fault Zone	Trend/Location	Hydrogeological Character
Barney Trend Corridor (new), which incorporates the Barney Hill Fault	East-west trending extending beneath the TSF and southeastern corner of the NOEF	Aquifer
Whelan's Fault	North-south trending, coinciding with the western pit boundary	Aquitard
Western Fault	North-south trending, located east of the pit	Aquitard
Emu Fault	North-south trending, located east of the Western fault, coincides with Barramundi Dreaming north of the pit	Not determined
Western Fault Block	North-south trending, located between the Western and Emu Faults	Generally an aquitard, apart from the area north of the pit near the Barney Creek diversion
Woyzbun Fault	Northeast-southwest trending, coinciding with the southern pit boundary	Aquitard
Myrtle Fault (new)*	North-south trending, located east of the pit between the Western and Emu Faults	Possible aquifer

The Western Fault Block is generally considered to have low permeability, apart from the area immediately north of the pit near the Barney Creek diversion. In this area karst features have been identified down to 100 m depth, which may be related to intersection of the Western Fault and Barney Trend Corridor. This area may be significant with respect to groundwater inflows to the pit and underground mine.

Interestingly, Logan (2017b and 2018) found no evidence for the Surprise Fault, which was previously thought to trend north–south underneath the TSF and provide a possible seepage conduit from Cell 1 to Surprise Creek.

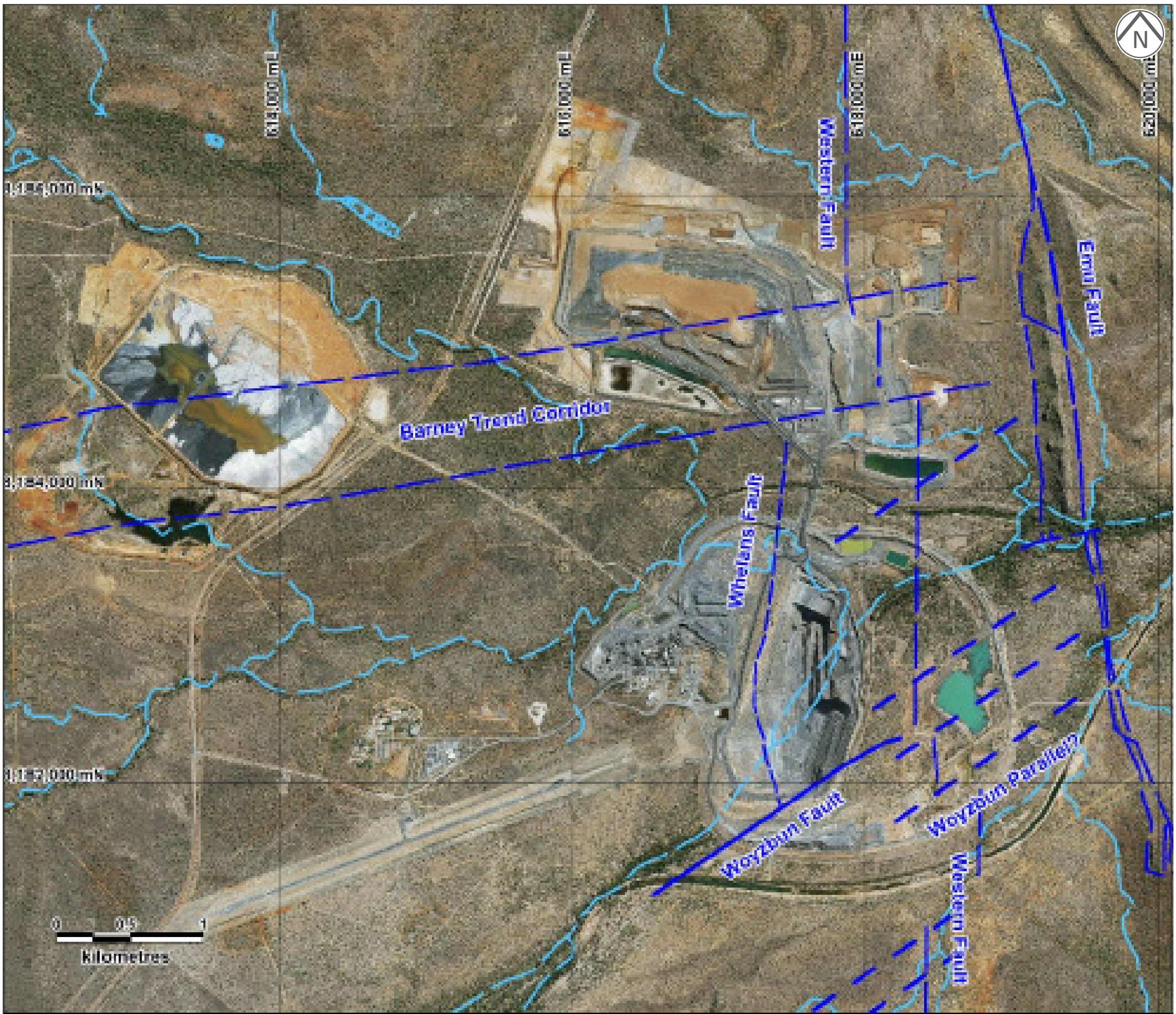
Geological and Hydrogeological Field Investigations

An extensive geological and hydrogeological field program was carried out in 2016 and 2017 (KCB, 2018a; Logan, 2017b and 2018) focusing on the TSF and NOEF areas. The program's aims were to further develop the conceptual hydrogeological model, identify higher permeability zones, characterise vertical hydraulic gradients, quantify aquifer properties and identify hydrogeological boundaries.

The program included:

- Drilling 6 diamond holes and 31 reverse circulation (RC) holes.
- Groundwater sampling at the RC drill holes.
- Constructing nine production bores, 13 monitoring bores and 12 vibrating wire piezometers.
- Test pumping of the two highest yielding production bores, with tracer testing using selected monitoring bores.

FIGURE 4.18



Source: KCB, 2017a.

- Slug testing on monitoring bores.
- Packer testing of six diamond holes to test features identified in the drill core.

The locations of the drill holes and bores, and a summary of the test results, are shown in Figure 4.19. The field program results are summarised in Table 4.23.

Table 4.23 – Summary of McArthur River Mine Field Program Results

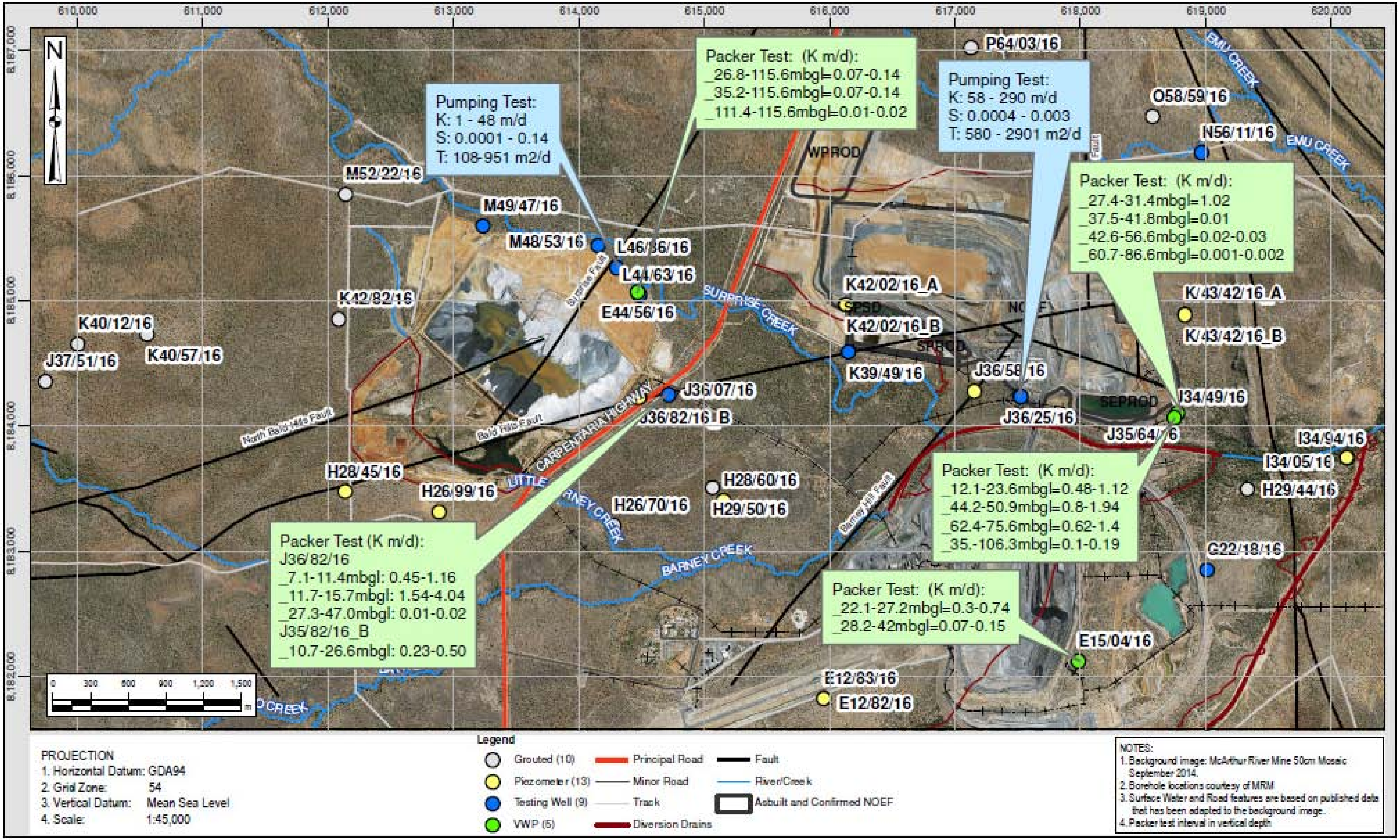
Area	Result
General	The geophysical survey was moderately successful in targeting drill sites
	The rock mass has generally low permeability, with low yields observed in most of the drill holes and low to modest hydraulic conductivities recorded during packer testing
	The groundwater system is compartmentalised, which is consistent with a fractured rock groundwater environment
	Faults are not associated with low permeability hydraulic barriers in the shallow aquifers
	No obvious groundwater-surface water connection was identified
	No obvious vertical hydraulic gradients were identified
	Changes in water quality were not observed during test pumping
North of TSF Cell 1 and south of Surprise Creek (bore L46/86/16)	A constant rate test was run at 3.6 L/s using production bore L46/86/16 located immediately northeast of TSF Cell 1, with monitoring in 12 nearby monitoring bores
	The maximum drawdown in the pumping bore at the end of the test was about 18.5 m
	After 1 hour, drawdowns were observed up to 250 m from the pumping bore
	At the end of the test, drawdowns were observed in 8 of the 10 monitoring bores, including bore GW154B located on the northern side of Surprise Creek
	The test analysis provides a hydraulic conductivity of 1 to 48 m/d, with an unconfined response and dual porosity effects
	Possible leaky effects were interpreted, from either Surprise Creek or the TSF
South of the NOEF and north of Barney Creek, between SPROD and SEPROD (J36/25/16)	The constant rate test was run at 7.3 L/s using production bore J36/25/16 located north of the Barney Creek diversion channel between the NOEF and SEPROD, with monitoring in 8 nearby monitoring bores
	The maximum drawdown in the pumping bore at the end of the test was about 5 m
	After 1 hour, drawdowns were observed up to 400 m from the pumping bore
	At the end of the test, drawdowns were observed in 7 of the 8 monitoring bores. Only monitoring bore GWNOEF2NSL, which is screened with the waste dump rather than the underlying overburden aquifer, failed to show a response
	Possible partial barrier effects were interpreted across the Barney Hill Fault
	The test analysis provides a hydraulic conductivity of 58 to 290 m/d, with an unconfined response

The program results indicate that there is a potential for rapid groundwater flow along discrete pathways, even in areas with modest groundwater yields, as would be expected in an environment dominated by fracture flow. This highlights the potential for movement of contaminants within the groundwater system and also suggests that attenuation/sorption of metals within the soil and rock medium might be less effective in retarding migration should seepage water enter the fractured rock network. This highlights the need to further assess the long-term effectiveness of attenuation in controlling the migration of metals in groundwater.

SUMMARY OF HYDROGEOLOGICAL TESTING AT McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.19



Source: KCB, 2018a.

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NIRB Independent Review

A review of the potential impacts from the NOEF and possible remedial options was undertaken by the NIRB, following instruction from the DMIR to 'investigate whether the placement and containment of mining waste at the NOEF is causing, or may cause, environmental harm to the receiving environment' (EcoMetrix, 2017a and 2017b). The review, which included release of gases, dust and surface water as well as groundwater, was divided into three reporting stages: an assessment and revision of MRM's monitoring programs, an assessment of interim remedial options, and a final report presenting the findings of the review.

The recommended changes to the groundwater monitoring program are summarised in Table 4.24.

Table 4.24 – Summary of NIRB Recommended Monitoring Changes

NIRB Recommendation	Status
Conduct quarterly groundwater gauging at all sites in and around the NOEF	Agreed by MRM and DPIR, instigated in the 2017-2018 OPR
Install water level loggers in selected bores to capture dry-wet season transitions	Agreed by MRM and DPIR, instigated in the 2017-2018 OPR
Include groundwater elevation data tabulated or in maps	Agreed by MRM and DPIR, instigated in the 2017-2018 OPR
Include wet and dry season contour maps of depth to water table	Agreed by MRM and DPIR, instigated in the 2017-2018 OPR
Provide a table and graphs of groundwater hydraulic gradients at nested sites throughout the year	Agreed by MRM and DPIR, instigated in the 2017-2018 OPR
Install level and EC loggers at nested sites closest to potential source areas and near Surprise Creek and the Barney Creek channel, and where EC values and SO_4 concentrations are changing	Agreed by MRM and DPIR, instigated in the 2017-2018 OPR
Present tables (and potentially graphs) that include data for all key analytes through time	Agreed by MRM and DPIR, instigated in the 2017-2018 OPR
Install additional nested bores to the east and down hydraulic gradient of the NOEF	Agreed by MRM and DPIR, instigated in the 2017-2018 OPR
Consider removing pH from the laboratory analyses suite	Rejected by the DPIR
Consider removing total suspended solids from the laboratory analyses suite	Agreed by MRM and DPIR, instigated in the 2017-2018 OPR
Continue to develop site-specific trigger values for groundwater that consider the background water quality conditions	Agreed by MRM and DPIR, instigated in the 2017-2018 OPR

The IM generally concurs with the NIRB's recommendations, although the requirement to contour the depth to water table is considered to be of limited value.

The assessment of interim remedial options was based on reducing risk and limiting harm to receptors, through either source control, pathway interruption or receptor exclusion. The NIRB identified that the main risk associated with groundwater relates to contaminated seepage from the NOEF directly to the underlying groundwater system. This assumes that seepage from the surrounding surface water containment system can be minimised through effective surface water management practices and lining of dams and sumps. The primary path was considered to be the shallow aquifers (overburden and weathered bedrock), which are hydraulically connected to nearby watercourses, and the primary receptor the surface water aquatic environment.

The NIRB concluded that further source controls, given MRM is already exceeding best practice in the construction of the NOEF, and receptor exclusion (beyond restricting groundwater use in contaminated areas) are not practical. Remedial options therefore focused on pathway interruption based on installation of an interception trench possibly equipped with deeper recovery bores.

Various trench and trench and bore configurations were tested using KCB's site-wide numerical groundwater flow model, which had been refined to reduce the model cell size in the areas of interest. The main outcomes are summarised as follows:

- Groundwater discharge to surface drainages is limited to the Barney Creek diversion channel, therefore the interception system is only required around the southeastern corner of the NOEF.
- Groundwater levels along the southeastern side of the NOEF nearest the pit are predicted to fall as dewatering impacts increase. Therefore, the interception system will need to be deepened to capture contaminated groundwater, likely requiring the inclusion of recovery bores.
- Recovery bores should not be required after the cessation of mining when the pit is flooded and the groundwater levels recover.

Further Development of Conceptual and Numerical Groundwater Models

The conceptual hydrogeological model for the McArthur River Mine and the corresponding site-wide numerical groundwater flow and contaminant transport model were updated as part of the OMP SEIS (KCB, 2017a). Updates to the numerical model included improved delineation of geological structures and their aquifer properties, in particular the Barney Trend Corridor (which was previously defined as the Bald Hills Fault), removal of the Surprise Creek Fault and incorporation of revised seepage rates from the NOEF. The revised NOEF seepage rates reflect proposed changes to the final dump cover incorporating a low permeability geosynthetic liner, which is expected to reduce rainfall infiltration rates from between about 5.5% and 7% down to less than 1% of incident rainfall. McArthur River Mining has also improved the hydraulic modelling of the NOEF, with new NOEF models developed using TOUGH2 and GoldSim.

The updated site-wide numerical model was recalibrated to the available groundwater level and water quality data, baseflows in the McArthur River diversion channel upstream and downstream of the mine, and inflow rates to the underground mine up to 2005 and the pit since surface mining started in 2006. Model calibration was constrained by the conceptual hydrogeological model and to expected or measured hydraulic parameter values.

A base case predictive transient simulation was completed covering the operating period from 2015 to 2037, and post-closure period from 2037 to 3048. McArthur River Mining's preferred closure options were adopted for the simulation, i.e., reprocessing the tailings with final disposal in the pit void, capping of the NOEF and flooding of the pit to form a pit lake. The solute transport model included SO_4, which was assumed to be conservative, and four metals (As, Cd, Pb and

Zn). Metal ions are considered non-conservative due to attenuation by the soil and rock medium, which is supported by monitoring data that shows low concentrations of metals in bores affected by high SO_4 levels, as well as test results completed by KCB. The retardation factors used in the predictive simulations were based on field test results with preliminary calibration against measured concentrations in the monitoring record. The IM notes that recent monitoring data from bore GW95S near the SPROD suggests that attenuation may not be effective in the longer term and recommends that the impacts of this assumption on the predicted metal concentrations be further assessed.

The site-wide modelling results were broadly consistent with results from the Draft OMP EIS. A number of the key modelling outcomes are summarised in Table 4.25.

Table 4.25 – Summary of Site-Wide Numerical Modelling Results

Model Stage	Outcome	Prediction
Life of mine	Baseflows to surface drainages	Reduced baseflows to McArthur River and the McArthur River diversion immediately upstream and downstream of the pit and adjacent to the pit as drawdown impacts from dewatering increase Negligible impact on baseflows to Barney Creek and Little Barney Creek west and upstream of the pit and Surprise Creek upstream of the TSF Reduced baseflow to the lower reaches of Surprise Creek and the Barney Creek as drawdown impacts from dewatering increase
	Pit inflows	Pit inflows increase as the mine extends and deepens, peaking at about 40 L/s at the end of mining
	Sulfate concentrations	Groundwater SO_4 concentrations increase around the OEFs and TSF in response to continuing seepage. The most pronounced increases are seen east of the TSF and south and east of the NOEF Sulfate concentrations of greater than 5,000 mg/L are predicted 500 m east of the TSF High SO_4 seepage from the NOEF initially reports to the Barney Creek diversion. NOEF seepage is captured within the pit drawdown cone during the later stages of mining, thereby limiting loads entering the diversion channel
	Metals concentrations	Elevated metal concentrations are restricted to the source areas, because of retardation (adsorption) High metal concentrations are also predicted in inferred mineralised areas east of the TSF and north of the NOEF near Emu Creek
	Sulfate loads	Sulfate loads entering McArthur River and the McArthur River diversion channel immediately upstream and downstream of the pit and adjacent to the pit reduce in response to reductions in baseflow Sulfate loads to Barney Creek and Little Barney Creek west and upstream of the pit remain close to background Sulfate loads to Surprise Creek near TSF Cell 1 increase over the life of mine because of contaminant migration from the TSF Sulfate loads to Surprise Creek adjacent to the NOEF and downstream of the TSF fall to near background values once the SPROD is lined and seepage losses minimised Sulfate loads to the Barney Creek diversion channel initially rise in response to seepage impacts from the NOEF, but then fall as the drawdown from pit dewatering extends under the creek, thereby reducing baseflows

Table 4.25 – Summary of Site-Wide Numerical Modelling Results (cont'd)

Model Stage	Outcome	Prediction
Life of mine (cont'd)	Metal loads	Metal loads remain at background levels in all drainages, because of the effects of retardation
	Drawdown at Djirrinmini Waterhole	Drawdowns of between 0.4 and 0.65 m are predicted at Djirrinmini Waterhole, which is consistent with previous estimates and within trigger limits
Post closure	Baseflows to surface drainages	Baseflows to McArthur River and the McArthur River diversion channel immediately upstream and downstream of the pit recover after mining in response to flooding of the pit Baseflows to Barney Creek and Little Barney Creek west and upstream of the pit and Surprise Creek upstream of the TSF are unchanged Baseflows to Surprise Creek adjacent to the TSF initially fall, after the tailings are relocated to the pit and seepage from the TSF ceases, then stabilise to pre-mining rates Baseflows to the lower reaches of Surprise Creek adjacent to the NOEF and downstream of the TSF remain stable Baseflows to the Barney Creek diversion channel rapidly increase in response to flooding of the pit. The longer term prediction shows a gradual rise, possibly in response to reversal of flows from the pit lake
	Sulfate concentrations	The SO_4 plume developed around the TSF during operations dissipates and migrates eastwards towards the pit The SO_4 plume around the NOEF continues to migrate to the southeast reporting to the Barney Creek diversion channel. There also appears to be a reversal of flows from the pit lake to the lower reaches of the Barney Creek diversion channel, which is associated with a migration of SO_4-contaminated water Sulfate plumes associated with the EOEF and SOEF dissipate over time once the waste rock is relocated into the pit The WOEF continues to act as a SO_4 source on the western side of the pit
	Metals concentrations	Elevated metal concentrations are restricted to the remaining source areas (NOEF and WOEF) with limited migration, because of retardation (adsorption). Seepage with high concentrations of metals are not predicted to reach the surface water drainages over the 1,000-year run period Metal concentrations reduce where source areas have been removed (e.g., the TSF, EOEF and SOEF) in response to dispersion and dilution through rainfall recharge High metal concentrations are also maintained in inferred mineralised areas east of the TSF and north of the NOEF near Emu Creek
	Sulfate loads	Sulfate loads to McArthur River and McArthur River diversion channel immediately upstream and downstream of the pit initially increase in response to increases in baseflows before stabilising Sulfate loads to Barney Creek and Little Barney Creek west and upstream of the pit remain close to background Sulfate loads to Surprise Creek adjacent to the TSF fall back to near background levels following relocation of the tailings at the end of operations Sulfate loads to the lower reaches of Surprise Creek adjacent to the NOEF remain close to background values

Table 4.25 – Summary of Site-Wide Numerical Modelling Results (cont'd)

Model Stage	Outcome	Prediction
Post closure (cont'd)	Sulfate loads (cont'd)	Sulfate loads to the Barney Creek diversion channel continue to increase after closure in response to groundwater level recoveries after flooding of the pit and long-term seepage from the NOEF. The load to the diversion reaches around 4,000 kg/day after 1,000 years
	Metal loads	Metal loads remain close to background in all drainages, apart from the McArthur River diversion channel immediately east of the pit and the Barney Creek diversion where minor increases are predicted, e.g. increases in Zn loading at the Barney Creek diversion from about 0.03 kg/day to 0.045 kg/day after 1,000 years

The IM considers the continued development of the site-wide numerical groundwater flow and contaminant transport model, in conjunction with the conceptual models for the mine site, appropriate in assessing impacts from the operation and evaluating options to mitigate these impacts. However, the IM also recognises that there are a number of major gaps in the understanding of the groundwater system, which need to be addressed. These include:

- The hydrogeological feature controlling high groundwater inflows to the underground workings, which are seasonally estimated at between 90 L/s and 200 L/s (KCB, 2016a). Discussions with site personnel during this year's site visit suggest some of these flows may be associated with surface water inflows to the pit that had not been previously recognised, which requires further investigation.
- The locations of naturally mineralised zones, which have been inferred from anomalous monitoring results. The assessment by Logan (2017a) is not seen by the IM as definitive and further investigations are required to confirm the source of the high contaminant concentrations away from operational centres, particularly east of the TSF and northeast of the NOEF near Emu Creek.
- The attenuation of metals, which:
  - Does not adequately allow for flow via discrete pathways, given the MODFLOW code was used based on an Equivalent Porous Medium approach.
  - Assumes the range in partition coefficients tested in the model are appropriate over the entire model domain.
  - Assumes that using partition coefficients to simulate complex geochemical processes associated with adsorption/desorption of contaminants is appropriate.
  - Assumes the relative proportions of free or unoccupied surface adsorption sites within the aquifer media greatly exceeds total adsorbate remaining in solution.

There is also a significant risk associated with the long-term performance of the NOEF (i.e., after decommissioning and closure when MRM's site presence will be limited).

These issues will require ongoing assessments to improve MRM's understanding of the groundwater system at the mine site and the seepage risks from the NOEF. A number of these assessments are expected to be undertaken as part of MRM's planned adaptive management approach to environmental concerns, e.g. the long-term effectiveness of attenuation. However, the issues associated with the high inflows to the underground mine and the confirmation of the presence of natural mineralised zones requires more immediate attention.

Further Development of the Pit Lake Model

The GoldSim pit lake water and solute balance model was updated as part of the OMP SEIS (KCB, 2017c). The updates included:

- Revising the groundwater inflows based on the latest results from the site-wide numerical groundwater flow and contaminant transport model.
- Improving the simulation of hydro-chemical and geochemical processes (e.g., oxygen depletion and geochemical thermodynamics).
- Including stratification, based on hydro-dynamic modelling of the pit lake (TWS, 2017).

The main findings from the updated modelling include the following:

- Rapid filling of the pit after relocation of the tailings is important to inundate the tailings and reactive rocks exposed in the pit wall and reduce exposure to oxygen and dilute poor quality tailings water.
- A predicted brief period of loading occurs while the pit is receiving tailings and during the initial flooding period, when SO_4 concentrations are predicted to exceed 5,000 mg/L and Zn concentrations predicted to exceed 10 mg/L, after which reaction rates are minimised.
- The pit lake water remains pH circum-neutral.
- McArthur River Mining's closure plan includes opening the pit to McArthur River downstream of the diversion channel (the so called back water connection). The pit lake is predicted to stratify once this connection to the river is established, which will further limit oxygen transfer to the deeper parts of the pit lake.
- In the longer term, allowing for ongoing assessment of the performance of the pit lake, MRM may elect to open up the southern (upstream) connection between McArthur River and the pit to allow limited through flow. This will allow periodic dilution of the upper parts of the pit lake (epilimnion) during the wet season. However, turbulent flow is not predicted to impact the deeper parts of the pit lake (hypolimnion) even under extreme climatic conditions.
- Long-term pit lake water quality within the epilimnion is expected to have moderate salinity, neutral pH, SO_4 concentrations around 100 m/L and Zn concentrations of about 0.02 mg/L.

Generally, the pit lake modelling is considered by the IM to be of a high standard, given the uncertainties associated with simulating dynamic surface water systems in a variable climate. However, a number of uncertainties exist. These include the likely presence of a deep groundwater pathway between the underground mine and either McArthur River or Barney Creek and the impact this could have on the pit lake modelling results and the likelihood that the pit lake will stratify in the manner predicted.

Improvements to the Site Monitoring Infrastructure

A number of improvements were made to the site monitoring infrastructure (MRM, 2017a; 2018a) during the review period, which included:

- Installation of eight new paired monitoring bores (GW156S/D, GW157S/D, GW158S/D and GW159S/D) during the 2016-2017 OPR reporting period to better assess groundwater conditions at the McArthur River Mine and as replacements for damaged bores.
- Installation of additional data loggers during the 2016-2017 OPR reporting period to collect high frequency groundwater level and EC readings at the Djirrinmini Waterhole, the NOEF, and near the pit and ELS.
- Installation of six additional monitoring bores (GW017-004 to GW017-009) in the vicinity of the SPROD during the 2017-2018 OPR reporting period to better identify reductions in pH and increased concentrations of metals.
- Installation of additional data loggers during the 2017-2018 OPR reporting period to collect high frequency groundwater level readings in the palaeochannel sediments south of the pit.

The installation of data loggers at the NOEF bores was recommended as part of the NIRB independent review carried out by EcoMetrix (2017a; 2017b) and the installation of additional monitoring bores in the vicinity of the SPROD was undertaken in response to high concentrations of Zn and falling pH values in monitoring bore GW95S (MRM, 2017e), shown in Figure 4.20.

Assessment of ELS Seepage Impacts

McArthur River Mining has undertaken an assessment of the potential seepage impacts from operation of the ELS on the quality of the water in the McArthur River diversion channel (MRM, 2018f). The memorandum discusses the process that may be responsible for high EC values measured in McArthur River at surface water monitoring station SW16 during low flow periods (Figure 4.21).

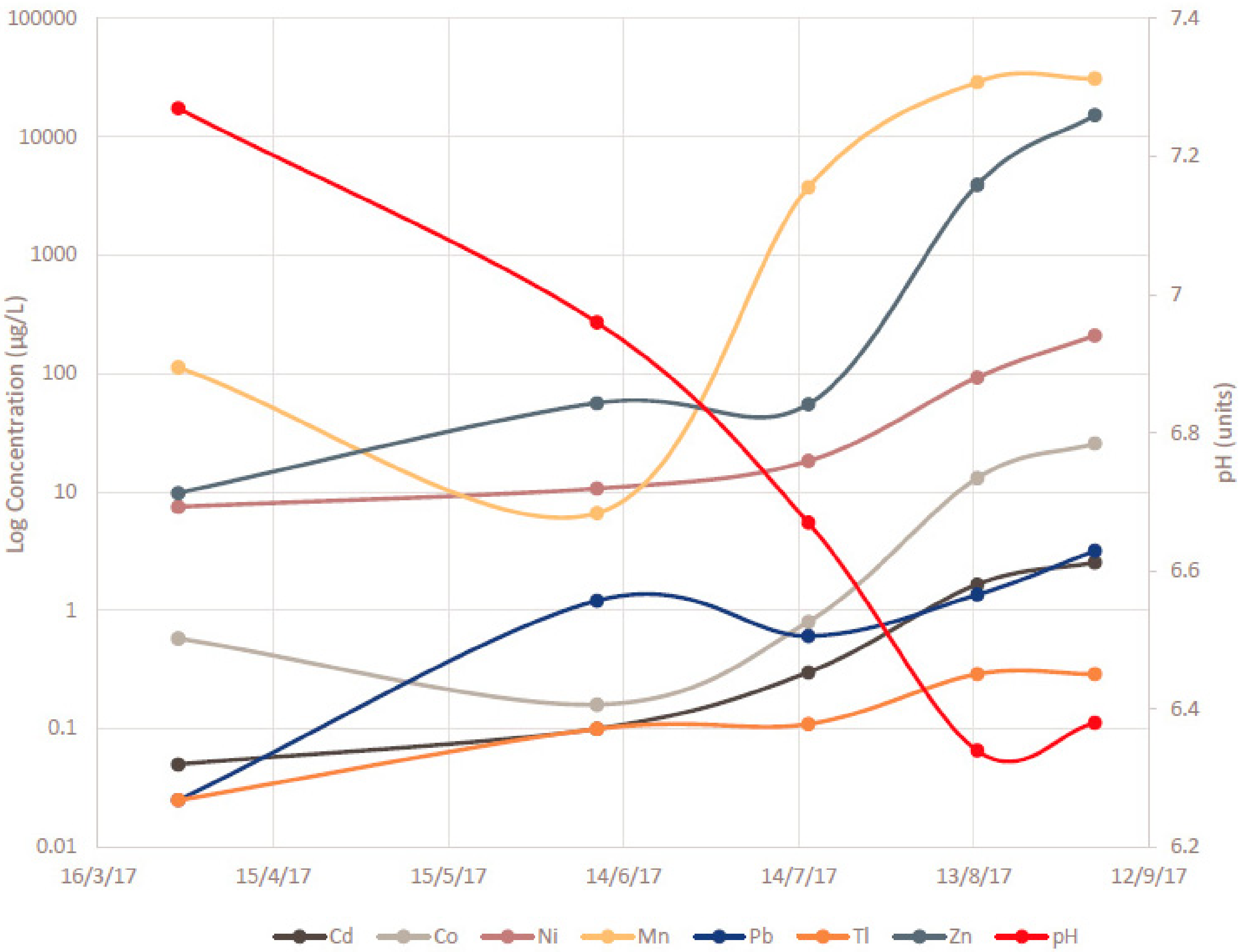
The high EC values had previously been thought to relate to operation of the ELS which had been used to store excess poor-quality mine water between 2011 and 2015. McArthur River Mining now proposes that the impacts are more likely to be from physical loading effects from the ELS and compression of the underlying aquifers, because of the short response time between impoundment of water and observed changes in the river water quality and changes in nearby groundwater levels and quality. The minimum hydraulic conductivity (250 m/d) was back-calculated, based on the flow path length (660 m), breakthrough time (17 months), assumed porosity (0.2) and measured hydraulic gradient (0.001).

However, the IM notes that the assumed porosity of 0.2, although suitable for a porous medium, is not consistent with a fractured rock medium where values are likely to be 0.05 or less. The groundwater study for the OMP SEIS utilised values of between 0.15 and 0.05.

WATER QUALITY RESULTS AT BORE GW95S

McArthur River Mine Project

FIGURE 4.20



Source: MRM, 2017e.

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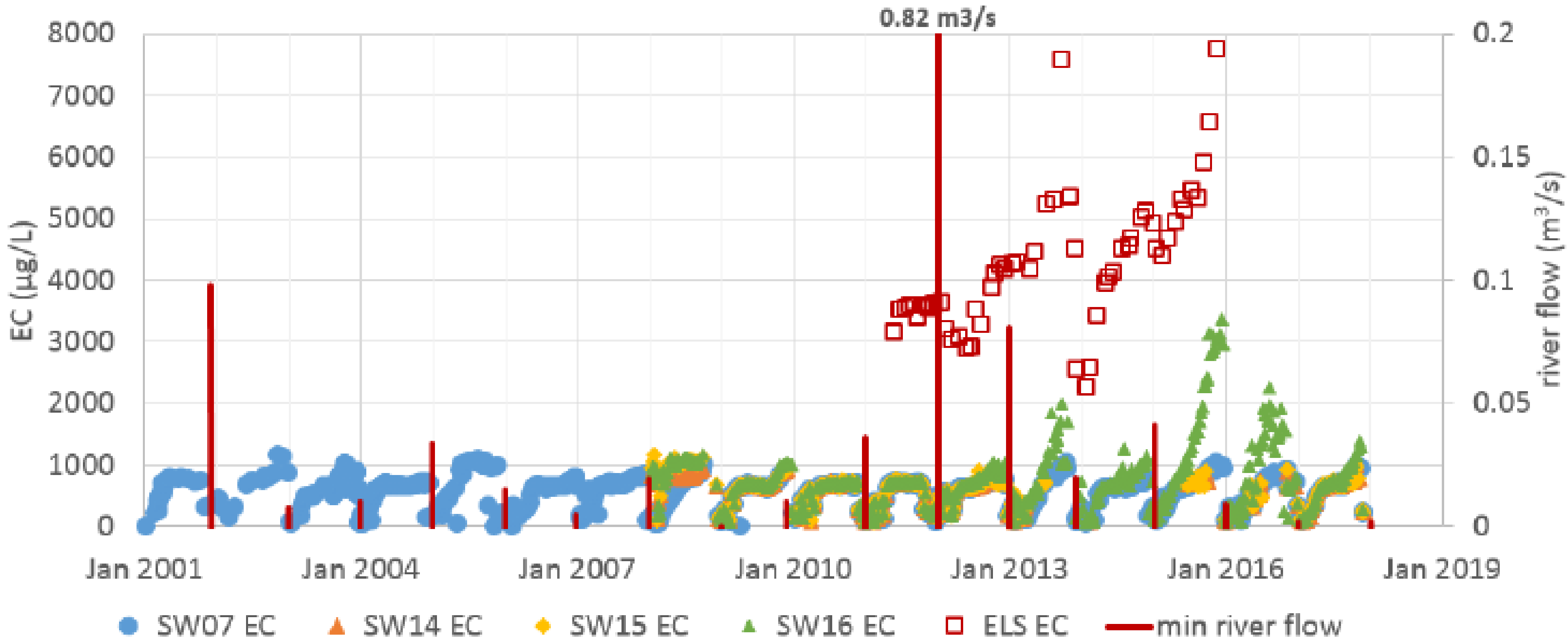
COMPARISON OF EC MEASUREMENTS IN THE ELS AND McARTHUR RIVER

McArthur River Mine Project

FIGURE 4.21



Source: MRM, 2018f.

Furthermore, the results from recent aquifer testing carried out around the TSF and NOEF (KCB, 2018a) have identified:

- Rapid groundwater level responses to pumping at similar distances (i.e., 400 m from the production bore within 48 hours).
- Break-through times of around 16 minutes from a monitoring bore located 50 m away from the pumping bore using tracers.
- Unconfined or semi-confined responses in the overburden and weathered bedrock aquifers, which will limit the extent of loading effects.

These outcomes suggest that elevated groundwater levels in nearby monitoring bores and high SO_4 concentrations in nearby monitoring bores and in the baseflow to the McArthur River diversion channel are more likely the result of seepage from the ELS rather than physical loading.

The impact of the ELS on the river water quality is significant given the juxtaposition of the proposed EOEF with the ELS and the potential for seepage from the facility to the McArthur River diversion channel. Further investigations are strongly recommended to help ensure that the design of the EOEF seepage controls are adequate, e.g., the use of temporary covers to limit rainfall infiltration and seepage interception systems.

Diesel Spill Remediation

Hydrocarbon spills have been recorded at McArthur River Mine on three occasions, the most recent being in 2011 when 28,000 L of diesel was released from the fuel storage near the old power station. The largest spill occurred in 1997 when 155,800 L of diesel was released in the same area.

Since the 2011 spill, MRM has been engaged in remediation of the affected area. This work has included installation of 25 monitoring bores, implementation of a comprehensive monitoring program, and assessment and reporting of results both quarterly and annually. The IM concurs with the conceptual site contamination model and remedial approach presented in MRM’s remediation action plan (Xstrata, 2012).

The results from the remediation program are presented as quarterly reports submitted to DPIR (MRM, 2017b; 2017c; 2017d; 2018b) and annual reports submitted to DPIR as part of the 2016-17 OPR and 2017-2018 OPR.

The reports indicate that both the light non-aqueous phase liquid (LNAPL) and the dissolved contaminant plumes initially extended to the northwest and west, and to a lesser extent to the east. It is not possible to estimate the full extent of western migration due to the lack of monitoring bores, which (it is understood) could not be installed due to topographic/operational constraints. The results suggest that the plume is stable (i.e., it is not moving).

The plume extents have been influenced by fracture flow rather than radial flow. Total product recovery as of 1 April 2018 was 4,324 L, which represents around 15.6% of the spill volume. Natural attenuation may be active in the area of contamination, although there are large temporal variations in measured concentrations of indicator parameters (e.g., SO_4, alkalinity, ferrous Fe and Mn). An assessment of the effects of natural attenuation was carried out by KCB (KCB, 2018b), which concluded that geochemical conditions are favourable for degradation. However, the direct evidence of processes associated with the degradation of soluble phases could not be confirmed.

Importantly, the risks to Barney Creek and McArthur River are considered to be negligible due to the capture zone around the pit and underground mine from dewatering activities. The IM notes that MRM has installed sentinel monitoring bores DRW03, DRW01 and URS15 at the northern end of the site between the spill location and Barney Creek and that none of these bores has detected the presence of LNAPL or dissolved hydrocarbons. This is consistent with the surface water sampling results that show no measurable hydrocarbons at the nearest sampling point SW18 on Barney Creek.

An independent review of the diesel spill monitoring data was conducted by KCB (2018c). The results of the review are summarised as follows:

- The free phase LNAPL plume does not appear to be migrating away from the spill area and the risk of significant impact on the receiving environment is low.
- The LNAPL plume appears to be reducing in thickness.
- There is no evidence of dissolved hydrocarbons migrating to the receiving environment.
- Drawdown impacts from pit dewatering will reduce the probability of the plume migrating towards Barney Creek.
- There has been no detection of hydrocarbons in Barney Creek at the SW18 sampling point.

On the basis of the review, KCB supports a reduction in the sampling frequency to quarterly, which should be sufficient to allow detection of significant migration of the plume. The IM concurs with KCB's findings and recommends that the suggested reductions in the monitoring and reporting programs proposed by MRM be adopted.

4.5.4 Review of Environmental Performance

4.5.4.1 Incidents and Non-compliances

Incidents

One groundwater incident was reported during the review period (MRM, 2018a), relating to groundwater seepage observed in the Little Barney Creek diversion channel immediately downstream of the WMD. The seepage is thought to be derived from the WMD and is being managed via sumping, with the discharge reporting back to the WMD. The IM considers this response appropriate.

Non-compliances

Two non-compliances were reported during the review period:

- High Zn concentrations of up to 59 mg/L were recorded at monitoring bore GW95S, which exceeded the ANZECC/ARMCANZ (2000) livestock drinking water trigger value of 20 mg/L

(MRM, 2018a). This exceedance is considered significant as it likely relates to seepage from the SPROD, where installation of a synthetic liner has been delayed (but is reportedly planned and included in the 2019 budget). The original clay liner was reworked in 2016 in attempt to reduce the permeability of the dam floor. However, this seems to have had only a limited or temporary affect. More importantly, the exceedance also suggests that the attenuation of metals may not be affective in the long-term prevention of unacceptable concentrations in the receiving groundwater environment, which supports the IM's recommendation to further assess the effectiveness of attenuation in mitigating impacts.

- A number of bores in the plant area and at the TSF and Bing Bong Loading Facility are scheduled for sampling and analysis of BTEXN and total petroleum hydrocarbons biannually (see Table 4.21). The majority of these bores were last sampled at the end of the first quarter 2017 and bores GW149A and GW149B at the TSF were last sampled in October 2016.

An additional number of exceedances with respect to livestock drinking water quality guidelines were identified by the IM. These relate to results at both the McArthur River Mine and the Bing Bong Loading Facility and are summarised in Table 4.26. The locations of bores with particularly elevated SO_4 and TDS concentrations (based on groundwater trigger values) are shown in Figure 4.22 for the mine site and Figure 4.23 for Bing Bong Loading Facility.

Table 4.26 – Groundwater Quality Exceedances not Reported by MRM

Analyte	Stock Limit (mg/L)	McArthur River Mine	Bing Bong Loading Facility
Calcium	1,000	NA	GWBB009A, GWBB009B, GWBB010A, GWBB010B, GWBB05C, GWBB06C, GWBB07B, GWBB08C
Magnesium	2,000	GW017-009, GW095S, GW159S	GWBB009A, GWBB009B, GWBB010A, GWBB010B, GWBB05C, GWBB06C, GWBB08C
Sulfate	2,000	GW SS6-1, GW SS6-2, GW003A, GW004, GW014, GW016, GW017-004, GW017-005, GW017-006, GW017-007, GW017-008, GW017-009, GW018, GW019, GW020A, GW020B, GW021, GW043A, GW043B, GW044, GW045B, GW047B, GW047C, GW048, GW049, GW050, GW051, GW052A, GW052B, GW056, GW058, GW059, GW062, GW063, GW064D, GW064S, GW065D, GW065S, GW087D, GW088D, GW090, GW092A, GW093, GW094D, GW095D, GW095S, GW096D, GW096S, GW097, GW100, GW102, GW103D, GW104D, GW104S	GWBB009A, GWBB009B, GWBB010A, GWBB010B, GWBB02, GWBB03A, GWBB03B, GWBB04B, GWBB05A, GWBB05B, GWBB05C, GWBB06C, GWBB07B, GWBB08A, GWBB08B, GWBB08C
Sulfate (ongoing)	2,000	GW105, GW109, GW109B, GW110, GW110B, GW115B, GW116, GW118, GW125D, GW128, GW129D, GW136, GW137, GW138A, GW138B, GW138C, GW139, GW140A, GW140B, GW141A, GW141B, GW142A, GW142B, GW143D,	

Table 4.26 – Groundwater Quality Exceedances not Reported by MRM (cont'd)

Analyte	Stock Limit (mg/L)	McArthur River Mine	Bing Bong Loading Facility
Sulfate (ongoing) (cont'd)		GW143S, GW144D, GW145D, GW145S, GW149D, GW152D, GW152S, GW153D, GW153S, GW154B, GW159D, GW159S	
TDS	5,000	GW SS6-1, GW SS6-2, GW004, GW014, GW017-004, GW017-005, GW017-006, GW017-007, GW017-008, GW017-009, GW018, GW019, GW020A, GW020B, GW021, GW043A, GW043B, GW044, GW045B, GW047B, GW047C, GW048, GW049, GW050, GW051, GW052A, GW052B, GW056, GW062, GW063, GW064D, GW064S, GW065D, GW065S, GW087D, GW088D, GW090, GW092A, GW093, GW094D, GW095D, GW095S, GW096D, GW096S, GW097, GW100, GW102, GW105, GW109, GW109B, GW110, GW110B, GW115B, GW116, GW125D, GW128, GW129D, GW132, GW136, GW138A, GW139, GW140A, GW140B, GW141A, GW141B, GW142A, GW142B, GW144D, GW145D, GW145S, GW154B, GW158D, GW158S, GW159D, GW159S	GWBB009A, GWBB009B, GWBB010A, GWBB010B, GWBB01A, GWBB01B, GWBB02, GWBB03A, GWBB03B, GWBB04B, GWBB05A, GWBB05B, GWBB05C, GWBB06C, GWBB07A, GWBB07B, GWBB08A, GWBB08B, GWBB08C
Boron	5	GW105, GW132	GWBB03B, GWBB04B
Fluoride	2	GW004, GW006, GW014, GW015, GW017-004, GW017-005, GW017-006, GW017-007, GW017-008, GW018, GW042A, GW043B, GW044, GW049, GW061, GW062, GW063, GW065D, GW065S, GW090, GW094D, GW095D, GW095S, GW096D, GW096S, GW097, GW099D, GW099S, GW100, GW102, GW105, GW106, GW115B, GW119D, GW119S, GW126S, GW128, GW132, GW134, GW141A, GW141B, GW154B	GWBB009A, GWBB009B, GWBB010A, GWBB010B, GWBB01A, GWBB01B, GWBB04B, GWBB05C, GWBB06A, GWBB06B, GWBB06C, GWBB07A, GWBB08C
Lead	0.1	GW015, GW122D, GW122S, GW130	NA
Mercury	0.002	NA	GWBB010B
Selenium	0.02	GW110, GW128	GWBB009B, GWBB010B, GWBB05C

Note: NA=not applicable.

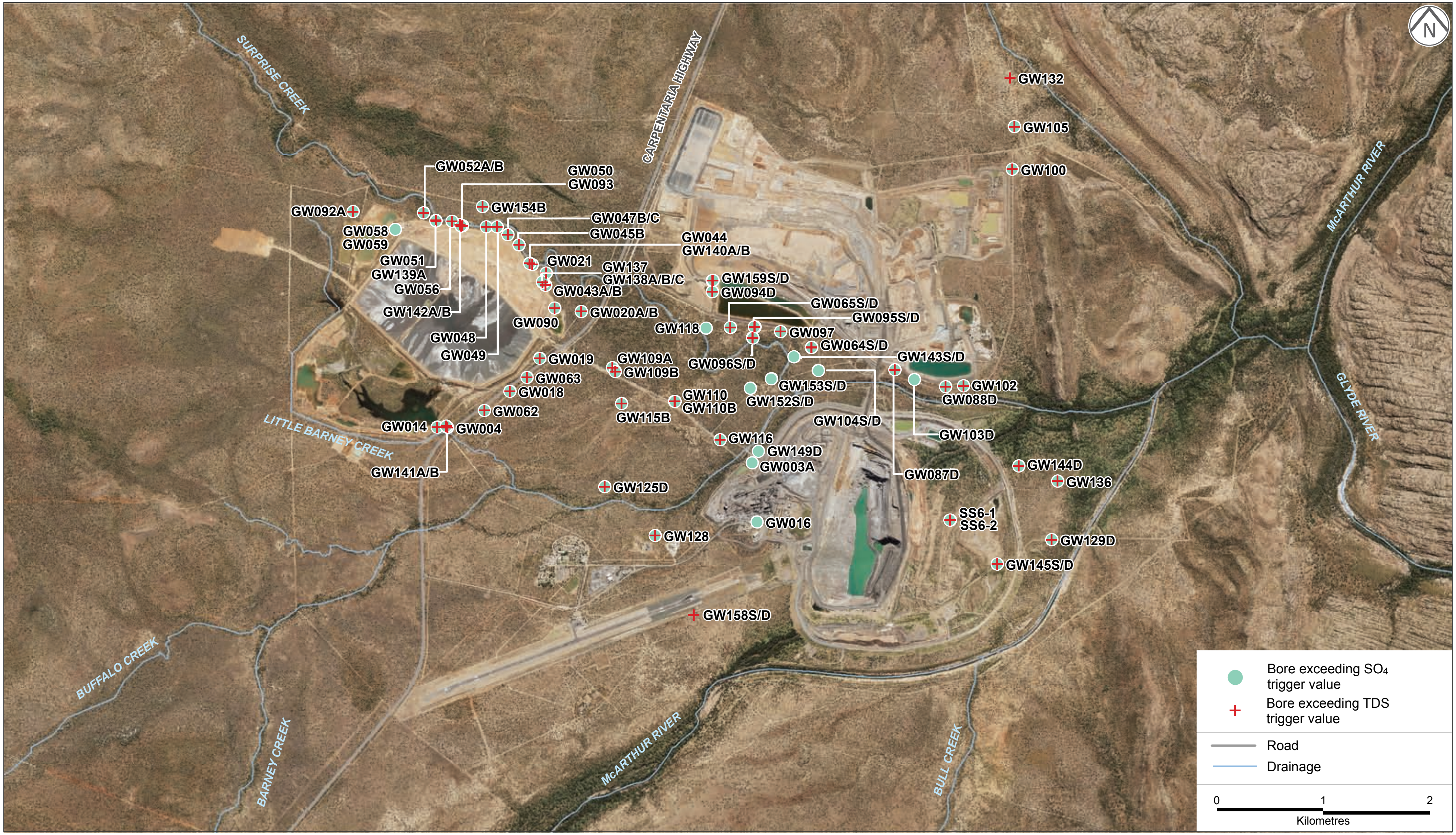
The locations of the mine site monitoring bores showing exceedances in SO_4 and TDS are consistent with seepage from the TSF, SPROD and NOEF. They also correlate to high EC values in surveys of water quality along Surprise Creek and Barney Creek conducted during the 2015-2016 reporting period.

A significant number of the bores at the Bing Bong Loading Facility exceeded the livestock limits for TDS, SO_4, Ca and F. However, the general groundwater quality at the loading facility indicates that the site is naturally affected by mixing groundwater with marine water and possibly evaporative concentration of salt where groundwater levels lie close to surface immediately south

GROUNDWATER TOTAL DISSOLVED SOLIDS AND SULFATE EXCEEDANCES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.22



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GROUNDWATER TOTAL DISSOLVED SOLIDS AND SULFATE EXCEEDANCES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.23

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of the dredge ponds. Under these conditions, the use of stock limits as trigger values is considered inappropriate and the IM recommends that site-specific trigger values (SSTVs) be developed (see Table 4.28). It is noted that MRM has committed in the 2016-2017 OPR and 2017-2018 OPR to develop SSTVs as part of the Groundwater Management Plan, which is scheduled for the third quarter (Q3) 2018.

4.5.4.2 Progress and New Issues

One new issue was identified during the review, and this relates to the declining groundwater quality near the SPROD, especially at bore GW95S where Zn concentrations have triggered a non-compliance. The source of the contamination has not been identified, but most likely relates to ongoing seepage from the SPROD. The IM notes that MRM is planning to install a synthetic liner at the dam, which should improve the nearby groundwater quality, although this will need to be confirmed with ongoing monitoring.

Significant progress was made over the review period, much of it associated with the work undertaken for the OMP SEIS, which included:

- A comprehensive review of historical geological, geochemical and geophysical datasets (Section 4.5.3.2), which has assisted in identifying faults and fault zones that may be hydrogeologically significant, and in the drill-hole targeting for a subsequent field program.
- A detailed field program of drilling, aquifer testing and groundwater sampling in the vicinity of the NOEF and TSF (Section 4.5.3.2), which has helped to characterise the groundwater environment (e.g., the influence of faults and connectivity to surface water features) and aquifer units (e.g., the predominance of unconfined conditions and dual porosity effects), as well as providing estimates of aquifer properties.
- Updating of the conceptual hydrogeological model for the McArthur River Mine and the site-wide numerical groundwater flow and contaminant transport model, which was used to assess impacts on the groundwater and surface water environments as part of the OMP SEIS.
- The identification of previously unidentified surface water inflows to the pit during the 2017/18 wet season (MRM, 2018a). These flows could contribute to the high mine dewatering rates measured during the wet season, which may in turn enable MRM to introduce further surface water controls and reduce abstraction from the pit and underground and (more importantly) the management requirements for poor quality mine water. However, further investigations are required to quantify the flow rates and correlate them with pumping records.
- Groundwater monitoring at the McArthur River Mine and Bing Bong Loading Facility has been improved with the installation of new monitoring bores and equipping of selected bores with loggers.
- Continued remediation of the diesel spill with further product recovery and no evidence of offsite impacts.

McArthur River Mining's performance against previous IM review recommendations relating to groundwater management, excluding those that have been flagged in previous IM reports as being completed, is outlined in Table 4.27.

Table 4.27 – Groundwater Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
OEF	Groundwater investigations are required south of the SEPROD and north of the Barney Creek diversion channel to identify the cause of deteriorating groundwater quality, particularly in bore GW102, and identify a suitable mitigation strategy. The investigations should include a field program to: ♦ Delineate the extent of the contamination ♦ Identify possible aquifer pathways ♦ Identify possible sources	Ongoing Field investigations were carried out in the vicinity of the SEPROD to further develop the conceptual hydrogeological model at the McArthur River Mine (Section 4.5.3.2). However, the investigations failed to identified the source of the poor water quality in bore GW102. The site water balance estimates very low seepage rates from the SEPROD. This suggests contamination from other sources, possibly nearby sumps and drains or the NOEF The source of this contamination needs to be identified and suitable controls applied
	Assessment of seepage impacts from the NOEF to confirm the effectiveness of the PAF containment system This should include installation of monitoring bores around the current footprint and progressive installation of monitoring bores around the expansion area and completion of EM geophysical surveys The IM recognises that MRM has commenced installation of monitoring bores in the area marked for NOEF expansion. However, there are no monitoring bores located along the northern, eastern and western perimeters of the facility, which could be used to assess the success of the PAF encapsulation system adopted by MRM In addition, a schedule should be prepared showing the progressive installation of future monitoring bores in the NOEF expansion area, which should correspond to the planned development of the facility The seepage from the SPROD needs to be addressed. McArthur River Mining should commit to option(s) to prevent seepage at source. This work is likely to include a commitment to design and install a full liner at the dam	Ongoing McArthur River Mining has installed bores around the NOEF, with 10 new bores installed over the review period. The current monitoring bore distribution is considered sufficient for general monitoring of the groundwater conditions around the NOEF. However, additional bores will be required where seepage impacts are identified, e.g., around the SPROD, where falling pH values and rising Zn concentrations have been observed, and near the SEPROD where high SO_4 concentrations have been measured
Seepage from storages	The various storages across the mine site and Bing Bong Loading Facility are potential sources of contamination. The IM recommends that the site-wide water balances developed by WRM should be used to estimate seepage rates from	Completed Seepage rates from storages are discussed in the 2017-2018 OPR

Table 4.27 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Seepage from storages (cont'd)	the storages. These estimates should be included in the groundwater monitoring report. Further investigations should be carried out where high seepage rates are estimated	
TSF	The seepage from TSF Cell 1 needs to be addressed. McArthur River Mining should commit to option(s) to prevent seepage at source, e.g., installation of a permanent cover designed to limit recharge to the deposited tailings or reprocessing of the tailings McArthur River Mining has installed a temporary cover, which the available monitoring data suggest is (so far) ineffective in controlling recharge to the deposited tailings. The continued exceedances in salinity and SO_4 concentrations in a number of monitoring bores contravene the groundwater trigger values for the mine site. The seepage along the southeastern perimeter of the TSF Cell 3 WMD needs to be addressed. McArthur River Mining should commit to option(s) to prevent seepage under this section of the embankment which likely relates to the presence of higher permeability alluvium associated with the original Little Barney Creek channel. Preventative options include installation of an interception trench across the original channel and installation of recovery bores McArthur River Mining has already installed a geopolymer barrier along the southeastern wall of the Cell 3 WMD and a recovery sump within the original Little Barney Creek channel. The continued exceedance in SO_4 concentrations in bores GW04 and GW14 indicate these measures are inadequate. The importance in addressing the seepage issue is highlighted by MRM's intention to use the dam to store treated poor quality mine water and process water and potential overflow from the TSF as part of the mine water management strategy The seepage from the southeastern corner of TSF Cell 2 needs to be addressed. McArthur River Mining should identify suitable options to mitigate this seepage. Preventative options include installation of recovery bores to augment the existing interception trench and geopolymer barrier The importance of addressing this issue is highlighted by MRM's intention of using the active TSF cell to store contaminated water as part of their mine water management strategy	Ongoing A field program has recently been completed mostly centred around Surprise Creek north of the TSF and south and southeast of the NOEF. The study included: ♦ Extensive field investigations (drilling, sampling and aquifer testing) ♦ Updating the conceptual hydrogeological model and site-wide numerical groundwater flow and contaminant transport model, including the area around the TSF ♦ Developing detailed designs for the interception system between TSF Cell 1 and Surprise Creek The IM recommends that further investigations be undertaken east of the TSF where the impacts from long-term seepage are evident It is understood that MRM plans to install the TSF Cell 1 interception system this year, which will assist in managing seepages through the overburden, but may be less effective in managing deeper groundwater flows The effectiveness of the planned interception system will need to be assessed as part of future groundwater monitoring reports

Table 4.27 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
TSF (cont'd)	The tailings stored in TSF Cell 1 should be removed for reprocessing	Ongoing The preferred closure option, under the Draft OMP EIS, is to reprocess and store tailings in the open pit at closure. If this option is confirmed then the recommendation will be satisfied
	A limestone or calcium-rich cover should be installed on the TSF	Ongoing McArthur River Mining plans to amalgamate Cells 1 and 2, as part of the life of mine tailings management option, as well relocate the tailings to the pit void at closure. There will be no requirement to cover the TSF if these options are approved
	Kinetic tests should be carried out to estimate the attenuation characteristics of the alluvium underlying the TSF	Deleted The IM recommends that the effects of attenuation be assessed through further calibration of the numerical groundwater flow and contaminant transport model, rather than laboratory testing
Open pit and underground mine	It is recommended that MRM continue to investigate options to dewater aquifers responsible for inflows to the pit and (in particular) the former underground mine. The high inflow rates estimated from water volume increases during the wet season strongly indicate the presence of high permeability aquifers, likely linking McArthur River to the underground mine. There could be significant benefit in reducing the requirement to manage contaminated mine water if groundwater inflows to the mine can be reduced, assuming the quality of the intercepted groundwater is sufficient to enable controlled environmental release The investigation could include an assessment of possible aquifer locations based upon the recorded locations of groundwater inflows to underground mine, and the interpretation of geological, structural and geophysical information. It is suggested that groundwater exploration drilling be conducted using reverse circulation methods with drill holes orientated to maximise the likelihood of intercepting groundwater features geological, structural and geophysical information. It is suggested that groundwater exploration drilling be conducted using reverse circulation methods with drill holes orientated to maximise the likelihood of intercepting groundwater features	A review of the available geological, geochemical and geophysical has been completed, but failed to delineate geological structures that could provide a pathway from nearby watercourses to the pit/underground mine. No groundwater exploration drilling has been reported Observations during the 2017/18 wet season suggest that previously unaccounted surface water inflows to the pit may be contributing to the wet season high mine dewatering rates. It is recommended these flows be quantified during the 2018/19 wet season and correlated with the pumping record

Table 4.27 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Borefields	Constructing hydrographs of pressure levels in all borefield abstraction bores and nearby observation bores, including rainfall and abstraction volumes and rates	Completed Hydrographs for production and nearby monitoring bores were provided in the 2017-2018 OPR
	Assessing data such as recovery rates following cessation of pumping and drawdown rates during constant discharge	Ongoing An assessment of the recovery rates for monitoring bore WZ-C1 located adjacent to W-WZ1P was provided in the 2017-2018 OPR. Assessments of the remaining production bores were not sighted. These should be provided in future groundwater monitoring reports
Trigger limits, data interpretation and reporting	McArthur River Mining and its consultants have undertaken a large amount of field work over the last two review periods, but the results from these investigations are not always adequately reported. It is recommended that a summary be provided either in the operational performance report or groundwater monitoring report. The summary should include details of the drill holes and bores completed, descriptions of the hydraulic tests undertaken and the test results, groundwater quality analyses and interpretation of the findings	Not sighted in the 2016-2017 OPR or 2017-2018 OPR
	A strong reliance will be placed on groundwater modelling to assess controls. It is therefore recommended that all groundwater models be reviewed by a specialist modeller to help ensure: ♦ Adequacy of the conceptual hydrogeological model as a basis for a numerical model given the outcomes being sought ♦ Suitable construction using appropriate boundary conditions, mesh sizes and stress periods/time step lengths ♦ Adequate model calibration to both steady-state and transient data ♦ Adoption of suitable initial conditions ♦ Identification and understanding of model uncertainties	The table of groundwater commitments provided in the 2017-2018 OPR has identified this recommendation as completed. However, no report on the review has been sighted
	The use of water quality guideline limits for stock watering is considered inappropriate given the background groundwater quality variation, particularly at the Bing Bong Loading Facility. It is recommended that the available water quality data be used to develop trigger values that reflect this variation and the surrounding ecosystems and environment in accordance with the approach presented in ANZECC/ARMCANZ (2000)	Ongoing McArthur River Mining proposes to develop SSTVs for all monitoring bores, based on standard deviations in conjunction with control charts (MRM, 2018a). A revised bore classification is also proposed based on compliance and diagnostic bores The suitability of the proposed scheme, once finalised, should be assessed as part of future IM reviews

Table 4.27 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Trigger limits, data interpretation and reporting (cont'd)	A review should be carried out on the commitments presented in the MMP to include all MRM commitments, remove any duplicates and (where required) clarify wording The commitments are currently presented over a number of sections and include repetitive comments from third parties. Clarification of MRM's commitments would assist in identifying where breaches have occurred	Ongoing A listing of MRM's groundwater monitoring commitments was provided (MRM, 2017f). It is recommended that these commitments be summarised along with any other commitments (e.g., groundwater trigger values) in future MMPs/ OPRs and annual groundwater reviews. The IM notes that 'Summary of all groundwater commitments presented in future MMPs and annual groundwater reviews' is included in the compliance register
	McArthur River Mining should commit to reporting all breaches of their groundwater commitments to the DPIR. In particular, there appears to be an acceptance that exceedance concentrations of SO_4 and salinity in areas previously affected by seepage do not warrant reporting	There appears to be minimal change with respect to reporting breaches of MRM's commitments. This issue should be addressed in future MMPs and operational performance reports The IM notes that MRM is developing SSTV (discussed above), which, when finalised, should be used to identify non-compliances
Site-wide conceptual hydro-geological model	A site-wide conceptual model is required to provide a better understanding of the impacts upon the general environment from potential sources of contamination. This will require the following: ♦ Field investigations to (i) confirm the presence of the overburden/alluvial, weathered bedrock and fresh rock aquifers, and features associated with preferred groundwater pathways, and (ii) estimate the hydraulic properties of these hydrogeological units. The field investigations should include: – Groundwater exploration drilling – Installation of test bores – Hydraulic testing of newly-installed bores, comprising either full-scale pumping tests (where flows are sufficient) or small-scale permeability test for lower yielding bores ♦ Integration of this information with other field studies at the pit, TSF and NOEF (as recommended above) ♦ Collaboration with other disciplines to facilitate the incorporation of any additional hydrogeological information into the conceptual model and help ensure that a consensus is reached, thereby promoting the use of a single model when assessing impacts and controls	Ongoing A significant amount of progress was made during the review period. However, this work needs to continue as data becomes available. Key uncertainties where further field studies are recommended include: ♦ Possible pathways to the underground mine, including pathways from McArthur River and Barney Creek ♦ The influence of the Western Fault Block north of the pit where karst features have been identified ♦ The hydrogeological conditions around the ELS, where high SO_4 concentrations in groundwater persist and contamination of the nearby McArthur River diversion channel is evident ♦ The influence of the Emu Fault both east of the pit and north of Barney Creek

Table 4.27 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Diesel spill	It is recommended that diesel spill monitoring bore URS03, which was destroyed during the review period, be replaced and an additional monitoring bore be installed east or northeast of bore URS17 to increase the coverage to the east and northeast of the plume	Deleted Ongoing monitoring of the diesel spill and recent reviews by KCB (2018b and 2018c) indicate the free phase LNAPL and dissolved hydrocarbon plumes are static, the LNAPL thickness is likely reducing, and the probability of the plumes migrating to Barney Creek is low. On this basis the IM's view is that the current monitoring bore network is sufficient. It is also recommended that DPIR considers the reductions in the monitoring and reporting program suggested by MRM and KCB

4.5.4.3 Successes

Significant progress was made on many issues during the review period (see Section 4.5.4.2). However, none of the issues, the majority of which are long term and affect large areas of the mine site, have been resolved.

4.5.5 Conclusion

A summary of the findings during the review period is provided below:

- Collation and review of historical geochemical datasets:
  - A review of historical geochemical datasets was undertaken to identify areas of natural mineralisation.
  - The review was unable to provide reliable information on the location of mineralised areas that might be associated with high concentrations of SO_4 in the monitoring bores located east of the TSF or near Emu Creek north of the NOEF.
  - Further investigations are recommended.
- Collation, processing and review of recent and historical geophysical and drill hole data:
  - A review of historical and recent geophysical and geological datasets was undertaken to identify and characterise faults, and identify permeable zones and hydrogeological drilling targets.
  - Seven fault or fault zones were identified and the majority characterised as either aquifers or aquitards.
  - One previously inferred fault (Surprise Fault) was not confirmed.

  - Various hydrogeological target areas were identified which were tested as part of subsequent field investigations.

- Geological/hydrogeological field investigations carried out in 2016 and 2017:

  - An extensive geological and hydrogeological field program was carried out in 2016 and 2017, including drilling, installation of bores and vibrating wire piezometers, and hydraulic testing.

  - The results indicate that: the McArthur River Mine is generally associated with low permeability conditions with a potential for rapid groundwater flow along discrete pathways, which results in a compartmentalised groundwater system; faults do not appear to act as barriers to groundwater flow; and the connection between the groundwater and surface water systems is limited. The results also suggest that geophysical surveys are moderately successful in identifying groundwater targets,

- An independent review by the NOEF Independent Review Board (NIRB) of potential impacts from the NOEF and remedial options:

  - An independent review was completed which included an assessment of MRM's monitoring program, an assessment of remedial options to reduce risk and harm to environmental receptors, and a final report.

  - A number of revisions to MRM's monitoring program were recommended, which have generally been accepted by DPIR and MRM and are in the process of being instigated.

  - A remedial option focussing on pathway interruption was proposed, comprising installation of a seepage interception system between the NOEF and the Barney Creek diversion, which was refined using the site-wide numerical groundwater flow and contaminant transport model.

  - The IM recommends this option be further assessed along with the environmental values associated with the Barney Creek diversion channel.

- Further development of the site-wide conceptual and numerical groundwater flow models, completed as part of the OMP SEIS:

  - The site-wide numerical groundwater flow and contaminant transport model was updated as part of the OMP SEIS, which included revision of seepage rates from the NOEF, inclusion of hydrogeological features identified it the 2016-2017 field program, and model recalibration.

  - The modelling results are consistent with the Draft OMP EIS, e.g., reduced baseflows to McArthur River and Barney Creek during mining from continued pit dewatering, pit inflows peaking at about 40 L/s, continued SO_4 seepage down hydraulic gradient of the TSF and OEFs, limited migration of metals because of attenuation, increasing SO_4 loads to Surprise Creek from the TSF (operations) and the Barney Creek diversion channel from the NOEF (operations and closure), and drawdowns of less than 0.7 m at Djirrinmini Waterhole.

  - The main uncertainties included groundwater inflows to the underground mine, the locations of naturally mineralised zones, and the long-term attenuation of metals and whether this will limit metals migration.

- Improvements to the site monitoring infrastructure:

  - A number of new monitoring bores were installed at the McArthur River Mine and a number of bores equipped with data loggers to collect high frequency groundwater level and EC readings.

- Assessment of seepage impacts from the ELS:

  - McArthur River Mining undertook an assessment of the potential seepage impacts from operation of the ELS on water quality in McArthur River.
  - The assessment proposed that impacts on the river water quality could have been due to physical loading following impoundment of mine water at the ELS, based on response times.
  - The IM does not concur with this outcome.
  - This issue is considered significant because of the juxtaposition of the proposed EOEF and the ELS, and further assessment is required to ensure adequate seepage controls.

- Ongoing investigations at the site of the 2011 diesel spill near the power station:

  - Ongoing assessment of the diesel spill site by MRM and reviews by KCB indicate that the contaminant plumes are not mobile, the LNAPL plume is likely reducing in thickness, and the risks to Barney Creek are low.
  - The IM concurs with this assessment and recommends that DPIR considers the reductions in the monitoring and reporting program suggested by MRM.

Ongoing and new IM recommendations related to groundwater issues are provided in Table 4.28.

Table 4.28 – New and Ongoing Groundwater Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Open pit and underground mine	The following revised recommendations are made regarding options to dewater aquifers responsible for inflows to the pit and underground mine: ♦ Field investigations should be undertaken to identify groundwater pathways associated with the pit and underground, including the: – Western Fault Block north of the pit – Emu Fault ♦ The field investigations should include groundwater exploration drilling, installation of test bores and hydraulic testing of newly-installed bores (i.e., full-scale pumping tests where flows are sufficient or small-scale permeability test for lower yielding bores) ♦ The conceptual model for the pit and underground should be updated to include the field program results	High

Table 4.28 – New and Ongoing Groundwater Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Open pit and underground mine (cont'd)	♦ Site-wide numerical groundwater flow and contaminant transport model should be updated to identify effective groundwater inflow controls, which may include installation of production bores to intercept groundwater flows towards the pit or underground	
NOEF	The following revised recommendation is made regarding the NOEF: ♦ An assessment should be carried out to identify the source of poor quality groundwater south of the NOEF and SEPROD and north of the Barney Creek diversion channel, particularly at bore GW102, and suitable controls applied	Medium
SPROD	The following revised recommendations are made regarding the SPROD: ♦ A synthetic liner should be installed as a long-term seepage control ♦ Monitoring data collected after the installation of the SPROD synthetic liner should be assessed to confirm that there are no ongoing unacceptable impacts on the surrounding groundwater environment. If elevated concentrations of SO_4 and Zn persist then further investigations will be required to identify the contaminant source	High
TSF	The following revised recommendations are made regarding the assessment of seepage impacts around the TSF: ♦ Further field investigations should be undertaken to better identify groundwater pathways around the TSF where high concentrations of SO_4 and TDS persist and estimate their hydraulic properties. The IM notes that the groundwater commitments register presented in the 2017-2018 OPR has identified this commitment as having been completed. However, the recent field program was centred around Surprise Creek north of the TSF. Further assessment is required along the eastern boundary of the TSF where the impacts from long-term seepage are evident. These investigations should include: – Groundwater exploration drilling to identify pathways – Installation of test bores – Hydraulic testing of newly-installed bores, comprising either full-scale pumping tests (where flows are sufficient) or small-scale permeability test (for lower yielding bores) ♦ The conceptual model for the TSF should be updated to include the field program results ♦ The updated conceptual model should be used to revise the TSF groundwater model and the revised model used to estimate current and future seepage impacts as well as suitable mitigation options both during operations and after closure. The simulations should include all TSF closure options being considered by MRM	High
General data interpretation and reporting	A summary of all groundwater commitments should be presented in future MMPs and operational performance reviews. The information presented the 2016-2017 OPR and 2017-2018 OPR needs to be expanded to include a summary of the groundwater monitoring commitments, both site wide and for the 2011 diesel spill, and other actions related to the diesel spill. SSTVs should also be included once they become available	Low
	Site-specific trigger values need to be developed for all groundwater monitoring sites to facilitate data interpretation and identification of unacceptable impacts, with these SSTVs being assessed in future IM reviews	Medium

Table 4.28 – New and Ongoing Groundwater Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
General data interpretation and reporting (cont'd)	McArthur River Mining should commit to reporting all breaches of their groundwater commitments to DPIR. In particular, there appears to be an acceptance that exceedance concentrations of SO_4 and salinity in areas previously affected by seepage do not warrant reporting	Low
New Items		
Surface water runoff inflows to the pit	An assessment of the recently identified surface inflows to the pit is recommended during the 2018/19 wet season, which should include field measurements of flow rates and observations of flow durations. These should be included in the pit and underground mine water balance to better estimate the groundwater contribution to the mine dewatering requirements. Efforts should also be made to improve the surface water controls around the pit to prevent unnecessary inflows and reduce the requirements to manage poor quality mine water	High
Seepage processes at the ELS	A recent assessment by MRM proposed that historical seepage from the ELS to McArthur River may have been due to physical loading affects (Section 4.5.3.2). The IM believes this may not be the case. It is recommended that further investigations be undertaken to determine the seepage processes, because of the juxtaposition of the proposed EOEF and the ELS, and possible future seepage impacts on McArthur River. The investigations should include a field program to identify possible aquifer pathways and estimate aquifer properties. The results of the field program should used to assess the adequacy of the seepage control measures at the EOEF	High
Attenuation of metals	The recent site-wide numerical groundwater flow and contaminant transport modelling carried out for the OMP SEIS (Section 4.5.3.2) suggests limited migration of metal contaminant plumes, because of attenuation. The long-term effectiveness of attenuation processes, particularly given the potential for rapid groundwater flow along discrete pathways, needs to be confirmed through further model calibration. It is recommended this be undertaken as part of the site's commitments, possibly as part of future MMPs	High
Natural mineralisation	Further studies are required to identify the source of high SO_4 concentrations in groundwater away for mine-related activities (e.g., east of the TSF and northeast of the NOEF near Emu Creek, which MRM relates to areas of natural mineralisation	High
NOEF interception trench	The option to install a seepage interception system between the NOEF and the Barney Creek diversion channel should be considered in accordance with the recommendations from the NIRB (Section 4.5.3.2). This should be undertaken in conjunction with an assessment of the environmental values associated with the Barney Creek diversion channel	Moderate
Assessment of groundwater level and quality trends	The 2016-2017 OPR included an assessment of the recorded groundwater level and quality trends using statistical methods (e.g., the Mann-Kendall test). The IM believes that this approach adds value, assisting in the screening of monitoring data and identification of environmental impacts. It is therefore recommended that future operational performance reports include this approach	Low
Groundwater model review	The review of groundwater models should be included in the information provided to the IM	Low
Diesel spill	DPIR should consider the reductions in the monitoring and reporting program suggested by MRM and KCB	Low
Borefields	An assessment of the recovery rates should be carried out on all water supply bores	Low

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4.6 Geochemistry

4.6.1 Introduction

The McArthur River Mine deposit includes some of the most strongly pyritic materials observed by the IM, and mine waste geochemistry (and its implications) remains the most significant environmental issue for the site. In addition to acid, metalliferous and saline drainage (AMD) issues, some mine materials have spontaneous combustion potential where there is abundant fine-grained pyrite and organic carbon. McArthur River Mining has made considerable progress in regard to understanding the AMD potential and leaching kinetics of mine materials (including waste rock, tailings, open cut walls/void and stockpiles) in recent years. This, together with more thorough definition of surface and groundwater AMD transport pathways, has enabled development of better and more defensible geochemical modelling and prediction of potential short- and long-term impacts. McArthur River Mining's proposed AMD management strategies have evolved over the last five years with increasing knowledge. The current proposed approaches to AMD management are detailed in the Draft Overburden Management Project Environmental Impact Statement (OMP EIS) (MRM, 2017a) and Overburden Management Project Supplementary Environmental Impact Statement (OMP SEIS) (MRM, 2018a). The OMP SEIS also reports on the bulk of geochemical investigations carried out in the current IM reporting period.

This section addresses MRM's performance during the reporting period with regards to monitoring and management of geochemistry, and is based on:

- Observations and discussions with MRM personnel during the site inspection.
- Various reports prepared by MRM and consultants, with particular reference to the 2016-2017 OPR (MRM, 2017b) and 2017-2018 OPR (MRM, 2018b), and geochemical investigations carried out as part of the Draft OMP EIS, MRM 2017a).
- Excel spreadsheets provided by MRM that contain collated laboratory and in situ data.
- Various MRM documents such as procedures and manuals (MRM, 2018c; 2018d; 2018e), incident registers, and correspondence between MRM, regulators and third parties.

4.6.2 Key Risks

Since the last IM report, MRM has further advanced geochemical studies and investigations in support of the OMP SEIS. This has addressed many of the AMD concerns raised by the ERIAS Group review of the Draft OMP EIS (ERIAS Group, 2017a), and has resulted in a much-improved approach to long-term management. However, because the strategies outlined in the Draft OMP EIS and OMP SEIS have yet to receive regulatory approval, the main geochemical risks remain largely unchanged from the last IM report.

The NOEF, TSF and open pit contain reactive and highly pyritic materials, and represent the key potential sources of AMD, and inadequate management of seepage/run off during operations and/or failure or non-implementation of closure mitigation strategies could result in long-term impacts on groundwater and terrestrial and aquatic ecosystems in perpetuity. These are outlined below.

NOEF

- Inadequate management of seepage during operations and failure or non-implementation of closure strategies could lead to saline and metalliferous neutral drainage and localised acid drainage impacts in perpetuity on groundwater, and terrestrial and aquatic ecosystems. There are a number of uncertainties in regard to performance of the proposed geosynthetic liner (GSL) cover system relating to constructability, erosion control, service life, sensitivity to temperature, effects of differential settlement, and potential for slope failure due to saturation of the GSL protection layer, which will need to be addressed with trials and further investigations.

- A major factor that contributes to the above risk is historic end-dumping of potentially acid-forming (PAF) materials that has resulted in segregation of coarse and fine materials and creation of chimney structures that encourage rapid convective oxidation (including spontaneous combustion), promoting greater rates of sulfide oxidation and release of AMD. It is uncertain how effectively the advection covers being installed will control rapid oxidation in these actively convecting zones.

TSF

- Inadequate management of seepage during operations and failure or non-implementation of closure strategies could lead to tailings leachate reporting to groundwater and ultimately to surface drainage down-gradient, impacting groundwater and terrestrial and aquatic ecosystems. Tailings process water will be the key source of contamination during operations, resulting in neutral pH saline and metalliferous leachate, but in the long term the tailings are highly pyritic and acid forming, and will produce acid leachate with high salinity and metal/metalloid concentrations if oxidation is not controlled. The proposed pit backfill and inundation of tailings would greatly reduce the AMD risk.

Open Pit

- Failure or non-implementation of closure strategies could lead to acid and/or saline and metalliferous pit water after closure due to oxidation of exposed pyritic PAF and non-acid-forming (NAF) materials in-pit walls or backfill, resulting in local impacts on flora and fauna and potential impacts on surface water quality through overtopping and groundwater through seepage, thereby affecting terrestrial and aquatic ecosystems.

4.6.3 Controls

The IM review of geochemical performance at McArthur River Mine considered controls on AMD in regard to prediction, classification, monitoring, investigations/reviews and management of mine materials.

4.6.3.1 Previously Reported Controls

As with previous IM reviews, the current IM review identified considerable progress in geochemical prediction, classification and monitoring of mine materials, including:

- Revision and refinement of waste rock classification criteria based on kinetic test results.

- Continuation of kinetic test results.

- Improvements to block modelling, materials tracking and checks.
- Reconstruction of the NOEF waste rock composition and better understanding of the composition of the SOEF and WOEF.
- Groundwater investigations and modelling for the NOEF, SOEF and WOEF.
- Cover design modelling and assessment.
- Modelling of sulfide oxidation loadings for the current NOEF.
- Assessment of optimal PAF dump lift heights.
- Erosion modelling.
- Continued routine geochemical testing of final tailings deposited into the Cell 2 facility.
- Third party review of kinetic test work and analytical results for 200 tailings supernatant samples collected from 6 November 2002 to 3 May 2015.
- Third party review and assessment of the influence of the PBOX process on TSF chemistry.
- Assessment of tailings oxidation and lag times.

Management controls instigated in the previous IM reporting period and described in last year's IM report include:

- Implementation of a well organised system for identification and stockpiling of materials suitable for compacted clay layers (CCLs) and advection barriers.
- Identification of sufficient LS-NAF resources for the proposed life of mine with development of the Woyzbun Quarry.
- Initial construction of advection controls on the West Stage of the NOEF, including placement of a metalliferous saline NAF (MS-NAF) halo around the west, south and east faces, and alluvium covers started on the western face and west part of the southern face.
- Greatly improved control of extreme oxidation events (spontaneous combustion) in new areas with 2-m paddock dumping and traffic compaction of PAF high capacity (PAF(HC)) and PAF reactive (PAF(RE)) materials, and staged placement of advection control layers described above.
- Greatly reduced seepage from the PRODs with clay lining of the NOEF SPSD and NOEF SPROD, consistent with the NOEF SEPROD.
- Continued active beaching of tailings around the perimeter of the cell using multiple spigots, lower water content in the tailings discharge slurry, and removal of excess decant water to improve TSF embankment stability.

4.6.3.2 New Controls – Implemented and Planned

McArthur River Mining carried out additional investigations to better understand the geochemical issues on site and to support the recently submitted OMP SEIS. Management of mine materials has continued to progress since the last IM review, although implementation of the key improvements planned by MRM are awaiting regulatory approval of the management strategies outlined in the Draft OMP EIS and OMP SEIS. New controls are discussed in the following, split according to mine source, and prediction/monitoring and management aspects.

Waste Rock Materials - Geochemical Prediction and Monitoring

Progress on waste rock geochemical prediction and monitoring in the current IM review period includes the following:

- Continuation of kinetic test results.
- Improvements to procedures for materials segregation, tracking and checks.
- Drilling of additional monitoring holes and an updated NOEF temperature monitoring assessment.
- Updated cover design modelling and assessment, and designs for cover trials.
- Alternate modelling of sulfide oxidation loadings for the current NOEF.

The main mine lithostratigraphic units at McArthur River Mine are as follows (MRM, 2017a):

- Hanging wall:
  - Alluvium (Quaternary).
  - Cooley Dolomite.
  - Upper Breccia.
  - Upper Dolomitic Shale.
  - Upper Pyritic Shale.
  - Black Bituminous Shale.
  - Lower Pyritic Shale.
- Orebody: Here's Your Chance Mineralised Shales (Mineralised Interval).
- Foot wall:
  - Lower Dolomitic Shale.
  - W-Fold Shale.
  - Teena Dolomite.

Figure 4.24 shows a simplified cross-section of the above lithostratigraphic units with the Phase 2 and proposed Phase 3 pit outlines. The Black Bituminous Shale is the unit between the Lower Pyritic Shale and Upper Pyritic Shale. The Upper Breccia unit overlies the Upper Dolomitic Shale but is not shown in the figure as it only occurs south of the Woyzbun Fault, restricted to southeast of the pit.

Overburden is split into five classes (MRM, 2017a):

- **Low salinity non–acid-forming high capacity** (LS-NAF(HC)). Considered low risk of generating AMD. Generally characterised by a high acid consumption capacity.
- **Metalliferous saline non–acid-forming high capacity** (MS-NAF(HC)). Considered low risk of generating acid drainage (AD) but higher risk of generating saline drainage (SD) and neutral metalliferous drainage (NMD). Generally characterised by a high acid consumption capacity.
- **Metalliferous saline non–acid-forming low capacity** (MS-NAF(LC)). Considered low risk of generating AD but higher risk of generating SD or NMD. While non–acid-forming, this material is likely to provide limited acid consumption capacity.
- **Potentially acid-forming high capacity** (PAF(HC)). Considered higher risk of generating AD, and is likely to have a significant capacity to do so.
- **Potentially acid-forming reactive** (PAF(RE)). Reactive PAF Material considered high risk of generating AD, and high risk of self-heating which may progress into spontaneous combustion.

As mentioned in the previous IM report, MRM proposes to modify the geochemical waste rock classification scheme in relation to refinement of the metal/metalloids used in the criteria and cut off values for the LS-NAF(HC) class, and introduction of a lithological criterion for the PAF(RE) class (MRM, 2017a). These updated criteria have not yet been implemented, with the 2016-2017 and 2017-2018 OPRs (MRM, 2017b and 2018b) referring to the criteria definitions in the 2013-2015 MMP (MRM, 2015). Justification for the 10%S cut-off to distinguish PAF(RE) from PAF(HC) for Black Bituminous Shale materials with an NPR <1 was not provided, although the IM was advised during the site visit that work on this has progressed.

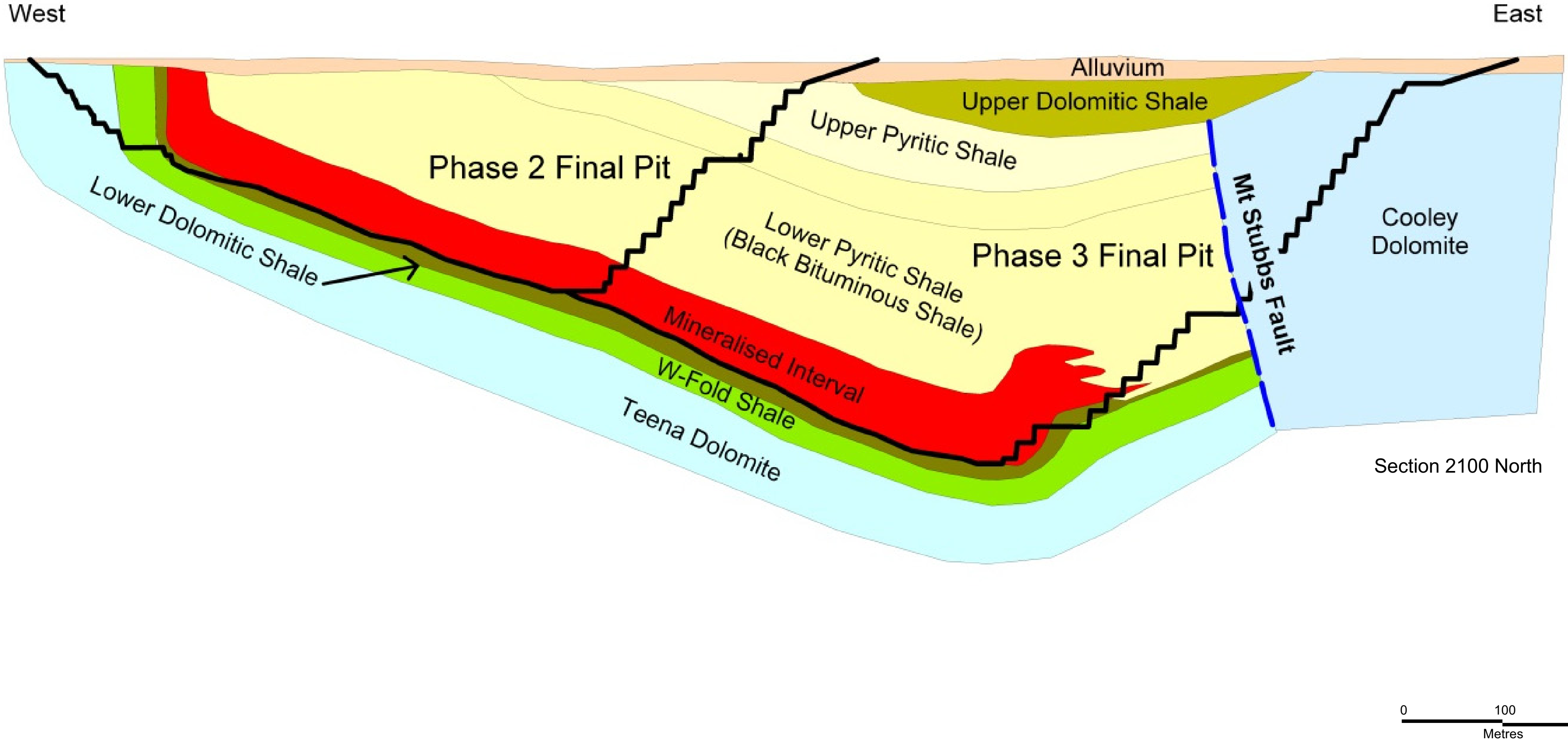
Material classified as PAF hanging wall (PAF(HW)) has 20%S or more but is not Black Bituminous Shale. Currently, this material is handled the same way as PAF(RE) (based on the 10%S cut off), but for the proposed future operational activities it would be stored in the East OEF (EOEF) and re-handled to be placed into the pit for ultimate inundation on mine closure. Both the Draft OMP EIS and OMP SEIS (MRM, 2017a and 2018a) state that this is not a new class since it is for operational purposes only. As per the last IM report, since PAF(HW) materials will be handled differently from other PAF materials, this should be formally included as a separate waste rock class to avoid confusion.

No updated kinetic testing reports were provided to the IM, but the 2017-2018 OPR states that these tests are continuing (Table 46, MRM 2018b).

CROSS-SECTION SHOWING WASTE ROCK TYPES AND OPEN PIT LIMITS

McArthur River Mine Project

FIGURE 4.24



Source: MRM, 2017a.

Classification using in-pit grade control S, Ca, Mg and metals/metalloids test results continues to be the primary means of segregation and selective handing of geochemical rock types. The IM was advised during the site visit that off-site inductively coupled plasma (ICP) analysis (carried out by ALS) is still the main analysis method, but that portable X-ray fluorescence (pXRF) analysis is used 30 to 40% of the time when off-site ICP turnaround is an issue. The IM noted the poor correlations between pXRF and ICP in the 2017 report (ERIAS Group, 2017b), and recommended phasing out use of pXRF. The IM was advised that the on-site laboratory is now NATA-accredited, and quality control work is in progress to allow onsite grade control testing. It was also commented that the testing capacity of the on-site laboratory would be unlikely to keep up with demand, and at this stage external ICP testing will still be required. The IM encourages MRM to continue development of on- and off-site ICP testing to avoid further use of pXRF.

McArthur River Mining provided three procedure updates in regard to materials handling and checks: one relating to ore spotting and grade control procedures (MRM, 2018c), another updating the OEF sampling procedure (MRM, 2018d), and a third updating APS (MRM's GPS fleet management system to track placement of waste rock) load movement validation (MRM, 2018e).

The ore spotting and grade control procedure is an integrated outline of the process of waste and ore segregation, criteria used and approaches, and also clarifies how geology can be used to assist waste rock classification.

The OEF sampling procedure has been updated to include recommendations made in the 2017 IM report (ERIAS Group, 2017b) to improve the sample representativeness of dumped waste rock, which has a large range in particle sizes and high very coarse fraction. The procedure now includes the following:

- Omit clasts greater than 100 mm.
- Collect 2- to 3-kg samples at three random locations for each sample site using a shovel/ pick to 20- to 30-cm depth.
- Composite individual samples into one bulk sample for each site.

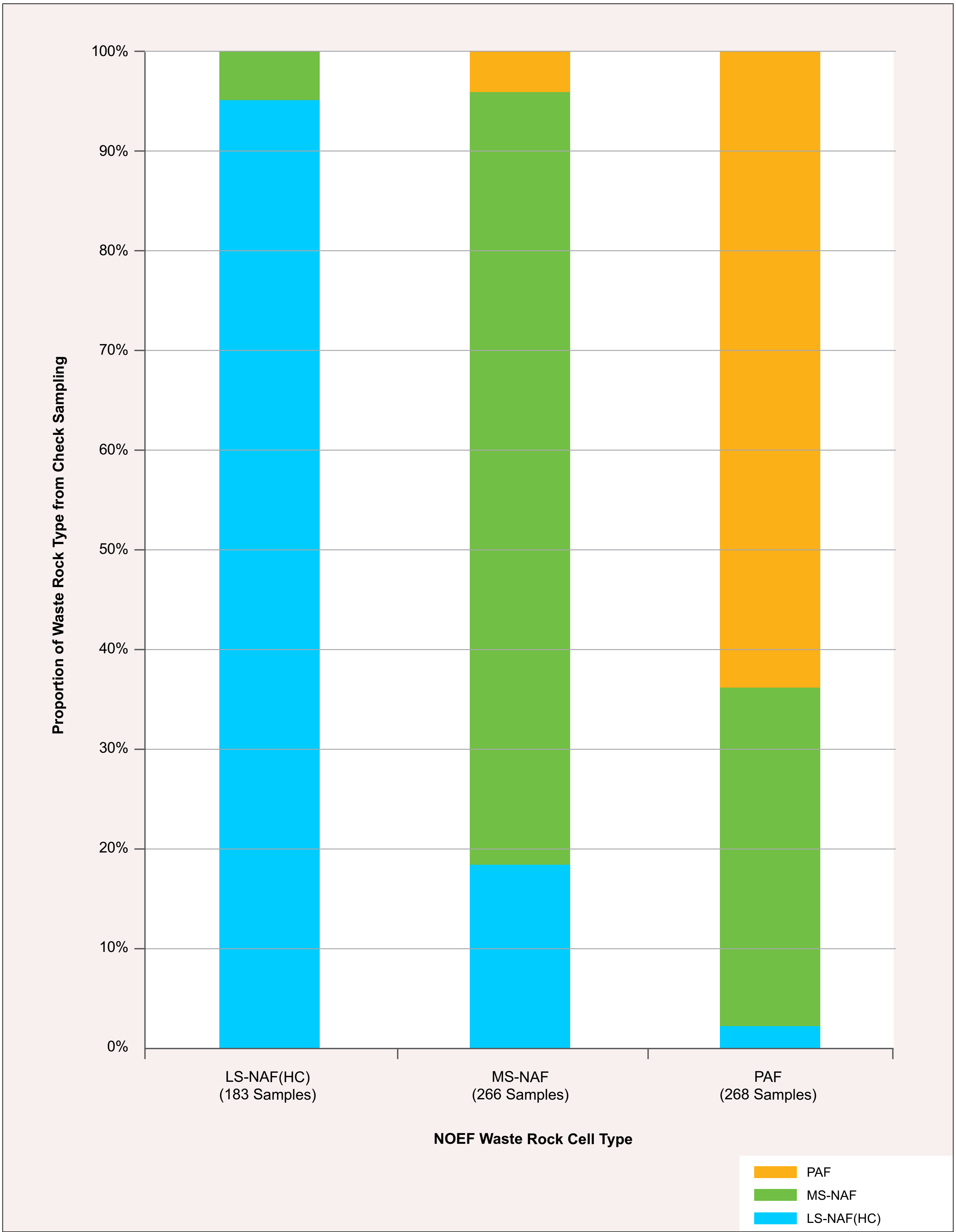
The updated APS load movement validation includes elaboration on the review and decision-making process in cases of non-conformance, addressing IM recommendations from the previous report (ERIAS Group, 2017b).

McArthur River Mining provided results for NOEF check sampling and testing of 717 samples from October 2016 to March 2018. Figure 4.25 shows the proportions of different waste rock types for each waste rock cell in the dump. Results show that 95% of check samples from LS-NAF cells were classified as LS-NAF, with low median S values of 0.09%S and high median acid-neutralising capacity (ANC) values of 260 kg H_2SO_4/t, consistent with criteria (with a high factor of safety) for LS-NAF classification and providing confidence in the overall system of waste rock segregation and handling. This was an improvement in results from the 2016 IM report (ERIAS Group, 2016), in which 80% of check samples from LS-NAF cells were classified as LS-NAF. The MS-NAF cell samples are also generally MS-NAF, and the PAF cell samples mainly PAF. The small amount of PAF material (<5%) within the MS-NAF is unlikely to affect the overall

WASTE ROCK TYPE PROPORTIONS FROM CHECK SAMPLING OF NOEF WASTE ROCK CELLS

McArthur River Mine Project

FIGURE 4.25



geochemical characteristics of the materials placed. The PAF cells include around 30% of MS-NAF materials, most likely reflecting the degree of conservatism used in marking up PAF waste rock types in the pit.

A reconciliation of waste mined against budget was carried out by MRM geologists as part of a general mining reconciliation report (MRM, 2018f). Table 4.29 compares reconciled tonnes of waste with the grade control (GC) and reserve models for the 2017 mine period. The total tonnes actually mined in 2017 were close to both GC and reserve models at 3% greater than modelled, but there were significant differences between mined versus modelled with respect to individual classes. However, these were much improved over the 2016 results provided in the last IM report (ERIAS Group, 2017b).

Table 4.29 – Comparison of Reconciled Waste Tonnes Mined in 2017 with Predictions from the GC Model and Reserve Model

Class	Reconciled Mined (t)	Reserve Model (t)	GC Model (t)	Reserve Difference	GC Difference
Alluvium	2,663,032	2,839,480	2,881,227	-6%	-8%
LS-NAF(HC)	3,743,954	5,143,343	3,983,848	-27%	-6%
MS-NAF(HC)	7,280,965	5,580,534	6,734,182	30%	8%
MS-NAF(LC)	1,083,045	862,190	844,011	26%	28%
PAF(HC)	771,538	1,257,053	1,279,588	-39%	-40%
PAF(RE)	2,941,148	2,299,921	2,259,632	28%	30%
Total	18,483,682	17,982,521	17,982,488	3%	3%

Source: MRM, 2018f.

The reconciled tonnes show much lower PAF(HC) and much higher PAF(RE) than both GC and reserve models, due to a degree of conservatism applied during mining. Currently, PAF(HC) and PAF(RE) are managed in the same way, with 2-m paddock dumping and traffic compaction, but in the Draft OMP EIS and OMP SEIS (MRM 2017a and 2018a), PAF(HC) is proposed to be treated differently, with up to 7.5-m lifts. The IM recommends that the PAF(HC) and PAF(RE) continue to be managed as per current practice, but if there are justifiable changes, accurately distinguishing between PAF(HC) and PAF(RE) in the GC and reserve models will be key input to mine planning. Both GC and reserve models have around 30% less MS-NAF(LC) than mined, but this is not explained in the document. There were also some differences in the modelled proportions of LS-NAF(HC) and MS-NAF(HC) in the GC model versus the reserve model, which are well explained by MRM. Overall, MRM demonstrates appropriate geological understanding of the deposit and strong capability in distribution modelling of waste rock classes.

An update on temperature monitoring was provided in the OMP SEIS (Appendix F, MRM 2018a), which included additional monitoring holes drilled in 2017. Temperature results show evidence of cooling from the extreme combustion conditions previously measured, but still indicate convective oxidation processes, with average temperatures still considered to be high at over 70°C. Temperatures below 40°C would be closer to expected background, depending on the thermal properties of the waste rock materials and ambient air temperatures. Advection control to date may be helping to limit spontaneous combustion but is not stopping rapid oxidation rates and

AMD generation associated with convection. The report demonstrates an improved understanding of gas transport processes.

The OMP SEIS (MRM 2018a) includes a proposed change in the multi-layered cover system for the NOEF that was outlined in the Draft OMP EIS by replacing the compacted clay layer (CCL) with a geosynthetic liner (GSL) in the final cover. Cover system modelling and design considerations are detailed in OKC (2017a) and ICI et al. (2017).

Properly constructed GSLs such as high-density polyethylene (HDPE) and bituminous geomembrane (BGM) can be expected to provide high performance infiltration control over the long term, which is supported by numerical modelling presented in OKC (2017a). The results of the cover modelling predict very low values of net percolation (NP) of less than 5% of rainfall. The numerical model adopted for computing cover performance with respect to surface fluxes, interflow and NP is comprehensive, well defined, and considered highly credible. Furthermore, the parameters selected for the soil-plant-atmosphere continuum are appropriate and defensible. However, the cover modelling does not appear to adequately address slope stability for the base case. Interflow simulations for various 3-day storm events ranging from a 1-in-50 year to a 1-in-1,000 year storm event indicate that saturated conditions are expected to reach the surface of the cover profile. Such events may result in slope failures seated in the loose alluvium above the soil/geomembrane interface. A simple semi-infinite slope stability analysis indicates that the factor of safety (FoS) may decrease to a value less than one or a batter slope of 1:3, depending on the interface friction angle available for the geomembrane material. The minimum FoS must be well above one for this case since such a failure could produce a large-scale liquefaction flow slide. Further detailed analysis and design modifications must be carried out to ensure adequate slope stability for all batter slopes during extreme events. This appears to be at least partly addressed in a geotechnical assessment report (Pando, 2017), and considered in the trial pad designs (OKC, 2018) but has not been adequately incorporated into the cover design and performance simulations. The design will need to be improved with the use of other materials and improved drainage. It is recommended that the cover system design be independently reviewed in regard to saturation of the alluvium layer above the GSL and implications for slope stability.

The documentation provided in relation to GSL design details (ICI et al., 2017) is comprehensive and appropriate for the purpose of selecting of the most suitable GSL. High-density polyethylene and BGM were determined to have the longest service life, but BGM was selected by MRM as the preferred option because of the degradation sensitivity of the HDPE to elevated temperatures such as those present in the NOEF.

Use of the BGM is preferred over the CCL, but there are still a number of uncertainties not addressed in investigations carried out to date:

- Constructability on a large scale.
- Maintaining protection from sunlight and weather (erosion control).
- Life of the GSL.
- Temperature effects from existing convection and ongoing convection from newly placed materials.

- Susceptibility to differential settlement.

The cover trials proposed in OKC (2017b) and OKC (2018) will provide information on constructability of the BGM option, but should include more physical and chemical testing as recommended in ICI et al. (2017), particularly UV and temperature sensitivity. These trials would provide more information on the adequacy of the proposed 70 to 80 year period of adaptive management.

In addition to potential mass failure described above due to saturation effects, the GSL cover system will be sensitive to erosion. There have been no updates to erosion modelling and maintenance described in OKC (2016a) included in the Draft OMP EIS. The inherent assumption in the OMP SEIS (MRM 2018a) is that costs and resources required to maintain the NOEF cover will be minimal, requiring filling of erosion gullies, weed management and similar. This assumption would need to be verified during operations with trials and observation of rehabilitated areas. An approach to erosion monitoring as part of cover trials is recommended in Section 3.2.6 of OKC (2018), which should be included.

Differential movement could occur through normal dump settling or the effects of temperature differentials and local pressure effects in zones of active convection. Pando (2017) Section 4.3 discusses results of preliminary settlement modelling, which determined the modelled settlement was well within tolerances for the BGM option. A more comprehensive settlement assessment is recommended, supported by site observation and settlement monitoring during dump construction.

The OMP SEIS (MRM 2018a) includes an updated report on geochemical modelling of the NOEF (KCB, 2017a), which uses an alternate approach to the previous NOEF modelling conducted by O'Kane Consultants using the OKC DumpSim proprietary software (OKC, 2016b). The purpose of the KCB modelling was to provide an independent assessment of the previous OKC modelling results and include both the CCL and GSL liner options for the cover system. In addition, modelling of various scenarios was carried out to assess outcomes from partial cover failures, localised acid seepage, and different basal layer construction. This addresses recommendations made by ERIAS Group in a review of the Draft OMP EIS for independent review of OKC DumpSim model results using other industry standard models with assessment of sensitivity (ERIAS Group, 2017a). Both the OKC and KCB models predicted that NOEF seepage quality was largely controlled by solubility constraints, but the KCB model predicted higher infiltration rates for the CCL cover system. Note that with the GSL cover system, which is the new proposed option, infiltration rates were predicted to be very low at less than 1% net percolation, which may be a conservative assumption to be confirmed with constructability trials. The overall approach and predictions appear appropriate and are considered by the IM as a valid basis for assessment of down-gradient effects from the NOEF.

There has been no advancement in defining the distribution of geochemical rock types placed in the WOEF since the last IM report, but Table 10 of the 2017-2018 OPR (MRM, 2018b) states that an as built block model has been constructed.

Waste Rock Materials - Management

The vast majority of waste rock was placed in the NOEF during the reporting period, with focus on the Central West (CW) Alpha and Bravo, and West A, B, C and D stages. Only minor materials were placed in the SOEF and WOEF.

Waste rock was primarily being placed in the CW stage of the NOEF during the 2018 IM site visit, with PAF(HC) and PAF(RE) materials being end tipped in 2-m lifts, dozed flat (Plate 4.1) and traffic compacted, as per previous activities. The end tip profile was examined during the IM site visit, and it was clear there was no significant segregation at a 2-m lift height, with the materials relatively well graded (Plate 4.2). However, the materials do include blocky portions, and significant segregation may occur at the higher tip heads proposed for PAF(HC) in the Draft OMP EIS (MRM, 2017a).

Plate 4.1 – Example of Dozing PAF Cell Placement in CW Stage of the NOEF

McArthur River Mining proposes to continue placement of PAF(RE) materials in 2-m lifts, but PAF(HC) materials would be placed in up to 7.5-m lifts (2-m base followed by 5.5-m tip head). The IM still has concerns with the proposed 7.5-m lifts for PAF(HC) materials, which are unlikely to result in spontaneous combustion but could still cause high convective oxidation rates and generation of AMD. Given the highly pyritic nature of PAF(HC) materials (median S values of around 8%S), it is recommended that the PAF(HC) materials also be placed in 2-m lifts to minimise AMD loadings and reduce liabilities during all stages of dump construction, and in case the proposed final cover system is not fully successful.

Plate 4.2 – End-tipped PAF Profile in the CW Stage of the NOEF

Advection control measures continued to be implemented at the NOEF, with focus on installation of an interim advection barrier on the northern batter between the older dump areas and the CW stage (Plate 4.3), which is appropriate to help reduce extreme oxidation rates in the older end-tipped portions of the dump. A number of levels of advection control are being carried out:

- Interim 0.1-m thick alluvium layers on each PAF lift.
- Interim 0.5-m thick alluvium layers on older PAF dump areas that will be covered by other dump stages or a 5- to 20-m true thickness halo zones (thinner in the plateau zone) within six months.
- Interim 0.5- to 1.2-m thick alluvium layers (thinner in the plateau zone), followed by a 0.2- to 1.5-m thick MS-NAF protection layer (thinner in the plateau zone) with on older PAF dump areas that will be exposed for more than six months.
- Final 5- to 20-m true thickness halo zones (thinner in the plateau zone).

These advection control measures for the PAF(HC) and PAF(RE) currently being placed in new dump areas are expected to be successful in controlling extreme oxidation and combustion and reducing convection, and are an appropriate use of materials available on site. The control on older PAF dump zones is uncertain. As mentioned previously, although the updated temperature monitoring shows some evidence of reduced temperatures, background temperatures are still high and full control of convection has not been demonstrated. It should therefore be assumed that the older PAF areas will continue to contribute high AMD loadings into seepage during operations until infiltration is controlled. The high temperature zones are not expected to directly affect the alluvium advection barriers. Note that there are still very high temperature zones in the NOEF, and this could potentially cause differential settlement which may affect the integrity of the cover through desiccation effects, but the existing temperature gradient will tend to encourage convective pathways and continued high rates of pyrite oxidation. These advection layers are suitable as an interim measure to control extreme spontaneous combustion, but final control of AMD effects relies on limiting infiltration and transport. Spontaneous combustion was not observed during the site visit, whereas isolated occurrences were observed in the 2017 visit.

Plate 4.3 – Interim 0.5 m Advection Barrier Between the Older NOEF Dump Area and CW Stage

As with the previous site visit, it was apparent that the identification and stockpiling of materials suitable for the CCLs and advection barriers was well organised, along with staging the various components of the NOEF construction, including NAF wedge, CCL base, PAF cells, MS-NAF haloes, and advection barriers (Plate 4.4).

The generation of acid water due to rehandling and dust suppression during low grade ore (LGO) recovery from the NOEF was addressed in the last IM report. At the time of the site visit, the acid water was being held in the NOEF SPSD and NOEF SPROD, with a portion also being held in SEPROD. None of the acidic and metalliferous water was discharged. Various water treatment approaches to mitigate the issue are detailed in 2016-2017 OPR (MRM, 2017b) and 2017-2018

OPR (MRM, 2018b), and a method of in line hydrated lime treatment using a mixing plant was selected as most effective in bringing the water to a quality suitable for eventual discharge (Plate 4.5), with Zn precipitation being the key target (and note that the SEPROD also receives water from the underground void). The volumes of combined contaminated underground void water and SPSD/SPROD water duration of treatment required is not clear, but the next wet season will put pressure on the current storage, and MRM is seeking permission to enable direct release from the WMD to Little Barney Creek (MRM, 2018g). The current storage in SPROD is also preventing installation of a HDPE liner to better control seepage from this facility. An internal MRM memorandum was provided to the IM that outlines the cause of the acidification and steps to ensure it does not recur (MRM, 2018h).

Plate 4.4 – Construction Activities for the Various Components of the CW Stage

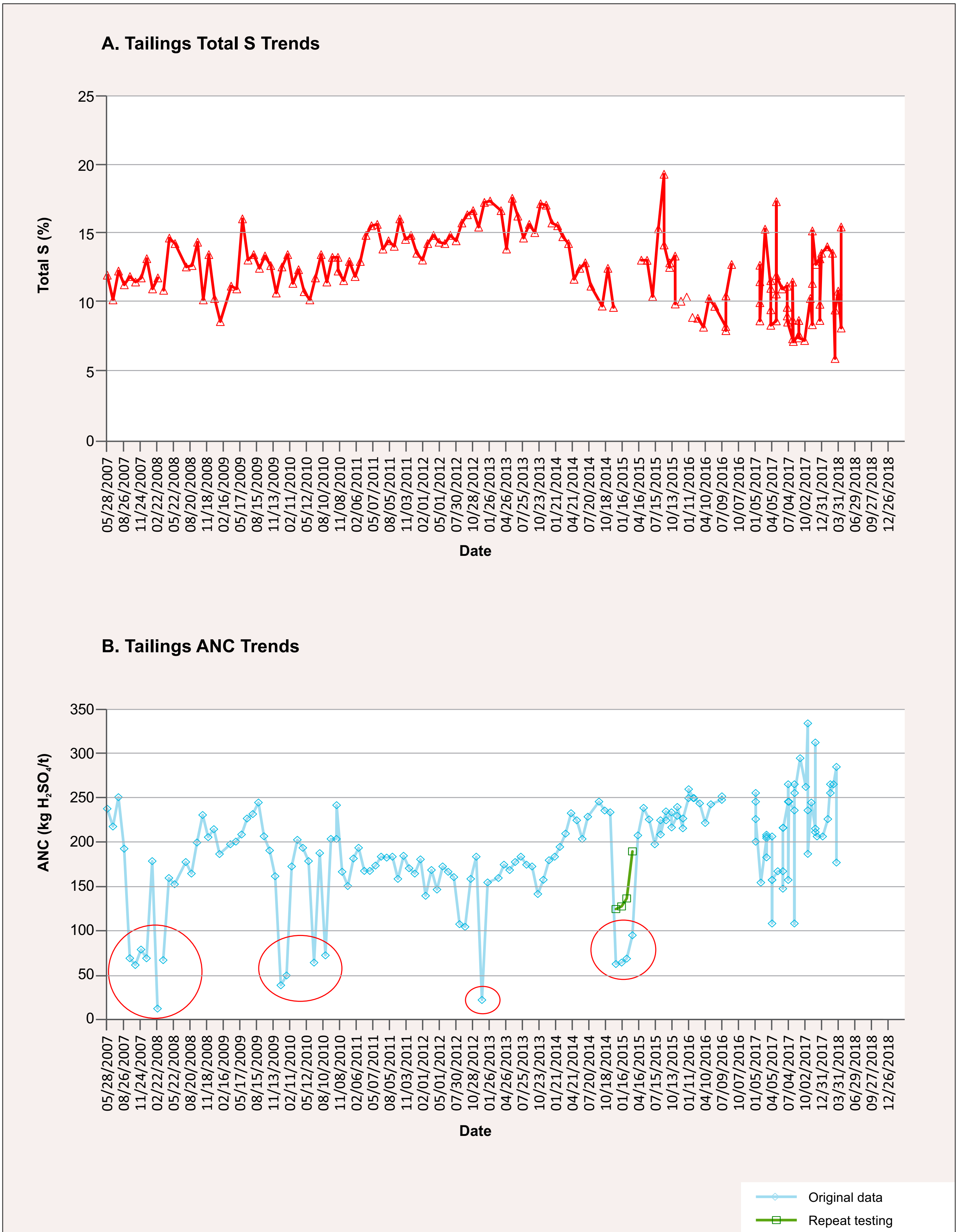
Tailings Materials

Tailings S and ANC results provided by MRM from May 2007 to April 2018 are shown in Figure 4.26, and the results from the current IM review period continue to show that the tailings are PAF with very high acid generating capacity, but generally with high ANC, and a lag would be expected before acid conditions develop after exposure to atmospheric oxidation conditions. The lower ANC values for tailings collected in December 2014 to March 2015 were confirmed as anomalous, with the majority of tailings samples having high ANC of greater than 150 kg H_2SO_4/t.

TAILINGS TOTAL S AND ANC TRENDS FOR TSF CELL 2 (2007 TO 2018)

McArthur River Mine Project

FIGURE 4.26



White salts were commonly observed on the tailings beaches during the IM site visit (Plate 4.6), more so than the previous visit, which are primarily expected to be due to drying out of process water. A DPIR site inspection report also noted extensive dry tailings surfaces and dust being generated in September 2017 (DPIR, 2017), and MRM advised that this was temporary while spigots were off line. These observations suggest that the TSF surface is regularly dry, and some surface oxidation of the highly pyritic tailings is undoubtedly occurring. However, results of review and oxygen penetration test work carried out in 2016 and 2017 (Earth Systems 2016a; 2016b; 2017a) and reported in the previous IM report indicate that acid conditions are unlikely to develop within tailings pore water during operations in which only partial surface drying of tailings occurs due to spigot cycling, and maintenance of 80% to 90% saturation.

Plate 4.5 – Hydrated Lime Mixing Plant at SEPROD

Plate 4.6 – TSF Cell 2 Showing Salt Crusting on Surface

Surface sampling of deposited dry tailings close to spigot locations was carried out for water extraction testing as per IM recommendations. Figure 4.27 is a plot of saturated paste pH by date, which shows generally circum-neutral pH, except for one sample with a slightly acidic pH of 5.9. These results confirm the lack of significant acid generation from oxidising tailings at the locations sampled. Further clarification of the relative contribution of tailings sulfide oxidation and acid generation to AMD loadings from the TSF is recommended. The surface sampling should continue, and include targeted sampling of TSF surfaces that have been exposed for extended periods with strong salt generation. Sample descriptions would assist interpretation of results. The relative contribution of tailings sulfide oxidation and acid generation will be further addressed in a proposed work program by Earth Systems (2017b).

Tailings Materials - Management

The TSF is split into three cells, i.e., Cell 1 (which is filled and inactive), Cell 2 (which is active), and a water management dam (WMD) (Cell 3). The Draft OMP EIS (MRM, 2017a) discusses the planned life-of-mine (LOM) management of the TSF, which involves combining Cell 1 and Cell 2 into one large cell and hydraulic mining and reprocessing of the tailings once mining operations cease. Cell 2 tailings disposal will continue until regulatory approvals are obtained for combined deposition. Cell 3 will continue to be used for water management, and the originally proposed Cell 4 would no longer be required.

Management of Cell 1 and Cell 2 has not changed from the last IM report. Management of seepage from Cell 1 relies primarily on repair of a temporary and eroded 500-mm clay cover over the tailings before each wet season, with various drains and sumps in place to direct and handle the runoff. This cover was primarily designed for dust control, which tends to erode during the wet season, and hence its effectiveness in controlling infiltration is doubtful. A seepage interception trench between Cell 1 and Surprise Creek has been designed but won't be installed until the mitigation strategies in the Draft OMP EIS are approved.

The current management of Cell 2 (GHD, 2017) minimises the water stored in the facility, with active beaching of tailings around the perimeter of the cell using multiple spigots, lower water content in the tailings discharge slurry, and water reclaim from the TSF for return to the concentrator runoff pond (CRP) for use in the processing plant.

Open Pit, Underground Workings and Infrastructure

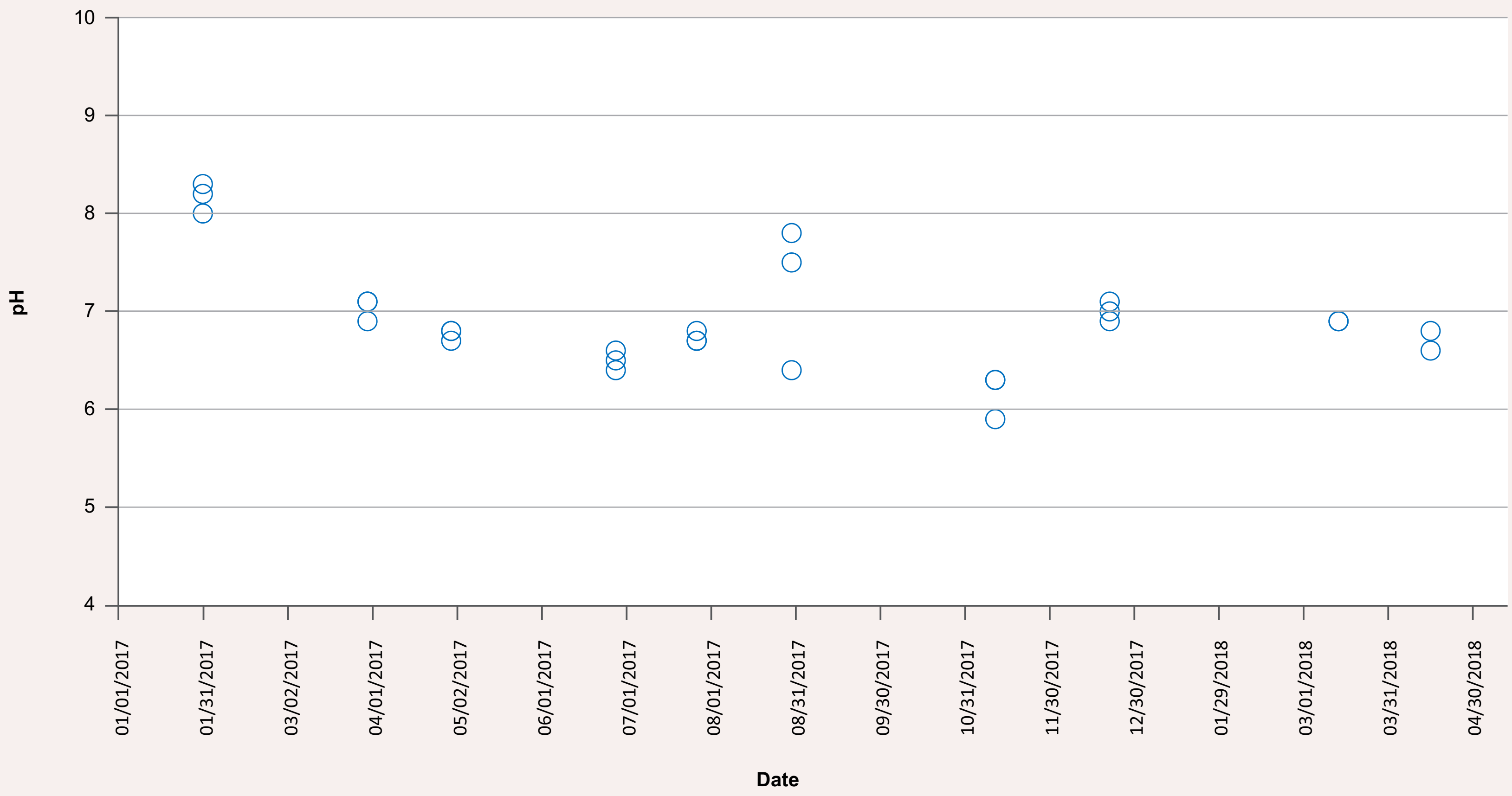
There were no changes to pit water management in the current reporting period, with water from the pit and underground workings classified as contaminated, and managed by pumping and evaporation.

The planned closure of the open pit void described in the OMP SEIS (MRM, 2018a) remained largely consistent with the Draft OMP EIS (MRM, 2017a), with focus on tailings backfill and maintenance of tailings inundation during this process, and rapid pit fill to minimise oxidation of pit walls and provide dilution. The key modification was that the pit would no longer automatically progress to a flow through system, but would be maintained as a non discharge (backflow) system unless performance monitoring and assessment indicated that the flow through system was appropriate. Controlling the oxidation of tailings and pit wall materials through complete inundation as proposed is the most secure long-term management approach for these materials.

SATURATED PASTE pH BY DATE FOR TSF CELL 2

McArthur River Mine Project

FIGURE 4.27



An updated pit void quality modelling report (KCB, 2017b) was carried out as part of the OMP SEIS (MRM, 2018a). The modelling approach was similar to that carried out for the Draft OMP EIS and is considered appropriate, with clear descriptions of the assumptions used and how the model was structured. The updated modelling accounted for some modifications of water balance (including groundwater) inputs, effects of stratification, and isolation of secondary minerals formed during tailings deposition in the tailings voids. Additional sensitivity analysis was also carried out, and overall the modelling predictions indicate that long-term control of the open pit water quality to meet surface water quality requirements at SW11 is possible.

Current understanding of the long-term geochemical behaviour of the open pit relies solely on the KCB pit water quality modelling. Given that the open pit represents a major geochemical hazard for the site, the IM recommends that model predictions should be verified by an independent expert.

4.6.4 Review of Environmental Performance

4.6.4.1 Incidents and Non-compliances

Incidents

No specific geochemical incidents were identified from documents supplied.

Non-compliances

No specific geochemical non-compliances were identified from documents supplied.

4.6.4.2 Progress with Previous Issues

McArthur River Mining's performance against previous IM review recommendations relating to geochemistry is outlined in Table 4.30. Those recommendations already completed or combined into subsequent years' recommendations have been omitted.

Table 4.30 – Geochemistry Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
NOEF	Installation and maintenance of the proposed multi-layer cover systems on the NOEF will be challenging. The performance of the cover in controlling infiltration, and its long-term (1,000 years) sustainability, need to be better demonstrated	Ongoing A GSL cover system is now proposed, which addresses many of the performance issues identified for the CCL system originally proposed. Recommendations have been updated in Table 4.31 for the new cover system
	Carry out more drill testing of dumped materials to more confidently define the distribution of historically dumped materials and check the reconstruction of dump material types based on the new block model	Completed Additional drilling carried out
	Carry out further investigations to determine the direct seepage contribution from the NOEF to the groundwater system	Completed Evidence to date indicates that with the thick clay base under the NOEF, the PRODs have been the main source of seepage

Table 4.30 – Geochemistry Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
NOEF (cont'd)	Review the frequency of check sampling of dumped materials, particularly for LS-NAF	Completed Reviewed and frequency increased, and procedures updated
	Determine whether elevated SO_4 concentrations in groundwater bores to the northeast of the NOEF (GW105, GW100, GW131 and GW134) are related to shallow seepage from the NOEF along natural drainage	Ongoing No update viewed
	Proceed with trial cover designs in 2017 as planned	Ongoing Trial covers for the new cover system have been designed but not implemented
	Carry out field trials and monitoring of the end-tipped dump portions of the NOEF to confirm effectiveness of advection covers	Ongoing Advection barriers are being implemented on end-tipped dump portions and monitoring bores in NOEF are being used to monitor effectiveness
	Progress field confirmation of erosion modelling predictions, as erosion could have significant implications for long-term cover system integrity and maintenance resources required	Ongoing Not carried out
	Complete treatment of acid water in NOEF SPSD/SPROD before the next wet season to avoid uncontrolled release	Ongoing Treatment in progress in SPSD/SPROD/ SEPROD, and may take a number of wet seasons to complete. Requires a clearer treatment and water management schedule
	Document procedures to avoid generation of AMD from highly pyritic PAF materials in older end-tipped parts of the NOEF	Completed A review of the LGO acid seepage incident was provided, which included measures to avoid reoccurrence (MRM, 2018h)
	Continue paddock dumping and traffic compacting PAF(HC) materials, which are still highly pyritic, to maximise stability and minimise oxidation and infiltration	Ongoing Currently, PAF(HC) together with PAF(RE) are being end tipped in 2-m lifts and traffic compacted to help control convection The Draft OMP EIS and OMP SEIS describe options for 7.5-m PAF(HC) lifts, which require better justification
	Review/compile existing data and/or undertake a test program to confirm the distribution of geochemical rock types at the WOEF and finalise closure options	Ongoing Planned for 2018
WOEF	Fully switch to ICP analysis by progressing the on-site ICP testing capacity or arranging back up external testing capability to avoid further contingency use of pXRF	Ongoing

Table 4.30 – Geochemistry Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Waste rock segregation, handling and checks	Resolve discrepancies between mined and modelled waste rock classes	Completed Improvements made, and good geological understanding demonstrated to explain causes for previous discrepancies. Recommendation updated in regard to accurately distinguishing between PAF(HC) and PAF(RE) in the GC and reserve models
	Update technical work instructions manuals with more on the review and decision-making process when using APS tracking information to check for misplaced loads. Including examples would assist	Completed Update provided
	Include more detailed instructions on sampling methods in the OEF sampling procedure, including photos showing typical sampling	Completed Update provided
	Provide explanation for why there was a two-month gap between OEF sampling and recording of the misplacement of MS-NAF material for the incident reported on the 4 October 2016	Ongoing No explanation given, but new procedures are expected to avoid repeat
	Consider continuing LS-NAF humidity cells/columns to demonstrate the expected long-term benign nature of these materials	Ongoing Kinetic testing of LS-NAF continuing, but no results provided
Waste rock kinetic testing	Consider instigating a controlled watering regime for barrel tests, set to reflect a particular wet/dry climatic scenario, to make leachate volumes collected at each barrel more comparable to provide better and more interpretable results	Ongoing Not actioned
Waste rock criteria	Better demonstrate the validity of the PAF(RE) 10%S cut off	Ongoing No progress
	Add PAF(HW) to the proposed waste rock classes since it would be handled differently from other materials	Ongoing No progress
TSF	Monitor sulfide oxidation and pore water quality in beach tailings during operations to check for evidence of acid and salinity production. This could include pH/EC water extracts on surface tailings	Completed Carried out. Updated recommendation made
Tailings kinetic testing	Prepare a tailings kinetic test report for the next IM reporting period	Ongoing Will be available in the next reporting period
Infrastructure sites	Carry out more extensive sampling at infrastructure sites tested to date to be confident in the relative proportions of geochemical rock types. Sampling should be extended to cover placed waste rock materials and excavated in situ sulfidic materials at the Barney Creek diversion channel and McArthur River diversion channel	Ongoing No progress

Table 4.30 – Geochemistry Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Mine site	Assess the long-term local impacts of exposed sulfidic rock in the McArthur River diversion channel on water quality and revegetation success on the lower parts of the diversion	Ongoing No specific investigations provided
Bing Bong dredge spoil	Carry out an acid sulfate soil assessment of the spoon drain around the dredge spoil ponds and other potential sources at Bing Bong Loading Facility	Ongoing No progress, but site personnel advised that this was planned

4.6.4.3 Successes

McArthur River Mining continues to make progress in geochemical prediction and management of mine materials, including the following:

- Proposed use of a GSL in the final NOEF cover system to provide much greater infiltration control.
- Additional drilling of monitoring bores into the NOEF to improve understanding of temperature and gas transport processes in the dump.
- Updated geochemical modelling of the NOEF using an alternate approach to the previous DumpSim modelling as an independent check of findings.
- Improvements to block modelling, materials tracking and checks.
- Use of the more reliable ICP analysis, and phasing out of pXRF, for grade control to assign waste rock classification.
- Continued placement of newly-mined PAF(HC) and PAF(RE) in paddock-dumped and traffic-compacted (2 m) lifts and placement of advection covers to help control rapid (convective) oxidation.
- Preferential construction of advection control layers on older, end-tipped dump areas of the NOEF.
- Initiation of surface sampling and water extraction testing of deposited tailings, which confirm the lack of significant acid generation from oxidising tailings.

4.6.5 Conclusion

As with previous years, considerable efforts have been carried out by MRM in regard to site geochemistry issues since the last IM report, greatly improving the understanding of AMD potential of mine materials and long-term risks, and better defining management options to mitigate current mining impacts, and future impacts during operations and closure. The management approaches outlined in the Draft OMP EIS (MRM, 2017a) and OMP SEIS (MRM, 2018a) are expected to significantly improve AMD control during operations and closure, but these are yet to have regulatory approval, and the NOEF, TSF and open pit remain major potential sources of AMD.

Waste rock materials in the NOEF contain large amounts of fast-reacting pyrite and currently represent a long-term source of sulfate salinity and metals, with potential localised acidity. The IM accepts that based on data collected to date, although the waste rock has very high pyrite content, the material placed in the NOEF has an overall excess of ANC, and the combined NOEF seepage is likely to be circum-neutral. Current management has focussed on controlling extreme oxidation (spontaneous combustion) and improving seepage collection systems, including lining the PRODs. Given the local climatic conditions at MacArthur River Mine, the IM does not consider it feasible to control oxidation rates from these highly pyritic materials to the extent that contaminant release is negligible, and hence managing transport of AMD products will be the key control of AMD impacts. The proposed capture of NOEF toe seepage and collection of basal seepage reporting to the Barney Creek diversion channel outlined in the Draft OMP EIS and OMP SEIS (MRM, 2017a and 2018a) seems likely to manage seepage during operations so that surface water quality requirements at SW11 are met, but upstream sites receiving mine-affected water, such as Barney Creek and Surprise Creek, are expected to have poor water quality into the long term. Once the GSL cover system is successfully placed over the whole NOEF, further transport of pyrite oxidation products should cease (or greatly reduce), and the continuation of AMD reporting to drainage (and consequent collection and treatment) will be due to drawdown of seepage within the dump and contaminants already in the groundwater system, as long as the cover functions according to design expectations. The cover system is unlikely to act as a completely sealed oxygen barrier, so that oxidation and accumulation of pyrite oxidation products will continue (via slower diffusion rather than convective rates), but these will not be transported as AMD (again, as long as the final cover functions as designed). Modelling from KCB suggests a decrease in AMD effects in 50 years after successful closure (KCB, 2017a), and the proposed adaptive management phase of 70 to 80 years post closure would cover that period (Section 3.3.3 of OMP SEIS, MRM, 2018a).

The BGM cover for the NOEF is MRM's current preferred option, but there are a number of uncertainties in regard to performance relating to constructability, erosion control, service life, sensitivity to temperature, effects of differential settlement, and potential for slope failure due to saturation of the BGM protection layer, which will need to be addressed with trials and further investigations. Despite these uncertainties, the use of a GSL liner system incorporating a BGM appears to be the best and most achievable option for final closure of the NOEF. Note that implementation of this cover system will not necessarily preclude the need for continued seepage/ runoff collection and treatment beyond MRM's proposed active closure phase, nominally set to end in 2100 (MRM, 2018a).

The Draft OMP EIS (MRM, 2017a) and OMP SEIS (MRM, 2018a) propose reprocessing of tailings and subsequent pit disposal. The tailings are classified PAF, albeit with a long lag time, and have very high S (greater than 10%S) and will ultimately produce acid leachate. As such, they represent the greatest AMD hazard on site. Preferential placement of tailings in the pit and ultimate inundation of both tailings and pit walls is the most secure long-term strategy for these materials and is strongly supported by the IM. The pit void modelling approach is considered appropriate, which indicates that long-term control of the open pit water quality to acceptable concentrations is possible.

New IM recommendations related to geochemistry issues have been consolidated in Table 4.31, with updated recommendations from previous IM reviews also being included.

Table 4.31 – New and Ongoing Geochemistry Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
NOEF	Determine whether elevated SO_4 concentrations in groundwater bores to the northeast of the NOEF (GW105, GW100, GW131 and GW134) are related to shallow seepage from the NOEF along natural drainage	Low
	Progress field confirmation of erosion modelling predictions, as erosion could have significant implications for long-term cover system integrity and maintenance resources required	High
	Prepare a treatment and water management schedule for acid and contaminated water in NOEF SPSD/SPROD/SEPROD to ensure there is adequate storage to avoid uncontrolled release	High
	Given that PAF(HC) materials are still highly pyritic, continue end tipping in 2-m lifts and traffic compaction of these materials to maximise stability and minimise oxidation and infiltration	High
WOEF	Review/compile existing data and/or undertake a test program to confirm the distribution of geochemical rock types at the WOEF and finalise closure options	Medium
Waste rock segregation, handling and checks	Fully switch to ICP analysis by progressing the on-site and off-site ICP testing capacity to avoid further contingency use of pXRF	Medium
Waste rock criteria	Better demonstrate the validity of the PAF(RE) 10%S cut off	Medium
	Formally include PAF(HW) as a waste rock class to avoid confusion since it would be handled differently from other materials	Medium
Tailings kinetic testing	Prepare a tailings kinetic test report for the next IM reporting period	Medium
Infrastructure sites	Carry out more extensive sampling at infrastructure sites tested to date to be confident in the relative proportions of geochemical rock types. Sampling should be extended to cover placed waste rock materials and excavated in situ sulfidic materials at the Barney Creek diversion channel and McArthur River diversion channel	Low
Mine site	Assess the long-term local impacts of exposed sulfidic rock in the McArthur River diversion channel on water quality and revegetation success on the lower parts of the diversion	Low
Bing Bong dredge spoil	Carry out an acid sulfate soil assessment of the spoon drain around the dredge spoil ponds and other potential sources at Bing Bong Loading Facility	Low
Waste rock kinetic testing	Consider continuing LS-NAF humidity cells/columns to demonstrate longer-term low rates of contaminant release	Low
	Consider instigating a controlled watering regime for barrel tests, set to reflect a particular wet/dry climatic scenario, to make leachate volumes collected at each barrel more comparable to provide better and more interpretable results	Low

Table 4.31 – New and Ongoing Geochemistry Recommendations (cont'd)

Subject	Recommendation	Priority
New Items		
NOEF	If there are justifiable changes to managing PAF(HC) materials differently from PAF(RE) materials, then develop more accurate methods of distinguishing between PAF(HC) and PAF(RE) mining blocks that can be effectively selectively handled	Medium
	Proceed with trial cover designs of the new GSL cover system as planned to determine constructability and performance, and include physical and chemical testing of the proposed BGM as part of the cover trials, with particular focus on UV and temperature sensitivity	High
	Undertake an independent review of the GSL cover system design in regard to saturation of the alluvium layer above the GSL and implications for slope stability	High
	Carry out a more comprehensive settlement assessment for the NOEF in regard to potential effects on the proposed BGM layer, supported by site observation and settlement monitoring during dump construction	Medium
TSF	Continue TSF surface sampling of deposited dry tailings and water extract testing, and include targeted sampling of TSF surfaces that have been exposed for extended periods with strong salt generation, and record sample descriptions to assist interpretation of results. In addition, proceed with the proposed tailings acidity load estimation work program (Earth Systems, 2017b)	Low
Open pit	Current understanding of the long-term geochemical behaviour of the open pit relies solely on the KCB pit water quality modelling. Given that the open pit represents a major geochemical hazard for the site, have an independent expert verify the model predictions	Medium

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4.7 Geotechnical

4.7.1 Tailings Storage Facility

4.7.1.1 Introduction

This section addresses MRM's performance during the reporting period with regard to management of geotechnical issues at the TSF and is based on:

- Observations and discussions with MRM personnel during the site inspection.
- Review of various reports prepared by MRM and its consultants.
- Design reports for the TSF.
- Incidents reports.
- Measured piezometric levels and survey data.
- Quarterly reports and monthly monitoring reports for the TSF.
- Inspection reports and compliance audits undertaken by DPIR.
- Aerial and other photographs of the McArthur River Mine provided by MRM.
- Topographic (ALS) data of the McArthur River Mine provided by MRM.

4.7.1.2 Key Risks

The key risks to management of geotechnical issues at the TSF, as described in the risk register (Appendix 1), are:

- Embankment failure (loss of containment): embankment slope failure or excessive deformation due to static, seismic or pore pressure loading resulting in loss of tailings and tailings water.
- Embankment failure (overtopping): embankment overtopping due to storm events leading to loss of water and tailings (due to subsequent scour) from the storage.
- Piping (internal embankment erosion): internal erosion within the embankment or foundation leading to loss of water and tailings from the storage.
- Foundation failure: embankment failure due to sliding resulting in loss of water and tailings from the storage.
- Tailings line failure: erosion leading to embankment failure when it occurs on the crest, and loss of water and tailings when it occurs between the process plant and the TSF.
- Seepage: seepage from the TSF polluting groundwater and surface water.
- Operation failure: operation of the tailings dam outside of its intended design, such as a water holding dam, leading to one of more of the above risks.

- Combination failure: a combination of more than one of the above at the same time resulting in embankment failure, and loss of water and tailings from the storage.

All of the above risks would potentially result in impacts to the terrestrial and aquatic flora and fauna in and around Surprise and Little Barney creeks and other downstream creeks and rivers.

4.7.1.3 Controls

Previously Reported Controls

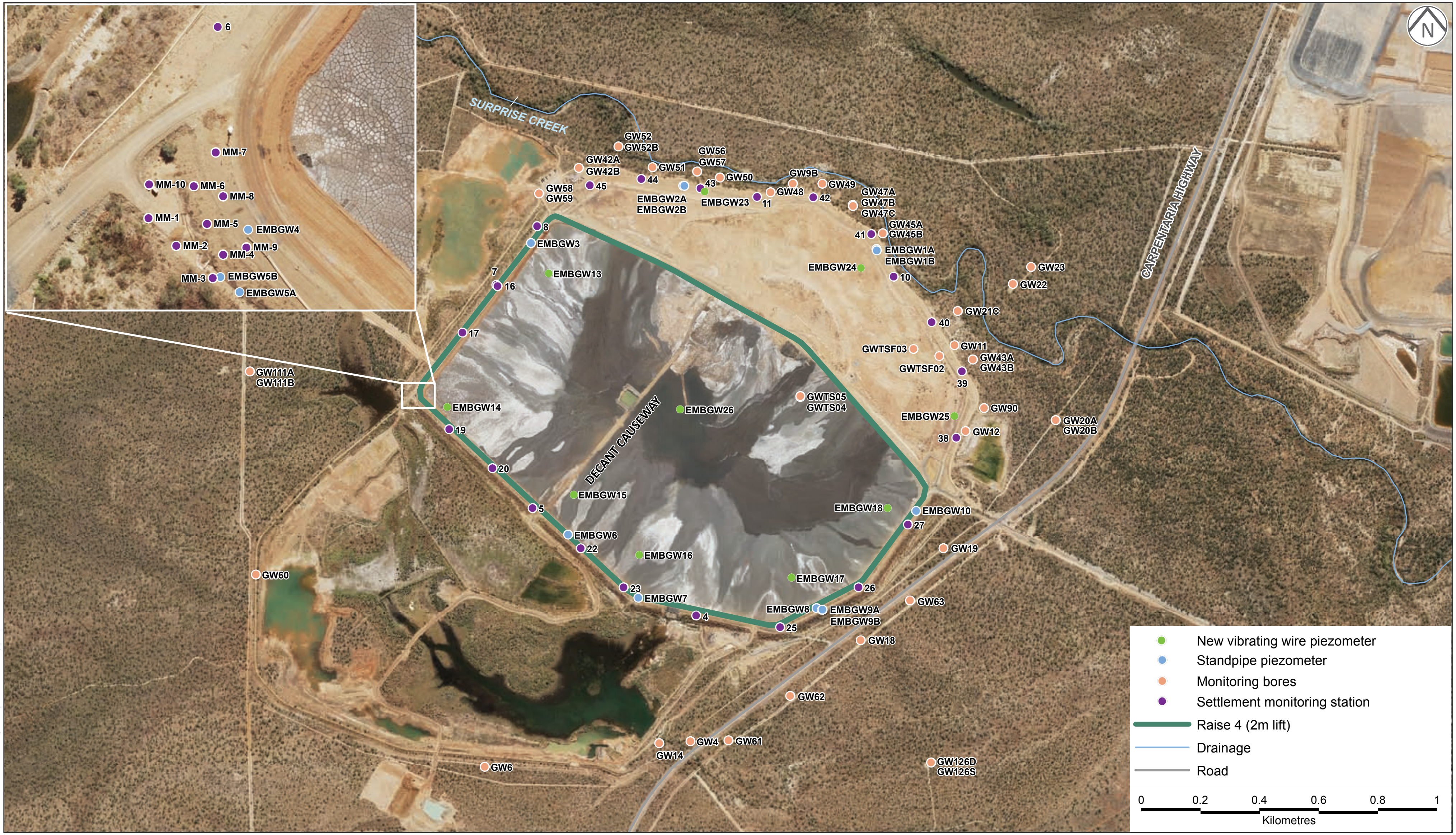
The controls that have been implemented by MRM to minimise the likelihood of these hazards are shown in Figure 4.28 where applicable, and include:

- Design and analysis of future TSF works to meet ANCOLD (2012) guidelines for a 'High C' dam failure consequence and a 'Significant' dam spill consequence.
- Supervision during construction, and certification that the TSF has been constructed in accordance with design and is fit for purpose under the expected operating conditions. Cell 2 Raise 4 was undertaken between June and November 2017.
- A perimeter discharge system that promotes formation of a tailings beach that allows movement of liberated surface water away from the embankments to a central decant pond. There are currently 55 spigots spaced 100 m apart, which are cycled on a monthly basis.
- A decant system that allows the pond to be positioned well away from the perimeter walls and controlled in size so that the phreatic surface within the embankments can be kept below design limits.
- An operating manual prepared by the designer or suitable delegate that prescribes the correct operational parameters such that the TSF is operated within acceptable design limits. The operating manual was updated in February 2017.
- Quarterly hydrographic surveys of the TSF pond aerial extent.
- Quarterly level surveys of 11 monuments within and around the TSF Cell 1 and TSF Cell 2 embankments.
- Embankment crest and toe surveys during raising.
- Nominally weekly piezometric surveys of 14 standpipes within and around the TSF Cell 1 and TSF Cell 2 embankments. These were read on average every 10 days during the reporting period.
- A site-wide water balance model updated annually.
- Installation of a contoured capping over TSF Cell 1 to promote efficient surface water drainage and removal.
- A system of sumps, pumps and pipes to move collected surface or decant water such that the likelihood of overtopping and increased subsurface pore pressures is minimised.

OVERVIEW OF TSF SHOWING MONITORING LOCATIONS

McArthur River Mine Project

FIGURE 4.28



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- Regular pipeline inspections and monitoring of wall thickness to identify potential pipeline breakage and scheduled maintenance.
- Inspections and measurements of known seepage from the southwest corner of TSF Cell 2 and its spillway including seepage volumes, water quality testing and additional survey marks.
- Monthly site inspections of the TSF recording climate, water levels, deposition quantities, construction or maintenance activities and observed impacts such as seepage and erosion. The IM was provided with nine monthly reports from October 2016 to May 2017.
- Annual inspections by the TSF designer, GHD. An annual inspection was undertaken on 13 November 2017 (GHD, 2018d).

The DPIR undertakes regular inspections in addition to the above. In the current reporting period, the DPIR undertook inspections of the TSF in October 2016 and January, March, August, September, December 2017 and February 2018.

New Controls – Implemented and Planned

New controls implemented within the reporting period include:

- Construction of a new 50-m spillway for Cell 2 along the southern embankment. The old spillway has been decommissioned.
- Completion of Cell 2 Stage 4, 2-m raise to 10,057 mRL.
- Quarterly Operational Reports (QORs) summarising the operational management, observations and performance of the TSF. Reports were provided for September 2017 (MRM, 2017b), December 2017 (MRM, 2017d), March 2018 (MRM, 2018b) and April 2018 (MRM, 2018c). These QORs are being prepared in place of monthly reports, which is consistent with the requirements of the Mining Authorisation.
- Installation of southeast and southwest seepage collection drains on 2 and 3 October as part of Cell 2 Stage 4 (MRM, 2017d).
- Installation of a new rock mattress dewatering bore on 6 October 2017 at the old spillway (MRM, 2017d).
- Trial ploughing of tailings surface using an All Terrain Vehicle (ATV) from 10 to 20 October 2017 to increase compaction and density (MRM, 2017d).
- Completion of an internal ‘wet season readiness’ audit on 9 November 2017 (MRM, 2017d).
- Installation of a new drain along the western wall of the WMD to Lower Barney Creek diversion in December 2017, to drain a ponded area and reduce the risk of external water flooding into the WMD (MRM, 2018b).
- Improvement works at Cell 1 undertaken during December 2017 comprising (MRM, 2018b):
  - De-silting the detention basin.

  - A new dividing bund to reduce the East Sump (C1SB) catchment area and increase the West Sump (C1SA) catchment.
  - Rock armouring of the C1SB/spillway approach.
  - Upgrade works of the C1SA spillway to ensure that spills are captured in the Western Borrow Pit (WBP).

- Installation of flow meters on the WMD inlet, outlet pipes and the seepage collection bore at the old spillway undertaken in December 2017 (MRM, 2018b).
- Tailings beach survey scan frequency increased from quarterly to monthly, for input into operational planning (MRM, 2018b).
- Switching eleven spigot valves from knife gate to butterfly valve (MRM, 2018b).
- Switching seepage collection at the old spillway bore, collection sump and SW corner to an automated system with solar/battery and a level switch in January 2018 (MRM, 2018b).
- Installation of an additional decant pump along the causeway in January 2018 increasing overall pumping capacity to over 350 L/s (MRM, 2018b).
- Installation of nineteen vibrating wire piezometers (VWPs) EMBGW13A, 13B, 14A, 14B, 15A, 15B, 16A, 16B, 17A, 17B, 18A, 18B, 18C, 23, 24, 25, 26A, 26B and 26C in late 2016 with recorded readings varying from 4 to 48 hr.
- Inspection of the TSF by the ESP Manager (undertaken July 2017).
- Completion inspection of Cell 2 Raise 4 (undertaken November 2017).
- Annual site visit by MRM and the Independent Technical Review Board (ITRB) (undertaken November 2017).
- A site visit for a Cell 1 design workshop and tailings beach investigation by GHD (undertaken January 2018).
- Construction of a central pivot irrigator on the surface of Cell 1 to aid the evaporation of pond water. The irrigator was proposed in MRM (2017p) and subsequently implemented under the approval of the DPIR. The irrigator continues to be operated under MRM (2018d).
- Cessation of pumping Cell 1 Sumps A and B to the WMD (DPIR, 2017a).

Planned controls include:

- Switching thirteen spigot valves from knife gate to butterfly valves (MRM, 2018b).
- A proposal by GHD to halve the spigot spacing in the Cell 2 Raise 4 and Raise 5 design reports is understood to be in progress.
- Proposed raising of Cell 1 to 56 mAHD (Stage 4) including a new spillway to facilitate tailings discharge from the full TSF footprint (GHD, 2018b).

- Proposed construction of a seepage interception trench between Cell 1 and Surprise Creek (MRM, 2017p; 2018d, GHD, 2017b).

Proposed raising of Cell 1 and construction of a seepage interception trench are subject to regulatory approval.

4.7.1.4 Review of Environmental Performance

Incidents and Non-compliances

Incidents – Introduction

The IM has been provided with an updated 'Incident Register Nov 2016 to Mar 2018' (MRM, 2018a), which contains reportable incidents as defined by Section 29 of the Mining Management Act.

Overflow of C1SA Following Significant Rainfall – 25 January 2017

This incident is reported as summarised from MRM (2018a) as follows:

- McArthur River Mining detected an overflow from C1SA into the WBP along the adjacent spillway/access road with the overflow estimated to be approximately 5 L/s.
- The overflow occurred due to a combination of:
  - Residual water within C1SA.
  - The C1SA pump not being in operation.
  - Runoff from the C1SA catchment in response to 55 mm of rainfall over 24 to 25 January 2017.
  - A failure of the Cell 1 central dividing bund leading to additional runoff from the eastern catchment reporting to C1SA.
- All water from the overflow reported to WBP, where it was contained. Following the identification of overflow from C1SA, MRM implemented the following emergency and remedial actions:
  - Pump out of C1SA sump.
  - Inspection of the drainage infrastructure and catchment.
  - Collection of water quality samples of overflow water and water collected in WBP.
- An internal review of the cause of the overflow resulted in the implantation of the following corrective actions:
  - Real time water level monitoring for C1SA relayed to the Mill Control Room.
  - Review of the Cell 1 drainage system.

  - Design and implement an inspection and maintenance program for the Cell 1 drainage system.
  - Lift and install spacers underneath the C1SA pump-out line.
- Formal incident notification (MRM, 2017a; 2017g) was submitted to the DPIR on 27 January 2017 and an investigation report (MRM, 2017c) was submitted to the DPIR on 21 February 2017.

Overflow of CS1B – 19 February 2017

This incident is summarised in the MRM Incident Register (MRM, 2018a) as follows:

- Overflow at the C1SB spillway was observed by the TSF supervisor during nightshift, during a significant rainfall event. At the time the flow rate over the C1SB spillway was estimated to be between 100 and 200 L/s. Initially, overflow from C1SB reported to a culvert under the Carpentaria Highway. From the culvert the flow, along with local runoff, continued east towards Surprise Creek. A drain and diversion bund was constructed to direct the flow to borrow pit to the east of C1SB (EBP), where it was contained for the remainder of the event.
- The overflow was assessed to have occurred due to a combination of:
  - Residual water in C1SB.
  - A high intensity rainfall with around 130 mm falling on the 18 and 19 February 2017.
  - A reduced pumping capacity to avoid tripping of the pump electrical circuit.
- In response MRM implemented the following corrective actions:
  - A TSF operator was stationed at the pump to ensure that the pump did not trip for any significant period of time.
  - A diversion was constructed to direct flow to the unused Eastern Borrow Pit (EBP).
  - Water quality sampling of overflow water.
- An internal review of the cause of the overflow resulted in proposed implementation of the following corrective actions:
  - Real time water level monitoring for C1SB relayed to the Mill Control Room at the Mill.
  - Redesigning the sump pumps to operate automatically.
  - Equip the flow meter at C1SB for real time data recording viewing of real time data.
  - Investigate the cause of tripping of the pump electrical circuits.
  - Install a secondary pump to decant residual water from C1SB to ensure maximised sump capacity prior to rain events and to serve as a contingency in case of failure of the main pump.

  - Develop a maintenance and cleaning schedule for C1SA and C1SB.
  - Undertake measures such as revegetation or installing a filter on the surface of Cell 1 to reduce silt accumulation in the sumps.
  - Recover the water in EBP and manage it according to the waste discharge licence (WDL 174-09).
- A formal incident notification was submitted to the DPIR on 20 February 2017 (MRM, 2017e) and an investigation report (MRM, 2017f) was submitted to the DPIR on 22 March 2017.

Seepage in Barney Creek Diversion – 10 November 2017

A seepage expression as noted on 10 November 2017 in a section of the Barney Creek diversion channel immediately downstream of the WMD:

- The incident is reported in the MRM Incident Register (MRM, 2018a) as follows:
  - The source of the water was considered to be the WMD.
  - The estimated expression rate was less than 0.1 L/s.
  - The water drained towards the Little Barney Creek highway culvert.
  - The water extent terminated before the highway culvert.
- McArthur River Mining implemented the following emergency and remedial actions in response to this incident:
  - An electric pump was installed to pump water back to the WMD.
  - Monitoring of the site has been included in the TSF daily inspection schedule.

  Formal incident notification was submitted to the DPIR on 10 November 2017 (MRM, 2017k).

Overflow of C1SA and C1SB – 24 January 2018

Overflow of C1SA and C1SB occurred on 24 January 2018 at around 6 pm. The incident is reported in the MRM Incident Register (MRM, 2018a) as follows:

- The C1SB overflow rate was estimated at approximately 75 L/s.
- The C1SA overflow rate was estimated at approximately 100 L/s.
- Overflow from Cell 1 was contained within the borrow pits with C1SA overflowing to the WBP and C1SB overflowing to EBP.

In the incident register MRM noted that C1SA and C1SB are both designed for a 1 in 20 average reoccurrence interval (ARI) rainfall event and that the responsible rainfall event exceeded this design value. Sump pumps were started 24 hours prior to the overflow event due to heavy rainfall on preceding days and this minimised discharges from Cell 1.

No additional corrective actions were implemented in response to this incident. Formal incident notification was submitted to the DPIR on 30 January 2018 (MRM, 2018a).

Tailings Pipeline Failure – 23 December 2016

A tailings pipeline failure occurred in the northwest corner of the Cell 1 and Cell 1 dividing wall on 23 December 2016. The incident was recorded in MRM (2017m) with supplementary photos and email correspondence as follows:

- The tailings line split at a weld and tailings discharged on the internal Cell 2.
- Released tailings ran down onto Cell 1, through the drainage detention culvert and into C1SA.
- The spillage was fully contained within the TSF footprint.
- The area was secured and clean-up work is understood to have begun soon after.
- Excavated spilt material was disposed in the tailings dam.

The volume of the release was not reported. This incident is noted as Category 1 in the HSEC monthly report MRM (2017m). No formal notification of this incident was reported to the DPIR.

Tailings Pipeline Failure – 4 February 2018

A tailings pipeline failure occurred on the western embankment of Cell 2 on 4 February 2018 after being impacted by a grader. The incident was formally reported to the DPIR as an environmental incident as follows:

- The incident occurred on the western embankment of Cell 2 when a grader travelling along the TSF Cell 2 dam embankment (western side) came into contact with the tailings deposition pipeline resulting in a rupture approximately 500 mm by 140 mm.
- The grader operator immediately contacted Mill Control and pumping was shut down.
- The grader operator then constructed an earthen bund on the dam wall crest to limit the spill.
- The total volume of tailings was estimated to be approximately 30 m^3 with no tailings reported as having travelled beyond the Cell 2 crest.

Affected material was excavated from the dam wall crest and disposed of within Cell 2.

Other Issues

Site inspections by DPIR Mining Officers have reported a number of issues including:

- McArthur River Mining advised Mining Officers during their September 2016 site inspection that cracking that occurred in the TSF embankment during construction during the Stage 3 raise was due to settlement associated with ramp construction (DPIR, 2016). Mining Officers advised MRM that the ITRB and the Independent Certifying Engineer (ICE) should be made aware of cracking so that they could assess their potential implications on operation and future embankment raises.

- Water was observed in the southwest corner seepage pump sump during the January 2017 inspection (DPIR, 2017a). Mining Officers advised MRM to sample this water to determine its origin. The outcome of this testing is unknown.
- Mining Officers observed that the C1SA overflow was not an engineered clay and rock-lined spillway (DPIR, 2017a). Mining Officers reiterated to MRM to:
  - Submit an incident notification to the department as soon as practicable in accordance with Section 29 of the Mining Management Act.
  - Provide the DPIR with a written investigation report detailing the outcomes of the investigation including the remedial actions taken, or to be taken, and recommendations for the prevention of similar incidents.
- During the March 2017 site inspection, Mining Officers noted that Cell 1 tailings had been exposed in some areas due to erosion (DPIR, 2017b). It was unclear to Mining Officers what, if any, remedial works were planned.
- Seepage from the Cell 2 Spillway was observed by Mining Officers during inspections in 2017 to be continuing (DPIR, 2017b; 2017c; 2017d).
- In August 2017 Mining Officers observed salts and a 'damp spot' adjacent to a pipe going through the embankment adjacent to the seepage recovery sump in the southwest corner of Cell 2 (DPIR, 2017c). The Mining Officers asked MRM to confirm the nature and cause of the expression; MRM personnel advised that they would follow up and provide advice to the DPIR. During their next inspection Mining Officers noted that the pipe appeared to have tailings-like material inside (DPIR, 2017d); MRM personnel advised that they would fill the pipe with concrete and cover with filter material.
- In September 2017 Mining Officers noted dust was being generated from the desiccated tailings beaches, which was dispersing beyond the confinement of the TSF into the surrounding area (DPIR, 2017d).
- An area in the southwest corner of the TSF was found to have what appeared to be tailings material on the outside of the wall (DPIR, 2018). Both MRM and Mining Officers agreed that the source of tailings was likely to be the pipe identified in earlier inspections (DPIR, 2017d). It is not known whether the remedial actions proposed by MRM have been implemented.

Non-compliances

There are no non-compliance issues known to the IM to report.

Progress and New Issues

Progress in the last reporting period includes:

- Construction of TSF Cell 2 upstream raise to RL 57 mAHD.
- Construction of a new and considerably larger spillway for TSF Cell 2.
- Construction of a buttress along the Stage 1 crest of the eastern embankment.

- A visual reduction in seepage at the 'old' Cell 2 spillway since the installation of the recovery bore in the rock mattress (DPIR, 2018).
- Reduced water expression in the southwest corner well (DPIR, 2018).

New issues include:

- Sump overflow incidents.
- Seepage through the Cell 2 embankment.
- Tailings release incidents.
- Reconciliation of embankment stability assessment and elevated pore pressure readings.
- Changes to the embankment crest width and outer embankment material.

Each of the issues is discussed separately below.

Sump Overflow Incidents

Several overflow incidents have occurred in TSF sumps. These incidents raise concerns over ongoing stormwater water management given their relatively high frequency of occurrence. The overflows have occurred due to a combination of:

- Overflows of higher intensity rainfall significantly exceeding the installed capacity of the existing pump and/or pipelines.
- Residual water and sediment in the sump at the start of the rainfall event.
- Failure of diversion or retaining structures resulting in additional runoff reporting to sumps.
- Inability to meet pumping demand due to sub-optimal pump capacity or intermittent tripping of electrical circuits.

A number of emergency and remedial actions have been taken by MRM in response to incidents that occurred in the 2016/17 wet season. McArthur River Mining further proposed additional corrective actions to prevent or limit further occurrences as outlined in Section 4.7.1.4. In addition, DPIR Mining Officers advised MRM in January 2017 that the C1SA overflow was not an engineered clay and rock lined spillway and requested a number of corrective actions (DPIR, 2017a).

The IM understands the actions that have been undertaken in response to these events are as follows:

- Mining Officers from the DPIR were informed that the control box for the pumping station had been replaced during their March 2017 inspection (DPIR, 2017b).
- To analyse the hydraulic performance of C1SA and C1SB, WRM (2017b) was engaged and found that minimum dewatering pump rates for C1SB significantly exceed the installed capacity. A number of remedial options were recommended including minor drainage works

to alter the catchment area reporting to each sump and switching the C1SA and C1SB pumps in order to limit spill probability for each sump to the 1:20 year Annual Exceedance Probability (AEP) event. The IM understands that MRM has implemented the recommended changes (MRM, pers. com., 29 August 2018); WRM indicated that once these upgrades are completed both sumps will have 5% AEP flood immunity.

- A new dividing bund was constructed in December 2017 to decrease the C1SB catchment area and increase the C1SA catchment (MRM, 2018b). This measure had been employed previously and had failed in January 2017 (MRM, 2018a).

The IM has not been provided with any evidence of any other actions such as overflow improvements to C1SA, swapping of C1SA and C1SB pumps, implementing automated pump initiation, water level monitoring or surface improvements to Cell 1 within the reporting period. However, MRM has advised that pumps have been swapped, with sumps being de-silted and armoured. Instrumentation has not been installed, with MRM considering automation not to be practical (MRM, pers. com., 29 August 2018).

It is considered by WRM (2017b) that the 72-hour storm is usually the critical event for C1SA and C1SB sumps. Based on BoM IFD curves, overflow events correspond to the following likelihood of occurrence for this storm duration:

- 23 to 25 January 2017: 84.6 mm over 72 hours, which corresponds to an AEP of about 82% (occurring about twice per year on average).
- 18 to 20 February 2017: 158.8 mm over 72 hours, which corresponds to an AEP of about 40% (occurring about every 2 years on average).
- 23 to 25 January 2018: 359.6 mm over 72 hours, which corresponds to an AEP of about 2.4% (occurring about every 40 years on average).

Based on these AEP values, it could be concluded that C1SB is relatively close to its 2% AEP design while C1SA falls short of its 1% design AEP. However, the IM notes that significant rainfall fell prior to, and after, these events with 66 mm of rain in the 3 days prior to 23 January 2018 and 117 mm for the 3 days thereafter. This event has been assessed by WRM to be approximately a 1% AEP on both a one-hour and seven-day storm duration basis. The IM understands that works to provide spill immunity for 5% AEP events for C1SA and C1SB were completed by the 2017/18 wet season. Therefore, the magnitude of the January 2018 event could reasonably be expected to exceed the design immunity of the sumps.

At the same time, the 23 to 25 January 72 hour storm is essentially the only event of significance to occur in the 2017/18 wet season. It is therefore difficult to gauge the performance of C1SA and C1SB under events of lower intensity similar to those that resulted in overflow in January and February 2017.

It has been noted by WRM (2017b) that spills from C1SA and C1SB during 1% and 2% AEP events would be accommodated in respective borrow areas WBP and EBP. However, during the spill on 19 February 2017 flow from C1SB did not initially flow to the EBP. A diversion bund had to be constructed during the flood to direct flow to EBP. Additionally, the WRM (2017b) analysis does not include any consideration of the available storage of borrow pits during storm events, which will be affected by other inputs such as direct rainfall. The borrow pits are relatively shallow and therefore a design 1% AEP of around 440 mm over 72 hours may significantly reduce borrow pit capacities to capture C1SA and C1SB overflow. The IM recommends that the dynamic capacity of the borrow areas and consideration of the flow pathway be included in the assessment of the Cell 1 stormwater system.

Seepage Through the Cell 2 Embankment

Seepage through the Cell 2 embankment has been an ongoing issue at the TSF, particularly at the southwest corner of Cell 2. No large quantities of seepage have been observed in this area but some scouring of the wall was observed by the DPIR during the February 2018 inspection (DPIR, 2018). An area directly adjacent to the southwest corner sump showed more significant erosion. The DPIR advised MRM to monitor and repair if necessary.

Seepage at the following two locations was noted by GHD (2018d) during the annual inspection:

- Downstream batter of the southern embankment adjacent to the decant causeway.
- Downstream batter of the southern embankment immediately east of the old spillway.

In both cases seepage was observed at or near the interface between Stage 1 and 2 embankments and discovered as a result of vegetation clearing in October 2017. It is possible that seepage in these areas has been occurring for some time.

It has been noted by GHD (2018d) that seepage adjacent to the decant causeway was not observed in measurable quantities and was characterised by soft, damp zones and areas of sulfate deposition at the surface. It is inferred by GHD (2018d) to be associated with locally elevated pore water pressure within the rock mattress that lies immediately upstream of the Stage 1 crest.

The Stage 1 rockfill decant was known initially to be hydraulically connected to the rock mattress. Two attempts have been made to separate the rock decant and mattress with the second using clay bentonite plug considered successful. It was postulated by GHD (2018d) that the ongoing seepage is possibly the result of either:

- Water continuing to find a path around the plug and into the mattress, thereby contributing to the observed seepage.
- Pore water dissipation from tailings consolidation finding its way into the high permeability rock mattress.

Seepage immediately east of the old spillway was not observed in measurable quantities and was characterised by soft, damp zones and areas of sulfate deposition at the surface. It is also inferred by GHD (2018d) to be associated with locally elevated pore water pressure within the adjacent rock mattress on which the Stage 2 raise was founded. The surface expression in this location is likely exacerbated by ponding of seepage upstream of the concrete spillway plinth.

It is considered by GHD (2018d) that seepage at these two locations does not currently present an immediate risk to dam safety. This area is currently included in routine visual inspections for evidence of increased seepage.

Tailings Release Incidents

Two pipeline failures were recorded during the reporting period. While these events are undesirable, to have only two failures over an extended reporting period is a substantial improvement over previous years. In both cases the release appears to have been contained quickly and effectively.

Reconciliation of Embankment Stability Assessment and Elevated Pore Pressure Readings

McArthur River Mining has provided the IM with a number of new assessments and analyses of piezometric records for the TSF (MRM, 2018e). These analyses are contained in a spreadsheet and include:

- Water level readings for 14 standpipe piezometers: EMBGW1A, 1B, 2A, 2B, 3, 4, 5A, 5B, 6, 7, 8, 9A, 9B and 10.
- Pressure transducer readings for 19 VWPs: EMBGW13A, 13B, 14A, 14B, 15A, 15B, 16A, 16B, 17A, 17B, 18A, 18B, 18C, 23, 24, 25, 26A, 26B and 26C.
- Snapshot and time series plots of readings for piezometers along nine sections lines, those located in the rock mattress and comparisons of these with rainfall and Cell 2 pond levels.
- Comparison of current and past maximum readings with 'Normal' (green), 'Troubleshoot' (orange) and 'Unsafe' (red) trigger levels for 28 of the 32 piezometers (one is considered to be malfunctioning and three others were installed adjacent to the decant pond for 'future design purposes').

Most piezometer records in MRM (2018e) contain time series data to 31 March 2018, while some VWPs only contain data to 29 January 2018. The same plots of piezometric levels on these nine sections have been replicated in GHD (2018d) and MRM (2018c). This data shows that there have been rapid increases in pore pressure readings during the last two wet seasons. These are discussed further below.

Between 17 and 24 February 2017 recorded rainfall was around 171 mm and these piezometric increases were recorded:

- Piezometer EMBGW2A increased from 40.51 to 42.07 then dropped to 40.39 mAHD.
- Piezometer EMBGW2B increased from 42.341 to 42.92 mAHD.
- Piezometer EMBGW9A increased from 36.05 to 38.56 then dropped to 38.35 mAHD.
- Piezometer EMBGW9B increased from 42.60 to 43.25 mAHD.
- Piezometer EMBGW10 increased from 48.76 to 52.94 then dropped to 48.76 mAHD.

The most rapid of these increases occurred in EMBGW2B at 1.39 m/day averaged over three days.

McArthur River Mining (MRM, 2018e) has compared maximum piezometric levels against piezometric trigger levels which vary according to section location. This dataset provides an assessment of groundwater level triggers as at 13 December 2017, while data has been provided to end of March 2018.

The exact derivation of these trigger levels is unknown but appears to be a combination of past observation and experience and design water levels used in stability analyses. The reading for EMBGW10 on 20 February 2017 exceeds the orange 'Troublesheet Zone' trigger but has been omitted from the MRM (2018e) trigger assessment. The time series for EMBG10 is shown in Figure 4.29. The readings for EMBGW18A were also relatively high at that time and are included in Figure 4.29.

Piezometer EMBGW10 is located in the Cell 2 eastern embankment along a section identified in MRM (2018e) as 18-XS. In the January 2017 MRM TSF Communication Report it is noted that:

> The piezometer EMBGW10 in the rock mattress continues to record low readings below the bottom of the piezometer screen. The positive readings **may** have been a result of rainfall infiltrating the standpipe and are not currently cause for concern for the stability of the TSF.

In MRM (2018c) a review of piezometer data undertaken by GHD found that for EMBGW10:

> Readings appear reliable, erroneous reading obtained on 20/2/2017.

Based on the above it would appear that the very high EMBGW10 reading on 20 February 2017 has been discounted. This issue was raised with MRM who responded by stating that (MRM, pers. com., 4 September 2018):

> MRM/GHD considered that the spike was associated with either human error or rainfall infiltration around the casing following 125 mm rainfall on the 19th Feb (day previous to the spike). GHD recommended a review of all standpipes to ensure proper sealing of casing and a water shedding surface. EMBGW10 has been observed as dry since the 9th April 2017.

The IM can confirm that readings from EMBGW10 indicate it has been dry since 9 April 2017.

Between 21 and 27 January 2018 recorded rainfall was around 538 mm and these piezometric increases were recorded:

- Piezometer EMBGW2A increased from 41.2 to 41.55 mAHD.
- Piezometer EMBGW2B increased from 42.34 to 48.57 mAHD then dropped to 46.52 mAHD.
- Piezometer EMBGW5A increased from 40.64 to 42.57 mAHD.

The most rapid of these occurred in EMBGW2B at 0.52 m/day averaged over eight days. Rates of rise are likely to have been higher in the shorter term but standpipe piezometers are only measured every seven days on average.

The trigger assessment in MRM (2018e) indicates that, as at 13 December 2017, all readings at that time were below the green 'Normal Zone' levels (excluding the EMBGW10 as discussed

TIME SERIES OF MEASURED PIEZOMETRIC LEVELS ON SECTION 18-XS

McArthur River Mine Project

FIGURE 4.29

above). Analysis of triggers by the IM after 13 December 2017 indicates that some triggers have been exceeded. For example, the maximum for EMBGW2B of 48.57 mAHD recorded on 10 February 2018 exceeds the red ‘Unsafe Zone’ trigger for this piezometer.

McArthur River Mining has indicated to the IM that checks on trigger levels after 13 December 2017 have been undertaken and reported in the April 2018 quarterly report (MRM, pers. com., 4 September 2018).

The piezometer assessment contained in MRM (2018c) shows the recorded values for EMBGW2B as a time series and notes the following under the piezometer review in Attachment B of that document:

> Rainfall runoff entered the collar of the standpipe in January 2018 and readings have since been unreliable as water is likely to be still dissipating from the borehole… Seal collar of standpipe to prevent rainfall runoff entering the standpipe… Readings appear reliable.

The IM understands from these statements that the high readings for piezometer EMBGW2B (and EMBGW2A) on and around 10 February 2018 are considered erroneous and have been ignored for the purposes of stability assessment.

Time series plots for EMBGW2A, EMBGW2B and EMBGW23 are shown on Figure 4.30. The piezometers are on Section 23 and 2 through the northern wall of Cell 1 as identified in MRM (2018e). It is clear from Figure 4.30 that:

- Increases in piezometers EMBGW2A, EMBGW2B and EMBGW23 are in direct response to rainfall as expected.
- The response in the 2016/17 wet season is less for all instruments reflecting the lower rainfall in this period compared to the 2017/18 wet season.
- The rate of increase in water levels for EMBGW2A and EMBGW2B in February 2018 appears to be similar.

Piezometer EMBGW23 shows a similar response to EMBGW2B during the 2016/17 wet season. The IM has not been provided with data for EMBGW23 beyond 21 December 2017 and therefore this piezometer cannot be used for comparison thereafter. The IM also notes that EMBGW2A, EMBGW2B and EMBGW23 are located near a break in the internal bund of the C1SA catchment area, as evident in the June 2017 aerial photo. It is expected that this break will result in a local surge in surface water levels in this location.

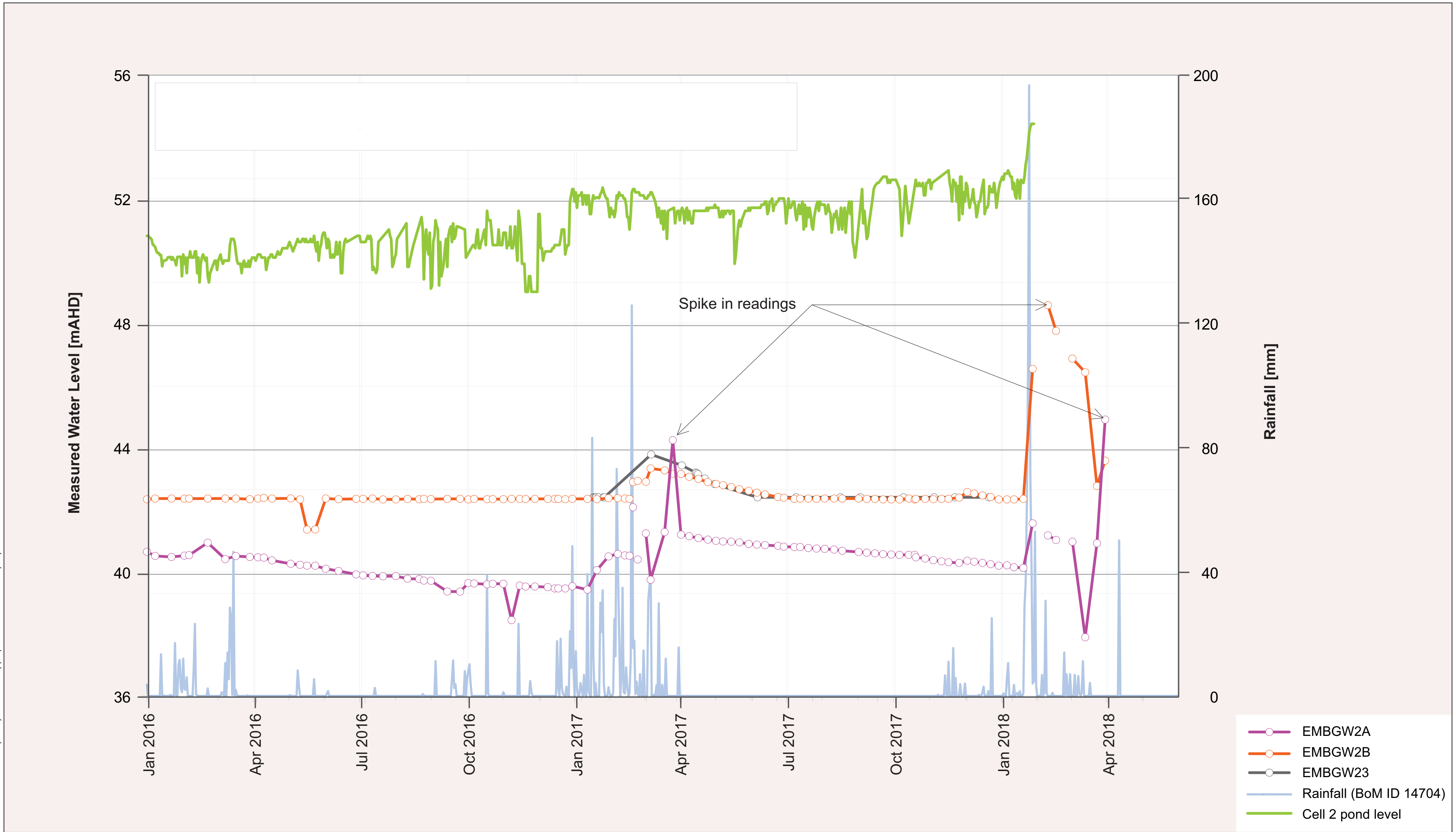
On the basis of the evidence provided and the piezometric response of nearby groundwater monitoring bores the IM agrees that the sharp increase in readings for EMBGW2A, EMBGW2B and EMBGW10 are **likely** to be due to ingress of surface water into standpipe piezometer openings. However, the TSF design is based on an observational approach, this being (GHD, 2018b):

> The observational approach allows the TSF to be optimised over time as monitoring information becomes available and the design and construction methodologies evolve. The observational approach allows any changes that might occur during the life of the TSF to be accommodated whilst meeting the design criteria and objectives over the entire life of the TSF.

TIME SERIES OF MEASURED PIEZOMETRIC LEVELS ON SECTION 23&2-XS

McArthur River Mine Project

FIGURE 4.30



The use of such an approach is only as good as the data being collected and analysed. Consequently, unusual or irregular data should not be readily ignored without careful investigation and assessment. Based on the current information it is possible, though unlikely, that recorded piezometric levels in EMBGW2B are real and therefore embankment stability in January 2018 compromised. In the IM's opinion, the observational approach requires that data cannot be readily discounted if it does not conform to previous trends.

Incidents such as these temporary increases in pore pressure need to be carefully investigated to determine whether they are real or otherwise. If this investigation proves to be uncertain, as in this case, then steps need to be taken as soon as possible to reduce this uncertainty.

In the main body of MRM (2018c) it is noted that:

> The collar of the standpipes EMBGW5A and EMBGW2B should be sealed to prevent rainfall runoff infiltrating the borehole. It is understood that MRM intend to install fully grouted vibrating wire instruments in these locations which is acceptable.

The IM concurs that such action should be undertaken. Importantly, remedial actions of this nature need to be undertaken as soon as possible so that the basis of the observational approach is not undermined. On a minor note the IM notes that the top and bottom location of the EMBGW3 screen as shown in time series and sectional plots has been calculated incorrectly. This has no material impact on TSF performance but may lead to misinterpretation of piezometric levels.

McArthur River Mining has responded to this issue as follows (MRM, pers. com., 4 September 2018):

> Based on a combination of documented operator observations of ponding water over the piezometer casing, combined with the lack of response in EMBGW2A (3 m below), it was considered there was sufficient evidence to support the assessment made at the time. The behaviour and reliability of EMBGW2B is however subject to further investigation. There are plans for implementing the GHD recommendation of replacing Piezo EMBGW2B with a fully grouted vibrating wire piezometer. MRM will inform the DPIR on outcomes.

Changes to the Embankment Crest Width and Outer Embankment Material

The Cell 2 Stage 4 raise included two significant design changes over the Stage 3 design, as follows:

- A reduction in crest width from 9 m to 7 m.
- The use of Zone 3 material for the outer 4 m of the raise.

Zone 3 is denoted 'general rockfill' in the body and 'weathered rockfill' in the drawings of the design report (GHD, 2017c). The use of Zone 3 material has been stated in MRM (2018d) as being for protection of the clay zone from desiccation and erosion.

The combined effect of these changes is a 6-m reduction in the width of Zone 1 material. Zone 1 provides not only relatively high strength of 10 kPa cohesion and 30-degree angle of friction but also reduced permeability of around 1×10^{-9} m/s as it is placed and tested in accordance with a compaction specification (GHD, 2017c). Zone 3 material comprises 'well graded highly weathered to fresh rockfill sourced from benign mine waste rock or nominated local borrow areas' (GHD, 2017c). The Stage 4 design states that Zone 3 (GHD, 2017c) is:

- To be compacted in 600 mm lifts and proof rolled.
- To 'typically' have less than 15% of fines after compaction.
- To be visibly assessed by the site engineer as having met these compaction criteria.
- Unlikely to require testing.

This material represents a relaxing of the material previously used to armour the outer batter with an expected strength of 0 kPa cohesion and 38-degree angle of friction and an expected permeability of 1 x 10^{-5} m/s (Table 16 of GHD (2017c)).

The Stage 4 construction report confirms that assessment of Zone 3 properties and placements was undertaken on a visual basis (GHD, 2017d).

The IM does not consider the reduction in crest width on its own to be significant provided that ANCOLD (2012) recommended factors of safety are met. However, none of the stability analyses in GHD (2017c) (Appendix E) appear to include Zone 3. McArthur River Mining has responded to this issue as follows (MRM, pers. com., 4 September 2018):

> The design of the Cell 2 Stage 4 raise was an iterative process to achieve optimal design geometry. Substituting Zone 1 clay for a higher strength Zone 3 rockfill in the top 2 raise would have no material impact on the results of the stability analysis (i.e. no impact to minimum factors of safety) due to critical failures being at depth. It is noted that the detailed design of Cell 2 Stage 5 Raise (currently under construction) included stability modelling with the 4 m wide Zone 3 as per the design geometry. This later modelling supersedes previous modelling for the Stage 4 raise.

The IM accepts MRM's assessment that the omission of Zone 3 properties in stability analyses provided in GHD (2017c) would not have any material impact on reported factors of safety.

McArthur River Mining's performance against previous IM review recommendations relating to geotechnical issues at the TSF is outlined in Table 4.32.

Table 4.32 – Geotechnical (TSF) Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
Tailings pipe delivery system	Inspection of the entire tailings pipeline including checking flange bolts to confirm correct assembly Update reporting procedures for reporting the incidents and remediation of tailings pipeline breaches	Completed Regular inspections of the tailings pipeline have been undertaken including thermography surveys of key areas undertaken in August 2017 and February 2018 by SKF
TSF piezometers	Use VWPs to record water levels	Completed A total of 19 VWPs are in operation around the TSF which in conjunction with the 14 standpipes is considered sufficient
TSF piezometers	Piezometer plots are shown as a continuous record and actual data points are not identified. This obviates the actual data density and periods for which there is no data. In addition, the plot is	Completed The latest version of the QOR presents piezometer data more clearly and appropriately and is

Table 4.32 – Geotechnical (TSF) Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
TSF piezometers (cont'd)	smoothed which artificially gives the impression of smooth rises and falls in the water table. Data should be plotted without smoothing showing gaps and actual data points to avoid misinterpretation	commended. McArthur River Mining is encouraged to maintain this standard for future QORs
TSF density	Undertake a reconciliation of deposited mass and surveyed volume to estimate in situ density	Completed Density reconciliation undertaken in September 2017 after photogrammetry survey completed in June 2017
TSF seepage	Investigate and assess the reasons why seepage and piezometric levels appear to be higher than anticipated Provide options for limiting further seepage and reducing water levels within the embankment	Completed This issue was resolved in the prior reporting period and is less likely to occur under the recent changes to TSF reporting
TSF operations manual	Reconcile a number of discrepancies within the operations manual	Ongoing The C1SA and C1SB stated capacities in the operations manual are 6 and 60 ML respectively. The WRM site water balance model states capacities at 3.5 and 36 ML respectively. McArthur River Mining has indicated that this discrepancy will be checked and resolved.
TSF design	All future correspondence on the TSF should clearly indicate whether it is the advice of the designer or the ICE The independence of the ICE and the designer should be reviewed by MRM and the DPIR	Completed It is now easier to differentiate between these roles based on the documentation provided
TSF surface water management	There are discrepancies between GHD and WRM on the capacity and efficacy of the C1SA. GHD (2017e) states the capacity as 6 ML and inadequate for the catchment area while WRM (2017b) states the capacity as being 8 ML and with only a 1% chance of spilling each year. At the same time this sump has been known to spill under a 1:20 year event. These discrepancies need to be resolved and the sump modified to meet design requirements	Ongoing These discrepancies remain in GHD (2017e) and WRM (2017b), which are both considered current
TSF design	Ensure the Cell 1 drainage and detention system can accommodate a 1 in 100-year storm event through assessment and modification as required	Ongoing ANCOLD specify design to a 1 in 100 year event for a High C TSF as in this case. However, recent reports from MRM suggest this has been revised down to a design requirement of 1 in 20 year event. The justification for this reduction has not been provided
TSF seepage	The efficacy of the systems put in place to limit seepage to Surprise Creek needs to be assessed, namely:	Ongoing GHD has proposed the construction of a seepage

Table 4.32 – Geotechnical (TSF) Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
TSF seepage (cont'd)	♦ The geopolymer barrier ♦ The interception bores Previously, the IM questioned the efficacy of the interception bore field and this was primarily based on the lack of such a means of assessment. This assessment was quoted by MRM as a reason to discontinue this recovery method. The IM recommends that MRM focus on a successful means of measuring the efficacy of these systems as the current methods do not appear to be conclusive. This will help to focus and improve recovery efforts	interception trench between Cell 1 and Surprise Creek (GHD, 2017b). Further analysis and investigations are planned for detailed design
TSF construction	All future civil works should provide evidence of testing type and results, compliance (pass/fail), testing frequency and test distribution. For test failures evidence should be provided of what specific action and retesting has been undertaken to rectify areas where tests have failed	Completed for the Cell 2 Stage 3 and Stage 4 lifts
TSF seepage	McArthur River Mining to review the current strategy for preventing seepage to Surprise Creek in light of recent groundwater monitoring, EM remote sensing and any other relevant data. This review should present evidence as to the effect of existing mitigation strategies, their longevity and long-term feasibility in consideration with other mitigation works such as final capping of Cell 1	Ongoing GHD has proposed the construction of a seepage interception trench between Cell 1 and Surprise Creek (GHD, 2017b). Further analysis and investigations are planned for detailed design
	McArthur River Mining to consider discharge of collected seepage north of Cell 1 to other areas of the TSF and not back onto the Cell 1 surface	Under review pending the outcome of the seepage trench design
TSF monitoring	For MRM to fulfil commitments with respect to monitoring piezometric levels within the Cell 2 embankments so that design factors of safety can be confirmed that the dam is being operated safely. This recommendation was made in the previous two IM reports. The previous IM report also requested that detailed stability analyses need to include monitored (as opposed to estimated) phreatic surfaces in the tailings and embankments. These items remain outstanding and were rated previously as high priority	Completed Fourteen piezometers installed in the TSF continue to be read every fortnight. An additional 19 VWPs were installed late 2016. Standpipes and VWPs have been extended after the Stage 3 lift

Successes

The most significant success for the TSF in this reporting period is continued effective management of the pond, cyclic deposition, tailings strength gain and monitoring.

Specific successes include:

- Completion of the 2-m raise of TSF Cell 2 to RL 57 mAHD.
- Construction of new spillway for TSF Cell 2.
- Construction of a buttress along the Stage 1 crest of the eastern embankment.

- Updated operating guidelines, operating limits, triggers and actions.
- Ongoing monitoring of piezometric levels, settlement, pond levels, reclaim volumes and beach angles.

4.7.1.5 Conclusion

Overall, the TSF continues to be well managed in terms of operation, inspections and external review for the current reporting period.

The main issues that occurred during the reporting period relate to the monitoring and management of surface water at Cell 1. Ponding stormwater appears to have impacted the recorded water levels and the interpretation of piezometric levels in the Cell 1 embankment at a time when stability is likely to be at its lowest factor of safety. Ponding stormwater is also likely to be contributing to ongoing seepage from Cell 1 into Surprise Creek.

McArthur River Mining has proposed a number of measures to limit these impacts in future and the IM understands that some of these have been implemented. Some measures have failed, most notably the use of a dividing bund to adjust the catchment areas for C1SA and C1SB (although this was subsequently repaired and a new bund installed along a new alignment in the following wet season). This is likely to exacerbate the issues relating to reliable reading of piezometers and increased seepage. The operation of C1SA and C1SB based on the significant rainfall event in January 2018 appears to be at or close to design, although there are no other events in the same wet season for comparison.

Seepage through the Cell 2 embankment is an ongoing issue and should continue to be monitored as part of routine visual inspections for evidence of increased seepage.

Ongoing and new IM recommendations related to TSF geotechnical issues are provided in Table 4.33.

Table 4.33 – New and Ongoing Geotechnical (TSF) Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
TSF seepage	♦ The origin and veracity of fault mapping in the vicinity of the TSF need to be investigated further ♦ Further investigations are needed to quantify preferential flow paths for seepage. These investigations should use all available geological information to maximise efficiency and improve the basis for subsequent modelling. Mapping should be used to set the depth of modelling which may need to be increased from 20 m to substantially greater depths ♦ The WRM water balance needs to be updated to include estimates of TSF evaporation and seepage. Seepage estimates are likely to be improved through the actions described above	High
	McArthur River Mining should review the current strategy for preventing seepage to Surprise Creek in light of recent groundwater monitoring, EM remote sensing and any other relevant data. This review should present evidence as to the effect of existing mitigation strategies, their longevity and long-term feasibility in consideration with other mitigation works such as final capping of Cell 1	High

Table 4.33– New and Ongoing Geotechnical (TSF) Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
TSF density	Undertake a reconciliation of deposited mass and surveyed volume to estimate in situ density	Medium
TSF operations manual	Reconcile a number of discrepancies within the operations manual	Low
New Items		
TSF design	Include the effects of dynamic capacity of borrow pit areas and flow pathways in future stormwater capacity assessments	Medium
TSF design	The TSF designer should confirm that Zone 3 material has been included in the stability assessments provided in GHD (2017c)	Medium
TSF operation	Modify piezometers so that they are not impacted by stormwater. This may include converting some standpipe piezometers to VWPs	High
TSF operation	Provide a more definitive assessment as to the likely cause of increased piezometer levels at EMBGW10 and EMBGW2B and the implications on wall stability	High
TSF operation	Provide an update on what C1SA and C1SB improvements have been completed, including pump changes, pump automation and diving bund changes or repairs	Medium
TSF operation	Update the MRM (2018e) trigger assessment spreadsheet to capture maximum and current water levels, and updated trigger assessment	Medium
TSF monitoring	The frequency at which VWPs are currently logged varies across the TSF and generally higher than stated in the TSF operations manual (GHD, 2017e). The frequency VWPs operations manual should be standardised across the TSF to a relatively high frequency (say 4 or 5 times per day) and the operations manual updated accordingly	Medium
TSF monitoring	The top and bottom location of the EMBGW3 screen as shown in time series plots should be corrected	Low

4.7.2 Overburden Emplacement Facilities

4.7.2.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of geotechnical issues at the OEFs, and is based on:

- Observations and discussions with MRM personnel during the site inspection.
- Review of various reports prepared by MRM and its consultants, with particular reference to MRM's mining management plan (MRM, 2015) and 2016-2017 and 2017-2018 OPRs (MRM, 2017p; 2018d).
- Inspection reports by the DPIR.
- Construction progress reports prepared by the ICE (currently GHD). Reports vary in length from one to three months. These reports contain photographs, test results and any specific site instructions. Reports provided to the IM were for October 2016, November 2016, December 2016, January to March 2017, April 2017, May 2017, June 2017, July to September 2017, and October to November 2017.

- Review of laboratory and in situ testing of compaction materials (provided in spreadsheet form).
- Review of various MRM forms survey results, incident notification letters, and correspondence between MRM, regulators and third parties.
- Aerial and other photographs of the McArthur River Mine provided by MRM.
- Airborne laser scanning (ALS) (topographic) data of the mine site provided by MRM.

McArthur River Mining uses the term ‘permeability’ in the OEFs to refer to the hydraulic conductivity of materials tested. This convention has been retained for this section.

4.7.2.2 Key Risks

The key risks to management of geotechnical issues at the OEFs, as described in the risk assessment (Appendix 1), are:

- Failure of the clay barrier to provide a barrier against water ingress into the PAF material, and hence the formation of leachate and/or ingress of oxygen leading to oxidation of the PAF material. This may manifest by:
  - Erosion of the clay liner due to exposure, resulting in its failure.
  - Failure of the liner to form a continuous barrier due to slope instability under static or seismic loading, exposing PAF materials.
  - Desiccation cracking of the liner resulting in an increase in its permeability to air and water.
  - Sub-optimal construction quality control resulting in the liner not achieving the required permeability.
  - Differential settlement of waste rock leading to excessive strain and cracking of the liner.
  - Use of material outside of the specification resulting in substandard performance including increased permeability.
- Slope instability or excessive displacement of the perimeter runoff dams resulting in loss of fluids or excessive seepage.

4.7.2.3 Controls

Previously Reported Controls

The following controls were in place for management of OEF geotechnical risks in the previous reporting period:

- Design report for the NOEF including specifications for clay liner (URS, 2008).
- Sustainable Development Mining Management Plan 2013-2015 (MRM, 2015).

- The 2015-2016 OPR (MRM, 2016a).
- Specification for clay liner, MIN-TEC-PRO-1000-0026 (MRM, 2012a).
- Sampling procedure, MIN-TEC-PRO-1000-0015 (MRM, 2012b).
- As-built review and signoff procedure, MIN-TEC-PRO-1000-0025 (MRM, 2011).
- Overburden emplacement facility management plan (MET Serve, 2012).
- Rehabilitation of the NOEF (OKC, 2014).
- The 2016 OPR (MRM, 2016a).

New Controls – Implemented and Planned

Work continued on the design and construction of the central west phase of the northern overburden emplacement facility (CWNOEF). The CWNOEF design is specified in the following documents:

- Sustainable Development Mining Management Plan 2013-2015 (MRM, 2015) and amendments, particularly the amendment as approved by the DPIR (MRM, 2016d, DPIR 2016b).
- CWNOEF Design, Construction and Operations Manual version 2.1 (MRM, 2016b) with modifications as approved by DPIR (MRM, 2016d, DPIR 2016b).
- Monthly construction reports for the CWNOEF from October 2016 to November 2017.
- 2016-2017 OPR (MRM, 2017n).
- 2017-2018 OPR (MRM, 2018d).

The CWNOEF design has undergone a number of revisions. Version 2.1 of the Design, Construction and Operations Manual (MRM, 2016b) was accepted by DPIR based on modifications proposed by MRM. This has been confirmed in a Variation of Authorisation from the DPIR dated 29 November 2017.

Version 2.1 of the CWNOEF Design, Construction and Operations Manual (MRM, 2016b) contains a number of controls for OEF construction, these being:

- A revised compaction specification for the subgrade (in situ material), subgrade base (benign waste placed within the 1 in 100 AEP flood level) and compacted clay liners (CCLs).
- Placement of all PAF rock using paddock dumping with a 2-m tiphead.
- A new campaign of testing to assess the suitability of in situ materials comprising over 160 test pits and 23 drill holes including particle size, Atterberg limits, compaction, moisture, strength, permeability and dispersion testing.
- Stability assessment of the NOEF using finite element analysis.

- A number of CCL controls including:
  - A compaction maximum moisture from 0 to +3% of optimum.
  - A minimum dry density ratio to 98% of maximum dry density (standard).
  - A maximum loose layer thickness from 200 to 300 mm and a maximum particle size limit of 75 mm.
  - Use of a vibrating pad foot roller with a minimum static mass of 10 t.
  - Density and moisture testing at 1 per 500 m^3 for placed CCL material.
  - Particle size and Atterberg limits testing at 1 in 20,000 m^3 for placed CCL material.
  - Permeability testing at 1 in 10,000 m^3 for placed CCL material.
  - Dispersion testing (Emerson Class and pinhole dispersion) at a rate of 1 per 20,000 m^3
  - Use of protective covers on areas of completed CCL to limit the effects of desiccation.
- An engineered subgrade (the CCL foundation) comprising select earthfill for the top 200 mm and rockfill below this, such that:
  - Rockfill comprises: fresh to moderately weathered, durable, angular rock with a maximum particle size of 0.6 m and a minimum size of 80% passing 0.2 m. Maximum lift height of 1 m in thickness and compacted using six passes of a vibratory, flat drum roller with a minimum static mass of 10 t.
  - Earthfill comprises: moisture conditioning to the range -3 to +3% of optimum moisture content and to at least 95% of maximum dry density (standard). Use of a vibrating pad foot roller with a minimum static mass of 10 t when the subgrade materials are predominantly fined grained soils.

Alluvium is being used to cover PAF cells CCLs after completion to limit advective oxygen ingress. This is an additional measure not included in MRM (2016b).

Several activities and studies were completed as part of the Draft OMP EIS and the OMP SEIS that will provide information and possible future controls irrespective of the EIS outcome. These are:

- Assessments on how closure trials may be implemented, instrumented and monitored (OKC, 2017a; 2017c; 2018).
- Single and multi-phase modelling of oxygen and water ingress and egress though proposed cover and liner systems (OKC, 2016a; 2016c; 2017b).
- Modelling potential long-term erosion of proposed cover systems (OKC, 2016b).

- Expansion of the NOEF groundwater, gas and temperature monitoring program (MRM, 2016c; 2017q). There are now 9 piezometers and 21 temperature and monitoring wells. Temperature and gas monitoring wells have three to four sensors over their depth.

There are a number of planned controls specified in MRM (2016b). These are:

- A drilling investigation to identify and quantify the extent of possible faults or paleochannels beneath CWNOEF.

- Closure trial lysimeters and cover test pads.

In the current reporting period, progress reports refer to Version 2.2 of the Design, Construction and Operations Manual. The IM has not been provided with this document and the approval status is currently unknown.

4.7.2.4 Review of Environmental Performance

Incidents and Non-compliances

Incidents

One incident was reported during the reporting period related to geotechnical matters at the NOEF and is discussed below.

Venting Incident on NOEF Batters – 25 January 2017

A venting incident was noted in the MRM Incident Register (MRM, 2018a) as having occurred on 25 January 2017 on the northern and southern batters of the NOEF:

- Formal incident notification (MRM, 2017h) was submitted to the DPIR on 27 January 2017. An incident report was prepared at the request of DPIR and provided in MRM (2017o). The incident was reported by MRM as follows.

- Water vapour was observed on the top batter of the West AB and the northern face of the NOEF following heavy rainfall on 24 January 2017. Minor venting was also observed on the southern batter of the NOEF. The presence of water vapour indicates the oxidation of waste rock material. Inspection of the area confirmed minor combustion of loose rock that had recently been emplaced in areas of the NOEF designed for non-benign waste rock material (i.e., cells). The areas where water vapour was observed were in active areas of faces of the NOEF that were yet to be covered and battered to final design.

- At the time the venting was observed mitigation could not be undertaken immediately due to the heavy rainfall and associated conditions on the dump restricting the use of mining equipment.

- McArthur River Mining proposed the following remediation steps to control the source of combustion:

  – Search for sources of combustion by visual inspection, infra-red camera, SO_2 emissions and drone surveys.

- Remediate these sources by using a dozer to spread the source material and cover with a layer of clay to prevent further oxygen ingress.
- Undertake follow-up inspections and maintenance of remediated areas to confirm effectiveness of capping.

McArthur River Mining assessed that the incident was due to unavoidable delays in covering non-benign material after placement and assessed the severity as Class 1 (relatively low).

The DPIR accepted MRM's report of the incident. However, they provided a number of comments on how the incident was handled by MRM. Most notably, the DPIR highlighted that the event had been witnessed prior to 25 January but only reported and acted on after a DPIR inspection on this date.

Other Issues

Site inspections by the DPIR have reported a number of issues including:

- During the January 2017 inspection the lined CWNOEF sump was receiving surface water runoff from the CWNOEF area. This water appeared to be potentially flowing underneath the liner and the DPIR requested further monitoring (DPIR, 2017a).
- During the March 2017 inspection discharge was occurring at the Mine Levee Discharge Point and DPIR noted that there may be potential for erosion to occur if controls are not in place (DPIR, 2017b).
- During the March 2017 inspections DPIR raised concerns regarding the discoloration and apparent stress in vegetation to the north of the Mine Levee Discharge Point (DPIR, 2017b; 2017c). The DPIR raised this issue during the subsequent inspection in August 2017 but MRM personnel were unable to advise of the outcome of a review of this issue (DPIR, 2017c). This issue was again raised in the DPIR February 2018 inspection and MRM was instructed to investigate the cause (DPIR, 2018). McArthur River Mining has subsequently advised of a commitment to undertake informal inspections of the NC1A vegetation with follow up investigation should any be noted (MRM, pers. com., 29 August 2018).
- The DPIR raised concerns during the October 2016 and March 2017 inspections regarding the stability of the SOEF in relation to cracking observed in the structure (DPIR, 2016a; 2017b).
- On several occasions DPIR noted SO_2 production and salt expression on the SOEF, related to the presence of reactive material or/and inappropriately stored material (DPIR, 2016a; 2017b; 2017d).
- Erosion and scouring of the alluvial material on the SOEF was noted (DPIR, 2018).
- Scouring of the interim cover was noted on the western side of the NOEF (DPIR, 2018).

Concerns were raised by the DPIR over the ongoing water management given the increased volumes of water observed on site (DPIR, 2018):

- The DPIR noted that the pit was utilised as a contingency water storage during the 2016/17 wet season. McArthur River Mining planned to incorporate the WPROD in the water management strategy going forward. In 2017, pit water was transferred to the WPROD to allow mining operations to re-commence. The limited available storage of the WPROD over the current wet season has resulted in water again being transferred to the pit. Significant volumes of water were also noted in the unlined WMD at the TSF.
- Overall, the DPIR has concerns regarding the ongoing management of water volumes and qualities across the site and the increasing reliance on discharge to the environment as a management measure. Specifically, the DPIR is concerned that increasing volumes of water on site may compound potential water quality issues including seepage from various facilities (see Section 4.6), broader groundwater impacts from the NOEF (see Section 4.5), and dust and sedimentation issues in Barney Creek diversion channel (see Sections 4.12 and 4.13).

Non-compliances

The IM is not aware of any geotechnically related non-compliances for the reporting period.

Progress and New Issues

CWNOEF

The CWNOEF has seen substantial progress with the construction of the subgrade works and the basal clay liner on the Alpha and Bravo stages of the NOEF. Examination of the testing records indicates that during the reporting period the following material and compaction testing was undertaken:

- For the Basal CCL:
  - Around 281 material tests (particle size, Atterburg limits, pinhole dispersion, Emerson dispersion and moisture content).
  - Around 71 cation exchange capacity (CEC) tests.
  - Around 654 compaction, moisture and density tests.
  - Around 32 permeability tests.
  - Around 76 geochemical tests (elemental analysis).
- For the Wedge CCL:
  - Around 279 material tests (particle size, Atterburg limits, pinhole dispersion, Emerson dispersion and moisture content).
  - Around 40 CEC tests.
  - Around 400 compaction, moisture and density tests.
  - Around 40 permeability tests.
  - Around 31 geochemical tests (elemental analysis).

- For the Subgrade:
  - Around 20 material tests (particle size, Atterburg limits, pinhole dispersion, Emerson dispersion and moisture content).
  - Around 308 compaction, moisture and density tests.
  - Around 5 permeability tests.
- For the 22 borrow areas:
  - Around 432 material tests on particle size, Atterburg, pinhole dispersion, Emerson dispersion and moisture content.
  - Around 201 CEC tests.
  - Around 246 geochemical tests (elemental analysis).
  - A limited number of permeability tests.

These results are those that have passed the MRM (2016b) requirements. Tests reported as having 'failed' are not included as they result in replacement, re-compaction and re-testing until affected areas pass.

The current testing database shows that substantial material, compaction, permeability, CEC and geochemical testing has been undertaken on all aspects of the CWNOEF liner system. The total number of tests during the reporting period was over 3,400.

The IM has been provided with ICE construction reports for October 2016, November 2016, December 2016, January to March 2017, April 2017, May 2017, June 2017, July to September 2017 and October to November 2017. Reports are generally of a high standard containing sufficient detail to confirm the extent of works and testing undertaken.

The ICE reports indicate the following:

- Testing frequency is in accordance with the approved CWNOEF design.
- Incidents of CCL placement prior to subgrade inspection were rectified by removal of placed CCL, inspection then reapplication.
- Incidents of placement of incorrect material were rectified by removal and reapplication.
- Documentation of failed test areas having being replaced and or reworked to meet the specification.
- Issuing of non-conformance notifications.
- The successful development of method-based compaction specifications whereby moisture and density control are consistently achieved by a standard handling and placement procedure derived specifically for site materials and conditions.

The evidence provided to the IM supports these findings.

The following specific issues related to the construction of the CWNOEF are indicated in the construction reports:

- Works were observed to be inefficient at times, slowing progress, but this did not affect the quality of works (GHD, 2016a).
- The quality of subfloor drainage decreased for December when compared to previous months' construction (GHD, 2016b). This was due to two factors:
  - Drainage aggregate material not meeting specifications resulting in material that was potentially not as free-draining.
  - Works were observed as non-conforming on occasion, whereby the geofabric was not wrapped around the aggregate properly and clay was placed directly on gravel. The contractor was instructed to repair this issue.
- Construction works were slowed by significant rain over the period with further works delayed until April 2017 (GHD, 2017f).
- Construction works were slowed by issues with the construction plant, primarily the GPS guidance system. This was resolved towards the end of April (GHD, 2017g).

WPROD

Construction of the Western Perimeter Runoff Dam (WPROD) was completed during the reporting period. During the construction period, the following issues were reported in the construction reports:

- Lining works were scheduled to be completed in December 2016. The final section of the dam in the vicinity of the sump and access road on the western side was not able to be finished prior to significant rainfall at the start of the 2016/17 wet season.

  GHD personnel were on site for an inspection when some works were completed in late January 2017, and were in contact with MRM during the remainder of construction. Works were found to be problematic due to the wet weather, and temporary solutions for the subgrade were proposed so that lining works could be completed (GHD, 2017f).

  To minimise damage due to uncompleted works, temporary measures for Lot F5 were put in place until further works could continue. The mitigation measures were inspected by GHD during the January 2017 site visit to determine effectiveness and damage. Overall, the measures appeared to have been successful but some issues were identified and subsequently repaired.
- Quality issues observed in the surface of the CCL were related to desiccation and the presence of sharp gravel particles. These may lead to an elevated level of risk of liner seepage or puncture during the operational phase of the dam. A regular program of leak detection, repair and maintenance is detailed in the operations and maintenance manual to provide a framework for addressing this issue (GHD, 2016a).

- Upon completion of lining works, it was found that water was under the liner in the southwestern corner of the storage, along the western drain and along the central drain. The inability to provide continuous pump out of the WPROD underdrains, combined with significant wet season rainfall and ponding of water on the outside of the embankment, is likely to have resulted in an elevated phreatic surface at various locations around the perimeter embankment, particularly on the southern side of the WPROD. It is likely that groundwater pressure has developed under the CCL, potentially explaining the observed wet areas below the HDPE and the trapped water between the HDPE and CCL. Mitigation measures were recommended by GHD (2017f).
- Final inspection of the WPROD was undertaken on the 1 July 2017, prior to water being pumped to the dam for filling and reported in the Construction and Commissioning Report (GHD, 2017j). The following works were identified prior to full commissioning:
  - Complete construction of the downstream spillway Zone 4 rockfill, including laying geotextile between the rockfill and the embankment fill.
  - Replace temporary standpipe piezometers with automated vibrating wire piezometers, as per the design.
  - Repair depressions and ruts in the crest surface of the embankment, and provide appropriate wearing course for the full embankment length.
  - Double-line Central West inlet locations.
  - Complete perimeter toe drains to ensure that water drains away effectively and does not pond against the downstream batter.
  - Provide power and automated system for underdrains and alarms.
- Further works to rectify these issues were conducted in the months following as reported in GHD (2017h, 2017i) including re-work of the CCL at the WPROD inlet culvert location.

McArthur River Mining's performance against previous IM review recommendations relating to geotechnical issues at the OEFs is outlined in Table 4.34.

Table 4.34 – Geotechnical (OEFs) Recommendations from Previous IM Reviews

Area	Recommendation	IM Comment
SOEF	Irrespective of the removal of known PAF material, there is a need for overall improvement in management of surface water, groundwater and oxidation of this facility given that it will still contain non-benign waste. The IM understands that further investigation of the environmental performance of the SOEF has been initiated as part of the Draft OMP EIS	Ongoing The SOEF continues to show signs of cracking and erosion which reflect increased potential for AMD or SO_2 release. It will continue to require regular inspections and maintenance to minimise environmental impacts until remediated
CWNOEF construction	There are a number of recommended minor corrections and updates to the CWNOEF design report as described elsewhere	Completed The design report has been updated and these issues resolved

Table 4.34 – Geotechnical (OEFs) Recommendations from Previous IM Reviews (cont'd)

Area	Recommendation	IM Comment
CWNOEF closure	McArthur River Mining should undertake direct testing of candidate materials likely to be used for the NOEF final cover. McArthur River Mining should also expand the limited sensitivity studies on the CCL to examine how differences in the permeability contrast may affect net percolation	Completed McArthur River Mining has substantially expanded material testing in borrow areas. New CEC and geochemical testing provide a much more definitive means of assessing the long-term performance of cover materials
NOEF design	McArthur River Mining should provide a clear timetable of outstanding activities required to finalise clay cover and liner designs including compaction trials, improved assessment of clay types, exploratory drilling and lysimeter testing. The timetable should prioritise these tests and identify what the outcomes will achieve. McArthur River Mining needs to allocate test areas in accordance with these priorities and before the Draft OMP EIS has been finalised	Ongoing Substantial progress has been made in terms of understanding the composition of borrow materials. This issue should be revisited once the outcome of the Draft OMP EIS and SEIS is known

Successes

There have been a number of successes this reporting period, namely:

- Completion of the construction of the WPROD.
- Completion of portions of the CWNOEF basal CCL, overlying LS-NAF and wedge CCL to allow placement of PAF material in Alpha and Bravo areas.
- The use of alluvium advection barriers to reduce oxygen ingress into non-benign wastes. Limited monitoring to date suggests the new areas of CWNOEF are currently showing lower temperatures than older areas. However, this may be due to a range of factors including lower waste reactivity.
- Identification of new resources of clay and alluvium material in the pit and borrow areas for subgrade, wedge, liner and cover construction. Assessment includes an expanded set of geochemical testing to identify suitability. Updated targets and actual quantities are now routinely reported in OPRs.
- Extensive reporting by the ICE to document progress, testing and specification, and evidence of conformance to the CWNOEF specification.
- Improvements in the handling and placement of clays that have significantly reduced the number of CCL tests not meeting the specification. Therefore, the number of lots requiring excavation and re-compaction has also significantly reduced with an overall improvement in CCL consistency.
- The West A and B portions of the NOEF have been improved through replacement of the CCL base and reconstruction of a proportion of the original PAF cell.
- The West D portion of the NOEF has been improved through improved encapsulation of PAF material through the use of new halo material and outer CCL.

- Expansion of the NOEF groundwater, gas and temperature monitoring program.
- Completion of a number of relatively detailed studies on NOEF design, testing and predicted behaviour as part of the Draft OMP EIS and the OMP SEIS. These studies improve the understanding of how the NOEF will perform in the short, medium and long term.
- The preparation of OPRs is generally seen as successful in terms of more clearly showing activities and progress undertaken during reporting periods.

4.7.2.5 Conclusion

This reporting period largely consisted of a period of construction of the CWNOEF and WPROD. Significant progress has been made on the design and construction and verification of the CWNOEF and WPROD in preparation for receiving non-benign material and collecting the surface and seepage water. These activities have remained essentially unchanged over the 2016-2017 and 2017-2018 OPRs.

Improvements in CCL sourcing, testing, construction and reporting have increased confidence in the ability of the CWNOEF facility to safely store non-benign waste.

Areas of the west portions of the NOEF have been improved through replacement of CCLs and re-encapsulation of problematic PAF areas.

The studies undertaken for the Draft OMP EIS and the OMP SEIS represent a significant improvement in understanding in key areas. Programs relevant to the current operations, such as testing and monitoring, should continue. The program of instrumented boreholes for measuring groundwater levels, temperature and gas composition in particular should be expanded to the CWNOEF.

Generally, the IM has seen significant improvement over the last 5 years in terms of design, operation, monitoring, compliance and reporting.

Ongoing and new IM recommendations related to OEFs geotechnical issues are provided in Table 4.35.

Table 4.35 – New and Ongoing Geotechnical (OEFs) Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
NOEF design	McArthur River Mining has made substantial progress in understanding the composition of borrow materials and this needs to be continued. A clear timetable of outstanding activities required to finalise OEF cover design will need to prepared as soon as practicable. The timetable should specify and prioritise additional testing and identify required outcomes.	Medium
NOEF rehabilitation	A plan needs to be developed which describes how progressive rehabilitation will be undertaken and in what sequence. The IM understands that some of the detail of this may be pending future trials and/or approvals. However, developing a plan would identify rehabilitation targets and clarify trial and approval priorities	Medium

Table 4.35 – New and Ongoing Geotechnical (OEFs) Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
SOEF operation	The SOEF continues to exhibit signs of cracking, water ingress and overall poor performance indicative of the uncontrolled manner of construction. The management of this facility needs to be improved through proper encapsulation or removal as soon as practicable	Medium
New Items		
CWNOEF	Groundwater levels, temperature and gas composition monitoring at the NOEF is focussed on the historic areas of waste placement under the original EIS. This program should be expanded to the CWNOEF to allow the efficacy of design changes to be quantified.	High

4.7.3 Bing Bong Loading Facility Dredge Spoil Area

4.7.3.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of geotechnical issues at the Bing Bong Loading Facility dredge spoil area and is based on:

- Observations and discussions with MRM personnel during the IM site inspection.
- Review of various reports prepared by MRM and its consultants, with particular reference to MRM's mining management plan (MRM, 2015) and 2016-2017 and 2017-2018 OPRs (MRM, 2017n; 2018d).
- Aerial and other photographs of the McArthur River Mine provided by MRM.
- Review of other documents such as inspection reports.

There has been no dredging activity during the reporting period.

4.7.3.2 Key Risks

The main geotechnical risk associated with the Bing Bong Loading Facility dredge spoil area is potential failure of the external cell walls, leading to inundation of adjacent areas with saline and/or dredged material. Additional risks are associated with excessive seepage of saline water impacting vegetation surrounding the dredge spoil area.

The risk of wall failure is related to:

- The minimalist approach to engineering due to relaxed requirements when compared to other storages such as the TSF.
- The rapid flooding of the ponds when dredge operations are undertaken.
- Elevated groundwater levels during extreme rainfall events.

Annual safety inspections of the dredge spoil embankments are undertaken by GHD. These inspections recognise that the dredge spoil ponds should be assessed in accordance with

ANCOLD (2012). Currently, GHD assesses the consequence category for the dredge spoil embankments to be low.

The IM recognises that the approach taken to date at the Bing Bong Loading Facility incorporates minimal design requirements given the height of embankments, the more benign nature of materials and water not being contained, and that dredge operations are of short duration and relatively infrequent. The IM also recognises the difficulties in maintaining well-engineered embankments at the site where inundation by flooding or seawater ingress is a regular occurrence. However, this approach must be compensated through effective monitoring, rapid response to repairs, and rebuilding prior to major impact cycles such as dredging activities or the wet season.

There has been no dredging activity for the reporting period and therefore the risk of breach, embankment failure and inundation is relatively low. However, these events can still occur under storm events if embankments, spillways and drainage channels are not properly maintained.

4.7.3.3 Controls

Previously Reported Controls

The following controls are in place for management of the geotechnical risks at the Bing Bong Loading Facility dredge spoil area:

- Bing Bong dredging and spoil disposal management plan (EcOz, 2012).
- Hazardous dam stability assessment TSF and Bing Bong Loading Facility dredge spoil (AWA, 2012).
- Monthly visual inspections and safety audits (no evidence of these has been provided for the current reporting period).
- Surface water quality, air quality and dust monitoring.
- Ten standpipes for measuring groundwater quality and levels in the perimeter embankment (identified with the prefix 'BBEMB').
- Annual safety inspections undertaken on 18 November 2016 (GHD, 2017a) and 14 November 2017 (GHD, 2018c).
- Provision of training to MRM personnel on TSF surveillance by GHD (undertaken November 2017)

The IM notes that there are no records of monthly inspections having taken place during the reporting period or thereafter. Monthly visual inspections have been recommended by GHD (2017) (GHD, 2018c). Additionally, there is no record of measurements of the BBEMB series piezometers.

New Controls – Implemented and Planned

An updated water balance report for 2017-2018 (WRM, 2018) was compiled. There are no additional new controls related to the current reporting period.

4.7.3.4 Review of Environmental Performance

Incidents and Non-compliances

Incidents

There were no reportable incidents related to the management of geotechnical issues at the Bing Bong Loading Facility dredge spoil area for the reporting period.

Non-compliances

The IM is not aware of any geotechnically related non-compliances at Bing Bong Loading Facility for the reporting period.

Progress and New Issues

BBDS

During the reporting period, MRM commenced implementation of some of the recommendations contained in the annual inspection report (GHD, 2017a). These include:

1. Regrade the crest to provide minimum 3% fall towards the upstream side of the crest.
2. Use the spoil from regrading to patch the eroded areas by digging out as necessary, and replacing and compacting fill with a wacker packer.
3. Construct safety bund (0.3 m high) on downstream using spoil from the regrading.
4. Remove medium to large trees from downstream embankment.
5. Repair and rock-line spillways.
6. Review the design and operation of the diversion channel system.
7. Clear sediment from the pipe culvert or deconstruct access ramp.
8. Repair erosion on the external batter of the diversion channel.

These recommendations were essentially unchanged from the 2015 Annual Inspection Report (GHD, 2015).

During the last annual inspection GHD (2018c) confirmed that items 1 to 4 of these previous recommendations had been completed and provided the following comments and recommendations:

- The embankment, crest, downstream and upstream batters and the downstream toe of the ponds were inspected by GHD and generally found to be in adequate condition. Re-grading of the embankment crest, installation of a safety bund and repair of some eroded sections of embankment were reported by GHD as having been recently been completed. Crest drainage provisions should be provided to prevent ponding between the new crest bunds. Anecdotal evidence indicates that the embankment batters are readily erodible and hence regular (i.e., <20 m) spacing of drainage breaks in the bund should be implemented, where possible on the upstream side.

- Some localised erosion, animal tracks and shallow slips were evident on downstream batters. GHD considers that these do not currently present a risk to dam safety but should be monitored as part of routine visual inspections and corrective actions taken if they worsen.

- The internal spillways between Pond 1 and Pond 2, Pond 2 and Pond 4, Pond 4 and Pond 5 and Pond 5 and the Retention Pond were found by GHD to be eroded to varying extents. In their current condition, GHD considers that they do not pose a risk for loss of containment. However, GHD recommended that they should be monitored following large rainfall events.
- GHD recommended that a review of the design and operation of the external diversion channel be undertaken to understand the flood risk posed under present conditions.

During the recent site inspection by the IM, large erosional features and large gullies were noted in the embankments. No repair work appears to have been undertaken since the last recent wet season to repair these features.

Previously, MRM has undertaken inspections and provided these to the IM. The IM has not, however, received any inspection reports for this reporting period. It is unclear whether these inspections are taking place and, if so, whether they are being documented. The IM recommends that this omission be redressed.

McArthur River Mining's performance against previous IM review recommendations relating to geotechnical issues at the Bing Bong Loading Facility dredge spoil area is summarised in Table 4.36.

Table 4.36 – Geotechnical (Bing Bong Loading Facility Dredge Spoil Area) Recommendations from Previous IM Reviews

Area	Recommendation	IM Comment
Bing Bong Loading Facility dredge spoil – monitoring	Set a frequency of water level measurement and sampling (where possible) for new piezometers (BBEMB series) outside of active dredging. Suggested frequency is at least every three months and monthly for three months prior to and three months after planned dredging and operation of the dredged spoil ponds. Additional measurements should be undertaken after periods of heavy rainfall	Ongoing Currently measurements at all other groundwater wells at Bing Bong are taking place every three months even if they are found to be dry. The BBEMB series wells should be measured in the same manner with additional measurements after periods of heavy rain
	Schedule and document regular inspection of the storage ponds outside of active dredging. The IM suggests monthly inspections during the wet season	Ongoing Monthly inspections have been recommended by GHD but do not appear to be taking place
Bing Bong Loading Facility dredge spoil – maintenance	Undertake all of the recommendations given in the annual inspection report, GHD (2015), at least three months before dredging or the next wet season, whichever comes first. These remaining recommendations are summarised as: ♦ Review the design and operation of spillways ♦ Line the Cell 5 spillway to the environment with rock ♦ Repair damaged section of the Cell 5 embankment toe ♦ Clear out sediment from the pipe culvert and rock line the outlet	Ongoing Some of these tasks are known to have taken place while several remain outstanding

Table 4.36 – Geotechnical (Bing Bong Loading Facility Dredge Spoil Area) Recommendations from Previous IM Reviews (cont'd)

Area	Recommendation	IM Comment
Monitoring	McArthur River Mining has reported that survey marks have been installed; however, there is currently no documentation to support this. The IM recommends the immediate commencement of monitoring reports that detail what has been installed, location and readings. Reports should be generated monthly when dredging is in operation and quarterly at other times	The survey locations are reportedly controls for previous works and are not associated with geotechnical monitoring
Bing Bong Loading Facility dredge spoil – embankments	Item: ♦ Review operation and design of spillways ♦ Lining the Cell 5 spillway ♦ Repair and rock lining of the more severely damaged sections of drain along Cell 5 embankment toe	Status: ♦ Ongoing ♦ Incomplete ♦ Incomplete
Bing Bong Loading Facility dredge spoil – drainage	Item: ♦ Review the design and operation of the drainage system ♦ Clearing of sediment from the pipe culvert and rock lining of the outlet be undertaken	Status: ♦ Ongoing ♦ Incomplete
Bing Bong Loading Facility dredge spoil – monitoring-	Measurement of the embankment crest RL at known areas of movement or likely instability and at the extremities	The IM has not been provided with any evidence of measurements having been undertaken. Given the dormant state of the site surface contours, laser survey (or similar) may be sufficient to confirm that the crest RL has not changed significantly
Bing Bong Loading Facility dredge spoil embankment design	A design should be prepared that outlines the geometry and method construction of embankments up to the anticipated maximum RL. This design should incorporate expected piezometric levels based on measurements taken to date and other assessments and freeboard requirements. This design does not need to be overly complicated given the nature of materials being stored and the observed performance of the embankments to date	Ongoing A Life of Mine conceptual design has been prepared (GHD, 2016c). This design includes flattening of outer batters and re-contouring of the pond surface to create a single catchment sloping at 1 in 100 to the existing northeast discharge point

Successes

Successes include regrading of the crest road and construction of a safety bund on the downstream side of the crest, repair of eroded embankments, and removal of trees from embankments. However, the recent site inspection by the IM found that further repair works to the embankments are required following the recent wet season. It is likely that ongoing repair works of this nature will be required until the facility is decommissioned and the IM understands that maintenance is to be undertaken prior to the next wet season.

4.7.3.5 Conclusion

There has not been any dredging activity in the current reporting period and consequently the risk of impacts from the Bing Bong Loading Facility dredge spoil area is relatively low. However, there continue to be issues related to monitoring that have not been resolved, namely:

- Monthly visual inspections as recommended by the IM and GHD.
- Evidence that installed embankment piezometers have been inspected and their water levels recorded when possible.
- Evidence that embankment surveys are being undertaken to confirm that the embankment levels remain relatively unchanged.

The annual inspections by GHD (2017a, 2018c) highlighted a number of issues that need to be addressed and a number of recommendations outlined. Some of these recommendations have been completed while others are in progress. New issues include:

- Provide crest drainage every 20 m to prevent ponding between (thought to mean behind) the crest bund.
- McArthur River Mining to review the design and operation of the diversion channel system.
- McArthur River Mining to develop a routine inspection checklist and instigate routine surveillance inspections for the BBDS ponds.

These recommendations are similar to those given by the IM and relate to improved monitoring and surface water management at the site.

The four recommendations from the previous annual inspection (GHD, 2017a) understood to have not yet been implemented are not included in GHD (2018c). These recommendations all relate to improving surface water control at the site. It is not known whether the new recommendations in GHD (2018c) (and in particular the creation of crest drainage every 20 m) are intended to replace these outstanding recommendations. This should be clarified with GHD.

The IM recommends that the actions recommended by GHD (2017a, 2018c) be undertaken at least three months before any dredging activity or the next wet season, whichever comes first.

A summary of new and ongoing IM recommendations is provided in Table 4.37.

Table 4.37 – New and Ongoing Geotechnical (Bing Bong Loading Facility)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Design	A life of mine concept design has been prepared. However, the IM is still unaware of a design document for the dredge ponds that can be used to determine performance against measurement, such as settlement and pore pressures	High

Table 4.37 – New and Ongoing Geotechnical (Bing Bong Loading Facility) (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Maintenance	Undertake all of the recommendations given in the annual inspection reports, i.e., GHD (2017a) and GHD (2018c), at least three months before dredging or the next wet season, whichever comes first. These remaining recommendations are summarised as: ♦ Review the design and operation of spillways ♦ Line the Cell 5 spillway to the environment with rock ♦ Repair damaged section of the Cell 5 embankment toe ♦ Clear out sediment from the pipe culvert and rock line the outlet ♦ Provide crest drainage every 20 m ♦ McArthur River Mining to review the design and operation of the diversion channel system Some of these recommendations may have been superseded and this should be clarified with GHD	Medium to high (depending on planned dredging)
Monitoring	McArthur River Mining is to develop a routine (nominally monthly) inspection checklist and instigate routine surveillance inspections for the BBDS ponds as per GHD and IM recommendations. The IM recommends monthly inspections when dredging is in operation and quarterly at other times	High
Monitoring	Establish survey locations at the dredge pond locations and a benchmark in preparation for future dredging. Undertake surveys in accordance with ANCOLD (2012).	Medium
Monitoring	The BBEMB series piezometers should be included in the regular groundwater monitoring campaigns. Their groundwater levels should be recorded or otherwise noted as being dry as undertaken for all other Bing Bong wells. Suggested frequency is monthly during the wet season and during dredging, 3 monthly otherwise	Medium
New Items		
No new items		

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4.8 Closure Planning

4.8.1 Introduction

The currently approved mine closure plan was prepared by MET Serve (2012) as part of the Phase 3 Environmental Impact Statement. Over the past six years, MRM has completed numerous technical investigations which have significantly changed the understanding of the hydrogeology and geochemistry of the site and the materials that will be mined. As a result of this increased knowledge, new closure strategies have been developed which have been outlined in the Draft OMP EIS (MRM, 2017a) and OMP Supplementary Environmental Impact Statement (OMP SEIS) (MRM, 2018a).

The Draft OMP EIS and OMP SEIS outlined significantly different closure strategies from the currently approved closure plan in many areas, particularly the following:

- Revised cover design for overburden emplacement facilities.
- Retreatment and placement of tailings back into the open pit following the cessation of mining.
- Accelerated filling of the open pit and a weir structure to be constructed in the mine levee wall to allow McArthur River to flow through the pit at high flows.

As the Draft OMP EIS has not been approved, the status of the above changes remains proposed and subject to approval. If the Draft OMP EIS is not approved, these changes may not be implemented and/or the approaches outlined in the Draft OMP EIS may be modified.

The IM's review of MRM's performance during the reporting period with regards to closure planning is based on review on the following:

- Observations and discussions with MRM personnel during the site inspection.
- The current mine closure plan prepared by MET Serve (2012) as part of the Phase 3 Environmental Impact Statement.
- Excel spreadsheets provided by MRM that contain mine closure costs (MRM, 2015a).

If the revised closure strategies as outlined in the Draft OMP EIS and OMP SEIS are accepted, some of the risks outlined in this section will require revision and updating to align with the new closure strategies. In this section, where appropriate and to provide the current status of mine closure planning, reference is made to the Draft OMP EIS conceptual mine closure plan. However, the reader must note that this plan has not been approved.

4.8.2 Key Risks

Key risks identified in previous IM reports (ERIAS Group, 2017) remain the management of mine wastes (tailings and waste rock) and the final pit lake water quality. An additional new risk that has been included following review of documentation concerns the long-term stability of the

McArthur River diversion channel. These are outlined in Appendix 1 and are summarised as follows:

- Long-term stability of the NOEF landform. Demonstrating that the material properties of the waste rock proposed to be used to construct the cover will achieve long-term stability (i.e., 500 to 1,000 years) of the landform is essential in being able to demonstrate a successful closure strategy. A revised cover design has been detailed in the OMP SEIS.
- Integrity of the cover placed over the NOEF fails to meet design specifications. In the short- or long-term the cover may not meet design specifications, resulting in increased rates of oxygen diffusion and water infiltration through the cover and into waste rock which has the potential to generate acid, saline and/or metalliferous drainage (AMD). The resulting impact of the full or partial failure of the cover is therefore the generation of poor quality runoff and/or seepage, which could adversely impact terrestrial and aquatic ecosystems, including increased bioaccumulation of metals.
- Long-term stability of the TSF landform. The currently approved TSF landform after closure involves retaining the existing series of benches and batters. No drainage is provided to safely remove surface water from the outer surface of the TSF. There is a consequent risk to the long-term stability (1,000 years) of the TSF as a result of surface water ponding on a bench and then overtopping, resulting in concentrated flow eroding the batter which, if left unchecked, will develop a gully and potentially result in the exposure of tailings. As the tailings are PAF, their exposure to oxygen and water will/may result in acid drainage and discharge of salts (sulfates) and trace metals (Pb, Zn, As, Cd and Cu) to the terrestrial and aquatic environments. The EIS conceptual closure plan developed for the Draft OMP EIS proposes to retreat tailings at the end of mining and place this material into the open pit. Therefore, if the Draft OMP EIS is approved, no above-ground TSF would exist following closure and the long- term stability of the TSF would no longer be a risk.
- The final pit lake is a key feature that will remain after closure. The currently approved strategy is that the pit will remain a sink, i.e., with no discharge to McArthur River. The Draft OMP EIS has proposed that this strategy be revised to allow the accelerated filling of the pit by diverting high flows from McArthur River to the pit. Ultimately, if water quality is consistent with model results, high flows from the river would flow through the pit. However, uncertainty remains regarding whether the post-closure water quality will be good enough to allow this to occur.
- Long-term stability of the mine levee wall surrounding the open pit after closure. The mine levee wall has been designed for a 1:500 year event. There is evidence of erosion of the mine levee wall since its construction in 2009. Ongoing monitoring and maintenance of the mine levee wall is currently not specifically included in the post-closure monitoring and maintenance costs.
- Long-term stablilty of the McArthur River diversion channel. A geomorphological assessment of the McArthur River and Barney Creek diversion channels (Hydrobiology, 2016) has identified an active avulsion which may result in McArthur River changing direction and realigning with the old channel. The resulting impact may include:

  - Erosion of large quantities of sediment as the river discharges back into the diversion channel after realigning with the old channel.
  - Increasing the risk of erosion and failure of the mine levee wall potentially resulting in the discharge of potentially contaminated water from the pit.
- Long-term stability of dredge spoil ponds at the Bing Bong Loading Facility. The embankments of the dredge spoil ponds have not been constructed to the same standard as those of the TSF and there is evidence of erosion of the embankments. No strategy currently exists with regard to how the dredge spoil ponds will be rehabilitated. There is potential to impact terrestrial ecosystems due to sedimentation and or sediment blocking drains resulting in flooding.
- Post-closure monitoring and maintenance period funding. The current mine closure costs have assumed a post-closure monitoring and maintenance period of 25 years. However, the Draft OMP EIS has identified that post-closure monitoring and maintenance will be required for a significantly longer period.
- Closure criteria outlined in the currently approved closure plan do not have specific performance indicators by which MRM can demonstrate the orderly progression of outcomes to achieve closure success. Closure criteria are the measures by which MRM will demonstrate that commitments have been met and request the mine lease to be relinquished. Revised closure criteria have been proposed in the EIS conceptual closure plan submitted as part of the Draft OMP EIS.

4.8.3 Controls

4.8.3.1 Previously Reported Controls

An EIS conceptual mine closure plan has been prepared as part of the Draft OMP EIS and this will require updating following approval to align with changes in the cover design which were outlined in the OMP SEIS and to reflect approval conditions. The mine closure plan prepared as part of the Phase 3 EIS (Met Serve, 2012) remains the currently approved closure plan; however, the closure strategies proposed in the Draft OMP EIS and SEIS for the three key risk areas (i.e., the TSF, OEFs and open pit) contain significant differences from the currently approved mine closure plan.

4.8.3.2 New Controls – Implemented and Planned

Construction of the central west area of the NOEF has commenced and this has implemented new design features with regard to NOEF construction. The new design features have been approved as an amendment to the 2013-2015 MMP and have been incorporated into the Draft OMP EIS NOEF design.

4.8.4 Review of Environmental Performance

4.8.4.1 Incidents and Non-compliances

Incidents

No incidents relating to mine closure were recorded during the reporting period.

Non-compliances

The operational performance reports (OPR) (MRM, 2017b and MRM, 2018b) provide a list of commitments from the following documents:

- The 2013-2015 MMP (MRM, 2015b).
- 2016-2017 and 2017-2018 OPRs.
- Various monitoring programs, e.g., soil monitoring, aquatic fauna monitoring.

McArthur River Mining's reporting against commitments has changed from that in the 2015-2016 OPR (MRM, 2016). In reviewing performance against commitments, it was noted that some commitments reported in the 2015-2016 OPR have not been addressed in the 2016-2017 and 2017-2018 OPRs. For example, in the 2015-2016 OPR the following commitment was reported under operational activities:

> Erosion modelling has been undertaken to identify viable batter geometries, and the thickness of rock required to protect the CCL in the cover. The design and specification of water management structures will be conducted by qualified engineers with experience in long-term performance of waste rock dumps.

In the 2015-2016 OPR, the progress was reported as:

- In progress. MRM has engaged O'Kane Consultants and GHD for these works.

In neither the 2016-2017 nor the 2017-2018 OPR did MRM provide an update on this commitment.

The IM appreciates that the complexity of the operation and the current uncertainty with regard to the Overburden Management Project has resulted in a number of amendments to the current 2013-2015 MMP. This has resulted in some commitments no longer being valid due to changes in the project. An updated MMP will likely address a number of these issues. The IM also believes that commitments need to be focused towards environmental performance with a number of commitments in the 2013-2015 MMP relating to operational improvements which have no or limited impact on environmental performance. This would result in fewer commitments, thereby making tracking of commitments easier.

4.8.4.2 Progress and New Issues

During the reporting period there has been no progress pending the outcome of the OMP EIS. Progress on recommendations from previous IM reviews is outlined in Table 4.38.

Table 4.38 – Closure Planning Recommendations from Previous IM Reviews

Subject	Recommendation	Status
Closure objectives, criteria and performance indicators	The current mine closure objectives, criteria and performance indicators should be revised. The objectives should be outcome based and focused on the proposed post-mining land use. The closure criteria and performance indicators should be site specific and capable of objective measurement or verification	Ongoing Revised closure objectives and criteria are outlined in the Draft OMP EIS conceptual mine closure plan. Further work is required to finalise these closure objectives and criteria, since the need to meet

Table 4.38 – Closure Planning Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	Status
Closure objectives, criteria and performance indicators (cont'd)		closure objectives provides direction to operational activities
Bing Bong Loading Facility	Prepare detailed closure costs for the Bing Bong Loading Facility and present these as a separate domain from the mine closure costs	No progress
Mine closure costs	A comprehensive review is required of the closure costs. The IM understands that this will occur following assessment of the Draft OMP EIS. A specific focus of this review should be on developing a comprehensive understanding of post-closure management, monitoring and maintenance costs with any assumptions clearly documented	Ongoing Mine closure costs were updated in 2015 which resulted in a material increase in these costs. No further update has been provided to the IM and it is expected that this will occur following the outcome of the OMP EIS process
Cover trial	Undertake a trial to construct a cover to the required specification and regularity of thickness to prevent seepage in perpetuity. Samples from the trial compacted clay liner to be tested for density and permeability after compaction with testing to be undertaken at intervals over the full thickness of the liner	Ongoing Revised cover design outlined in the OMP SEIS. MRM has received a report which was included in the OMP SEIS that outlines the cover trial design and objectives, etc.
TSF	An interim cover design has been developed for TSF Cell 1. MRM currently does not have any plans for retreatment of the tailings within Cell 1, although with further technological advances retreatment may be possible. An opportunity exists for MRM to develop its TSF closure strategy by implementing a final cover over either all or part of Cell 1. The IM recommends that a final cover strategy trial be undertaken on Cell 1 for at least part of the area	On hold pending outcome of OMP EIS process and also proposed amalgamation of Cells 1 and 2 to form one TSF

4.8.4.3 Successes

The Draft OMP EIS and SEIS have been reviewed during this period and implementation of strategies outlined in these documents has not commenced.

4.8.5 Conclusion

As highlighted in the last IM report (ERIAS Group, 2017), planning for closure of the McArthur River Mine has advanced significantly in the past five years. It is clearly evident from the investigations that have been completed and subsequent development of closure strategies, and from discussions with MRM personnel on site, that closure is central to the operation of the mine.

No new recommendations regarding closure planning have been made following review of the 2017 performance year. Ongoing closure planning recommendations are outlined in Table 4.39.

Table 4.39 – Ongoing Closure Planning Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Mine closure commitments	As part of the review of the mine closure plan, MRM should review all previous rehabilitation and closure commitments that have been made since underground mining commenced. All commitments should be upgraded to reflect the current status of the operation, community expectations and good industry practice	High
Mine closure costs	A comprehensive review is required of the closure costs. Determining the timeframe that post-closure monitoring and maintenance will be required should be a key aspect of this review. Allowance should be made for: ♦ Costs (drill, blast and haul) associated with the selective mining of LS-NAF(HC) are included in the revised mine closure cost estimate ♦ Long-term monitoring of cover performance ♦ Maintenance of the cover system, including inspection of geotechnical integrity ♦ Collection and treatment of leachates (surface and groundwater), and active water management post-closure including potentially the pit lake ♦ Monitoring and maintenance of the mine levee wall ♦ Monitoring and maintenance of McArthur River diversion channel	High
NOEF	A trial should be undertaken to construct a cover to the required specification and regularity of thickness to demonstrate that the cover can perform for the period of its design life. Samples from the trial compacted clay liner should be tested for density and permeability after compaction, with testing to be undertaken at intervals over the full thickness of the liner	High
	The potential for differential settlement of the NOEF to compromise the cover design should be evaluated, with particular focus on the potential implications for highly reactive PAF material to settle faster than other waste rock contained in the NOEF	Medium
TSF	An interim cover design has been developed for TSF Cell 1. McArthur River Mining currently does not have any plans for retreatment of the tailings within Cell 1, although with further technological advances retreatment may be possible. An opportunity exists for MRM to develop its TSF closure strategy by implementing a final cover over either all or part of Cell 1. A final cover strategy trial should be undertaken on Cell 1 for at least part of the area. The IM understands that MRM's preferred closure strategy for the TSF has changed and relocation of tailings to the open pit is the preferred strategy. This change in strategy once confirmed will change the IM's recommendations with regard to TSF closure	High
	Erosion and sediment transport modelling of the proposed TSF landform should be undertaken to identify the depth of NAF cover material required to ensure the functionality of the cover for 100, 500 and 1,000 years	Medium
Closure objectives, criteria and performance indicators	The current mine closure objectives, criteria and performance indicators should be revised. The objectives should be outcome based and focused on the proposed post-mining land use. The closure criteria and performance indicators should be site specific and capable of objective measurement or verification	Medium
Bing Bong Loading Facility	Prepare detailed closure costs for the Bing Bong Loading Facility and present these as a separate domain from the mine closure costs	High

4.8.6 References

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4.9 Terrestrial Ecology

4.9.1 Introduction

This section addresses MRM's performance during the reporting period from October 2016 to March 2018 with regards to management of terrestrial ecology and is based on the review of:

- Reports prepared by MRM, including the MMP 2013-2015 operational performance report 2017 (referred to as the 2016-2017 OPR) (MRM, 2017a) and the MMP 2013-2015 operational performance report 2018 (referred to as the 2017-2018 OPR) (MRM, 2018a).
- Management plans developed by MRM including those related to rehabilitation, weed management, cattle management and fire.
- Monitoring reports prepared by MRM's consultants relating to vegetation monitoring, avian monitoring and disturbance.
- Revegetation, planting, nursery stock and weed control registers in the form of Excel spreadsheets provided by MRM.
- Various MRM forms and similar documents such as field data forms, survey results, incident notification letters and correspondence between MRM, regulators and third parties.
- Aerial and other photographs of the McArthur River Mine, Bing Bong Loading Facility and surrounds, provided by MRM and/or taken during the IM site visit in May 2018.
- Discussions with MRM personnel and consultants during the IM site visit in May 2018.

4.9.2 Key Risks

The key risks to terrestrial ecology, as described in the risk assessment (Appendix 1), are unchanged from the previous IM report (ERIAS Group, 2017) and are as follows:

- Slow revegetation of the McArthur River diversion channel as a result of:
  - Flooding and high flow rates during the wet season, causing significant erosion of the embankment, redistribution of soils, and removal of planted tube stock.
  - Trampling and grazing of surviving vegetation by large herbivores, predominantly cattle, significantly reducing rehabilitation success.

  The lack of vegetation along the diversion channels impacts the stability of soil on the channel banks and, in turn, ecosystem development and health. Slow revegetation retards the development of important riparian habitat for terrestrial flora and fauna. It also affects the ecological health of the McArthur River through lack of shade, potential long-term increase in downstream sedimentation, and weed infestation.
- Creation of vegetation communities along the diversion channels that are different to the natural communities found along Barney Creek and the McArthur River. This occurs through planting and seeding of non-local species, encroachment of weeds and/or creation of homogeneous vegetation communities.

- Fragmentation of habitat (excluding that related to the river diversion channels as described above) as a result of vegetation clearing or slow revegetation. Habitat fragmentation can prevent the movement of fauna species, restricting breeding and safe access to food and water resources, as the lack of vegetation cover can leave small mammals, reptiles and grassbirds vulnerable to predation.

- Presence of noxious weed species at the mine site and Bing Bong Loading Facility due to:

  - Historical mining and pastoral activities.

  - Additional land clearing by MRM, which has allowed weeds to encroach into new areas.

  Weed infestations can exclude native flora species and/or reduce the quality of habitat for native fauna, as well as affecting the success of rehabilitation works.

- Development of salt and/or heavy metal loads in vegetation, soils and sediments, potentially causing vegetation dieback. Salt and heavy metals can affect vegetation by entering soils and sediments through deposition of airborne dust, runoff of settled dust from roadways and/or seepage of contaminated waters from MRM's operation areas. This results in the assimilation of SO_4 and heavy metals into vegetation through the roots, changes in the pH of the soil, and/or reduced photosynthetic ability of plants, causing poor health and/or death of vegetation. Vegetation dieback may result in the reduction of habitat for terrestrial fauna, shade for aquatic fauna, and/or compromised soil stability, increasing erosion potential and facilitating the spread of weeds.

- Localised mortality of vegetation surrounding the Bing Bong Loading Facility dredge spoil ponds, with associated alteration of habitat, due to factors such as:

  - Saline leachate draining from the dredge spoil.

  - Seawater retention against the outside of the drain bund for a prolonged period after the tide recedes.

  - The historical placement of dredge spoils on a minor drainage line, resulting in floodwaters ponding to the west of the spoil ponds and causing trees to drown. This issue has since been rectified but vegetation is slow to recover.

- Lack of vegetation on the dredge spoil ponds at Bing Bong Loading Facility, leading to the creation of dust, with potential impacts on adjacent habitat.

- Potential heavy metal bioaccumulation in the food sources of important migratory bird and wader populations, as a result of dust migration and/or concentrate spillage from Bing Bong Loading Facility.

- Reduced availability of suitable breeding/nesting and foraging habitat for the Gouldian finch (*Erythrura gouldiae*) due to vegetation clearing near the mine site.

4.9.3 Controls

4.9.3.1 Previously Reported Controls

Summary

The following controls relating to terrestrial ecology are ongoing controls that have been reported in previous IM reports and were also completed in the current reporting period:

- Bi-annual riparian bird monitoring was conducted along the McArthur River and Barney Creek diversion channels in October/November 2016 and 2017 and May 2017 (EMS, 2017a; 2018a; 2018b).
- Bi-annual migratory shorebird and wader survey along the Port McArthur coast and between Rosie Creek and Limmen Bight River to the northwest, along with testing of sediments in important shorebird feeding locations (EMS, 2017b; 2017c; 2018c).
- Weeds controlled in liaison with Weeds District Officer according to the weed management plan and maintenance of weed management logs and weed spraying register (MRM, 2017b; 2017c; 2018a).
- Annual vegetation monitoring program surrounding the Bing Bong Loading Facility dredge spoil ponds to monitor the impact of saline leachate from the dredge spoil ponds and recovery of vegetation (EcOz, 2017c).
- Bing Bong dam annual safety inspection including the assessment of erosion of the Bing Bong Loading Facility dredge spoil and associated external diversion drain (GHD, 2017; 2018).
- Targeted planting of tube stock along the McArthur River diversion channel, grown in the MRM nursery and/or sourced from suppliers (MRM, 2016a; 2017d).
- Dust monitoring at the McArthur River Mine and Bing Bong Loading Facility to assess the risk of heavy metal contamination from operational dust emissions on terrestrial and aquatic biota and watercourses (TAS, 2017).
- Livestock management, including cattle exclusion fences surrounding the mine site and diversion channels and the Bing Bong Loading Facility dredge spoil ponds, and livestock mustering and culling (MRM, 2016b; 2017e; 2017f).
- Gouldian finch targeted surveys were conducted in April/June 2014, November 2015 and September 2016 with a review of Gouldian finch habitat within the mine site conducted in the 2015 and 2016 surveys (EMS, 2017d). No surveys targeting Gouldian finches was conducted during the reviewed operational period.

4.9.3.2 New Controls or Changes – Implemented and Planned

Fire Management Plan

During the reviewed operational period, MRM implemented a fire management plan (FMP) to provide a fire management directive, ensuring the safety of mine assets and personnel, and the protection of the environment (MRM, 2017g). The FMP characterises the mine site into three fire management zones: fire tolerant, fire sensitive and fire protected zones (Figure 4.31). This allows for targeted fire management based on the landform and vegetation type. Burn frequency is specified according to each zone type as listed below:

- Fire tolerant: fires no more frequently than once every two years.
- Fire sensitive: fires no more frequently than one every ten years.
- Fire protected: never burn.

The FMP contains detailed sections on both directly and indirect impacts of fire on the spread of weeds and on fauna. In particular the plan details how fire can be a threatening process for at-risk species through habitat alteration, including for the endangered Gouldian finch. The plan also details clear procedures for conducting controlled burns and suppressing uncontrolled fires.

The FMP is an excellent addition to MRM's toolkit to ensure the protection of undisturbed habitat on and surrounding the mine, while giving rehabilitation areas the greatest chance of success.

Fluvial Erosion Study

One of the major impediments to the successful rehabilitation of the diversion channels, particularly the McArthur River diversion channel, is the erosion and avulsion of the banks during flood events, resulting in the removed sediment being deposited further downstream and/or the removal of vegetation from the banks. A fluvial study of the diversion channels was conducted by WRM (2018) to identify areas at risk of erosion and sedimentation. Using hydrologic and hydraulic flood models, maps were created detailing the predicted erosion risk, velocity, bed shear stress and stream power for the banks of each diversion. The information gained through this study will inform targeted planting at locations where tube stock is most likely to survive. The banks were categorised according to Annandale risk levels (low to extreme) for 1-year, 2-year, 20-year, 50-year and 100-year average recurrence interval (ARI) events and the Queensland Department of Natural Resources and Mines (DNRM) risk levels for 2-year, 50-year and combined ARI risks. The study assessed proposed revegetation areas based on planned tube stock planting over the next three years (2018 to 2020).

The study concluded that revegetation works planned along the north side of the McArthur River diversion channel had the highest risk of being impacted by erosion, while the southern bank has a low risk, although erosion may still have an effect. The report recommended that planting should be targeted outside of high erosion risk areas to increase the likelihood of tube stock survival. The fluvial erosion study and its results are discussed in more detail in Section 4.4, but from a terrestrial ecology perspective, this detailed flood modelling will be a valuable resource when targeting areas for revegetation along the diversion channels, and will hopefully lead to more efficient, successful and cost-effective rehabilitation works.

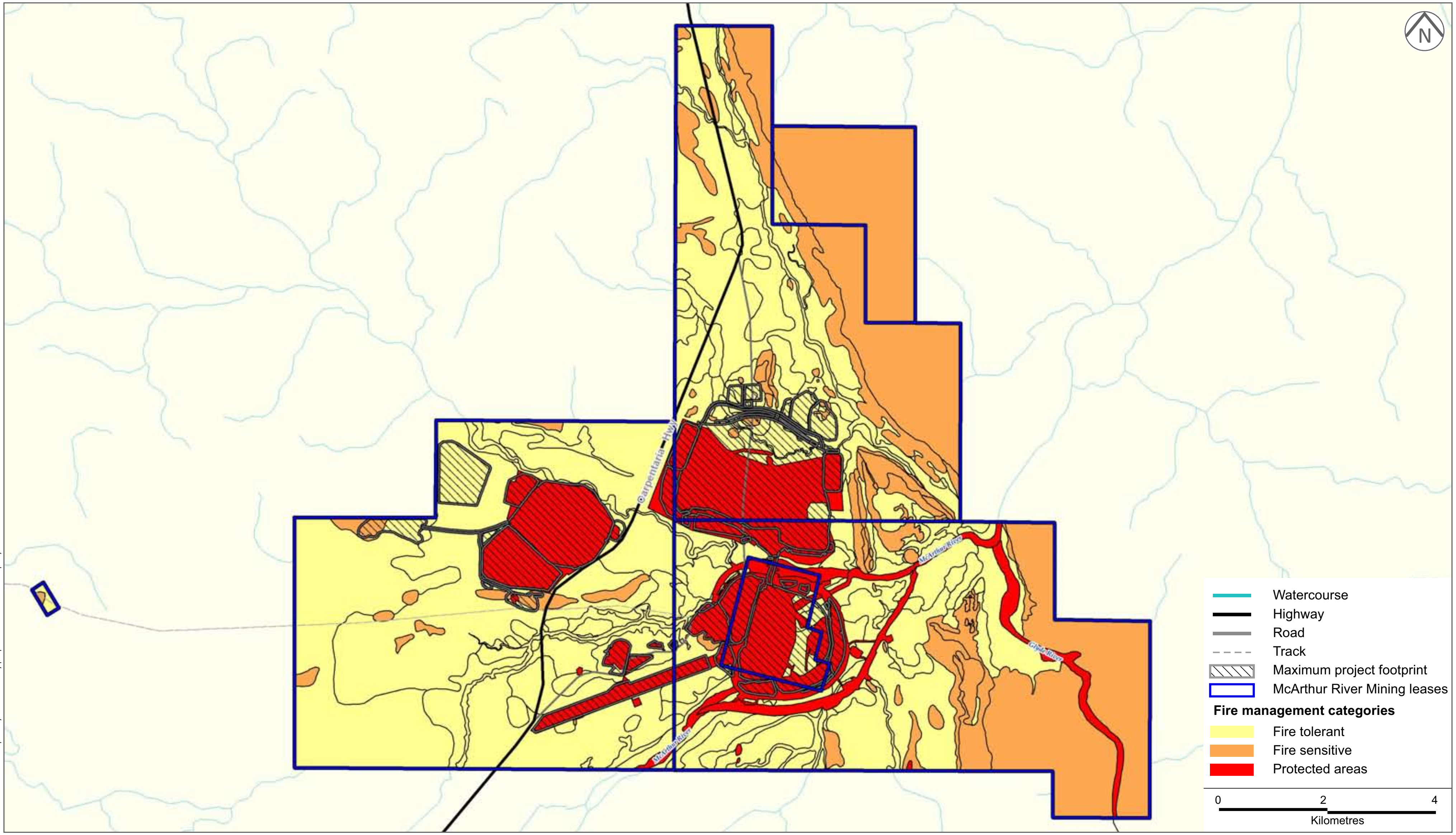
Small Woody Debris

In 2018 McArthur River Mining added the placement of small woody debris (SWD) (Plate 4.7) to the large woody debris (LWD) placement program (MRM, 2018b). Small woody debris is sourced from land clearing as part of ongoing mine operations, and is stockpiled and added to the

McARTHUR RIVER MINE FIRE MANAGEMENT ZONES

McArthur River Mine Project

FIGURE 4.31



Source: MRM, 2017g.

ERIAS Group | 01164F_1_F4-31_v2

McArthur River and Barney Creek diversion channels at the end of the wet season. It is hoped that the SWD will be retained in the channel along the banks and behind existing LWD piles to create more complex habitats for small fish and macroinvertebrates.

Plate 4.7 – Small Woody Debris Being Placed into the McArthur River Diversion Channel

Source: MRM, 2018c.

Metal Testing in Forage Species Surrounding the Tailings Storage Facility

In early 2016, MRM engaged Indo-Pacific Environmental (IPE) to investigate levels of Pb, Cu, Cd and As in common forage species (*Heteropogon contortus, Panicum decompositum* and *Vachellia farnesciana)* consumed by cattle within the McArthur River Mine (IPE, 2017a). Surface soil samples were also collected. The purpose of the study was to identify locations with high metal concentrations and to ensure that the current fencing boundary was sufficient to restrict cattle from these areas. The study found that areas with high metal detections were contained within the fence boundary and are therefore not accessible by cattle. In the 2017 IM report (ERIAS Group, 2017), a recommendation was made to expand the study to the TSF area, as this was the location of significant dust migration and seepage in previous years. McArthur River Mining again engaged IPE to conduct this study (MRM, pers. com., 14/15 May 2018). While plant material was collected from the TSF area during the operational period, unfortunately, the results were not available at the time of the IM review.

Metal Testing in Food Species Important to the Local Community

In addition to testing of pasture species, MRM initiated a study of metals in edible bush plants after concerns were raised that the mine may be impacting bush foods in the region (IPE, 2017b). The aim was to determine if metals were present in edible plants, and if present, the concentration of these metals and the risk to the local community. Community consultation was used to identify consumption practices and collecting locations. Metal testing has not yet been conducted on edible plants but is planned in the future (Thorburn, pers. com., 14/15 May 2018).

Ethnobotanical Study

In October 2017, at the request of MRM, IPE met with Gurdanji, Yanyuwa, Garrawa and Marra representatives from the Borroloola community over a three-day period, with the aim of cataloguing important cultural plants and producing a guide that included language names for each of plant. The study included visits to sites within the mine site area to identify plants, sit-down meetings on-site and a meeting at the aged care facility in Borroloola for those who could not visit the mine. The program resulted in 55 plant species being catalogued and the production of an identification report (IPE, 2017c) for the community. The report included photographs of each species, the common name, language name and information about its cultural use (Plate 4.8).

Plate 4.8 – An Example of a Species Description Provided in the Ethnobotanical Report


Erythrina vespertilio FABACEAE

Common name: Bat's Wing Coral Tree
Language name: (Ga) Kurin, Gorin

This tree gowns in a variety of habitats and flowering (October-May) was an indication to be carful around waterways as this coincided with the mating season of crocodiles. Flowering also indicated crocodiles were laying eggs and it was the time of year to collect them.

Source: IPE, 2017c

This study was a valuable community engagement exercise and has will provide useful information for future MRM rehabilitation works. Most importantly, the project is helping to catalogue traditional names of plants in predominantly unwritten languages, ensuring they are not lost to future generations.

Gouldian Finch and Woodland Bird Surveys

Gouldian finches were first detected on the McArthur River Mine in 2013 in the vicinity of the TSF. In 2014 MRM initiated a Gouldian finch monitoring program to assess the presence of the species on site (EMS, 2017d). Following this, further targeted surveys were conducted in 2015 and 2016 in conjunction with an assessment of suitable Gouldian Finch habitat within the mine site. Gouldian finches were observed in several locations along Emu Creek in 2014, 2015 and 2016, indicating that the area is important for the species. The habitat assessment provided information for when clearing was required, to avoid important Gouldian finch nesting and foraging habitat. Gouldian finches are a highly mobile species and therefore the protection of habitat is a more effective method of mitigating the impact to Gouldian finches than targeted surveys to identify individuals on site. Therefore, after the review of the 2015 operational period, the IM recommended that targeted surveys be discontinued and detailed mapping of type mine site vegetation be conducted (ERIAS Group, 2016). Therefore, no surveys relating to Gouldian finches were conducted during the current operational period. The IM also recommended that updated vegetation mapping be translated into a map figure clearly showing where both important nesting and foraging habitat is found within the McArthur River Mine, to be used as a reference during clearing planning. McArthur River Mining has produced a map figure clearing showing nesting habitat however information collected on foraging habitat has not yet been added to this figure. The IM was informed during the 2018 IM visit that this will be completed during the next operational period.

Revegetation Monitoring Program

Revegetation monitoring was not conducted within the operational period. Instead, after ten years of monitoring, MRM conducted an extensive review of the revegetation monitoring methods and the rehabilitation management plan (RMP). The changes implemented since the previous operational year are summarised below (MRM, 2017h):

- Primary species have been removed from the completion criteria leaving just key species. Key species have been broken down for each rehabilitation domain i.e., Barney Creek, McArthur River corridor and McArthur River woodland. The number of key species required has also been broken down by domain and lower, mid and upper strata.
- Performance indicators are used to determine a ‘revegetation status’ for each plot. Revegetation status has four levels; early stage maintenance, rework, maintenance, monitor and acceptable. The criteria for each are outlined in Table 4.40. Note that two levels are labelled as level 2 and should be edited in the procedure for clarity.
- Revegetation monitoring conducted in April/May instead of August to allow identification of annual species.
- Vegetation surveys conducted along a pre-defined 20 m transect instead of randomised plots.

Table 4.40 – Revegetation Status Levels, Triggers and Actions

Level	Revegetation Status	Trigger	Action (If Trigger Exceeded)
0	**Early Stage Maintenance** – completion criteria not yet assessed	Revegetation areas between 1 to 3 years old will be assessed against survival rates and diversity. Sites are considered to require additional work if monitoring identifies that: ♦ Survival rate of planted tube stock is less than 50% in the first year of planting ♦ Less than 30% of key species present in the second and third year of planting	Infill planting of key species identified with low survival rates, directed by the results of monitoring. Additional seeding of grass species on the mid bank and upper bank areas where bare patches may result in erosion
3	**Rework** – does not meet completion criteria	The monitoring site characteristics do not meet completion criteria. Sites are considered to be “level three” if monitoring identifies: ♦ Site characteristics are less than 30% of the completion criteria ♦ There is a significant reduction (40% to 100%) in performance (by comparison to monitoring data from previous years and control sites) ♦ Erosion is assessed as level 4 or level 5	Extensive rework required that would not typically form part of a rehabilitation maintenance program (e.g., slopes do not comply with approval requirements, bare within the active revegetation areas greater than 0.1 ha, large erosion gullies)
2	**Maintenance** – does not meet completion criteria	The monitoring site characteristics do not meet completion criteria. Sites are considered to be “level two” if monitoring identifies: ♦ Site characteristics are between 30% and 60% of the completion criteria ♦ There is a minor reduction (1% to 40%) in performance (by comparison to monitoring data from previous years and control sites) ♦ Erosion is assessed as level 3	Routine rehabilitation maintenance works required (e.g., weed control, infill seeding/plantings, repair of minor erosion, fertiliser application)
1	**Monitor** – tracking towards completion criteria but does not meet all criteria	The monitoring site characteristics are tracking towards completion criteria but do not meet all criteria. Sites are considered to be “level one” if monitoring identifies: ♦ Site characteristics are greater than 60% of the completion criteria ♦ There is improvement in performance (by comparison to monitoring data from previous years and control sites) ♦ Erosion is assessed as level 1 or 2	No intervention is required, but continue monitoring
2	**Acceptable**	Meets all completion criteria	No rehabilitation or monitoring action required. Ready for sign off by stakeholders. Continue to manage and monitor to maintain status until signoff

Source: MRM, 2017h.

4.9.4 Review of Environmental Performance

4.9.4.1 Incidents and Non-compliances

Incidents

No incidents directly related to terrestrial ecology were reported during the reviewed operational period.

Non-compliances

Table 4.41 provides an assessment or comment on commitments that were not met in the operational period, or could not be confirmed as having been completed from the IM review. Table 4.41 is a subset of a table of commitments provided in MRM's compliance register (MRM, 2017i).

Table 4.41 – Commitments Not Met Within the Operational Period Related to Terrestrial Ecology

Source	Section	Commitment	Comment
2013-2015 MMP (MRM, 2015)	5.4.7.3	Mosquito management plan	No reference to mosquito management plan in the 2016-2017 OPR or the 2017-2018 OPR (MRM, 2018a; 2017a). No management plan in provided documents
MRM Operational Performance Report 2016 (MRM, 2016c)	3.1.4.2.1	Annual revegetation program report	The annual revegetation program report was not produced within the operational year. Instead, MRM conducted a review of the rehabilitation management plan (MRM, 2018b) and revegetation procedure (MRM, 2017h)
MRM Operational Performance Report 2016 (MRM, 2016c)	3.1.8	Investigation the correlation between dust and vegetation foliage	No evidence sighted, the IM was advised that this will be included in the 2018 revegetation monitoring program
MRM Operational Performance Report 2016 (MRM, 2016c)	3.1.8	Rehabilitation monitoring of gorge sections of the McArthur River diversion channel	No rehabilitation monitoring was conducted during the operational period as MRM conducted a review of monitoring methods and put the program on hold while the approach is being revised
MRM Operational Performance Report 2016 (MRM, 2016c)	3.1.8	Photo monitoring of the McArthur River diversion channel (should be undertaken every year)	Photo monitoring is usually conducted as part of the rehabilitation monitoring program. As the program was put on hold, photo monitoring was not completed
MRM Operational Performance Report 2016 (MRM, 2016c)	3.1.4.2.1.3	Develop unique completion criteria for different environments along the McArthur River diversion channel	Mostly completed but the rocky gorge section of the McArthur River diversion channel is not included in the monitoring program

Table 4.41 – Commitments Not Met Within the Operational Period Related to Terrestrial Ecology (cont'd)

Source	Section	Commitment	Comment
MRM Operational Performance Report 2016 (MRM, 2016c)	3.1.4.2.1.3	Improve erosion monitoring and remove flood impact monitoring	While MRM did commission the fluvial erosion study to identify areas along the diversion at risk of erosion or sedimentation, the annual erosion monitoring technique has not been improved. McArthur River Mining will include aspects from a landscape function analysis (LFA) based method in the future (MRM, pers. com., 14/15 May 2018)
MRM Overburden Management Project Supplementary EIS	Not provided	Pest animal management plan	A pest animal management plan has not been sighted

Source: MRM, 2017i.

4.9.4.2 Progress and New Issues

Revegetation of the McArthur River and Barney Creek Diversion Channels

McArthur River Mining continues to increase their success with growing tube stock in the on-site nursery and the number of tube stock planted. In 2017, 84,000 tube stock were planted, predominantly along the McArthur River diversion channel, with 96% of tube stock grown on-site in the MRM nursery (MRM, pers. com., 14/15 May 2018). This included infill planting between surface water monitoring sites SW14 and SW15, where previous planting locations have experienced wet season plant removal and mortality (MRM, 2018a).

January 2018 experienced 627 mm of rain with 86% of the month's total rainfall (538 mm) falling in one week (21 to 27 January 2018) and the heaviest daily rainfall event ever recorded at the site since records began in 1968, on 25 January 2018, with 196.4 mm of rainfall. Despite this, grass cover planted along the diversion in 2017 survived well. Additionally, LWD installed in the diversion channels in 2016 and 2017 also appeared to have been retained in the channels and are helping to create sedimentation banks, which consequently aid in the reduction of water velocities in the wet season. Twelve moxy truck loads of LWD were added to the McArthur River diversion channel during the operational period (MRM, 2018a). Vegetation planted near the McArthur River diversion channel lookout had noticeably matured since the previous IM visit (Plate 4.9). The IM also visited the Barney-Surprise Creek confluence. In past years, this site has had an impressive cover of vegetation, however, in 2018 the high rainfall events in January had had a noticeable impact, with evidence of vegetation being completely removed or visibly damaged (Plate 4.10).

During the IM visit, MRM were in the process of re-commissioning an irrigation bore (Donkey bore) located on the southern side of the McArthur River diversion channel (MRM, pers. com., 14/15 May 2018). The bore will allow continuous irrigation of planted tube stock when required, using irrigation sleds installed on the banks. In the past, water was sourced from the McArthur River diversion channel, but the river was often too low in the late dry season to facilitate water extraction. Increased irrigation opportunities will aid in the growth of the tube stock and development of roots prior to the wet season increasing the chance of tube stock survival. Irrigation requirements are determined using the channel irrigation trigger action response plan (TARP), with the trigger based on the survival rate of tube stock (MRM, 2018d).

Plate 4.9 – Revegetated Bank Next to the McArthur River Diversion Channel Lookout

Plate 4.10 – Salt Deposition and Flood Damaged Vegetation at the Barney-Surprise Creek Confluence Observed During the 2018 IM Site Visit

As discussed in Section 4.9.3.2, revegetation monitoring was not conducted within the operational period. Eco Logical Australia (2017a) did however conduct a review of revegetation monitoring methods and the rehabilitation management plan (RMP). The review included an assessment of the study methods and consideration of recommendations made by the IM in previous years.

The review recommended changes to the survey timing, success indicators, completion criteria, GIS rankings, key and primary species, survey methods and data analysis.

The review supported the IM's recommendations, including:

- Incorporating additional revegetation and control sites in the McArthur River diversion channel rocky gorge area, with tailored completion criteria for this habitat.
- The establishment of measurable targets for rehabilitation success such as plant survival.
- The need for improved erosion assessment. The reviewer commented that LFA (Tongway and Ludwig, 2007) requires assessment to begin when the rehabilitation site is a 'blank slate'. Although the IM agrees the LFA methods in their entirety will not suit the current stage of rehabilitation, quantitative analysis methods adapted from LFA would greatly improve the robustness of the erosion monitoring.
- The revision of key and primary species for McArthur River and Barney Creek catchments and tailored completion criteria for both.

The review by Eco Logical Australia (2017a) was thorough and provided essential guidance for improving the RMP. As a result, MRM updated the RMP to 'establish a rehabilitation monitoring and management system that enables MRM to progress rehabilitation towards closure objectives' (MRM, 2018b).

The updated RMP details background information including historical uses, climatic conditions, landform, vegetation and fauna communities of the mine site and more specifically, the McArthur River and Barney Creek diversion channels, which also includes rehabilitation history. Closure objectives and key rehabilitation issues (i.e., erosion and faunal disturbance) are discussed. The RMP outlines planned revegetation works for 2018 to 2020. Revegetation will be assessed using two methods; an annual revegetation monitoring program and a fortnightly revegetation assessment during the dry season. The fortnightly assessments will be conducted at temporary monitoring sites at active revegetation areas to determine tube stock survival, to gauge success at a finer level and inform plant infill, pest and weed control actions.

Overall, the changes to the revegetation monitoring program greatly improve the quantitative assessment, reproducibility and clarity of the program and will provide an improved understanding of how the rehabilitation along the diversion channels is progressing, while also allowing time-efficient mitigation measures to be put in place when issues are detected. In the previous IM report (ERIAS Group, 2017), it was recommended that the method of erosion assessment be amended, as the five-category assessment used was too broad to pick up most changes to erosion annually. The IM recommended that an LFA based method be investigated as an alternative quantitative method. The revised revegetation monitoring procedure however still includes the five-category rating system, although MRM informed the IM that they are looking into more quantitative methods (MRM, pers. com., 14/15 May 2018). Additionally, in the last operational period review (ERIAS Group, 2017), the IM recommended that the rocky gorge section of the McArthur River diversion channel be treated as a separate habitat for rehabilitation purposes and as such, requires revegetation monitoring sites and suitable control sites as well as tailored completion criteria. This has not occurred within the current operational period as MRM are currently considering further earthworks in the rocky gorge section to decrease the angle of the slope. Conducting such earthworks should be considered carefully, as such a large disturbance may negatively affect the McArthur River aquatic community, by increasing turbidity and erosion risk. In addition, a lack of suitable substrate (given the underlying rocky material in the gorge section) may not improve the chances of revegetation. The IM recommends that the rocky gorge is rehabilitated as is (i.e., without further major earthworks), with a focus on ensuring the vegetation cover and assemblage along the batter (flat area at the top of the slope) is sufficient to provide a corridor for riparian birds traversing the diversion.

Overall, the IM is impressed with the level of effort that has been put into reassessing the rehabilitation monitoring program over the current operational period and MRM's commitment to successfully rehabilitate the diversion channels in a timely manner.

One of MRM's four environmental objectives is to facilitate the development of the ecosystems and their functions along the McArthur River and Barney Creek diversion channels. This includes Tier 1 management measures such as revegetation activities outlined in the rehabilitation management plan and active management of the revegetation areas, as well as channel revegetation monitoring (Tier 2 management measure). The IM notes however that in the executive summary of the 2017-2018 OPR there is no update on the status of these key management measures in the assessment of performance for this environmental objective. While the IM notes that the rehabilitation management plan and revegetation procedures were under review, and as such no monitoring was undertaken during the operational period, some comment as to the status of these programs is warranted in the performance assessment.

Riparian Bird Monitoring Program

Riparian bird monitoring conducted in October/November 2016, May 2017 and October/ November 2017 along the diversion channels showed continuing improvement in the bird assemblage along the Barney Creek diversion channel when compared to control sites (EMS, 2017a; 2018a; 2018b). The surveys, which consist of 20-minute bird counts within fixed 2-hectare quadrats on the lower and upper banks of the diversion channels and natural channels (Figure 4.32), found that the McArthur River diversion channel continues to show a disparity between the upper and lower sites and the central diversion channel area. Habitat data collected showed that the riparian bird assemblage is correlated with vegetation diversity and the central McArthur River diversion channel is continuing to struggle with substrate and vegetation retainment. To date, the indicator species buff-sided robin (*Poecilodryas cerviniventris*) and purple-crowned fairy-wren (PCFW) (*Malurus coronatus*) have yet to be detected along the McArthur River diversion channel.

In addition to the regular survey program, a survey of PCFWs within the mine levee wall was conducted in January 2018. This area is planned to be cleared in the future (subject to approvals) and therefore a translocation plan is currently being developed. The survey identified 23 PCFWs

RIPARIAN BIRD STUDY SITES

McArthur River Mine Project

FIGURE 4.32

Source: EMS, 2018a.

in six family groups (MRM, 2018a). McArthur River Mining has fenced off a 147 ha area on the southeast end of the airport to allow recovery from cattle damage and provide new habitat for the translocated PCFWs.

An inconsistency in the timing of the early dry season surveys was noted, with the 2016 survey conducted in July and the 2017 survey in May. Timing of the surveys should be standardised to ensure results are comparable from year to year.

Impact of Saline Seepage on Vegetation

Annual vegetation monitoring to detect the impact of saline seepage was not conducted during the operational period. In August 2017, MRM commissioned a review of the saline impact monitoring program (Eco Logical Australia, 2017b). The review provided good suggestions on alterations to the timing of surveys and the vegetation monitoring methods, including how ground and canopy cover is measured, as well as vegetation structure. In addition, the review looked at the feasibility of using remote sensing to detect likely areas of saline seepage and locations for saline impact monitoring. The review concluded that a multi-step process using Landsat thematic mapper/enhanced thematic mapper (TM/ETM) analysis and RapidEye analysis, together with field validation, would be suitable for this purpose.

Following the review, remote sensing to detect saline seepages was conducted within the mine site (Eco Logical Australia, 2017b). Saline seepage was identified on aerial maps as open water or moist soils, anomalies in vegetation patterns, salt or acid scaled areas and/or discoloured water. Sixty five points of interest (POI) were identified as possible seepage points. The POIs were reviewed and low likelihood seepage points and grouped POIs in close proximity were removed. From this, nine distinct areas of interest (AOI) were identified. These AOI are shown in Figure 4.33. These locations include north of the NOEF, east of the mine pit inside the levee wall, north of the SOEF, the northwestern side of the Barney Creek diversion channel, east of the SPROD, and in the water management dam next to the TSF. A ground-truthing study is planned to determine the accuracy of this method for determining saline seepage.

While remote sensing is a useful addition to the survey method for identifying significant seepage, it is recommended that in conjunction, on-ground surveys for detection of areas of seepage are continued. The current criteria are likely to miss saline seepages along vegetated waterways as salt deposition or colour changes are hidden by vegetation and the density of vegetation may be considered normal for this habitat, unless substantial dieback has occurred. Areas which were not identified during the remote sensing study included the north of the TSF at Barney Creek and the Barney Creek-Surprise Creek confluence, where extensive salt deposition has previously been identified (see Plate 4.10).

Impact on Migratory Birds

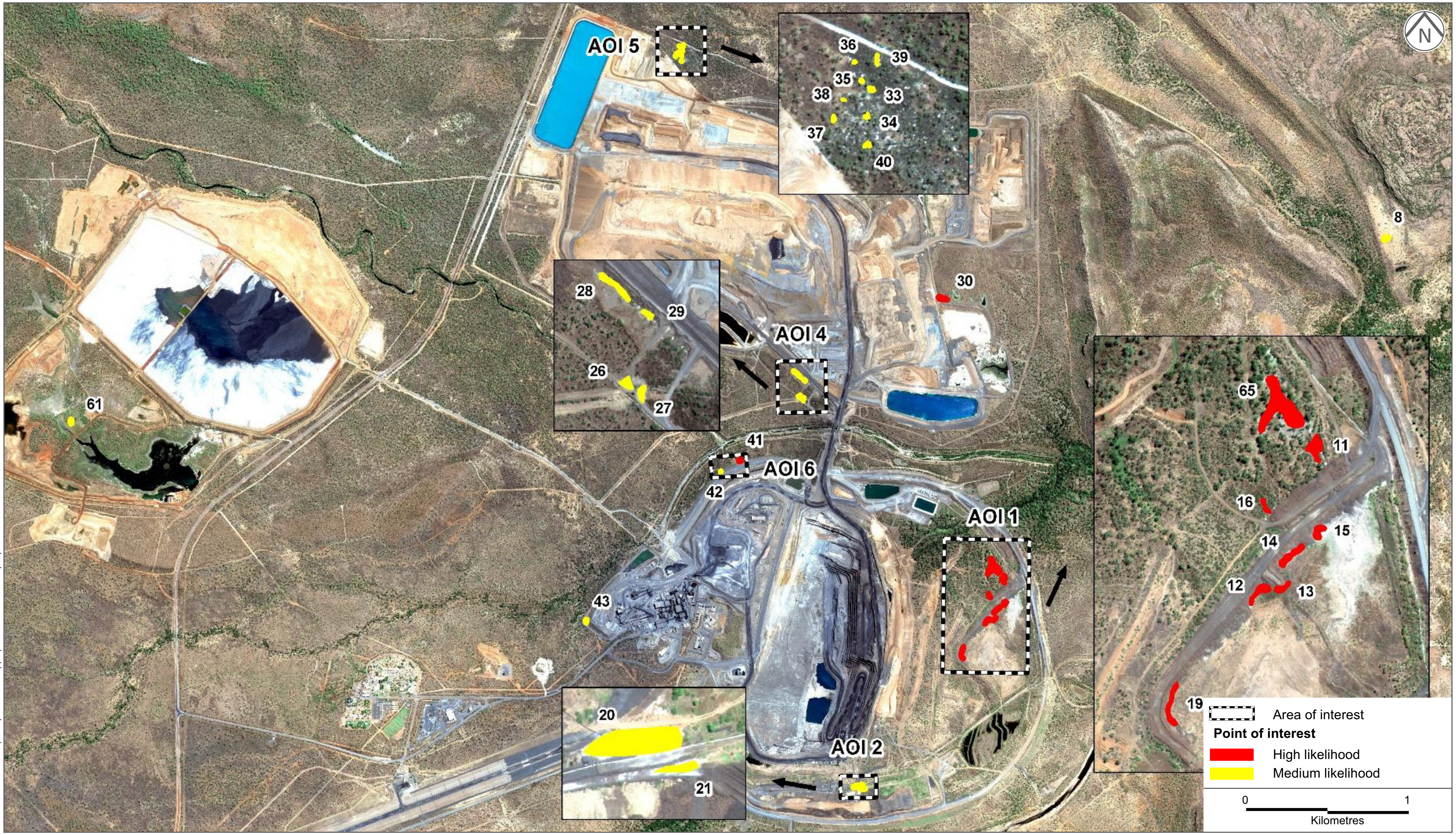
A migratory bird-monitoring program is conducted biannually to assess if there are significant changes in shorebird numbers or assemblage as a result of operations at the Bing Bong Loading Facility.

Migratory bird surveys were conducted in Port McArthur and along the coast from Rosie Creek to the Limmen Bight River coastal floodplains in February to March 2017 (summer 2017), April 2017 (northern staging period) and January 2018 (summer 2018) (EMS, 2017b; 2017c; 2018c) using

IDENTIFIED AREAS OF INTEREST BASED ON THE SALINE SEEPAGE REMOTE SENSING STUDY

McArthur River Mine Project

FIGURE 4.33



Source: Eco Logical Australia, 2017b.

aerial transects and on-ground check sites (Figure 4.34). Marine sediment samples were also collected at important feeding areas within the survey area and tested for metals. The survey consisted of ground and aerial bird counts and the methodology was consistent with previous years. Results from the surveys showed that the Port McArthur coastal area continues to be an important staging area for shorebirds and waders. Metal levels in marine sediments were low and below trigger levels outlined in the ANZECC/ARMCANZ (2000) interim sediment quality guidelines. These guidelines have been superseded and comparison should be in reference to Simpson and Batley (2016). All guideline values, with the exception of silver, have remained the same in the updated guidelines and concentrations of metals in sampled sediment were well below these guidelines.

The migratory bird monitoring program is currently unable to determine whether operations at the Bing Bong Loading facility are having a measurable impact on migratory birds. While the surveys provide important information about the use of the Port McArthur key biodiversity area by shorebirds and waders, fluctuations in numbers are unexplainable due to the size and complexity of the east Asian Australasian (EAA) flyway. This limits the ability to make inferences about the impact of the McArthur River Mine. Given the limitations, the IM recommends MRM review the migratory bird monitoring program to assess if current methods are still suitable and investigate alternative avenues such as focussing on a small number of key species and/or collaborating with other research teams in other locations along the flyway. The biannual monitoring of migratory birds is however a condition of Commonwealth government approvals, and as such discussions about the future of the program would need to be held with the relevant regulators.

Weed Management

Weed control is an ongoing challenge at the McArthur River Mine due to historical pastoral and mining activities as well as current mining and ongoing disturbance of the region. McArthur River and Barney Creek, in particular, provide a pathway for the spread of weeds from properties upstream and the potential to spread weeds downstream of the mine. Vehicle traffic and the import of seed and substrate (rock or soil) to site are also significant potential pathways.

McArthur River Mining maintains a weed management plan (MRM, 2017b), which is updated every three years. The plan details high-risk weed areas, procedures to minimise the spread of weeds, methods used to actively control weeds, weed species profiles and the actions conducted over the previous year.

Weeds that are currently actively controlled onsite include kapok bush/saddle bag weed (*Aerva javanica*, neem tree (*Azadirachta indica*), hyptis (*Hyptis suaveloens*), bellyache bush (*Jatropha gossypiifolia*), devil's claw (*Martynia annua*), parkinsonia (*Parkinsonia aculeata*) and Noogoora burr (*Xanthium strumarium*). From June 2016 to May 2017, MRM reported that weed control covered 654.54 ha, while in the period from June 2017 to May 2018, a total of 47.37 ha was treated for weeds (MRM, 2018a; 2017a). McArthur River Mining has also advised that an additional 13.27 ha of fence lines were sprayed in the 2017-2018 operational period (MRM, pers. com., 22 August 2018). A figure showing targeted weed areas in the 2017-2018 OPR (MRM, 2018a) indicates that the weed control area was however much greater than 47 ha and this estimation may be an error in the report. While the eradication of a large weed infestation in 2016 likely reduced the area needing to be targeted in 2017/2018 it appears to have been substantially

MIGRATORY BIRD SURVEY AREAS

McArthur River Mine Project

FIGURE 4.34

Source: Google Image 2005

more than 47 ha. McArthur River Mining use a range of methods to control weeds onsite which includes:

- Biological control: biological control agents have been trialled at Bing Bong dredge spoil ponds to control parkinsonia. McArthur River Mining is currently researching the use of biological controls for Noogoora burr and devil's claw.
- Chemical control: herbicide is applied to weeds through soil application, basal barking, foliar spraying, stem injection, cut and paint method and/or aerial spraying. McArthur River Mining maintain a weed spray register recording all targeted locations and timing of spraying (MRM, 2017c).
- Mechanical and manual control: this involves pulling of weeds by hand or using machinery and vehicles using a drive through wheel wash before leaving site.

McArthur River Mining has had a number of successes with the management of weeds, including the control of neem tree at known infestation sites at the Bing Bong Loading Facility, with no plants identified in 2017. An infestation of devil's claw previously occurred in the McArthur River floodplain. After working with McArthur River Station to eradicate this species through aerial spraying no devil's claw was observed from inspections conducted in 2017.

Noogoora burr is still a significant issue at the McArthur River Mine, despite intensive weed control by MRM. Significant stands of this weed were observed during the site visit particularly at Djirrinmini Waterhole (Plate 4.11).

Plate 4.11 – Noogoora Burr Infestation Observed at Djirrinmini Waterhole During the 2018 IM Site Visit

Cattle Management

According to the cattle management plan (MRM, 2017e), a total of 47 km of fencing has been installed that encloses the MRM mine site and the McArthur River diversion channel, the airport and the TSF. In addition, an area of approximately 147 ha, at the southeastern end of the airport, has been fenced off to provide suitable habitat for future translocated PCFWs originating from within the levee wall (MRM, pers. com., 14/15 May 2018).

Fencing is four strand barbed wire, with the exception of an 8 km section south of the McArthur River diversion channel, which is an electrical fence. Fence lines are inspected weekly with damage noted on a fence line inspection form (MRM, 2016b) and repairs are conducted as soon as possible.

Cattle (and donkey) mustering is conducted approximately every six weeks during the dry season in collaboration with McArthur River Station and the DPIR. Mustering is conducted using a helicopter and light vehicles. Cattle that are unable to be mustered out of the mine site using the helicopter or vehicles may be destroyed. Mustered cattle are tagged and quarantined in a cattle yard while blood samples can be analysed for Pb levels. Cattle with acceptable Pb levels remain tagged but are released back to McArthur River Station. Cattle that have unacceptable Pb levels remain restricted and are ineligible for live-export or human consumption.

McArthur River Mining also trialled lick blocks to discourage cattle from accessing the water in the McArthur diversion channel but they have been unsuccessful and so they have been discontinued (MRM, pers. com., 14/15 May 2018).

Dredge Spoil Vegetation Monitoring Program

The dredge spoil vegetation monitoring program was initiated in 2012 after vegetation surrounding the dredge spoil ponds was observed to be in poor condition. Prior to the commencement of the monitoring program, a diversion drain was constructed in 2010 that was built to divert saline water out to sea and away from surrounding vegetation to prevent further dieback of vegetation.

The monitoring program was carried out in July 2017 (EcOz, 2017c) at 18 monitoring transects and four control transects, each 100-m long (Figure 4.35). Surface soil samples were also taken at each end of the transects for measurement of electrical conductivity. Little change in the vegetation assemblage has been recorded since the survey program began in 2012, despite a large reduction in soil salinity after the first monitoring year at most sites. This indicates that the habitat is unlikely to recover to its original assemblage and may be permanently changed to a salt-pan habitat type. Although altered, the saltflat habitat now surrounding the dredge spoil is a common type in the region.

During the 2017 survey, an increase in soil salinity was detected at two sites (see sites 6B and 6C on Figure 4.35), located close to the two breaches in the northeast corner in the dredge spoil storage facility wall. Although the source of the spike is unknown, a breach in the dredge spoil wall was recorded nearby.

VEGETATION MONITORING SITES AT THE BING BONG LOADING FACILITY DREDGE SPOIL EMPLACEMENT AREA

McArthur River Mine Project

FIGURE 4.35

Source: EcOz, 2015.

ERIAS Group | 01164F_1_F4-35_v2

Overall, the source of the initial die-off is still unknown however the following are three possible scenarios:

1 Saline water is leaching from the dredge spoil.
2 The obstruction of an ephemeral stream at the southeast toe of the dredge spoil is preventing water run-off.
3 Tidal seawater is being retained against the dredge spoil bund for extended periods of time.

As additional dredge spoil will be added to the ponds in the near future, knowledge of the cause of the vegetation die-off would be useful to prevent further disturbance. It is advised that MRM develop a dredge spoil management plan, prior to the next dredging event, and complete a desktop assessment of the likely cause of the vegetation die-off.

It is unlikely that the vegetation surrounding the dredge spoil will return to its former composition in the short or medium term. The current vegetation type fits within a coastal saltflat habitat, which is common in the region. As the impact is localised, it should be considered if a cover of salt tolerant species is an acceptable outcome.

EcOz (2017c) recommended that the dredge spoil vegetation monitoring program should occur every three years rather than annually due to the difficulty in detecting changes from year to year. The IM supports this recommendation.

McArthur River Mining engaged GHD in late 2016 and 2017 to conduct an inspection of the Bing Bong dam (GHD, 2017; 2018). This included the inspection of the dredge spoil and the perimeter drains designed to divert any saline water out to sea. This inspection identified several areas of erosion along the edge of the dredge spoil and recommended that the design of the external diversion drain be re-evaluated. Several locations of erosion were also observed during the IM visit.

McArthur River Mining has noted the difficulty with excluding cattle from the Bing Bong dredge spoil. Cattle are however likely to be one of the significant causes of the breakdown of the dredge spoil walls and subsequent erosion therefore efforts must be made to exclude cattle.

Progress

McArthur River Mining's performance against previous IM review recommendations relating to terrestrial ecology issues are outlined in Table 4.42.

Table 4.42 – Terrestrial Ecology Recommendations from Previous IM Reports

Subject	Recommendation	Status
Flora	Conduct testing for metal concentrations in common forage species at sites surround the TSF	Completed (April 2018) Results not available at time of IM review
Flora	Measure the survival rate of seedlings being planted to enable an assessment of whether the current strategy of planting seedlings is successful	Completed The measurement of plant survival is now included in the updated revegetation monitoring program

Table 4.42 – Terrestrial Ecology Recommendations from Previous IM Reports (cont'd)

Subject	Recommendation	Status
Fencing	Remove decommissioned fencing to avoid causing injury to fauna and/or mine personnel and animals	Complete but no evidence sighted MRM advised that decommissioning works were completed in December 2017 and January 2018
Revegetation Monitoring	Results from dust monitoring sites DMV25 and DMV23 should be assessed against foliage cover results from vegetation control sites BCC1 and BCC2 respectively, to identify whether airborne dust is a causal factor in decreasing foliage density	Not completed To be included in the 2018 revegetation monitoring program
Fauna	Replace the current Gouldian finch monitoring program with an assessment of suitable breeding and foraging habitats located within, and in the vicinity, of the mine. Construct a map of habitat, graded as to suitability for Gouldian finches, for use in clearing and construction projects, allowing disturbance of important habitat to be avoided	Partially completed A map figure has been constructed for nesting habitat. Foraging habitat has been mapped, but the information has not been added to a clear map figure. The IM was informed that a map figure that detailed foraging habitat, as well as nesting habitat, would be produced in the near future to aid in preserving important Gouldian finch habitat when clearing
Bing Bong Loading Facility	Investigate ponding of seawater against bund wall and the cause of damage to the surrounding drain at the Bing Bong Loading Facility dredge spoil ponds	Partially completed McArthur River Mining advised that the dredge spoil emplacement area is inspected by GHD annually (GHD, 2017; 2018) for maintenance requirements but a review of the documents show that ponding of seawater against the bund wall was not investigated. Cause of damage to bund wall was however discussed
Bing Bong Loading Facility	Include an inspection of the outside of the drain bund wall in monthly inspections of the dredge spoil cells, to assess for example if tidal seawater is ponding against the bund	Ongoing MRM advised that the dredge spoil emplacement area is reviewed by GHD annually for maintenance requirements (GHD, 2017; 2018). GHD included a recommendation in their annual maintenance report for MRM to develop a routine inspection checklist and instigate monthly visual inspections
Rehabilitation	Investigate using the saline seepage assessment sites located on the Barney Creek diversion channel as part of the revegetation monitoring program, as they will provide representation for an area downstream of the Barney Creek haul road bridge which is lacking data. Many of the methods already conducted are very similar and would allow the data to be analysed with the diversion channel revegetation monitoring program as well as the saline impact monitoring program	Ongoing Saline seepage monitoring was not conducted during the operational period. Instead, a review of the monitoring program and a remote sensing trial was conducted. MRM advised that additional monitoring sites are included in the scope of works for 2017/2018

Table 4.42 – Terrestrial Ecology Recommendations from Previous IM Reports (cont'd)

Subject	Recommendation	Status
Rehabilitation (cont'd)	Include a monitoring site in the rocky gorge area of the McArthur River diversion channel (downstream, below MRR6) along with a suitable control site, as this location will not rehabilitate in the same manner as other sites and data is required to ensure that it is also rehabilitated to an appropriate stage. It is unlikely that areas such as this would meet completion criteria set out for more sloped sites	Ongoing A decision will be made by MRM in 2019 as to whether to rework the rocky gorge area or rehabilitate it in its current form
	Include a monitoring site next to the TSF along Surprise Creek where seepage has previously occurred, as part of the saline seepage impact monitoring program	Ongoing Saline seepage monitoring was not conducted during the operational period. Instead, a review of the monitoring program and a remote sensing trial was conducted. MRM advised that additional monitoring sites are included in the scope of works for saline impact monitoring in 2017/2018
Flora	Research the use of a more landscape function-based monitoring program such as drainage-line assessment to provide more information on erosion and stability of Barney Creek and McArthur River diversion channels	Ongoing A review of the revegetation monitoring program by Eco Logical agreed that a more quantitative method of assessment was required, but stated that LFA would not be suitable as assessment needs to begin when the revegetation site is a 'blank slate'. Although not suitable in its entirety, aspects of LFA erosion assessment should still be considered. MRM advised that this recommendation will be included in the revegetation monitoring program although no evidence of changes to the erosion monitoring methods have been sighted
	Conduct a review of rehabilitation works to date including total tube stock and kilograms of seed used, total areas planted and percentage of successful revegetation to assess the likely timeframe and cost for diversion channel rehabilitation, including an expected completion year in future MMPs	Mostly completed MRM completed an extensive review of rehabilitation works and procedures including a detailed register of available tube stock, amount of seed used and areas planted. An explicit target completion year for revegetation works has not yet been provided in the OPR documents or the rehabilitation management plan
Bing Bong Loading Facility dredge spoil ponds	Compare data collected during the migratory bird monitoring program with historical data for the region and surveys completed in other locations on the EAA flyway. Conduct a review of the current monitoring program to assess if it is sufficient to determine if MRM activities are impacting migratory birds	Ongoing Some comparison with data from previous years has been undertaken but it is still unclear whether the Bing Bong Loading Facility is having an impact on migratory birds or not. A review of the survey should be conducted

4.9.4.3 Successes

In the reviewed operational period, successes relating to terrestrial ecology have included:

- The initiation of community engagement projects including the common edible species survey and the 'Traditional Plants and their Uses in the McArthur River Area Report'.
- Planting of 84,000 tube stock in 2017 with approximately 96% grown in the onsite nursery, with a further 50,000 tube stock ready to be planted in May during the IM visit. Many of the seeds used are also collected on-site, and planting involves the employment of the local community to collect provenance seed, which is important for rehabilitation success. The target for 2018 is planting 100,000 tube stock along the southern bank of the McArthur River diversion channel.
- Successful retainment of many of the grasses that were planted even after a significant wet season event in January 2018.
- An extensive review of the rehabilitation program was conducted resulting in considerable positive improvements to revegetation methods and the monitoring program.
- The development of a fire management plan for the McArthur River Mine.
- Successful eradication of weed infestations of neem tree at Bing Bong Port and devil's claw at the McArthur River floodplain with no plants identified during inspections in 2017.

4.9.5 Conclusion

McArthur River Mining has made substantial improvements during the 2017-2018 operational period in relation to terrestrial ecology. Firstly, MRM has dedicated a lot of time and effort reviewing and improving existing procedures and putting new plans in place, where needed, such as the fire management plan. The revegetation progress of the McArthur River diversion channel has noticeably improved since the previous IM visit, with an apparent increase in the success of tube stock retainment. It is obvious that MRM is committed to the rehabilitation of the diversion channels and has exhibited a willingness to evolve methods based on comment from expert consultants and the IM. Despite this, significant issues still remain. Notably, the McArthur River diversion channel, although progressing, is still in poor condition and its rehabilitation represents a significant challenge for MRM. Saline seepage across the mine site is still an issue and the source is still largely unresolved. In addition, cattle continue to represent a problem in the vicinity of the Bing Bong Loading Facility. Ongoing and new IM recommendations related to terrestrial ecology issues are provided in Table 4.43.

Table 4.43 – New and Ongoing Terrestrial Ecology Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Rehabilitation	Add known saline and/or SO_4 seepage sites (e.g., Barney/Surprise Creek confluence and Surprise Creek next to the TSF) to the seepage impacts vegetation monitoring program*	High
	Include a revegetation monitoring site in the downstream area in the rocky gorge along the McArthur River diversion channel along with a suitable control site, as this location will not rehabilitate in the same manner as other sites and data is required to ensure that it is also rehabilitated to an appropriate stage	Medium

Table 4.43 – New and Ongoing Terrestrial Ecology Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Revegetation monitoring	Results from dust monitoring sites DMV25 and DMV23 should be assessed against foliage cover results from vegetation control sites BCC1 and BCC2 respectively, to identify whether airborne dust is a causal factor in decreasing foliage density	Medium
Fauna	Compare data collected during the migratory bird monitoring program with historical data for the region and surveys completed in other locations on the EAA flyway. Conduct a review of the current monitoring program to assess if it is sufficient to determine if MRM activities are impacting migratory birds	Medium
Bing Bong Loading Facility	Investigate recent ponding of tidal seawater against the bund wall during the annual GHD inspection and once identified address the cause	High
Bing Bong Loading Facility dredge spoil ponds	Include an inspection of the outside of the drain bund wall in monthly inspections of the dredge spoil cells, to assess if tidal seawater is ponding against the bund, for new erosion or cattle damage. Annual monitoring is not sufficient to allow timely repair of damage and to prevent further disturbance of the surrounding vegetation	Medium
Fauna	Add information on vegetation mapping units that are important foraging habitats to the Gouldian finch habitat map figure. Units have already been mapped but are yet to included on a figure	Medium
Rehabilitation monitoring	Monitoring to be based on an ecosystem function assessment such as the ephemeral drainage-line assessment (Tongway and Ludwig, 2011)	High
Rehabilitation Monitoring	Include a targeted completion year for revegetation works along the diversion channels in future MMPs based on results of rehabilitation monitoring programs and tube stock survival rates	High
New Items		
Fauna	Standardise timing of early dry season riparian bird surveys to ensure results are comparable from year to year	High
Rehabilitation	Continue on-ground study of saline seepage in conjunction with remote sensing to ensure seepage points such as those hidden by dense riparian vegetation are detected	High
Fauna and Flora	Sediment quality studies to reference Simpson and Batley (2016) as this superseded the ANZECC/ARMCANZ (2000) interim sediment quality guidelines	Medium
Bing Bong Loading Facility dredge spoil	Develop a dredge spoil management plan prior to any future dredging works. Include a desktop assessment investigating the source of the saline water that caused previous vegetation die-back to avoid further disturbance	Medium
	Reduce vegetation monitoring at Bing Bong dredge spoil ponds to every three years	Medium
	Ensure cattle are excluded from the dredge spoil ponds and the perimeter drain as they could impact the drain and pond walls resulting in saline water leaching in to the surrounding vegetation	High
Rehabilitation	Consider rehabilitating the rocky gorge section of the McArthur River diversion as is. Further earthworks could have considerable negative impacts on the aquatic environment and are unlikely to significantly increase rehabilitation success	High
Flora	Ensure weed control includes the area surrounding Djirrinmini Waterhole to protect this area of high conservation and cultural value	High

* McArthur River Mining has advised that sites located at Barney/Surprise Creek confluence and Surprise Creek next to the TSF were included in the July 2018 survey (MRM, pers. com., 22 August 2018), although this is outside the reviewed operational period.

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4.10 Freshwater Ecology

4.10.1 Introduction

This section assesses MRM's management of freshwater ecology during the reporting period and is based on a review of:

- Reports regarding monitoring of freshwater biota, including:
  - Freshwater fish diversity, abundance and habitat associations, including the threatened freshwater sawfish (*Pristis pristis*) in the early and late dry season (IPE, 2017a; 2017b; 2017c; 2017d; 2018).
  - Metals and As concentrations and Pb isotope ratios (PbIRs) in freshwater fauna in the early and late dry season (IPE, 2017e; 2017f).
  - Freshwater macroinvertebrates (Barden, 2017).
- Additional monitoring and other reports prepared by MRM and its consultants, with particular reference to MRM's mining management plan (MRM, 2015), operational performance reports (MRM, 2017; 2018) and monitoring of surface water and fluvial sediments (Eco Logical Australia, 2017, KCB, 2018), and dust (TAS, 2017; 2018).
- Observations and discussions with MRM personnel during the site inspection.
- Incident notification letters and correspondence between MRM, regulators and third parties.

4.10.2 Key Risks

The key risks to freshwater ecosystems as outlined in the risk register (Appendix 1) relate to contamination, habitat loss and slow rehabilitation of the diversion channels. Specifically, the key risks are:

- The potential contamination of Surprise, Barney, Little Barney and Emu creeks by seepage, dust and/or runoff from the TSF, ROM pad, crushing circuit, processing plant, WOEF, NOEF, haul roads and their associated water storage infrastructure may cause loss of flora/fauna and/or bioaccumulation of metals within tissues of freshwater biota. Contamination and/or contaminated biota could migrate downstream to McArthur River.
- Failure of infrastructure (such as pipelines, bunds, TSF walls or water storage dams), potentially leading to contamination of McArthur River and/or Barney Creek (or their diversion channels), Little Barney Creek, Surprise Creek and/or Emu Creek. This could cause the loss of flora/fauna and/or lead to the uptake of contaminants by freshwater biota with potentially lethal or chronic sub-lethal effects in the immediate vicinity of the mine and/or downstream of activities.
- The McArthur River and/or Barney Creek diversion channels may create a physical and/or biological barrier to fish migration. This may prevent fish from migrating upstream to breed and/or disperse, and reduce replenishment of waterholes upstream of McArthur River Mine.

- Slow revegetation of the diversion channels limits the restoration of in-channel habitat and provision of shade, which may lead to reduced diversity and abundance of freshwater fauna in the diversion channels and reduced ecosystem function.
- Inability to recreate riparian habitat and/or creation of incorrect habitat along the river diversion channel banks prevents the diversion channels returning to an environment approaching that of the original channel. This may provide unsuitable habitat for freshwater fauna, reducing freshwater fauna diversity and abundance in the diversion channels.
- Contaminated biota may migrate off the lease and could then be caught and consumed by local fishers, potentially leading to human health impacts.

4.10.3 Controls

4.10.3.1 Previously Reported Controls

Summary

McArthur River Mine has controls in place to minimise the risk to freshwater fauna, and these controls are underpinned by monitoring of freshwater fauna and their environment. This monitoring program is explained below and includes:

- Freshwater fish and crustacean diversity and abundance, including the threatened freshwater sawfish (*P. pristis*) (IPE, 2017a; 2017b; 2017c; 2017d; 2018).
- Freshwater macroinvertebrate diversity and abundance (Barden, 2017).
- Metals and As and PbIRs in freshwater fauna (IPE, 2017e; 2017f).
- Riparian revegetation program along the diversion channels (EcOz, 2017).

Large woody debris (LWD) is also added to the McArthur River diversion channel to provide in-stream habitat (with 431 moxy loads added to the upstream, mid and downstream McArthur River diversion channel between 2010 and 2016).

Since freshwater biota may be contaminated as a consequence of contamination of other aspects of the physical environment (e.g., water and sediments), monitoring of freshwater ecosystems is informed and supplemented by MRM's other monitoring programs, including (but not limited to):

- Surface water and groundwater quality, outlined in Sections 4.3 and 4.5.
- Contamination of fluvial sediments, soil and dust, outlined in Sections 4.12 and 4.13.

In addition to monitoring, MRM has ongoing controls to minimise/eliminate contamination as a result of mining operations. These controls are discussed in more detail in other sections of this report, but include:

- A water management system to prevent contaminated water from entering the river system (Sections 4.2 and 4.3).
- Dust emission controls to prevent contamination of waterways via dust (Section 4.13).

- A waste discharge license that outlines the conditions under which contaminated water may be released into the surrounding waterways to minimise contamination (Section 4.3).
- A detailed design for the NOEF, which includes various quality control checks including the requirement for an Independent Certified Engineer.
- A detailed design for the TSF, which includes various quality control checks including the requirement for an Independent Certified Engineer and Independent Tailings Review Board.
- Seepage-capture ponds and sumps to prevent contaminated seepage from entering waterways (Section 4.5).
- Routine inspections and monitoring of infrastructure.

Freshwater Fauna Monitoring Program

During the current reporting period, freshwater fauna were surveyed in the late dry season of 2016 (October 2016) and the early and late dry season in 2017 (April/May 2017 and October 2017, respectively) by Indo-Pacific Environmental (IPE, 2017a; 2017b; 2018). Freshwater fauna surveys assist in meeting the commitments outlined in the 2013-2015 MMP (MRM, 2015) to:

- Prevent the loss of listed species.
- Ensure that mining activities are not impacting freshwater communities.
- Adhere to the Freshwater Sawfish Management Plan.
- Monitor abundance and diversity of freshwater biota and performance of the diversion channels, including migration of biota through the diversion channels.

The freshwater surveys monitor fish abundance and diversity in permanent and semi-permanent pools in the McArthur River (within, upstream and downstream of the diversion channel), Surprise Creek, Barney Creek and the Barney Creek diversion channel. Specifically, the surveys:

- Monitor the presence of freshwater sawfish in and above the McArthur River diversion channel. The freshwater sawfish is listed as vulnerable under the Commonwealth Government's *Environment Protection and Biodiversity Conservation Act 1999*. Long-term freshwater sawfish recapture and sighting data is also collated.
- Compare fish communities in the McArthur River diversion channel with those in the original McArthur River prior to construction of the diversion.
- Compare fish communities in the McArthur River with sites upstream and downstream of the diversion channels.
- Assess the effectiveness of LWD as habitat for freshwater biota in the McArthur River diversion channel.
- Assess fish passage through the diversion channels by tagging key migratory fish species.

- Compare the size, distribution and abundance of freshwater prawns (*Macrobrachium* spp.) within and outside the McArthur River diversion channel.

- Although not specifically targeted, size and distribution data on freshwater reptiles captured during surveys in the McArthur River are also collected.

The freshwater fauna monitoring sites surveyed during the reporting period are shown in Figure 4.36.

Freshwater Macroinvertebrates Monitoring Program

Freshwater macroinvertebrates are surveyed annually, four to six weeks after the last major wet season flood (generally April to June). Diversity, abundance and community structure of freshwater macroinvertebrates are included in the monitoring program for receiving waters, as they are early indicators of change in freshwater ecosystems, e.g., as a result of contamination from mining operations or ineffective river diversion channels. Thirty sites were surveyed for macroinvertebrates in 2017, covering the McArthur River and Barney Creek diversion channels, minor and major reference drainage lines, and exposed sites (below the TSF and ROM pad). Figure 4.37 shows the macroinvertebrate sampling sites.

Where possible, macroinvertebrates are sampled along river edges and in riffles at each site. However, at seven sites there is no riffle habitat, while at an additional two sites in Barney Creek, which usually have riffle habitat, an absence of flow meant no riffle habitats were sampled in 2017. While surveying macroinvertebrates, environmental data and fluvial sediment and surface water samples are also collected from the same sites at the same time, so inferences can be made about the processes affecting macroinvertebrate communities. The monitoring program is based on the NT AUSRIVAS protocol (Lloyd and Cook, 2002). The macroinvertebrate surveys meet the MMP commitments to survey freshwater invertebrates and to monitor the impact of activities on freshwater biota (MRM, 2015).

Metals and Pb Isotope Ratios in Freshwater Fauna Monitoring Program

The metals and PbIRs in freshwater fauna monitoring program assesses metal concentrations and whether biota within and downstream of the mine site has elevated concentrations of metals compared to those found at undisturbed reference sites. The concentrations of metals and PbIRs in freshwater fauna (environmental indicator and commonly consumed species) are assessed in the early dry season, and since 2016, additional assessment of commonly consumed species has also been undertaken in the late dry season (see Section 4.10.3.2). The monitoring sites where samples were collected are shown in Figure 4.38.

Monitoring of metals and Pb isotopes also helps to assess whether commitments to minimise dust, soil, and surface water and groundwater contamination as a result of operations are being met (MRM, 2015).

Citizen Science Program

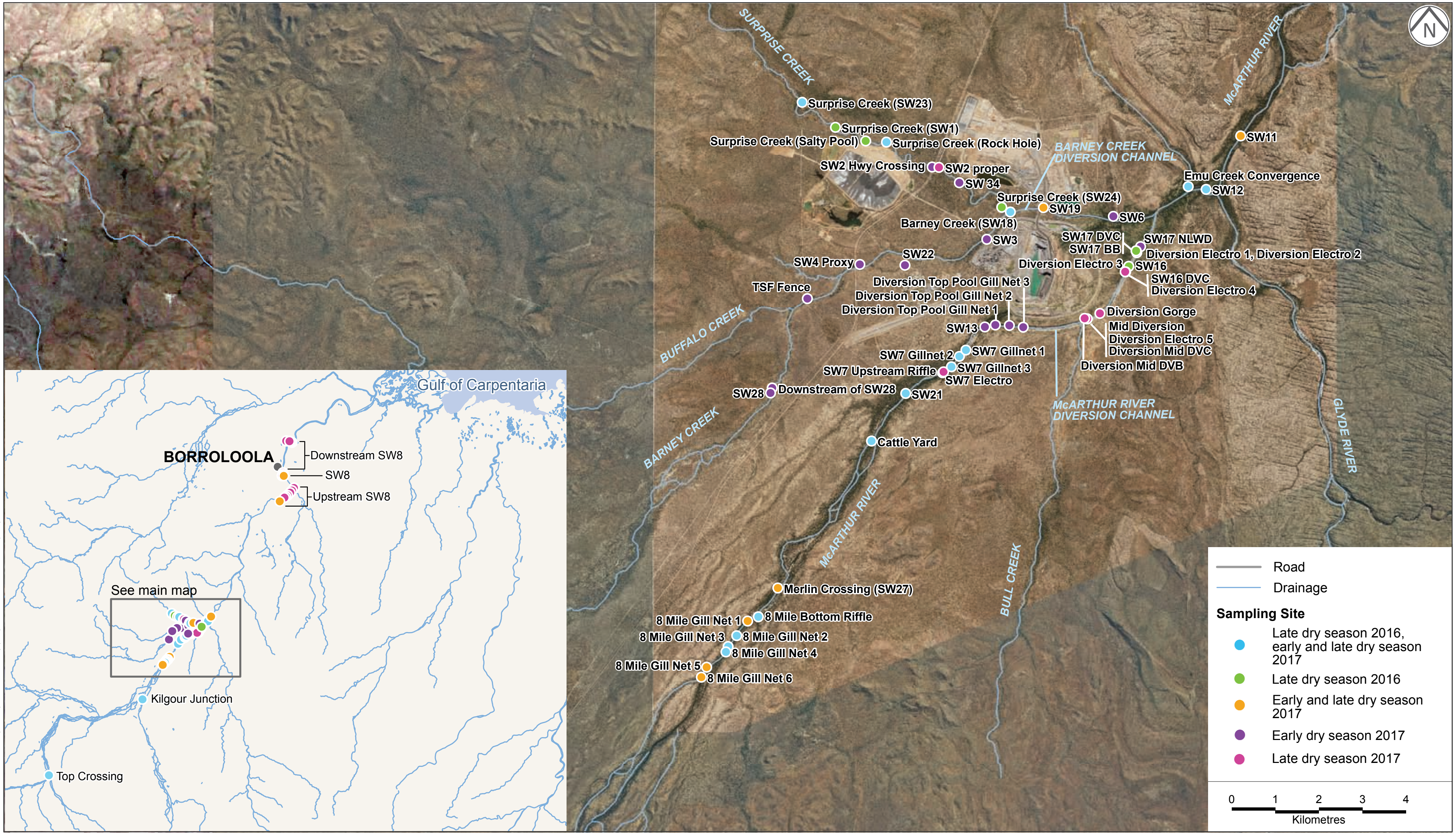
In response to concerns raised by some community members about the monitoring of metals in fish not meeting their interests, MRM commenced a 'citizen science' program to allow the analysis of metals in barramundi caught by the community in the McArthur River and surrounding catchments (IPE, 2017e). Large freezers were placed within the Borroloola township as well as at

SAMPLING LOCATIONS OF FRESHWATER FISH, CRUSTACEANS AND MUSSELS IN THE VICINITY OF McARTHUR RIVER IN 2016 AND 2017

McArthur River Mine Project

FIGURE 4.36

ERIAS GROUP



Source: IPE, 2017a, 2017b and 2018.

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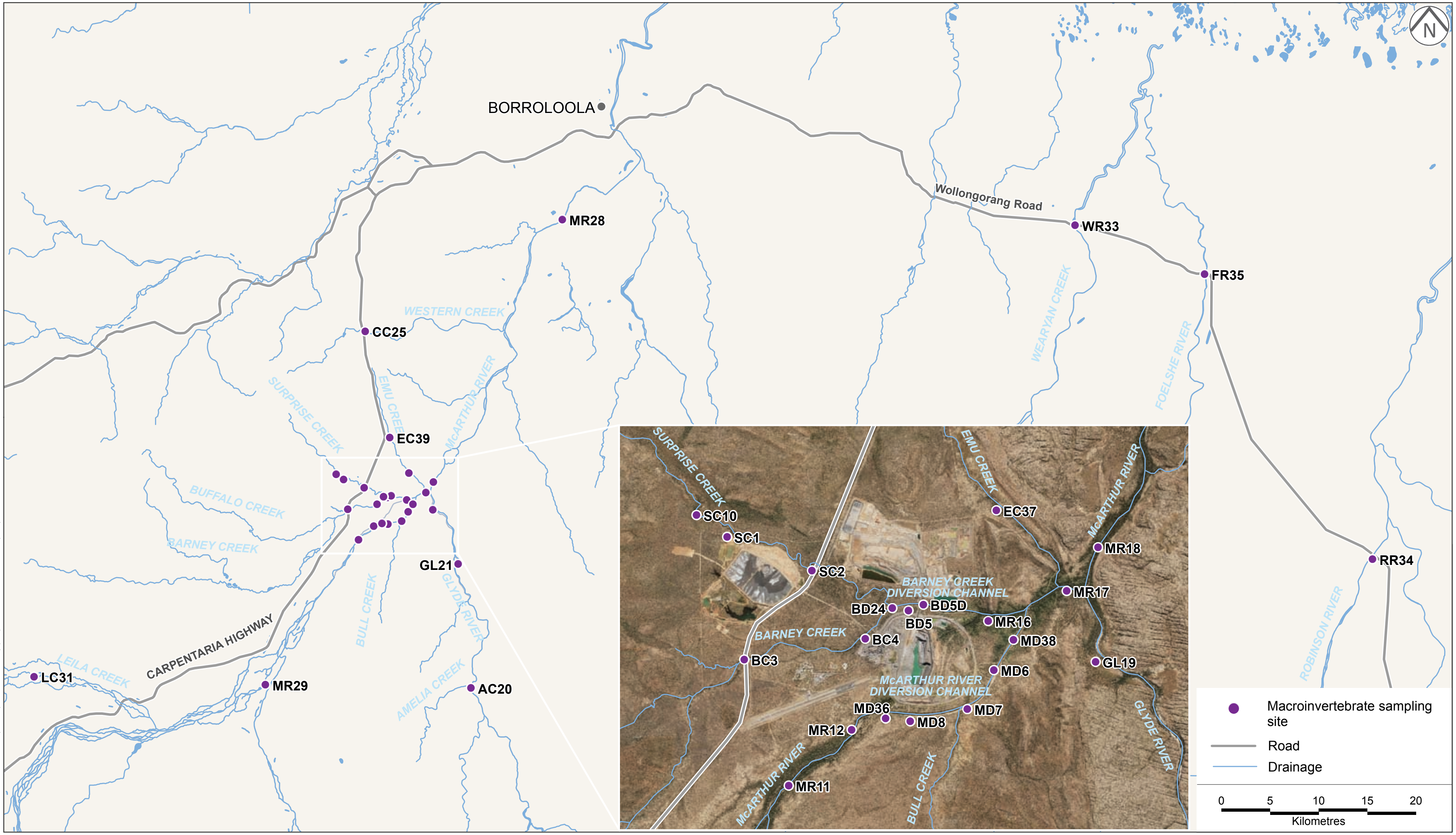
MACROINVERTEBRATE SAMPLING SITES

McArthur River Mine Project

FIGURE 4.37

ERIAS GROUP



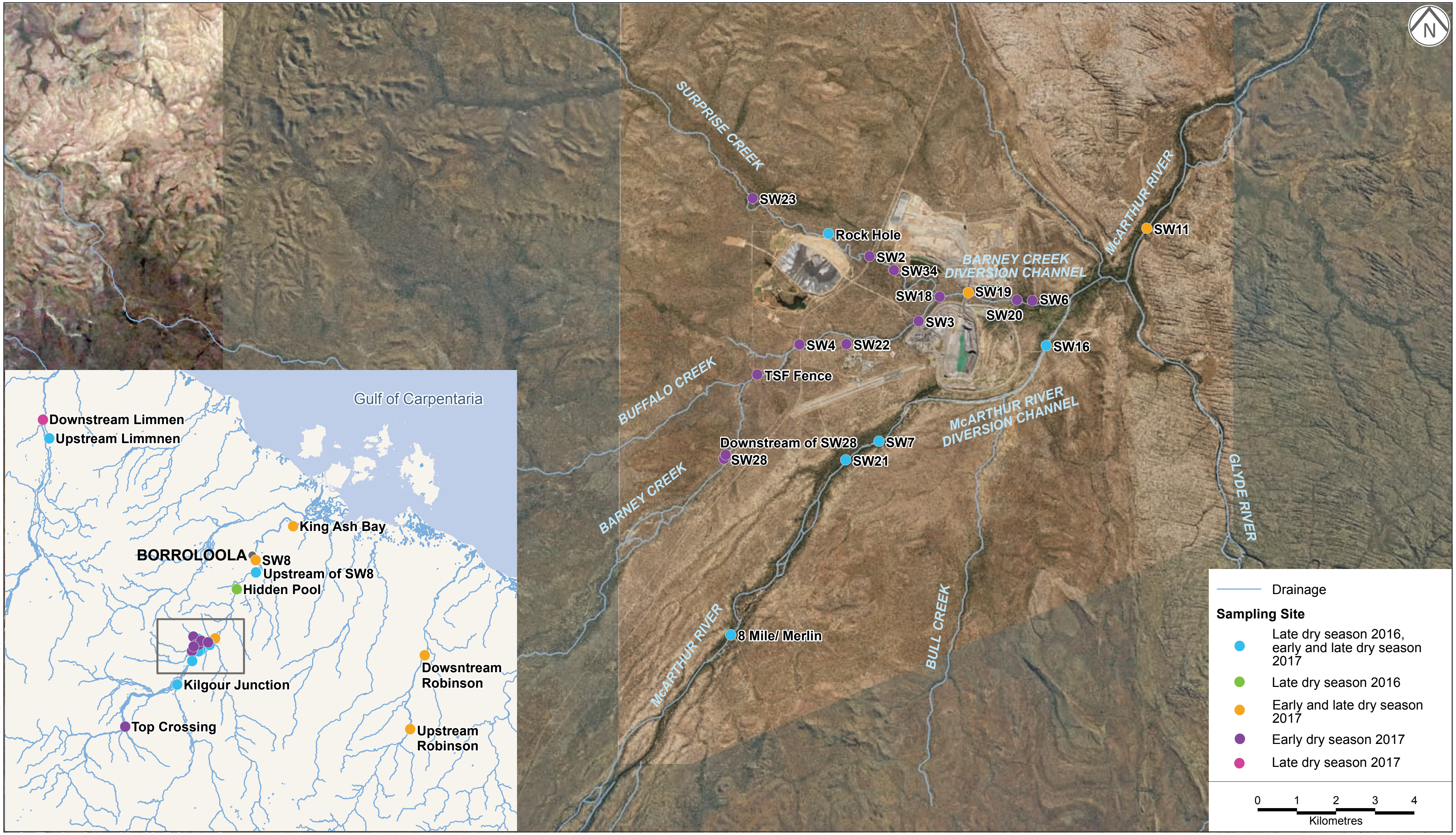
Source: Barden, 2017.

ERIAS Group | 01164F_1_F4-37_v2

LOCATIONS SAMPLED FOR FRESHWATER BIOTA AS PART OF THE METAL AND LEAD ISOTOPE RATIOS MONITORING PROGRAM IN 2016 and 2017

McArthur River Mine Project

FIGURE 4.38



Source: IPE, 2017e, 2017f.

ERIAS Group | 01164F_1_F4-38_v2

Manangoora Station, a regional collection point. Community members are able to deposit barramundi frames into the freezer for collection and subsequent analysis, with the results then reported back to the community and individuals if requested.

Metals in Freshwater Vegetation Investigation

In 2015 and 2016 concentrations of metals (Pb, Cu, As and Cd) in aquatic macrophytes (*Chara sp.*) were assessed to investigate the suitability of using aquatic plants for environmental monitoring (IPE, 2017g). Macrophytes from 12 sites were surveyed in the diversion channels, McArthur River and Barney and Surprise creeks. Results from this initial study were promising with an apparent observed correlation between sediment concentrations and to a lesser degree surface water concentrations and macrophytes, however further assessment of metals in freshwater vegetation was not reported on during the current reporting period. It is however understood MRM are still exploring the technique as an alternative to sampling of aquatic fauna tissues.

Fish Consumption Survey

In June 2016, IPE conducted a survey of local community members to determine local fish consumption patterns and to ensure representative species are targeted for assessing concentrations of metals in commonly consumed species (IPE, 2016). The fishing and fish consumption habits of at least 10% of the population of Borroloola were surveyed.

4.10.3.2 New Controls – Implemented and Planned

Monitoring of Metals in Biota

To provide an indication of the maximum concentrations of metals in fauna and seasonal variations, MRM has added late dry season (generally October or November) monitoring of metals in freshwater biota. The first round of late dry season monitoring was completed in October and early November 2016 and subsequently in November 2017 (IPE, 2017e; 2017f).

The following additional refinements to the metals and PbIRs in fauna monitoring program were also made following the results of the fish consumption survey:

- The inclusion of sevenspot archerfish in the sampling program.
- The collection of samples from Limmen Bight and Robinson River catchments biannually to act as control sites.
- The addition of key fishing sites on the McArthur River, including Ryans Bend.
- An investigation into the potential of obtaining freshwater turtle tissue samples from members of the community, as turtles were consumed by nearly 5% of respondents.
- The investigation of non-lethal sampling methods.

Acoustic Tagging of Migratory Species

Due to the expansion of the monitoring of metals in biota program in 2013, the majority of fish captured during monitoring are retained for analysis, and few fish are visually tagged and released. As a result, the previously successful visual tagging program was no longer effective. In

November 2016, MRM established an acoustic tagging system to track the movement of fish within McArthur River, as acoustic tagging programs require fewer individual fish to be tagged than visual tagging programs to be effective. McArthur River Mining established a network of 10 acoustic receivers from King Ash Bay to the Kilgour River, including receivers in the upper and lower McArthur River diversion channel. Initially, one freshwater sawfish and eight barramundi were fitted with tags in November 2016, with an additional two freshwater sawfish tagged in the early dry season aquatic fauna survey undertaken in May 2017. In August 2017, nine of the ten receivers were recovered. The receiver at Cattle Yard could not be recovered and so a replacement was installed, while the receiver in the Kilgour River upstream of the junction with the McArthur River was moved further upstream to a known permanent water body. The results of the first data download are discussed in Section 4.10.4.2.

Installation and Monitoring of Woody Debris

Twelve moxy loads of large woody debris (LWD) were added to the McArthur River diversion channel in 2017 in close proximity to a new access ramp, mid channel.

To supplement the LWD program, small and medium sized woody debris has also been added to the McArthur River diversion channel, with the aim of adding additional organic matter to the channel in an attempt to improve macroinvertebrate assemblages in particular. This smaller debris was observed accumulating behind the LWD during the May 2018 site visit.

The IM was advised that MRM has started documenting the persistence of LWD as part of the annual channel erosion monitoring (which recommenced in 2018), which is usually carried out at the beginning of the dry season (MRM, pers., com., 30 July 2018). A register tracking volumes and locations relating to the small woody debris program is also maintained.

4.10.4 Review of Environmental Performance

4.10.4.1 Incidents and Non-compliances

Incidents

Fish Kill at South-East Levee 1

On 26 May 2017, several hundred fish (primarily small bony bream [*Nematalosa erebi*]*)* were killed during the draining of the South-East Levee 1 (SEL1) at the end of the wet season. Fish enter SEL1 during backflow from the McArthur River in the wet season and have no way of returning once backflow subsides.

The water contained behind SEL1 was drained for operational reasons. Field measurements taken on 26 May 2017 indicated that dissolved oxygen concentrations were very low (17%) and this was the likely cause of the fish deaths. As SEL1 was to be completely drained, all remaining fish within SEL1 were expected to perish.

Fish entered the water held behind the levee during backflow from the McArthur River over the 2016/17 wet season. It was not considered practicable to remove fish prior to dewatering due to dense reeds, the small size and large numbers of fish present. There were also concerns around relocating potentially contaminated biota to the receiving environment and as such no attempt was made to relocate the fish prior to draining. It is noted that if SEL1 had not been drained, fish kills would still have eventuated as SEL1 dried out over the dry season. Similar incidents have also occurred in past years.

Other Relevant Incidents

While there were no other reported incidents that were specifically related to freshwater biota, a number of overflow/runoff events occurred during the reporting period which had the potential to effect freshwater ecosystems, these are discussed in more detail in Section 4.3 and summarised below:

- Cell 1 Eastern Sump at the TSF overflow of around 100 to 200 L/s over a 24-hour rainfall period with potential impacts to Surprise Creek, Barney Creek diversion channel and/or the McArthur River.
- Central West Alpha Sump (CWAS) overflow during extreme rainfall event. Water was discharged to the environment at approximately 200 L/s. Discharge from Central West region of the NOEF reported to Central West C Sediment Trap (CWCST) before reporting to an unnamed tributary to the north of the NOEF. Discharge included runoff water from portions of Central West as well as water from the CWAS. Related to a 1-in-100-year average recurrence interval one-hour rainfall event.
- Runoff from the West D area of the NOEF entered a clean water drain, which eventually reports to Surprise Creek, with an estimated overflow rate of 5 L/s. Substantial water was in the clean water drain and South West Sediment Trap at the time, so impacts to water quality at the receiving environment are expected to have been negligible. Works have been completed to reinstate the bund, remove accumulated sediment and improve drainage.

Given the high flows in the receiving environment, which would have occurred during each of the above incidents, it is likely that minimal impact to the receiving environment and consequently freshwater biota occurred.

Non-compliances

The 2013-2015 MMP does not contain a definitive list of commitments against which to assess non-compliances.

Waste Discharge License Exceedances

There were a number of exceedances of MRM's site-specific trigger values for SW11 for filtered Al, dissolved oxygen, electrical conductivity and NO_3 and these are discussed in more detail in Section 4.3. These exceedances were unlikely to have any effect on freshwater biota as the exceedances were related to natural sources/processes and biota occurring in the area is therefore considered to be well adapted to these conditions.

4.10.4.2 Progress and New Issues

Freshwater Fauna Surveys

During the current reporting period, freshwater fauna were surveyed in the late dry season of 2016 (October 2016) and the early and late dry season in 2017 (April/May 2017 and October 2017, respectively) by IPE (2017a; 2017b; 2018).

Thirty six sites were surveyed during the 2016 late dry season survey, while 54 and 40 sites were surveyed during the early and late dry season surveys in 2017 respectively (see Figure 4.36).

Table 4.44 outlines the results of the early and late dry season freshwater surveys since 2012. Diversity and abundances of fishes in the 2016 late dry season were similar compared to 2015, but lower than some previous years (2014 and 2013). Both the 2016 and 2015 late dry season surveys followed wet seasons with below average rainfall. It should be noted however that due to very low water levels, fyke nets could not be deployed in the 2016 late dry season survey and seine nets were used minimally, so the sampling techniques were not directly comparable to previous years. In the 2017 late dry season, fish diversity was higher than 2015 and 2016 and overall abundance was the highest for a late dry season since 2012, most likely a reflection of the higher than average rainfall during the preceding 2016/17 wet season. Diversity of fishes in the 2017 early dry season was higher than 2016 and similar to earlier years, while abundance was the highest recorded.

Table 4.44 – Number of Species of Bony Fish and Elasmobranchs and Abundance of Fish Caught During Freshwater Fauna Surveys at All Sites from 2012 to 2017

Year	Season	Number Caught			
		Spp. of Bony Fish	Spp. of Elasmobranch	Total Fish	Freshwater Sawfish
2012	Early dry	30	2	1,596	3
	Late dry	23	2	1,954	1
2013	Early dry	31	1	2,194	0
	Late dry	28	2	5,152	1
2014	Early dry	28	2	2,214	3
	Late dry	30	2	4,933	2
2015	Early dry	27	2	2,953	0
	Late dry	17	2	2,858	2
2016	Early dry	23	1	3,306	2
	Late dry	19	2	3,147	1
2017	Early dry	29	2	7,005	4
	Late dry	24	1	5,395	0

During the 2017 early dry season survey a marked decline in mean catch rates using standardised fyke netting in all three areas was noted (Table 4.45), compared to 2016. This is thought to relate to a decreased abundance of species of gobies (*Glossogobius* spp.) and giant gudgeon (*Oxyeleotris selheimi*) and a reduction in available in-stream macrophyte habitat as a result of above average flow rates (IPE, 2017b). Mean catches of fish in the McArthur River diversion channel were lower compared to sites downstream (Table 4.45) but similar to upstream.

Table 4.45 – Fyke Net Catch in the Vicinity of the McArthur River Diversion Channel (Early Dry Season Surveys, 2014 to 2017)

Survey Area	Year	Mean Number of Fish per Net per Night	Diversity (Species)	Mean *Macrobrachium* per Net per Night
Upstream	2014	3.17	7	8
	2015	16.78	10	6.11
	2016	30.78	12	17
	2017	3.56	13	14.89
McArthur River Diversion Channel	2008*	47.4	16	NA
	2014	2	9	1.33
	2015	3.67	9	5.56
	2016	8.22	18	3.89
	2017	4.89	12	5.56
Downstream	2014	3.83	10	22
	2015	7.67	7	9.67
	2016	39	14	17
	2017	14.33	18	34

* Catch in the original McArthur River channel prior to construction of the diversion channel.

Macrobrachium spp. abundance in fyke nets downstream in the McArthur River doubled in comparison to 2016, while abundances within the diversion channel and upstream were similar to 2016. Abundances of *Macrobrachium* spp. remains notably lower within the diversion channel compared to both upstream and downstream. The notably higher abundances recorded downstream are thought to be linked to the presence of higher amounts of leaf litter and vegetative matter, which provide important habitat and was notably absent from the diversion channel (IPE, 2017b). The placement of small and medium woody debris (see Section 4.10.3.2) aims to address the lack of organic matter in the McArthur River diversion channel.

In the 2016 late dry season, species diversity and abundances from electrofishing followed a similar pattern to previous late dry season sampling with diversity and abundance highest at downstream complex habitat, followed by upstream complex habitats and lowest at McArthur River diversion channel complex and bare bank habitats. IPE (2017a) state that direct comparisons of the numbers between to previous years is limited given the extreme low water levels encountered during the 2016 late dry season survey. Furthermore, IPE (2017a) suggests that species diversity and abundance recorded from electrofishing was a reflection of where water had remained rather than the habitat type of the particular pool. *Macrobrachium* spp. were only recorded in low densities and were found exclusively in upstream complex habitats.

In the 2017 early dry season, species diversity from electrofishing was generally slightly higher than 2015 and 2016, particularly within the McArthur River diversion channel, which had equal or higher diversity than upstream and downstream habitats. Abundances were also notably higher in the diversion channel compared to previous surveys, particularly within complex habitats where abundances were higher than all other habitat types. Fish within the bare bank habitat in the diversion channel were also noted to be clustered around structures such as wood or rocks, rather than evenly distributed along transects. The increased diversity and abundance in the diversion channel illustrates the effectiveness of placing LWD in the diversion channel and is an encouraging result.

In the 2017 early dry season, *Macrobrachium* spp. were recorded in all habitat types by electrofishing, with abundance decreasing moving upstream. This result is in contrast to previous years where abundances of *Macrobrachium* spp. have been highest at upstream complex habitat sites. The *Macrobrachium* spp. density upstream was the lowest recorded since 2011 (despite fyke net captures being equal to or greater than previous years). The low upstream densities are thought to be related to the small size of individuals encountered in the 2017 early dry season, poor water clarity and a lack of macrophytes (IPE, 2017b).

In the 2017 late dry season, species diversity from electrofishing was slightly higher at upstream and diversion channel complex habitats than in 2015 and 2016, and slightly lower at diversion channel bare bank and downstream complex habitats. Abundances were highest at diversion channel complex habitats and similar to downstream complex habitats while lowest at diversions channel bare bank sites. Due to the increased amount of LWD in the diversion channel, there are less bare bank habitats, with those that remained having very low water levels during the 2017 late dry season survey. Direct comparison to previous diversions channel bare bank results is therefore not possible. The increases in diversity and abundances at some sites is likely attributable to the preceding above average wet season rainfall creating more habitable water at sites for longer time periods (IPE, 2017b) and the placement of additional LWD in the diversion channel in November 2016.

Despite few sites containing habitable water during the 2016 late dry season (one in Barney Creek and five in Surprise Creek), 10 species were recorded within Barney and Surprise Creeks with similar species recorded to previous years. During the early dry season in 2017, 18 fish species were identified from sites within the Barney Creek diversion channel and Surprise Creek, while nine species were recorded within the natural sections of Barney Creek. Consistent with previous early dry season surveys, the Barney Creek diversion channel and Surprise Creek had a larger fish assemblage compared to the natural section of Barney Creek, attributed to the availability of preferred habitat (i.e., deep pools with persisting water) in the Barney Creek diversion channel and Surprise Creek. Crustaceans and aquatic reptiles were only found in the Barney Creek diversion channel although previously recorded in Surprise Creek, their absence during the 2017 early dry season may be a result of the removal of reeds in Surprise Creek following strong wet season flows (IPE, 2017b). Similar to previous late dry season surveys, in 2017 only fives sites contained habitable amounts of water (two in the Barney Creek diversion channel and three in Surprise Creek). Thirteen species were recorded which was slightly higher than previous late dry season surveys with comparable species to previous years recorded.

A single large female freshwater sawfish (2.75 m) was caught in the McArthur River downstream of Borroloola in the 2016 late dry season survey, representing the largest individual caught to date, and estimated to be around four years old. It is thought the individual entered the river as a juvenile during the 2011/2012 wet season and migrated upstream where it has remained since. Individuals of this size are known to navigate back downstream to the ocean (Thorburn et al., 2007). This capture indicates that McArthur River provides suitable conditions for the extended growth and survival of freshwater sawfish. Another individual was caught during the initiation of the acoustic monitoring program in November 2016, in an isolated pool within the diversion channel and was also caught during the preceding early dry season. The individual had grown from 0.92 to 1.23 m, providing further evidence that the diversion channel provides acceptable conditions for the growth and survival of this species.

Four freshwater sawfish were captured (from three sites) during the 2017 early dry season survey. Two males (1.05 and 1.03 m in length) captured in the McArthur River (upstream of Borroloola) and the McArthur River diversion channel and one female (0.96 m in length) captured in the Djirrinmini Waterhole (upstream of the McArthur River diversion channel), which had not been previously captured. These individuals are thought to be around one year old and most likely entered the McArthur River during the 2016/17 wet season. The new freshwater sawfish individuals captured during the 2017 early dry season survey indicate that below, within and above the McArthur River diversion channel provides suitable habitat for the growth and survival of the species. The remaining freshwater sawfish captured was previously captured in April 2016, and was found at the large pool at the upstream end of the McArthur River diversion channel. This individual had grown 0.53 m since its prior capture, this together with its overall health provide further evidence that the McArthur River diversion channel provides suitable conditions to support freshwater sawfish.

No freshwater sawfish were captured during the 2017 late dry season survey. However, MRM staff did observe a free-swimming individual within the McArthur River diversion channel just prior to the survey. The remains of a deceased individual (0.85 m in length) were found nearby during the survey; however, it is considered unlikely that this was the individual observed by MRM staff based on the advanced state of decomposition. It is believed the juvenile became stranded in a pool that dried out. Three juveniles were also captured and acoustically tagged from Hidden Pool, located downstream of the McArthur River Mine, in August 2016 as a part of the acoustic monitoring program.

Freshwater Fauna Survey Conclusions

The results of the freshwater fauna surveys from the reporting period illustrate the influence of wet season rainfall and the duration of river inundation on freshwater biota. The below average wet season which preceded the late dry season survey in 2016 and the above average rainfall during the following wet season in 2017 generally resulted in lower diversity and abundances in 2016 to some previous years and higher diversity and abundances in 2017. The effectiveness of the placement of LWD in the McArthur River diversion channel was demonstrated by the results from the 2017 early and late dry season surveys with a noted improvement in fish assemblages observed around complex habitats in the diversion channel. As planned, the placement of woody debris and the improvement of riparian vegetation in the diversion channel should continue as a priority to further improve freshwater biota assemblages within the diversion channel.

Acoustic Monitoring Program

The first download of acoustic data showed that between November 2016 and August 2017, two tagged freshwater sawfish from the upper McArthur River diversion channel remained in close proximity to the locations they were initially tagged, while the third tagged individual was recorded only briefly at Frazer Creek Junction after being tagged in May 2017, with no further recordings. One of the freshwater sawfish from the diversion channel was recorded moving from the upper to the lower diversion channel for short periods of time, when water levels increased, and may have moved further upstream in January, February and May 2017.

From the eight tagged barramundi, data was obtained for six individuals that mostly indicated a high degree of residency remaining within close proximity to the area they were originally tagged. Only one individual was recorded at more than one receiver station with this individual travelling between Eight Mile and the McArthur River upstream of the junction with the Kilgour River and travelled at least 48 km over 13 days.

An additional three freshwater sawfish from Hidden Pool (downstream of the McArthur River Mine) and six barramundi collected from Hidden Pool, Cattle Yard, Eight Mile and the Kilgour River were tagged in August 2017.

The first data set demonstrates the effectiveness of the technique for monitoring movements of migratory species. While some movement between the upper and lower sections of the diversion channel were observed for one individual freshwater sawfish, movement from the diversion channel into the McArthur River main channel has not yet been observed. The installation of additional receiving stations between the Upper Diversion and Cattle Yard (e.g., SW21 and/or SW07), Lower Diversion and Hidden Pool and the Glyde River would provide more detailed information on movements of freshwater sawfish and barramundi through the MRM lease and McArthur River diversion channel. As discussed in IPE (2017d) there are constraints around doing this, mainly the availability of permanent water or shade for protection of the receivers, however the IM agrees additional receivers would be beneficial to the acoustic monitoring program.

Macroinvertebrate Surveys

Ecological Management Services conducted the annual macroinvertebrate survey in May 2017, following above average rainfall during the 2016/17 wet season and no rainfall in April 2017 (Barden, 2017).

Sixty one taxa (family level or higher order) were identified from edge and riffle habitat from 30 surveyed sites during the 2017 the early dry season (May). As explained in Section 4.10.3.1, there were nine surveyed sites where edge habitats occurred but riffle habitats were absent. Similar to previous years, sites in Barney Creek adjacent to the mine processing areas and within the Barney Creek diversion channel had elevated Pb and Zn concentrations in sediment compared to reference sites (see Section 4.12)

Edge Macroinvertebrates

Overall, edge macroinvertebrate taxa diversity declined slightly at most sites in 2017 in comparison to 2016, possibly as a result of high flows during the wet season and slower recovery times of edge macroinvertebrate assemblages (Barden, 2017). Concentrations of Zn and Pb, as well as high levels of soluble salts, were found to be important factors influencing differences in edge macroinvertebrate assemblages.

There was no statistically significant difference between exposed/diversion sites from Surprise Creek and Barney Creek and minor drainage line reference sites, indicating an improvement of edge macroinvertebrate assemblage in the Barney Creek diversion channel. It is thought this improvement is related to wet season flushing and flows following above average rainfall during the 2016/2017 wet season and bank conditions improving in the Barney Creek diversion channel as vegetation develops (Barden, 2017).

Two sites from Barney Creek (BC4 and MR16, see Figure 4.37) were considered outliers and had atypical edge habitat structure as a result of high amounts of depositional mud and silt. According to Barden (2017) the atypical results may also reflect poor surface water quality and habitat disturbance at these sites. Reference sites from Leila and Caranbirini Creeks also had atypical conditions in 2017 with high levels of depositional silt from wet season runoff observed.

Within the McArthur River diversion channel, edge macroinvertebrate assemblages improved in comparisons to previous surveys, attributed to improved flow, riparian vegetation and the addition of LWD (Barden, 2017). There were no statistically significant differences when comparing the McArthur River diversion channel and the McArthur River reference sites, suggesting an improvement on edge conditions within the diversion channel.

Riffle Macroinvertebrates

Overall, riffle macroinvertebrate taxa diversity declined slightly at most sites in 2017 in comparison to 2016, as was found for edge macroinvertebrates, which may have been influenced by high flows during the wet season. Variables found to influence differences between sites were physical riffle characteristics (e.g., stream width, riparian vegetation, habitat availability) and concentrations of Zn, Ni, Pb and soluble salts, which were notably different between Surprise Creek and Barney Creek diversion channel sites and reference sites.

Consistent with previous years, there were statistically significant differences between riffle macroinvertebrates from lower Surprise Creek and Barney Creek compared to equivalent reference sites, thought to be linked to impaired surface water quality and the presence of fine sediment covering rifle habitats at the Surprise Creek and Barney Creek sites.

Within the McArthur River diversion channel, riffle macroinvertebrates were similar (no statistically significant difference) to reference sites in the McArthur River, however macroinvertebrate assemblages are considered less resilient to changes in seasonal flow conditions in comparison to equivalent reference sites, with elevated and or extended impacts noted for diversion channel assemblages (Barden, 2017).

Macroinvertebrate Survey Conclusions

Although there was an overall decline in riffle and edge macroinvertebrate taxa diversity in 2017 at most sites, some improvement was noted for the Barney Creek and McArthur River diversion channel. The regeneration of bankside riparian vegetation and the addition of LWD in the McArthur River diversion channel could explain the noted improvements in edge macroinvertebrate communities within the McArthur River diversion channel in 2017.

While analysis of data from 2008 to 2017 shows that macroinvertebrate assemblages and riffle structure within the McArthur River diversion channel resembled reference conditions within two years, there continues to be some indications that habitats and associated biota have a reduced resilience to impacts from extreme flood events and dry periods.

As planned, the placement of woody debris and the improvement of riparian vegetation in the diversion channel should continue to further benefit macroinvertebrate assemblages and to provide improved resilience to extreme weather.

Metals in Freshwater Biota

Six species of fish (sooty grunter [*Hephaestus fuliginosus*], barramundi [*Lates calcarifer*], bony bream [*Nematalosa erebi*], chequered rainbowfish [*Melanotaenia splendida*], archerfish [*Toxotes chatareus*] and spangled perch [*Leiopotherapon unicolor*]), one crustacean species (cherabin, *Macrobrachium* spp.) and the freshwater mussel (*Velesunio angasi*) were collected. Muscle tissue as well as liver (if the individual organism was of sufficient size) was analysed in all fish except for *M. splendida*. In *M. splendida* the trunk (the body with the head, tail, fins and gut removed) was analysed. The tail from prawns and tissue with the gut removed from mussels were analysed. Sites where samples were collected are shown in Figure 4.38.

Metals were assessed in freshwater biota during the late dry season in 2016 for the first time, and subsequently in the early and late dry season of 2017. Metals are assessed in environmental indicator species (spangled perch, chequered rainbowfish and bony bream) during the dry season only, while commonly consumed species (barramundi, sooty grunter, archer fish, cherabin and freshwater mussels) are assessed in both the early and late dry season.

Tissues were analysed for 20 metals (nine metals in sooty grunter, barramundi, freshwater mussels and freshwater prawns), As and PbIRs for 207Pb:206Pb and 208Pb:206Pb. Lead isotope ratio testing was undertaken to determine whether freshwater organisms are bioaccumulating mine-derived Pb, which has elevated isotopic ratios compared to the present day crustal average for naturally occurring Pb. This can be used to determine whether Pb is entering the environment as a result of MRM's operations. Due to other areas in the region with naturally elevated PbIRs similar to that of the McArthur River Mine orebody, the McArthur River area is not ideal for using PbIRs to determine sources of contamination. However, using this approach gives a good indication of whether or not mine-derived Pb is entering the system, as long as the results are interpreted cautiously.

The results of these surveys are discussed in the following sections.

Commonly Consumed Species

<u>Late Dry 2016</u>

During the first late dry season assessment (October and November 2016) there were no exceedances of the maximum permitted concentration (MPC) for Pb in commonly consumed fish (0.5 mg/kg) or molluscs (2 mg/kg). The highest concentrations of Pb in fish muscle tissue and liver was from the upstream Robinson River regional reference site recorded in sooty grunter (*Hephaestus fuliginosus*) with mean concentrations of 0.074 mg.kg (muscle) and 0.263 mg/kg (liver), which were below the MPC. Lead isotope data indicated Pb was not related to the McArthur River Mine orebody or mining operations. Single samples from seven-spot archerfish (*Toxotes chatareus*) close to the mine site, at sites SW7 and SW16 (see Figure 4.38), had Pb concentrations in liver of 0.27 and 0.31 mg/kg respectively and PbIRs reflective of the MRM ore. In IPE (2017e) it is theorised that archerfish at these sites may have fed on terrestrial insects that had been exposed to MRM dust, however TAS (2017) reports that dust concentrations along the part of the McArthur River and the McArthur River diversion channel were very low. While insects may accumulate Pb from spending time closer to the processing facilities without further information this theory is unsupported and the source of the Pb remains unknown. Barramundi had Pb muscle concentrations between 0.05 and 0.017 mg/kg and liver concentrations between 0.012 and 0.72 mg/kg.

The highest mean Pb concentration for freshwater mussels (*Velesunio angasi*) was from SW21 (located upstream of MRM operations, see Figure 4.38) with a mean concentration of 1.03 mg/kg. This is almost half the MPC of 2 mg/kg for molluscs, but over twice the mean concentration recorded for freshwater mussels at SW21 in the 2016 early dry season, suggesting potential seasonal accumulation, with this trend also observed at other sites.

Consistent with 2016 early dry season sampling, freshwater mussels were found to have the highest maximum Zn concentrations of any species, with 58 mg/kg recorded from an individual collected from SW21 (upstream of the mine site) in an isolated pool. Mean Zn concentrations were higher at SW21 (50 mg/kg) in comparison to other sites located further from the mine (8 Mile/Merlin, U/S SW8 and U/S Robinson) which all had similar mean Zn concentrations of around 35 mg/kg. Considering the highest individual concentration of 58 mg/kg, an 80 kg adult male could consume 1.12 kg of freshwater mussels (approximately 160 individuals) before exceeding the recommended daily intake for Zn (IPE, 2017e).

Copper concentrations in all commonly consumed species were generally consistent with the early dry season concentrations from previous years and were low (i.e., less than 1.2 mg/kg for fish, 1.86 mg/kg for freshwater mussels and 10.70 mg/kg for cherabin) for all species across all sites.

Early Dry 2017

The commonly consumed species barramundi, sooty grunter, archerfish, cherabin and freshwater mussels were sampled during the 2017 early season surveys.

There were no exceedances of the MPC of 0.50 mg/kg for Pb in commonly consumed fish and crustaceans. The highest mean concentrations of Pb in fish muscle tissue was from the McArthur River catchment (SW3) recorded in archerfish with a mean concentration of 0.045 mg/kg, while the highest mean concentration in liver was from SW19 with a mean concentration of 0.10 mg/kg recorded in sooty grunter. These concentrations of Pb in muscle and liver were well below the MPC of 0.50 mg/kg.

Samples from a number of freshwater mussels collected within the Barney Creek diversion channel (within the mine lease) exceeded the MPC of 2 mg/kg for Pb in molluscs during the 2017 early dry season. Freshwater mussels were collected from SW3 and for the first time from SW20. The highest mean Pb concentration was recorded at SW20 of 10.9 mg/kg followed by SW3 with 9.0 mg/kg, while the highest individual concentration was 17.0 mg/kg at SW20. The PbIRs in freshwater mussels collected from SW3 and SW20 were close to that of the orebody and suggest impacts from MRM operations. The mean Pb concentrations for freshwater mussels in the Limmen, Robinson and Glyde catchment were less than 0.38 mg/kg.

While the concentrations of Pb in freshwater mussels would pose a human health risk if consumed, these exceedances relate to areas that are inaccessible to the public, they occur in very low densities and are unlikely to move to the McArthur River main channel (or other areas that are more accessible to the pubic). Not withstanding this, IPE (2017f) concludes that given high concentrations of Pb (and Al, Mn, Fe and As) have been recorded in freshwater mussels throughout the region, including catchments outside of the influence of the mine site, the intake of freshwater mussels should be limited regardless of where they are found.

Mean Cu concentrations in fish muscle were low (i.e., less than 0.51 mg/kg) and mostly similar between sites within the McArthur River, Limmen and Robinson catchments while mean Cu concentrations in fish livers were more variable.

Mean Zn concentrations in fish muscle ranged from 2.8 to 8.3 mg/kg and were highest in archerfish, particularly in the Barney Creek diversion channel inferred to be a result from anthropogenic activities (IPE, 2017f). Mean Zn concentrations in liver ranged from 11.5 to 28.5 mg/kg and were highest in sooty grunter. Mean concentrations of Zn in freshwater mussels were elevated at three sites (Top Crossing, SW3 and SW20) within the McArthur River catchment, with concentrations of 84, 92 and 205 mg/kg respectively, while they were less than 37 mg/kg for all other sites in both the McArthur River catchment and reference catchments.

Late Dry 2017

The commonly consumed species barramundi, sooty grunter, archerfish, cherabin and freshwater mussels were sampled during the 2017 late dry season survey. There were no exceedances of the MPC of 0.50 mg/kg for Pb in commonly consumed fish or crustaceans.

The highest mean concentrations of Pb in fish muscle tissue during this survey were from the McArthur River catchment at King Ash Bay (downstream of the McArthur River Mine) recorded in barramundi, with a mean concentration of 0.053 mg/kg, followed by 0.018 mg/kg in barramundi at U/S SW8 (see Figure 4.38) and 0.016 mg/kg in archerfish at the Upstream Limmen catchment, with the remaining results less than 0.007 mg/kg. The PbIRs from barramundi muscle tissue from King Ash Bay and U/S SW8 were similar to the McArthur River Mine orebody in the late dry season samples, but dissimilar to the orebody in the early dry season. Furthermore, barramundi collected between these two sites (SW8) and closer to the mine site (SW11 and SW16) had undetectable Pb concentrations in muscle tissue and PbIRs that were dissimilar to the mine orebody. As noted in IPE (2017f), while PbIRs can be a useful tool for assessing potential impacts from MRM's operations, the MRM orebody is known to exist over a large geographical area and extends into regional reference areas including the Wearyan and Limmen Rivers. As such, while useful, detecting a PbIR in aquatic biota which is similar to the MRM orebody, ion its own, this does not provide conclusive evidence of an impact from MRM's operations. In consideration of this information, the higher concentrations of Pb noted in barramundi at King Ash Bay and U/S SW8 in the late dry season are considered unlikely to be related to MRM operations. The highest mean Pb concentration in liver in the late dry season in 2017 was from sooty grunter at SW19 with a mean concentration of 0.055 mg/kg. These concentrations of Pb in muscle and tissue were well below the MPC of 0.50 mg/kg.

One freshwater mussel collected from the remnant section of the original McArthur River channel ('Old McArthur') in the vicinity of SW20 (see Figure 4.38) had a Pb concentration of 4.1 mg/kg, which exceeded the MPC of 2 mg/kg for Pb in molluscs. Concentrations in freshwater mussels collected from SW20 (in the Barney Creek diversion channel) during the early dry season were considerably higher. While all other freshwater mussels collected in the late dry season had Pb concentrations below 2 mg/kg, given the higher concentrations of Pb (and Al, Mn, Fe and As) that have been recorded in freshwater mussels throughout the region, including catchments outside of the influence of the mine site, IPE (2017f) concludes that the intake of freshwater mussels should still be limited regardless of where they're found.

Copper concentrations in fish muscle were low (i.e., less than 0.32 mg/kg) and similar between catchments and species while Cu concentrations in liver were more variable.

Mean Zn concentrations in fish muscle and liver tissue were similar between catchments and species ranging from 2.2 to 6.8 mg/kg for muscle and 13 to 25.5 mg/kg for liver. These results were also consistent with the early dry season. Zinc concentrations in freshwater mussels were similar between U/S SW8 and the Robinson catchment (25 to 28 mg/kg) but notably higher from a single individual collected from Old McArthur with a concentration of 130 mg/kg, the same large individual that also had elevated Pb.

Environmental Indicator Species (Early Dry Season 2017)

For the first time since 2013, no individual environmental indicator species was found to have Pb concentrations above the MPC of 0.5 mg/kg. The highest individual Pb concentration in an environmental indicator species was 0.45 mg/kg from a chequered rainbowfish at SW3. Generally, mean Pb concentrations were higher in chequered rainbowfish and bony bream than in spangled perch which had substantially lower Pb concentrations than the other indicator species. Sites SW3, SW6 and SW19 (within the Barney Creek diversion channel) and SW16 (in the McArthur River diversion channel; see Figure 4.38) had notably higher Pb concentrations in some environmental indicator species compared to the remaining survey sites suggesting an impact from operations close to the mine pit, Barney Creek haul road and the NOEF.

For all environmental indicator species, the samples with the highest concentrations of Pb also had PbIRs which were most similar to the MRM ore body. Although Pb concentrations in environmental indicator species within the Barney Creek diversion channel were consistently higher than those from other sites, a decline in the magnitude of these differences has continued since 2013. For example in 2013, prior to remediation works at SW19 chequered rainbowfish sampled from this site had mean Pb concentrations of 2.16 mg/kg. The decline is thought to be a result of the improved management of inputs into the Barney Creek diversion channel (i.e., sediment and dust), including around SW19 with a reduction in fluvial sediment concentrations also noted (see Section 4.12).

Mean concentrations of Zn and Cu were similar across the different catchments (both McArthur River and regional references) for spangled perch and chequered rainbowfish. While concentrations of Zn and Cu were considered low in bony bream, mean concentrations of Zn from SW19 and SW3 (Barney Creek diversion channel) and the Rockhole opposite the TSF (see Figure 4.38) were around twice that of other sites in the McArthur River and regional reference catchments (i.e., 6.5 to 8.7 mg/kg compared to less than 4.2 mg/kg) with higher Zn sediment loads also noted at these sites (see Section 4.12). Copper concentrations were also higher in bony bream from SW19, SW3 and the Rockhole compared to other sites within the McArthur

River catchment (i.e., 0.64 to 0.78 mg/kg compared to less than 0.28 mg/kg) but were similar to upstream references sites in the Limmen and Robinson catchments (0.64 and 0.68 mg/kg respectively).

Citizen Science Program

In 2016, a number of fish frames were provided to this program by King Ash Bay and Manangoora community members, while none were provided in Borroloola. Unfortunately, sample information tags were not completed for any of the frames deposited and very few frames were provided in the supplied sample bags. In addition to barramundi, many other species were placed in the freezers.

Without specific capture location information or basic correct storage, the results of the program were limited. Five samples from the King Ash Bay freezer for the early dry season and eight from the later dry season were selected for analysis in conjunction with ten sampled from the Manangoora Station. From the samples analysed, no analyte concentrations exceeded applicable MPCs and apart from Zn within muscle tissue, analyte concentrations were comparable to regional data. Zinc concentrations in barramundi from King Ash Bay and Manangoora Station were much higher compared to other sites where barramundi were collected by IPE during the late dry season survey in 2016 (i.e., 10 to 44 mg/kg compared to less than 6 mg/kg). This is however considered to be a result of analysing cheek tissue rather than the usual dorsal tissue. The results of the citizen science program indicated no risk to human health from the consumption of any barramundi analysed.

Metals in Freshwater Biota Survey Conclusions

The results from the late dry season in 2016 and early and late dry season in 2017 indicate that the regular consumption of barramundi, sooty grunter, archer fish and cherabin from the McArthur River catchment (and the Limmen and Robinson catchments) presents a very low risk to human health. Consumption of freshwater mussels should however be limited irrespective of where they are found given high concentrations of Pb (and Al, Mn, Fe and As) have been recorded in freshwater mussels throughout the region, including catchments outside of the influence of the mine site.

The results from the reporting period indicate an improvement in Pb concentrations, with no exceedances of the MPC for environmental indicator species for the first time since 2013. However, freshwater biota found close to the mine site continue to be impacted by MRM operations particularly within the Barney Creek diversion channel (i.e., at SW3, SW6, SW19 and SW20) and at SW16 in the McArthur River diversions channel, although a decline in Pb concentrations has continued at these sites.

Diversion Channel Revegetation

Healthy riparian vegetation is essential for aquatic ecosystem function in the diversion channels. Revegetation along the waterline in the McArthur River diversion channel continues and there are incremental improvements each year. Despite these improvements, the McArthur River diversion channel continues to underperform compared to reference sites, particularly in the middle of the diversion channel where there is very little vegetation. Revegetation along the Barney Creek diversion channel is performing relatively well compared to reference sites, likely due to the lower flow rates and shorter periods of high flow compared to the McArthur River diversion channel. The considerable erosion along both diversion channels makes rehabilitation increasingly difficult (EcOz, 2017, see Section 4.9 for further details).

Riparian vegetation plays a vital role in creating habitat, shading waterways, and reducing flow rates and erosion in the diversion channel, and lack of such vegetation may create a barrier to dispersal of aquatic biota during high flow events and during high water temperatures late in the dry season. Additionally, the lack of in-stream habitat has likely increased predation risk in the McArthur River diversion channel. While there has been improvement in the riparian rehabilitation program, this needs to continue to rehabilitate the diversion channels to the extent possible. McArthur River Mining should continue intensive planting of suitable species along the riparian zone in the early dry season and in patches of sediment deposited around LWD.

Baseflow Measurement Structures

In the 2016 and 2017 OPRs (MRM, 2017; 2018) MRM discusses establishing permanent concrete weir-like structures to measure low flow rates in McArthur River and Barney and Surprise creeks. Depending on the size of these structures, they may prevent fish, including freshwater sawfish, from migrating upstream, or reduce the number of days per year that fish can migrate upstream and therefore reduce connectivity within the catchment. This has the potential to alter fish communities in McArthur River and its tributaries. The potential effects of such structures on freshwater organisms need to be assessed before construction, and mitigated against. If they prevent the movement of fish, fishways may need to be constructed to enable fish passage.

Progress Against IM Recommendations

McArthur River Mining's performance against previous IM review recommendations relating to freshwater ecology issues are outlined in Table 4.46.

Table 4.46 – Freshwater Ecology Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
Assess and mitigate potential ecological impact of flow monitoring infrastructure	McArthur River Mining is planning to construct low flow monitoring stations on McArthur River and Surprise or Barney Creek that would require a concrete weir-like structure. Any structure that acts as a barrier to fish movement has the potential to alter fish communities upstream of the structure. Prior to construction, the potential ecological impacts of such infrastructure should be assessed, and mitigation (e.g., fishways) planned and implemented if required	Ongoing No structures have yet been installed. From discussions had during the site visit in May 2018 these structures may still be considered, but are proposed to target low flow events. The IM was advised that aquatic specialists would be engaged during the design phase. Due consideration of fish passage should still be made
Movement of contaminated biota	A desktop investigation should be undertaken regarding potential movement of contaminated biota in McArthur River and how long biota needs to spend at exposed sites to uptake elevated levels of contaminants	Ongoing Not addressed in the 2017-2018 operational period, however the IM was advised that MRM has engaged IPE to prepare a scope of works for the monitoring of the movement of contaminated biota in the McArthur River. MRM are currently undertaking a cost benefit analysis

Table 4.46 – Freshwater Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Reduce emissions at ROM pad	Additional monitoring of Barney and Surprise creeks in the vicinity of the ROM pad (SW03, SW18) shows that there are elevated levels of Pb in biota from these sites, likely as a result of dust emissions from the mill and associated concentrate stockpiles. McArthur River Mining should investigate ways to reduce dust emissions from this site	Ongoing It is understood that a primary crusher dust suppression system for the ROM Bin is being designed. The IM was also advised that dust monitoring continues to assess impacts from crushing on Barney Creek and that the removal of sediment at SW3 is being investigated
Management of the SEL	McArthur River Mining needs to determine the primary role of the SEL and investigate whether the SEL is adequately designed to meet its purpose, and whether it should be modified so it better fulfils its role either as flood protection or for capturing and containing contaminated water	Ongoing MRM advised that the role of the SEL is not for flood protection but its role is currently uncertain and will depend on the outcomes of the Draft OMP EIS
Identify potential sources of contamination in Barney Creek diversion channel	McArthur River Mining should conduct a full review and synthesis of the monitoring programs, including metals in freshwater fauna, macroinvertebrates, surface water, groundwater, fluvial sediments, dust and soil to identify additional sources of contamination at the mine site. Potential sources may include dust emissions from the haul road and the processing plant and associated stockpiles and seepage from the ROM sump. Legacy impacts should also be addressed If additional sources of contamination are identified, suitable controls can be implemented	Ongoing While there has been some synthesis of data, each individual monitoring program is still largely treated independently and there is little synthesis of the overall monitoring program at McArthur River Mine. Using a conceptual site model could be a useful approach to integrate monitoring programs (NTEPA, 2013). The IM was advised that the water management plan which is being developed will include a review of the freshwater and marine monitoring programs, as well as surface water, groundwater and fluvial sediment programs
Additional monitoring of contaminants along Barney Creek diversion channel	Every effort should be made to monitor contamination in freshwater biota along Barney Creek and the Barney Creek diversion channel between SW22 and the McArthur River diversion channel to assess the extent of contamination. The monitoring should be conducted as quickly as possible following the wet season when creeks still contain water. A flexible method should be utilised that allows collections to be made at sites containing water, rather than only at the designated surface water sites, should the surface water sites not contain water	Completed Additional sites along Barney and Surprise creeks were added to the 2015 and 2016 monitoring programs, and an additional site (SW20) was surveyed between SW19 and SW06 in 2017
Monitoring LWD	McArthur River Mining should continue annual monitoring of LWD to ensure that the wood remains in position and the best method of establishing LWD sites can be determined. McArthur River Mining should commit to additional large-scale projects to install LWD along poorly revegetated sections of the	Ongoing The IM was advised during the 2018 site visit that MRM has started monitoring and documenting the persistence of LWD. During preparation of this report, MRM advised the IM that this has been

Table 4.46 – Freshwater Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Monitoring LWD (cont'd)	diversion channel, to ensure continuity of habitat along the diversion In addition, MRM should consider excavation or blasting of lateral bank and central river bottom in areas of poorest rehabilitation to create eddies. Creating eddy sites would facilitate soil deposition and eventual vegetation establishment to improve freshwater habitat	documented in MRM's Channel Erosion Monitoring Procedure (not sighted) and that monitoring of LWD persistence was undertaken in April 2018 (outside the current reporting period) and will be undertaken annually. This should be reviewed in the next IM report The IM was also advised that excavating or blasting is yet to be considered
Drawdown at Djirrinmini Waterhole	An investigation should be undertaken to determine the ecological impacts (including to freshwater sawfish) of a predicted drawdown of 0.7 m at Djirrinmini Waterhole, and possible mitigation of the impacts	Ongoing The IM was advised that this will be considered in the water management plan
New background Pb isotope ratio	Monitoring would benefit from the establishment of a more regionally relevant background level for Pb isotopes, as for all monitoring sites the average isotopic ratios were closer to the ore body than background levels. Establishing a regionally relevant background isotope ratio would be better for determining whether mine-derived Pb is entering freshwater fauna	Completed

4.10.4.3 Successes

The results from monitoring of the freshwater ecosystem around McArthur River Mine continue to improve yearly. The most positive developments in the current reporting period include:

- Declining levels of contamination in environmental indicator species (including from SW19) likely due to controls implemented by MRM (such as the installation of sediment sumps at SW19 and a berm along the eastern side of the haul road).
- No exceedances of the MPC of 0.5 mg/kg for Pb in environmental indicator species for the first time since 2013.
- No exceedances of the MPC of 0.5 mg/kg for Pb in muscle or liver of commonly consumed finfish species in the current reporting period, including from sites within the mine lease.
- The inclusion of calculated maximum daily consumptions amounts for commonly consumed species in addition to comparisons to MPC in the metals in aquatic fauna reports.
- Continued installation of LWD in the McArthur River diversion channel and the installation of a new ramp to allow improved access to distribute the LWD.
- The addition of small and medium woody debris to the McArthur River diversion channel to improve habitat structure and organic loads in the McArthur River diversion channel.

- Continued development of the acoustic monitoring program of migratory species (freshwater sawfish and barramundi) and the first data download and analysis of fish movements within the McArthur River and diversion channel.
- Improved edge conditions within the Barney Creek diversion channel following wet season flushing and improved bank conditions.

4.10.5 Conclusion

The freshwater fauna survey results continue to demonstrate the influence of wet season rainfall and the duration of river inundation on freshwater biota (i.e., there is lower diversity and abundance when wet season rainfall is below average, and vice versa in wetter years). Ongoing improvements in relation to freshwater ecology include the following:

- Results from monitoring of freshwater biota at McArthur River Mine continue to improve.
- Contamination levels in biota have continued to decline and levels of metals in commonly consumed fish have been demonstrated to present minimal risk to human health.
- The aquatic ecology of the McArthur River diversion channel is performing better as more habitat is provided. The effectiveness of the placement of LWD in the McArthur River diversion channel was demonstrated by the 2017 results with a noted improvement in fish assemblages observed around complex habitats.

Despite these improvements, freshwater biota found within the mine lease continue to be impacted by MRM operations in areas of modified habitat.

The first data set from the acoustic monitoring program provided useful information about the movements of freshwater sawfish and barramundi and indicated that the McArthur River diversion channel provides suitable conditions for the growth and survival of these species. Acoustic monitoring data is however yet to show these species moving downstream through the McArthur River diversion channel and into the McArthur River. Additional acoustic monitoring stations as well as using non-destructive sampling methods could allow for improvements to the program.

Ongoing and new IM recommendations related to freshwater ecology issues are provided in Table 4.47.

Table 4.47 – New and Ongoing Freshwater Ecology Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Assess and mitigate potential ecological impact of flow monitoring infrastructure	McArthur River Mining is planning to construct flow monitoring stations on McArthur River and Surprise or Barney Creek that would require a concrete weir-like structure. Any structure that acts as a barrier to fish movement has the potential to alter fish communities upstream of the structure. Prior to construction, the potential ecological impacts of such infrastructure should be assessed, and mitigation (e.g., fishways) planned and implemented if required	High
Movement of contaminated biota	A desktop investigation should be undertaken regarding potential movement of contaminated biota in McArthur River and how long biota needs to spend at exposed sites to uptake elevated levels of contaminants	Medium

Table 4.47 – New and Ongoing Freshwater Ecology Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Reduce emissions at ROM pad	Additional monitoring of Barney and Surprise creeks in the vicinity of the ROM pad (SW03, SW18) shows that there are elevated levels of Pb in biota from these sites, likely as a result of dust emissions and/or related runoff from the vicinity of the mill and associated concentrate stockpiles. McArthur River Mining should investigate and implement ways to reduce dust emissions and/or contaminated runoff in the vicinity of these sites	High
Management of the SEL	Determine the future role of the SEL as it is currently uncertain and is dependant upon on the outcomes of the OMP EIS	Low
Identify potential sources of contamination in Barney Creek diversion channel	McArthur River Mining should, as part of its forthcoming water management plan, conduct a full review and synthesis of the monitoring programs at McArthur River Mine, including metals in freshwater fauna, macroinvertebrates, surface water, groundwater and fluvial sediments, to identify additional sources of contamination at the mine site. The IM understands that the dust and soil programs will not form part of that document; however, a review of those programs should also be undertaken in relation to potential sources of contamination in Barney Creek diversion channel. Using a conceptual site model could be a useful approach to integrate monitoring programs (NTEPA, 2013). Legacy impacts should also be addressed	Medium
McArthur River diversion channel rehabilitation	McArthur River Mining should consider excavating or blasting of riverbanks and/or the central channel in areas of poorest rehabilitation to create eddies, improve sinuosity, slow flow rates and facilitate soil deposition and eventual vegetation establishment to improve freshwater habitat	Medium
Drawdown at Djirrinmini Waterhole	An investigation should be undertaken to determine the ecological impacts (including to freshwater sawfish) of a predicted drawdown of 0.7 m at Djirrinmini Waterhole, and possible mitigation of the impacts. The outcomes of the investigation should be documented in the water management plan and made available to the IM	Medium
New Items		
Suitability of non-destructive sampling methods for freshwater fauna	Non-destructive sampling methods should be used for barramundi in particular to allow for more individuals to be tagged as part of the tagging/ acoustic monitoring program while still being able to collect samples for metals analysis. This would provide more detailed data on trends over time and in individuals if recaptured while reducing the number of commonly consumed species taken from the study area	Medium
Additional acoustic monitoring stations	The installation of additional receiving stations between the Upper Diversion and Cattle Yard (e.g., SW21 and/or SW07), Lower Diversion and Hidden Pool and the Glyde River would provide more detailed information on movements of freshwater sawfish and barramundi through the MRM lease and McArthur River diversion channel	Medium

4.10.6 References

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4.11 Marine Ecology

4.11.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of the marine ecosystem, and is based on the review of:

- The 2016 and 2017 annual marine monitoring program (AMMP), which covers the monitoring of water, sediment[1] and biota (fish, crustaceans, molluscs and seagrass) in the vicinity of Bing Bong Loading Facility, the mouth of the McArthur River and the Sir Edward Pellew Group of Islands (SEPI) to the east, and to Rosie Creek and Pine Creek to the northwest (Indo-Pacific Environmental (IPE), 2017a; 2018a).
- The 2016 and 2017 annual seagrass surveys, which assess the extent and species composition of seagrass meadows around Bing Bong Loading Facility and regional reference sites (IPE, 2016; 2017b).
- Incident notification letters and correspondence between MRM, regulators and third parties.

These are supplemented by additional monitoring of nearshore sediments, the trans-shipment area sediments and seawater during the operational period, as addressed in Sections 4.12 and 4.3 of this report respectively.

4.11.2 Key Risks

The key risks to marine ecosystems as outlined in the risk register (Appendix 1) are:

- While loading concentrate onto the MV Aburri and from the MV Aburri onto larger transport vessels, dust and spillage may contaminate seawater and sediments in the Bing Bong Loading Facility swing basin, the trans-shipment area and/or surrounding area. Metals in dust and spilled concentrate can bioaccumulate in marine biota, which may have lethal and/or sub-lethal chronic effects on biota.
- Dust migration and surface water runoff from the Bing Bong Loading Facility concentrate storage shed and associated road vehicles may cause contamination of marine sediments and seawater in Bing Bong Loading Facility and surrounding areas, which may contaminate local biota.
- Shipping activities and dredging of the shipping channel increases turbidity, which may lead to the loss of seagrass by reducing light availability and, in turn, reduced photosynthesis. In extreme cases, suspended sediments may smother seagrass and negatively affect seagrass-dependent communities or populations (e.g., fish, dugongs, turtles).
- In the absence of adequate controls for managing dust and surface water, runoff at the McArthur River Mine may lead to contaminated water and sediments washing down McArthur River, potentially resulting in the accumulation of metals in sediments and marine

[1] Sediment monitoring undertaken as part of the AMMP is addressed in Section 4.12 of this report.

biota in the vicinity of SEPI and the mouth of the McArthur River. This may have unknown lethal or sub-lethal/chronic effects on marine fauna.

- Biota that are targeted and eaten by local anglers, such as barramundi (*Lates calcarifer*) or oysters (*Saccostrea spp*.), may be contaminated by Pb, Zn and other metals as a result of MRM's activities. Contaminated biota may be caught and consumed by local fishers, which then has the potential to affect human health.

4.11.3 Controls

4.11.3.1 Previously Reported Controls

Summary

McArthur River Mine has controls in place to minimise the risk to marine biota and undertakes monitoring of marine biota and the marine environment. The controls in place remain largely unchanged from the previous reporting period and include:

- Dust control measures such as covered conveyer belts and transport vehicles, doors on the concentrate shed, a dust extraction system and a vehicle wash-down facility (discussed in more detail in Section 4.13.3).
- Dredge spoil settled in ponds on land to reduce turbidity and contamination from resuspended sediments during dredging.
- Monitoring of the marine environment through the AMMP (IPE, 2017a; 2018a) and annual seagrass surveys (IPE, 2016; 2017b). These are discussed in more detail below.

In addition to the monitoring listed above, MRM also assesses marine sediment and seawater contamination. This includes:

- Annual assessment of metals and Pb isotope ratios of seafloor sediments in the McArthur River Mine trans-shipment area (IPE, 2017c; 2018b).
- Monthly monitoring of seawater contaminants by diffusive gradients in thin films (DGTs) (Tsang, 2017; 2018).

The DGT and marine sediment monitoring programs are discussed further in Sections 4.3 and 4.12 of this report, respectively.

Annual Marine Monitoring Program

The AMMP was established to ensure MRM is meeting its commitments to monitor the environment and operations are not contaminating the Bing Bong Loading Facility and the surrounding area via dust emissions and concentrate spillage while loading and unloading ships.

The aims of the AMMP are to:

- Assess seawater and sediment quality in the vicinity of Bing Bong Loading Facility, the McArthur River estuary and SEPI.

- Quantify impacts to sediment and seawater quality as a result of MRM's operations.
- Determine whether there is contamination of biota as a result of MRM's activities within the vicinity of the Bing Bong Loading Facility.

The AMMP sampling was carried out in December 2016 and November/December 2017 by IPE (2017a; 2018a).

Twenty one sites were sampled in the 2016 monitoring program, which were consistent with the 2015 sampling program. In 2017, 20 sites were sampled, with some new sites added and old sites refined. Marine sediments were sampled at an additional ten sites within the swing basin and shipping channel in 2016 and 2017. Sampling sites are discussed in more detail in Section 4.11.3.2 and shown in Figure 4.39.

Annual Seagrass Monitoring

Seagrass is monitored annually in the vicinity of the Bing Bong Loading Facility between Pine Reef and West Island, to assess changes in seagrass communities (with potential subsequent effects on seagrass-dependent fauna such as dugong (*Dugong dugon*) and fish species). Monitoring aims to:

- Identify and describe broad-scale patterns in the seagrass assemblage structure occurring around the Bing Bong Loading Facility.
- Identify and categorise the relative cover and/or abundance of seagrass (and macroalgae).
- Provide an assessment of spatial and temporal patterns in seagrass assemblages relative to past monitoring results.
- Provide an assessment and comparison of the seagrass assemblages in the broader region with those adjacent to the Bing Bong Loading Facility.
- Identify any key changes in seagrass communities around the Bing Bong Loading Facility and implications for future management of the site.
- Provide recommendations for future monitoring events.

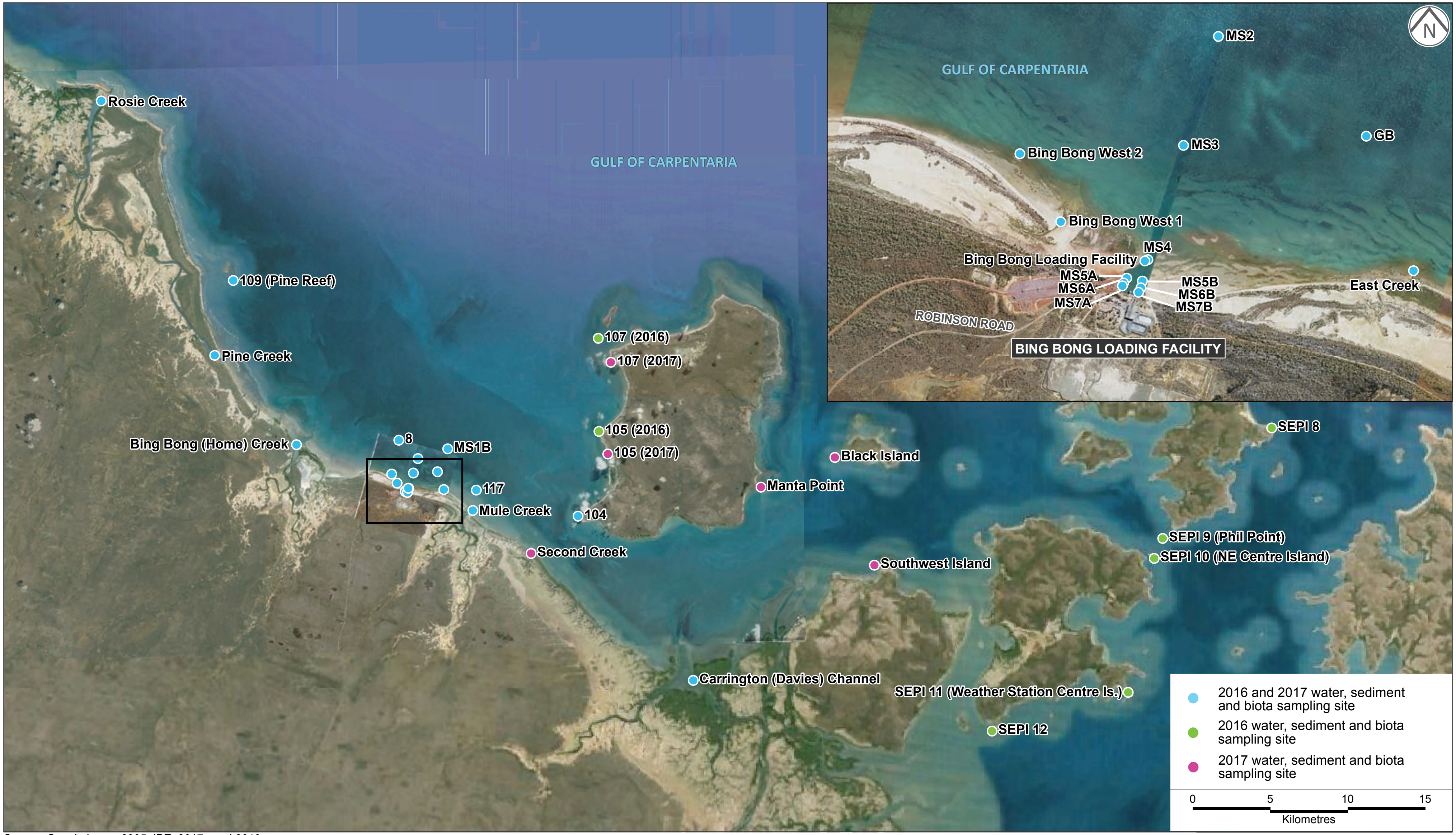
Monitoring of seagrass includes control sites (Sectors 3, 5 and 6) (Figure 4.40) so that the underlying causes of seagrass community dynamics can be better understood (i.e., natural variation, operations at the Bing Bong Loading Facility, or other influences). The control sectors are situated between approximately 7 and 14 km from the Bing Bong Loading Facility.

The annual seagrass surveys were completed in October 2016 and September 2017 with 203 sites sampled, including 95 adjacent to the Bing Bong Loading Facility and 36 sites within each of the three control sectors. Sites adjacent to the Bing Bong Loading Facility and within Sectors 5 and 6 remained unchanged from previous years, while some sites within Sector 3 were refined for the 2017 survey, discussed in Section 4.11.3.2.

SURVEY SITES FOR THE 2016 AND 2017 ANNUAL MARINE MONITORING PROGRAM

McArthur River Mine Project

FIGURE 4.39



Source: Google image 2005; IPE, 2017a and 2018a.

ERIAS Group | 01164F_1_F4-39_v2

LOCATION OF SEAGRASS SURVEY AREAS IN 2016 AND 2017

McArthur River Mine Project

FIGURE 4.40

Source: Google, 2005; IPE, 2016 and 2017b.

ERIAS Group | 01164F_1_F4-40_v2

4.11.3.2 New Controls – Implemented and Planned

The AMMP monitoring sites for water, sediment and biota were refined for the 2017 survey. Sampling of sites around the SEPI, located around 50 km to the east of the Bing Bong Loading Facility, were discontinued in 2017. These sites were added to the program in 2007 in response to the near sinking of a Zn concentrate transfer barge (a Zinifex Limited barge (MV Wunma) based out of Karumba) in the eastern Gulf of Carpentaria in that year, to provide an indication of potential effects on the nearby environment. After 10 years of monitoring, the results indicated that the likelihood of water in the vicinity of the Bing Bong Loading Facility being influenced by this incident was low. Monitoring of sites SEPI 8 to SEPI 12 was therefore discontinued. In place of these, new monitoring sites were added to the east of the Bing Bong Loading Facility at Black Island, Manta Point, South West Island and 2nd Creek (see Figure 4.39). These new sites were considered necessary to monitor potential sources of contaminants. In addition, Site 105, located on the west side of West Island, was moved 1.5 km to the south due to previous difficulties obtaining biota from this site location.

McArthur River Mining has replaced the four smaller roller doors on the concentrate storage shed to reduce dust emissions. The two large roller doors in the centre of the concentrate storage shed where the road trains enter and exit still require replacing and have not been operational since at least June 2015. These were scheduled to be replaced in Q2 2017. It should be noted that the IM was advised that the roller doors would be replaced soon during the 2015, 2016 and 2017 site visits. See Section 4.13.4.2 for further detail.

One of the control sites (Sector 3) in the seagrass monitoring program was slightly realigned in the October 2016 survey to avoid a mobile sandbar and improve its suitability as a control site. While some historical sites were retained, all sites along the mobile sandbar were disregarded and instead additional sites were added seaward, resulting in 36 sample locations arranged in an equally spaced grid with six transects with six sample points per transect. No changes were made to the monitoring program for the 2017 survey.

4.11.4 Review of Environmental Performance

4.11.4.1 Incidents and Non-compliances

Incidents

During the reporting period (October 2016 to March 2018) there were no reported incidents at the Bing Bong Loading Facility with potential to impact marine biota.

During the reporting period several site-specific trigger values (SSTVs) for pH and filtered Al, As, Cu, Mn, Hg and Zn were exceeded at the Bing Bong dredge discharge point (BBDDP), i.e., in the discharge from the dredge spoil settling ponds. Exceedances occurred in January, February, March, April and May in 2017 and January and February in 2018. Exceedances of the site-specific trigger values are provide in Table 4.9 in Section 4.3.4.1. At the BBDDP passive released water flows across the intertidal flats to the Gulf of Carpentaria via the Bing Bong navigation channel.

As already discussed in Section 4.3.4.1 the SSTV exceedances up to and including May 2017 were attributed to increased seepage from the DSEA into the perimeter drain as has been the case with previous exceedances, while no explanation was provided for the more recent exceedances. The IM considers that the risk posed to the receiving environment from the exceedances was minor. See Section 4.3.5 for IM recommendations concerning these exceedances.

There were also exceedances of applicable sediment quality guideline values for Pb and Zn in the swing basin, discussed in more detail in Section 4.12.4.1. Impacts to marine biota from elevated Pb and Zn are considered to be primarily limited to the Bing Bong Loading Facility swing basin and adjacent areas. Impacts would mainly be restricted to sessile species, species of low mobility and individuals of species which have extended residency times in the shipping channel and swing basin.

Although there were exceedances of the applicable ANZECC/ARMCANZ (2000) marine trigger values for unfiltered and filtered Cu and Co in seawater in 2016 and 2017, these were considered within typical background concentrations for the study area and unrelated to MRM's operations. Similarly, exceedances of the Cd MPC for rock oysters were also reflective of elevated background levels in the study area. These exceedances were not considered reportable incidents and are discussed in more detail in Section 4.11.4.2.

Non-compliances

The 2013-2015 MMP (MRM, 2015) does not contain a definitive list of commitments against which to assess non-compliances, however, MRM provided the IM with a compliance register. No non-compliances were identified following a review of the compliance register, however, a summary of the exceedances for metals in biota and seawater as part of the AMMP are discussed in Section 4.11.4.2, while results from the DGT monitoring are discussed in Section 4.3 and sediment results are discussed in Section 4.12.

4.11.4.2 Progress and New Issues

Monitoring of Marine Environment

Seawater Monitoring

The results from the December 2016 monitoring are summarise below:

- There were no exceedances of the ANZECC/ARMCANZ (2000) trigger value of 2.2 µg/L for unfiltered or filtered concentrations of Pb from any sampled sites, although a sample from Rosie Creek (32 km northwest of the Bing Bong Loading Facility and outside of the expected zone of influence) had an unfiltered Pb concentration of 2.1 µg/L (the highest recorded from an AMMP). Filtered concentrations were however less than 0.1 µg/L at this site. Lead concentrations closest to the Bing Bong Loading Facility were similar to those for the rest of the study area.
- A continued decline in unfiltered Pb concentrations at BBW1 from 2014 (1.8 µg/L) to 2016 (0.2 µg/L) was observed, as shown in Table 4.48.
- Consistent with previous years, unfiltered and filtered concentrations of Cu from all samples exceeded the ANZECC/ARMCANZ (2000) trigger value of 0.3 µg/L. All unfiltered and most filtered concentrations exceeded the ANZECC/ARMCANZ (2000) trigger value of 0.005 µg/L

for Co throughout the study area, but are considered within natural background levels of northern Australian waters. Elevated concentrations of Cu at BBW1 and BBW2 are considered within historical values and are not thought to be linked to operations at the Bing Bong Loading Facility (IPE, 2017a).

- Despite exceedances of the ANZECC/ARMCANZ (2000) trigger value for Zn (7 µg/L) at BBW1 and BBW2 in 2014, unfiltered concentrations in 2016 were less than 2 µg/L at these sites. Overall Zn concentration within the study area were similar to previous years.
- Unfiltered Al concentrations at Mule Creek and SEPI 8 were notably higher than in 2015 with concentrations of 130 µg/L and 100 µg/L respectively in comparison to 2015 results of 37 and 40 µg/L respectively, but are considered to be within natural variability. Filtered concentrations of Al remained low in the study area.
- Iron concentrations at BBW1 were similar to the rest of the study area, indicating that residual effects from Western Desert Resources' operations (which ceased in 2014) have likely abated.

Table 4.48 – Summary of Pb and Zn Results from BBW1 and BBW2 2014 to 2017

Metal/Trigger Value* (µg/L)	Sample Type	BBW1				BBW2			
		2014	2015	2016	2017	2014	2015	2016	2017
Pb – 2.2	Filtered	0.2	0.2	0.1	0.3	0.1	<0.1	<0.1	0.90
	Unfiltered	1.8	0.5	0.2	0.9	0.6	0.2	0.7	1.8
Zn – 7	Filtered	3	<1	1	1	1	<1	<1	5
	Unfiltered	**9**	<1	1	2	**8**	<1	2	4

Bold results indicate concentrations exceed the trigger values.
*Trigger values are ANZECC/ARMCANZ (2000) for 99% species protection in marine waters.

The results from the November/December 2017 monitoring are summarise below:

- There were no exceedances of the ANZECC/ARMCANZ (2000) trigger value of 2.2 µg/L for unfiltered or filtered concentrations of Pb from any sampled sites. Lead in both filtered and unfiltered samples from BBW1 and BBW2 did however increase notably from 2016 (see Table 4.48). With respect to unfiltered concentrations, there was a slight increase at BBW1 in 2017 and a more notable increase at BBW2 with a concentration of 1.8 µg/L in 2017 (see Table 4.48). Given the proximity of BBW1 and BBW2 to the Bing Bong Loading Facility and their location (i.e., to the west and in the direction of net current movement) elevated Pb at these sites could be a result of MRM operations. However, this is uncertain given that concentrations were higher at BBW2 which is further from the loading facility and considering the elevated levels at other sites beyond the expected influence of MRM operations. The IM recommends including PbIRs for water samples collected from sites close to the Bing Bong Loading Facility to provide further clarification as to the potential source of Pb at these sites.
- Filtered concentrations of Pb were also notably higher at Rosie Creek, Pine Reef, Pine Creek and Site GB in 2017 in comparison to previous years. Consistent with the 2016 results, the highest unfiltered Pb concentration was from Rosie Creek (1.9 µg/L). Given the distance from the Bing Bong Loading Facility it is unlikely this is related to MRM operations, particularly

given concentrations decrease moving southeast towards Bing Bong Loading Facility, and more likely a reflection of natural variation. These results illustrate the constraints in assessing potential impacts from MRM operations at the Bing Bong Loading Facility in comparison to naturally elevated Pb levels within the broader study area.

- Consistent with previous years, unfiltered and filtered concentrations of Cu from all samples were equal to, or exceeded, the ANZECC/ARMCANZ (2000) trigger value of 0.3 µg/L. All unfiltered and the majority of filtered concentrations exceeded the ANZECC/ARMCANZ (2000) trigger value of 0.005 µg/L for Co throughout the study area but are considered within natural background levels of northern Australian waters. While Cu was slightly elevated at BBW1 and BBW2 with unfiltered concentrations of 1.0 and 0.9 µg/L respectively and filtered concentrations of 1.0 and 0.7 µg/L respectively, concentrations at these sites were comparable to historical results throughout the AMMP and are unlikely to indicate impacts from operations at Bing Bong Loading Facility. Unfiltered Cu concentrations were highest at Mule creek (1.3 µg/L) with concentrations in previous years around 0.6 µg/L; however, the filtered concentration of 0.6 µg/L was comparable to previous years and other survey sites.

- Both filtered and unfiltered concentrations of Zn were mostly similar to results from 2016 with all results below the ANZECC/ARMCANZ (2000) trigger value of 7 µg/L. The highest unfiltered concentration was 4 µg/L from BBW2 and Rosie Creek. The highest filtered concentration was 5 µg/L from BBW2, which was a notable increase from less than 1 µg/L in 2016. A comparable increase was also noted at Rosie Creek, which is considered outside the potential area affected by operations at Bing Bong Loading Facility. Given no increase was noted at BBW1 (located closer to the Bing Bong Loading Facility) or at the Bing Bong Loading Facility itself, natural variation or localised variation most likely explains the 2017 results.

- Unfiltered Al concentrations continued to increase at Mule Creek with a concentration of 390 µg/L, in comparison to 130 µg/L in 2016 and 37 µg/L in 2015, while filtered concentrations were below 5 µg/L for all sites.

- Generally filtered concentrations of Al, Mn, Ni and Cd were comparable between sites and to 2016 results as was the case for unfiltered concentrations of Cd, Ni and Mn. Manganese concentrations did however increase to some degree at all sites northwest of the Bing Bong Loading Facility.

- Iron concentrations were higher at a number of sites in 2017 in comparison to 2016 in particular at Pine Reef, BBW1, BBW2 and Mule Creek, which is thought to be related to either increased runoff or the resuspension of Fe contained in sediment within the vicinity of the Wester Desert Resources facility (where large volumes of iron ore remain).

Marine Biota

The biota assessed for potential contamination in the current reporting period were:

- Barramundi (*Lates calcarifer*).

- Giant queenfish (*Scomberoides commersonnianus*).

- Bluetail mullet (*Valamugil buchanani*).
- Giant mud crab (*Scylla serrata*).
- Rock oyster (*Saccostrea spp.*).
- A snail (*Terebralia semistriata*).
- A snail (*Telescopium telescopium*).
- Seagrass (*Halodule uninervis*) (2016 only).
- Mud mussel *Polymesoda* spp. (2017 only).

Although assessed in previous years, metals in the seagrass species *H. uninervis* were not assessed in 2017. There was considered to be little benefit to continuing this monitoring, given that:

- Concentrations of Pb and Zn within *H. uninervis* in particular have been found to be derived from natural sources.
- Seagrass diversity and abundance is monitored separately on an annual basis, and this is most likely to provide a better indication of impacts to seagrass communities than monitoring of metals within seagrass species.

For ease of interpretation, this report will refer to species by their common name, except for the snails, which will be referred to by their genera (*Terebralia* and *Telescopium*). A summary of the 2016 and 2017 AMMP results is provided below.

In 2016 there were no exceedances of any applicable maximum permitted concentration (MPC) from 349 tissue samples taken from seven species, while in 2017 the MPC for Cd of 2 mg/kg was met in rock oysters collected from Site 105 and was exceeded in a single sample from Black Island, with a concentration of 2.4 mg/kg. Given Site 105 and Black Island are located about 11 and 28 km northeast of the Bing Bong Loading Facility respectively, the fact there were no other exceedances of Cd at closer sites, and historical results, it is highly unlikely these elevated Cd levels were due to MRM operations. Additionally, Cd concentrations within biota do not appear to be linked directly to sediment or water, but rather potentially a biotic component such as algae, which is accumulated by filter feeding biota such as rock oysters. There were no other exceedances of applicable MPCs in 2017 from the 405 tissue samples analysed.

In both 2016 and 2017 the highest concentration of Pb was found in rock oysters from within the Bing Bong Loading Facility, with a mean concentrations of 0.226 mg/kg in both years, which was slightly lower than the mean of 0.272 mg/kg in 2015 (Table 4.49). Although well below the MPC of 2 mg/kg for molluscs, mean Pb concentrations in rock oysters continued to be substantially higher than those found throughout the remainder of the survey area, indicating impacts from MRM operations. Both the molluscs *Terebralia* and *Telescopium* also had elevated mean Pb concentrations at the Bing Bong Loading Facility in 2016 and 2017 in comparison to other survey areas. However, similar results were recorded between these years and a notable decline was observed in 2016 compared to 2015 (Table 4.49). In 2016 and 2017, mean Pb concentrations in giant mud crabs were considered low throughout the study area with most results less than 0.01 mg/kg. Specimens from the Bing Bong Loading Facility had particularly low concentrations (less than 0.008 mg/kg). Mean Pb levels in bluetail mullet were less than 0.032 mg/kg in 2016 and 2017 for all sites, with Pb isotope ratios dissimilar to that of the MRM orebody.

Table 4.49 – Mean Total Concentrations of Pb and Zn in Rock Oysters and Barramundi at Bing Bong Loading Facility 2015 to 2017

Species	Metal	Mean Total Concentration (mg/kg)		
		2015	2016	2017
Rock oysters (*Sacostrea* spp.)	Pb	0.272	0.226	0.226
	Zn	876	622	876
Barramundi (*Lates calcarifer*)	Pb (muscle)	NA	0.170	0.002
	Pb (liver)	NA	0.168	0.012
	Zn (muscle)	NA	4.0	2.3
	Zn (liver)	NA	36.7	30.7
Telescopium	Pb	0.238	0.051	0.105
	Zn	12.0	12.8	15.0
Terebralia	Pb	0.504	0.054	0.079
	Zn	22.0	11.8	12.6

NA no data available.

In regards to commonly consumed species in the region, barramundi from the Bing Bong Loading Facility had mean Pb muscle concentrations of 0.170 mg/kg and 0.002 mg/kg in 2016 and 2017 respectively (see Table 4.49), with one individual in 2016 recording a Pb concentration of 0.49 mg/kg, just below the MPC of 0.50 mg/kg. Two other individuals collected from the same site, however, had Pb concentrations of 0.016 and 0.003 mg/kg. The Pb isotope ratios from barramundi collected from the Bing Bong Loading Facility in 2016 were very close to that of the mine orebody, suggesting impacts from MRM operations. The mean Pb concentrations in barramundi recorded at the Bing Bong Loading Facility in 2017 were the lowest to date, with Pb isotope ratios more dissimilar to the MRM ore body compared to 2016. Giant queenfish, a highly mobile but also commonly consumed species, had very low muscle and liver Pb concentrations in both 2016 and 2017, including individuals from the Bing Bong Loading Facility.

Rock oysters from the Bing Bong Loading Facility had the highest concentrations of Zn of all sampled species and of all sites within the study area in both 2016 and 2017. While a decline was noted in 2016 an increase was noted in 2017, with a mean concentration equal to that of 2015 (876 mg/kg) (see Table 4.49). Concentrations in rock oysters from the Bing Bong Loading Facility in 2016 and 2017 were substantially higher than from other sites in the study area. Zinc concentrations for giant mud crabs and fish were similar between sites and between years (2016 and 2017), ranging from 26 to 81 mg/kg for crabs and 2.3 and 7.4 mg/kg (muscle) for fish.

In 2016 and 2017, Cu concentrations were highest in rock oysters from Site 107 (about 13 km northeast of the Bing Bong Loading Facility), with mean concentrations of 64.8 mg/kg. In 2017 concentrations were highest in rock oysters from the Bing Bong Loading Facility with a mean of 44.0 mg/kg, similar to mean concentrations found elsewhere in the study area, including Site 104 and Pine Reef, located around 7 and 14 km from the Bing Bong Loading Facility respectively.

Overall, results from Pb isotope analyses show similar trends from 2015 to 2017, indicating that operations are having a measurable impact on sessile biota and those with low mobility within 700 m of the Bing Bong Loading Facility. Operations do not appear to be affecting biota to the east of the Bing Bong Loading Facility.

From the perspective of safe consumption levels of marine fauna from the study area, naturally derived Cd has been shown to be the key metal on which to base safe consumption levels of rock oysters for all sites, except for Bing Bong Loading Facility where Zn is the limiting metal. Based on the calculations provided in IPE (2017a; 2018a) only a small number of rock oysters taken from most sites within the study area would be required to exceed the recommended daily consumption amounts:

- From sites near West Island, the recommended rock oyster consumption limit for a 74 kg male is three per day, due to Cd levels.
- From Bing Bong Loading Facility, the recommended rock oyster consumption limit is five per day for a 74 kg male, or two per day for a 36 kg child, due to Zn levels.

Based on these findings, the consumption of rock oysters across the study area should be limited, predominantly due to naturally derived concentrations of Cd.

Annual Marine Monitoring Program Conclusion

While a decline in Pb in seawater was noted from 2015 to 2016 at BBW1, concentrations increased in 2017. This is of some concern and may indicate impacts from MRM operations, however, there is uncertainty in this regard as Pb continues to be elevated at sites beyond the expected influence of MRM operations and the expected concentration gradients were not observed.

While there were no exceedances of the MPCs for biota in 2016, a single barramundi collected from the Bing Bong Loading Facility (off the wharf) had a muscle tissue concentration of 0.49 mg/kg just below the MPC of 0.50 mg/kg, although two other specimens were collected from the area and had muscle tissue concentrations below 0.017 mg/kg. Despite this, all three barramundi had Pb isotope ratios extremely close to that of the MRM orebody. These results indicate that MRM operations are likely impacting barramundi within the Bing Bong Loading Facility. In contrast, results in 2017 from three barramundi sampled from the Bing Bong Loading Facility had the lowest concentrations of Pb to date and Pb isotope ratios further from the orebody in comparison to 2016. The monitoring program would benefit from gaining a better understanding of contaminant uptake pathways, timeframes and dispersal, as previously recommended (ERIAS Group, 2017). In particular as discussed in IPE (2017a; 2018a), the use of a tagging program and non-destructive sampling techniques (should they be proved effective) would aid in addressing this data gap.

While in 2017 there were exceedances of the MPC for Cd in rock oysters from two sites beyond the expected influence of MRM operations, this finding is consistent with those of previous years which have found naturally occurring Cd to be a key analyte of concern for the study area with respect to safe consumption limits.

Overall, the 2016 and 2017 AMMPs combined with evidence from the annual monitoring of nearshore sediment and monthly DGT monitoring of metals in seawater in the Bing Bong Loading Facility swing basin (discussed in Sections 4.12 and 4.3, respectively) demonstrate that the measurable impacts from MRM operations are limited to biota and sediments from sites within 700 m of the loading facility, beyond which there is no measureable impact on the environment.

Seagrass Monitoring Program

Although conducted in October 2016 and within the current reporting period, the results of the 2016 seagrass monitoring are discussed in the 2017 IM report (ERIAS Group, 2017). In summary, a slight decline in seagrass density was observed, attributable to the shift from pioneer species (*Halophila ovalis* and *Halodule uninervis*) to colonising species (*Syringodium isoetifolium* and *Cymodocea serrulata*) that form less dense meadows, and an increase in macroalgae cover across all sectors in 2016.

Qualitative analysis indicates seagrass coverage remained very high in 2017, with seagrass present at 99% of monitoring sites near the Bing Bong Loading Facility (Table 4.50). Seagrass coverage at control sites at Sectors 3, 5 and 6 also remained high, with seagrass present at 89% in Sector 3 and all sites in Sectors 5 and 6. Four seagrass species were identified throughout all sectors in the study area (*Halophila ovalis, Halodule uninervis, C. serrulata, S. isoetifolium*) while in Sector 6, *Halophila spinulosa* was also recorded.

Table 4.50 – Seagrass Coverage Adjacent to Bing Bong Loading Facility (2011 to 2017) and at Control Sites (2012 to 2017) (%)

Seagrass Coverage	2011	2012	2013	2014	2015	2016	2017
Bing Bong Loading Facility							
Bare substrate	1	1	3	1	1	1	1
Very sparse	0	0	5	2	5	16	11
Sparse	12	52	44	21	23	29	9
Moderate	54	44	51	55	53	47	57
Dense	27	3	8	17	13	4	20
Very dense	6	0	0	4	4	2	2
Sites with seagrass	99	99	97	99	99	99	99
*Sector 3**							
Bare substrate	NA	57	26	14	27	14	11
Very sparse	NA	0	33	31	15	22	8
Sparse	NA	6.	10	28	15	42	0
Moderate	NA	17	31	28	37	19	50
Dense	NA	13	0	0	7	3	14
Very dense	NA	6	0	0	0	0	17
Sites with seagrass	NA	43	74	86	73	86	89
Sector 5(cont'd)*							
Bare substrate	NA	NA	NA	0	0	0	0
Very sparse	NA	NA	NA	11	11	6	3
Sparse	NA	NA	NA	6	22	6	8
Moderate	NA	NA	NA	58	31	53	39
Dense	NA	NA	NA	25	25	36	44

Table 4.50 – Seagrass Coverage Adjacent to Bing Bong Loading Facility (2011 to 2017) and at Control Sites (2012 to 2017) (%) (cont'd)

Seagrass Coverage	2011	2012	2013	2014	2015	2016	2017
Sector 5(cont'd)*							
Very dense	NA	NA	NA	0	11	0	6
Sites with seagrass	NA	NA	NA	100	100	100	100
*Sector 6**							
Bare substrate	NA	NA	NA	NA	0	3	0
Very sparse	NA	NA	NA	NA	19	8	0
Sparse	NA	NA	NA	NA	6	22	3
Moderate	NA	NA	NA	NA	50	58	11
Dense	NA	NA	NA	NA	25	8	69
Very dense	NA	NA	NA	NA	0	0	17
Sites with seagrass	NA	NA	NA	NA	100	97	100

NA no data available.
*Control sites. Data from sectors 3 and 4 was first collected in 2012, from sector 5 in 2014 and sector 6 in 2015.

The quantitative approach (Table 4.51) shows seagrass coverage has continued to increase at all sites since records began in 2013[2]. Between 2016 and 2017 seagrass coverage increased overall at the Bing Bong Loading Facility, Sector 3 and Sector 6 with average increases of 39, 27 and 27% respectively, while at Sector 5 a slight decrease in seagrass coverage was noted for three of the six transects with an average overall decrease of 4% coverage for the sector. This slight decrease is likely caused by an increase in macroalgae cover in some transects, with a slight overall average increase from 8% macroalgae cover in 2016 to 12% in 2017 (Table 4.52). Macroalgae at the Bing Bong Loading Facility, Sector 3 and Sector 6 decreased by an average of 14, 5 and 12% respectively in 2017 compared to 2016 (Table 4.52).

Table 4.51 – Percentage Cover of Seagrass and Change in Cover at Bing Bong Loading Facility and Control Sites from 2013 to 2017 (%)

Transect	Percentage Cover of Seagrass					% Change in Cover	
	2013	2014	2015	2016	2017	2013-2017	2016-2017
Bing Bong Loading Facility							
1	45	43	61	42	63	18	21
2	24	38	68	29	61	37	32
3	28	42	17	29	77	49	48
4	39	58	35	43	48	9	5
5	50	55	56	56	63	13	7
6	27	63	82	57	43	16	-14
7	40	82	43	58	49	9	-9
8	34	63	47	60	60	26	0
9	54	68	44	49	61	7	12

[2] Monitoring of seagrasses adjacent to the Bing Bong Loading Facility was initiated in 1994 by the Commonwealth Scientific and Industrial Research Organisation and later by MRM in 2003, with IPE engaged by MRM in 2013 to undertake annual quantitative monitoring of seagrass.

Table 4.51 – Percentage Cover of Seagrass and Change in Cover at Bing Bong Loading Facility and Control Sites from 2013 to 2017 (%) (cont'd)

Transect	Percentage Cover of Seagrass					% Change in Cover	
	2013	2014	2015	2016	2017	2013-2017	2016-2017
Bing Bong Loading Facility (cont'd)							
10	43	55	55	36	58	15	22
11	31	63	60	40	43	12	3
12	42	48	43	57	59	17	2
Average	38	57	51	47	56	18	9
Sector 3†*							
2	32	38	57	47	88	56	41
3	43	53	71	73	92	49	19
4	16	18	24	33	49	33	16
5	19	30	41	37	79	60	42
6	17	5	22	12	41	24	29
7	0	28	17	37	55	55	18
Average	22	28	40	40	67	45	27
*Sector 5**							
1	NA	64	24	47	51	-13#	4
2	NA	67	31	67	61	-6#	-6
3	NA	60	47	85	86	26#	1
4	NA	48	65	84	87	39#	3
5	NA	43	76	71	67	24#	-4
6	NA	39	61	91	68	53#	-23
Average	NA	53	51	74	70	17#	-4
*Sector 6**							
1	NA	NA	47	69	76	29**	7
2	NA	NA	44	57	92	48**	35
3	NA	NA	53	53	90	37**	37
4	NA	NA	46	55	89	43**	34
5	NA	NA	45	64	87	42**	23
6	NA	NA	63	55	80	17**	25
Average	NA	NA	50	59	86	36**	27

NA no data available.
* Control sites.
# Comparison between 2014 and 2017, not 2013 and 2017.
† Two transects could not be sampled in Sector 3 due to the presence of a mobile sandbar.
** Comparison between 2015 and 2017, not 2013 and 2017.

Table 4.52 – Comparison of Mean Percentage Cover of Macroalgae by Sector 2015 to 2017 (%)

Sector	2015	2016	2017	% Change in Cover 2016-2017
Bing Bong Loading Facility	17	42	28	-14
Sector 3	3	9	4	-5
Sector 5	5	8	12	4
Sector 6	4	15	3	-12

Consistent with 2016, *Syringodium isoetifolium* was the dominant seagrass species at the Bing Bong Loading Facility and Sectors 3, 5 and 6, and was also widespread within these sectors (Table 4.53). Notably at Sector 3, *S. isoetifolium* increased in dominance from 39% in 2016 to 66% in 2017 while the dominance of *Halophila ovalis* and *Halodule uninervis* have continued to decline.

Table 4.53 – Percentage of Sites Where Seagrass Species Were Recorded in the Shipping Channel and Control Sectors (%)

Seagrass Species	2011	2012	2013	2014	2015	2016	2017
Bing Bong Loading Facility							
Halophila ovalis	68	60	83	99	78	38	16
Halodule uninervis	92	94	92	97	89	78	25
Cymodocea serrulata	5	6	10	22	13	27	22
Syringodium isoetifolium	31	16	24	45	56	92	91
Thalassia hemprichii	4	0	0	0	0	0	0
Sector 3*							
Halophila ovalis	-	36	46	67	61	64	47
Halodule uninervis	-	34	56	42	37	78	58
Cymodocea serrulata	-	0	8	17	10	31	42
Syringodium isoetifolium	-	15	26	22	22	53	81
Sector 5*							
Halophila ovalis	-	-	-	100	78	25	14
Halodule uninervis	NA	NA	NA	81	92	67	11
Cymodocea serrulata	NA	NA	NA	11	22	39	50
Syringodium isoetifolium	NA	NA	NA	33	78	92	89
Sector 6*							
Halophila ovalis	NA	NA	NA	NA	81	58	25
Halodule uninervis	NA	NA	NA	NA	94	69	17
Cymodocea serrulata	NA	NA	NA	NA	22	44	50
Syringodium isoetifolium	NA	NA	NA	NA	42	86	92
Halophila spinulosa	NA	NA	NA	NA	14	25	8

NA no data available.
*Control sites. Data from Sector 3 was first collected in 2012, from Sector 5 in 2014 and sector 6 in 2015.

Seagrass cover, density and diversity continue to improve throughout the region, as seagrass meadows recover and undergo natural successional changes following Cyclone Grant in 2011. Cyclones are a major disturbance to seagrass communities, and play an important role in shaping seagrass communities in northern Australia (Roelofs et al., 2005).

Overall changes observed within the Bing Bong Loading Facility sector are consistent with the other sectors, with the continued succession of seagrass species away from the pioneer species *Halophila ovalis* and *Halodule uninervis,* towards colonising species *S. isoetifolium* and *C. serrulata.* An increase in seagrass coverage and decrease in macroalgae coverage was observed across most sectors in 2017 when compared to 2016. Overall, the 2017 results indicate that operations at the Bing Bong Loading Facility are not having a measurable impact on seagrass communities.

Progress

McArthur River Mining's performance against previous IM review recommendations relating to marine ecology issues is outlined in Table 4.54.

Table 4.54 – Marine Ecology Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
Contaminant uptake and dispersal in biota	As barramundi with elevated, mine-derived Pb were caught in the Bing Bong Loading Facility shipping channel, and a single fish with elevated, mine-derived Pb may have moved away from the loading facility, a report should be prepared covering the available literature on: ♦ The time it takes for a measurable contaminant load to be taken up in mobile species (e.g., barramundi, giant queenfish, mud crab, blue-tailed mullet) ♦ Sources of contamination in these species – are contaminants absorbed by consuming contaminated prey species and/or merely by persisting in the Bing Bong Loading Facility swing basin? ♦ Likelihood of dispersal in these species and potential dispersal distances	Ongoing Not addressed in the 2016 and 2017 AMMPs. The 2016 and 2017 AMMPs indicate that the approach is being discussed which may include an acoustic monitoring array, a tagging program and non-destructive sampling techniques
New DGT monitoring sites	As seawater from BBW1 had elevated levels of contaminants in 2015, the IM suggests establishing DGT monitoring stations at BBW1 and 2, if feasible, to determine fine-scale patterns of contamination at these sites	Completed Option assessed and deemed not feasible as BBW1 and BBW2 are located in the intertidal zone
Inclusion of long-term datasets in reports	♦ As the DGT monitoring program has been running since 2013, long-term datasets should be included in the report so consistent patterns and inconsistencies can be more easily identified	Completed Long-term datasets were included in the most recent AMMPs, seagrass, nearshore sediment monitoring and DGT reports
Timing of dredging	Do not dredge during rain events to ensure that particulate matter will have enough time to settle out before flowing out of the dredge spoil ponds. Dredging only in the dry season would be preferable, as there will be minimal chance of intense rain	Ongoing No dredging was undertaken during the reviewed reporting period
Consistent timing of water samples	Coastal water samples should consistently be taken just before low tide to show the potential maximum concentration of contaminants in seawater at a survey site	Ongoing No information regarding the timing of water sample collection provided in the 2016 and 2017 AMMP reports, however MRM advised that most coastal sites in are sampled at low tide due to

Table 4.54 – Marine Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Consistent timing of water samples (cont'd)		ease of safe access at this part of the tide cycle
Inclusion of macroalgal cover in seagrass monitoring at all sites	Macroalgae cover is increasing in seagrass meadows around Bing Bong Loading Facility and may be excluding seagrass at some sites. The monitoring program needs to include macroalgal cover at all sites, rather than just Bing Bong Loading Facility and Sector 6, so the processes driving seagrass cover and density can be better understood and quantified	Completed Macroalgae cover was quantified and included in the 2016 and 2017 AMMP for all sectors, with results also included from 2015. Macroalgae cover should continue to be quantified in future AMMPs
Identify cause of macroalgal cover	A desktop study should be conducted to identify the potential cause of increased macroalgal cover to ensure the increase in macroalgae is due to natural processes, such as succession, rather than anthropogenic impacts, such as eutrophication	Completed Although the desktop study was not undertaken, however macroalgae cover declined in most sectors in 2017 suggesting the increase noted in 2016 was most likely due to natural processes. Macroalgae should continue to be monitored and quantified in all sectors

4.11.4.3 Successes

In the 2016 to 2018 reporting period, successes relating to marine ecology have included:

- No exceedances of the ANZECC/ARMCANZ (2000) trigger value for unfiltered or filtered concentrations of Pb or Zn from any sampled sites.
- No exceedances in 2016 of any applicable MPCs, including for Pb, from 349 tissue samples taken from seven different species as part of the AMMP.
- Only one exceedance in 2017 of applicable MPCs and one result equal to an MPC from 405 tissue samples taken from eight different species, with the two elevated results probably being related to naturally derived concentrations of Cd at sites far removed from the Bing Bong Loading Facility operations.
- The refinement of the seagrass monitoring program in 2016, with seagrass sampling sites modified within Sector 3 in 2016 to address historical issues caused by a moving sandbar.
- The refinement of monitoring sites for the AMMP in 2017, with sites around SEPI discontinued and instead additional sites to the east of the Bing Bong Loading Facility added to better understand sources of contaminants in the study area.
- The quantification of macroalgal cover in all sectors for the first time in the 2016 and 2017 reports, which allowed for useful comparisons of short-term trends between years and sectors.

- The collection of barramundi for metal analysis proved more successful in 2016 and 2017 compared to 2015 and allowed for more meaningful comparisons of metal concentrations between the Bing Bong Loading Facility and other locations within the study area. The results of the 2016 survey in particular illustrated the need to continue to target this species, despite the effort required to obtain specimens and the variability noted between individuals.

4.11.5 Conclusion

Overall, impacts to the marine environment at the Bing Bong Loading Facility are almost exclusively restricted to the shipping channel, swing basin and the tidal flat area immediately west of the facility. The impacts to biota in these areas are mainly restricted to sessile species, species of low mobility and individuals of species which have extended residency times in the shipping channel and swing basin (e.g., barramundi). These groups of biota have been found to have higher Zn and Pb levels compared to biota collected from other sites away from the Bing Bong Loading Facility, and at times have had Pb isotope ratios extremely close to that of the MRM orebody.

Where metal concentrations were detected in biota, they were below applicable MPCs, except for Cd in rock oysters from two sites in 2017, located at some distance from the Bing Bong Loading Facility, but elevated concentrations did not appear to be due to MRM's operations. Cadmium levels in rock oysters continue to be elevated within the study area and (with the exception of the Bing Bong Loading Facility) are the limiting element from which safe consumption limits should be based, which can be exceeded by consuming as few as three or four individuals. Within the Bing Bong Loading Facility however, Zn continues to be the limiting contaminant.

At the Bing Bong Loading Facility, while concentrations of Pb and Zn decreased in some biota in 2016 and 2017 (notably in *Terebralia* and *Telescopium*), Zn concentrations in rock oysters increased from 2016 to 2017, returning to more elevated 2015 levels. While this is of some concern, the results do not necessarily indicate impacts from MRM operations and monitoring should be ongoing to assist in identifying the source.

Seagrass communities continue to show successional change and an overall decrease in macroalgae cover in 2017, with operations at the Bing Bong Loading Facility having no measurable impact.

Ongoing and new IM recommendations related to marine ecology issues are provided in Table 4.55.

Table 4.55 – New and Ongoing Marine Ecology Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Timing of dredging	Do not dredge during rain events to ensure that particulate matter will have enough time to settle out before flowing out of the dredge spoil ponds. Dredging only in the dry season would be preferable, as there will be minimal chance of intense rain	Low

Table 4.55 – New and Ongoing Marine Ecology Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Contaminant uptake and dispersal in biota	As fish with elevated, mine-derived Pb have previously been caught in the Bing Bong Loading Facility shipping channel and such fish may move away from the facility, the following should be investigated: ♦ The time it takes for a measurable contaminant load to be taken up in mobile species (e.g., barramundi, giant queenfish, mud crab, blue-tailed mullet) ♦ Sources of contamination in these species – are contaminants absorbed by consuming contaminated prey species and/or merely by persisting in the swing basin? ♦ Likelihood of dispersal in these species and potential dispersal distances As discussed in IPE (2017a; 2018a) this recommendation could be addressed by a tagging program, acoustic arrays and non-destructive sampling methods	Medium
New Items		
Increased habitat for rock oysters at Bing Bong Loading Facility	As highlighted in IPE (2017a) and previous AMMP reports, there are limited remaining rock oysters at the Bing Bong Loading Facility occurring on natural rock for future sample collection. As such, increasing habitat available for settlement should be explored and implemented soon to allow sufficient time for settlement and growth of sufficient individuals to ensure rock oysters can continue to be sampled from Bing Bong Loading Facility, particularly given their effectiveness as environmental indicator species	Medium
Suitability of non-destructive sampling methods for marine fauna	Non-destructive sampling methods should be used for barramundi in particular to allow for a tagging program to be implemented while still being able to collect samples for metals analysis. This would provide more detailed data on trends over time and in individuals if recaptured, particularly given the high variability in concentrations within individuals of the same species from the same location	Medium
Seagrass survey report	Continue to include long-term data sets in the data tables (while the 2016 report included data from 2013 to 2016, the 2017 report presented data from 2015 only)	Low
AMMP report	Provide information regarding the timing of collecting coastal water samples. A table showing the time the sample was collected and the corresponding tide level would be useful to demonstrate this previous IM recommendation is being addressed. Add detail about timing of sampling to the methods section	Medium
PbIRs for marine water	Include PbIR analyses for marine water samples for sites closest to the Bing Bong Loading Facility as well as reference sites Rosie Creek, Pine Creek and Pine Reef to provide further lines of evidence to demonstrate whether elevated Pb concentrations are from MRM operations or other sources	High

4.11.6 References

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IPE. 2017b. Annual Seagrass Survey of the Bing Bong Loading Facility 2017. Prepared by Indo-Pacific Environmental for McArthur River Mining Pty Ltd, Winnellie, NT.

IPE. 2017c. Assessment of Metals and Lead Isotope Ratios of Seafloor Sediments in the McArthur River Mine Transhipment Area, December 2016. Prepared by Indo-Pacific Environmental for McArthur River Mining Pty Ltd, Winnellie, NT.

IPE. 2018a. Annual Marine Monitoring Program McArthur River Mine, December 2017. Prepared by Indo-Pacific Environmental for McArthur River Mining Pty Ltd, Winnellie, NT.

IPE. 2018b. Assessment of Metals and Lead Isotope Ratios of Seafloor Sediments in the McArthur River Transhipment Area, November 2017. Prepared by Indo-Pacific Environmental for McArthur River Mining Pty Ltd, Winnellie, NT.

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Tsang, J. J. 2018. Monitoring the Concentrations of Bioavailable Metals and Lead Isotope Rations in Seawater by Diffusive Gradients in Thin Films Deployed Around Bing Bong Loading Facility: Review of 2016-2017 Data. Report Prepared by the Australian Institute of Marine Science for McArthur River Mining Pty Ltd, Winnellie, NT.

4.12 Soil and Sediment Quality

4.12.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of soil and sediment quality, and is based on review of:

- Observations and discussions with MRM personnel during the site inspection in May 2018.
- Various reports prepared by MRM and its consultants, with particular reference to:
  - McArthur River Mining's 2016-2017 operational performance report (OPR) (1 June 2016 to 31 May 2017) (MRM, 2017a) and 2017-2018 OPR (1 June 2017 to 31 March 2018) (MRM, 2018a).
  - Reports addressing part or all of the 2017-2018 operational period with regards to soil monitoring (TAS, 2017a; 2018) and fluvial sediment monitoring (ELA, 2017)[1].
  - Reports addressing part or all of the 2017-2018 operational period with regards to marine sediments, including annual marine monitoring, nearshore sediments and trans-shipment sediments (IPE; 2017a; 2017b; 2018a; 2018b; 2018c).
- Responses by MRM to recommendations raised in the previous IM report.

4.12.2 Key Risks

The risk assessment undertaken to support the review identified a number of key risks concerning soils, fluvial sediments and marine sediments (see Appendix 1). These remain largely as described in last year's IM report and are summarised below.

Soils

The main causes of soil contamination at the mine site and Bing Bong Loading Facility are:

- Direct and localised contamination of soil from depositional dust generated by operational activities including:
  - Mining and processing operations, primarily from the OEFs, haul roads, TSF, ore crushing plant, ROM pad and external concentrate storage area at the mine site.
  - Barge loading and other materials handling tasks at Bing Bong Loading Facility and, to a lesser extent, placement of dredge spoil in the dredge spoil emplacement area.
- Groundwater seepage 'daylighting' on the ground surface.
- Other activities associated with mining operations and/or processing or transport of mine-derived materials resulting in, for example, spillages.

[1] Due to persistent flows in the rivers and creeks, MRM was unable to safely sample fluvial sediments during the June 2017 to March 2018 reporting period, and hence a fluvial sediment report was not appended to the 2017-2018 OPR (MRM, 2018a).

In addition to affecting soil quality, soil contamination may:

- Impact on the health of native vegetation and/or pasture, which can have adverse impacts on terrestrial fauna and/or livestock.
- Contribute to poor water quality (pH, salts, trace metals) in adjacent surface waters and increase the costs of mine closure. As noted previously (Section 4.3.2), this can have adverse impacts on aquatic or marine flora/fauna and, potentially, human or animal health via bioaccumulation.

Fluvial Sediments

As for surface water, a number of related risks have been recognised in terms of fluvial sediment quality at the mine site:

- Poor quality seepage and surface runoff, primarily from areas such as the TSF and NOEF, may result in poor sediment quality in Surprise Creek and Barney Creek diversion channel and, ultimately, in McArthur River. The environmental impacts are as described in relation to surface water quality at McArthur River Mine (Section 4.3). Changes in water quality in McArthur River due to the possible influence of the Cooley deposits and oxidising pyritic shale that is intercepted by the McArthur River diversion channel also requires consideration in terms of potential impacts on fluvial sediments.
- Dust generated by mining and processing operations may deposit directly into watercourses or may contaminate soil, thereby contributing to poor quality surface runoff. These processes may cause poor water quality (pH, salts, trace metals) in Surprise Creek, Barney Creek or McArthur River diversion channels, and/or McArthur River below the mine site. The environmental impacts are as described for surface water quality risks (Section 4.3).

Marine Sediments

Risks associated with marine sediment are as described in terms of water quality risks in the marine environment:

- Contamination of bed sediments in the nearshore environment by poor quality surface runoff (which has been contaminated by depositional dust generated by loading operations and/or dredge spoil). This can have adverse impacts on aquatic and marine flora/fauna and, potentially, human health or marine animal health via bioaccumulation.
- Contamination of bed sediments in the nearshore and offshore environments as a result of concentrate spillages or direct dust deposition during barge loading or trans-shipment also affecting coastal or marine water quality, with resulting adverse impacts as described above.

Additional risks are also as previously described:

- Acidic leachate from acid sulfate soils.
- Contamination in the vicinity of the Sir Edward Pellew Group of Islands and/or the McArthur River estuary from MRM upstream mine activities or Bing Bong Loading Facility operations.

4.12.3 Controls

4.12.3.1 Previously Reported Controls

Soils

General Controls

In terms of the main sources of contaminants that can affect soils, existing controls are discussed in the relevant sections that address:

- Surface water management (Section 4.3).
- Materials management and generation of contaminated dust (Section 4.13).

An additional soil contamination control implemented at the mine site and at the Bing Bong Loading Facility is the removal and stockpiling of topsoil prior to undertaking activities that may result in soil contamination.

Monitoring Program

The MRM surface soil monitoring program has been undertaken annually since 2008. As noted in MRM (2015a), the aim of this program is to provide a health and environmental risk assessment of soil strata to which people and other receptors could feasibly be exposed. The specific objectives of the surface soil monitoring program are to:

- Assist in identifying potential sources of impacts from mining operations and activities associated with the Bing Bong Loading Facility.
- Assess soil metal and physicochemical properties, provide accurate assessment of soil contamination, and identify trends that may be occurring.
- Provide data to complement the current dust monitoring program.

The most recent soil monitoring reports for the mine and loading facility (TAS, 2017a; 2018) describe the aim of the program more narrowly, i.e.:

> …to measure the concentration of contaminants in the soil surrounding the operational areas of McArthur River Mine and the Bing Bong loading facility. Soil contaminants occur both naturally and due to the transport of dust generated from the mining activity… [measurement of contaminants in soils] can provide a measure of the effectiveness of the current dust controls utilised at the operations.

The IM notes that this definition is focused on dust-derived soil contamination, and does not take into account other potential sources of impacts on soils as noted in Section 4.12.2.

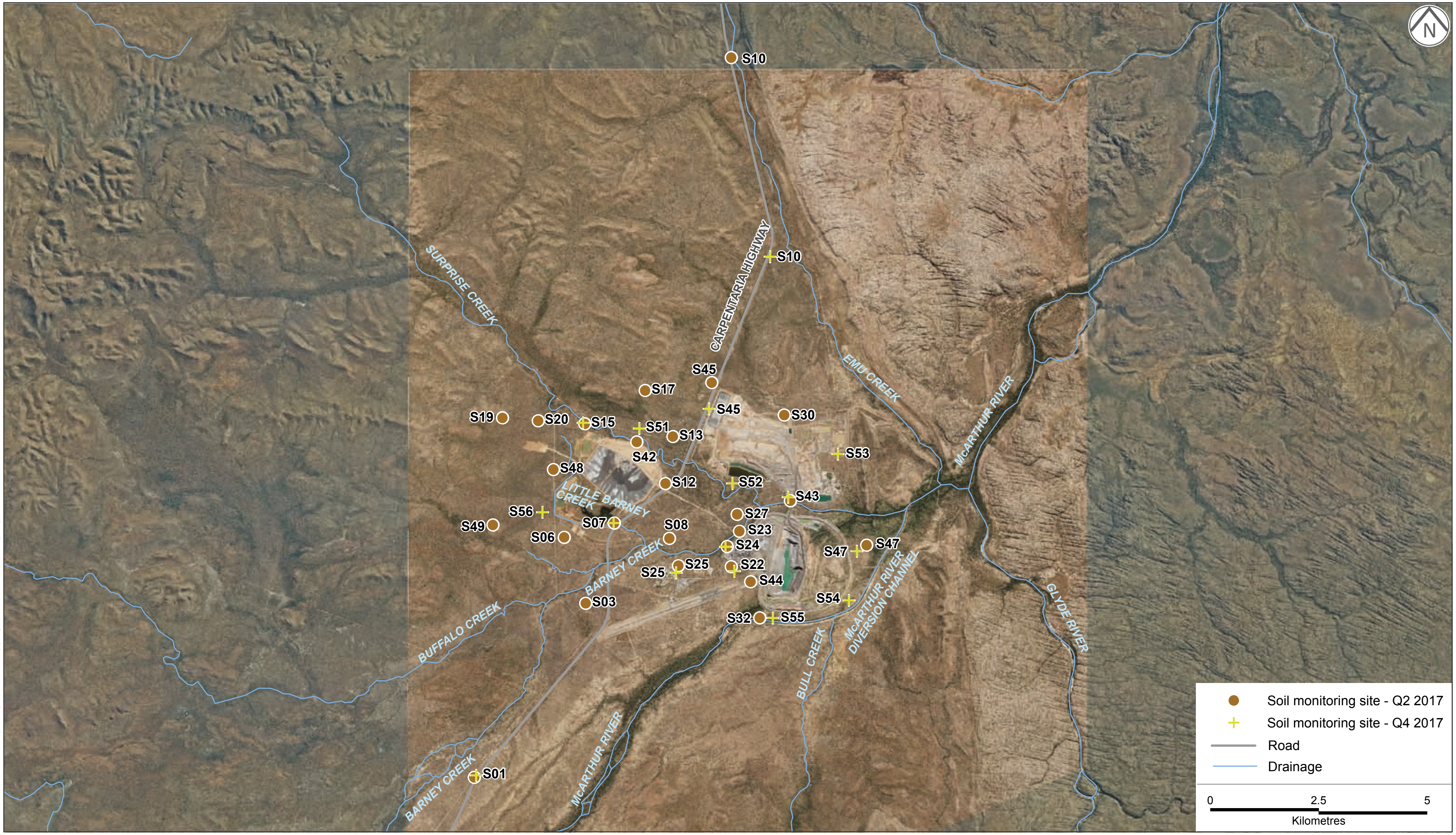
The key elements of the surface soil monitoring program include:

- Sampling sites as shown in Figure 4.41 (McArthur River Mine) and Figure 4.42 (Bing Bong Loading Facility) for the 2017-2018 operational period:

SOIL MONITORING SITES AT McARTHUR RIVER MINE IN Q2 AND Q4, 2017

McArthur River Mine Project

FIGURE 4.41



Source: TAS, 2017a and 2018

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SOIL MONITORING SITES AT BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.42

Source: TAS, 2017a and 2018.

ERIAS Group | 01164F_1_F4-42_v2

  - Sampling sites at the mine site are reported (TAS, 2017a; 2018) in terms of control sites and impact sites. Data is also presented graphically in terms of distance from main dust point sources.
  - Soil sampling at Bing Bong Loading Facility included two sites in the dredge spoil emplacement area, as well as four sites near the Bing Bong Loading Facility concentrate shed/loading conveyor and swing basin.
- Sampling soils on an annual basis during the dry season. During the 2017-2018 operational period, soil sampling was undertaken in April/May (Q2) 2017 and in October (Q4) 2017 (TAS, 2017a; 2018). In most instances, surface soil monitoring sites correspond to 'dust mini vol' (DMV) monitoring sites, which are sampled as part of the separate dust/air quality monitoring program (Section 4.13).
- Sampling of both surface soils (1 to 10 cm depth) and subsoils (40 to 50 cm depth), during the Q2 2017 sampling event (TAS, 2017a) and earlier events. Sampling undertaken in Q4 2017 included only surface soils (TAS, 2018), with no explanation provided for the removal of subsoil sampling from the program.
- Laboratory testing including pH and EC (paste), cation exchange capacity, major ions and trace metals.
- Assessment of soil quality results by comparison with the National Environmental Protection (Assessment of Site Contamination) Measure 1999 (the NEPM), as amended in 2013 (NEPC, 2013). Sample analysis results have been compared with health investigation levels (HILs), as well as ecological investigation levels (EILs) where these exist, so as to provide a more conservative assessment than would be the case using HILs for all sample results.

Fluvial Sediments

General Controls

In terms of the main sources of contaminants that can affect fluvial sediments, existing controls are discussed in the relevant sections that address:

- Surface water management (Section 4.3).
- Materials management and generation of contaminated dust (Section 4.13).

As indicated in Figure 4.43, additional controls that are specific to fluvial sediments (and reducing input of contaminated sediment) near Barney Creek haul road bridge include:

- Sediment sumps to the northwest, southeast and southwest of the bridge[2]. Recent upgrades to these structures are described in Section 4.12.3.2 – New Controls.

[2] The Barney Creek haul road bridge is oriented north–south, while the Barney Creek diversion channel at this point flows from west to east.

SEDIMENT CONTROL STRUCTURES NEAR BARNEY CREEK HAUL ROAD BRIDGE

McArthur River Mine Project

FIGURE 4.43

ERIAS GROUP

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- Northeast of the bridge – a berm along the eastern side of the haul road that is maintained to direct runoff across the bridge towards the southeast sediment basin. This, combined with the topography of this quadrant, minimises sediment runoff towards the diversion channel. Recent works in this area are described in Section 4.12.3.2 – New Controls.
- Immediately downstream of the bridge at FS19/SW19 – a bund/small dam constructed within the Barney Creek diversion channel during the 2014 operational year to capture contaminated water and sediment (although flow still occurs to varying degrees in all but the driest months).

Monitoring Program

As noted in MRM (2015a), the purpose of the fluvial sediment monitoring program is to assess potential sediment-associated pollutant fluxes in McArthur River and its tributaries close to the mine site.

The specific objectives of the program are to:

- Identify potential variations in physicochemical parameters of river and creek sediments in the survey area.
- Provide information regarding long-term trends in water quality through sediment sample analysis.
- Allow contaminated runoff – should this occur – to be traced.

Objectives of the program are further specified by ELA (2017) as being 'to identify potential impacts to water quality and sediment in the receiving environment due to current mining operations', and to:

- Identify sediments where contaminant concentrations are likely to cause adverse effects on sediment ecological health and potentially cause impact to sensitive receptors.
- Identify sediments with the potential for remobilisation of contaminants in the water column and/or into the aquatic food chains.
- Establish a measure of background fluvial sediment quality to create appropriate benchmarks for ongoing monitoring criteria, followed by assessment of current fluvial sediment data against baseline data and/or site-specific trigger guidelines to identify potential exceedances.
- Identify the potential sources of pollutants detected in contaminated bed sediments.

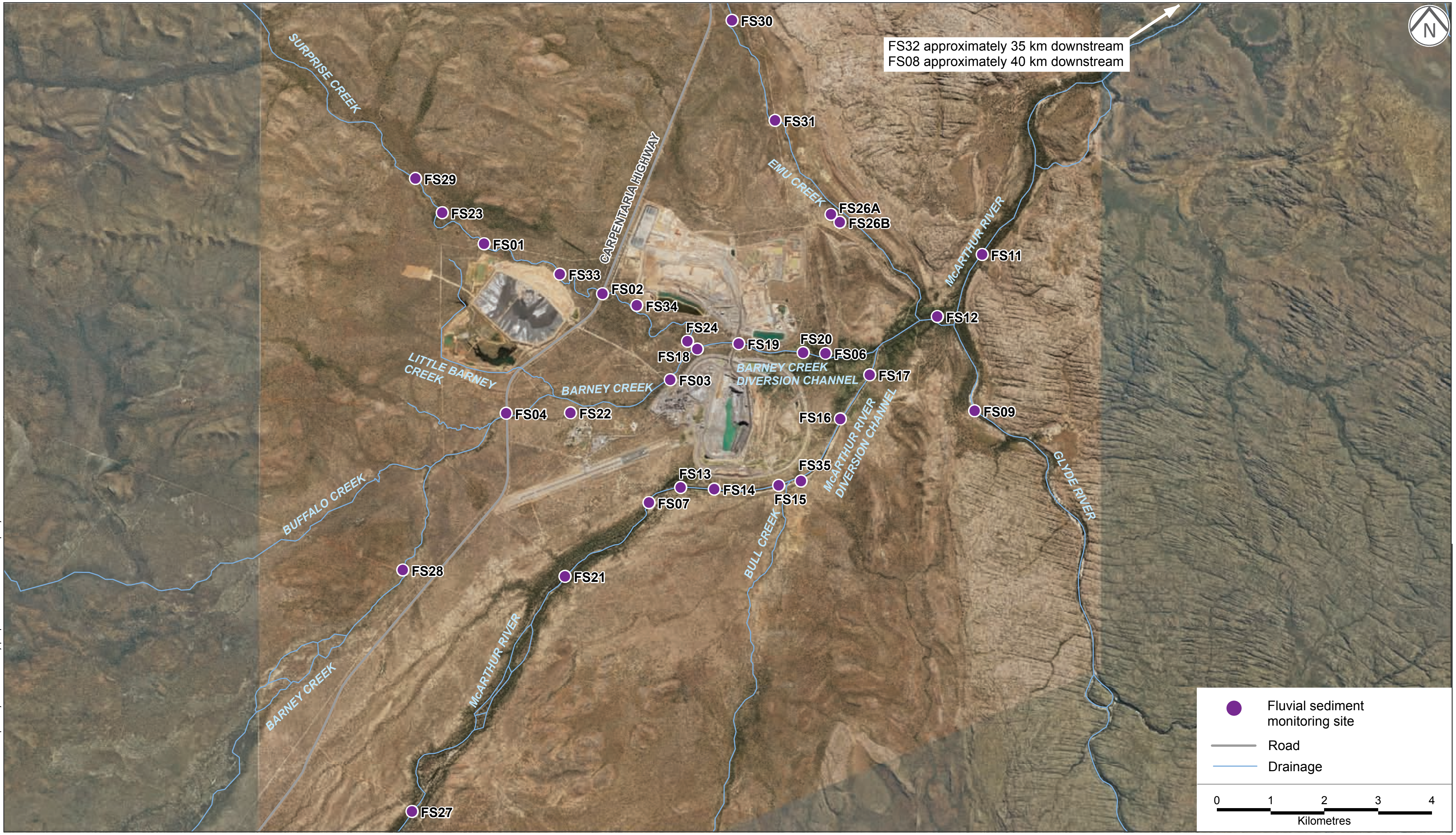
The key elements of the program include:

- Fluvial sediment sampling sites as shown in Figure 4.44 for the 2017-2018 operational period. These are in the same locations as the natural surface water sampling sites (see Figure 4.3).

FLUVIAL SEDIMENT MONITORING SITES AT McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.44



Source: ELA, 2017.

ERIAS Group | 01164F_1_F4-44_v2

- Sampling annually in the early dry season (in the 2017-2018 operational period, this occurred in April 2017, i.e., on only one occasion due to high flows preventing safe access towards the end of the reporting period).

- Laboratory testing including pH and EC (paste), particle size distribution, major ions, Pb isotope ratios, and metals analysis on the <63 μm fraction (analysed separately after both weak acid (1M HCl) digestion and strong acid (i.e., 'near total'/four-acid: HNO_3/$HClO_4$/HF/HCl) digestion).

Assessment of the data obtained from fluvial sediment sampling in the 2017-2018 operational period involved comparison with Simpson and Batley's (2016) sediment quality guidelines. The sediment quality guideline values (SQGVs) represent concentrations below which the frequency of adverse biological effects is expected to be low, while SQG-high values represent concentrations above which adverse biological effects are expected to be more likely to occur. Simpson and Batley (2016) supersedes Simpson et al. (2013), but the guideline values applicable to parameters monitored by MRM have not changed (although it should be noted that Simpson and Batley (2016) use the terms SQGV and SQGV-high rather than SQG-low and SQG-high as used in the 2017-2018 OPR (MRM, 2018a).

Marine Sediments

General Controls

In terms of the main sources of contaminants that can affect marine sediments, existing controls are discussed in the relevant sections that address:

- Surface water management (Section 4.3).

- Materials management and generation of contaminated dust (Section 4.13).

Monitoring Program

The aim of the marine sediment monitoring program is to assess impacts and manage risks of activities at Bing Bong Loading Facility with regards to the local marine environment. The specific objectives of the program are to (MRM, 2015a):

- Determine the sediment characteristics and chemistry of the receiving environment.

- Assess the impact of loading facility operations on the receiving environment, and determine if any detected impact is acceptable or unacceptable.

- Provide data to guide management decisions.

- Complete statutory monitoring and monitor compliance in accordance with requirements of the waste discharge licence.

The key elements of the program include:

- Seasonal marine sediment sampling events during the operational period, as part of:

  - The annual marine monitoring program (AMMP) undertaken in December 2016 (IPE, 2017a) and November/December 2017 (IPE, 2018a), with sampling sites as shown in Figure 4.39.
  - The nearshore sediment assessment undertaken in September 2017 (IPE, 2018b), with sampling sites as shown in Figure 4.45.
  - The trans-shipment area seafloor sediment assessment, undertaken in December 2016 (IPE, 2017b) and November 2017 (IPE, 2018c), with sampling sites as per Figure 4.46.
- Analysis of Pb isotope ratios in marine sediments as part of both the AMMP and trans-shipment area assessments.
- Analysis of metals in marine sediment for the three programs as follows:
  - For 2016 AMMP samples, analysis of trace metals was undertaken in both the <2 mm fraction (after strong acid (HCl/HNO_3) digestion) and the <63 μm fraction (analysed separately after weak acid (1M HCl) digestion). For 2017 AMMP samples, only analysis of the <63 μm fraction (after weak acid digestion) was undertaken. This change is discussed in Section 4.12.4.2 – Progress and New Issues.
  - As with the AMMP, 2016 trans-shipment area seafloor sediment samples were analysed for trace metals in both the <2 mm fraction (after strong acid digestion) and the <63 μm fraction (analysed separately after weak acid digestion). For 2017 trans-shipment area samples, only analysis of the <63 μm fraction (after weak acid digestion) was undertaken. This change to the analysis suite is discussed in Section 4.12.4.2.
  - The nearshore sediment assessment analysed trace metals in the <63 μm fraction (after weak acid digestion).

Data obtained from the three marine sediment sampling programs during the 2017-2018 operational period has been assessed against the Simpson et al. (2013) sediment quality guidelines. As noted in the fluvial sediment discussion above, Simpson et al. (2013) has now been superseded by Simpson and Batley (2016). Although the guideline values applicable to parameters monitored by MRM have not changed, the current document should be referred to in future marine sediment assessment reports.

4.12.3.2 New or Changed Controls – Implemented and Planned

Soils

There were no changes to the Bing Bong loading facility soil monitoring sites during the reporting period, although as mentioned above under Soils – Monitoring Program, subsoil sampling ceased at both Bing Bong loading facility and the mine site after the Q2 2017 sampling period.

At the mine site, two soils sampling sites – S02 and S28 – were removed from the program between 2016 and Q2 2017. While 26 soil sampling sites were included in the Q2 2017 program, this was reduced to 15 sites in Q4 2017. This was intended to simplify the program alongside changes to the dust monitoring program, in accordance with MRM's recent air quality

NEARSHORE SEDIMENT ASSESSMENT SAMPLING SITES

McArthur River Mine Project

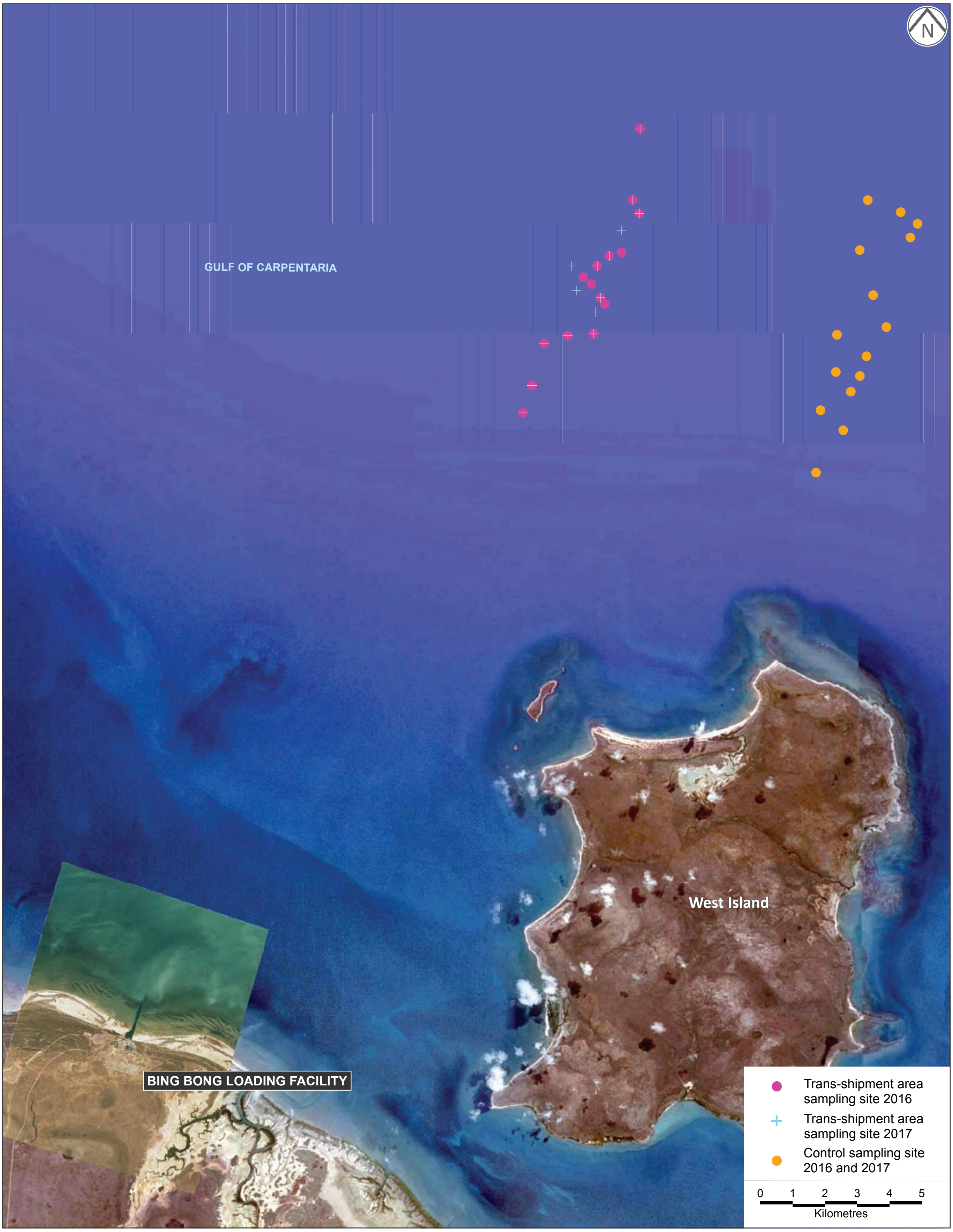
FIGURE 4.45

Source: IPE, 2018b.

TRANS-SHIPMENT AREA SAMPLING SITES IN 2016 AND 2017

McArthur River Mine Project

FIGURE 4.46



Source: Google, 2015; IPE, 2017b and 2018c.

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management planning (TAS, 2018). This is discussed under Section 4.12.4.2 – New and Evolving Issues. New or changed surface soil controls in the 2017-2018 operational period included the following, detailed in Table 4.56 and discussed further in Section 4.12.4.2:

- In response to previous IM recommendations, an additional surface soil monitoring site (S49) was established for the Q2 2017 sampling program, near the location of the decommissioned site S05 (see Figure 4.41). This site was not sampled in Q4 2017, but a new site S56 was established approximately 1.25 km to the east, closer to the water management dam.
- Control site S10 was moved approximately 4.5 km to the south of its former location in the Q4 2017 sampling program (to coincide with air quality monitoring sites DMV10, DDG10, TEOM03 and Van).
- Sites S45 and S47 were moved shorter distances (although still hundreds of metres), while sites S32 and S42 were replaced by new sites close to the original locations. Three new sites were established, while 13 sites were removed without replacement (see Table 4.56).

Table 4.56 – Soil Monitoring Site Changes from Q2 to Q4 2017

Apr/May 2017 Site No.	Oct 2017 Site No.	Location/Comment
Removed Sites (No Nearby Replacements)		
S03	Nil	No nearby replacements
S08		
S12		
S13		
S17		
S19		
S20		
S23		
S27		
S30		
S33		
S44		
S48		
Changed and New Sites		
S06; S49	New site S56	S06 and S49 were to the south and west-southwest (respectively) of the WMD; new site S56 indirectly replaces both, closer to southwest of WMD
S10	Moved S10	S10 moved approx. 4.5 km south of former location
S32	New site S55	To south of pit near McArthur River diversion channel, S55 replaces S32
S42	New site S51	To north of TSF near Surprise Creek, S51 replaces S42
S45	Moved S45	S45 moved approx. 500 m south of former location
S47	Moved S47	S47 moved approx. 200 m to southeast
Nil	New site S52	New site to south of SPROD
Nil	New site S53	New site to east of TSF
Nil	New site S54	New site to east-southeast of pit near McArthur River diversion channel

Fluvial Sediments

New fluvial sediment controls at the mine site during the operational period were as follows:

- Additional fluvial sediment monitoring sites established in 2017 included FS33 (on Surprise Creek, adjacent to Cell 1 of the TSF), FS34 (on Surprise Creek, downstream of the Carpentaria Highway crossing and upstream of SPROD, near the NOEF) and FS35 (Bull Creek near the junction with the McArthur River diversion channel).

- While not new controls as such, fluvial sediment sampling was reinstated at sites FS14, FS15 and FS17, all within the McArthur River diversion channel.

- To the northwest of FS19, the MIA (Mine Infrastructure Area) sump (see Figure 4.43) was under construction during the 2017 and 2018 site visits. This new sump is designed to capture sediment and contaminated runoff from adjacent haul roads, and particularly the roads to the south/southwest of the NOEF. It is designed for a 1-in-10 year 36-hour rainfall event (MRM, 2017b) and is expected to reduce inputs to the existing sediment sump northwest of the haul road bridge. The MIA sump has been constructed with a compacted clay liner and an HDPE liner. While construction of the sump itself was completed during 2017, completion of the associated inlet culvert and drainage works is expected during the 2018 dry season (i.e., before November 2018).

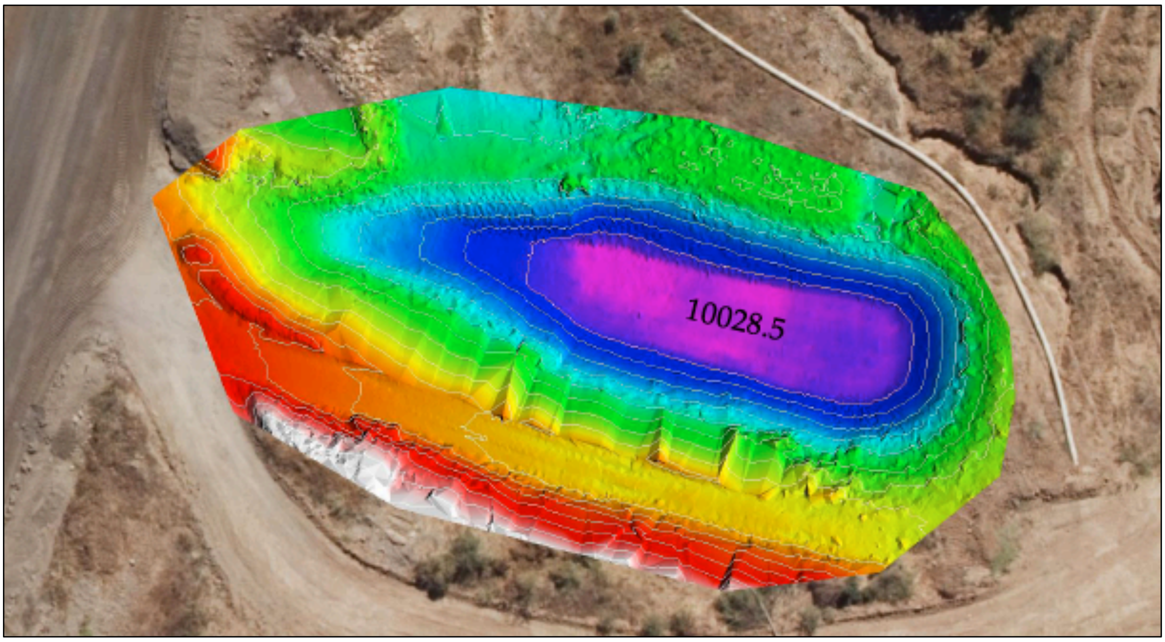
- Sediment containment structures to the northwest (NW), southwest (SW) and southeast (SE) of Barney Creek haul road bridge, along with water diversion structures to the northeast of the bridge, were assessed and upgraded during 2017 (MRM, 2018b), as follows (see Figure 4.43):

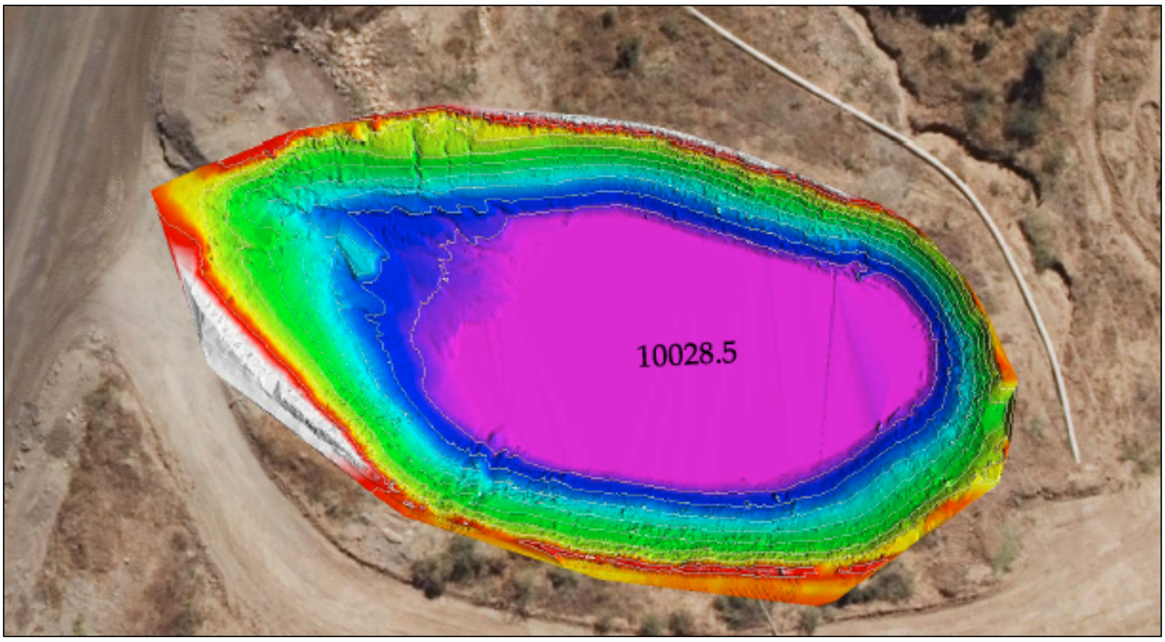
  - Catchments and water flows (including both clean water and impacted/contaminated flows) were assessed in relation to the three sumps. Since scupper holes in the bridge have been closed, the SW and SE sumps have larger catchments including runoff from the bridge decks and approaching slopes to the north of the bridge. Excluding clean water inputs and assuming that the new MIA sump captures runoff from haul road segments further to the north and west, the NW, SE and SW sumps now have catchments of 0.7 ha, 1.5 ha, and 0.9 ha, respectively.

  - It was identified that that 'significant amounts of clean water enters the NW and the SE sumps, and thus limits the available sump capacity for impacted water'. Based on this assessment, it was deemed critical that the surrounding landscape be reshaped to avoid clean water reporting to the sumps, thus minimising overflow.

  - Based on the above assessment, SE sump was expanded towards the south to meet the increased capacity requirement (Plate 4.12). Land to the south of SE sump was filled/raised, and the sump bunded, with a drain to divert clean runoff directly to Barney Creek diversion channel. The sump spillway was moved from the north to the east to reduce erosion/stability risks from floodwaters.

Plate 4.12 – Upgrades to Haul Road Bridge Southeast Sump (Before/After)





Source: MRM (2018b)

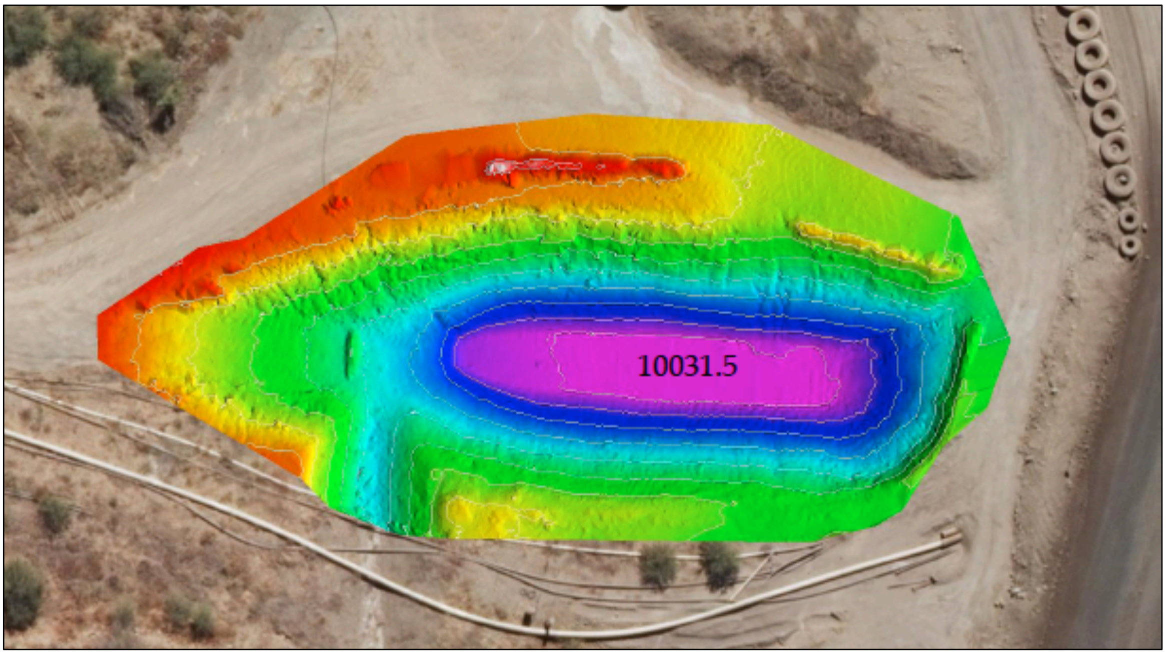
- The SW sump was deepened and expanded towards the west (Plate 4.13).
- Works were undertaken to prevent clean runoff from entering NW sump. The sump was expanded to the north (Plate 4.14).
- The upgraded sumps are designed to have capacity for up to 1-in-10 year floods.
- Following construction of new sump pumps/electrical infrastructure to the northeast of the bridge, the associated new access point had potential to divert impacted runoff from

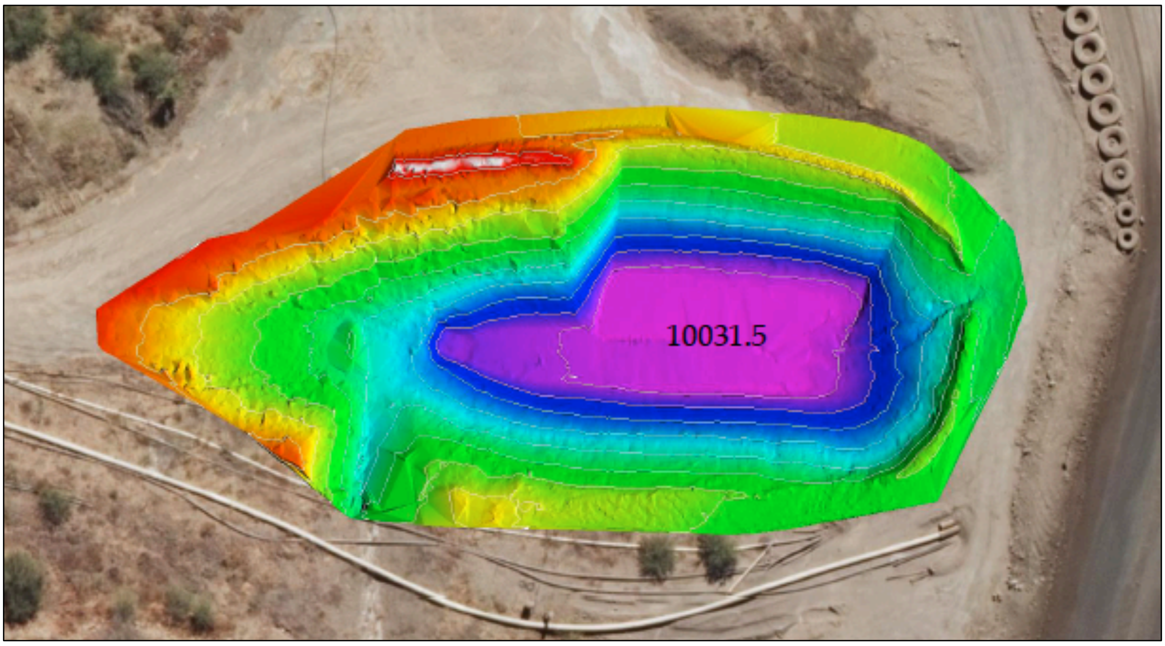
the haul road towards the Barney Creek diversion channel. A low (0.4 m) bund/berm was constructed at this point prior to the start of the 2017/18 wet season to allow vehicle access while diverting runoff across the bridge to SE sump.

Plate 4.13 – Upgrades to Haul Road Bridge Southwest Sump (Before/After)

Source: MRM (2018b)

Plate 4.14 – Upgrades to Haul Road Bridge Northwest Sump (Before/After)





Source: MRM (2018b)

With regards to the fluvial sediment monitoring program, the previous reporting period (KCB, 2016) included analysis of total sulfur as S, net acid producing potential (NAPP (ANC/MPA)) and net acid generation (NAG). This was not reported in the most recent fluvial sediment report, i.e., ELA (2017). The IM notes that the current environmental monitoring schedule (MRM, 2018c) includes total sulfur as S for fluvial sediments, but not NAPP or NAG. The next fluvial sediment report should explain the rationale for inclusion or exclusion of these analyses in the program.

Marine Sediments

New or changed marine sediment controls during the 2017-2018 operational period were confined to the AMMP, as follows:

- While the AMMP was unchanged for the December 2016 program, changes in December 2017 included the following (discussed further in Section 4.12.4.2):
  - Sampling sites SEPI 8, 9, 10, 11 and 12 (all on the eastern side of North and Centre islands, within the Sir Edward Pellew Group of islands ('the SEPI')) were removed, i.e., not sampled, as part of the 2017 AMMP.
  - Four new sampling sites were included within the SEPI: 'Black Island' on the western tip of Black Islet, 'Manta Point' on the southeast coast of West Island, 'South West Island' (also referred to as 'SW Isl') on the northern tip of South West Island, and '2nd Creek' on the coastline southeast of the existing sampling site Mule Creek, to the southwest of West Island.
  - Site 105 was moved 1.5 km to the south.

4.12.4 Review of Environmental Performance

4.12.4.1 Incidents and Non-compliances

Incidents

January 2018 Rainfall Event

A rainfall event in late January 2018 resulted in 86% of the month's total rainfall (538 mm) in one week, with heaviest falls on 24 January (103 mm) and 25 January (196 mm) – the latter being the highest daily rainfall ever recorded at this site since records commenced in 1968, and higher than the long-term median rainfall for the full month of January (BOM, 2018). Peak 1-hour rainfall intensity was recorded during the evening of 24 January, with 79.8 mm between 5.00 and 6.00 p.m. (WRM, 2018). In relation to this rainfall event, three overflow incidents were recorded:

- Overflow from TSF Cell 1 eastern and western sumps was contained within borrow pits and, as such, impacts on Surprise Creek were not anticipated (MRM, 2018d).
- Runoff from parts of the NOEF Central West area and from the Central West Alpha Sump (CWAS) reported to Central West C Sediment Trap (CWCST) and from there to the unnamed tributary north of the NOEF, which flows into Emu Creek (MRM, 2018e). Pumping from CWAS and CWCST to WPROD and SEPROD was undertaken to minimise the overflow. In relation to this incident, MRM (2018e) noted that 'given the high flows in the receiving catchment, the environmental impact is deemed negligible'.
- Runoff from the West D area of the NOEF breached a bund, flowing into the adjacent 'clean water' drain, reporting to South West Sediment Trap (SWST) and from there to Surprise Creek (MRM, 2018f). Works were undertaken to reinstate the bund, remove accumulated sediment and improve drainage in the vicinity. It was noted by MRM (2018f) that 'substantial

water was in the clean water drain and SWST and as such the impacts to water quality within the receiving environment would have been negligible'.

The latter two incidents had some, albeit limited, potential to impact on fluvial sediment quality in nearby watercourses. The IM recommends that following the next sampling period, fluvial sediment results for site FS26 (Emu Creek, downstream of the junction with the unnamed tributary) and sites FS34 and FS24 (Surprise Creek, in the vicinity of the SWST and SPROD) should be reviewed in relation to the potential impacts of this runoff.

Soil Impacts of July 2016 Dust Incident

A dust incident was reported at the NOEF on 23 July 2016 (DME, 2016). As dust incidents have potential to impact on nearby surface soils, the IM has reviewed relevant data. In comparing surface soil results for sites within 2 km of the NOEF between the June 2016 sampling event (one month prior to the dust incident) and the next sampling event in Q2 2017 (TAS, 2017a), the following is noted:

- Only the Zn EIL (45 mg/kg) was exceeded at any sites within this group, in either sampling event.
- Results at Site S45 – to the northwest of the NOEF – increased from a minor EIL exceedance of 53 mg/kg in 2016 to an exceedance of 91.0 mg/kg in Q2 2017.
- Results at Site S43 – to the south of the NOEF – included an EIL exceedance of 124 mg/kg in 2016; unfortunately, no soil sampling was undertaken at this site during Q2 2017 to enable comparison to previous years.
- Results at Site S30 – to the north of the NOEF – increased from a non-exceedance of 29.5 mg/kg in 2016 to an exceedance of 70.5 mg/kg in Q2 2017 (the latter being the duplicate result for this site, with the primary result being a non-exceedance of 32.5 mg/kg).

It is possible that the elevated results at S45 and S30 in Q2 2017 (up by 72% and 139% from 2016, respectively) were related to the July 2016 dust incident. However, 2015 soils metal results were considerably higher at these two sites, and the increases from 2016 to 2017 may relate to other factors, including soil heterogeneity or potential sampling error as illustrated by the difference between the two results at S30. Recommendations applicable to dust are included in Section 4.13 of this report.

Exceedances as Incidents

The IM has previously recommended (e.g., ERIAS Group, 2017) that all exceedances of applicable soils and sediment criteria should be reported as incidents. This recommendation has been reviewed in relation to applicable Northern Territory legislation, in particular the Mining Management Act (MMA) (as in force 1 July 2015), which states:

Section 4 – Definitions:

Environmental incident means an incident on a mining site that causes environmental harm.

> Environmental harm means: (a) any harm to or adverse effect on the environment; or (b) any potential harm (including the risk of harm and future harm) to or potential adverse effect on the environment, of any degree or duration and includes environmental nuisance.

Section 29 – Operator must report environmental incident or serious environmental incident:

> (1) As soon as practicable after the operator for a mining site becomes aware of the occurrence of an environmental incident or serious environmental incident on the site, the operator must notify the Chief Executive Officer of the occurrence.

Environmental incident reports as submitted by MRM to the DPIR are in response to the requirements of Section 29 of the MMA.

The IM notes that:

- Some soil/sediment exceedances are not the result of MRM's activities, as they relate to background conditions in in situ materials (e.g., soil metal results at S05 and S49). Such results should not be considered incidents or non-compliances on the part of MRM.
- Soil and sediment exceedances may directly or indirectly cause environmental harm. As per the MMA definitions, they may be a source of potential future harm to the environment as a result of adverse flow-on effects to vegetation, water quality and/or biota. On this basis, exceedances may be considered incidents.
- Some criteria currently used by MRM to assess soil/sediment exceedances are highly conservative and exceedances identified on the basis of these criteria do not necessarily indicate a source of potential environmental harm (see discussion under Non-compliances – Soils, below).
- In terms of environmental incidents being harm caused by 'an incident on a mining site', the generally accepted definition of an incident is an instance, event or occurrence of something – i.e., a singular occasion of some importance. As such, events that may result in soil contamination (e.g., a dust event, or runoff or seepage of contaminated water) may be more appropriate to consider as incidents as opposed to the consequence of soil criteria exceedances themselves – particularly given the annual nature of the monitoring programs. This appears to be the general approach that MRM applies in reporting incidents under the MMA, with the majority of reported incidents being events such as oil spills and sump overflows (MRM, 2018g).
- Given the large number of typically minor exceedances recorded by MRM during the annual soil and sediment assessment programs, the bureaucratic burden (on both MRM and DPIR) of reporting these as MMA s.29 incidents would be substantial.
- Nonetheless, continuation of recording and reporting exceedances of adopted environmental standards – as MRM does via its annual OPR – is required by the regulatory authorities. Furthermore, exceedances in a given sampling period (and particularly the more noteworthy

examples[3]) should not be treated as 'normal', but should be reviewed and investigated as part of the annual reporting of soil/sediment programs. Where appropriate, new or revised management measures should be implemented to address the identified issues in the next period.

- It is noted that MRM (2018h) refers to the previous recommendation on this topic as completed on the basis of being 'noted' – the IM considers that this item is not closed and should be addressed based on the above discussion. While the IM acknowledges the previous position, it is recommended that MRM and DPIR discuss this matter further in an effort to reach an agreed position whereby legal requirements are met, appropriate criteria are established, an appropriate level of environmental protection is achieved and bureaucratic burdens are minimised. A process such as a trigger action response plan may be suitable to deal with ongoing exceedances, identifying under what circumstances certain actions should apply.

Non-compliances

The 2013-2015 MMP (MRM, 2015b) does not contain a definitive list of commitments against which to assess non-compliances. However:

- The 2016-2017 and 2017-2018 OPRs (MRM, 2017a; 2018a) summarise the status of various commitments. These are discussed in Section 4.12.4.2.

- The IM has reviewed MRM's compliance register (environment) (MRM, 2017c), and discussion and recommendations within this chapter are consistent with that source. A summary of the soil and sediment guideline exceedances recorded at the mine site and at or near Bing Bong Loading Facility are provided in the following sections.

Soils

During the 2017-2018 operational period, soil monitoring reports were prepared for the periods June 2016 to May 2017 (TAS, 2017a), and April 2017 to March 2018 (TAS, 2018), with sampling periods in Q2 2017 and Q4 2017. The results from those reports form the basis of this review.

Table 4.57 summarises those soil analysis results for metals in the total fraction of soil that exceeded NEPM (NEPC, 2013) guideline levels, with yellow cells indicating exceedances of EIL criteria. No exceedances of HIL(D) criteria (where 'D' relates to industrial sites) were recorded at either the mine site or Bing Bong Loading Facility, including sites within 1 km of the ore crushing plant/ROM pad, in either sampling period. Blank cells relate to sites and sample depths for which no exceedance was recorded for the specified metal.

The IM notes the limitations of comparing soil contaminant concentrations to NEPC (2013) EILs to determine exceedances, particularly for Zn given that sphalerite (ZnS) is the mine's principle mineral of interest. Ecological assessments in accordance with NEPC (2013) may include

[3] 'Noteworthy exceedances' may include examples such as results significantly higher than the previous year/s or well above EIL or SQGV criteria, SQGV-high exceedances in the potentially bioavailable fraction of fluvial or marine sediments analysed after weak acid digestion, and exceedances outside the swing basin or beyond the expected mine area of influence.

establishment of site-specific ecological trigger values, which are derived by the sum of 'ambient background concentration' (ABC) and 'added contaminant limit' (ACL). Given that the ABC for McArthur River Mine was not used in calculating the appropriate site-specific trigger values, the adopted (ACL-derived) trigger values are conservative.

Furthermore, as the mine is situated in a mineralised area, it would be reasonable to expect that the ABC would be relatively high (which would increase an ABC plus ACL trigger value), and that the soil ecology would have some level of tolerance to elevated Zn present naturally in the environment. As such, exceedances as reported in the following section should be treated with caution, primarily as a tool to review trends in data rather than necessarily implying potential ecological harm.

Table 4.57 – Soil Metal Results from Q2 and Q4 2017 Exceeding NEPM (NEPC, 2013) Criteria

Group/ Sampling Event	Site No.	Sample Depth	Concentration (mg/kg) (Dry Weight) (Total Fraction)			
			As	Cu	Pb	Zn
Ore crushing plant/ROM pad <1 km group						
Q2 2017	S22*	0 to 10 cm				146
	S22*	40 to 50 cm				62.0
	S23	0 to 10 cm				64.0
	S24	0 to 10 cm		48	640	1,280**
	S24	40 to 50 cm				331
	S27	0 to 10 cm				73.0
	S44†	0 to 10 cm	99		695	1,630**
	S44†	40 to 50 cm				223
Q4 2017	S22	0 to 10 cm##				723
	S24			52		1,080
Ore crushing plant/ROM pad 1 to 2 km group						
Q2 2017	S08†	0 to 10 cm				591
	S08†	40 to 50 cm				758
	S25	0 to 10 cm				84.0
	S25	40 to 50 cm				73.0
Q4 2017	S25	0 to 10 cm##				113
	S55					150
NOEF <2 km						
Q2 2017	S30† (Dup)	0 to 10 cm				70.5
	S45†					91.0
Q4 2017	S43	0 to 10 cm##				242
	S45					137
	S52					233
	S53					24.5
	S53 (Dup)					55

Table 4.57 – Soil Metal Results from Q2 and Q4 2017 Exceeding NEPM (NEPC, 2013) Criteria (cont'd)

Group/ Sampling Event	Site No.	Sample Depth	Concentration (mg/kg) (Dry Weight) (Total Fraction)			
NOEF 2 to 3 km						
Q4 2017	S47	0 to 10 cm##				57.5
TSF <2 km						
Q2 2017	S42	0 to 10 cm				246
	S42 (Dup)					237
Q4 2017	S07	0 to 10 cm##				291
	S15					158
	S51					92.5
	S56					191
TSF 2 to 3 km						
Q2 2017	S03†	0 to 10 cm				74.5
	S03†	40 to 50 cm				69.0
	S03† (Dup)	40 to 50 cm				73.5
	S19*†	40 to 50 cm				72.0
	S49*†	0 to 10 cm	105	72	1,000	2,750**
	S49*†	40 to 50 cm				5,090**
Control						
Q4 2017	S10	0 to 10 cm##				98
Bing Bong Loading Facility						
Q2 2017	BBS01	0 to 10 cm				189
	BBS01 (Dup)					225
	BBS02			54.5	516	2,330**
	BBS03					64.0
	BBS05					173
	BBS07			49.5		1,920**
Q4 2017	BBS01	0 to 10 cm##				411
	BBS02					1,380
	BBS03					230
	BBS03 (Dup)					224
	BBS04					86
	BBS05					258
	BBS07					1,210
HIL (D) criteria#			3,000	240,000	1,500	400,000
EIL criteria#†			80	45	440	45

* Soil monitoring sites which were not sampled in the 2016 operational period.
# HIL (D) and EIL criteria provided are both for commercial/industrial sites.
† EIL criteria provided are for 'fresh' contaminants associated with current industrial activity and which have been in the soil for <2 years, and are the minimum criteria as per Table 7.1 of TAS (2017a). Note that the application of these

minimum criteria is conservative and does not take into account the ambient background concentration (ABC) plus added contaminant limits (ACL) as per the NEPM (2013).
**Results that exceed the maximum criterion for Zn in 'fresh' soils (800 mg/kg) (S24, S44, BBS07) and/or the maximum criterion for Zn in 'aged' soils (2,000 mg/kg) (S49 and BBS02), as per Table 4.2 of TAS (2017a).
Subsoil (40-50 cm) samples were not collected during the Q4 2017 sampling event.
†† Sites either not sampled or moved during Q4 2017.

The IM concurs with TAS (2018) that the long-term data shows that the most recent Pb, Zn, Cd, Cu, As and Mn results from October 2017 were relatively low compared to historical measurements. From approximately 2007 (when open cut mining commenced), levels of Pb, Zn, Cd and Cu generally increased at sampling locations closest to the processing plant (e.g., S22, S24, S28), with fluctuations from year to year. Results for these metals at S22 and S24 stabilised from around 2012, although Pb and Cu results at S28 had a generally upward trend until sampling ceased at that site in 2016. Results slightly further from the processing plant to the northwest (S23 and S27) have remained consistently low, and as such the most elevated concentrations as a result of mining operations appear to be localised. Results at the majority of other sampling location were relatively stable.

At the mine site, two EIL exceedance for As were recorded in Q2 2017 at sites S44 (higher than the past three years at this site) and S49 (which was not sampled before or since), and exceedances of the Cu EIL were recorded as S24 (in both 2017 sampling events) and at S49. Both S24 and S44 had exceedances of the EIL for Pb (although improved from previous years); both are within 1 km of the ore crushing plant. Neither S44 nor S49 were sampled in Q4 2017, so no comparison can be made. Site S49 is discussed under Section 4.12.4.2 – New and Evolving Issues.

Exceedances of the minimum EIL criterion for Zn continue to occur at a number of sites within 2 km of key mine infrastructure, most notably the processing plant, in both surface (0 to 10 cm) and subsoil (40 to 50 cm) soil profiles (the latter not being sampled in Q4 2017). Although TAS (2018) notes that a synthesis of 60+ years of geochemical surveys has indicated a zone of Pb and Zn mineralisation at Barney Hill (near S22 and S24), surface soil results near the processing plant were substantially higher than subsoil results and have markedly increased since 2005 (TAS, 2018), implying that processing activities have a greater influence than existing mineralisation in this vicinity. In Q2 2017, the majority of metals results at the mine site were an improvement on the previous operational period. However, in Q4 2017 Zn results were mixed, with markedly poorer results for some sites (e.g., S22, and S55 which replaced nearby S32) and improvements for others (e.g., S51 which replaced S42). Importantly, seven sites that previously had Zn exceedances were removed without replacement or were moved significant distances, and as such no discussion of improvement or deterioration can be made for these sites. This is discussed under Section 4.12.4.2 – New and Evolving Issues – Surface Soil Sampling Changes.

In comparison to 2016, only one site within 1 km of the ore crushing plant (S44) had poorer surface soil results in Q2 2017. These included exceedances of As and Pb (unlike in 2016) and increased Zn results (up to 1,630 mg/kg from 311 mg/kg). Nearby site S22 had Zn exceedances in both events, though more elevated in Q4 2017 (146 vs. 728 mg/kg).

While there were no exceedances for sites within 2 to 3 km of the TSF during 2016, several exceedances of Zn EILs were recorded in Q2 2017 at sites S03, S19 and S49 (see Figure 4.41). The latter two sites were not sampled during 2016. The highest Zn results within this group (and on the mine site more broadly) in 2017 were recorded at S49, with 5,090 mg/kg in the subsoil, and 2,750 mg/kg in surface soils. These results appear anomalous given the distance of this site from mine facilities (compared to other elevated results at S24, S44, BBS02 and BBS07), and are therefore discussed further in Section 4.12.4.2.

At Bing Bong Loading Facility, surface soil results in Q2 2017 (unlike 2016) included minor exceedances of EILs for Cu (at BBS02 and BBS07, both to the northwest of the concentrate shed) and an exceedance for Pb (also at BBS02). These exceedances were not repeated in Q4 2017. Results for Zn continue to be elevated above the EIL, with exceedances recorded to the west and northwest of the concentrate shed at BBS02, BBS05 and BBS07 (up 285%, 63% and 432% respectively, in Q2 2017). The highest Zn result in Q2 2017 (2,330 mg/kg) was again at the closest site to the concentrate shed, BBS02, which is in the path of prevailing southeasterly winds. Relatively minor exceedances of Zn EILs were also recorded at BBS01 (to the northeast of the concentrate shed) and at BBS03 (southeast of the shed within the dredge spoil ponds). In Q4 2017, Zn results improved for BBS02 and BBS07, but declined for sites BBS01, BBS03 and BBS05.

Fluvial Sediments

Fluvial sediment monitoring sites with elevated concentrations of Pb and/or Zn (in the potentially bioavailable fraction, i.e., trace metals in the <63 μm fraction after weak acid digestion, as well as ‘near total’ metals after strong acid digestion (ELA, 2017) are shown in Table 4.58. Yellow cells indicate exceedances of Simpson and Batley (2016) SQGVs, while pink cells indicate exceedances of the applicable SQG-high value.

Table 4.58 – Fluvial Sediment Results from 2017 Showing Elevated Concentrations of Metals in the <63 μm Fraction

Monitoring Site		EC (μS/cm)	Concentration (mg/kg) (Dry Weight)			
Number	Location		Pb		Zn	
			WA*	SA*	WA	SA
Emu Creek						
FS31	Emu Creek, upstream of mine facilities	65	34.7	54	28.8	53.5
Surprise Creek						
FS33	Surprise Creek, adjacent to Cell 1 of the TSF	460	75.7	98.8	143	194
FS34	Surprise Creek, upstream of SPROD near the NOEF	630	83.1	96.2	142	189
Barney Creek						
FS03	Barney Creek diversion channel next to crushing plant	490	110	134	143	281
FS18	Barney Creek diversion channel/Surprise Creek confluence	415	107	131	202	333
FS19	Barney Creek haul road bridge (diversion channel)	670	185	223	344	559
FS20	Barney Creek diversion channel between FS19 and FS06	300	61.7	87.6	107	223

Table 4.58 – Fluvial Sediment Results from 2017 Showing Elevated Concentrations of Metals in the <63 μm Fraction (cont'd)

Monitoring Site		EC (μS/cm)	Concentration (mg/kg) (Dry Weight)			
Number	Location		Pb		Zn	
			WA*	SA*	WA	SA
Barney Creek (cont'd)						
FS06	Barney Creek diversion channel/ unnamed creek confluence	430	47.1	62.2	83.9	174
		SQGV-high#	220		410	
		SQGV#	50		200	

*WA = weak acid digestion. SA = strong acid digestion. #Criteria are as per Simpson and Batley (2016). Data source: ELA, 2017.

Site FS31 on Emu Creek had a minor exceedance of the Pb SQGV after strong-acid digestion; the source of this Pb is not likely to be related to mine activities given the upstream location of this site. New Surprise Creek sites (S33 and S34) both exceeded the SQGV for Pb after both weak- and strong-acid digestion, potentially reflecting inputs from the TSF and the NOEF, respectively.

In Barney Creek, metals results at FS06 were reduced compared to the previous reporting period, while EC increased marginally. Results for FS03 near the crushing plant showed increases in EC, and Zn after strong acid digestion, but improvements in Pb as well as Zn after weak acid digestion.

Results from FS19 (Barney Creek diversion channel below the haul road bridge) – particularly with regards to Pb and Zn – have continued to improve over the past several years (Table 4.59). This correlates with MRM's ongoing efforts to improve sediment controls in this area (see Section 4.12.3) and is to be commended. In 2017, only strong-acid digestion results exceeded the SQG-high value for Pb; weak-acid Pb results and both weak- and strong-acid results for Zn exceeded SQGVs, but not SQG-high values. Results for EC were more than five times lower in 2017, although slightly higher than 2015. Results downstream at FS20 have similarly improved. Upstream at FS18, while metal results are only slightly improved since 2016, EC results are more than six times lower.

Table 4.59 – Fluvial Sediment Results at FS19 from 2014 to 2017

Sampling Year	EC (μS/cm)	Concentration (mg/kg) (Dry Weight)				
		As	Pb		Zn	
		SA*	WA*	SA*	WA	SA
2014	3,320	27.7 †	1,590 †	-	2,210 †	-
2015	650	22.5	235	268	466	711
2016	3,380	30.0	241	273	495	749
2017	670	22.5	185	223	344	559
	SQGV-high#	70	220		410	
	SQGV#	20	50		200	

* WA = weak acid digestion (for 2015 to 2017 results, this applies to metals in the <63 μm fraction). SA = 'near total' metals after strong acid digestion.
† 2014 results are for dilute acid-soluble metal concentrations for the total sample.
# Criteria are as per Simpson and Batley (2016).

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Of all the fluvial sediment sites, only FS19 had an exceedance for metals/metalloids other than Pb and Zn in 2017. Specifically, strong acid digestion results showed a minor exceedance of the SQGV for As (22.5 mg/kg versus the SQGV of 20 mg/kg, down from 30 mg/kg in 2016, see Table 4.59) at this site. There were no strong-acid digestion exceedances for other metals criteria at this site, and results after weak acid digestion (i.e., the potentially bioavailable fraction) were well below relevant guidelines values. Results for all fluvial sediment sampling locations were well below the SQGVs for As and Cd after weak acid digestion.

As shown in Table 4.58, results from strong acid digestion were consistently higher than those from weak acid digestion (with the latter representing the potentially bioavailable fraction), as expected. Exceedances for Pb were again only slightly higher under strong acid digestion, while results for Zn were notably higher after strong acid digestion, exceeding the SQGV at FS20. The difference between results for strong acid versus weak acid digestion for this sample suggests that a substantial proportion of the Zn was present in forms that are not likely to be bioavailable.

Marine Sediments – Annual Marine Monitoring Program

Within sediments sampled as part of the AMMP during the operational period, analysis of the potentially bioavailable fraction (<63 μm using a weak acid digestion) again showed no exceedances of SQGV criteria for As or Cd, and no exceedances of SQG-high values except for Pb at sites MS6A and MS7A, in the west and southwest of the swing basin (see Figure 4.39; Table 4.60)

Table 4.60 – AMMP Results Showing Elevated Concentrations of Metals in Marine Sediments

Monitoring Site		Concentration (mg/kg) (Dry Weight)							
		As		Cd		Pb		Zn	
Name	Location	WA*	SA*	WA	SA	WA	SA	WA	SA
December 2016									
Pine Reef	Approx. 15 km northwest of BBLF	4.1	20	0.06	0.03	9.4	5.3	5.0	5.0
8	Northwest of BBLF	3.6	24	0.04	0.02	15	11	6.0	3.0
GB	Northeast of BBLF	4.4	38	0.04	<0.02	18	19	5.0	5.0
117	East of BBLF	5.0	32	0.05	0.02	11	16	5.0	7.0
MS1B	Northeast of BBLF	4.7	38	0.04	0.02	9.6	20	7.0	7.0
MS5A	Swing basin NW	4.0	16	0.67	2.2	190	160	230	890
MS5B	Swing basin NE	3.4	13	0.45	1.0	110	72	160	430
MS6A	Swing basin W	3.6	14	0.84	2.9	260	220	310	1,300
MS6B	Swing basin E	2.4	16	0.42	0.96	110	72	150	390
MS7A	Swing basin SW	3.6	13	0.89	2.8	270	210	320	1,200
MS7B	Swing basin SE	3.4	15	0.36	0.72	110	64	140	310
December 2017									
MS5A	Swing basin NW	4.3	NA[#]	0.51	NA	142	NA	190	NA
MS6A	Swing basin W	5.6	NA	0.61	NA	155	NA	224	NA
MS7A	Swing basin SW	4.4	NA	0.59	NA	179	NA	218	NA

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Table 4.60 – AMMP Results Showing Elevated Concentrations of Metals in Marine Sediments (cont'd)

Monitoring Site		Concentration (mg/kg) (Dry Weight)							
		As		Cd		Pb		Zn	
Name	Location	WA*	SA*	WA	SA	WA	SA	WA	SA
December 2017 (cont'd)									
MS7B	Swing basin SE	4.8	NA	0.56	NA	150	NA	253	NA
	SQGV-high*	70		10		220		410	
	SQGV*	20		1.5		50		200	

Data source: IPE, 2017a; 2018a. *WA = weak acid digestion, performed on the <63 μm sediment fraction. SA = strong acid digestion, performed on the <2 mm fraction. #Strong acid digestion on the <2 mm fraction was not undertaken in the December 2017 program.

In this fraction, exceedances of SQGVs for Pb and Zn were confined to the swing basin in both 2016 and 2017, with concentrations of these metals being significantly higher at the swing basin sites than at more distant sites. Results for As outside the swing basin to the east (GB and 117) again improved from 2015 to 2016, and again from 2016 to 2017, while As in the swing basin itself deteriorated slightly from 2015 to 2016 to 2017. Nonetheless, all potentially bioavailable As results remain well below the SQGV. Results for Cd, Pb and Zn results within the swing basin have generally improved.

As shown in Table 4.60, Pb results in 2016 after strong acid digestion were generally lower than those after weak acid digestion, reflecting analysis of different size fractions (strong acid on the <2 mm fraction, and weak acid on the <63 μm fraction) with lower total surface area in the coarser fraction. Analysis of this fraction after strong acid digestion in 2016 showed exceedances of the As SQGV at four sites in the near vicinity of the swing basin, as well as at Pine Reef to the northwest. There were no such exceedances in the swing basin itself.

As for 2016, 2017 results for Zn after strong acid digestion exceeded the SQG-high value along the western side of the swing basin at MS5A, MS6A and MS7A, as well as MS5B on the eastern side, and the SQGV was exceeded at MS6B. As for fluvial sediments, the differences between marine sediment results for strong acid digestion versus those for weak acid digestion for these samples suggest that a substantial proportion of the Zn was present in forms that are not likely to be bioavailable. Reflecting this, in the December 2017 AMMP, strong acid analysis of the <2 mm fraction was discontinued – this change is discussed in Section 4.12.4.2 under New and Evolving Issues. The absence of this analysis is reflected in Table 4.60, as no sites outside the swing basin had exceedances in the potentially bioavailable fraction in the 2015, 2016 or 2017 AMMPs.

Marine Sediments – Nearshore

Nearshore sediment results (for the <63 μm size fraction after weak acid digestion) during the operational period showed no exceedances of Simpson et al. (2013)[4] SQGVs for As or Cd. Results for Pb and Zn within potential impact zones (Zones 2, 3 and 4, near to Bing Bong loading

[4] Nearshore sediment data was assessed against Simpson et al. (2013), which has now been superseded by Simpson and Batley (2016). The guideline values applicable to parameters monitored by MRM have not changed.

facility) were similar in 2017 to those in 2016 and 2015, and largely well below the relevant SQGVs, constituting a low biological risk (IPE, 2018b).

In Zone 2, immediately to the west of the swing basin (see Figure 4.45), one site (Z2-3) had minor exceedances of Pb and Zn SQGVs, and somewhat elevated Cd and Cu, while all other results in this zone remained low. Indo-Pacific Environmental (IPE, 2018b) notes that these localised elevated results were likely due to dust deposition from MRM's activities at Bing Bong Loading Facility, combined with limited flushing of the inshore section of Zone 2. Specifically, dust emissions from the concentrate storage shed and/or dust generated during loading of concentrate onto the MV Aburri may have contributed to nearshore sediment contamination near the swing basin.

There were no Pb exceedances in any other zone in this sampling period, and mean metals concentrations in each zone remained well below the relevant SQGVs (IPE, 2018b).

Within Zone 5, halfway between BBDDP and Eastern Control, two sites had more noteworthy Zn exceedances of 257 and 391 mg/kg (the Zn SQGV is 200 mg/kg), at least double that of other sites in this zone. However, Pb results at these sites were very low. Indo-Pacific Environmental (IPE, 2018b) comments that given this and the distance from the loading facility, Zn concentrations at these sites are unlikely to originate from MRM shipping concentrate – although an alternative source is not suggested. The IM notes that Zn exceedances in Zone 5 are unusual, with none in the previous three sampling periods. Moreover, the percentage of <63 µm sediments at these sites was very low, indicating low bioavailability. It is recommended that Zn results in Zone 5 be reviewed in the next sampling period. If they continue to be elevated, the source should be investigated.

For metals that do not have a SQG value, IPE (2018b) calculated interim criteria based on background concentrations in control zones. The IM notes that the calculation method is not made clear in IPE's reporting; this is recommended for the next reporting period. A number of individual exceedances of these interim criteria occurred in 2017, however, sediments within the immediate vicinity of the Bing Bong Loading Facility (Zones 2, 3 and 4) are considered to be of low risk (IPE, 2018b). Mean results (by zone) which exceeded the interim criteria included B in Zone 4, and Ba, Mn and Tl from BBDDP. Indo-Pacific Environmental (IPE, 2018b) does not consider the B results to be of environmental concern, and states that they are unlikely to be related to mining/shipping activities.

At the BBDDP, mean Tl in sediment reduced from 2.7 mg/kg in 2016 to 0.157 mg/kg in 2017, although this remains notably elevated compared to the interim criteria of 0.041 mg/kg. Results were 5 to 10 times higher than concentrations recorded in the wider study area (including potential impact locations) (IPE, 2018b). This is discussed in Section 4.12.4.3 – New and Evolving Issues.

Marine Sediments – Trans-shipment Area

Within the trans-shipment area sediment results during the operational period, there were no exceedances of Simpson et al. (2013)[5] values. For 2016 results, this included both the <2 mm size fraction after strong acid digestion and the <63 µm size fraction after weak acid digestion. For 2017 results, only the latter was assessed. This change to the analysis suite is discussed in Section 4.12.4.2 (New and Evolving Issues).

Mean sediment concentrations of a majority of analytes within the trans-shipment area (TA) were comparable to those within the control area (CA). Bioavailable results for Zn, and to lesser degree Pb, have remained higher within the TA than the CA across 2015 to 2017, but are still well below the relevant SQG criteria (IPE, 2018c).

4.12.4.2 Progress and New Issues

Progress

The 2016-2017 and 2017-2018 OPRs (MRM, 2017a; 2018a) summarise the status of MRM's various environmental commitments. In particular, a reconciliation of environmental management commitments and actions is provided. In the latter document, Table 29 (pp109-118) outlines MRM's implementation approach and progress in addressing recommendations of specialists that undertook environmental monitoring programs during the 2017-2018 OPR reporting period, and recommendations from the 2013-2015 MMP and previous OPRs. Aspects of this content relating to soils and sediment are presented in Table 4.61 together with IM commentary. Where applicable, these recommendations/commitments have been included in the IM's recommendations for the 2017-2018 reporting period.

Table 4.61 – Reconciliation of MRM's Commitments Regarding Soil and Sediment Management

Action/Recommendation	Implementation/Comment
Source: Soil Monitoring Program	
TAS (2018) recommends the contaminants emitted be minimised wherever it is practical and feasible to do so	MRM Comment: Complete. The AQMP was developed to manage and monitor the mine's emissions and to minimise them where practical and feasible to do so. The AQMP was completed and implemented in Q3 2017 IM Comment: TAS (2018) is the latest soil monitoring report, however both the term 'emitted' and MRM's comment relate only to soil contamination as a result of dust emissions (as opposed to seepage, concentrate spillage, etc.). The IM notes that soil contamination is not exclusively related to dust impacts. This is discussed further under New and Evolving Issues – Surface Soil Sampling Changes

[5] Trans-shipment area sediment data was assessed against Simpson et al. (2013), which has now been superseded by Simpson and Batley (2016). The applicable guideline values have not changed.

Table 4.61 – Reconciliation of MRM's Commitments Regarding Soil and Sediment Management (cont'd)

Action/Recommendation	Implementation/Comment
Source: 2016-17 OPR	
TAS (2017a; 2017b) recommended that the sampling and analysis process be reviewed with a focus on ensuring all reasonably possible paths of contamination are minimised	MRM Comment: Complete IM Comment: The focus stated here is commended, however, the sampling and analysis process does not directly act to minimise contamination, unless TAS is referring to sample contamination. The above recommendation relates to 'all reasonably possible paths of contamination'; no further recommendations at this time
TAS (2017a; 2017b) noted that as the recorded Pb levels on the site are high, it is possible that there may be risks to the health of workers near to the processing plant, and also some risk to the environment. TAS (2017a; 2017b) recommended the contaminants emitted be minimised wherever it is practical and feasible to do so	MRM Comment: Complete IM Comment: Potential risk to health of workers is not an environmental commitment and is outside the scope of this review, however the potential risk to the environment is acknowledged. The recommendation to minimise emissions of contaminants where possible should be considered integral to MRM's environmental performance; no further recommendations at this time

Source (Actions/Recommendations and MRM Comments): MRM, 2018a.

McArthur River Mining's progress and performance against previous IM review recommendations relating to soil and sediment issues is summarised in Table 4.62.

Table 4.62 – Soil and Sediment Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
General/Multiple Programs		
Incident reporting	Exceedances of soil and sediment guideline levels should be reported as environmental incidents, with subsequent investigation to address the reasons for exceedances and potential management measures	Ongoing No soil or sediment incidents were reported in the 2017-2018 operational period, although exceedances were again recorded for soils, fluvial sediments, nearshore sediments and marine sediments in the AMMP program. See full discussion in Section 4.12.4.1 – Exceedances as Incidents. The IM notes: ♦ In accordance with MMA definitions, exceedances may be considered incidents. However, given the numbers of typically minor soil/sediment exceedances recorded each year, the bureaucratic burden of reporting all as incidents would be substantial. Notwithstanding this observation, the ongoing recording and reporting of exceedances via the annual OPR is a minimum requirement ♦ The IM recommends that exceedances (and particularly more noteworthy examples) should not be treated as 'normal', but should be reviewed and investigated as part of annual reporting. Where appropriate, new or revised

Table 4.62 – Soil and Sediment Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
General/Multiple Programs (cont'd)		
Incident reporting (cont'd)		management measures should be implemented to address the identified issues in the next period ♦ The IM recommends that MRM and DPIR discuss this matter further to reach an agreed position whereby appropriate criteria are established, legal requirements are met, an appropriate level of environmental protection is achieved, and bureaucratic burdens are minimised. A process such as a trigger action response plan may be appropriate to deal with ongoing exceedances, identifying under what circumstances certain actions should apply
Sediment monitoring data – assessment	The next version of the MMP, as well as future fluvial and marine sediment monitoring reports, should reference Simpson et al. (2013) which has superseded ANZECC/ ARMCANZ (2000), with regards to sediment quality guidelines	♦ Completed – for fluvial sediment: The fluvial sediment assessment (ELA, 2017) has referenced Simpson and Batley (2016), which replaces both Simpson et al. (2013) and ANZECC/ARMCANZ (2000). The IM commends this change ♦ Ongoing – for marine sediment: During the 2017-2018 operational period, the three marine sediment sampling programs (IPE; 2017a, 2017b, 2018a, 2018b and 2018c). assessed data against Simpson et al. (2013) guidelines. As noted, Simpson et al. (2013) has been superseded by Simpson and Batley (2016). Although the guideline values applicable to parameters monitored by MRM have not changed, the current document should be referred to in future marine sediment assessment reports ♦ Ongoing – for the next MMP: The next version of MRM's MMP should also reference Simpson and Batley (2016)
Soil, fluvial sediment and marine sediment monitoring program – reporting	Quality assurance/quality control (QA/QC) data for sample analyses, and subsequent discussion, should be presented in the next version of the MMP as well as surface soil, fluvial sediment and marine sediment (AMMP, nearshore, and trans-shipment) monitoring reports for the 2017 operational year While the IM notes that some discussion of QA/QC is provided in the fluvial sediment monitoring report (KCB, 2016a), this could be improved. The discussion provided for the surface water	Ongoing ♦ Soils – The latest report (TAS, 2018) includes some discussion of QA/QC, including relative percentage difference (RPD) of duplicate samples. This improvement is commended, but QA/QC could be improved further (e.g., by inclusion of sample blanks) ♦ Fluvial sediments – The latest report (ELA, 2017) includes some discussion of QA/QC, including RPD of duplicate samples. Reference is made to analysis of blank samples and tabulation of these results, however this data was not apparent in the report or appendices ♦ AMMP – The latest AMMP report for 2017 (IPE, 2018a) included method blanks and duplicates for sediments ♦ Trans-shipment area sediments – The latest assessment for 2017 (IPE, 2018c) included

Table 4.62 – Soil and Sediment Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
General/Multiple Programs (cont'd)		
Soil, fluvial sediment and marine sediment monitoring program – reporting (cont'd)	quality monitoring program within the current MMP (MRM, 2015a) provides a possible model for all aspects of the soil/sediment program	method blanks and duplicates ♦ Nearshore sediments – The latest report for September 2017 sampling (IPE, 2018b) includes assessment of duplicates (but not blanks) ♦ Improvements to QA/QC for the surface soil and marine sediment programs are commended. All of the above programs could be further improved. The QA/QC discussion provided for the surface water quality monitoring program within Section 2.1.16 of the current MMP (MRM, 2015a) provides a possible model for all of the soil/ sediment programs, and also for inclusion in these aspects of the next MMP. QA/QC should include trip blanks (to identify potential sampling contamination), records of holding time compliance, and method blanks, laboratory control spikes and matrix spikes (to identify potential laboratory contamination/ errors)
General data interpretation and reporting	A reconciliation/discussion of actual versus proposed/ committed sampling events should be provided as part of 2017 reporting. Rationale should be provided for data gaps or sites not sampled, where applicable	Ongoing McArthur River Mining (2018h) notes that this is 'included in the scope of work for the 2017-18 Report'. A similar comment was made in 2017. It is not clear which report is referred to, however such a reconciliation is not included in TAS (2018). No such information was sighted for the 2014, 2015, 2016 or 2017 operational periods. The IM recommends this be completed as part of 2018 reporting. The importance of this is increased given the extensive changes to the most recent soil sampling program. See further discussion below under 'New and Evolving Issues'
Surface Soils		
Surface soil monitoring	Within the 2017 operational year, S05 should be replaced with a new control site that is not in the immediate vicinity of the 1970s quarry, i.e., in a more 'natural' location	Completed ♦ Site S05 was replaced by a new site, S49, within the Q2 2017 (TAS, 2017a) soil report. Metals results from S49 (like S05) were elevated compared with other mine site monitoring locations; it appears that these results may relate to historical soil contamination rather than MRM's operations (possibly related to past quarry operations in the vicinity) – as such it was not appropriate as either a control or impact site ♦ In the Q4 2017 soil sampling event (TAS, 2018), S49 was not sampled, but instead a new site S56 was established closer to the water management dam. Site S56 appears to be acceptable as an impact site ♦ The above, and surface soil control sites in general, are discussed further below under 'New and Evolving Issues'

Table 4.62 – Soil and Sediment Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Surface Soils (cont'd)		
Surface soil monitoring (cont'd)	Monitoring of surface soil control sites S04 and S10 should be recommenced in the 2017 period	Ongoing ♦ Sampling of control sites S01 and S10 (recommencement at the latter) was undertaken in Q2 2017 with results including in TAS (2017a). In Q4 2017, site S10 was moved 4.5 km closer to the mine (TAS, 2018). The IM strongly recommends reinstating the original site S10. This is discussed further below under 'New and Evolving Issues' ♦ Monitoring at control site S04 did not occur in the 2016 or 2017-2018 operational periods. The IM recommends monitoring of a third control site (in addition to S01 and the original S10), as ongoing monitoring of control sites is necessary to provide a comparison for potentially impacted sites. As such, the IM recommends that site S04 be reinstated in the next sampling period
Soil results reporting	The 2017 soils report should improve clarity and consistency throughout the report as to which size fraction results relate to (i.e., <63µm versus <2 mm fraction)	Completed The 2017 report (TAS, 2017a) refers to the total fraction for all results
Surface soil HIL exceedances	The next soil monitoring report to be prepared by MRM should review results from surface soil sites S28 and S44 within the context of long-term trends to clarify reasons for Pb HIL exceedances and the variation in results between years	Completed The latest soil monitoring report (TAS, 2018) includes graphical presentation and brief discussion of historical trends of metals in soils, including Pb and Zn. From this perspective, this recommendation is completed. However, the discussion of reasons for Pb trends at these sites, and particularly the fluctuations at S28, is inadequate. Sampling ceased at S28 after 2016, and at S44 after Q2 2017, and as such this discussion has become less relevant – or superseded by the discussion of sampling site changes and rationale
Fluvial Sediments		
Fluvial sediment contamination at Barney Creek haul road bridge	McArthur River Mining should continue to monitor sediment traps near the bridge to ensure that they are functioning effectively to capture sediment-laden runoff and prevent inputs to the creek, and upgrade these or review if necessary	Completed Construction of the new MIA sump, and upgrades to sediment containment and diversion structures surrounding Barney Creek haul road bridge are commended
EC results at FS24	The cause of high EC results at FS24 should be investigated during the 2017 operational year	Completed ♦ MRM (2018h) has commented that this issue has been investigated. The following comments are provided: 'SW24 is located in the lower reach of Surprise Creek. This section of the

Table 4.62 – Soil and Sediment Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Fluvial Sediments (cont'd)		
EC results at FS24 (cont'd)		creek is known to be impacted by dry season base flow and mine affected groundwater discharge from upper Surprise Creek catchment. The deep pool at SW24 causes evapoconcentration of TDS over dry season months leading to higher sediment EC. Similar trends are also observed in catchment pools located at SW02 and SW19' ♦ The high EC results recorded at FS24 in 2016 were not discussed further in ELA (2017) ♦ The IM notes that EC results at this site within 2017 are within an acceptable range
Marine Sediments		
Tl in nearshore sediment at BBDDP	The cause of exceedances of interim criteria for Tl within nearshore sediments in the vicinity of BBDDP should be investigated	Ongoing ♦ Mean Tl results were again elevated at BBDDP. IPE (2018b) has again recommended ongoing monitoring and investigation of the potential Tl sources at this location, advising that it may originate from the dredge spoil ponds ♦ The IM recommends analysis of Tl within the dredge spoil ponds, and in swing basin sediments as part of the AMMP, in addition to fluvial sediments as suggested by IPE (2018b). The next nearshore sediment report should discuss the potential ecotoxicological effects of Tl, comment on the implications of observed trends and advise required actions if Tl is elevated due to MRM activities. The IM endorses MRM's (2018a) plan to investigate the geochemical characteristics of the dredge spoil in 2019 ♦ See full discussion below under 'New and Evolving Issues'

New and Evolving Issues

Surface Soil Control Sites

While the 2017 soil sampling events (TAS, 2017a; 2018) provided data for control sites S01 and S10, no results were presented in 2016 or 2017 for the previous control sites S04 or S05.

Control site S05 was removed from the soil monitoring program prior to the 2016 sampling event, as it was neither an appropriate control site (being close to an old quarry) nor an appropriate impact site (as impacts appeared more likely to be related to past quarry operations than to recent/current mine operations). A new site, S49, was included in the Q2 2017 sampling event (TAS, 2017a) in the near vicinity of the old S05 site. Site S49 was not indicated as a control site, but rather an impact site in the 'West' group. However, given its location near S05, it indirectly served as a replacement for S05. The IM and TAS (2017a, 2018) both note that metals results (including As, Cu, Pb, Zn, Cd, Mn and Ni) from S49 were elevated compared with other mine site monitoring locations, including nearby sites closer to the TSF (S06 and S48). Furthermore, dust results were not elevated at the nearest monitoring site (DMV05) (TAS, 2017b). As such, it appears that elevated soil metal results at S49 may have related to historical soil contamination in a similar manner to that of the decommissioned site S05. As for site S05, the IM contends that S49 was neither an appropriate control site nor of relevance to impacts from MRM's operations.

In the Q4 2017 soil sampling event (TAS, 2018), S49 was not sampled, but instead a new site S56 was established approximately 1.25 km to the east, close to the water management dam. Given its location <2 km from the TSF, S56 is clearly not a control site, but it serves to fill a gap in impact monitoring in this vicinity, which is commended.

Also in the Q4 2017 soil sampling event (TAS, 2018), control site S10 was moved approximately 4.5 km closer to the mine site, for co-location with air quality monitoring sites including DMV10. Zinc results at the original S10 were 9 mg/kg in Q2 2017, but were more than tenfold higher at the new southerly site in Q4 2017, with a value of 98 mg/kg – exceeding the relevant NEPM criteria of 45 mg/kg (NEPC, 2013). The IM considers that the new location of S10 is not appropriate as a control site given its proximity to the mine. It does not allow for ongoing comparison with historical data – moving a site by such a distance makes results across years incomparable. The original S10 sampling location should be reinstated in 2018. If the 'new S10' site is retained to enable comparison with air quality results at this location, it should be renamed and indicated as an impact site.

A third control site (in addition to S01 and the original S10) is recommended, as ongoing monitoring of control sites is necessary to provide a baseline/comparison for potentially impacted sites. The IM recommends that previous control site S04 be reinstated in the 2018 sampling event.

Surface Soil Sampling Changes

Surface soil sampling changes in 2017 included:

- Site S22 (within 1 km of the processing facility) was sampled instead of nearby S28 in both 2017 sampling events.
- As previously discussed, S49 was sampled instead of nearby instead of S05 in Q2 2017, but was replaced by S56 in Q4 2017.
- Results were not presented in 2016 or 2017 for site S31 on the southern side of the McArthur River diversion channel.
- Site S43 near Barney Creek haul road bridge was reinstated as part of the 2016 program in response to an IM recommendation, but in a different location further to the west of the bridge (to better represent impacts of depositional dust, rather than reflecting introduced soil/ rock materials). This site was not sampled as part of the Q2 2017 program, but was reinstated in Q4 2017.
- Numerous changes were made to sampling locations in Q4 2017, as discussed in Section 4.12.3.2.

Rationales for specific sampling site changes are not provided by TAS (2017a, 2018). The general need to alter the sampling program between years is explained as being 'due to changing conditions or development on-site preventing access to the sample location'. While the IM understands and acknowledges this, reporting of soils monitoring and results should reconcile monitoring planned versus that actually undertaken, and provide a rationale for gaps or sites not sampled, where applicable.

The extensive changes to the soil sampling program between Q2 and Q4 2017 are not adequately explained by TAS (2018) or MRM (2018a). While the intent to simplify the soil and dust sampling programs is reasonable, the extent of the changes compromises the ability to compare results between years. For example, moving sites by hundreds of metres (S45 and S47) or several kilometres (S10) is likely to lead to confusion. Removal of numerous other sites which are known to have a history of exceedances removes the possibility of ongoing monitoring and analysis of trends. Although contaminants in dust are likely to contribute to contaminant levels in soil (and TAS (2018) proposed review of dust deposition results versus soil results is commended), soil contamination is not exclusively related to dust impacts, and soil monitoring sites are not required to necessarily be paired with dust monitoring sites.

The IM recommends that the rationale for monitoring program changes should be considered and reported on a site-by-site basis. The range of potential soil contamination sources should be considered and discussed in soil monitoring reports – including dust, seepage, runoff/deposition of sediment and/or spillage of product – along with historical trends. If a site is known to have exceedances, the reasons should be assessed, and monitoring should continue at such a location unless there is a clearly stated reason to cease. Where moving a monitoring site is considered to be necessary, a consistent and rational approach must be applied to site naming, in contrast to 2017 changes such as moving site S45 approximately 500 m (with the same name), while replacing site S32 with new site S55 in almost the same location. If moving a site more than, say, 30 m, it should be identified as a new site. At a minimum, adding a suffix (e.g., S45A versus S45B) would minimise confusion and ensure that genuine comparison of results can be made across sampling periods.

Fluvial Sediments

The IM has been advised by MRM that sediment captured within the sumps surrounding the Barney Creek haul road bridge is cleared out annually during the dry season, if required. Further to this, MRM (2018b) states that (underlining IM's own):

> Sediment storage of the Barney Creek Sumps should be maintained to ensure the minimum water storage capacity is available. The accumulated sediment will need to be removed <u>at least annually</u> to maintain sufficient storage space. The annual sediment build up rate can also be <u>monitored by measuring the sediment level after each significant event</u> and before cleaning it out. This could be used to determine if sediment rates are significant and additional sediment storage is required to manage the spill risk.

Given that the sumps are designed for a 1-in-10 year flood and are known to be completely submerged during significant flood events (Plate 4.15), the IM commends the above update to MRM's position, and considers that at least annual cleanout of these sumps is essential, along with monitoring of sediment levels after significant rainfall/runoff events.

Plate 4.15 – Flooding Below Barney Creek Haul Road Bridge, 27 January 2018

Source: MRM, 2018i.

Marine Sediments

In relation to the nearshore sediment program, IPE (2018b) has again recommended ongoing monitoring and investigation of the potential sources of Tl in the vicinity of the BBDDP, given ongoing elevated sampling results for Tl at this location, its potential toxicity, and concentration patterns in other mine site operational areas. They also advise that Tl levels considered 'normal' for marine sediments are generally in the range of 0.14 to 1.13 mg/kg.

Indo-Pacific Environmental (IPE, 2018b) advises that:

> Tl is known to occur in sulphide ores of heavy metals, in particular Pb, Zn and Cu. In consideration of this, and its comparatively high concentration at the BBDDP, it is possible that Tl at the BBDDP has originated from the dredge spoil ponds. This theory is further strengthened by current observations within fluvial sediments collected from operation areas of the MRM mine site (IPE report in publication).

Thallium results are not included in the ELA (2017) results for April 2017 fluvial sediment sampling, or the most recent soil monitoring, AMMP or trans-shipment area results, as such the above comment cannot be verified at this time, though it is implied that the 2018 fluvial sediment report will provide this information. The IM notes that the correlation between metals in fluvial sediments at the mine site and those potentially in dredge spoil is indirect. It would be appropriate to analyse Tl within the dredge spoil ponds themselves as a first priority, followed by swing basin sediments as part of the AMMP, in addition to fluvial sediments. In response to exceedances at BBDDP, MRM (2018a) is continuing monitoring of Tl in sediments at this location, and plans to investigate the geochemical characteristics of the dredge spoil in 2019. The IM recommends that the next fluvial sediment assessment should include analysis and presentation of the mentioned Tl results, and inclusion of Tl analysis in the next AMMP should be considered. The next nearshore sediment report should discuss the potential ecotoxicological effects of Tl, comment on the implications of observed trends (beyond comparison to interim criteria/background levels) and advise required actions if Tl is elevated due to MRM activities.

Changes to Analysis Suite Within Marine Sediment Programs

For both the AMMP and the trans-shipment area (TSA) sediment samples in 2017 (unlike in previous years), analysis of the <2 mm fraction after strong acid digestion was not undertaken, i.e., only analysis of the <63 μm fraction (after weak acid digestion) was carried out in both programs. There was no comment on this change within the 2017 TSA report (IPE, 2018c). With regards to the change to the 2017 AMMP, IPE (2018a) commented that this was at the request of MRM, and that:

> This aimed to align the analysis with other sediment analyses undertaken by MRM and the generally held opinion that the <63 µm fraction of a sediment sample is considered to represent that portion which is available for uptake by biota. Removal of the 2 mm sediment fraction analysis was considered somewhat acceptable in this instance as analysis of the <63 µm sediment fraction had been undertaken for several successive AMMPs which provided a historic data set for comparison. However, quantification of the percentage contribution of the <63 µm sediment fraction at each site was considered necessary to facilitate the practical comparison of results between sites.

Regarding aiming to align the analysis with other MRM sediment programs, the IM notes that both the AMMP and the TSA program have changed this year (removing analysis of the <2 mm fraction), but both the nearshore and fluvial sediment programs have analysed only the <63 μm fraction during previous operational periods. The IM acknowledges that the bioavailable fraction is of most interest and that weak acid extraction is appropriate (Simpson and Batley, 2016; p57). Analysis of the <63 μm fraction (with its larger surface area per unit weight than the <2 mm fraction) is also appropriate as a conservative approach. The IM commends IPE's (2018a, 2018c) approach of quantifying the percentage contribution of this sediment fraction to allow comparison between sites and to more accurately assess risk to biota (noting that analysis of the <63 μm fraction needs to continue). It is recommended that this approach be continued in both the AMMP and the TSA program.

Changes to Marine Sediment Sampling Sites

In relation to the removal of sampling sites SEPI 8, 9, 10, 11 and 12 (all on the eastern side of North and Centre islands) from the 2017 AMMP at the request of MRM, IPE (2018a) has commented:

> Monitoring of these sites aimed to detect any potential effect from the near sinking of a zinc concentrate transfer barge in the eastern Gulf of Carpentaria. After 10 years of sampling these sites, however, and based on the data collected, the likelihood of waters in the vicinity of the BBLF being influenced by this incident was considered to be low.

The IM concurs with this statement and notes that sediment results from these sites have included no exceedances during at least the past five years. While SEPI 8 to 12 had value as reference sites, the data collected from these sites to date along with their replacement by four new sites discussed below is acceptable.

Regarding the addition of four new sampling sites within the SEPI (Black Island, Manta Point, South West Island and 2nd Creek), east of Bing Bong Loading Facility but further to the west than the removed SEPI sites, IPE (2018a) has advised:

> Noting the net westerly movement of water currents in the area, and that output from the McArthur River has a major bearing on nearshore waters in the vicinity of the BBLF, new survey sites to the east of the BBLF were considered necessary to determine potential sources of analytes should elevated concentrations to the east of the BBLF be detected.

Site 105 was moved 1.5 km to the south in an attempt to capture a wider range of biota for analysis, as biota had been consistently difficult to obtain at the previous location (IPE, 2018a). The IM considers this change to be acceptable.

Recommendations

Recommendations to address these new issues, where applicable, are included in Section 4.12.5 along with recommendations that are ongoing (and in some cases have been modified).

4.12.4.3 Successes/Improvements

Soils

In the 2017-2018 operational period, successes or improvements relating to surface soils include the following:

- As for the previous period, no exceedances of HILs were recorded in the period October 2016 to October 2017, including from sites within 1 km of the ore crushing plant/ROM pad.
- Improved results were recorded at a number of sampling locations within 1 km of the ore crushing plant:
  - Sites S23 and S27 had no EIL exceedances in subsoils during Q2 2017.
  - Surface soil results for Cu, Pb and Zn at site S24 reduced by more than half between 2016 and Q2 2017. In Q4 2017, Cu results remained steady while Pb and Zn results improved further.
  - Site S27 surface Zn results reduced from 208 mg/kg to 73 mg/kg between 2016 and Q2 2017. This site was not sampled in Q4 2017.
- Results for Zn in surface soils also improved within 2 km of the TSF at site S42, where results more than halved from 2016 to Q2 2017, and again to Q4 2017 (when S42 was replaced by S51 slightly further to the north).

However, the ability to identify successes or improvements in this operational period has been limited by the extensive changes to the soil sampling program during 2017.

Fluvial Sediments

In the 2017-2018 operational period, improvements relating to fluvial sediments include the following:

- No EC results exceeded 1,000 μS/cm in 2017, whereas in 2016 sites FS18 and FS24 had elevated results of 2,660 and 4,520 μS/cm respectively, and in 2015 several sites exceeded this level. Site FS24 (on Surprise Creek, upstream of FS18) had a much-improved EC result of 790 μS/cm in 2017. According to ANZECC/ARMCANZ (2000), EC results of <1,000 μS/cm (in soils and irrigation water) are tolerated by the majority of plants. On this basis, the IM considers the maintenance of EC results below this level as a good benchmark for fluvial sediments on site, and commends the 2017 results.

- The completion of the MIA sump construction during 2017, and the imminent completion of the associated inlet culvert and drainage works, are commended. The upgrades to sediment containment and diversion structures surrounding Barney Creek haul road bridge are also commended.

- Only one minor exceedance of an SQG-high value was recorded, again at FS19 at the haul road bridge, for Pb after strong acid digestion. Results from FS19 have continued to improve for both Pb and Zn, as well as EC, implying that current MRM management actions have stabilised the issues at this location. The IM commends MRM on the improvements to date.

- Also in the Barney Creek diversion channel, metals results at FS06 improved, as did results at FS03, with improvements in Pb as well as Zn after weak acid digestion.

- Potentially bioavailable As and Cd results were well below relevant guideline levels at all fluvial sediment sampling locations.

Marine Sediments

In the 2017-2018 operational period, improvements relating to marine sediments include the following:

- Trans-shipment area sediment results continued to demonstrate low risk, being well below SQV values.

- There were no exceedances of SQGV criteria for As or Cd in either the AMMP or the nearshore program.

- In the AMMP, results for As outside the swing basin to the east improved from 2015 to 2016, and from 2016 to 2017, with all potentially bioavailable As results well below the SQGV. Exceedances of SQGVs for Pb and Zn were confined to the swing basin in 2016 and 2017.

- In the nearshore program, there were no Pb exceedances outside of Zone 2, and mean metals concentrations in each zone remained well below the relevant SQGVs.

4.12.5 Conclusion

The 2017-2018 IM review has found that while there are ongoing issues relating to soil and sediment at the mine site and in the vicinity of Bing Bong Loading Facility, with a few exceptions, results are stable or improving. Management practices and most monitoring programs continue to improve, however the changes to the soil program during 2017 are of concern due to the potentially compromised ability to compare results between years and lack of consideration of soil contamination sources other than dust, such as groundwater seepage, runoff/deposition of sediment and/or spillages of mine-derived materials.

Ongoing and new IM recommendations related to soil and sediment issues are provided in Table 4.63. Recommendations have been categorised as either high, medium or low. High priority recommendations focus on the need to review the approach to management and reporting of exceedances in conjunction with DPIR, the issue of ongoing Tl exceedances at BBDDP, and the need to reinstate soil control sites.

Table 4.63 – New and Ongoing Soil and Sediment Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Exceedance/ incident reporting	♦ Ongoing reporting of exceedances via annual OPRs is a minimum requirement. Exceedances should not be treated as 'normal', but rather be reviewed and investigated as part of annual reporting. Where appropriate, new or revised management measures should be implemented to address the identified issues in the next period ♦ MRM and DPIR should review this matter to reach an agreed position whereby appropriate criteria are established, legal requirements are met, an appropriate level of environmental protection is achieved, and bureaucratic burdens are minimised. A process such as a trigger action response plan may be appropriate to deal with ongoing exceedances, identifying under what circumstances certain actions should apply	High
Sediment monitoring data – assessment	The next version of the MMP, as well as future marine sediment monitoring reports, should reference Simpson and Batley (2016), which has superseded both Simpson et al. (2013) and ANZECC/ARMCANZ (2000), with regards to sediment quality guidelines	Low
Soil, fluvial sediment and marine sediment monitoring program – reporting	♦ QA/QC control data for sample analyses, and subsequent discussion, should be presented in the next version of the MMP ♦ While the IM notes that some discussion of QA/QC is now provided in all soil and sediment monitoring reports, this should be improved in the next operational period ♦ The QA/QC discussion for the surface water quality monitoring program in the current MMP (MRM, 2015a) provides a possible model for the soil/sediment programs. QA/QC should include trip blanks, records of holding time compliance, and method blanks, laboratory control spikes and matrix spikes	Medium
General data interpretation and reporting	♦ A reconciliation/discussion of actual versus proposed/committed sampling events should be provided as part of all future soil and sediment reporting periods ♦ The rationale for monitoring program changes should be considered and reported on a site-by-site basis. The range of potential contamination sources should be considered along with historical trends. If a site is known to have exceedances, the reasons should be assessed, and monitoring should continue at such a location unless there is a clearly stated reason to cease. Where it is necessary to move a monitoring site, a consistent and rational approach must be applied to site identification to minimise confusion and ensure that genuine comparison of results can be made across sampling periods	Medium

Table 4.63 – New and Ongoing Soil and Sediment Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Surface soil monitoring	Monitoring of surface soil at control sites S10 (original location as per Q2 2017 and earlier) and S04 should be reinstated in 2018	High
Tl in nearshore sediment at BBDDP	The cause of exceedances of interim criteria for Tl within nearshore sediments at BBDDP should be investigated and the ecotoxicological implications of the data presented, with advice on required actions if Tl is found to be elevated due to MRM activities. This should include analysis of Tl within the dredge spoil ponds (potentially in 2019 as part of MRM's proposed geochemical investigation of the dredge spoil), and in swing basin sediments as part of the AMMP, in addition to fluvial sediments at the mine site as discussed	High
New Items		
Fluvial sediments – potential impacts of January 2018 rainfall event	In the 2018 fluvial sediment assessment, results for sites FS26, FS34 and FS24 should be reviewed in relation to the potential impacts of runoff incidents from parts of the NOEF following the January high rainfall event	Medium
Fluvial sediments – analytes	The next fluvial sediment report should explain the rationale for inclusion or exclusion of total sulfur as S, NAPP (ANC/MPA) and NAG in the program	Low
Nearshore sediments – Zone 5 Zn exceedances	In the 2018 nearshore sediment assessment, Zn results in Zone 5 should be reviewed. If they continue to be elevated, the source should be investigated	Medium
Nearshore sediments – interim values	The next nearshore sediment assessment report should advise the calculation method for interim criteria	Low
Marine sediments – contribution of sediment fractions versus concentrations	The approach used in 2017 in both the AMMP and the TSA programs of quantifying the percentage contribution of the <63 μm sediment fraction to allow comparison between sites and to assess risk to biota should be continued in 2018 (noting that analysis of the <63 μm fraction should continue)	Medium

4.12.6 References

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4.13 Dust

4.13.1 Introduction

This section addresses MRM's performance during the reporting period with regards to management of dust and is based on review of:

- Notes of observations and discussions with MRM personnel during the site inspection in May 2018.
- Various reports prepared by MRM and its consultants.
- Responses by MRM to recommendations raised in the previous IM report, as well as responses to comments raised by DPIR.

4.13.2 Key Risks

The key risks associated with dust as described in the risk register (Appendix 1) are:

- Fugitive dust emissions from operations at the ROM pad, crushed ore stockpile and bulk concentrate stockpile, and from spilled materials surrounding the process plant at the mine site, which may lead to heavy metal contamination of water and sediments in receiving waterways and diversion channels, and subsequently, bioaccumulation in freshwater biota.
- Dust emissions from exposed areas of the TSF, NOEF, WOEF, SOEF and haul roads, which may cause water, sediments and biota in receiving waterways and diversion channels to be exposed to heavy metal contamination.
- Generation of dust during loading of concentrate onto transport vehicles at the mine site and during transport to Bing Bong Loading Facility, which may cause heavy metal contamination of water and sediment in diversion channels and waterways, with potential impacts on biota.
- Emissions of dust from the Bing Bong Loading Facility concentrate storage shed and associated road vehicles and/or from the dredge spoil ponds to the marine environment, which may result in heavy metal contamination of seawater, marine sediments and marine biota[1].
- Generation of dust during loading of concentrate onto the MV Aburri at Bing Bong Loading Facility and from the MV Aburri onto export vessels in the trans-shipment area, which may lead to contamination of seawater and marine sediments, and bioaccumulation in marine biota.

[1] An additional potential source of dust external to MRM's operations is the adjacent iron ore stockpile and loading conveyor previously operated by Western Desert Resources (WDR), situated immediately to the northwest of Bing Bong Loading Facility, which ceased operations during 2014. This facility was acquired In November 2017 by Nathan River Resources Pte Limited, and recommenced shipping of iron ore during Q2 2018 (British Marine, 2018; Fabri, 2018).

4.13.3 Controls

4.13.3.1 Previously Reported Controls

General Controls

Measures to control dust at the mine site include (MRM, 2017a):

- Hauling on unsealed roads: watering of haul road surfaces and prevention of material being spilled on haul roads.
- At the TSF:
  - Capping of TSF Cell 1 with a clay layer to minimise generation of tailings dust.
  - Tailings deposition via 47 spigots around the periphery of Cell 2, where these spigots are operated on a rotation/cycle of approximately 35 to 40 days to keep the exposed tailings surface at least periodically damp, thereby reducing dust generation.
- Material extraction (mining)/unloading: application of water using dust suppression sprinklers on areas that are dusty prior to extraction/mining; water truck with water cannon to supply selective dust suppression when required.
- Exposed areas and stockpiles:
  - Regular watering of cleared or exposed areas and stockpiles, where appropriate.
  - A concrete base at the mine site external concentrate storage area (bulk concentrate stockpile), which is graded towards contaminated water drainage systems.
- At the NOEF: operation of two water carts that spray the operating ‘muck piles’, roads and dumps. Compacted clay liners/advection layers assist in encapsulating potentially contaminated materials that could be mobilised via wind. Areas of OEFs are rehabilitated as soon as feasible.
- Mill/processing plant:
  - Enclosed facilities with internal water sprays at feeder, crusher, conveyor and transfer points. Water sprays, enclosures and windbreaks are used for crushers and screens.
  - Double-layered skirting on horizontal rubber guarding.
  - A dust extraction system fitted to the secondary tertiary crusher building.
  - Water sprays to minimise dust when unloading ROM to hopper, and manual implementation of water sprays and/or water cart around the general area during dusty periods. Use of a mini street-sweeper around the process plant to remove small spills.
- A dust extraction system in the concentrate shed (consisting of an extraction fan and a wet scrubber) to reduce particulate emissions from the shed.

- A vehicle washdown facility for all vehicles prior to leaving the mine site for Bing Bong Loading Facility and other destinations.

Measures to control dust at the Bing Bong Loading Facility include (MRM, 2017a):

- Doors on the concentrate shed to reduce fugitive emissions (during the 2014, 2015, 2016, 2017 and 2018 site visits, the IM was informed that at least some of the doors were not operational and remained open at all times – this ongoing issue is discussed in Section 4.13.4.2).
- A system designed to maintain a negative pressure differential in the concentrate shed, with dust extraction around the main entry and exit points, from which extracted air passes through a bag house filter. This system is intended to reduce fugitive dust emissions during transport vehicle unloading, moving concentrate and loading the MV Aburri. (The current effectiveness of this system is limited – this issue is discussed in Section 4.13.4.2).
- Covered, height-adjustable conveyor belts at the loading facility, along with a funnel, to minimise fugitive dust emissions during loading of concentrate to the MV Aburri. The vessel hold is sealed to prevent wind affects on dust.
- Covers on concentrate transport vehicles.
- The concrete apron (at the ship-loader) is washed down following completion of each ship-loading event (except when the next event is scheduled shortly afterwards). Contaminated wash-down water is directed to a sump.
- A truck wheel wash to minimise dust emissions from heavy vehicles leaving the facility.

Monitoring Program

As noted in MRM (2015a), the MRM dust monitoring program aims to:

- Assess the concentration of particulate contaminants in the ambient air around the mine site and Bing Bong Loading Facility, and compare these concentrations to national guidelines.
- Assess the effectiveness of the current dust controls in place at both locations.
- Provide data to justify additional dust controls if necessary, to ensure that the values of the surrounding environment (including McArthur River and the marine environment) are protected.

The 2018 OPR (MRM, 2018a) states that the objectives of the program are ‘minimisation of air quality related impacts with respect to human health and the environment’ and to ‘measure the concentration of contaminants in the ambient air near the operational areas of the mine and the Bing Bong Loading Facility and to determine the effectiveness of the air quality controls’.

The key elements of the dust monitoring program include:

- A network of air quality monitoring sites at the McArthur River Mine (Figure 4.47) and Bing Bong Loading Facility (Figure 4.48), as reported by TAS (2017a; 2018).

DUST MONITORING LOCATIONS - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.47

Source: TAS, 2017a and 2018

DUST MONITORING LOCATIONS - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.48

Source: TAS, 2017a and 2018

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Monitoring locations have been selected on the basis of the prevailing wind directions and potential sources of fugitive dust emissions. Changes to the monitoring network within the reporting period are discussed in Section 4.13.3.2.

- Up until March 2017 (TAS, 2017a), low-volume portable air samplers (referred to as 'Dust MiniVol' (DMV) samplers) were deployed at all dust monitoring sites, typically monthly for a 24-hour period. The samplers collect ambient dust (i.e., airborne particulate matter) with an aerodynamic diameter equal to or less than 10 µm ($\leq PM_{10}$). Samples from DMV units are analysed for parameters associated with airborne particulate matter, including total suspended particulates (TSP), and particulate base metals: Pb, Zn, Mn, Cu, Cd and As (in PM_{10}). Changes to the DMV program since April 2017 are described in Section 4.13.3.2.
- Throughout the reporting period, additional air quality monitoring included:
  - A High Volume Air Sampler (HVAS01) at the mine site near the processing facilities, between the primary crusher and Barney Creek, to increase the frequency, duration and accuracy of dust monitoring in this area. The HVAS is used to measure TSP concentrations in ambient air, at a greater volume per period than DMV samplers. The HVAS monitoring is conducted approximately every six days for a 24-hour monitoring period.
  - Tapered Element Oscillating Microbalance (TEOM) units – one at the mine site near the accommodation facilities (MRM TEOM, renamed TEOM01 in 2017) and one at Bing Bong Loading Facility (BBTEOM, renamed TEOM02 in 2017) – are used to continuously measure concentrations of particulates (PM_{10}), recorded at approximately five-minute intervals, with 'live' data transfer. These units are also fitted with weather monitoring equipment.
  - Sulfur dioxide (SO_2) monitoring to the west of the NOEF at the 'SO_2 Caravan NOEF' site[2].
- Quality assurance/quality control (QA/QC): duplicate sampling and field blank sampling were undertaken for dust monitoring (DMV) sites at both McArthur River Mine and Bing Bong Loading Facility during the operational period (TAS, 2017a; 2018).

Changes or additions to the monitoring programs are discussed in the following section.

4.13.3.2 New or Changed Controls in the Reporting Period

Existing

NOEF LGO Dust Management Plan

In response to a dust incident and a subsequent request from DPIR, MRM developed a Dust Management Plan (DMP) for reclamation of the low grade ore (LGO) and waste rock located at the NOEF (MRM, 2016a). As part of this DMP, three temporary DMV monitoring sites

[2] The impacts of SO_2 primarily relate to human health, thereby being outside the scope of this report.

(LGO_West, LGO_East and LGO_South; see Figure 4.47) were established in the vicinity of the NOEF. These, along with pre-existing monitoring sites DMV30, DMV43 and DMV45 (to the north, south and west of the NOEF, respectively) were sampled 11 times between 5 October and 22 November 2016 (TAS, 2017). The LGO sites were discontinued after this period, and the DMP has since been superseded by the Air Quality Management Plan (AQMP) (MRM, 2017a).

Air Quality Management Plan

A formal and comprehensive AQMP was developed during the reporting period by MRM in consultation with air quality specialists Todoroski Air Sciences (TAS) and DPIR. Key points to note are (MRM, 2017a):

- The AQMP states that its focus is ‘to establish an air quality monitoring and management system that demonstrates MRM operations are not resulting in off-site exceedances of human health air quality standards at relevant receptor locations’.
- The AQMP superseded the previous Air Quality and Greenhouse Gas EMP, which was a much more succinct plan presented in Table 24 of the 2015-2016 OPR (MRM, 2016b).
- The AQMP serves as a formal dust mitigation plan for both the mine site and the Bing Bong Loading Facility, targeting the most impacted areas as identified by previous monitoring, and is intended to support ongoing improvements in the monitoring and management of air quality at both sites. Performance in accordance with this document will be reviewed and reported annually.
- The AQMP describes a revised and consolidated monitoring network and management measures for air quality in the vicinity of the mine and the loading facility. Implementation of the revisions to the monitoring network began in mid-2017, although the AQMP was finalised in September 2017 (MRM, 2017b).
- As part of the AQMP, a decision tool for visual dust triggers and associated management actions has been developed and implemented at the mine site, relating to various work areas/equipment (Figure 4.49).
- The AQMP also includes a trigger action response plan (TARP) with operational performance indicators identified for a subset of monitoring locations, and associated response protocols in the event of an exceedance. The TARP goals include maintaining or improving air quality surrounding the mine and the loading facility. The TARP includes:
  - Monitoring of real-time PM_{10} at TEOM sites, with a trigger of rolling 24-hour PM_{10} >50 $\mu g/m^3$ for three consecutive hours.
  - Monitoring at depositional dust gauge (DDG) sites 15, 43, 47, 54 and 55, and BBDDG01 and 02, with an objective of no increase compared to historic dust deposition.
  - Monitoring at DMV25, BBDMV01 and BBDMV02, with a trigger of average Pb >0.5 $\mu g/m^3$ and/or Zn >120 $\mu g/m^3$ in 24-hour PM_{10} (another part of the AQMP, outside of the TARP, implies that these results are also to be compared against historical data).

VISUAL DUST TRIGGERS AND ASSOCIATED ACTIONS

McArthur River Mine Project

FIGURE 4.49

	Normal State		Level 2 Triggers		Level 3 Triggers	
Work Area/ Equipment	**Trigger**	**Action/ Response**	**Trigger**	**Action/ Response**	**Trigger**	**Action/ Response**
Haul trucks / haul roads	Dust below wheel height 	• Continue work/ tasks as normal. Maintain dust suppression activities. • Continue to monitor operation	Dust above wheel height, but below tray height. 	• Truck Operator to reduce speed & notify water cart operators for additional dust suppression. • Limit grading activities. • Consolidate haul roads and dumps in use. • Reduce haul distance if possible. Shut non-essential roads.	Dust above tray height 	• Truck operators to notify Mining Supervisor and STOP work. • Mining Supervisor to call for additional dust suppression. • Work to resume once water cart operator has advised roadway is adequately watered.
Water carts	Normal operation	• Water carts to be manned as required. Services to be planned for night shifts. • Zone watering technique to be applied where possible.	Minor breakdown(s)	• Water carts to be hot seated during crib breaks. Limit grading activities. • Consolidate haul roads and dumps in use. Reduce haul distance if possible. • Shut non-essential roads.	Major breakdown(s)	• Water truck operators to inform supervisor if they cannot control dust. • Work to resume once water cart operator has advised roadway is adequately watered.
Dozers / Dumps		• Continue work/ tasks as normal. Continue to monitor operation		• Dozer operator / Supervisor to limit activity to leeward side of area. • Reduced drop height of material. • Cease non-essential activities and operations in wind exposed areas. • Limit travel speeds. • Water work areas		• Limit dumping to paddock dumping only. • Dozer operators to notify Mining Supervisor and STOP where paddock dump unavailable. • Work to resume only when controls are sufficient or weather conditions permit.
Loaders/ Excavators		• Continue work/ tasks as normal. • Continue to monitor operation		• Mining Supervisor to ensure sprinkler system functioning correctly. • Limit tramming or pushing distances. • Limit number of operations being conducted. • Increase watering of area. • Change material type		• Dust suppression system to be checked for operational issues and maintenance requirements. • Only recommence work if the sprinkler system is operable, site preparation is adequate and weather conditions permit. • Change material type
Drills	No dust visible below deck height 	• Continue work/ tasks as normal. Maintain dust suppression activities. • Continue to monitor operation	Dust visible at deck height. Sporadic event. 	• Drill operators to ensure dust suppression system functioning correctly. • Mining Supervisor monitor conditions. • Assess impact of weather conditions and modify operations as required.	Persistent emissions of dust above deck height. 	• Drill operator STOP operations. • Dust suppression system to be checked for operational issues and maintenance requirements. • Only recommence work if the dust suppression system is operable, site preparation is adequate and weather conditions permit.

Source: MRM, 2017a.

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- Response actions for all sites commencing with a data validity check, review of wind direction data to confirm possible source/s, and/or review of data from upwind monitors, if applicable.
- A range of contingency measures if emissions appear to be related to mine operations, to be implemented progressively in three stages until subsequent monitoring shows results are below the relevant trigger level or dust emissions are reduced at the source.
- More straightforward contingency measures if emissions are related to loading facility operations, to be applied depending on the source (concentrate shed, roads, or conveyors).
- For DMV and DDG sites, as neither triggers or responses are real-time, MRM is to establish the potential level of risk based on analysis of other relevant monitoring data (e.g., for DDG sites, review water quality and/or fluvial sediment monitoring data to establish potential risks to water quality/sediment quality; for DMV sites, review TEOM data and indicative Pb:PM_{10} ratio established from other DMV monitoring).
- For all sites, MRM will record actions undertaken to reduce emissions and their effectiveness, as well as conditions resulting in the exceedance/s, to inform ongoing management.

General Dust Controls Newly Documented in the AQMP

New dust controls implemented at the mine site in the 2017-2018 operational period, as per the AQMP (MRM, 2017a), are as follows[3]:

- Hauling on unsealed roads:
  - Trafficable areas clearly marked and minimised, and vehicle movements restricted to these areas; speed limits on all roads. Trafficable areas and vehicle manoeuvring areas regularly maintained, and disused roads rehabilitated as soon as practicable.
  - Visual monitoring and inspections of dust to determine control effectiveness.
- Material extraction/unloading:
  - Minimisation of the double handling and stockpiling of material.
  - Minimisation of fall distance of materials during loading and unloading.
  - Operations relocated/rescheduled during high dust periods, where practicable.
- Dozer and grader operation:
  - Dozer and grader use avoided during unfavourable conditions (i.e., high wind speeds), and travel speed minimised in dusty conditions.

[3] Although some of these controls may have been implemented during previous reporting periods, they are newly documented in the AQMP.

  - Travel on defined routes between work areas with pre-watering of route where feasible.
  - Visual monitoring and inspections of dust levels from dozer operations.
  - Watering of haul roads immediately after grading where possible.

- Exposed areas and stockpiles: minimisation of disturbance areas to the extent necessary for mining, and stabilisation of areas inactive for long periods.
- Mill/processing plant:
  - Fitting all conveyors with appropriate cleaning and collection devices. Areas where spilt material can build up (e.g., under transfer chutes/conveyors) are regularly cleaned.
  - Slower tipping at ROM hopper during adverse weather conditions, and minimising drop heights when stacking.
  - Using visual triggers for implementation of further dust mitigation; visual surveillance of dust plumes during activity.

New dust controls implemented at the Bing Bong Loading Facility in the reporting period include:

- Spraying roads with water at least once per day during the dry season (MRM, 2017a).
- Sampling of concentrate and analysis/monitoring of the 'transportable moisture limit' (TML) of the product prior to transporting to Bing Bong Loading Facility and/or prior to loading of the MV Aburri or transfer to bulk carriers in the trans-shipment area, with a target level of 13.5% moisture by weight (Bampton, pers. comm., 15 May 2018). (While this may have been a control during previous reporting periods, the IM first learned of it during the May 2018 site visit.)

New or Changed Dust Monitoring

Extensive changes were made to the dust monitoring program as part of the development and implementation of the AQMP (MRM, 2017a), as discussed further in Section 4.13.4. These changes included:

- Between April 2017 and March 2018, 14 DMV sites in the vicinity of the mine were decommissioned, while 10 DMV sites were moved or replaced with another site within approximately 700 m of their previous location (TAS, 2018) (see Figure 4.47, Table 4.64). Section 7.1.5 (Figure 7-4) of TAS (2018) implies that the retained DMV sites include those with the most noteworthy exceedances in recent years.
- While there are now fewer DMV sites (10 in total), the sampling frequency of these monitors has increased from 24 hours once per month to approximately once every 12 days (TAS, 2018).
- Previous monitoring has demonstrated that while metals other than Pb and Zn (e.g., Cd, As and Hg) may be present as a component of particulate matter emissions at the mine site, the emissions of these metals are consistently further below their applicable criteria. As such,

MRM (2017a) has reduced monitoring of these metals to a 6-monthly (rather than monthly) basis, to provide ongoing confirmation of their low concentrations.

Table 4.64 – Dust Monitoring Changes at the Mine Site - 2017 to 2018

DMV Site at April 2017	DMV Site at March 2018	New DDG Site (2018)	Location/Comment
Removed Sites (No Nearby Replacements)			
DMV03	Nil	Nil	No nearby replacements
DMV08			
DMV12			
DMV13			
DMV17			
DMV19			
DMV20			
DMV23			
DMV27			
DMV28			
DMV31			
DMV44			
DMV46			
DMV48			
Changed and New Sites			
DMV01	DMV01	DDG01	Control, unmoved, DDG added
DMV07	Moved DMV07	DDG07	DMV07 moved approx. 500 m south of former site
DMV10	DMV10	DDG10	Control, unmoved, DDG added along with new TEOM03 and moved SO_2 van
DMV15	Moved DMV15	DDG15	Moved slightly west; new DDG
DMV22	Moved DMV22	DDG22	Moved slightly southwest; new DDG
DMV24	Nil	DDG24	Moved slightly northeast adjacent to HVAS01; DMV replaced by DDG
DMV25	Moved DMV25	DDG25	Moved slightly south adjacent to TEOM01; DDG added
DMV42	Nil	DDG51	DMV42 was to the north of the TSF near Surprise Creek, DDG51 indirectly replaces this, approx. 200 m further north
DMV43	DMV43	DDG43	Unmoved, DDG added
DMV45	Moved DMV45	DDG45	DMV45 moved approx. 500 m north of former location (with DDG added)
DMV47	Moved DMV47	DDG47	DMV47 moved approx. 200 m to southeast (DDG added)
Nil	Nil	DDG50	New site close to DMV22
Nil	Nil	DDG52	New site to south of SPROD
Nil	Nil	DDG53	New site to east of TSF
Nil	Nil	DDG54	New site to east-southeast of pit near McArthur River diversion channel
DMV32	New site DMV55	DDG55	South of pit near McArthur River diversion channel, DMV/DDG55 replaces DMV32 approx. 200 m further south

Table 4.64 – Dust Monitoring Changes at the Mine Site - 2017 to 2018 (cont'd)

DMV Site at April 2017	DMV Site at March 2018	New DDG Site (2018)	Location/Comment
Changed and New Sites (cont'd)			
DMV05; DMV06	Nil	DDG56	DMV05 and DMV06 were to the west-southwest and south of the WMD; new site DDG56 indirectly replaces both, approx. 700 m northwest of the DMV06 former location

- Commencing in January 2018, 17 new DDG monitoring sites were established at the mine, including at both control sites (see Figure 4.47, Table 4.64). Nine of these are joint DMV/DDG locations and four are in new locations that do not replace or add to a pre-existing DMV site. The DDG units are typically sampled monthly. The collected material (deposited dust, as opposed to ambient/airborne dust monitored by the DMV units) is subjected to gravimetric analysis to determine the total insoluble matter in g/m^2/month. Metals are analysed by inductively coupled plasma-atomic emission spectrometry (ICPAES), reported in milligrams per kilogram (mg/kg) (TAS, 2018). The dust deposition criteria applied to DDG results as per MRM (2017a) are sourced from the NSW EPA (2016), which itself references NERDDC (1988).

- Four DMV sites (BBDMV03, 04, 05, 07) were decommissioned at Bing Bong Loading Facility, with all but BBDMV05 replaced with DDG sites. Two DDG sites were established in conjunction with the retained BBDMV01 and 02, while a sixth DDG site was established near the entrance road to the west (see Figure 4.48).

- In addition to the existing TEOM units at the mine site (TEOM01) and at Bing Bong Loading Facility (TEOM02), a third TEOM unit (TEOM03) was established to the north of the mine site, adjacent to control site DMV/DDG10, to act as a control site (MRM, 2017a).

- In agreement with the NTEPA, the Borroloola and Devils Springs SO_2 monitors were decommissioned in September 2016 (just prior to the reporting period) given the very low concentrations recorded at those sites (MRM, 2017b). The Borroloola SO_2 monitor was subsequently relocated to the MRM Caravan NOEF monitoring site, with SO_2 monitoring conducted at that site between April 2017 and July 2017. This monitor was then relocated to the DMV/DDG10 location some 4.5 km further north-northeast, and renamed the Van SO_2 monitor (TAS, 2018).

- Provision of HVAS and TEOM results and analysis for the current reporting period are presented in the 2016-2017 and 2017-2018 OPRs (MRM, 2017b; 2018a) and discussed in Section 4.13.4 of this report. Raw data for the 2016 operational period was previously supplied to the IM for these monitoring sites but analysis had not been provided as at the time of the 2017 IM report. The above-mentioned OPRs along with the AQMP now include a TSP criterion to facilitate interpretation of results from the new HVAS unit.

- An independent third party consultant (EcoMetrix) was engaged by MRM (in response to an instruction by the DPIR in March 2016) to investigate whether the placement and containment of mining waste at the NOEF was causing, or may cause, environmental harm to the receiving environment. EcoMetrix (2017) prepared an investigation report which included, among other matters, discussion of air quality impacts including those from dust. EcoMetrix concluded that:

> Dust from the NOEF is considered to be a potential risk only during operations and will be eliminated after closure. The results of the dispersion modelling for both ambient dust concentration and dust deposition indicate that concentrations where people reside are below criteria. This is primarily due to the distance of these receptors from [the mine].

The IM notes that these conclusions relate to the health and amenity impacts of dust, rather than environmental impacts, whereby deposition of dust during operation of the NOEF (and the mine in general) may result in ongoing impacts to soils and watercourses (and subsequently, flora and fauna) after closure.

- An Air Quality Impact and Greenhouse Gas Assessment was prepared by TAS (2017b) during the reporting period to investigate the potential air quality effects and determine the greenhouse gas emissions that may arise as a result of the proposed Overburden Management Project. This project is the subject of an EIS which is pending approval and hence is not discussed in the current IM report.
- With regards to QA/QC, blank sampling was initiated for the MRM HVAS monitoring site during the operational period, and in general was undertaken monthly from January 2017 to March 2018.

The intent of the above changes to the air quality monitoring program was 'to provide more consistent results and more useful data' (TAS, 2018). The IM agrees that the increased frequency of sampling the remaining DMV sites, along with the addition of DDG sites, should contribute to this goal. However, while the previous dust monitoring network coverage was extensive, the revised program is considerably sparser. The most notable gaps in the current monitoring network are to the west of the TSF (previously occupied by DMV19 and 48), between the TSF and the processing facilities (ex-DMV08 and 27), between the TSF and the NOEF (ex-DMV12 and 13), and to the north of the NOEF (ex-DMV30). Of the mentioned sites, DMV12, 13, 30 and 48 each recorded PM_{10} exceedances (either 24-hour or annual average) within the current or previous reporting period. The advantages and disadvantages of the revised network are expected to become clearer as more data is collected in the next reporting period.

Additionally, at this time it is unclear how metals from DDG monitoring are to be assessed beyond comparison with historical levels, or how DDG sites are intended to replace DMV monitors in relation to metals monitoring (where DDG and DMV sites are not co-located), given the lack of criteria. Further discussion on DDG results in provided in Section 4.13.4.1.

Controls Planned for or Implemented After the 2017-2018 Operational Period

The following dust controls were planned during the operational period and have been or are intended to be implemented after March 2018 or in later operational periods (and hence will be addressed in future IM reports as appropriate):

- By the time of the 2018-2019 OPR, sufficient data is expected to be available from the newly installed DDG units to allow an in-depth review to be included. This may enable improved assessment of the relationship between contaminant levels in dust and soil (MRM, 2018a).

- Additional, real-time PM_{10} monitoring will be measured using six 'E-samplers' (i.e., portable light-scattering aerosol monitors). These monitors (to be labelled 'DRT') are initially proposed to be situated alongside sites DDG15, 22, 43, 52, 53 and 55, however they are able to be relocated according to changes in the location of major activities (or areas known to be impacted by dust) occurring at the mine (MRM, 2017a). This is intended to assist with reactive management responses as dust issues arise.

4.13.4 Review of Environmental Performance

4.13.4.1 Incidents and Non-compliances

Incidents

No incidents were reported by MRM between October 2016 and March 2018 in relation to dust.

Regarding the NOEF dust incident in July of the 2016 operational period (discussed in the previous IM report (ERIAS Group, 2017), related to reclamation and cartage of low-grade ore and waste rock from the NOEF, these operations were completed in the first two months of the current operational period. A report that addressed this reclamation (MRM, 2016c) was submitted to DPIR in December 2016 and concluded that the mitigation measures and control strategies implemented as per the NOEF West A Reclamation Dust Management Plan (MRM, 2016a) had been successful in minimising the dust levels from the NOEF during this period. Results showed that reclamation activities did not discernibly increase dust emissions around the site. However, the results highlighted the requirement for further dust mitigation measures in the vicinity of Barney Creek haul road bridge. The MRM (2016c) report stated that initiatives for dust suppression in this area – such as the application of dust suppressants to the road surface, dust screens and further revegetation activities in the Barney Creek corridor – were to be elaborated upon within the AQMP. This was not undertaken (MRM, 2017a). The 2017-2018 OPR (MRM, 2018a subsequently noted that the application of dust suppressants to the road surface has not been progressed due to concerns regarding traction on the bridge surface.

Non-compliances

The 2013-2015 MMP (MRM, 2015b) does not contain a definitive list of commitments against which to assess non-compliances. However:

- The 2016-2017 and 2017-2018 OPRs (MRM, 2017b; 2018a) summarise the status of various commitments. This is discussed in Section 4.13.4.2.
- The IM has reviewed MRM's compliance register (environment) (MRM, 2017c), and discussion and recommendations within this chapter are consistent with that source. A summary of the dust guideline exceedances recorded at the mine site and at or near Bing Bong Loading Facility is provided in the following sections. Air quality standards as shown in Table 4.65 have been adopted by MRM (2017a).

In accordance with NEPC (2002), valid averages require a minimum of 75% data availability for the averaging period. To make a valid assessment of compliance for annual reporting, annual compliance statistics must be based on daily data that are at least 75% complete in each calendar quarter (in addition to an annual data availability of at least 75% based on valid daily data). However, years with less than 75% data availability can demonstrate non-compliance if sufficient exceedances of the standard are reported. Dust monitoring was previously conducted monthly for a 24-hour period at each DMV site, however due to site constraints, sites were not always sampled each month (TAS, 2016). As such, some statistical calculations based on daily data that were less than 75% complete in each calendar quarter (NEPC, 2002) could not be made strictly in accordance with the NEPM. The recently updated DMV monitoring program now samples, on average, every 12 days. This should enable more consistently compliant calculations of annual averages. In the interim, individual (24-hour) exceedances of the specified maximum concentrations continue to be used as thresholds for discussion of results, and to illustrate the air quality of the mine site and of Bing Bong Loading Facility and surrounds.

Table 4.65 – Adopted Air Quality Standards for Dust

Pollutant	Averaging Period	Maximum Concentration	Max. Allowable Exceedances	Source
Particulates as PM_{10}	24 hours	50 µg/m^3	None	NEPC (2016)
	1 year	25 µg/m^3	None	NEPC (2016)
TSP	1 year	90 µg/m^3	-	NSW EPA (2016)
Deposited dust (as total insoluble matter)	1 year	2 g/m^2/month (maximum increase in dust level)	-	NSW EPA (2016)
		4 g/m^2/month (maximum total dust level)		
Pb*	1 year	0.5 µg/m^3	None	NEPC (2016)
Zn	24 hours	120 µg/m$^{3\#}$	-	Ontario MOE (2012)
As	24 hours	0.3 µg/m$^{3\#}$	-	Ontario MOE (2012)
Cd	24 hours*†	0.025 µg/m$^{3\#}$	-	Ontario MOE (2012)
Cu	24 hours	50 µg/m$^{3\#}$	-	Ontario MOE (2012)
Mn	24 hours	0.2 µg/m^3 (Mn in PM_{10})# 0.4 µg/m^3 (Mn in TSP)#	-	Ontario MOE (2012)

* The Ontario MOE (2012) criterion for Pb in a 24-hour averaging period (0.5 µg/m^3) was previously applied by MRM (TAS, 2016) in addition to the annual criteria, and is used in this report for interpretive purposes.
# Ambient air quality criteria (AAQC) which is defined as 'a desirable concentration of a contaminant in air based on protection against adverse effects on health or the environment' (Ontario MOE, 2012).
† Cd criterion is below the DMV limit of reporting (LOR).

A summary of the individual 24-hour air quality exceedances from DMV units at the mine site and Bing Bong Loading Facility during the operational period is provided in Table 4.66. The 2017 and 2018 ambient air monitoring reports (TAS, 2017a; 2018) respectively present dust monitoring data collected in June 2016 to May 2017, and April 2017 to March 2018. Where possible, data from outside the operational period (commencing in October 2016) has been excluded from the following discussion.

The use of NEPM criteria was initiated by MRM during the 2014 operational period, and the IM has used these criteria for discussion of performance in the absence of any other criteria. However, it is acknowledged that NEPM standards have not been designed to apply to monitoring locations situated next to mining activities.

Table 4.66 – 24-hour Air Quality Exceedances in the 2017-2018 Operational Period

Monitoring Group	Site	Exceedances of the Mean Maximum Concentration Within a 24-hour Monitoring Period			
		PM_{10} ≥50 µg/m^3		Pb ≥0.5 µg/m^3	
		Days/ Total*	Results (Month/Year)	Days/ Total*	Results (Month/Year)
McArthur River Mine					
<1 km from processing plant	DMV22#	6/26	74.86 (11/16); 50.55 (07/17); 154.93, 136.56 (09/17); 96.16 (10/17); 51.88 (12/17)	14/26	0.81 (11/16); 0.79 (12/16); 0.61 (07/17); 0.55 (08/17); 5.40, 0.78, 2.49 (09/17); 2.63, 1.12 (10/17); 0.83, 1.20 (11/17); 0.87, 0.69 (12/17); 0.66 (02/18)
	DMV24**	-	-	2/8	0.71 (05/17)
	DMV28# **	1/8	50.28 (11/16)	1/8	0.93 (12/16)
1-3 km from processing plant	DMV25	2/29	51.53 (11/16), 75.16 (12/17)	-	-
	DMV31# **	1/5	51.39 (11/16)	-	-
	DMV32 **	-	-	1/7	0.72 (12/16)
	DMV33# **	1/6	50.00 (11/16)	-	-
	DMV55#	2/21	66.09, 53.84 (11/17)	-	-
<2 km from NOEF	DMV43†# ††	32/39	58.06, 64.44, 65.28, 65.28, 49.17, 49.17, 81.81 (10/16); 82.92, 83.06, 59.17 (11/16); 88.61 (01/17); 60.68 (04/17); 52.74 (05/17); 101.01 (06/17); 90.52, 97.67, 150.16 (07/17); 66.29, 150.61 (08/17); 98.06, 85.24, 60.88 (09/17); 55.00, 74.60 (10/17); 96.51, 80.60 (11/17); 81.64, 176.64 (12/17); 121.30 (01/18); 168.37 (02/18); 61.70, 63.17 (03/18)	1/39	0.67 (02/18)
	DMV45†#	4/40	66.53 (10/16), 62.08 (11/16), 59.75 (11/17), 206.43 (02/18)	-	-
	LGO South†# **	2/11	50.28, 60.83 (11/16)	-	-
	LGO East†# **	-	-	-	-
	LGO West†# **	-	-	-	-

Table 4.66 – 24-hour Air Quality Exceedances in the 2017-2018 Operational Period (cont'd)

Monitoring Group	Site	Exceedances of the Mean Maximum Concentration Within a 24-hour Monitoring Period			
		PM_{10} ≥50 μg/m^3		Pb ≥0.5 μg/m^3	
		Days/ Total*	Results (Month/Year)	Days/ Total*	Results (Month/Year)
McArthur River Mine (cont'd)					
<2 km from TSF	DMV07	1/30	53.88 (02/18)	-	-
	DMV13 **	1/8	61.25 (11/16)	-	-
	DMV15	1/28	112.25 (06/17)		
Bing Bong Loading Facility					
Bing Bong Loading Facility	BBDMV01	1/30	56.94 (11/16)	2/30	0.63 (08/17), 0.57 (02/18)
	BBDMV02 ††	-	-	-	-
	BBDMV04 **	1/9	54.03 (10/16)	-	-
	BBDMV05 **	1/9	74.72 (10/16)	-	-

* Represents number of days of exceedances out of total sampling events in the period, e.g., for DMV25, there were two PM_{10} exceedances and 29 sampling events in total between October 2016 and March 2018 inclusive.
† Sites with additional sampling between October and November 2017 as part of dust management associated with the NOEF LGO reclamation program.
# Sites that exceeded the annual average PM_{10} criterion (25 μg/m^3) between June 2016 and May 2017, or between April 2017 and March 2018, or during both periods; sites LGO East and LGO West exceeded the annual criterion but not the 24-hour criterion.
** Sites decommissioned during the reporting period.
†† Recorded 24-hour exceedances for Mn during the reporting period.

McArthur River Mine – DMV Results

Within the October 2016 to March 2018 reporting period, particulates as PM_{10} regularly exceeded the maximum concentration standard of 50 μg/m^3 during single 24-hour averaging periods within all monitoring groups at the mine site, except for 2-3 km from the TSF, and reference sites (see Table 4.66). Individual 24-hour exceedances were as follows:

- The majority of individual PM_{10} exceedances (38 out of 90 sampling events (42%)) occurred within 2 km of the NOEF, with 32 of these (out of 39 sampling events (82%)) at site DMV43 adjacent to Barney Creek diversion channel at the haul road bridge. This monitoring group also recorded the highest PM_{10} exceedances in the period, with 206.43 μg/m^3 at DMV45 in February 2018, and 176.64 μg/m^3 at DMV43 in December 2017. This is a significant departure from previous years (even accounting for the current 18-month reporting period), when this group only recorded three dust exceedances (out of 11 sampling events (27%), all at DMV43), and both the number and level of exceedances was highest at sites within 1 km of the processing plant. This may in part reflect:
  - Comment by MRM (2016c) that exceedances at DMV43 are attributable to the adjacent hauling activities near the Barney Creek haul bridge, while those at DMV45 are predominantly attributed to continuous construction works associated with the West Perimeter Runoff Dam (WPROD). However, these activities also occurred in the

previous operational period, and this does not explain the increases in the current period.

- Dust associated with the reclamation of LGO in the southeastern part of the NOEF in October/November 2017, and the additional sampling in the vicinity during this period, within which 15 of the 38 exceedances in this group were recorded. However, 61% of exceedances – as well as the highest exceedances – occurred outside that period.

- Site DMV45 was moved north approximately 500 m, apparently after November 2017 (MRM, 2016a), which may have influenced the results recorded.

- The decommissioning of several sites within 1 km of the processing plant, including DMV23, DMV24 and DMV28, which typically accounted for a number of exceedances (i.e., the relative number of exceedances in that group may therefore be lower than the NOEF group in the current period).

- The next largest numbers of exceedances occurred within 1 km of the processing plant (seven out of 34 sampling events (21%), of which six were at DMV22) and within 1-3 km of the plant (six of 61 sampling events (10%), across five sites). In comparison, these two groups had six of 36 (17%) and three of 20 (15%) exceedances, respectively, in the previous reporting period. Within these two groups, site DMV22 (southwest of the processing facility) continues to have the most exceedances of any site, while several of the sites with exceedances have now been decommissioned.

- There were also three exceedances (of 66 sampling events (5%), down from 9% last year) within 2 km of the TSF, to the south of the facility (DMV07, which was moved approx. 500 m south in 2017), west (DMV15) and northeast (DMV13, towards the NOEF, since decommissioned). Sites within this group that have previously had exceedances (DMV42 and 48) have now been decommissioned.

- The unusually dry months of December 2017 and February 2018 (with 35 and 62 mm of rainfall respectively, compared to the long term averages of 125 and 181 mm) (BOM, 2018) may have contributed to dust exceedances at all sites during those months (noting, however, that January was unusually wet).

Exceedances of the annual average criterion for PM_{10} (25 µg/m^3) were recorded in the same groups as the 24-hour exceedances, with TAS (2017a; 2018) reporting that, of sites that had sufficient data for an annual average calculation:

- Six sites exceeded the annual criterion between June 2016 and May 2017 (including the now-decommissioned sites DMV28, 31 and 33, along with the three LGO sites). Sites LGO East and LGO West exceeded the annual criterion but not the 24-hour criterion.

- One site (new site DMV55) exceeded the criterion only between April 2017 and March 2018.

- Three sites (DMV22, 43 and 45) exceeded the criterion during both periods.

The highest annual average PM_{10} recorded was at DMV43, with a result of 53.7 µg/m^3 between June 2016 and May 2017, increasing to 86.54 µg/m^3 between April 2017 and March 2018. The latter is more than 75% higher than the highest annual average (at site DMV22) in the previous reporting period.

At the mine site, exceedances of the standard for Pb as PM_{10} during the reporting period were as follows:

- The maximum Pb concentration standard of 0.5 µg/m^3 was again exceeded during individual 24-hour periods[4] at three sites within 1 km to the west or southwest of the processing plant (DMV22, 24 and 28; see Figure 4.47, Table 4.66). Ore/concentrate materials processed by the facilities in this vicinity are likely to be the source of these dust exceedances. While eight exceedances (out of 34 sampling events (24%)) were recorded at these three sites in the previous reporting period, there were 17 (out of 42 (40%)) in the current period.
- The highest individual Pb results recorded were 5.40, 2.49 and 2.63 µg/m^3, all at site DMV22 in September/October 2017, well above the highest result at this site in the previous period (1.67 µg/m^3 in November 2015).
- Unlike the previous reporting period, Pb exceedances were also recorded in other monitoring groups: 0.72 µg/m^3 at DMV32 near the SOEF in December 2016 and 0.67 µg/m^3 at DMV43 near the haul road bridge in February 2018.
- While noting that DMV data is not appropriate for comparison against the NEPM[5] (NEPC, 2016), TAS (2017a; 2018) has reported annual average results for Pb in relation to the annual criterion of 0.5 µg/m^3. Site DMV22 exceeded the annual criterion for Pb, with 0.85 µg/m^3 between April 2017 and March 2018.
- Unlike in previous operational periods, one Mn exceedance (0.2 µg/m^3, equal to the 24-hour criterion for Mn in PM_{10} (Ontario MOE, 2012)) was recorded at DMV43 in July 2017. There were no other exceedances of this criterion, although elevated Mn results were recorded at DMV22 twice in September 2017 (0.18 and 0.19 µg/m^3) and at DMV45 in February 2018 (0.19 µg/m^3).
- There were no other metals exceedances at site DMV43, with metals results generally well below those of the monitoring group within 1 km of the processing plant. This supports the assertion that dust issues at DMV43 primarily derive from lower grade waste rock being hauled to the NOEF. There were no exceedances of other metals criteria (Zn, As or Cu) at the mine site during the reporting period.

The latest air quality reporting does not provide commentary on exceedances other than to say that these are expected near the processing area and other mining activities, that they are more elevated during the dry season, and that DMV43 'was likely impacted by mining activity and traffic volumes on the Barney Creek bridge crossing and along the highway to complete the construction of the dam WPROD (DMV45)' (TAS, 2018). The IM recommends that at a minimum, the more

[4] The NEPC (2016) averaging period for Pb is one year, although MRM (TAS, 2016) previously also applied the Ontario MOE (2012) 24-hour average criterion for Pb (0.5 µg/m^3).
[5] Due to the criterion being applicable: a) at sensitive receptors (rather than on the mine site), and b) in relation to the TSP size fraction (rather than PM_{10} as measured by DMV units).

'noteworthy' results (such as the increased exceedances near DMV43, and the elevated Mn results at DMV43 and DMV22) should be assessed and commented on in ambient air quality monitoring reports, including specific comment on trends noted in the vicinity, existing dust controls in this area (and why they were or were not adequate to mitigate impacts), potential implications of the results in question, and any further actions that are proposed to stabilise or improve results.

The latest ambient air quality monitoring report (TAS, 2018) does not mention any instances of exceeding TARP triggers (MRM, 2017a) in the reporting period. Any such triggers in the next reporting period (at either the mine site or loading facility), along with cause/s, actions and their effectiveness, should be reported in the next ambient air quality monitoring report.

Bing Bong Loading Facility – DMV Results

Within the reporting period, particulates as PM_{10} near Bing Bong Loading Facility exceeded the maximum concentration standard of 50 µg/m^3 during single 24-hour averaging periods once at each of BBDMV01 (northeast of the concentrate shed), BBDMV04 (in the western half of the dredge spoil ponds) and BBDMV05 (west of the concentrate shed), all within the 2016 dry season (see Table 4.66, Figure 4.48).

Sites BBDMV03, 04 and 05 exceeded the annual criterion for PM_{10} (25 µg/m^3) in the period June 2016 to May 2017 (TAS, 2017a). These three sites, along with BBDMV07, were all decommissioned during 2017, with all but BBDMV05 being replaced by DDG sites. Given this, only sites BBDMV01 and 02 had sufficient data for an annual average calculation in 2018, with neither exceeding the annual PM_{10} criterion for the period April 2017 to March 2018 (TAS, 2018). While the commencement of DDG monitoring at BBLF is expected to be useful in identifying dust depositional trends, it is unclear why four DMV sites were decommissioned or replaced.

With regards to metals, the Pb (as PM_{10}) maximum 24-hour concentration standard of 0.5 µg/m^3 was exceeded during individual periods at BBDMV01 in August 2017 and again in February 2018 (see Table 4.66). These were of a similar magnitude to Pb exceedances at Bing Bong Loading Facility in the previous reporting period, although to the northeast rather than the northwest of the concentrate shed.

Unlike the previous reporting period, exceedances of the 24-hour Mn criteria (0.2 µg/m^3) were recorded at BBDMV01 and at BBDMV02 (0.22 and 0.24 µg/m^3 respectively), both in January 2018. The latter site had no exceedances of PM_{10} or Pb criteria.

There were no exceedances of 24-hour criteria for other metals, or of annual average criteria for any metals including Pb, at the Bing Bong Loading Facility during the reporting period.

DDG Results

The first three months of DDG data are presented in TAS (2018). Annual average calculations are not possible at this time. Total insoluble matter, Pb and Zn concentrations results are presented graphically, while detectable Pb, Zn, Mn, Cd and Cu mass fractions collected from the DDG monitors (where sufficient mass was available for the analysis) are tabulated.

It appears from the chart of total insoluble matter that six sites exceeded the adopted criterion of a maximum increase in dust level per month of 2 g/m^2. It is difficult to determine which sites these are, due to similarities of colour coding for the 16 sites for which data is graphed. The IM recommends that such charts should be more clearly labelled, and that data should be tabulated along with written interpretation of results in relation to criteria and/or background levels. EcoMetrix (2017) recommends that natural dust deposition in the vicinity of the mine should be taken into account, thereby resulting in a standard of 2.6 g/m^2/month, expressed as an annual mean. The IM recommends that MRM considers this approach in the next ambient air quality monitoring report.

The tabulated metals data for deposited dust is raw data for a range of one- to three-month periods, with no interpretation provided. The highest reported metals results (including Pb and Zn) were recorded at DDG22, 24 and 50, which are the closest three units to the processing plant. The IM recommends that monthly DDG results (from sampling or subsequent averaging) be presented along with discussion of these results in the next ambient air quality monitoring report.

It is noted that the AQMP TARP (MRM, 2017a) includes an objective for DDG results of ‘no increase compared to historic(al) dust deposition’ for five of the 17 units at or near the mine site, and two of the six units near Bing Bong Loading Facility. It is unclear why the remaining DDG sites are not included in the TARP. The IM recommends that depositional dust data previously collected at the mine site prior to August 2012 should be collated and summarised in the next ambient air quality monitoring report, to contribute to a baseline to which the TARP objective can be applied. If possible, more specific relevant criteria should be adopted and/or developed for all sites to enable assessment of results, in alignment with the goals of the dust monitoring program. Any DDG TARP triggers in the next reporting period, along with cause/s, actions and their effectiveness, should be reported in the next ambient air quality monitoring report. Future commentary on both deposited dust and deposited metals results should include discussion of any operational aspects or weather patterns that may have influenced these results.

HVAS Results

Results from the HVAS unit in the current reporting period are presented in the 2016-2017 and 2017-2018 OPRs (MRM, 2017b; 2018a) and the associated ambient air monitoring reports.

It is noted by TAS (2018) that the adopted annual TSP and metals criteria (see Table 4.65) apply at sensitive receptors, and no environmental criteria apply at the HVAS unit which is located next to a crusher. Dust emissions at this location are primarily a worker health issue (and therefore outside of the scope of this report). However, collected data can be used for process management and to monitor trends in emission levels, and the adopted receptor criteria can be used as a basis for evaluating and comparing such trends.

Unsurprisingly, the highest levels of TSP and contaminants within the reporting period were recorded in the 2016 and 2017 dry seasons. Annual average results for TSP and Pb from HVAS monitoring were well over the receptor criteria in both 2016-2017 and 2017-2018. Results for As, Cd and Mn over a 24-hour averaging period were above receptor criteria, however Zn and Cu results remained well below the relevant criteria. All results were higher during April 2017 to March 2018 compared with the previous 12 months – for example, annual average Pb results increased by 39%, while the maximum 24-hour average Pb result increased by 185%. Data capture rates in 2017-2018 improved to 97%, from 82% for TSP and 74% for metals in 2016-2017.

While exceedances of adopted criteria are not of concern in relation to HVAS results as noted above, the IM recommends that the next ambient air quality monitoring report should assess and provide commentary on reasons for changes in emissions trends at this location between years, as well as advising on any changes to process management that may have influenced observed trends.

TEOM Results

Results from the TEOM units in the current reporting period are presented in the 2016-2017 and 2017-2018 OPRs (MRM, 2017b; 2018a) and the associated ambient air monitoring reports.

As for HVAS results, the highest PM_{10} results recorded by all three TEOM units occurred during the drier months. No exceedances of the 24-hour average criterion (50 µg/m^3) were recorded at the MRM TEOM (now called TEOM01) between October 2016 and June 2017 (TAS, 2017a), however two exceedances were recorded at this site in the 2017 dry season – with 56.1 and 94.9 µg/m^3 on 2 and 14 September respectively (TAS, 2018). While the former was not an unusually windy day, 14 September had the equal highest maximum wind of the month, at 43 km/hour (BOM, 2018).

The Bing Bong TEOM (now called TEOM02) recorded one exceedance of the 24-hour PM_{10} criterion between October 2016 and June 2017 (TAS, 2017a), this being 66.84 µg/m^3 on 3 November 2016. Seven exceedances were recorded at this site during the 2017 dry season (between 23 July and 9 November 2017), with the two highest results being 120.3 and 79.5 µg/m^3, on 14 and 15 September respectively (TAS, 2018). These highest results were not on unusually windy days, however recent months had been very dry, with zero rainfall recorded at either McArthur River Mine or Borroloola airports between June and September 2017 (BOM, 2018).

No PM_{10} exceedances were recorded at the new mine site TEOM (TEOM03, adjacent to control site DMV10) from its commencement in October 2017 until the end of the reporting period (TAS, 2018). The annual average PM_{10} results at all three TEOM sites were well below the criterion of 25 µg/m^3 throughout the reporting period.

The IM recommends that the next ambient air quality monitoring report should assess and provide commentary on TEOM exceedances, including advice on any operational aspects or weather patterns that may have influenced results.

It is noted that the AQMP TARP (MRM, 2017a) includes a trigger for TEOM results of rolling 24-hour PM_{10} >50 µg/m^3 for three consecutive hours. The latest ambient air quality monitoring report (TAS, 2018) does not mention any instances of this trigger in the reporting period. Any such triggers in the next reporting period, along with cause/s, actions and their effectiveness, should be reported in the next ambient air quality monitoring report.

4.13.4.2 Progress and New Issues

Progress

The 2016-2017 and 2017-2018 OPRs (MRM, 2017b; 2018a) summarise the status of MRM's various environmental commitments. In particular, a reconciliation of environmental management commitments and actions is provided. In the latter document, Table 29 (pp109-118) outlines MRM's implementation approach and progress in addressing recommendations of specialists that undertook environmental monitoring programs during the 2017-2018 OPR reporting period, and recommendations from the 2013-2015 MMP and previous OPRs. This content is presented in Table 4.67 along with IM commentary. Where applicable, these recommendations/commitments have been included in the IM's recommendations for the 2017-2018 reporting period.

Table 4.67 – Reconciliation of MRM's Commitments Regarding Dust Management

Action/Recommendation	Implementation/Comment
Source: 2015-16 OPR	
Develop a more strategic and holistic Dust Management Plan for the Mine and the BBLF. The plan is to be developed in association with: ♦ Review of the efficacy of the current dust monitoring program ♦ Recommendations from monitoring reports and expert site visits ♦ Identification and ranking of significant dust emission sources ♦ Potential mitigation actions to improve performance	MRM Comment: Complete. The AQMP was completed and implemented in Q3 2017 IM Comment: Agreed
To further reduce dust emissions from the BBLF concentrate storage shed, MRM will repair the roller doors on the road train entry and exit ramps. Doors can be closed when not in use to minimise the transport of contaminated dust from prevailing winds	MRM Comment: To be installed in Q2 2018 IM Comment: see Section 4.13.4.2 – Progress
To reduce dust from mining operations, MRM will increase the use of water carts for dust suppression along haul roads and at active mining fronts. MRM is targeting 70% utilisation of two water carts per non-wet day mining shift when under full production	MRM Comment: Ongoing IM Comment: MRM's use of water carts is noted as a current dust control; no further recommendations at this time
Dust emissions from the crushing circuit in processing have been identified as one of the major contributors of contamination to the receiving environment. To reduce dust emissions from the crushing circuit in processing, MRM will complete an engineering assessment of the performance of the dust suppression systems used on the crushers and conveyors including the spray bars, covers and scrubbers, and will implement design recommendations from the engineering review	MRM Comment: Ongoing. Testwork conducted during November 2016 showed that rotary atomisers have potential to provide effective dust suppression IM Comment: MRM (2017d) has subsequently undertaken further design work and assessment into a rotary atomiser-based dust suppression system for the ROM bin primary crusher. This is commended; the assessment should be concluded and implemented, if appropriate, in the 2018-19 operational period
The moisture content of concentrate influences the dust produced during transfers from the MV Aburri to other bulk carriers. To help minimise ambient dust emissions produced during the transfer of concentrate between bulk carriers in	MRM Comment: Ongoing IM Comment: the IM learned during the 2018 site visit that concentrate TML is monitored prior to transport/transfer, with a target level

Table 4.67 – Reconciliation of MRM's Commitments Regarding Dust Management (cont'd)

Action/Recommendation	Implementation/Comment
Source: 2015-16 OPR (cont'd)	
the transhipment zone, MRM will use a liquid dust suppressant when concentrate moisture contents are less than 12%	of 13.5% moisture, but were advised that this drops to approx. 10-11% moisture when concentrate is stored at Bing Bong Loading Facility for extended periods. The proposed use of a liquid dust suppressant is commended
Concentrate stored outside sheds is exposed and during the dry season months is susceptible to windblown erosion. This pathway has been identified as a major source of Pb contamination in the past… MRM will aim to reduce dust emissions from the stockpiling of concentrate material outside of covered and sealed storage sheds by aligning sales contracts with concentrate production to minimise the need to stockpile concentrate outside of sheds	MRM Comment: Ongoing IM Comment: MRM should include commentary in air quality monitoring reports where particular operational activities (including, but not limited to, concentrate being stockpiled outside) are known or suspected as sources of exceedances in certain areas. The proposed action to minimise the need for (or timeframe of) stockpiling is commended
Tailings material is susceptible to windblown erosion when dried. To manage and minimise dust emissions the exposed tailings beaches at the TSF will be kept moist with a minimum moisture content by rotating the spigots used for tailings deposition	MRM Comment: Ongoing IM Comment: MRM's effort to maintain moisture of tailings via rotation of spigots is noted as a current dust control; no further recommendations at this time
Dust emitted in the vicinity of the Barney Creek haul road bridge has been identified as a source of contamination to Barney Creek [diversion channel]. To reduce ambient dust emissions produced in the vicinity of the Barney Creek haul road bridge, MRM will trial a synthetic dust suppressant on the approaches to the Barney Creek haul road bridge and will determine through the trial if the suppressant has a measurable impact on dust produced from this source	MRM Comment: This trial did not progress due to concerns over traction on the concrete bridge surface IM Comment: The operational/OHS concerns with regards to this trial are noted; no further recommendations at this time
Source: 2016-17 OPR	
TAS (2017a; 2017c) recommended that the sampling and analysis process be reviewed with a focus on ensuring all reasonably possible paths of contamination are minimised	MRM Comment: Complete IM Comment: The focus stated here is commended, however, the sampling and analysis process does not directly act to minimise contamination, unless TAS is referring to sample contamination. No further recommendations at this time
TAS (2017a; 2017b) noted that as the recorded Pb levels on the site are high, it is possible that there may be risks to the health of workers near to the processing plant, and also some risk to the environment. TAS (2017a; 2017b) recommended the contaminants emitted be minimised wherever it is practical and feasible to do so	MRM Comment: Complete IM Comment: Potential risk to health of workers is not an environmental commitment and is outside the scope of this review, however the potential risk to the environment is acknowledged. The recommendation to minimise emissions of contaminants where possible should be considered integral to MRM's environmental performance; no further recommendations at this time
IPE (2016) recommended further investigation of potential pathways for the introduction of lead at SW3	MRM Comment: Ongoing. DDGs have been installed around the processing plant. Monitoring around this area will provide

Table 4.67 – Reconciliation of MRM's Commitments Regarding Dust Management (cont'd)

Action/Recommendation	Implementation/Comment
Source: 2016-17 OPR (cont'd)	
	further information on the impacts of dust emissions on Pb at SW03 IM Comment: The IM notes that DDG24 and HVAS01 are situated near to SW03, but that DMV sites in this vicinity (DMV23, 24, 27) were decommissioned in 2017. Results during the reporting period from DMV24 (prior to decommissioning), DDG24 (preliminary results) and the HVAS confirm that Pb exceedances are known in this vicinity. Analysis of DDG data planned for the next reporting period should contribute more information on dust deposition in this vicinity. The IM recommends that results be assessed in relation to operational aspects and/or weather patterns that may have influenced these results

Source (Actions/Recommendations and MRM Comments): MRM, 2018a.

McArthur River Mining's progress and performance against previous IM review recommendations relating to dust issues is outlined in Table 4.68.

Table 4.68 – Dust Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
Dust Management at the McArthur River Mine		
Dust management – near the haul road bridge	McArthur River Mining should develop a formal plan for dust minimisation in the vicinity of DMV43, as part of the upcoming AQMP and TARP. This plan should target the most impacted areas as identified by dust monitoring	Ongoing ♦ As noted in ERIAS Group (2017), dust issues near DMV43 are related to movement of heavy equipment and haul trucks in the vicinity; PM_{10} concentrations are strongly correlated with volume of waste rock haulage, outside the wet season ♦ McArthur River Mining has continued to be active in controlling contaminated runoff and sediment at this location (which relates to depositional dust), as described in Section 4.12 of this report ♦ The AQMP that was finalised during the reporting period (MRM, 2017a) more clearly documents the range of dust minimisation controls that MRM is implementing at the mine site in general. Many of the actions therein (e.g., application of the TARP in relation to DDG43, and responses relating to dust generated by haul trucks) are specifically applicable to that area. This is commended ♦ While MRM (2016b) states that further initiatives for dust suppression in this area (e.g., dust screens and further revegetation) were to be considered, this was not noted in the AQMP ♦ Results from the current reporting period show that there are ongoing PM_{10} exceedances at DMV43, and considerably more than the previous period, despite the improved controls stated in the AQMP

Table 4.68 – Dust Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Dust Management at the McArthur River Mine (cont'd)		
Dust management – near the haul road bridge (cont'd)		♦ The IM recommends that future ambient air quality monitoring reports should provide specific comment on DMV43/DDG43 trends, along with actions taken to minimise dust impacts in this area (and why they were or were not adequate to mitigate impacts), or any further actions that are proposed to stabilise or improve results
Dust management – TSF	An area immediately east of the decant wall on the TSF Cell 2 north wall is not being kept damp by tailings deposition; the IM understands that there is an embankment height issue at this location. This should be managed via irrigation and/or completion of the embankment raise with associated tailings deposition, during the 2017 operational period	Completed ♦ Before the TSF Cell 2 Raise 4 was completed in November 2017, a bund wall was constructed to allow fresh tailings to be deposited over the area to increase moisture content and limit dust emissions. This area is now well below the embankment crest and spigot discharge points (MRM, 2018b)
Dust Management at Bing Bong Loading Facility		
Dust management planning for Bing Bong Loading Facility	McArthur River Mining should develop a formal dust mitigation plan for Bing Bong Loading Facility during 2017, as part of the upcoming AQMP, targeting the most impacted areas as identified by dust monitoring	Completed ♦ The AQMP which was finalised during the reporting period (MRM, 2017a) and the visual dust triggers/actions (see Figure 4.49) along with the TARP contained therein document the range of dust minimisation controls which MRM is implementing at Bing Bong Loading Facility. This is commended
Dust management at Bing Bong Loading Facility – concentrate shed doors	The main doors of the Bing Bong Loading Facility concentrate shed should be replaced as soon as practicable. Once doors are operational, they should be kept closed as often as possible	Ongoing ♦ McArthur River Mining advised in June 2017 that replacement of the main (truck access) concentrate shed doors was imminent. As at the time of the May 2018 site visit (as per the past several years) these doors were still not operational. The IM was advised (and observed on site) that new main doors had been purchased but were of incorrect dimensions. The IM was advised that new doors had been ordered and were on their way to site as of May 2018 ♦ The IM recommends that the main doors be replaced as soon as practicable, as the continuously open state of the shed is very likely to be a source of ongoing contamination in the local area
Dust management at Bing Bong Loading Facility – dust extractor system	The vents of the dust extractor system in the Bing Bong Loading Facility concentrate shed should be replaced/made operable as soon as possible	Ongoing ♦ The dust extraction system was repaired during the 2015 operational period, however, given the non-operational central shed doors, there will be little to no pressure differential at present

Table 4.68 – Dust Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Dust Management at Bing Bong Loading Facility (cont'd)		
Dust management at Bing Bong Loading Facility – dust extractor system (cont'd)		♦ During the 2017 and 2018 site visits, it was apparent that the vents associated with the dust system were damaged and required replacing. The IM has been advised by MRM (2018b) that replacement is planned and that replacement parts have been ordered ♦ Regardless of the status of the dust extraction system, dust is still readily mobilised and transported from the concentrate shed by airflow through the open doorways on either side, which align with the prevailing easterly winds ♦ While the IM acknowledges the need to keep at least one shed door open at all times while unloading trucks (due to the length of trucks versus the width of the shed), it is recommended that in order for the dust extraction system to operate as intended: – The extraction system vents should be replaced as soon as possible – When doors are operational, they should be kept closed as often as possible
Dust management at Bing Bong Loading Facility – pavements	The bitumen surface surrounding the Bing Bong Loading Facility should be repaired to avoid future soils, water and/or dust management issues. The IM understands that these works will be undertaken during 2018	Ongoing ♦ During the May 2018 site visit: – The IM observed that the bitumen surface was in worse repair than during the previous three site visits – McArthur River Mining advised in 2016 that repairs were due to start by June of that year, with degraded bitumen to be replaced by concrete in high traffic areas, and new bitumen in lower traffic areas – This had not occurred as at May 2018, when MRM advised that new pavements at Bing Bong Loading Facility are in their 2018 CapEx budget. It is planned to have concrete pads close to the concentrate shed (in areas that receive most intense use), with bitumen on remaining areas ♦ Recommendation ongoing until these works are completed
Dust Monitoring and Analysis		
Dust monitoring and analysis – TEOM and HVAS	Data from the TEOM and HVAS units at Bing Bong Loading Facility and the mine site should be reported/ analysed and discussed during the 2017 operational period	Ongoing ♦ Results from the HVAS and TEOM units in the current reporting period are presented in the 2016-2017 and 2017-2018 OPRs (MRM, 2017b; 2018a) and the associated ambient air monitoring reports ♦ The IM recommends that the next air quality monitoring report should assess emissions trends recorded at the HVAS between periods, as well as exceedances recorded by TEOM units, with commentary on operational aspects or weather patterns that may have influenced results

Table 4.68 – Dust Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Dust Monitoring and Analysis (cont'd)		
Dust monitoring and analysis – TEOM and HVAS (cont'd)		♦ The IM recommends that any exceedances of the TARP TEOM trigger in the next reporting period, along with cause/s, response actions and their effectiveness, should be reported in the next ambient air quality monitoring report
Dust monitoring and analysis – QA/QC	McArthur River Mining should ensure that separate field blank sampling is undertaken for the mine site and Bing Bong Loading Facility dust monitoring programs, and discussed in the next dust report, to assist with QA/QC	Completed ♦ Duplicate sampling and field blank sampling were undertaken for DMV sites at both McArthur River Mine and Bing Bong Loading Facility during the operational period, with data and commentary reported in TAS (2017a; 2018) ♦ Blank sampling was initiated for the MRM HVAS monitoring site during the operational period, and in general was undertaken monthly from January 2017 to March 2018 ♦ Data from TEOM units was evaluated as per Australian Standard AS/NZS 3580.9.8-2008 ♦ The AQMP (MRM, 2017a) states that DDG sampling and analysis is to be undertaken in accordance with AS/NZS 3580.10.1:2003
Dust monitoring and analysis – gradient contour maps	In the next dust report, MRM should again prepare gradient contours maps based on ambient dust data from the mine site. Comment should be added to the report as to the low potential for dust impacts at the mine lease boundaries and nearest sensitive receptors, as demonstrated by previous modelling	Completed ♦ Gradient contour maps based on interpolation of ambient dust data were again provided in TAS (2017a, 2018), including average annual and 24-hour maximum PM_{10} concentration, and 24-hour maximum Pb and Zn concentration. This is commended ♦ It has been noted by TAS (2018) that interpolation of particulate monitoring data shows that elevated results were confined to areas near the MRM processing and mining areas. Monitors further from these areas generally recorded low pollutant levels, at or near the likely background concentrations. TAS (2018) asserts that this indicates that these pollutants only travel a short distance before they are dispersed and/or deposited, and that it can therefore be inferred from the data that concentrations due to mining activities at the nearest identified sensitive receptors (e.g., Devils Springs, Borroloola) would be significantly lower than those recorded by any MRM monitor, and would likely not be discernible from background concentrations
Dust monitoring and analysis – high impact sites	The revised monitoring program in the AQMP will cover increased frequency and analysis of PM_{10} and Pb at key locations for both DMV samplers and dust deposition; this will include 24-hour sampling with low-volume air	Completed ♦ This data was presented in the TAS (2018) ambient air quality monitoring report

Table 4.68 – Dust Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Dust Monitoring and Analysis (cont'd)		
Dust monitoring and analysis – high impact sites (cont'd)	samplers every 12 days. The findings of this monitoring should be reported during 2017	
Dust monitoring and analysis – long term data	The IM recommends that MRM presents all available long-term dust data (in particular, PM_{10} and Pb results) for Bing Bong Loading Facility and the mine site within the 2017 ambient dust monitoring report, to inform understanding and management of dust issues at each site. This report should also review and discuss the long-term trends in relation to dust	Ongoing ♦ The latest ambient air quality monitoring reports (TAS, 2017a; 2018) present all of the available 24-hour average PM_{10}, Pb and Zn concentrations recorded at DMV sites, from January 2012 to the end of the applicable reporting period. This is commended ♦ While very brief comment is provided along with this data, meaningful analysis is lacking. For example, in Figure 7-4 of the 2018 report (TAS, 2018), a clear trend is visible whereby PM_{10} results at sites DMV22 and DMV43 decreased and stabilised as of 2015, but began rising again from mid-2017 to March 2018 ♦ In addition to including long-term data, the next air quality monitoring report should include discussion of long-term trends (other than seasonality) and likely reasons
Dust results analysis – adopted criteria	The 'adopted standards' section of the next dust report should include the adopted NEPC (2016) maximum annual average concentration for Pb (versus the LOR)	Completed
Incident Reporting and Management of Exceedances		
Compliance with annual criteria	Exceedances of the maximum annual average criterion for Pb should be assessed and reported during the 2017 operational period to assess compliance against the adopted NEPC (2016) guideline, for both the mine site and Bing Bong Loading Facility	Completed
Incident reporting/ management of exceedances	Exceedances of dust guideline levels should continue to be reviewed and reported as part of ongoing environmental performance evaluation The IM recommends that MRM undertake an assessment of the potential environmental implications/ risks of dust guideline exceedances, and consider an alternative assessment	Ongoing ♦ The IM notes (and commends) that a dust TARP has been included in the AQMP (MRM, 2017a) (see Figure 4.49) ♦ The AQMP (MRM, 2017a) specifies that any exceedance of the NEPM goals at TEOM03 (next to control site DMV10) which is determined to have been caused by the mine (i.e., an incident) will be reported as soon as practicable to the DPIR following investigation of data validity ♦ The AQMP specifies that data will be reported annually as part of the OPR, and that validated

Table 4.68 – Dust Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
Incident Reporting and Management of Exceedances (cont'd)		
Incident reporting/ management of exceedances (cont'd)	framework (e.g., more appropriate criteria with triggers for management actions)	data will also be provided to the DPIR on a monthly basis ♦ The IM recommends that at a minimum, the more noteworthy dust results and long-term trends should not be treated as 'normal', but should be assessed and commented on in ambient air quality monitoring reports, including specific comment on trends noted, any operational aspects or weather patterns that may have influenced these results, why (if applicable) existing dust controls may not have been adequate to mitigate impacts, potential implications of the results in question, and any further actions that are proposed to stabilise or improve results in accordance with the goals of the AQMP and TARP ♦ The focus of the AQMP (MRM, 2017a) and the assessment framework therein should be expanded beyond a human health focus to reflect the dust monitoring program goals of the MMP (MRM, 2015a) and the OPR (MRM, 2018a) – i.e., including minimisation of air quality related impacts with respect to the environment and ensuring that the values of the surrounding environment are protected. Incident reporting should reflect this

New Issues

Many of the dust issues in the current IM review are ongoing or updated versions of previously identified issues, and are detailed in Table 4.68, and Table 4.69 where the issue has been brought forward.

The majority of new issues are related to the extensive revision of the air quality monitoring program in the current reporting period, and are discussed alongside explanation of those controls and results in preceding sections.

As discussed for the surface soil program discussed in Section 4.12, rationales for specific changes to the dust monitoring program are not provided in the AQMP (MRM, 2017a) or the latest air quality monitoring report (TAS, 2018). While the IM appreciates that the changes to the program may provide more consistent and useful data in the long term, the new dust network is considerably sparser. Reporting of dust monitoring and results should reconcile monitoring planned versus that actually undertaken, and provide a rationale for gaps or sites not sampled, where applicable.

The extent of the changes compromises the ability to compare results between years. For example, moving sites by hundreds of metres (DMV07, DMV45 and DMV47) is likely to lead to confusion. Removal of numerous other sites which are known to have a history of exceedances removes the possibility of ongoing monitoring and analysis of trends.

The IM recommends that the rationale for monitoring program changes should be considered and reported on a site-by-site basis. Where moving a monitoring site is considered to be necessary, a consistent and rational approach must be applied to site naming. At a minimum, adding a suffix (e.g., A/B) to the sampling site name would minimise confusion and ensure that genuine comparison of results can be made across sampling periods.

4.13.4.3 Successes

In the 2017-2018 operational period, successes relating to dust have included:

- Developing and implementing the AQMP, and associated TARP, for the mine site and loading facility. The improvements associated with this are discussed in previous sections.
- The re-introduction of depositional dust monitoring is expected to be useful in clarifying environmental impacts of dust in relation to its contribution to contamination of surface soils, sediments, water quality and/or vegetation. Similarly, the more frequent DMV monitoring should enable more consistent and useful results, including improved applicability of annual average criteria.
- The correction of adopted criteria tables (MRM, 2017a; TAS, 2017a; 2018) to include the NEPM Ambient Air Quality Measure (NEPC, 2016) goal for annual average Pb.
- The inclusion and reporting of data for the HVAS and TEOM units, the application of a relevant TSP criterion for the former, and installation of a third TEOM unit at the DMV10 control site.
- Ongoing improvements to QA/QC of the dust monitoring program, including for the HVAS monitor.

4.13.5 Conclusion

Extensive changes have occurred in the air quality monitoring program as well as in management of dust issues during the reporting period. While there are some issues with these changes, they are largely expected to improve data collection and dust management in the long term. Notwithstanding this, some monitoring results in the current period have deteriorated in contrast to previous years (most notably PM_{10} at DMV43, Pb near the processing plant, and elevated Mn at several sites). The key ongoing concerns relate to dust management near Barney Creek haul road bridge, the inoperability of the main concentrate shed doors at Bing Bong Loading Facility, and the lack of analysis and discussion of observed dust exceedances.

Ongoing and new IM recommendations related to dust issues are provided in Table 4.69.

Table 4.69 – New and Ongoing Dust Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Dust management – near the haul road bridge	Future air quality monitoring reports should provide specific comment on DMV43/DDG43 trends, along with actions taken to minimise dust impacts in this area (and why they were or were not adequate to mitigate impacts), or further actions that are proposed to stabilise or improve results	High

Table 4.69 – New and Ongoing Dust Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Dust management at Bing Bong Loading Facility	The main doors of the Bing Bong Loading Facility concentrate shed should be replaced as soon as practicable. Once doors are operational, they should be kept closed as often as possible	High
	The vents of the dust extractor system in the Bing Bong Loading Facility concentrate shed should be replaced/made operable as soon as possible	High
	The bitumen surface surrounding the Bing Bong Loading Facility should be repaired as soon as possible to avoid future soils, water and/or dust management issues. The IM understands that these works will be undertaken during 2018	Medium
Dust monitoring and analysis – TEOM and HVAS	The next air quality monitoring report should assess emissions trends recorded at the HVAS between periods, as well as exceedances recorded by TEOM units, with commentary on any operational aspects or weather patterns that may have influenced results	High
Dust monitoring and analysis – long term data	In addition to including long-term data, the next air quality monitoring report should include discussion and analysis of long-term trends (other than seasonality) and likely reasons	Medium
Reporting/ management of exceedances	The more noteworthy dust exceedances and long-term trends should not be treated as 'normal', but should be assessed and commented on in air quality monitoring reports, including specific comment on trends noted, any operational aspects or weather patterns that may have influenced these results, why (if applicable) existing dust controls may not have been adequate to mitigate impacts, or any further actions that are proposed to stabilise or improve results in accordance with the goals of the AQMP and TARP	High
	The focus of the AQMP (MRM, 2017a) and the assessment framework and TARP therein should be expanded beyond a human health focus to reflect the dust monitoring program goals of the MMP (MRM, 2015a) and the OPR (MRM, 2018a) – i.e., including minimisation of air quality related impacts with respect to the environment and ensuring that the values of the surrounding environment are protected. Incident reporting should reflect this	High
New Items		
Crusher dust suppression	The assessment of a rotary atomiser-based dust suppression system for the ROM bin primary crusher should be finalised and implemented, if appropriate, in the 2018-2019 operational period	Medium
Baseline data reporting	Depositional dust data previously collected at the mine site prior to August 2012 should be collated and summarised in the next ambient air quality monitoring report, to contribute to a baseline against which to assess the new DDG data, and to which the TARP objective can be applied	Medium
General data interpretation and reporting	The rationale for dust monitoring program changes should be considered and reported on a site-by-site basis. Where moving a monitoring site is necessary, a consistent and rational approach must be applied to site identification to minimise confusion and ensure that genuine comparison of results can be made across sampling periods	Medium
DDG reporting	♦ With regards to DDG reporting in the next ambient air quality monitoring report: – Monthly DDG results (including deposited dust and metals results	High

Table 4.69 – New and Ongoing Dust Recommendations (cont'd)

Subject	Recommendation	Priority
New Items (cont'd)		
DDG reporting (cont'd)	from sampling or subsequent calculations) should be tabulated along with written interpretation of results in relation to criteria and/or background levels – Charts should be more clearly labelled – Natural dust deposition in the vicinity of the mine should be taken into account, thereby resulting in a standard for incremental deposited dust increase of 2.6 g/m^2/month, expressed as an annual mean	
AQMP and TARP	♦ An update should be provided to the AQMP, addressing the following: – Rationale for removal of a large proportion of the previous monitoring network, and explanation of how DDG sites are intended to replace DMV monitors in relation to metals monitoring – If possible, more specific relevant criteria should be adopted and/or developed for DDG sites (particularly for metals) to enable assessment of results beyond comparison with historical levels – Rationale for the inclusion/exclusion of particular DDG and DMV sites in the TARP – Clarification of the TARP trigger for DMV sites (i.e., does it apply for a single Pb or Zn exceedance, or to be compared against historic data as stated in Section 10.1 of the AQMP)	High
	Any exceedances of the AQMP TARP triggers (TEOMs, DMVs and/or DDGs) in the next reporting period (at either the mine site or loading facility), along with cause/s, response actions and their effectiveness, should be reported in the next ambient air quality monitoring report to inform ongoing management	High
Reporting of exceedances	McArthur River Mining should include commentary in air quality monitoring reports where particular operational activities (e.g., concentrate being stockpiled outside) are known or suspected as being sources of exceedances in certain areas	High
Dust contributions to contaminant loads	McArthur River Mining should investigate dust/diffuse surface runoff contributions to contaminant loads reporting to surface drainages as part of the broader investigation into mine-derived loads as discussed in Section 4.3 of this report	Medium
Assessment criteria	The next ambient air quality monitoring report should correct the adopted criteria table (to match the AQMP) with regards to the TSP criterion, which is sourced from NSW EPA (2016) as opposed to the NEPM (NEPC, 2016)	Low

4.13.6 References

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4.14 Review of DPIR's Monitoring

4.14.1 Introduction

The Department of Primary Industry and Resources (DPIR) provided a number of files relating to the regulation of the McArthur River Mine during the reporting period. These files related to:

- Assessments and inspections to evaluate the environmental performance of the mine, including:
  - 2013-2015 MMP (including a number of amendments to the MMP).
  - Site inspection reports completed during the reporting period.
  - Third party expert advice (e.g., Independent Tailings Review Board (ITRB), Robertson GeoConsultants Inc.).
  - Environmental incidents.
  - Correspondence between DPIR and EPA.
  - Department of Primary Industry and Resources procedures and manuals.
  - Results of check monitoring undertaken by DPIR's environmental monitoring unit.

The IM conducted a review of DPIR in regulating the environmental performance of MRM under the Mining Management Act and regulations. This included review of:

- Department of Primary Industry and Resource's assessment of the MMP and subsequent amendments.
- Site inspection reports.
- Check monitoring results.
- Independent Monitor recommendations tracking and progress reports.
- Previous IM recommendations regarding DPIR performance.

4.14.2 Review of Compliance Auditing and Site Visits

4.14.2.1 Compliance Audits

No compliance audits were undertaken during the reporting period, however a number of site inspections were completed and these are discussed in Section 4.14.2.2.

4.14.2.2 Site Visits

During the reporting period DPIR undertook ten site inspections on the following dates:

- 5 October 2016.
- 25 January 2017.

- 22 March 2017.
- 27 April 2017 (with NT EPA EIS delegation).
- 30 May 2017 (with NT EPA).
- 1 June 2017 (with NT EPA EIS delegation).
- 2 August 2017.
- 27 September 2017.
- 20 December 2017 (opportunistic site visit following IM community presentation).
- 15 February 2018.

Following most of these site inspections, a detailed inspection report was compiled by DPIR, which discussed the objectives of the site visit, observations and findings and included supporting photographs. Inspection reports were not prepared following site visits undertaken with the NT EPA in April, May and June 2017 and the opportunistic site visit undertaken in December 2017.

During the reporting period an improvement was noted by the IM with the DPIR inspection reports. The IM has previously recommended that inspection reports adopt a consistent approach to including recommendations and required actions. While the structure of reports from earlier in the reporting period differs from those later on, the inclusion of the recommendations section was a useful addition to reports from March 2017 onwards and the addition of the ‘actions’ within the ‘observations’ section in the February 2018 report was another good addition which more clearly identify items for MRM to address. These actions and recommendations should be included in future reports, ensuring that all actions provided in the report are consistent with the recommendations at the end as there were instances where recommendations raised in the main section of the report were not captured in the recommendations section at the end. The IM suggests more clarity on whether actions/recommendations must be implemented by MRM or whether they are suggestions for consideration by MRM. Furthermore, a clear tracking mechanism showing MRM’s progress against the DPIR recommendations should be established. A summary of the recommendations or actions outlined in the inspection reports is provided in Table 4.70.

Table 4.70 – DPIR Recommendations from Site Inspection Reports

Inspection Report	DPIR Recommendation/Observations/Actions Issued to MRM
5 October 2017	♦ Dust observed at operations carting LS-NAF from stockpiles at the NOEF to the CWNOEF area ♦ Cracks on the surface of the SOEF had changed direction and were longer in extent than when they were first noted on 16 July 2016 by mining officers ♦ MRM must ensure the ITRB and the independent certifying engineer are aware of the issues with cracking at the TSF and the potential implications on the operation and planning of future embankment raises

Table 4.70 – DPIR Recommendations from Site Inspection Reports (cont'd)

Inspection Report	DPIR Recommendation/Observations/Actions Issued to MRM
25 January 2017	♦ Further monitoring of water which appeared to be flowing underneath the liner at CWNOEF sump required ♦ MRM to submit an incident notification (S29) to DPIR regarding the observed smokers at the NOEF ♦ MRM to confirm the quality of the seepage water from the rock gabion at the TSF Cell 2 Spillway and report on the outcomes in the monthly TSF Communications Report ♦ MRM to confirm the source and quality of water discharging from a pipe to the south east corner of the Water Management Dam (WMD), undertake appropriate actions and report on the outcomes in the monthly TSF Communications report ♦ MRM to take a water sample from the TSF south west corner seepage pump sump and pump the sump dry, if possible, to determine if it is being recharged by TSF seepage and report on the outcomes in the monthly TSF Communications Report ♦ MRM to submit an incident notification (S29) to DPIR regarding the Cell 1 Western Sump overflow incident
22 March 2017	♦ Further investigation required into the discolouration and apparent stress of vegetation to the north of the Mine Levee Discharge Point ♦ MRM to assess the SOEF area where circular cracking was observed for stability and presence of reactive material ♦ MRM to consider if mitigation works are required for erosion observed adjacent to the haul road near the Barney Creek sediment trap ♦ MRM to document progress against commitments from TSF Cell 1 Eastern and Western Sump overflow incident in the TSF Monthly Communication Report ♦ MRM must ensure overflow from TSF to Cell 4 is prevented and must sample water to determine quality and consider reducing volume by pumping to WMD with results of the sampling to be included in the TSF Monthly Communication Report ♦ MRM to report on progress on removal of sediment from the Concentrator Runoff Pond (CRP) in the TSF Monthly Communication Report ♦ MRM to investigate SO_2 presence on the SOEF to confirm it is related to inappropriately stored material and provide advice regarding management ♦ MRM to clean out Barney Creek sediment sumps prior to the next wet season ♦ Provide a proposal for implementation of upgrade works for the Barney Creek sediment sumps
2 August 2017	♦ Clarification required regarding the use of clay vs. alluvial blanket for the NOEF interim remedial works ♦ Follow up on outcomes of the review undertaken of bores in the area in regards to discolouration and vegetation stress near the mine levee discharge point ♦ Clarification required regarding the ongoing management of the SOEF during mining operations ♦ Undertake investigation into salts and damp spot observed adjacent to a pipe going through the embankment at the TSF and provide summary of findings, actions and progress in quarterly TSF Communication Report ♦ Consider lining Van Duncan's Dam to minimise risk of seepage and contamination ♦ Consider closely monitoring the Anti-Pollution Pond for seepage due to it's proximity to Barney Creek ♦ Provide advice regarding the repair of a small hole detected in the central area of the WPROD

Table 4.70 – DPIR Recommendations from Site Inspection Reports (cont'd)

Inspection Report	DPIR Recommendation/Observations/Actions Issued to MRM
2 August 2017 (cont'd)	♦ Provide an estimation of the volume of water discharged during the installation of a new flow meter at the Central West Sump Area ♦ Provide an update on the progress of the lime trial at the SEPROD in MMP-OPR submission ♦ Provide an update on progress against commitments from TSF Cell 1 Eastern and Western Sump overflow incident in the quarterly TSF Communication Report ♦ Confirm if a water quality monitoring program was implemented to confirm the water quality is suitable for the construction works at the TSF and ensure any change in water quality is promptly identified and managed appropriately and provide an update on the water monitoring program in the quarterly TSF Communication Report ♦ Report on progress of works to remove sediment from the CRP in the quarterly TSF Communication Report
27 September 2017	♦ Consider monitoring for hydrocarbons to ensure water quality in the WMD has not been compromised ♦ Monitor water quality in TSF waterhole to ensure it meets requirements for livestock drinking water ♦ Monitor southwest corner of TSF and develop contingency in event that there is water in the well to manage seepage issues during construction ♦ Assess material in the SOEF to ensure it is appropriate for the location (given the apparent SO_2 production and salt expression) ♦ Ensure tailings dust is not leaving Cell 1 or Cell 2 of the TSF
15 February 2018	♦ Report long-term water management strategies in future OPRs ♦ Repair erosion and scouring of the alluvial materials on the SOEF ♦ Stabilise areas of significant erosion along the McArthur River diversion channel ♦ Continue monitoring vegetation in the vicinity of NC1A and investigate potential causes of any deterioration in vegetation condition ♦ Repair scouring of interim cover of the western side of the NOEF ♦ Position conduit siphon containing water from CWAS in a location where it is not submersed below water level ♦ Consider if waters transferred to the WMD are acid and metalliferous drainage as transfer of these waters to the WMD may be in conflict with condition 26 of the Authorisation ♦ Monitor and repair (if necessary) scouring of the wall in the southwest corner of the TSF Cell 2 ♦ Ensure that any infrastructure, including pipeline in contact with contaminated material such as tailings, be cleaned and stored in an internally draining area to minimise the risk of contaminated runoff. Infrastructure or machinery that has been in contact with this material to be stored in externally draining areas to be thoroughly cleaned and inspected prior to storage.

In previous reports, the IM recommended that issues identified by DPIR arising from the site visits be documented in a register outlining the action that DPIR requires of MRM, together with MRM's responses and relevant dates for completion. While there has been a notable improvement in identifying and including recommendations or actions in the inspection reports, the IM has not been provided with any evidence that documentation of issues arising from site inspections (as outlined in Table 4.70) is being complied into a register to enable tracking of progress. While some items are directed to be reported in the TSF Communication Reports, it is unclear whether other recommendations made by DPIR have been addressed by MRM. The IM recommends

DPIR develop a system to easily track MRM's progress against the recommendations or actions provided in the inspection reports. Finally, the wording of recommendations and actions from DPIR has at times been confusing as to whether these are items that MRM must undertake/complete or whether they are just suggestions, i.e., 'MRM should' vs. 'MRM must'. The inspection reports would benefit from clearer directives from DPIR. It would also be useful to include a tracking table in follow up inspection reports which indicates progress against previous DPIR recommendations.

4.14.3 Review of DPIR Assessment of MMP and Amendments

As described in detail in the previous IM reports, a 2013-2018 MMP was submitted to DPIR on 21 November 2013. This document was then the source of considerable correspondence between DPIR and MRM which ultimately resulted in the withdrawal of the 2013-2018 MMP. An updated MMP covering an interim period of operations from 2013 to 2015 (to enable operations to continue while further assessment was undertaken via the environmental assessment process), i.e., the 2013-2015 MMP referred to as the interim 2013-2015 MMP (MRM, 2015), was submitted to DPIR on 2 May 2014. The 2013-2015 MMP was approved by the DME (now DPIR) on 23 December 2015.

McArthur River Mining requested a number of amendments during the reporting related to the following:

- TSF Cell 2 Raise 4.
- TSF Cell 1 Stage 1.
- TSF Seepage Interception Trench.
- TSF WMD release.
- CWA Sump Discharge.

As a number of these requested amendments were subject to EIS processes and review (which is still underway) they were not approved. The DPIR did however provide authorisation for TSF Cell 2 Raise 4 (authorisation 0059-01 and 0059-02). The detailed design was reviewed by the ITRB and Robertson Geoconsultants Inc. The remaining requested amendments are yet to be approved by DPIR.

4.14.4 Review of Instructions, Investigations and Incidents

4.14.4.1 Instructions

During the operational period (1 October 2016 to 31 March 2018) DPIR did not issue any instructions to MRM, as progress of regulatory issues was addressed by other mechanisms.

The IM has previously recommended that a register of instructions issued by DPIR to MRM be established to enable the tracking of the status of MRM's response and key dates. This register is now in place following a review of instructions issued since 2016 and has been sighted by the IM.

4.14.4.2 Incidents

The DPIR provided documentation for 27 incidents, the incidents included the following:

- An estimated 35 tonnes of bulk concentrate was spilled when a road train, en route to the Bing Bong Loading Facility, collided with a bull and two trailers were overturned (14 December 2016).
- Overflow of TSF Cell1 Western Sump to the Cell 4 borrow pit area (25 January 2017).
- Following heavy rainfall, water vapour was identified on the top batter of West AB and the northern face of the NOEF, indicating regions of oxidising waste rock, with minor combustion of loose rock situated on the surface of berm crests identified (25 January 2017).
- Following heavy rainfall the TSF Cell 1 Eastern Sump overflowed via it's spillway at approximately 100 to 200 L/s and flowed towards a highway drain (19 February 2017).
- Draining of water through an electrical conduit cable from the Central West Alpha Sump through the Central West Levee and to the receiving environment (to an unnamed tributary) at a rate of approximately 1 L/s after the repeated failure of a stand used to prop the conduit up (23 March 2017).
- Spillage of approximately 200 litres of diesel from an auxiliary tank on an EPSA crane on the Mine Haul Road and Southern Access Road (14 May 2017).
- Several hundred fish (primarily small bony bream [*Nematalosa erebi*]) were killed during the draining of the South-East Levee 1 (SEL1) at the end of the wet season, done for operational reasons. Relocating the fish was not feasible. (26 May 2017).
- A hydraulic oil spill of approximately 150 L from EX142 (Caterpillar 349 DL) while at the Mill stockpile (6 September 2017).
- A hydraulic oil spill of approximately 800 L from excavator EX04 (Komatsu PC5500) while in the MRM open pit (6 September 2017).
- A hydraulic oil spill of approximately 200 L from excavator EX02 while in the MRM open pit (Leibherr 9350) (8 September 2017).
- Release of between 72 and 300 kilolitres of mine-affected water to land as a result of a damaged pipeline from Central West Alpha Sump (26 September 2017).
- Exceedance of ANZECC/ARMCANZ (2000) filtered zinc concentrations for livestock drinking water (20 mg/L) in monitoring bore GW95S, located to the south of the SPROD (9 October 2017).
- A hydraulic oil spill of approximately 100 L from a haul truck (HT9008) while in the MRM open pit (23 October 2017).

- Expression of groundwater (approximate rate of 0.1 L/s) from weathered rock in an isolated section of the Little Barney Creek diversion immediately downstream of the Water Management Dam (28 October 2017).
- A hydraulic oil spill of approximately 700 L from Excavator 2 (EX02) in a void zone in the open pit (27 November 2017).
- A hydraulic oil spill of approximately 120 L Haul Truck 12 at the NOEF Central West dumping area (10 January 2018).
- A hydraulic oil spill of approximately 180 L from Bullldozer 07 (DZ07) at the NOEF (15 January 2018).
- Following an extreme rainfall event, discharge of approximately 200 L/s from the Central West region comprising runoff water from portions of Central West as well as water from the Central West Alpha Sump. Overflow reported to Central West C Sediment trap before reporting to the unnamed tributary to the north of the NOEF (24 January 2018).
- Following an extreme rainfall event, overflow of Cell 1 Western and Eastern sumps into the adjacent borrow pits (BP1 and BP2) (where it was contained) at rate of 75 L/s for the eastern sump and 100 L/s for the western sump (24 January 2018).
- Following an extreme rainfall event, runoff from the West D area of the NOEF breached a bund into an adjacent clear water drain which flows to the South West Sediment Trap which reports to Surprise Creek, the estimated flow rate of the discharge was 5 L/s (24 January 2018).
- A hydraulic oil spill of approximately 100 L from Excavator 9003 (EX9003) while in the open cut mining area (14 February 2018).
- A hydraulic oil spill of approximately 130 L from Excavator 9004 (EX9004) while in the open cut mining area (16 February 2018).
- A hydraulic oil spill of approximately 100 L from Excavator 9004 (EX9004) while in the open cut mining area (18 February 2018).
- A hydraulic oil spill of approximately 200 L from Haul Truck 11 (HT9011) in the Footwall Quarry work area (18 February 2018).
- A hydraulic oil spill of approximately 100 L from Loader 3 (LD03) while in the open cut mining area (23 February 2018).
- A hydraulic oil spill of approximately 150 L from Dozer 7 (DZ07) while in the Central West region of the NOEF (22 March 2018).
- A hydraulic oil spill of approximately 150 L from Drill Rig 4 (DR04) while in the Footwall Quarry (30 March 2018).

The number of incidents reported to DPIR and the number of incidents recorded in the MRM incident register matches, a marked improvement from previous years indicating a better understanding between parties on what incidents should be reported. There was, however, still some discrepancy between the dates incidents were filed under, i.e., between the date of the incident, the date of the report or the date the report was received. The IM has previously recommended that DPIR establish a consistent approach to record keeping and to align this with MRM's own tracking systems. In addition, the DPIR was slow to respond with a request for information (RFI) in relation to groundwater exceedances at GW95S. The RFI was sent in March 2018, nearly four months after the S29 notification was provided to DPIR. The IM recommends that future RFIs are requested from MRM in a timely manner.

As discussed in Section 4.12.4.1, it is recommended that DPIR and MRM discuss the recording and reporting of exceedances within the various monitoring programs that MRM undertakes, in terms of exceedances being considered non-compliances or incidents. The goal of this discussion should be to reach an agreed position whereby appropriate criteria are established, legal requirements are met, an appropriate level of environmental protection is achieved and bureaucratic burdens are minimised.

4.14.5 Review of Expert Advice

4.14.5.1 Independent Tailings Review Board

The ITRB was appointed in September 2015. During the current reporting period, the ITRB completed a review of the detailed design prepared by GHD for the TSF Cell 2 Raise 4 MMP amendment application (ITRB, 2017). The ITRB (2017) raised no significant issues in their review but included a number of recommendations in their report such as:

- Base planning on conservative tailings dry densities (TDD) and take care with mud farming techniques (if applied).
- Provide reasonable assurance that the final arrangement can be achieved given conservative assumptions for stability assessment.
- Resolve the apparent anomaly between increasing saturation with time after tailings deposition and increasing dry density.
- Ensure consistency between geological maps used in reports that address geology and foundation geotechnical investigations.
- Concerning the TSF embankment design, review the need for filters given the transient nature of the contact of water against the embankment.
- Refer to the application of the observational approach and the desirability of additional testing of shear strengths with regard to embankment stability analysis.
- Take into account a drop in the elevation of the tailings beach adjacent to the embankment between the spigots of 0.25 m when determining the MOL.
- Resolve the inconsistencies in the hydraulic conductivity values adopted for the geotechnical stability analysis in Table 15 of the design report or present a clear discussion of why different parameters have been applied.

- Ensure that Zone 1 materials separate tailings from the higher permeability embankment materials at all locations within the TSF, including those already constructed.
- Consider the head and chemistry (standpipe) results from TSF embankment piezometers in the KCB seepage model.

4.14.5.2 Robertson GeoConsultants Inc.

During the operational year DPIR engaged Robertson GeoConsultants Inc. (RGC) to provide expert advice and a review (RGC, 2017) of the TSF Cell 2 Raise 4 detailed design report prepared by GHD. Based on their review, RGC recommended that the report be approved and MRM be permitted to proceed with the raise and operation of the facility. However, the following recommendations were made regarding a number of design aspects:

- Avoid mudfarming to control acid drainage from the tailings.
- Retain the filters in the embankment in the area of the spillway.
- Avoid less conservative tailings strength parameters to avoid the use of buttresses.
- Review the International Council on Mining and Metals guidelines (Golder, 2016) and consider appointing an ‘Engineer of Record’.
- Consider installing warning systems on the road at various locations downstream in case of a dam break.
- Undertake light detection and ranging (LiDAR) surveys of the top surface every six months to confirm that the recommended top surface topography is being achieved and maintained and confirm actual beach slopes and profile.
- Consider using a filter between the rockfill and underlying materials to prevent erosion and spillway damage.
- Clarify the pool location, the shape of the phreatic line, seepage through the embankments, and correspondence with cone penetration testing and piezometer data.
- Consider additional critical operating parameters (e.g., distance of pool from embankment crest, calculated factor of safety of key sections, deviation from expected pool water quality and the presence of soft, wet areas on the sideslope of the perimeter embankment).
- Increase pumping capacity to remove excess pool water.

The IM supports the engagement of external specialist advice to supplement internal expertise and to facilitate DPIR’s review and approval process.

4.14.6 Review of DPIR Environmental Monitoring Unit

The Environmental Monitoring Unit (EMU) undertakes check monitoring at mine sites throughout the Northern Territory. During the reporting period, the MacArthur River Mine EMU monitoring schedule for both surface water and groundwater underwent substantial revision. Check monitoring is to be undertaken at MRM biannually during the late wet season and late dry season.

In the updated schedules, the monitoring sites at MRM have been identified and the justification for their inclusion provided as well as the analytical suite. The revised monitoring schedule provided to the IM did not however contain criteria for assessment of performance or a set of objectives of the check monitoring, as previously recommended for inclusion by the IM.

The Environmental Monitoring Unit (EMU) completed a surface water sampling event during the reporting period, in March 2018. Surface water samples were collected from 11 sites. While the raw data was provided to the IM, a report detailing the findings of the check monitoring and interpretation of the data was not available at the time of reporting.

4.14.7 Review of Previous IM Recommendations Regarding DPIR Performance

4.14.7.1 Progress

The DPIR's progress and performance against previous IM review recommendations is summarised in Table 4.71.

Table 4.71 – Recommendations from Previous IM Reviews Concerning DPIR Performance

Subject	Recommendation	IM Comment
Incident reporting	DPIR should clarify with MRM incident reporting requirements, process and incident ranking	DPIR advise that all incidents are reported but are currently reviewing this process
IM review findings	The DPIR should prepare: ♦ An action plan detailing how high priority recommendations will be addressed, including a timeline ♦ Quarterly updates on progress towards implementing the high priority recommendations	Completed 2018 Action plan developed to address the IM recommendations. First quarterly progress report provided in March 2018
Site visits	The DPIR should: ♦ Continue regular site visits and use these to facilitate the exchange of technical information, address information gaps and inconsistencies, and minimise misunderstandings between the two parties ♦ Ensure that field inspection reports adopt a consistent approach to including recommendations and required actions	Completed Annual schedule for site visits developed. Technical working group forum to facilitate exchange of information established. Inspection reports reviewed for consistency Recommendations and required actions communicated in a consistent manner from March 2017 onwards
Documentation	The DPIR should establish a database or register that captures instructions issued to MRM, and similar actions. This should include the date of the instruction, key points, status of MRM's response, and key dates	Completed Review of instructions issued since 2016 has commenced and a register of instructions relating to the NOEF and SOEF has been developed. No instructions issued since August 2016

Table 4.71 – Recommendations from Previous IM Reviews Concerning DPIR Performance (cont'd)

Subject	Recommendation	IM Comment
Documentation (cont'd)	The DPIR should establish a database or register that captures instructions issued to MRM, and similar actions. This should include the date of the instruction, key points, status of MRM's response, and key dates	Completed Review of instructions issued since 2016 has commenced and a register of instructions relating to the NOEF and SOEF has been developed. No instructions issued since August 2016
	The DPIR should investigate further with MRM how incidents and near misses are reported, and ensure that incidents and near misses are appropriately closed-out with relevant actions being captured in the database referred to above	Ongoing The DPIR still advise that all incidents are reported but are currently reviewing this process. IT services engaged to assist with management of information
ICE and ITRB	The DPIR should: ♦ Facilitate the resolution of GHD's potential conflict of interest given that GHD is both the ICE and TSF design engineer ♦ Promote clarity of roles between the ICE and ITRB and encourage MRM to explore possible synergies to ensure that maximum benefit is obtained from their engagement	Ongoing Matter was raised during the February 2018 site visit. Officers to work with MRM to confirm respective roles and synergies effected
MMP	The DPIR should ensure that MMP commitments (and OPR commitments where applicable) are: ♦ Reduced and collated into a single list contained within the main MMP document ♦ Specific, measureable, attainable, relevant and time-based	Ongoing The DPIR requested a consolidated list of SMART commitments be provided in the 2017 OPR. Consolidated list of commitments included in Authorisation 0059-01 and 0059-02 issued June 2017. Continued work is required on developing commitments that are specific, measureable, attainable, relevant and time based
Review of MMP and other approval documents	The DPIR should ensure that a convention is adopted with regard to a consistent method for referring to the dates of correspondence/ documents. Ideally, reference should be the date of correspondence/document (and this can be qualified with date received, if required)	Ongoing Correspondence reviewed by the IM indicated that reference to correspondence was inconsistent with respects to using the date of the document. While this recommendation was previously completed it has been reopened for the current reporting period

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Table 4.71 – Recommendations from Previous IM Reviews Concerning DPIR Performance (cont'd)

Subject	Recommendation	IM Comment
Review of MMP and other approval documents (cont'd)	The DPIR should revise the current MMP review process (including requests for additional information) so as to improve its efficiency (and ensure that it is applicable to the OPR). In particular, this should include review of the 2013-2018 and 2013-2015 MMP's assessment processes to identify deficiencies in the process and opportunities for improvement. Rather than refer whole documents to EPA for consideration, ensure that the particulars of the project requiring assessment are clearly defined. Referring the entire MMP resulted in confusion regarding aspects of the project which had not substantially changed and for which MRM had approval to implement	Ongoing Currently developing simplified MMP guidelines and clear minimum acceptable standards. MMP templates are due for completion in the next reporting period for exploration, extraction and mining
EMU check monitoring	The DPIR should: ♦ Prepare a schedule for EMU's check monitoring ♦ Review EMU procedures and include content on the purpose and objectives of the check monitoring site visit	Ongoing The DPIR advised that MRM check monitoring scheduled with one surface water sampling event completed during the current reporting period. Procedures identified and prioritised for updating
	The DPIR should prepare a field report for the check monitoring site visit that is provided to MRM. The report should clearly document the objectives of the check monitoring and provide an analysis of the results (in the context of MRM's monitoring results)	Ongoing The DPIR advised that the check monitoring report will provide MRM with confirmation of sites sample and analysis of results
Auditing	The DPIR should review its compliance audit protocol to include as part of its assessment of MMP compliance whether the operator is also complying with guidelines, e.g., ANZECC/ ARMCANZ guidelines for water quality rather than simply completing an action, e.g., groundwater monitoring being undertaken quarterly	Ongoing No audits were conducted during the reporting period. DPIR advised that the procedure is being updated. New authorisation issued in July 2017
	The DPIR should define and document 'best practice' for specific areas of the operation and include this as part of the DPIR audit protocol	Ongoing MMP guidelines currently under review should articulate the standards to which a mine intends to operate in line with leading industry practice
Auditing (cont'd)	The DPIR should establish a goal that audit reports are finalised within six weeks of the audit being conducted	Completed No audit was conducted during the reporting period. Mining Officers advised of six week timeframe to complete audit reports

4.14.7.2 New Issues

During the 2017-2018 operational year, DPIR continued undertaking regular site visits and approved one amendment to the MMP. For the first time, an action plan was developed and progress towards implementing previous IM recommendations has been documented and was provided to the IM as the first quarterly progress report (March 2018). After reviewing the performance of DPIR in regulating MRM, the IM has made one new recommendations but strongly encourages DPIR to continue to progress recommendations from previous IM reports. Table 4.72 outlines recommendations brought forward and/or modified from previous IM reports.

Table 4.72 – Ongoing DPIR Performance Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Incident reporting	The DPIR should clarify with MRM incident reporting requirements, process and incident ranking. The DPIR should investigate further with MRM how incidents and near misses are reported, and ensure that these are appropriately closed-out with relevant actions being captured in the database referred to above	Medium
IM review findings	The DPIR should continue to update the action plan for implementing the IM recommendations and continue to compile quarterly progress reports	High
Documentation	The DPIR should establish a database or register that captures instructions issued to MRM, and actions or recommendations from the inspection reports. This should include the date of the instruction, recommendations/actions, key points, status of MRM's response, and key dates	High
ICE and ITRB	The DPIR should: ♦ Facilitate the resolution of GHD's potential conflict of interest given that GHD is both the ICE and TSF design engineer ♦ Promote clarity of roles between the ICE and ITRB and encourage MRM to explore possible synergies to ensure that maximum benefit is obtained from their engagement	High
MMP	The DPIR should ensure that MMP commitments (and OPR commitments where applicable) are: ♦ Reduced and collated into a single list contained within the main MMP document ♦ Specific, measureable, attainable, relevant and time-based	High
Review of MMP and other approval documents	The DPIR should ensure that a convention is adopted with regard to a consistent method for referring to the dates of correspondence/ documents. Ideally, reference should be the date of correspondence/ document (and this can be qualified with date received, if required). While this was addressed during the previous reporting period, inconsistencies occurred during the current reporting period (hence this recommendation remains ongoing)	Low
	The DPIR should revise the current MMP review process (including requests for additional information) so as to improve its efficiency (and ensure that it is applicable to the OPR). In particular, this should include review of the 2013-2018 and 2013-2015 MMP assessment processes to identify deficiencies in the process and opportunities for improvement	High

Table 4.72 – Ongoing DPIR Performance Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
EMU check monitoring	The DPIR should review EMU procedures and include content on the purpose and objectives of the check monitoring site visit	Low
	The DPIR should prepare a field report for the check monitoring site visit that is provided to MRM. The report should clearly document the objectives of the check monitoring and provide an analysis of the results (in the context of MRM's monitoring results)	Medium
Auditing	The DPIR should review its compliance audit protocol to include as part of its assessment of MMP compliance whether MRM is also complying with guidelines, e.g., ANZECC/ARMCANZ guidelines for water quality, rather than simply completing an action, e.g., groundwater monitoring being undertaken quarterly	Medium
New Recommendations		
Site visit inspection reports	The DPIR should track recommendations or actions provided to MRM in the inspection reports. It would be useful to include a summary table in each inspection report showing progress against previous recommendations or required actions. In addition, DPIR needs to use clear language regarding recommendations/actions as to whether MRM is required to address them or if they are only for consideration	High
Requests for information	The DPIR should ensure that future RFIs are requested from MRM in a timely manner	Low
Exceedance/ incident reporting	The DPIR and MRM should discuss the recording and reporting of exceedances within the various monitoring programs, in terms of exceedances being considered non-compliances or incidents. The goal of this discussion should be to reach an agreed position whereby appropriate criteria are established, legal requirements are met, an appropriate level of environmental protection is achieved and bureaucratic burdens are minimised	High

4.14.8 References

Golder. 2016. Review of Tailings Management Guidelines and Recommendations for Improvement. Prepared by Golder Associates Pty Ltd for the International Council on Mining and Metals, London, United Kingdom.

ITRB. 2017. McArthur River Mining TSF Cell 2 Raise 4 to RL 10057 m Independent Technical Review. Report prepared by Bruce S. Brown, David J. Williams and Tamie Weaver of the Independent Technical/Tailings Review Board for McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2015. Sustainable Development Mining Management Plan 2013-2015, Volume 1. 3rd March 2015. Reference Number GEN-HSE-PLN-6040-0003, Issue Number: 7, revision Number: 0.

RGC. 2017. Technical Memorandum Review of TSF Raise 4 McArthur River Mind. Report prepared by Robertson GeoConsultants Inc. for McArthur River Mining Pty Ltd, Winnellie, NT.

5. Summary of Recommendations

5.1 2017 Recommendations

New IM recommendations are provided in Table 5.1. These have been grouped by topic and categorised as high, medium or low priority. High recommendations are considered a priority and relate to the more significant risks and information deficiencies. References are provided in the corresponding part of Section 4.

Table 5.1 – New Recommendations

Subject	Recommendation	Priority
Mine Site Water Balance (Section 4.2)		
Documentation and reporting	2017-2018 OPR: ♦ The numerous errors and inconsistencies within the OPR should be corrected to improve accuracy of representation of the status of on-site water management ♦ Water balance model calibration charts that misrepresent the models predictive ability should not be used in the OPR	Medium
Water storage ponds and tailings storage facilities	♦ It is recommended that a plan is developed for de-sludging the NOEF PRODs used for lime treatment ♦ A new waste discharge point from the TSF WMD to the adjacent Barney Creek is proposed. The ecological impact of these releases when Barney Creek flow is affected by backwater from high McArthur River flows needs to be considered ♦ The TSF Cell 1 east and west sumps overflows into the adjacent borrow pits. Changes to the sumps and/or pumps are required to prevent further sump overflows ♦ The TSF WMD currently has only a 39% (1 in 2.5) AEP flood immunity. It is recommended that the TSF WMD wall be modified to provide 1% AEP flood immunity	Medium
Accurate quantification of water balance model uncertainty	It is recommended that a comparison of model water balance parameters from year to year be undertaken as a measure of reduction in parameter uncertainty over time	Medium
Surface Water Quality (Section 4.3)		
General data interpretation and reporting	Clarification should be provided in the next surface water monitoring report as to: ♦ The total number of ASW sites, why data for only some of these are reported, and how the data for the remaining sites is used ♦ Discrepancies between the monitoring schedule, collated data and interpretative reports ♦ The status of DSD01 to DSD04 sites within MRM's monitoring program	Low
Diversion Channel Hydraulics Management (Section 4.4)		
Erosion	Ongoing monitoring of diversion channel and bank erosion should continue using ALS complemented by photograph monitoring and visual inspection. An annual report on observed erosion should then be completed. This should be undertaken every year to ensure an accurate record of erosion along the diversion channels. This can be done based on methods outlined by Hardie and Lucas (2002) as described by Hydrobiology (2016)	Medium

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Diversion Channel Hydraulics Management (Section 4.4) (cont'd)		
Integrity of the mine levee wall	Two independent inspection reports by Mining One (2016; 2018) have recommended erosion protection of a section of the mine levee wall. It is recommended that this is undertaken to reduce the likelihood of erosion impacting on the integrity of the levee	High
Sourcing materials	Given the need for rock armouring (both on the diversion channels and the levee wall), it is recommended that future sources for rock be investigated	High
Groundwater (Section 4.5)		
Surface water runoff inflows to the pit	An assessment of the recently identified surface inflows to the pit is recommended during the 2018/19 wet season, which should include field measurements of flow rates and observations of flow durations. These should be included in the pit and underground mine water balance to better estimate the groundwater contribution to the mine dewatering requirements. Efforts should also be made to improve the surface water controls around the pit to prevent unnecessary inflows and reduce the requirements to manage poor quality mine water	High
Seepage processes at the ELS	A recent assessment by MRM proposed that historical seepage from the ELS to McArthur River may have been due to physical loading affects (Section 4.5.3.2). However, the IM believes this may not be the case. It is recommended that further investigations be undertaken to determine the seepage processes, because of the juxtaposition of the proposed EOEF and the ELS, and possible future seepage impacts on McArthur River. The investigations should include a field program to identify possible aquifer pathways and estimate aquifer properties. The results of the field program should used to assess the adequacy of the seepage control measures at the EOEF	High
Attenuation of metals	The recent site-wide numerical groundwater flow and contaminant transport modelling carried out for the OMP SEIS (Section 4.5.3.2) suggests limited migration of metal contaminant plumes, because of attenuation. The long-term effectiveness of attenuation processes, particularly given the potential for rapid groundwater flow along discrete pathways, needs to be confirmed through further model calibration. It is recommended this be undertaken as part of the site's commitments, possibly as part of future MMPs	High
Natural mineralisation	Further studies are required to identify the source of high SO_4 concentrations in groundwater away for mine-related activities (e.g., east of the TSF and northeast of the NOEF near Emu Creek, which MRM relates to areas of natural mineralisation	High
NOEF interception trench	The option to install a seepage interception system between the NOEF and the Barney Creek diversion channel should be considered in accordance with the recommendations from the NIRB (Section 4.5.3.2). This should be undertaken in conjunction with an assessment of the environmental values associated with the Barney Creek diversion channel	Moderate
Assessment of groundwater level and quality trends	The 2016-2017 OPR included an assessment of the recorded groundwater level and quality trends using statistical methods (e.g., the Mann-Kendall test). The IM believes that this approach adds value, assisting in the screening of monitoring data and identification of environmental impacts. It is therefore recommended that future operational performance reports include this approach	Low
Groundwater model review	The review of groundwater models should be included in the information provided to the IM	Low

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Groundwater (Section 4.5) (cont'd)		
Diesel spill	DPIR should consider the reductions in the monitoring and reporting program suggested by MRM and KCB	Low
Borefields	An assessment of recovery rates should be carried out on all water supply bores	Low
Geochemistry (Section 4.6)		
NOEF	If there are justifiable changes to managing PAF(HC) materials differently from PAF(RE) materials, then develop more accurate methods of distinguishing between PAF(HC) and PAF(RE) mining blocks that can be effectively selectively handled	Medium
	Proceed with trial cover designs of the new GSL cover system as planned to determine constructability and performance, and include physical and chemical testing of the proposed BGM as part of the cover trials, with particular focus on UV and temperature sensitivity	High
	Undertake an independent review of the GSL cover system design in regard to saturation of the alluvium layer above the GSL and implications for slope stability	High
	Carry out a more comprehensive settlement assessment for the NOEF in regard to potential effects on the proposed BGM layer, supported by site observation and settlement monitoring during dump construction	Medium
TSF	Continue TSF surface sampling of deposited dry tailings and water extract testing, and include targeted sampling of TSF surfaces that have been exposed for extended periods with strong salt generation, and record sample descriptions to assist interpretation of results. In addition, proceed with the proposed tailings acidity load estimation work program (Earth Systems, 2017)	Low
Open pit	Current understanding of the long-term geochemical behaviour of the open pit relies solely on the KCB pit water quality modelling. Given that the open pit represents a major geochemical hazard for the site, have an independent expert verify the model predictions	Medium
Geotechnical (Section 4.7)		
TSF design	Include the effects of dynamic capacity of borrow pit areas and flow pathways in future stormwater capacity assessments	Medium
TSF design	The TSF designer should confirm that Zone 3 material has been included in the stability assessments provided in GHD (2017c)	Medium
TSF operation	Modify piezometers so that they are not impacted by stormwater. This may include converting some standpipe piezometers to VWPs	High
TSF operation	Provide a more definitive assessment as to the likely cause of increased piezometer levels at EMBGW10 and EMBGW2B and the implications on wall stability	High
TSF operation	Provide an update on what C1SA and C1SB improvements have been completed including pump changes, pump automation and diving bund changes or repairs	Medium
TSF operation	Update the MRM (2018e) trigger assessment spreadsheet to capture maximum and current water levels, and updated trigger assessment	Medium

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Geotechnical (Section 4.7) (cont'd)		
TSF monitoring	The frequency at which VWPs are currently logged varies across the TSF and generally higher than stated in the TSF operations manual (GHD (2017e). The frequency VWPs operations manual should be standardised across the TSF to a relatively high frequency (say 4 or 5 times per day) and the operations manual updated accordingly	Medium
TSF monitoring	The top and bottom location of the EMBGW3 screen as shown in time series plots should be corrected	Low
CWNOEF	Groundwater levels, temperature and gas composition monitoring at the NOEF is focussed on the historic areas of waste placement under the original EIS. This program should be expanded to the CWNOEF to allow the efficacy of design changes to be quantified	High
Closure Planning (Section 4.8)		
NONE		
Terrestrial Ecology (Section 4.9)		
Fauna	Standardise timing of early dry season riparian bird surveys to ensure results are comparable from year to year	High
Rehabilitation	Continue on-ground study of saline seepage in conjunction with remote sensing to ensure seepage points such as those hidden by dense riparian vegetation are detected	High
Fauna and flora	Sediment quality studies to reference Simpson and Batley (2016) as this superseded the ANZECC/ARMCANZ (2000) interim sediment quality guidelines	Medium
Bing Bong Loading Facility dredge spoil	Develop a dredge spoil management plan prior to any future dredging works. Include a desktop assessment investigating the source of the saline water that caused previous vegetation die-back to avoid further disturbance	Medium
	Reduce vegetation monitoring at Bing Bong dredge spoil ponds to every three years	Medium
	Ensure cattle are excluded from the dredge spoil ponds and the perimeter drain as they could impact the drain and pond walls resulting in saline water leaching in to the surrounding vegetation	High
Rehabilitation	Consider rehabilitating the rocky gorge section of the McArthur River diversion as is. Further earthworks could have considerable negative impacts on the aquatic environment and are unlikely to significantly increase rehabilitation success	High
Flora	Ensure weed control includes the area surrounding Djirrinmini Waterhole to protect this area of high conservation and cultural value	High
Freshwater Ecology (Section 4.10)		
Suitability of non-destructive sampling methods for freshwater fauna	Non-destructive sampling methods should be used for barramundi in particular to allow for more individuals to be tagged as part of the tagging/ acoustic monitoring program, while still being able to collect samples for metals analysis. This would provide more detailed data on trends over time and in individuals if recaptured while reducing the number of commonly consumed species taken from the study area	Medium
Additional acoustic monitoring stations	The installation of additional receiving stations between the Upper Diversion and Cattle Yard (e.g., SW21 and/or SW07), Lower Diversion and Hidden Pool and the Glyde River would provide more detailed information on movements of freshwater sawfish and barramundi through the MRM lease and McArthur River diversion channel	Medium

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Marine Ecology (Section 4.11)		
Increased habitat for rock oysters at Bing Bong Loading Facility	As highlighted in IPE (2017a) and previous AMMP reports, there are limited remaining rock oysters at the Bing Bong Loading Facility occurring on natural rock for future sample collection. As such, increasing habitat available for settlement should be explored and implemented soon to allow sufficient time for settlement and growth of sufficient individuals to ensure rock oysters can continue to be sampled from Bing Bong Loading Facility, particularly given their effectiveness as environmental indicator species	Medium
Suitability of non-destructive sampling methods for marine fauna	Non-destructive sampling methods should be used for barramundi in particular to allow for a tagging program to be implemented while still being able to collect samples for metals analysis. This would provide more detailed data on trends over time and in individuals if recaptured, particularly given the high variability in concentrations within individuals of the same species from the same location	Medium
Seagrass survey report	Continue to include long-term data sets in the data tables (while the 2016 report included data from 2013 to 2016, the 2017 report presented data from 2015 only)	Low
AMMP report	Provide information regarding the timing of collecting coastal water samples. A table showing the time the sample was collected and the corresponding tide level would be useful to demonstrate this previous IM recommendation is being addressed. Add detail about timing of sampling to the methods section	Medium
PbIRs for marine water	Include PbIR analyses for marine water samples for sites closest to the Bing Bong Loading Facility as well as reference sites Rosie Creek, Pine Creek and Pine Reef to provide further lines of evidence to demonstrate whether elevated Pb concentrations are from MRM operations or other sources	High
Soil and Sediment Quality (Section 4.12)		
Fluvial sediments – potential impacts of January 2018 rainfall event	In the 2018 fluvial sediment assessment, results for sites FS26, FS34 and FS24 should be reviewed in relation to the potential impacts of runoff incidents from parts of the NOEF following the January high rainfall event	Medium
Fluvial sediments – analytes	The next fluvial sediment report should explain the rationale for inclusion or exclusion of total sulfur as S, NAPP (ANC/MPA) and NAG in the program	Low
Nearshore sediments – Zone 5 Zn exceedances	In the 2018 nearshore sediment assessment, Zn results in Zone 5 should be reviewed. If they continue to be elevated, the source should be investigated	Medium
Nearshore sediments – interim values	The next nearshore sediment assessment report should advise the calculation method for interim criteria	Low
Marine sediments – contribution of sediment fractions versus concentrations	The approach used in 2017 in both the AMMP and the TSA programs of quantifying the percentage contribution of the <63 μm sediment fraction to allow comparison between sites and to assess risk to biota should be continued in 2018 (noting that analysis of the <63 μm fraction should continue)	Medium

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Dust (Section 4.13)		
Crusher dust suppression	The assessment of a rotary atomiser-based dust suppression system for the ROM bin primary crusher should be finalised and implemented, if appropriate, in the 2018-2019 operational period	Medium
Baseline data reporting	Depositional dust data previously collected at the mine site prior to August 2012 should be collated and summarised in the next ambient air quality monitoring report, to contribute to a baseline against which to assess the new DDG data, and to which the TARP objective can be applied	Medium
General data interpretation and reporting	The rationale for dust monitoring program changes should be considered and reported on a site-by-site basis. Where moving a monitoring site is necessary, a consistent and rational approach must be applied to site identification to minimise confusion and ensure that genuine comparison of results can be made across sampling periods	Medium
DDG reporting	♦ With regards to DDG reporting in the next ambient air quality monitoring report: – Monthly DDG results (including deposited dust and metals results from sampling or subsequent calculations) should be tabulated along with written interpretation of results in relation to criteria and/or background levels – Charts should be more clearly labelled – Natural dust deposition in the vicinity of the mine should be taken into account, thereby resulting in a standard for incremental deposited dust increase of 2.6 g/m^2/month, expressed as an annual mean	High
AQMP and TARP	♦ An update should be provided to the AQMP, addressing the following: – Rationale for removal of a large proportion of the previous monitoring network, and explanation of how DDG sites are intended to replace DMV monitors in relation to metals monitoring – If possible, more specific relevant criteria should be adopted and/or developed for DDG sites (particularly for metals) to enable assessment of results beyond comparison with historical levels – Rationale for the inclusion/exclusion of particular DDG and DMV sites in the TARP – Clarification of the TARP trigger for DMV sites (i.e., does it apply for a single Pb or Zn exceedance, or to be compared against historic data as stated in Section 10.1 of the AQMP)	High
	Any exceedances of the AQMP TARP triggers (TEOMs, DMVs and/or DDGs) in the next reporting period (at either the mine site or loading facility), along with cause/s, response actions and their effectiveness, should be reported in the next ambient air quality monitoring report to inform ongoing management	High
Reporting of exceedances	McArthur River Mining should include commentary in air quality monitoring reports where particular operational activities (e.g., concentrate being stockpiled outside) are known or suspected as being sources of exceedances in certain areas	High
Dust contributions to contaminant loads	McArthur River Mining should investigate dust/diffuse surface runoff contributions to contaminant loads reporting to surface drainages as part of the broader investigation into mine-derived loads as discussed in Section 4.3 of this report	Medium
Assessment criteria	The next ambient air quality monitoring report should correct the adopted criteria table (to match the AQMP) with regards to the TSP criterion, which is sourced from NSW EPA (2016) as opposed to the NEPM (NEPC, 2016)	Low

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
DPIR Performance (Section 4.14)		
Site visit inspection reports	The DPIR should track recommendations or actions provided to MRM in the inspection reports. It would be useful to include a summary table in each inspection report showing progress against previous recommendations or required actions. In addition, DPIR needs to use clear language regarding recommendations/actions as to whether MRM is required to address them or if they are only for consideration	High
Requests for information	The DPIR should ensure that future RFIs are requested from MRM in a timely manner	Low
Exceedance/ incident reporting	The DPIR and MRM should discuss the recording and reporting of exceedances within the various monitoring programs, in terms of exceedances being considered non-compliances or incidents. The goal of this discussion should be to reach an agreed position whereby appropriate criteria are established, legal requirements are met, an appropriate level of environmental protection is achieved and bureaucratic burdens are minimised	High

5.2 Ongoing Recommendations

In addition to the new recommendations summarised in Table 5.1, a number of recommendations have been identified from previous IM reviews that have either been partially addressed or not advanced at all. These ongoing recommendations, which in some cases have been modified to better address current site risks, are summarised in Table 5.2. References are provided in the corresponding parts of Section 4.

Table 5.2 – Ongoing Recommendations

Subject	Recommendation	Priority
Mine Site Water Balance (Section 4.2)		
Documentation and reporting	Water balance model reporting ♦ It is recommended that more tables are used to improve clarity, understanding and error checking	Medium
Water balance sensitivity analysis	Changes in water chemistry ♦ The 2015/16 water balance modelling report (WRM, 2015) undertook this analysis by changing the controlled release dilution rate from 1 part mine water to 15 parts McArthur River water (1:15) to 1:50. It was found the changes had negligible impact upon the overall site water balance. It is unknown why a 1:50 dilution ratio was chosen. The adopted change in site water quality needs to be justified with: – Current water quality monitoring data and/or predictions (e.g., pond water quality estimates, TSF/NOEF seepage estimates) – Input from professionals with expertise in geochemistry Runoff ♦ The 2016/17 and 2017/18 site water balance reports (WRM, 2016, 2018a) showed the NOEF SEPROD and NOEF WPROD were highly sensitivity to increases in runoff. This high sensitivity of changes to runoff volumes needs to be considered in all future water balance modelling	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Mine Site Water Balance (Section 4.2) (cont'd)		
Water storage ponds and tailings storage facilities	♦ While the risk of TSF Cell 2 spills to the TSF Mini Dam has been modelled, the impact (on the site water balance) of contaminating water stored in the WMD, thereby making it unsuitable for off-site release, should be assessed ♦ The MRM intent of improving TSF Cell 1 runoff quality is not reflected in current management of the cell's clay capping. This should be resolved	Medium
	The resilience of the site water management system to unforeseen changes: ♦ While the current site water balance modelling shows that the probability of uncontrolled off-site releases is within the design criterion (less than 5%), the key modelling assumption is that model inputs are correct and the system performs as modelled. There is no allowance for unforeseen changes to the water balance estimates (i.e., mine operations being different to those adopted in the model). McArthur River Mining needs to develop the surface water management system to the point where there is sufficient resilience to accommodate uncertainty in model estimates Variation in rainfall: ♦ McArthur River Mining needs to develop the surface water management system to the point where there is sufficient capacity that variation in rainfall between years (and sequences of consecutive wet/dry years) is treated as business as usual and not something abnormal	Medium
Accurate quantification of water balance model uncertainty	Model predictive uncertainty should be quantified. A readily available way to undertake this is to compare the predications (published in the previous year's water balance report) against the 'actual' site water balance for same period (based upon re-calibrated model results in the current year's report). This will greatly assist MRM in risk management	Medium
Accurate quantification of water balance processes	Model parameter uncertainty ♦ The uncertainty in model parameter estimation requires reduction. While this is implicit in all aspects of the water balance monitoring and modelling, high priority areas that should be addressed are: – The amount of simultaneous calibration of multiple parameters should be reduced – Evaporation fan/sprinkler/fountain performance should be accurately quantified – Groundwater inflow rates need more accurate estimation – Seepage rates and runoff rates need more accurate estimation	Medium
Surface Water Quality (Section 4.3)		
NOEF and TSF/ surface water monitoring program	Given the ongoing issues associated with the NOEF and TSF, a formal procedure is required whereby the review process for the surface water monitoring program, outcomes and required actions are documented (preferably in the proposed water management plan) and available for IM review	Medium
McArthur River/ SW11/other surface water sites	Environmental values to be protected in Barney Creek, Surprise Creek and McArthur River diversion should be determined in conjunction with relevant stakeholders, with the outcomes being used to direct measures to mitigate mine-derived elevated metal and major ion concentrations upstream of SW11	High

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Surface Water Quality (Section 4.3) (cont'd)		
McArthur River/ SW11/other surface water sites (cont'd)	A risk assessment should be undertaken concerning: ♦ Possible implications associated with elevated SO_4 concentrations and EC levels at sites within the ML that are next to or downstream of MRM facilities, e.g., McArthur River diversion channel, Surprise Creek and Barney Creek diversion channel, within the context of the environmental values that require protection and the relevant conditions in WDL 174-10 ♦ Likely causes (including groundwater inputs, surface water inputs and interaction of surface water with exposed mineralised areas) ♦ If MRM operations or activities are found to be a significant contributing factor, mitigation measures commensurate with the level of risk	High
	Mitigation of elevated concentrations of metals and major ions in Surprise and Barney creeks and the implementation of mechanisms additional to an interception trench between TSF Cell 1 and Surprise Creek should continue to be explored by MRM, with a view to preventing the need for dry season dewatering of Barney Creek and within the context of the environmental values upstream of SW11 that require protection	High
	The hypothesised (by MRM) role of Glyde River elevated on filterable Al and Fe at SW11 should be confirmed	Low
	McArthur River Mining should continue to determine changes in mine-derived TSS loads over time, taking into account flood events. This assessment should also address TSS from operations at the Bing Bong Loading Facility	Medium
Monitoring	Real-time in situ monitoring at SW11 should be implemented with the issues observed during previous wet season (e.g., burial of the probe, damage due to inundation) being appropriately addressed	High
	Continued focus should be placed on QA/QC as part of the water sampling program, including: ♦ Elevated trip blank Zn and Al levels ♦ Occasional poor precision for DGT analyses ♦ Potential contamination issues associated with operating an environmental laboratory on a mine site	Medium
	Additional effort should be devoted to the following in relation to mine-derived loads of contaminants: ♦ Contaminant load estimates should be determined, where these reflect both natural and mine-associated sources (including but not limited to the TSF, OEFs, ELS (including definition of the relative influence of ELS seepage versus inputs from mineralises areas), run-off dams and open pit) reporting to Surprise Creek, Barney Creek (and diversion channel), Emu Creek, and McArthur River (and diversion channel). Glyde River should also be included in these estimates (although this is a lower priority) ♦ Load calculations (and load balances) should take into account current and predicted natural and mine-derived loads, filtered and unfiltered metals, groundwater (e.g., seepage from various mine facilities) versus surface water inputs (e.g., discharges from MLDP), and seasonal variation ♦ The need to sample over specific flood events in McArthur River, Barney Creek, Surprise Creek and Emu Creek (and Glyde River) to complement the weekly sampling program and obtain robust load estimates should be considered, as should other measures to address the uncertainties identified in WRM (2018c) ♦ Using results from the above, mine-associated sources should be ranked in terms of contributions of contaminants to McArthur River at SW11 and further downstream, and used to prioritise management/mitigation actions	High

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Surface Water Quality (Section 4.3) (cont'd)		
Monitoring (cont'd)	Validation of the release calculator results should be explicitly and formally recorded	Low
	The recommendations in KCB (2016) should be fully implemented	High
Water management system	Specific surface water quality management objectives for the artificial surface water monitoring program should be formalised for Bing Bong Loading Facility and incorporated into relevant MRM documents, e.g., the proposed water management plan	Low
	Seepage through the DSEA embankments should be addressed prior to future placement of dredge spoil in the ponds. This should also include characterisation of spoil currently contained within the DSEA	High
	Maximising the volumes of Class 4 water that are discharged to McArthur River, thereby minimising the volumes of water stored on site and facilitating water management on site, should be undertaken <u>with due consideration of mine-derived loads and the need to maintain downstream water quality such that overall impacts on the environmental values associated with the river system remain protected</u>	High
	Further clarification of: ♦ Rules for release of Class 4 water, e.g., how the minimum McArthur River flow triggers are used, using mechanisms such as a decision tree or similar should be provided ♦ The status of class 5 water in relation to managed release and minimum river flow trigger values	Low
General data interpretation and reporting	A reconciliation of all actual versus proposed surface water sampling events should be completed annually and included in the surface water monitoring reports (where this addresses both natural and artificial surface waters)	Medium
	Comparison of metal and metalloid results with ANZECC/ARMCANZ (2000) values should include the 95th percentile values as well as median values for all surface water monitoring sites	Medium
	Future MRM reporting about progress in relation to (i) investigations to address information gaps, and (ii) meeting other commitments (e.g., those contained elsewhere in the OPR) in relation to surface water quality should include the original and revised (if necessary) completion dates, with supporting explanations concerning the revised dates Clarification should also be provided in relation to the actions/ recommendations in the 2016-2017 OPR and 2017-2018 OPR, and the knowledge gaps in the previous OPR Source documents in relation to MRM commitments should include MMP information requests, amendment and conditional approvals	Medium
Erosion	The proposed mitigation measures to address gully erosion near the walking track leading to NOEF SEL1 DP should be implemented prior to the 2018/19 wet season. Similarly, the potential for erosion at the actual pipe outlet should also be evaluated and addressed as required	Medium
Diversion Channel Hydraulics Management (Section 4.4)		
Overland flow path	The rock protection of the overland flow path appears to be adequate at present; however, it is recommended that the rock protection be inspected after each wet season to ensure its stability	Low

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Diversion Channel Hydraulics Management (Section 4.4) (cont'd)		
Stability of the McArthur River diversion channel offtake	The Fluvial Erosion Study and Hydraulic Modelling both support the future occurrence of an avulsion with potential significant impacts to the mine levee wall. It is recommended that the recommendation from the Hydrobiology (2016) report are adopted, including: ♦ An options assessment, supported by the revised hydraulic modelling, into mitigation options for the avulsion ♦ The options assessment should investigate and consider the extent of the bedrock bar at the downstream extent of Djirrinmini Waterhole	High
McArthur River diversion channel instabilities	It is recommended that options to address the McArthur River diversion channel instabilities be investigated, as described in the Hydrobiology (2016) report	Medium
Barney Creek diversion channel instabilities	It is recommended that the Barney Creek diversion channel be included in regular inspections and that consideration be given to filling the old channel for mine closure as described in the Hydrobiology (2016) report	Low
Lateral movement Surprise Creek near the TSF	It is recommended that Surprise Creek near the TSF should be monitored annually and following high flows and reassessed as require, as described in the Hydrobiology (2016) report	Medium
Surprise Creek channel instabilities	It is recommended that the areas of instability on Surprise Creek be investigated and an options assessment conducted on mitigating the ongoing gully erosion	Medium
Large woody debris	It is recommended that the LWD sourcing plan is regularly revisited to ensure that availability is maintained	Medium
Monitoring gaps	The following recommendations are made as described in the Hydrobiology (2016) report: ♦ Cross-sectional survey at several locations to obtain bathymetric information currently unavailable from LiDAR data ♦ Expanding annual LiDAR coverage to include the covered by the 2011 LiDAR for effective comparison ♦ Regular (2-yearly) diversion assessments to establish a trajectory for the diversion ♦ Establishing geomorphic monitoring locations to be regularly assessed by MRM personnel, based on methods outlined by Hardie and Lucas (2002)	Medium
Groundwater (Section 4.5)		
Open pit and underground mine	The following revised recommendations are made regarding options to dewater aquifers responsible for inflows to the pit and underground mine: ♦ Field investigations should be undertaken to identify groundwater pathways associated with the pit and underground, including the – Western Fault Block north of the pit – Emu Fault ♦ The field investigations should include groundwater exploration drilling, installation of test bores and hydraulic testing of newly-installed bores (i.e., full-scale pumping tests where flows are sufficient or small-scale permeability test for lower yielding bores) ♦The conceptual model for the pit and underground should be updated to include the field program results	High

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Groundwater (Section 4.5) (cont'd)		
Open pit and underground mine (cont'd)	♦ Site-wide numerical groundwater flow and contaminant transport model should be updated to identify effective groundwater inflow controls, which may include installation of production bores to intercept groundwater flows towards the pit or underground	
NOEF	The following revised recommendation is made regarding the NOEF: ♦ An assessment should be carried out to identify the source of poor quality groundwater south of the NOEF and SEPROD and north of the Barney Creek diversion channel, particularly at bore GW102, and suitable controls applied	Medium
SPROD	The following revised recommendations are made regarding the SPROD: ♦ A synthetic liner should be installed as a long-term seepage control ♦ Monitoring data collected after the installation of the SPROD synthetic liner should be assessed to confirm that there are no ongoing unacceptable impacts on the surrounding groundwater environment. If elevated concentrations of SO_4 and Zn persist then further investigations will be required to identify the contaminant source	High
TSF	The following revised recommendations are made regarding the assessment of seepage impacts around the TSF: ♦ Further field investigations should be undertaken to better identify groundwater pathways around the TSF where high concentrations of SO_4 and TDS persist and estimate their hydraulic properties. The IM notes that the groundwater commitments register presented in the 2017-2018 OPR has identified this commitment as having been completed. However, the recent field program was centred around Surprise Creek north of the TSF. Further assessment is required along the eastern boundary of the TSF where the impacts from long-term seepage are evident. These investigations should include: – Groundwater exploration drilling to identify pathways – Installation of test bores – Hydraulic testing of newly-installed bores, comprising either full-scale pumping tests (where flows are sufficient) or small-scale permeability test (for lower yielding bores) ♦ The conceptual model for the TSF should be updated to include the field program results ♦ The updated conceptual model should be used to revise the TSF groundwater model and the revised model used to estimate current and future seepage impacts as well as suitable mitigation options both during operations and after closure. The simulations should include all TSF closure options being considered by MRM	High
General data interpretation and reporting	A summary of all groundwater commitments should be presented in future MMPs and operational performance reviews. The information presented the 2016-2017 OPR and 2017-2018 OPR needs to be expanded to include a summary of the groundwater monitoring commitments, both site wide and for the 2011 diesel spill, and other actions related to the diesel spill. SSTVs should also be included once they become available	Low
	Site-specific trigger limits need to be developed for all groundwater monitoring sites to facilitate data interpretation and identification of unacceptable impacts, with these SSTVs being assessed in future IM reviews	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Groundwater (Section 4.5) (cont'd)		
General data interpretation and reporting (cont'd)	McArthur River Mining should commit to reporting all breaches of their groundwater commitments to DPIR. In particular, there appears to be an acceptance that exceedance concentrations of SO_4 and salinity in areas previously affected by seepage do not warrant reporting	Low
Geochemistry (Section 4.6)		
NOEF	Determine whether elevated SO_4 concentrations in groundwater bores to the northeast of the NOEF (GW105, GW100, GW131 and GW134) are related to shallow seepage from the NOEF along natural drainage	Low
	Progress field confirmation of erosion modelling predictions, as erosion could have significant implications for long-term cover system integrity and maintenance resources required	High
	Prepare a treatment and water management schedule for acid and contaminated water in NOEF SPSD/SPROD/SEPROD to ensure there is adequate storage to avoid uncontrolled release	High
	Given that PAF(HC) materials are still highly pyritic, continue end tipping in 2-m lifts and traffic compaction of these materials to maximise stability and minimise oxidation and infiltration	High
WOEF	Review/compile existing data and/or undertake a test program to confirm the distribution of geochemical rock types at the WOEF and finalise closure options	Medium
Waste rock segregation, handling and checks	Fully switch to ICP analysis by progressing the on-site and off-site ICP testing capacity to avoid further contingency use of pXRF	Medium
Waste rock criteria	Better demonstrate the validity of the PAF(RE) 10%S cut off	Medium
	Formally include PAF(HW) as a waste rock class to avoid confusion since it would be handled differently from other materials	Medium
Tailings kinetic testing	Prepare a tailings kinetic test report for the next IM reporting period	Medium
Infrastructure sites	Carry out more extensive sampling at infrastructure sites tested to date to be confident in the relative proportions of geochemical rock types. Sampling should be extended to cover placed waste rock materials and excavated in situ sulfidic materials at the Barney Creek diversion channel and McArthur River diversion channel	Low
Mine site	Assess the long-term local impacts of exposed sulfidic rock in the McArthur River diversion channel on water quality and revegetation success on the lower parts of the diversion	Low
Bing Bong dredge spoil	Carry out an acid sulfate soil assessment of the spoon drain around the dredge spoil ponds and other potential sources at Bing Bong Loading Facility	Low
Waste rock kinetic testing	Consider continuing LS-NAF humidity cells/columns to demonstrate longer-term low rates of contaminant release	Low
	Consider instigating a controlled watering regime for barrel tests, set to reflect a particular wet/dry climatic scenario, to make leachate volumes collected at each barrel more comparable to provide better and more interpretable results	Low

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Geotechnical (Section 4.7)		
TSF seepage	♦ The origin and veracity of fault mapping in the vicinity of the TSF need to be investigated further ♦ Further investigations are needed to quantify preferential flow paths for seepage. These investigations should use all available geological information to maximise efficiency and improve the basis for subsequent modelling. Mapping should be used to set the depth of modelling which may need to be increased from 20 m to substantially greater depths ♦ The WRM water balance needs to be updated to include estimates of TSF evaporation and seepage. Seepage estimates are likely to be improved through the actions described above.	High
	McArthur River Mining should review the current strategy for preventing seepage to Surprise Creek in light of recent groundwater monitoring, EM remote sensing and any other relevant data. This review should present evidence as to the effect of existing mitigation strategies, their longevity and long-term feasibility in consideration with other mitigation works such as final capping of Cell 1	High
TSF density	Undertake a reconciliation of deposited mass and surveyed volume to estimate in-situ density	Medium
TSF operations manual	Reconcile a number of discrepancies within the operations manual	Low
NOEF design	McArthur River Mining has made substantial progress in understanding the composition of borrow materials and this needs to be continued. A clear timetable of outstanding activities required to finalise OEF cover design will need to prepared as soon as practicable. The timetable should specify and prioritise additional testing and identify required outcomes.	Medium
NOEF rehabilitation	A plan needs to be developed which describes how progressive rehabilitation will be undertaken and in what sequence. The IM understands that some of the detail of this may be pending future trials and/or approvals. However, developing a plan would identify rehabilitation targets and clarify trial and approval priorities	Medium
SOEF operation	The SOEF continues to exhibit signs of cracking, water ingress and overall poor performance indicative of the uncontrolled manner of construction. The management of this facility needs to be improved through proper encapsulation or removal as soon as practicable.	Medium
Design	A life of mine concept design has been prepared. However the IM is still unaware of a design document for the dredge ponds that can be used to measure performance against measurement, such as settlement and pore pressures	High
Maintenance	Undertake all of the recommendations given in the annual inspection reports, GHD (GHD, 2017a) and (GHD, 2018c), at least three months before dredging or the next wet season, whichever comes first. These remaining recommendations are summarised as: ♦ Review the design and operation of spillways ♦ Line the Cell 5 spillway to the environment with rock ♦ Repair damaged section of the Cell 5 embankment toe ♦ Clear out sediment from the pipe culvert and rock line the outlet ♦ Provide crest drainage every 20 m	Medium to high (depending on planned dredging)

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Geotechnical (Section 4.7) (cont'd)		
Maintenance (cont'd)	♦ McArthur River Mining to review the design and operation of the diversion channel system Some of these recommendations may have been superseded and this should be clarified with GHD	
Monitoring	McArthur River Mining is to develop a routine (nominally monthly) inspection checklist and instigate routine surveillance inspections for the BBDS ponds as per GHD and IM recommendations. The IM recommends monthly inspections when dredging is in operation and quarterly at other times	High
	Establish survey locations at the dredge pond locations and a benchmark in preparation for future dredging. Undertake surveys in accordance with ANCOLD (2012)	Medium
	The BBEMB series piezometers should be included in the regular groundwater monitoring campaigns. Their groundwater levels should be recorded or otherwise noted as being dry as undertaken for all other Bing Bong wells. Suggested frequency is monthly during the wet season and during dredging, 3 monthly otherwise	Medium
Closure Planning (Section 4.8)		
Mine closure commitments	As part of the review of the mine closure plan, MRM should review all previous rehabilitation and closure commitments that have been made since underground mining commenced. All commitments should be upgraded to reflect the current status of the operation, community expectations and good industry practice	High
Mine closure costs	A comprehensive review is required of the closure costs. Determining the timeframe that post-closure monitoring and maintenance will be required should be a key aspect of this review. Allowance should be made for: ♦ Costs (drill, blast and haul) associated with the selective mining of LS-NAF(HC) are included in the revised mine closure cost estimate ♦ Long-term monitoring of cover performance ♦ Maintenance of the cover system, including inspection of geotechnical integrity ♦ Collection and treatment of leachates (surface and groundwater), and active water management post-closure including potentially the pit lake ♦ Monitoring and maintenance of the mine levee wall ♦ Monitoring and maintenance of McArthur River diversion channel	High
NOEF	A trial should be undertaken to construct a cover to the required specification and regularity of thickness to demonstrate that the cover can perform for the period of its design life. Samples from the trial compacted clay liner should be tested for density and permeability after compaction, with testing to be undertaken at intervals over the full thickness of the liner	High
	The potential for differential settlement of the NOEF to compromise the cover design should be evaluated, with particular focus on the potential implications for highly reactive PAF material to settle faster than other waste rock contained in the NOEF	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Closure Planning (Section 4.8) (cont'd)		
TSF	An interim cover design has been developed for TSF Cell 1. McArthur River Mining currently does not have any plans for retreatment of the tailings within Cell 1, although with further technological advances retreatment may be possible. An opportunity exists for MRM to develop its TSF closure strategy by implementing a final cover over either all or part of Cell 1. A final cover strategy trial should be undertaken on Cell 1 for at least part of the area. The IM understands that MRM's preferred closure strategy for the TSF has changed and relocation of tailings to the open pit is the preferred strategy. This change in strategy once confirmed will change the IM's recommendations with regard to TSF closure	High
	Erosion and sediment transport modelling of the proposed TSF landform should be undertaken to identify the depth of NAF cover material required to ensure the functionality of the cover for 100, 500 and 1,000 years	Medium
Closure objectives, criteria and performance indicators	The current mine closure objectives, criteria and performance indicators should be revised. The objectives should be outcome based and focused on the proposed post-mining land use. The closure criteria and performance indicators should be site specific and capable of objective measurement or verification	Medium
Bing Bong Loading Facility	Prepare detailed closure costs for the Bing Bong Loading Facility and present these as a separate domain from the mine closure costs	High
Terrestrial Ecology (Section 4.9)		
Rehabilitation	Add known saline and/or SO_4 seepage sites (e.g., Barney/Surprise Creek confluence and Surprise Creek next to the TSF) to the seepage impacts vegetation monitoring program	High
	Include a revegetation monitoring site in the downstream area in the rocky gorge along the McArthur River diversion channel along with a suitable control site, as this location will not rehabilitate in the same manner as other sites and data is required to ensure that it is also rehabilitated to an appropriate stage	Medium
Revegetation monitoring	Results from dust monitoring sites DMV25 and DMV23 should be assessed against foliage cover results from vegetation control sites BCC1 and BCC2 respectively, to identify whether airborne dust is a causal factor in decreasing foliage density	Medium
Fauna	Compare data collected during the migratory bird monitoring program with historical data for the region and surveys completed in other locations on the EAA flyway. Conduct a review of the current monitoring program to assess if it is sufficient to determine if MRM activities are impacting migratory birds	Medium
Bing Bong Loading Facility	Investigate recent ponding of tidal seawater against the bund wall during the annual GHD inspection and once identified address the cause	High
Bing Bong Loading Facility dredge spoil ponds	Include an inspection of the outside of the drain bund wall in monthly inspections of the dredge spoil cells, to assess if tidal seawater is ponding against the bund, for new erosion or cattle damage. Annual monitoring is not sufficient to allow timely repair of damage and to prevent further disturbance of the surrounding vegetation	Medium
Fauna	Add information on vegetation mapping units that are important foraging habitats to the Gouldian finch habitat map figure. Units have already been mapped but are yet to included on a figure	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Terrestrial Ecology (Section 4.9) (cont'd)		
Rehabilitation monitoring	Monitoring to be based on an ecosystem function assessment such as the ephemeral drainage-line assessment (Tongway and Ludwig, 2011)	High
	Include a targeted completion year for revegetation works along the diversion channels in future MMPs based on results of rehabilitation monitoring programs and tube stock survival rates	High
Aquatic Ecology (Section 4.10)		
Assess and mitigate potential ecological impact of flow monitoring infrastructure	McArthur River Mining is planning to construct flow monitoring stations on McArthur River and Surprise or Barney Creek that would require a concrete weir-like structure. Any structure that acts as a barrier to fish movement has the potential to alter fish communities upstream of the structure. Prior to construction, the potential ecological impacts of such infrastructure should be assessed, and mitigation (e.g., fishways) planned and implemented if required	High
Movement of contaminated biota	A desktop investigation should be undertaken regarding potential movement of contaminated biota in McArthur River and how long biota needs to spend at exposed sites to uptake elevated levels of contaminants	Medium
Reduce emissions at ROM pad	Additional monitoring of Barney and Surprise creeks in the vicinity of the ROM pad (SW03, SW18) shows that there are elevated levels of Pb in biota from these sites, likely as a result of dust emissions and/or related runoff from the vicinity of the mill and associated concentrate stockpiles. McArthur River Mining should investigate and implement ways to reduce dust emissions and/or contaminated runoff in the vicinity of these sites	High
Management of the SEL	Determine the future role of the SEL as it is currently uncertain and is dependant upon on the outcomes of the OMP EIS	Low
Identify potential sources of contamination in Barney Creek diversion channel	McArthur River Mining should, as part of its forthcoming water management plan, conduct a full review and synthesis of the monitoring programs at McArthur River Mine, including metals in freshwater fauna, macroinvertebrates, surface water, groundwater and fluvial sediments, to identify additional sources of contamination at the mine site. The IM understands that the dust and soil programs will not form part of that document; however, a review of those programs should also be undertaken in relation to potential sources of contamination in Barney Creek diversion channel. Using a conceptual site model could be a useful approach to integrate monitoring programs (NTEPA, 2013). Legacy impacts should also be addressed	Medium
McArthur River diversion channel rehabilitation	McArthur River Mining should consider excavating or blasting of riverbanks and/or the central channel in areas of poorest rehabilitation to create eddies, improve sinuosity, slow flow rates and facilitate soil deposition and eventual vegetation establishment to improve freshwater habitat	Medium
Drawdown at Djirrinmini Waterhole	An investigation should be undertaken to determine the ecological impacts (including to freshwater sawfish) of a predicted drawdown of 0.7 m at Djirrinmini Waterhole, and possible mitigation of the impacts. The outcomes of the investigation should be documented in the water management plan and made available to the IM	Medium
Marine Ecology (Section 4.11)		
Timing of dredging	Do not dredge during rain events to ensure that particulate matter will have enough time to settle out before flowing out of the dredge spoil ponds. Dredging only in the dry season would be preferable, as there will be minimal chance of intense rain	Low

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Marine Ecology (Section 4.11) (cont'd)		
Contaminant uptake and dispersal in biota	As fish with elevated, mine-derived Pb have previously been caught in the Bing Bong Loading Facility shipping channel and such fish may move away from the facility, the following should be investigated: ♦ The time it takes for a measurable contaminant load to be taken up in mobile species (e.g., barramundi, giant queenfish, mud crab, blue-tailed mullet) ♦ Sources of contamination in these species – are contaminants absorbed by consuming contaminated prey species and/or merely by persisting in the swing basin? ♦ Likelihood of dispersal in these species and potential dispersal distances As discussed in IPE (2017a; 2018a) this recommendation could be addressed by a tagging program, acoustic arrays and non-destructive sampling methods	Medium
Soil and Sediment Quality (Section 4.12)		
Exceedance/ incident reporting	♦ Ongoing reporting of exceedances via annual OPRs is a minimum requirement. Exceedances should not be treated as 'normal', but rather be reviewed and investigated as part of annual reporting. Where appropriate, new or revised management measures should be implemented to address the identified issues in the next period ♦ McArthur River Mining should review this matter with DPIR to reach an agreed position whereby legal requirements are met, an appropriate level of environmental protection is achieved, and bureaucratic burdens are minimised. A process such as a trigger action response plan may be appropriate to deal with ongoing exceedances, identifying under what circumstances certain actions should apply	High
Sediment monitoring data – assessment	The next version of the MMP, as well as future marine sediment monitoring reports, should reference Simpson and Batley (2016), which has superseded both Simpson et al. (2013) and ANZECC/ARMCANZ (2000), with regards to sediment quality guidelines	Low
Soil, fluvial sediment and marine sediment monitoring program – reporting	♦ QA/QC control data for sample analyses, and subsequent discussion, should be presented in the next version of the MMP ♦ While the IM notes that some discussion of QA/QC is now provided in all soil and sediment monitoring reports, this should be improved in the next operational period ♦ The QA/QC discussion for the surface water quality monitoring program in the current MMP (MRM, 2015a) provides a possible model for the soil/sediment programs. QA/QC should include trip blanks, records of holding time compliance, and method blanks, laboratory control spikes and matrix spikes	Medium
General data interpretation and reporting	♦ A reconciliation/discussion of actual versus proposed/committed sampling events should be provided as part of all future soil and sediment reporting periods ♦ The rationale for monitoring program changes should be considered and reported on a site-by-site basis. The range of potential contamination sources should be considered along with historical trends. If a site is known to have exceedances, the reasons should be assessed, and monitoring should continue at such a location unless there is a clearly stated reason to cease. Where it is necessary to move a monitoring site, a consistent and rational approach must be applied to site identification to minimise confusion and ensure that genuine comparison of results can be made across sampling periods	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Soil and Sediment Quality (Section 4.12) (cont'd)		
Surface soil monitoring	Monitoring of surface soil at control sites S10 (original location as per Q2 2017 and earlier) and S04 should be reinstated in 2018	High
Tl in nearshore sediment at BBDDP	The cause of exceedances of interim criteria for Tl within nearshore sediments at BBDDP should be investigated and the ecotoxicological implications of the data presented, with advice on required actions if Tl is found to be elevated due to MRM activities. This should include analysis of Tl within the dredge spoil ponds (potentially in 2019 as part of MRM's proposed geochemical investigation of the dredge spoil), and in swing basin sediments as part of the AMMP, in addition to fluvial sediments at the mine site as discussed	High
Dust (Section 4.13)		
Dust management – near the haul road bridge	Future air quality monitoring reports should provide specific comment on DMV43/DDG43 trends, along with actions taken to minimise dust impacts in this area (and why they were or were not adequate to mitigate impacts), or further actions that are proposed to stabilise or improve results	High
Dust management at Bing Bong Loading Facility	The main doors of the Bing Bong Loading Facility concentrate shed should be replaced as soon as practicable. Once doors are operational, they should be kept closed as often as possible	High
	The vents of the dust extractor system in the Bing Bong Loading Facility concentrate shed should be replaced/made operable as soon as possible	High
	The bitumen surface surrounding the Bing Bong Loading Facility should be repaired as soon as possible to avoid future soils, water and/or dust management issues. The IM understands that these works will be undertaken during 2018	Medium
Dust monitoring and analysis – TEOM and HVAS	The next air quality monitoring report should assess emissions trends recorded at the HVAS between periods, as well as exceedances recorded by TEOM units, with commentary on any operational aspects or weather patterns that may have influenced results	High
Dust monitoring and analysis – long term data	In addition to including long-term data, the next air quality monitoring report should include discussion and analysis of long-term trends (other than seasonality) and likely reasons	Medium
Reporting/ management of exceedances	The more noteworthy dust exceedances and long-term trends should not be treated as 'normal', but should be assessed and commented on in air quality monitoring reports, including specific comment on trends noted, any operational aspects or weather patterns that may have influenced these results, why (if applicable) existing dust controls may not have been adequate to mitigate impacts, or any further actions that are proposed to stabilise or improve results in accordance with the goals of the AQMP and TARP	High
	The focus of the AQMP (MRM, 2017a) and the assessment framework and TARP therein should be expanded beyond a human health focus to reflect the dust monitoring program goals of the MMP (MRM, 2015a) and the OPR (MRM, 2018a) – i.e., including minimisation of air quality related impacts with respect to the environment and ensuring that the values of the surrounding environment are protected. Incident reporting should reflect this	High

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
DPIR Performance (Section 4.14)		
Incident Reporting	The DPIR should clarify with MRM incident reporting requirements, process and incident ranking. The DPIR should investigate further with MRM how incidents and near misses are reported, and ensure that these are appropriately closed-out with relevant actions being captured in the database referred to above	Medium
IM review findings	The DPIR should continue to update the action plan for implementing the IM recommendations and continue to compile quarterly progress reports	High
Documentation	The DPIR should establish a database or register that captures instructions issued to MRM, and actions or recommendations from the inspection reports. This should include the date of the instruction, recommendations/actions, key points, status of MRM's response, and key dates	High
ICE and ITRB	The DPIR should: ♦ Facilitate the resolution of GHD's potential conflict of interest given that GHD is both the ICE and TSF design engineer ♦ Promote clarity of roles between the ICE and ITRB and encourage MRM to explore possible synergies to ensure that maximum benefit is obtained from their engagement	High
MMP	The DPIR should ensure that MMP commitments (and OPR commitments where applicable) are: ♦ Reduced and collated into a single list contained within the main MMP document ♦ Specific, measureable, attainable, relevant and time-based	High
Review of MMP and other approval documents	The DPIR should ensure that a convention is adopted with regard to a consistent method for referring to the dates of correspondence/ documents. Ideally, reference should be the date of correspondence/ document (and this can be qualified with date received, if required). While this was addressed during the previous reporting period, inconsistencies occurred during the current reporting period (hence this recommendation remains ongoing)	Low
	The DPIR should revise the current MMP review process (including requests for additional information) so as to improve its efficiency (and ensure that it is applicable to the OPR). In particular, this should include review of the 2013-2018 and 2013-2015 MMP assessment processes to identify deficiencies in the process and opportunities for improvement	High
EMU check monitoring	The DPIR should review EMU procedures and include content on the purpose and objectives of the check monitoring site visit	Low
	The DPIR should prepare a field report for the check monitoring site visit that is provided to MRM. The report should clearly document the objectives of the check monitoring and provide an analysis of the results (in the context of MRM's monitoring results)	Medium
Auditing	The DPIR should review its compliance audit protocol to include as part of its assessment of MMP compliance whether MRM is also complying with guidelines, e.g., ANZECC/ARMCANZ guidelines for water quality, rather than simply completing an action, e.g., groundwater monitoring being undertaken quarterly	Medium

6. Conclusions

As with previous years, considerable efforts have been carried out by MRM in regard to site geochemistry issues since the last IM report, greatly improving the understanding of AMD potential of mine materials and long-term risks, and better defining management options to mitigate both current mining impacts and future impacts during operations and closure. The management approaches outlined in the Draft OMP EIS (MRM, 2017) and OMP SEIS (MRM, 2018) are expected to significantly improve AMD control during operations and closure, but these are yet to have regulatory approval, and the NOEF, TSF and open pit remain major potential sources of AMD.

The Draft OMP EIS (MRM, 2017) and OMP SEIS (MRM, 2018) propose reprocessing of tailings and subsequent pit disposal. The tailings are classified as PAF, albeit with a long lag time, and have very high S (greater than 10%S) and will ultimately produce acid leachate. As such, they represent the greatest AMD hazard on site. Preferential placement of tailings in the pit and ultimate inundation of both tailings and pit walls is the most secure long-term strategy for these materials and is strongly supported by the IM. The pit void modelling approach is considered appropriate, and this indicates that long-term control of the open pit water quality to acceptable concentrations is possible.

The most significant success for the TSF in this reporting period is continued effective management of the decant pond, cyclic deposition, tailings strength gain and monitoring. Specific successes include:

- Completion of the 2-m raise of TSF Cell 2 to RL 57 mAHD.
- Construction of a new spillway for TSF Cell 2.
- Construction of a buttress along the Stage 1 crest of the eastern embankment.
- Updated operating guidelines, operating limits, triggers and actions.
- Ongoing monitoring of piezometric levels, settlement, pond levels, reclaim volumes and beach angles.

Seepage through the Cell 2 embankment is an ongoing issue and should be monitored as part of routine visual inspections with a specific focus on looking for evidence of increased seepage.

The CWNOEF has seen substantial progress with the construction of the subgrade works and the basal clay liner on the Alpha and Bravo stages of the NOEF. The current testing database shows that substantial material, compaction, permeability, CEC and geochemical testing has been undertaken on all aspects of the CWNOEF liner system. The total number of tests during the reporting period was over 3,400.

There have been a number of successes this reporting period, namely:

- Completing construction of the WPROD.

- Completing portions of the CWNOEF basal CCL, overlying LS-NAF and wedge CCL to allow placement of PAF material in Alpha and Bravo areas.
- Using alluvium advection barriers to reduce oxygen ingress into non-benign wastes. Limited monitoring to date suggests that new areas of the CWNOEF are currently showing lower temperatures than older areas. However, this may be due to due a range of factors including lower waste reactivity.
- Identifying new resources of clay and alluvium material in the pit and borrow areas for subgrade, wedge, liner and cover construction. Assessment includes an expanded set of geochemical testing to identify suitability. Updated targets and actual quantities are now routinely reported in OPRs.
- Extensive reporting by the ICE to document progress, testing and specification and evidence of conformance to the CWNOEF specification.
- Improved handling and placement of clays that has significantly reduced the number of CCL tests not meeting the specification. Consequently, the number of lots requiring excavation and re-compaction has also significantly reduced with an overall improvement in CCL consistency.
- Improving the West A and B portions of the NOEF through replacing the CCL base and reconstructing a proportion of the original PAF cell.
- Improving the West D portion of the NOEF through improved encapsulation of PAF material via the use of new halo material and outer CCL.
- Expanding the NOEF groundwater, gas and temperature monitoring program.
- Completing a number of relatively detailed studies on NOEF design, testing and predicted behaviour as part of the Draft OMP EIS (MRM, 2017) and the OMP SEIS (MRM, 2018). These studies improve the understanding of how the NOEF will perform in the short, medium and long term.

In addition, the preparation of OPRs is generally seen as a success in terms of more clearly showing activities and progress undertaken during reporting periods.

The site-wide numerical groundwater flow and contaminant transport model was updated as part of the OMP SEIS (MRM, 2018), which included revision of seepage rates from the NOEF, inclusion of hydrogeological features identified it the 2016-2017 field program, and model recalibration. The main uncertainties included groundwater inflows to the underground mine, the locations of naturally mineralised zones, and the long-term attenuation of metals and whether this will limit metals migration.

Water management is a key issue at both the mine site and Bing Bong Loading Facility and MRM has continued to improve in this area by increasing the number of monitoring sites with greater analysis of data and using this knowledge to improve management practices. Surface water quality monitoring data up to March 2018 indicates that adverse impacts on downstream surface waters due to the mine are currently limited, although some effects are noticeable in watercourses within the mine lease boundaries (and this is not unexpected). Compliance with WDL SSTVs at SW11 has improved, particularly in relation to EC and SO_4. Data from the DGT monitoring program suggests that adverse impacts on coastal waters near the Bing Bong Loading Facility similarly remain limited.

The IM also notes that MRM is devoting increased attention on the effects of the operation in terms of mine-derived loads reporting to McArthur River and the various sources that contribute to these loads, as has been advocated in a number of recent IM reports and is now required by various conditions in WDL 174-10. The existing (preliminary) information suggests that mine-derived loads for some contaminants is significant compared to background loads, and the next steps are for MRM to fully quantify these loads and changes over time, and determine the associated environmental risks, particularly in terms of downstream impacts within the context of the relevant environmental values.

The commissioning of the new SCADA network, together with the improved TARP tables, and the incorporation of both items into daily operations have produced a step change improvement in mine site water management. During the 2017/18 wet season, the adoption of these systems resulted in the controlled off-site release of 2,656 ML water as well as the successful management of the high rainfall that occurred in January 2018. It is unlikely that either would have been achieved without these systems.

There has been substantial improvement in the performance of the site water balance model since the 2012 operational period. The modelling tends to indicate that model predictions (one year ahead) are a reasonable representation of the actual water budget on site. Notwithstanding this, there remains uncertainty in the water balance modelling and the isolation of correlated parameters will be a multi-year task. Continual ongoing improvement of the water balance modelling is required, in particular in the reduction of parameter uncertainty.

The completion of the hydraulic assessment of potential fluvial erosion risk for the McArthur River and Barney Creek diversion channels (WRM, 2018) is a great step forward. These investigations were recommended in the geomorphic assessment commissioned by MRM and reported in Hydrobiology (2016) and the last IM report (ERIAS Group, 2017a), and their completion addresses those recommendations. However, the analysis supports the potential for erosion of the mine levee wall at the McArthur River off-take as identified in Hydrobiology (2016). This is a serious risk with potentially catastrophic consequences. Even if the avulsion doesn't immediately impact on the mine levee wall, the potential for considerable volumes of sediment to report to McArthur River is of great concern. Lateral migration of the channel will always be a concern (particularly when considering post-mine closure time frames) and preventing an avulsion in this scenario is likely to be far easier and less expensive than dealing with the impacts. An options assessment to mitigate the avulsion or its impacts is considered a priority for investigation for the next reporting period.

Impacts to the marine environment at the Bing Bong Loading Facility are almost exclusively restricted to the shipping channel, swing basin and the tidal flat area immediately west of the facility. The impacts to biota in these areas are mainly restricted to sessile species, species of low mobility and individuals of species which have extended residency times in the shipping channel and swing basin (e.g., barramundi). These groups of biota have been found to have higher Zn and Pb levels compared to biota collected from other sites away from the Bing Bong Loading Facility, and at times have had Pb isotope ratios extremely close to that of the MRM orebody.

In 2017, 84,000 tube stock were planted, predominantly along the McArthur River diversion channel, with 96% of tube stock grown on-site in the MRM nursery. No revegetation monitoring was conducted during the operational period, with a review of revegetation monitoring methods being undertaken and reported in ELA (2017), and the preparation of a rehabilitation management plan (RMP). The review included an assessment of the study methods and consideration of recommendations made by the IM in previous years, and recommended changes to the survey timing, success indicators, completion criteria, GIS rankings, key and primary species, survey methods and data analysis. The review of revegetation monitoring is timely and will be important in understanding the impact of fluvial erosion as identified in WRM (2018).

The 2017-2018 IM review of soils and sediments found that while there are ongoing issues relating to soil and sediment at the mine site and in the vicinity of Bing Bong Loading Facility, results are stable or improving (with a few exceptions). Management practices continue to improve, although changes to the soil monitoring program during 2017 are of concern due to the potentially compromised ability to compare results between years and lack of consideration of soil contamination sources other than dust.

Extensive changes have occurred in the air quality monitoring program as well as in management of dust issues during the reporting period. While there are some issues with these changes, they are largely expected to improve data collection and dust management in the long term. Some monitoring results in the current period have unfortunately worsened compared with previous years (most notably PM_{10} at DMV43, Pb near the processing plant and Mn at several sites), although monitoring programs as well as management practices continue to improve. The key ongoing concerns relate to dust management near Barney Creek haul road bridge, the inoperability of the main concentrate shed doors at Bing Bong Loading Facility, and the lack of analysis and discussion of observed dust exceedances.

In addition to the above findings, a major concern of the IM continues to relate to mine closure and the potential impacts on downstream water quality (including contaminant loads), given the issues associated with the NOEF, TSF and pit lake in terms of post-closure acid, saline and/or metalliferous drainage. This concern is detailed in ERIAS Group (2017b) and focuses on the need for MRM to consider what happens if the PAF waste encapsulation and NOEF cover are not as effective as envisaged in the modelling, and adaptive management is also not effective, i.e., the consequent downstream impacts that might occur in such a scenario.

The IM has also reviewed DPIR’s performance in regulating the McArthur River Mine. During the 2017-2018 operational period, the DPIR continued to undertake regular field inspections. The IM commends the DPIR on continuing these site visits and the comprehensive reports that are provided. During the reporting period, DPIR improved the inspection reports by including a recommendations section and the addition of ‘actions’ within the ‘observations’ section in the report which more clearly identify items for MRM to address.

In the last IM report it was noted that since commencing in the role as IM in 2014, a number of specific recommendations to improve the performance of DPIR have been made by the IM.

Progress on implementing these recommendations had been slow. The IM recognises that DPIR has completed a number of recommendations during the reporting period and has commenced work on all outstanding recommendations.

References

ELA. 2017a. MRM Revegetation Monitoring Review Briefing Paper. Prepared by Eco Logical Australia for McArthur River Mining, Winnellie, NT.

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Hydrobiology. 2016. Geomorphological Assessment: McArthur River and Barney Creek Diversions. Final Report, MRM1601_R_1_v2-0, December 2016. Prepared by Hydrobiology Pty Ltd for McArthur River Mining, Winnellie, NT.

MRM. 2017. McArthur River Mine Overburden Management Project, Draft Environmental Impact Statement. McArthur River Mining, Winnellie, NT.

MRM. 2018. McArthur River Mine Overburden Management Project Supplementary Environmental Impact Statement. McArthur River Mining, Winnellie, NT.

WRM. 2018. Hydraulic assessment of potential fluvial erosion risk for the McArthur River and Barney Creek Diversions. Report No 0790-44-C. Dated 9 March 2018. Prepared by WRM Water and Environment for McArthur River Mining, Winnellie, NT.

7. Limitations

7.1 Introduction

The following statements are intended to advise the reader of the scope of this report and the level to which conclusions may be drawn from the findings contained herein. These statements are not intended to reduce the level of responsibility accepted by ERIAS Group, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes by doing so.

7.2 General Limitations

ERIAS Group has prepared this environmental performance report in response to the following items and subject to the limitations contained therein:

- The McArthur River Mining Pty Ltd Authorisation 0059-02, and in particular the McArthur River Mine Independent Monitoring Assessment Conditions (IMACs).
- The specific scope of services set out in the Request for Tender issued by DPIR, and the subsequent notification of award of contract issued by the Department of Corporate and Information Services on behalf of the DPIR (Contract No.: D12-0274) on 9 December 2013.

This environmental performance report:

- Relates only to the areas referred to in the scope of works, being the McArthur River Mine and Bing Bong Loading Facility, Borroloola region, Northern Territory.
- Has reviewed environmental matters only. Issues relating to mine safety, health and/or social issues, personnel and administration matters or governance arrangements resulting from the operation of the mine have not been included in the assessment.
- Has been prepared for the particular purpose outlined in the DPIR scope of services and no responsibility is accepted for the use of this report, in whole or in part, in other contexts or for other purposes. This report may not be relied upon by any third party not named herein for any purpose except with the prior written consent of ERIAS Group.

7.3 Information Relied Upon

ERIAS Group has reviewed the information provided by MRM with regards to the environmental assessments and monitoring activities that the company has undertaken, as well as environmental assessments and audits undertaken by DPIR. This report has been prepared on the basis of:

- Information provided by MRM and DPIR, which was not verified by ERIAS Group except to the extent required by the scope of services. ERIAS Group has assumed that this information is correct unless otherwise stated, but does not accept responsibility for the accuracy or completeness of the provided information with respect to MRM's environmental performance.

- Information that existed at the time of production of this report and under the conditions specified. This report relates to the McArthur River Mine and Bing Bong Loading Facility as at the date of the most recent information provided by MRM, at the date of reporting. It is recognised that conditions may have changed thereafter due to site activities and/or natural processes. The scope of services allowed ERIAS Group to form an opinion of the actual performance of the site at the time of this assessment and this opinion does not apply to any subsequent changes at the site, or associated aspects.

7.4 Specific Constraints

Due to constraints of time during the assessment of environmental performance, ERIAS Group did not perform a complete assessment of all possible conditions or considerations at the site. For example, ERIAS Group has not:

- Undertaken a detailed site visit of the McArthur River Mine or Bing Bong Loading Facility (for example, not all monitoring locations were visited).
- Reviewed in detail all of the files provided by MRM or DPIR.
- Verified performance against commitments or IM recommendations for which information was not available at the time of this assessment.

At the time of preparing this report, the Draft OMP EIS and OMP SEIS findings were still being assessed by regulatory authorities and, as such, assumptions and findings contained herein with regards to overburden management (including current NOEF designs and overburden geochemical classification) may have limited applicability.

It should also be noted that reporting and interpretation of environmental monitoring data by MRM, which generally reflects the financial year (i.e., 1 July to 30 June) but is also supplemented by additional data where available and revised reporting periods, is not entirely consistent with the current IM review period (i.e., 1 October 2016 to 31 March 2018). This provides additional complexity to the IM's review of MRM's data and reports, and requires the IM to undertake data analysis and interpretation that is additional to that provided by MRM.

8. Definitions

8.1 Acronyms and Abbreviations

$\mu g/m^3$	micrograms per cubic metre
AEP	annual exceedance probability
ANC	acid neutralisation capacity
AMD	acid, metalliferous and saline drainage or acid mine drainage
AMMP	annual marine monitoring program
ANCOLD	Australian National Committee on Large Dams
ANZECC	Australian and New Zealand Environment Conservation Council
ARI	average recurrence interval
As	arsenic (element)
AS	Australian Standard
AS/NZS	Australian/New Zealand Standard
BBDDP	Bing Bong dredge discharge point
BCM	bank cubic metre, representing the content of a cubic metre of material in place, before it is drilled and blasted
BPEM	best practice environmental management
Cd	cadmium (element)
CCL	compacted clay liner
Cu	copper (element)
CWNOEF	northern overburden emplacement facility (central west phase)
DPIR	Department of Primary Industry and Resources
EIS	environmental impact statement
ELS	eastern levee storage
EMP	environmental management plan
EMS	environmental management system
EMU	Environmental Monitoring Unit
EPROD	east perimeter runoff dam
GDE	groundwater dependent ecosystem
IM	Independent Monitor

ISSTV	interim site-specific trigger value
ISQG	interim sediment quality guideline
ITRB	Independent Tailings Review Board
LiDAR	light detection and ranging
L/s	litres per second
LS-NAF(HC)	low salinity non-acid-forming rock (high capacity)
LWD	large woody debris
Mdmt	million dry metric tonnes
ML	megalitres
ML/d	megalitres per day
MLN	mining lease number
Mm^3	million cubic metres
MMP	mining management plan
Mn	manganese (element)
MPA	maximum potential acidity
MPC	maximum permitted concentration
MRM	McArthur River Mine
MS-NAF(HC)	metalliferous saline non-acid-forming rock (high capacity)
MS-NAF(LC)	metalliferous saline non-acid-forming rock (low capacity)
Mt CO_2-e	million tonnes of carbon dioxide equivalent
Mtpa	million tonnes per annum
NAF	non-acid-forming
NAG pH	net acid generation pH
NAPP	net acid production potential
NEPM	National Environment Protection Measure
NOEF	northern overburden emplacement facility
OEF	overburden emplacement facility
OCR	oxygen consumption rate
OMP	Overburden Management Project
NPR	neutralisation potential ratio
pa	per annum
PAF	potentially acid-forming

PAF(HC)	potentially acid-forming rock (high capacity)
PAF(RE)	potentially acid-forming rock (reactive)
Pb	lead (element)
PM_{10}	particulates with aerodynamic diameter less than 10 μm
$PM_{2.5}$	particulates with aerodynamic diameter less than 2.5 μm
PPE	personal protective equipment
ppm	parts per million
PSD	particle size distribution
QA/QC	quality assurance/quality control
RGC	Robertson GeoConsultants Inc.
RL	reduced level
ROM	run of mine
SEL	south east levee
SEPI	Sir Edward Pellew Group of Islands
SOEF	southern overburden emplacement facility
SPSD	southern perimeter sediment dam
SPROD	southern perimeter runoff dam
SEPROD	southeast perimeter runoff dam
SOEF	southern overburden emplacement facility
t	tonne(s)
TDS	total dissolved solids
tpa	tonnes per annum
TSF	tailings storage facility
TSP	total suspended particulates
WDL	waste discharge licence
WMD	water management dam
WMP	water management plan
WOEF	western overburden emplacement facility
WPROD	western perimeter runoff dam
Zn	zinc (element)

8.2 Glossary

abiotic	Of or relating to the non-living components of an ecosystem; physical rather than biological; not involving biological activity
abundance	(Biological and other sciences) the quantity or amount of something present in a particular area, volume, or sample, e.g., total numbers of individual animals or of taxonomic groups of animals
acid neutralising capacity (ANC)	Natural resistance of soils or rock to acid generation. It is the number of moles of protons per unit mass of soil required to raise the pH of the soil by one pH unit. ANC is measured as percentage $CaCO_3$
acid sulfate soil (ASS)	A soil containing iron sulfides deposited during either the Pleistocene or Holocene geological epochs (Quaternary aged) as sea levels rose and fell
acidify	To make acid; convert or change into an acid
alluvial	Describes material deposited by, or in transit in, flowing water
aquifer	A rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit quantities of water to wells and springs
background	The circumstances, situation, or levels of a particular parameter prevailing at the time of assessment; natural or pre-existing level of a variable
baseline	An initial value of a measure, parameter or variable
base metal	A general term applied to relatively less expensive metals, such as copper, zinc, nickel, lead, tin, iron and aluminium
benthic zone	The ecological region at the lowest level of a body of water, including the sediment surface and some sub-surface layers
berm	A cross-slope earthen bank constructed on reshaped spoil areas, typically at horizontal intervals of approximately 50 m and 1 to 1.5% longitudinal gradient, to reduce the effective slope length and control the runoff flow rate
biodiversity	Biological diversity; the variety of species (of plants, animals, etc.), their genes, and the ecosystems they comprise, in relation to a particular habitat. A high level of biodiversity is usually considered to be desirable and/or important

bioremediation	The use of naturally occurring micro-organisms for the restoration of polluted environments, in particular of contaminated land, and/or the groundwater associated with it
bioaccumulation	A process of concentration or accumulation within a 'food chain' of organisms
bore	A hydraulic structure that facilitates the monitoring of groundwater level, collection of groundwater samples, or extraction (or injection) of groundwater. Also known as a well, monitoring well or piezometer, although piezometers are typically of small diameter and only used for measuring the groundwater elevation or potentiometric surface
borehole	An uncased well drill hole
buffer	(Chemistry) a solution which resists changes in pH when acid or alkali is added to it. An ionic compound, usually a salt of a weak acid or base, added to a solution to resist changes in its acidity or alkalinity and thus stabilise its pH
catchment area	A recharge area or drainage basin and all areas that contribute water to it. The area that contributes water to a particular watercourse; a watershed
cation exchange capacity (CEC)	A measure of the potential or total capacity of a soil to retain exchangeable cations. The units are milliequivalents per 100 grams of material or centimoles of charge per kilogram of exchanger
clay	A fine-grained soil material composed of particles finer than 0.002 mm. When used as a soil texture group such soils contain at least 35% clay
commissioning	Process of testing, checking and inspecting all systems and components of a newly constructed facility, plant or piece of equipment to verify that it is installed and functioning according to design specifications and operational requirements
competent rock	Rock that has been proven by wetting and drying techniques to resist rapid weathering and thus maintain erosion resistant capability and durability
competent spoil	Non-acid, non-dispersive durable spoil with sufficient rock content to resist erosion
composite sample	(Soil, sediment or water sampling) a technique that combines a number of discrete samples collected from a body of material (one sampling location) into a single homogenised sample for the purpose of analysis, in order to represent the average conditions in the sampled body of material

concentrate	The product of the milling process, enriched in the valuable metal or mineral relative to the ore; typically a fine powder. The waste product of the concentration process is typically discarded as tailings
conductivity (EC)	Conductivity, or electrical conductivity (EC), is the degree to which a specified material (such as water) conducts electricity. This property is related to the ionic content of the sample, which is in turn a function of the total dissolved (ionisable) solids (TDS) concentration
confined aquifer	An aquifer that is confined between two low-permeability aquitards. The groundwater in these aquifers is usually under hydraulic pressure, i.e., its hydraulic head is above the top of the aquifer
confining layer	A layer with low vertical hydraulic conductivity that is stratigraphically adjacent to one or more aquifers. A confining layer is an aquitard. It may lie above or below the aquifer
contaminant	Something which contaminates, i.e., renders impure via pollution. In ecology, a substance which may degrade an environment (e.g., soil or water) due to toxicity to humans, animals or plants, or detriment to beneficial uses
contamination	Making or being made contaminated; to pollute a substance with another, unwanted, substance. Considered to have occurred when the concentration of a specific element or compound is established as being greater than the normally expected (or actually quantified) background concentration
controlled discharge	Release of a substance (e.g., wastewater) from a project area onto/into receiving land/water under conditions that meet a predetermined quality standard
cover material	Soil, alluvium, weathered basalt or other suitable plant growth medium placed on reshaped spoil surfaces; typically non-crusting and low salinity
density	(Botany, zoology, population geography) the quantity of plants, animals or people within a given area, or the average number of individuals per area sampled or assessed. For example, the number of animals or plants (individuals or taxa) per unit area
detritus	Particulate material that enters into a marine or aquatic system. If derived from decaying organic matter it is organic detritus
diversion channel	Structures for the controlled diversion of drainage lines and watercourses around open cut pits and infrastructure areas

diversity The state of being diverse. A diversity index is a quantitative measure that reflects how many different types (e.g., species) there are in a dataset, and takes into account how evenly the individuals are distributed among those types. Biological diversity (biodiversity) is the variety of species (of plants, animals, etc.), their genes, and the ecosystems they comprise, in a particular habitat

diffusion A process by which chemical species in solution move, driven by concentration gradients (from high to low)

dilution Making a solution diluted/weaker (lower concentration) by the addition of water or another solvent

discrete sample (Soil, sediment or water sampling) samples collected from different locations and/or depths that will not be composited but analysed individually

dispersion The act of dispersing; the state of being dispersed. A mixture of one substance dispersed in another medium, such as water or air. Ecology: the movement of individual animals, plants, etc., between sites; the pattern of distribution of individuals within a habitat

dissolved oxygen (DO) The level of oxygen in the gaseous phase dissolved in water (and available to aquatic organisms). Measured either as a concentration in mg/L or as a percentage of the theoretical saturation point, which is inversely related to temperature

disturbance The interruption of a settled condition. Ecology: a temporary change in environmental conditions causing a change or impact to an ecosystem

diversity The state of being diverse. A diversity index is a quantitative measure that reflects how many different types (e.g., species) there are in a dataset, and takes into account how evenly the individuals are distributed among those types. Biological diversity (biodiversity) is the variety of species (of plants, animals, etc.), their genes, and the ecosystems they comprise, in a particular habitat

drawdown Lowering of hydraulic head

ecosystem A community of organisms and their immediate physical, chemical and biological environment

elasmobranch An animal within the subclass of cartilaginous fishes which includes sharks, rays, skates and sawfish

electrical conductivity (EC)	Conductivity, or electrical conductivity (EC), is the degree to which a specified material (such as water) conducts electricity. This property is related to the ionic content of the sample, which is in turn a function of the total dissolved (ionisable) solids (TDS) concentration
environmental aspect	An element of an organisation's activities that can interact with the environment
environmental value	Particular values or uses of the environment that are important for healthy ecosystems or for public benefit, safety or health and that require protection from the effects of pollution
erosional stability	The ability of a rehabilitated area to resist the natural forces of soil erosion
externally drained	Rainfall runoff water that discharges to the external environment (off lease) via local drainage systems
flow path	The direction in which groundwater is moving
fluvial	A material deposited by, or in transit, in streams or watercourses
fracture	A break in the geological formation, e.g., a shear or a fault
geotechnical stability	Resistance of a slope to mass movement
gradient	The rate of inclination of a slope. The degree of deviation from the horizontal; also refers to pressure
groundwater	The water held in the pores in the ground below the watertable
groundwater elevation	The elevation of the groundwater surface measured relative to a specified datum such as the Australian Height Datum (m AHD) or an arbitrary survey datum onsite, or 'reduced level' (m RL)
gully erosion	The displacement of soil by running water that forms clearly defined, narrow channels that generally carry water only during or after heavy rain
hazard	A danger or risk; a situation that poses a level of threat to the environment, life, health or property
head space	The air space at the top of a soil, sediment or water sample

heavy metal	A metal of relatively high density, or of high relative atomic weight. There is no universally agreed definition, however, heavy metals commonly include (among others) cadmium (Cd), copper (Cu), lead (Pb), tin (Sn) and zinc (Zn)
horizon	Any definite position or interval in the stratigraphic column or the scheme of stratigraphic classification; generally used in a relative sense (geological)
hydraulic conductivity (K)	A coefficient describing the rate at which water can move through a permeable medium. It has units of length per time. The units for hydraulic conductivity are typically m^3/day/m^2 or m/day
hydraulic continuity	A water bridge or connection between two or more geological formations
hydraulic gradient (i)	A vector gradient between two or more hydraulic head measurements (liquid pressure at a given point) over the length of a flow path, i.e., the rate of change in total liquid pressure per unit of distance of flow in a given direction
hydraulic head (h)	A measure of liquid pressure above a geodetic datum, typically measured as a liquid surface elevation above a fixed datum, such as sea level. A measure of the mechanical energy that causes groundwater to flow
hydrocarbon	Any of the class of organic compounds containing only hydrogen and carbon, such as those which are the chief compounds in petroleum and natural gas
hydrocarbon, volatile	A hydrocarbon with a low boiling point (high vapour pressure). Normally taken to mean those with ten (or less) carbon atoms per molecule
impact	A marked effect or influence. Negative or positive effect/s caused directly or indirectly by an event or activity, or by the release of a substance into the environment, causing a change in the biological, physical and/or socio-economic environment
in situ bioremediation	Bioremediation of contaminated soil or (ground)water undertaken without excavation (i.e., removal); literally ‘bioremediation in place’
infiltration	The passage of water, under the influence of gravity, from the land surface into the subsurface
injection well	A groundwater bore constructed for the purpose of pumping water into an aquifer

ion	An electrically charged atom or molecule formed as a result of loss or gain or one or more electrons. Positively charged ions are called cations ($^+$), while negatively charged ions are called anions ($^-$). The major aqueous ions are those that dominate total dissolved solids (TDS). These include: Cl^-, SO_4^{2-}, HCO_3^-, Na^+, Ca^{2+}, Mg^{2+}, K^+, NH_4^+, NO_3^-, NO_2^-, F^- and PO_4^{3-}, and the heavy metals
ionic exchange	A reversible interchange of one kind of ion present on an insoluble solid with another of like charge present in a solution surrounding the solid
iron concretions	The accumulation of dissolved iron that results in the formation of soft to hard orange to red to maroon nodules, and can be diffuse or concentrated. A result of periodic wetting and drying
leachate	Water that has percolated through a solid or semi-solid material (e.g., soil or mine waste) and leached out some of the constituent impurities
lysimeter	A device for collecting drainage passing through overlying material. The term lysimeter is primarily used for field test apparatus. Lysimeters are installed in waste rock to measure the quality and/or quantity of drainage
massive	Refers to the condition of the soil layer in which the layer appears to be as a coherent or solid mass which is largely devoid of peds
maximum potential acidity	Determined by multiplying the sulfide-S values (in %) by 30.6, which accounts for the reaction stoichiometry for the complete oxidation of pyrrotite and pyrite by O_2 to $Fe(OH)_3$ and H_2SO_4. MPA does not take into account the effect of any acid-consuming materials in the rock material
metalloid	A class of elements chemically intermediate in properties between metals and non-metals including boron, silicon, germanium, arsenic and tellurium
micro-organism	A microscopic organism; includes viruses, bacteria, yeasts and fungi, and others
mitigation	Action(s) taken to avoid or reduce the impact of an activity on the environment, sociocultural and/or socioeconomic interests
mottled masses	Blobs or blotches of subdominant, varying colours in the soil matrix
net acid generation potential (NAGP)	The difference between the maximum potential acidity and acid neutralisation capacity reported on a kilogram H_2SO_4 production per tonne of soil or rock

organics	Chemical compounds comprising atoms of carbon, hydrogen and others (commonly oxygen, nitrogen, phosphorous, sulfur). Opposite is inorganic, referring to chemical species not containing carbon
overburden	The layers of clay, rock and similar covering or overlying a useful ore deposit. Also referred to as waste rock
oxidation	The act or process of being oxidised; loss of electrons or increase in oxidation state by a molecule, atom or ion; particularly used to refer to the addition of oxygen to elements
paddock dumping	Dumping loads on level ground, side by side, as opposed to over the windrow at the dump
parameter	Any constituent variable quality; a characteristic, feature or measurable factor forming one of a set that defines a system or sets the conditions of its operation
permeability (k)	(Fluid mechanics and earth sciences) a measure of the ability of a porous material (often, a rock or an unconsolidated material) to allow fluids to pass through it
piezometric or potentiometric surface	A surface that represents the level to which water will rise in cased bores. The water table is the potentiometric surface in an unconfined aquifer
pH	A figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acid and higher values more alkaline
plume	A mass of material, typically a pollutant/contaminant, spreading from a point source
precipitation (chemical)	The precipitating of a substance from a solution; the condensation of a solid from a solution during a chemical reaction
profile	The solum. This includes the soil A and B horizons and is basically the depth of soil to weathered rock
purge (wells)	The pumping out of well water to remove drilling debris or impurities; also conducted to bring fresh groundwater into the casing for sample collection. The later ensures that a more representative sample of an aquifer is taken
putrescible waste	Food waste, waste consisting of animal matter (including dead animals or animal parts) or biosolids

receptor	An entity (which may include an environmental value, conservation significance value, individual/s or communities of flora or fauna, as well as individuals, households or communities of people) that is exposed to a stressor. The sensitivity of a receptor interacts with the magnitude of an impact to derive an impact significance rating
recharge area	Location of the replenishment of an aquifer by a natural process such as addition of water at the ground surface, or by an artificial system such as addition through a well
recovery	The rate at which a water level in a well rises after pumping ceases
remediation	The action of remedying something, in particular of reversing or stopping environmental damage. Ecology: the restoration of an environment, land or groundwater contaminated by pollutants, to a state suitable for other, beneficial uses
representative sample	A subset of a statistical population that accurately reflects the members of the entire population; assumed not to be significantly different than the population of samples available
residual (impact)	Those impacts that remain after the effective implementation of avoidance, mitigation and management measures, which are designed to reduce the likelihood, consequence, magnitude or severity of the impact
rock mulch	Durable or competent rock purposely placed on an area under rehabilitation to provide additional resistance to erosion
sediment pond	Natural or constructed drainage impoundment used to reduce the concentration of suspended particles in surface run-off water or mine effluent prior to re-use or discharge to the environment
silt	Sediment with particles finer than sand and coarser than clay (comprised of particles between 0.002 and 0.075 mm in size)
silt trap	A small impoundment structure built within a drainage line that retards water flow and allows suspended sediments to settle out
species richness	The number of different species represented in a sample, taxonomic group, ecological community, landscape or region. Species richness is simply a count of species, and it does not take into account the abundances of the species or their relative abundance distributions
stand basal area	The cross-sectional area of trees at breast height per hectare of forest or planted area

standing water level (SWL)	The depth to the groundwater surface in a well or bore measured below a specific reference point – usually recorded as metres below the top of the well casing or below the ground surface
stratigraphy	A branch of geology dealing with the classification, nomenclature, correlation, and interpretation of stratified rocks, i.e., the order and relative position of strata and their relationship to the geological timescale. The structure of a particular set of strata or sequence of geological units
subaerial	Exposed to the atmosphere
subaqueous	Below water
subsidence	The downward settling of material with little horizontal movement
subsoil	Subsurface material comprising the B and C horizons of soils which lies below the topsoil or A horizon. The subsoil is not enriched with organic material as is the topsoil and often has higher clay content
sulfide oxidation	Exothermic oxidation of chemically reduced sulfide (S^{2-}) to a partially or fully oxidized form, such as sulfate (SO_4^{2-}). One indication of sulfide oxidation is elevated sulfate concentrations in mine site drainage
sump	Temporary excavation for the storage of water
suspended solids (SS)	Small solid particles which remain in suspension in water as colloids or due to the motion of the water. Used as one indicator of water quality
topsoil	Part of the soil profile, typically the A1 horizon, usually containing more organic matter than the underlying layers
total dissolved solids (TDS)	A measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionised or micro-granular suspended form
toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism
transmissivity	The rate at which water is transmitted through a unit width aquifer under a unit hydraulic gradient
turbidity	A measure of the relative clarity of a liquid, particularly water, as a result of the amount of suspended particulate matter present, such as sediment particles, algae, plankton, microbes and other substances. One indicator of water quality

volatile	Having a low boiling or subliming pressure (a high vapour pressure)
waste rock	Rock with insufficient amounts of economically valuable elements to warrant its extraction, but which has to be removed to allow physical access to the ore. Waste rock is typically blasted into smaller particles to allow its removal by truck and shovel
water balance	A term used in the context of mining to describe an inventory of drainage inputs and outputs, water volumes and the rate of flow
water quality criteria	Maximum or minimum values of physical, chemical or biological characteristics of water, biota or sediment whose exceedance under specified conditions may result in detrimental effects to a water use
water table	The interface between the saturated zone and unsaturated zones. The surface in an aquifer at which pore water pressure is equal to atmospheric pressure
well	A hydraulic structure that facilitates the monitoring of groundwater level, collection of groundwater samples, or the extraction (or injection) of groundwater. Also known as a bore

Appendix 1.
Risk Register

RISK MATRIX

Consequence		Likelihood (regardless of potential time latency)				
		1	2	3	4	5
		Certain	Likely	Possible	Unlikely	Improbable
1	Catastrophic	2	3	4	5	6
2	Major	3	4	5	6	7
3	Moderate	4	5	6	7	8
4	Minor	5	6	7	8	9
5	Insignificant	6	7	8	9	10

RISK RATING EXPLANATIONS

Risk Matrix Result	Risk Rating	Description
2 to 3	E	Extreme- Immediate intervention required to eliminate or reduce risk at a Senior Management/ Government level.
4 to 5	H	High Risk - It is essential to eliminate or reduce risk to a lower level by the introduction of monitoring and assessment measures implemented by senior management.
6 to 7	M	Moderate - Corrective action required, and monitoring and assessment responsibilities must be delegated.
8 to 10	L	Low Risk - Corrective action should be implemented where practicable, and risk should be managed by routine monitoring and assessment procedures.

KEY TO RISK REGISTER

Location of impact	
RI	Regional impact (>2km radius outside mining lease)
OM	Impact outside mine lease area - (<2km radius)
WM	Wide impact within mining lease boundaries
L	Localised area within mining lease boundaries
P	Small point source within mining lease boundary
Potential Duration of impact	
G	Geological long term (>100 years)
L	Long term (30- 100)
M	Medium term (5-30 years)
S	Short term (1-5 years)
E	Ephemeral/seasonal impact

Consequence Definitions

Consequence		Definition
1	Catastrophic	Severe environmental impact. Local species destruction and likely long recovery period. Extensive clean up involving external resources. Impact on regional scale.
2	Major	Major environmental impact. Considerable clean up effort using site and external resources. Impact may extend beyond lease boundaries.
3	Moderate	Moderate environmental impact. Clean up by site staff and/or contractors. Impact confined within lease boundaries. Or, minor impact off site: however, no irreversible damage.
4	Minor	Low environmental impact. Rapid clean up by site staff and/or contractors. Impact controlled to area currently impacted by operations.
5	Insignificant	No or very low environmental impact. Impact confined to small area. Site impact only.

Likelihood Definitions

Likelihood		Definition
1	Certain	Expected to occur frequently at this operation.
2	Likely	Expected to occur occasionally at this operation.
3	Possible	Has occurred or could occur for this or a comparable operation.
4	Unlikely	Known to occur in the global industry but unlikely.
5	Improbable	Not known to occur in the global industry but plausible.

Report Section	Asset	Consideration	Hazard / Aspect	Incident / Event	Consequence / Impact	Potential duration of impact	Location of impact	Existing Controls/Monitoring and Assessment Undertaken	Consequence	Likelihood	Matrix Result	Risk Rating	Additional Controls, Monitoring, Assessment or Actions Required
4.2	McArthur River	Water Balance Modelling	Deterioration in mine site seepage and/or runoff water quality beyond current estimates Cause is changes in the AMD from the NOEF. This may be due to 1) changes in the PAF/NAF ratio and/or 2) changes in the chemical reactions occurring	Uncontrolled releases of contaminated water from mine site to McArthur River and/or controlled releases that do not comply with the water quality criteria of the discharge license	Acute and/or chronic adverse impact on riverine and/or marine flora and/or fauna	E	L	Existing controls outlined in WRM report Site Water Balances for the McArthur River Mine and Bing Bong Loading Facility. Use of the Underground Void/Open Pit (UG&OP) for Water Storage	3	3	6	M	Scenarios need to be included in the water balance modelling to assess the impact and develop a management plan to mitigate this impact
4.2	McArthur River	Water Balance Modelling	Errors in the water balance model parameterisation mean that while the model can replicate the water balance behaviour under existing site conditions, it fails to accurately predict behaviour under changed site conditions	Uncontrolled releases of contaminated water from mine site to McArthur River and/or controlled releases that do not comply with the water quality criteria of the discharge license	Acute and/or chronic adverse impact on riverine and/or marine flora and/or fauna	E	L	Annual revision of the water balance model. Continual improvement in the monitoring of water balance components. Use of the Underground Void/Open Pit (UG&OP) for Water Storage	3	3	6	M	Substantial additional effort in model calibration, reporting and monitoring to identify the most sensitive parameters. Steps taken to reduce the parameter uncertainty based upon the prioritisation of their sensitivity
4.2	McArthur River Mine	Water Balance Modelling	The site water balance does not have enough safety margin to allow for the impact of unexpected changes (e.g., changes in water quality) to the mine site water management network (from that adopted in the modelling)	Uncontrolled releases of contaminated water from mine site to McArthur River and/or controlled releases that do not comply with the water quality criteria of the discharge license	Poor quality water (metals, acid) affect terrestrial and aquatic ecosystems; acute and/or chronic adverse impact on riverine flora and/or fauna	E	L	Existing controls outlined in annual Site Water Balance report for the McArthur River Mine. Annual revision of the water balance model. Continual improvement in the monitoring of water balance components. Use of the Underground Void/Open Pit (UG&OP) for Water Storage	3	3	6	M	The site water management network needs to have extra storage to allow for unexpected changes to the site water management. The water balance modelling needs to demonstrate that the site water balance can accommodate unexpected changes to the site water management
4.2	McArthur River Mine	Water Balance Modelling	Failure to incorporate water balance model results into mine site water management and operations	Uncontrolled releases of contaminated water from mine site to McArthur River and/or controlled releases that do not comply with the water quality criteria of the discharge license	Acute and/or chronic adverse impact on riverine and/or marine flora and/or fauna	E	L	Annual revision of the water balance model. Continual improvement in the monitoring of water balance components. Use of the Underground Void/Open Pit (UG&OP) for Water Storage	3	3	6	M	The water balance modelling needs to be fully utilised in mine site risk management and options analysis
4.4	River diversions	River diversion design performance	Lateral movement of Surprise Creek near the TSF	Potential for lateral movement of the creek to impact the integrity of the TSF.	Failure of the TSF into Surprise Creek	E	OM	Surprise Creek near the TSF appears to be vertically stable due to the presence of bedrock; however, lateral migration of the channel is occurring. The report identifies this as a potential risk to the stability of the TSF as the channel moves towards it. Even if the measures proposed in the EIS are approved (moving the tailings to the pit) the TSF is to remain where it is in the short to medium term	1	4	5	H	It is recommended that the area is monitored annually and following high flows and reassessed as required
4.4	River diversions	River diversion design performance	Mine levee wall	A greater than >500 ARI flood event leading to erosion of mine levy wall	Flooding of the pit from McArthur River resulting in reduced volume of water downstream in McArthur River impacting downstream ecosystems	L	L	Implementation of the revised Early Flood Warning System Procedure. The revised early flood warning system establishes relationships between flood levels at gauges and flood hazard benchmarks (spill way and mine levee) (Document Reference Number: ADM-ENV-PRO-6040-0011). The Site Emergency Response Plan has been updated to include procedure for flooding in the Mine Pit (Document Reference Number: GEN-GEN-PLN-6040-0001)	3	5	8	L	
4.4	River Diversions	River diversion design performance	Barney Creek Diversion Channel Instabilities	The confluence of Surprise Creek and the old Surprise Creek path may be engaged during flood.	Potential impact on mining infrastructure (roads).	L	L	This area was inspected during the 2017 IM site visit and was not considered to be a major risk. The report recommends that consideration be given to filling the old channel for mine closure	4	4	8	L	
4.4	River Diversions	River diversion design performance	Surprise Creek Channel Instabilities	Severe gullying was identified on the left bank of Surprise Creek near the south west corner of SPROD. These gullies extend up to 150 metres and, where observed, were up to 2 m deep	They are likely to continue eroding in the future unless mitigated, with potential effects on mining infrastructure	L	WM	No controls in place	3	3	6	M	It is recommended that the areas of instability are investigated and an options assessment conducted on mitigating the ongoing gullying
4.4	River diversions	Post Closure river diversion design performance	Stability of the McArthur River Diversion Chanel offtake following lease relinquishment	Active avulsion upstream results in McArthur River changing course and reverting to the old channel causing erosion and then failure of the Mine Levee Wall	Breach of the mine levee wall resulting in the discharge of contaminated water from the pit to Barney Creek and/or McArthur River impacting aquatic and terrestrial ecosystems . Liberation of substantial volumes of sediment into the McArthur River	M	WM	No control in place. Geomorphic Assessment recommends that that option to mitigate the avulsion are assessed and actions implemented.	1	2	3	E	Recommended that that option to mitigate the avulsion or its impacts are assessed and actions implemented. This should include an assessment of potential bedrock controls
4.5	Groundwater resource	Groundwater supply	Poor operation of borefields and dewatering systems	Over abstraction of groundwater	Over pumping, resulting in depletion of the groundwater resource, aquifer depressurisation, subsidence, reduced groundwater quality	S	L	Groundwater monitoring, groundwater modelling	4	4	8	L	An assessment of the drawdown impacts for all production bores should be undertaken and provided as part of future groundwater monitoring reports
4.5	Water storages	Water storage design	Poor water storage design/construction	Seepage of contaminated water	Seepage of contaminated water, impacting groundwater quality and aquatic and terrestrial ecosystems where groundwater is discharged to creeks/rivers or to the surface	L	OM	Storage design, seepage monitoring, surface water monitoring and groundwater monitoring WPROD, SEPROD lined with HDPE. Estimation of seepage rates using the site water balance to identify possible contaminant sources	3	1	4	H	Lining of all storages. Line SPROD and SPD with HDPE
4.5	Mine Pit	Pit Lake	Release of poor quality water from the pit void lake to the groundwater environment after closure	Release of contaminated water	Seepage of contaminated water, impacting groundwater quality and aquatic and terrestrial ecosystems where groundwater is discharged to creeks/rivers or to the surface	G	OM	Pit void lake water and solute balance modelling and three dimensional hydrographic modelling of the pit void lake	3	1	4	H	Ongoing refinement of the water and solute model and hydrographic model, including model calibration following closure

ERIAS GROUP

Report Section	Asset	Consideration	Hazard / Aspect	Incident / Event	Consequence / Impact	Potential duration of impact	Location of impact	Existing Controls/Monitoring and Assessment Undertaken	Consequence	Likelihood	Matrix Result	Risk Rating	Additional Controls, Monitoring, Assessment or Actions Required
4.5	Mine Pit	Pit Lake	Hydraulic link between underground workings and either McArthur River or lower reaches of Barney Creek	Contaminated water within the pit is transported via this hydraulic link and discharges into McArthur River and / or Barney Creek	Contaminated groundwater discharges to surface impacting aquatic and terrestrial ecosystems	G	RI	Preliminary field investigations completed in the area between the pit and the McArthur River diversion (geophysical surveys and three investigation drill-holes). Unaccounted for surface water inflows to the pit were identified during the 2017-2018 wet season, which were previously attributed to groundwater inflows to the underground	2	3	5	H	Investigations into possible groundwater pathways. Assessment of the recently identified surface inflows to the pit and updating of the mine water balance to better estimate the groundwater contribution to the mine dewatering requirements Monitoring of the McArthur River diversion after flooding of the pit lake to identify seepage impacts on river water quality. If impacts are identified then either the lake levels will need to be maintained below the water level in the diversion or the seepage pathway disrupted
4.5	Bing Bong dredge spoil	Dredge spoil pond management	Management of entrained dredge spoil water	Release of marine water	Seepage of marine water from the dredge spoil ponds, impacting groundwater quality and aquatic and terrestrial ecosystems	E	L	Operation of drainage system on and around the ponds, groundwater monitoring, surface water monitoring	4	3	7	M	All proposed actions have been implemented
4.5	Bing Bong Loading Facility	Hydrocarbon storage	Management of stored hydrocarbons	Release of contaminated water	Seepage of NAPL and aqueous phase hydrocarbons, impacting on groundwater quality and aquatic and terrestrial ecosystems where groundwater is discharged to creeks/ rivers/ sea or to the surface	S	OM	Containment system design, hydrocarbon audits, inspection procedures, monitoring of storages	3	3	6	M	Installation of high level alarm on storages
4.5	Bing Bong Loading Facility	Concentrate Storage	Management of stored concentrate	Discharge of metaliferous/low pH water	Seepage of contaminated water, impacting groundwater quality and aquatic and terrestrial ecosystems where groundwater is discharged to creeks/rivers/sea or to the surface	E	OM	Operation of containment system (lined drains, paved catchments, lined containment ponds), groundwater monitoring, surface water monitoring	4	3	7	M	Resurfacing of paved areas around the concentrate storage area
4.5	Mine site	Hydrocarbon storage	Management of stored hydrocarbons	Release of contaminated water	Seepage of NAPL and aqueous phase hydrocarbons, impacting on groundwater quality and aquatic and terrestrial ecosystems where groundwater is discharged to creeks/ rivers or to the surface	S	OM	Containment system design, hydrocarbon audits, inspection procedures, monitoring of storages, groundwater monitoring	3	3	6	M	Installation of high level alarm on storages
4.6	NOEF	Geochemical	Closure Strategies for NOEF fail or are not implemented in accordance with design	Inadequate design/implementation or premature mine closure	Saline and metalliferous neutral drainage and localised acid drainage impacts in perpetuity on groundwater, terrestrial and aquatic ecosystems	G	OM-RI	Cover system design with geosynthetic layer completed, which is expected to provide a high degree of infiltration control New areas of dump being constructed to minimise extreme oxidation	1	3	4	H	Obtain approval of management strategies in Draft OMP EIS and OMP SEIS Confirm long term cover system performance with planned cover trials. Key uncertainties include: • Constructability on a large scale. • Maintaining protection from sunlight and weather (erosion control). • Life of the GSL. • Temperature effects from existing convection and ongoing convection from newly placed materials. • Susceptibility to differential settlement. • Potential saturation of protection/growth layer and slope mass failure
4.6	TSF	Geochemical	Closure Strategies for tailings in TSF fail or are not implemented	Inadequate design/implementation or premature mine closure	Saline and metalliferous neutral drainage in short term and acid drainage in long term, with impacts in perpetuity on groundwater, terrestrial and aquatic ecosystems	G	OM-RI	Closure plan in EIS proposes re-processing and re-handling to pit Geochemical pit void modelling indicates long term control of the open pit water quality to acceptable concentrations is possible	1	3	4	H	Obtain approval of management strategies in Draft OMP EIS and OMP SEIS Monitoring of water quality during tailings placement in the pit and during pit filling to check against model predictions
4.6	NOEF	Geochemical	NOEF Seepage During Operations	NOEF seepage reports to groundwater during operations and ultimately to surface drainage down-gradient	Saline and metalliferous neutral drainage and localised acid drainage impacts on groundwater, terrestrial and aquatic ecosystems	L	WM	Monitoring of groundwater Leaking interception ponds NOEF SPROD/SPDS have been lined, which will reduce the major source of seepage. Seepage collection and treatment to prevent WQ impacts on SW11	3	1	4	H	Commissioning of the water treatment plant. Increased storage to ensure no uncontrolled off-site discharge Minimising convection from PAF(HC) as well as PAF(RE) materials. The proposed 7.5m lifts for PAF(HC) requires further investigation given the reported segregation propensity and observed convective oxidation from paddock dumped PAF materials
4.6	Open pit	Geochemical	Closure Strategies for Open Pit fail or are not implemented	The open pit lake becomes acid and/or saline and metalliferous after closure due to oxidation of exposed pyritic PAF and NAF materials in pit walls or backfill, with potential for overtopping to surface water systems and seepage to groundwater	Acid, saline and metalliferous drainage impacts on groundwater, terrestrial and aquatic ecosystems	G	OM	Rapid filling of pit planned to quickly inundate pyritic materials, with only small amounts of MS-NAF exposed at final fill level to contribute ongoing AMD loadings Geochemical pit void modelling indicates long term control of the open pit water quality to acceptable concentrations is possible	1	3	4	H	Independent verification of pit void modelling
4.6	TSF	Geochemical	Tailings leachate from TSF	Tailings leachate reports to groundwater during operations and ultimately to surface drainage down-gradient	Water quality impacts on groundwater, terrestrial and aquatic ecosystems Currently mainly elevated SO_4 salts and electrical conductivity	M	RI	Shallow cut-off barrier, seepage interception sump. Monitoring of surface water and groundwater. Placement of 0.5m clay cap on cell 1 for dust control. Geophysical analysis to track saline plumes. Shallow Interception trenches in place. Oxidation of the tailings minimised during operations by frequent layering of fresh tailings to limit exposure time Reduced water storage in Cell 2, reducing seepage rates Aquatic fauna surveying in Surprise Creek Overflow ponds completed Piezometers installed	3	2	5	H	Continue monitoring of acid and salinity generation in the tailings surface. Continue kinetic testing of tailings and assess lag times and acid, salinity and metal/metalloid generation rates, and implications for operational control of tailings beach areas and water quality. Continue routine geochemical characterisation of tailings. Maintain moisture in drier and less active areas of the Cell 2 tailings to minimise sulfide oxidation and dust. This may include spraying water onto the surface
4.6	TSF	Geochemical	Uncontrolled release from TSF	Uncontrolled release occurs due to high flow event	Water quality impacts on impacts on adjacent and downstream surface drainage Mainly elevated SO_4 salts and electrical conductivity, and possibly Zn and Mn. Could include acid and elevated metals if tailings acidify	M	WM	TSF operations manual with MOLs and TARPs designated for the TSF Cell 2 to minimise the likelihood of uncontrolled release.	3	4	7	M	Ensure ongoing applicability of MOLs and TARPs

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4.6	NOEF	Geochemical	Development of Convection Cells and Extreme Oxidation Rates (Spontaneous Combustion) in NOEF.	Segregation of coarse and fine materials during dumping of PAF(RE) materials and creation of chimney structures that encourage rapid convective oxidation and spontaneous combustion	Greater rates of oxidation and generation of acid, salinity and dissolved metals during operations, and consequent impacts on groundwater, terrestrial and aquatic ecosystems	L	WM	PAF(RE) and PAF(HC) are currently paddock-dumped and traffic-compacted, and the observation of spontaneous combustion events much less common, and temporary while advection controls are being put in place, comprising interim advection control layers with MS-NAF protection layers. Older end tipped PAF portions of the dump are preferentially targeted with MS-NAF halo zone construction and placement of interim advection control layers, with excavation and compaction carried out on active combustion zones	2	4	6	M	The effectiveness of the advection covers being placed on the NOEF needs to be demonstrated with continued monitoring, particularly for the existing end-tipped actively convecting PAF portions of the NOEF
4.6	Bing Bong dredge spoil	Geochemical	Potential for acid sulfate soils around the outer spoon drain	Acid sulfate soils exposed by excavation of the outer spoon drain, which causes acid leachate	Local impacts on re-vegetation, water quality	M	L	None	4	3	7	M	Progress acid sulfate soil assessment of spoon drain and other potential sources at Bing Bong Loading Facility
4.6	TSF	Geochemical	Failure of TSF cover	Cover breached through erosion, slumping, embankment failure etc. , leading to exposure of highly pyritic tailings to oxidation and infiltration	Water quality impacts on impacts on groundwater and surface drainage down-gradient Short Term - mainly elevated SO_4 salts and electrical conductivity Longer Term - acid and elevated metals once tailings acidify	G	OM-RI	Closure plan in EIS proposes re-processing and re-handling to pit	1	2	3	E	Additional controls will depend on the outcome of the EIS
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Piping through the foundation	Release of tailings and process water into the environment causing impacts to terrestrial and aquatic flora and fauna, sedimentation of Surprise Creek requiring major repair works	S	OM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, staff training, annual dam safety, monitoring of pond levels, pond extent surveys, operation manual as-built construction reports	3	5	8	L	Continued investigation of seepage flowpaths and rates through the base of the TSF
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Embankment failure due to excessive erosion due to wave action	Release of tailings and process water into the environment causing impacts to terrestrial and aquatic flora and fauna, sedimentation of Surprise Creek requiring major repair works	S	OM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, staff training, annual dam safety, monitoring of pond levels, pond extent surveys, operation manual, as-built construction reports.	3	5	8	L	No additional controls required
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Embankment failure due to instability	Release of tailings and process water into the environment causing impacts to terrestrial and aquatic flora and fauna, sedimentation of Surprise Creek requiring major repair works	S	OM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, staff training, annual dam safety, monitoring of pond levels, operation manual, as-built reports prepared by designer	1	5	6	M	Investigations have shown that reported water levels were not as high as shown by MRM and this specific issue has largely been resolved. The likelihood has been reduced accordingly
4.7.1	TSF	Geotechnical	Tailings pipeline	Burst tailings pipeline	Release of tailings and process water into the environment causing impacts to terrestrial and aquatic flora and fauna, sedimentation of Surprise Creek damage to embankment requiring minor repair works	S	WM	Visual inspections of the pipeline, annual monitoring of wear and reporting, spill bunds at pipe joins, emergency procedures, routine maintenance	4	3	7	M	There is reliable evidence of ongoing pipe testing and maintenance. Additionally the number of incidents compared to the previous reporting period has reduced and this risk has been reduced accordingly. Pipeline failure, however, remains a possibility and likely over time
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Excessive settlement of the embankment or excessive flooding leading to overtopping	Release of tailings and process water into the environment causing impacts to terrestrial and aquatic flora and fauna, sedimentation of Surprise Creek damage to embankment requiring minor to major repair works	S	WM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring and reporting of embankment levels, monthly reports, monitoring reports, annual dam safety review, as-built reports prepared by designer	3	4	7	M	There have been a number of incidents over the reporting period where the capacity of both Cell 1 sumps have been exceeded and overflow has occurred. In all cases overflow was contained in adjacent borrow pits. Several improvements have been made to the system which should reduce the likelihood of these impacts in future however overflow is still possible given the design capacity of only around 1 in 20 AEP. It is recognised that the consequence of overflow is not not significant as assessed by the IM previously as water flows into the borrow pits. However the existing capacity of the borrow pits does not appear to have been incorporated in flood storage modelling
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Piping through the embankment	Release of tailings and process water into the environment causing impacts to terrestrial and aquatic flora and fauna, sedimentation of Surprise Creek requiring major repair works	S	OM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, staff training, annual dam safety, monitoring of pond levels, operation manual, as-built reports prepared by designer	1	5	6	M	Investigations have shown that reported water levels were not as high as shown by MRM and this specific issue has largely been resolved. More generally there is an ongoing risk of piping given the presence of rock fill used in the Stage 2 raise. Key areas need to continue to be monitored for this possibility
4.7.1	TSF	Geotechnical	Storage of tailings and process water	Poor operation, monitoring or management leading to overtopping	Release of tailings and process water into the environment causing impacts to terrestrial and aquatic flora and fauna, sedimentation of Surprise Creek damage to embankment requiring minor to major repair works	S	WM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, staff training, annual dam safety, monitoring of pond levels, pond extent surveys, operation manual, as-built construction reports	2	5	7	M	Management practices have substantially improved over the past 4 years - no additional controls are considered necessary. It is difficult to reduce this risk further due to the generally high risks associated with TSFs.

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4.7.1	TSF	Geotechnical	Storage of tailings and process water	Seepage through embankment or the foundation	Release of process water into the environment causing impacts to terrestrial and aquatic flora and fauna	S	OM	Design to ANCOLD (2012), construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, staff training, annual dam safety, monitoring of pond levels, pond extent surveys, operation manual, as-built construction reports	3	4	7	M	Further investigations and analyses are needed to: · understand why seepage levels (those that have been correctly calculated) are significantly higher than anticipated in previous seepage modelling and stability assessments. · review all seepage parameters, geometry boundary conditions etc. to improve modelling compared to measured piezometric levels. · review stability analyses should predicted piezometric surfaces change substantially. · continually improve subsurface identification and interpretation of significant groundwater flow paths such as faults. These findings should then be translated where possible to improve seepage estimates from Cell 1 to Surprise Creek. Translate these findings where possible to improve seepage estimates from Cell 1 to Surprise Creek. The effect of dissolution of the TSF foundation materials needs to be considered in conceptual and numerical models; particularly in light of the likelihood of increased tailings acidity due to reduced pond size The WRM water balance needs to be updated to include estimates of TSF evaporation and seepage. Seepage estimates are likely to be improved through the actions described above. Evaporation may require combined estimates based on Penman based methods and (micro-) lysimeters
4.7.3	Bing Bong dredge spoil	Geotechnical	Storage of dredge spoil and seawater	Embankment failure due to instability	Release of sediment and sea water into the environment causing impacts to terrestrial and aquatic flora and fauna requiring major repair works - most likely during active discharge	S	OM	Construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment piezometers, annual dam safety review, as-built construction reports.	2	5	7	M	All previous recommnedations have been implemented and likelihood has been reduced. However It is difficuklt to reduce this risk further due to the generally high risks associated with TSFs.
4.7.3	Bing Bong dredge spoil	Geotechnical	Storage of dredge spoil and seawater	Excessive settlement of the embankment or excessive flooding leading to overtopping	Release of sediment and sea water into the environment causing impacts to terrestrial and aquatic flora and fauna, damage to embankment requiring minor to major repair works - most likely during active discharge	S	OM	Construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment piezometers, annual dam safety review, as-built construction reports.	2	4	6	M	Document and measure survey monitoring points. This does not appear to have been undertaken for the reporting period.
4.7.3	Bing Bong dredge spoil	Geotechnical	Storage of dredge spoil and seawater	Piping through the embankment	Release of sediment and sea water into the environment causing impacts to terrestrial and aquatic flora and fauna requiring major repair works - most likely during active discharge	S	OM	Construction QA/QC, visual inspections, monitoring of embankment levels, monthly reports, embankment pore pressure measurements, annual dam safety review, as-built construction reports.	3	4	7	M	Measure embankment piezometers (BBEMB series) at least every 3 months and more frequently after periods of heavy rainfall. This does not appear to have been undertaken for the reporting period.
4.8	Mine site	Security bonds	Closure costs have currently been calcualted based on the closure mitigation strategies oulined in the currently approved closure plan prepared in 2012	The OMP EIS and SEIS have developed alternative closure options and a longer period of post closure monitoring and maintenance.	Current closure costs are insufficient in the event of MRM being unable to complete rehabilitation of the site	G	OM	A security bond is currently in place. Note that the risk assessment framework does not adequately consider costs and this is a limitation of the risk framework	1	3	4	H	A comprehensive review is required of the closure costs following completion of the assessment of the Overburden Mangement Project EIS.
4.9	Bing Bong dredge spoil	Terrestrial Flora	Drain surrounding dredge spoil not protecting adjacent habitat from highly saline water	Seepage of highly saline water from dredge spoil into undisturbed habitat surrounding dredge spoil, seawater being retained for extended periods by drain bund wall or previous obstruction of creek line to the east of the spoil	Dieback and/or alteration of vegetation in undisturbed habitat surrounding the dredge spoil and/or extended periods of inundation by seawater	L	L	Annual maintenance of drain which channels saline water out to sea. Annual inspection of dredge spoil ponds by GHD. Annual vegetation monitoring of vegetation surrounding spoil area. South west corner of dredge spoil removed	3	2	5	H	Increase drain inspections to monthly checks and include identification of erosion, cracking and damage caused by cattle. Ensure cattle are excluded from dredge spoil pond area. Conduct remedial works if pooling or damage to drain is identified. Ensure a dredge spoil management plan is developed prior to any further dredging works. Conduct a desktop assessment to pinpoint the origin of the saline water i.e., from dredge spoil, from obstructed creekline or from pooling seawater against drain bund. Determine likelihood that disturbed area can be returned to original habitat or if low shrub saltflat is an acceptable final result. Reduce vegetation monitoring program to every 3 years, changes in sediment EC values and vegetation growth is too fine to detect changes annually
4.9	Mine Site and Bing Bong Loading Facility	Weed management	Infestation of weeds	Weeds present on mine leases, from historical mining and pastoral activities, or transported from upstream of the mine by Barney Creek and McArthur River, are colonising cleared areas uncolonised by native vegetation	Weed infestations exclude native vegetation and reduces habitat for fauna	L	RI	Weed management plan in place with targeted weed control carried out with liaison from Weeds District Officer. Weed inspections conducted annually and also included in revegetation monitoring. Parkinsonia biological control trials at Bing Bong Loading Facility dredge spoil ponds. Employment of local residents from Borroloola in weed management. Neem tree eradicated from Bing Bong Loading Facility and devil's claw eradicated from McArthur River floodplain	3	2	5	H	Follow weed management plan. Continue to investigate possibility of cooperative weed control with pastoral properties upstream on McArthur River
4.9	River diversions	River diversion revegetation	Slow revegetation of McArthur River diversion	Flooding and high flow rates in wet season causing erosion and soil redistribution resulting in the removal of vegetation.	Unstable channel banks, reduced riparian habitat, provide lack of shade for aquatic species and can facilitating the spread of weeds	M	L	Review of rehabilitation management plan and revegetation procedures. Hydraulic assessment of potential fluvial erosion risk for Barney Creek and McArthur River diversion channels. Annual revegetation monitoring (excluding 2017). Use of jute matting and large woody debris/small woody debris to reduce flow rates and create soil pockets. Targeted planting of tube stock according to habitat and position on bank	3	2	5	H	Improve method of erosion monitoring as part of revegetation monitoring along the diversions. Use more quantitative methods of measuring erosion such as those included in the landscape function analysis method
4.9	River diversions	River diversion vegetation	Slow revegetation of McArthur River diversion	Removal of planted vegetation through trampling and/or grazing by feral herbivores	Erosion caused by herbivore tracks and removal of vegetation. Failure or reduction of vegetation from foraging and/or trampling	L	M	Mustering/culling of cattle and donkeys and regular maintenance of exclusion fence	3	4	7	M	

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4.9	Bing Bong dredge spoil	Terrestrial Flora	Sections of dredge spoil left unvegetated and use of incorrect seed mix in revegetated areas	Areas of dredge spoil left unvegetated due to use of cells for storage of future dredging spoils. Area of cells revegetated and seeded with incorrect species. Spoil material is difficult for non-salt tolerant species to establish on	Alteration or loss of habitat, creation of dust	M	L	Previous monitoring by orthophoto mapping and ground truthing of vegetation. CDU PhD student began revegetation trials on a section of the spoil but was not completed. Vegetation monitoring within cell 1. Area of dredge spoil ponds reseeded with grasses in 2011	4	4	8	L	Continue with rehabilitation of dredge spoils - utilise landscaping of cells to promote vegetation growth despite future dredge plans. Use seed mixes consisting of salt tolerant species present in the coastal habitat surrounding the spoil. Continue to monitor dust from the dredge spoils
4.9	Mine site	Terrestrial fauna and flora	Fragmentation of habitat (excluding the diversion channels) as a result of the operations development	Cleared or areas slow to revegetate leaving unvegetated patches between vegetated areas	The lack of vegetation cover prevents the movement of small fauna including small mammals, reptiles and grass birds	M	L	Planting of tubestock, exclusion of cattle, weed control	5	3	8	L	Leave vegetation corridors where possible
4.9	PACRIM, ROM and TSF	Terrestrial fauna and flora	Fugitive dust emissions from Pacrim Yard and ROM Pad. Dust migration from unvegetated TSF. Dust transported to vegetation by air or as run-off	Heavy metal loads in vegetation, soils and sediments causing vegetation die-back	Loss of plants, reduction of habitat for flora and fauna, compromised success of rehabilitation areas, compromised stability of diversion banks, contamination of waterways.	M	WM	Dust monitoring program, sediment monitoring, vegetation monitoring, dust mitigation measures at mine site including water spray trucks, Introduction of double-lipped rubber lining to sides of PACRIM conveyors. Roller doors installed on concentrate storage shed, sediment sumps at Barney Creek haul road bridge. Cell 1 of TSF capped and seeded with shrubs and grass. Testing of heavy metals in vegetation including food species for the local community and pasture species for cattle at mine site and TSF	3	4	7	M	Compare dust monitoring data at locations of vegetation dieback to determine if fugitive dust is impacting vegetation
4.9	Barney and Surprise Creek	Terrestrial flora	Saline seepage from PAF run-off dam and TSF	High salt loads in terrestrial vegetation causing vegetation die-back	Loss of vegetation, reduction of habitat for fauna and flora, contamination of rivers and creeks	M	WM	Saline impact monitoring program, water management dams. Remote sensing study to detect potential locations of saline seepage	3	2	6	M	Review current saline impact monitoring sites. Consider adding sites in areas of known S04 deposition
4.9	River diversions	Terrestrial fauna and flora	Creation of unsuitable habitat along Barney Creek and McArthur River diversion channels	Planting vegetation along Barney Creek and McArthur River diversion channels not found at control sites, failure of growth of tubestock and seeds, infestation of weeds	Different vegetation community than that found up and downstream of channels, unsuitable habitat for fauna	L	L	Key riparian habitats identified. Review of the suitability of key and primary species conducted. Key species now broken down by habitat type and position on the bank. Recommendations provided in riparian bird monitoring reports detailing suitable riparian plant species. Propagation of riparian flora in MRM nursery. Targeted planting of important plants for riparian birds including canegrass and shrubs. Extensive weed control conducted	4	4	8	L	Include Rocky gorge area in future revegetation surveys, treat as separate habitat to other sites on the diversions and find suitable control. Concentrate on ensuring vegetation along the batter of rock gorge area is suitable to provide safe passage for riparian birds
4.9	Mine lease	Terrestrial fauna and flora	Clearing of Gouldian finch habitat	Removal of foraging or breeding habitat for Gouldian finches	Reduced habitat for Gouldian finches	M	L	Preliminary Gouldian finch survey conducted in 2013. Annual Gouldian finch monitoring program conducted 2014 to 2016. Revision of vegetation mapping units (VMUs) for the mine leases and assessment of importance for Gouldian finch breeding and foraging habitat	4	4	8	L	Update Gouldian finch habitat figure to include mapped important foraging areas. Avoid clearing or isolating areas identified as important for nesting and foraging
4.9	Bing Bong Loading Facility	Terrestrial Fauna	Dust migration and/or concentrate spillage from Bing Bong Loading Facility	Potential heavy metal bioaccumulation in the food sources of important migratory bird and wader populations	Mortality/decreased condition of shorebirds and waders	L	RI	Procedures to prevent spillage while loading concentrate onto the MV Aburri. Spinkler system at Bing Bong Loading Facility to supress fugitive dust. Covered trailers on haul trucks. Biannual monitoring of shorebirds and waders in the Port McArthur Area. Testing of metals in sediments in important feeding areas	3	4	7	M	Complete installation of roller doors at concentrate storage shed at Bing Bong Loading Facility
4.10	Mine site	Aquatic Fauna	Fugitive dust emissions from TSF, haul roads, NOEF and ROM pad as a result of operations	Dust emissions from the TSF, haul roads and ROM pad affect water and fluvial sediment quality in McArthur River and Barney, Little Barney and Surprise creeks	Reduction in diversity, abundance and/or health of aquatic biota including species of conservation significance. Contaminants migrate downstream from MRM. Contaminated biota move from exposed sites around McArthur River Mine outside of the mining leases	M	RI	Measures to control dust include: • Regular watering of haul roads, ore stockpiles, exposed construction areas and other exposed areas around the project site, subject to vehicle and machinery movements. • At the NOEF, operation of two water carts that spray the operating 'muck piles', roads and dumps. In addition, a compacted clay liner was placed over PAF material before the 2014/15 wet season, which helps to encapsulate potentially contaminated materials that could be mobilised via wind. • At the TSF, tailings deposition rotation via the use of the spigots around the periphery to keep the exposed tailings surface damp, thereby reducing dust generation. Capping of TSF Cell 1 with a clay layer to minimise generation of tailings dust	4	4	8	L	Continue current monitoring and controls. Finalise assessment of rotary atomiser-based dust suppression system for the ROM bin and implement if appropriate
4.10	Mine site	Aquatic Fauna	Seepage and/or runoff from TSF, NOEF, ROM pad/processing plant; runoff from haul roads	Seepage and/or runoff from TSF, NOEF, ROM pad/processing plant affect water and fluvial sediment quality in McArthur River and Barney, Little Barney and Surprise creeks.	Reduction in diversity, abundance and/or health of aquatic biota including species of conservation significance. Metals bioaccumulate in aquatic fauna causing unknown lethal and/or sub-lethal/ chronic effects. Contaminants migrate downstream from MRM. Contaminated biota move from exposed sites around McArthur River Mine outside of the mining leases to regional reference sites	M	RI	Drains constructed around TSF and NOEF to capture seepage and lining the WPROD to stop seepage. Diverting drainage from the Barney Creek haul road bridge to sediment sumps and increased spraying of roads. Monitoring contaminants in fluvial sediments, water quality, aquatic fauna diversity and abundance and assessing bioaccumulation of metals in fish around the mine site. Routine inspections of infrastructure	3	4	7	M	Continue current monitoring and controls. Understand effect of loads on biota. Line SPROD
4.10	Mine site	Freshwater Fauna	Infrastructure, pipelines etc., on site	Infrastructure fails on site, leading to contamination of waterways with metals and salts	Reduction in diversity, abundance and/or health of aquatic biota including species of conservation significance. Contaminants migrate downstream from MRM. Contaminated biota move from exposed sites around McArthur River Mine outside of the mining leases	M	RI	Regular inspections and maintenance of infrastructure. Regular water and sediment monitoring, annual monitoring of metals and other contaminants in freshwater fauna	2	4	6	M	NIL

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4.10	River diversions	Freshwater flora and fauna	Inadequate, slow or incorrect rehabilitation of the McArthur River and Barney Creek and Little Barney Creek diversions	River diversion rehabilitation creates poor quality freshwater habitat and/or a physical /biological barrier to fish migration	Loss of in stream habitat, changed flow regimes and reduced water quality leads to lower diversity and abundance of freshwater fauna in the diversions. Lack of shelter means predation rates are high. Reduced ability for fish, including marine migrants such as freshwater sawfish, to migrate through the diversion to breed or disperse, impacting upstream fish communities	L	RI	Freshwater sawfish monitoring and management program in place. Aquatic freshwater fauna monitoring takes places twice annually. Revegetation of diversions to increase shade and habitat in the future. Addition of large and small woody debris to improve fish habitat and provide resting areas for fish migrating through the diversion. An acoustic tagging and monitoring program was established in November 2016 to monitor fish migration in the McArthur River and its diversion channel	3	3	6	M	Continue to add and monitor large and small woody debris to provide additional habitat for fish and capture sediment. Continue planting riparian vegetation in sediment deposited around large woody debris as soon as possible following the wet season to maximise the likelihood of vegetation taking hold prior to the onset of the wet season. Continue to tag captured fish with acoustic tags and monitor movements. Consider adding additional acoustic stations between some of the existing ones to capture finer scale movements of migratory species, particularly in and out of the McArthur River diversion channel
4.11	Bing Bong Loading Facility	Heavy metals	Spillage of concentrate while loading the MV Aburri at Bing Bong Loading Facility	Spillage of concentrate during barge load out causes contamination of marine environment with metals	Biota bioaccumulate metals which in turn affects the health, diversity and abundance of marine biota and or poses a health risk to local fishers	M	RI	Fully contained conveyor system with cascade chute that feeds into a funnel on the MV Abburi. Annual marine monitoring of heavy metals in seawater, sediments and biota. Monthly monitoring of seawater using DGTs	4	3	7	M	Continue current monitoring and controls
4.11	Bing Bong Loading Facility	Heavy metals	Dust emissions from unloading of concentrate from road trains and/or from the loading of concentrate and transfer to MV Aburri barge	Dust emissions of concentrate causes contamination of marine (and terrestrial) environment with metals	Contamination of seawater and sediments with metals in the swing basin, shipping channel and surrounding area. Biota in the area, including conservation-listed migratory seabirds and waders, bioaccumulate metals with unknown lethal and/or sub-lethal/chronic effects and potential health impacts for local fishers	M	RI	Dust monitoring program and dust mitigation measures. Annual marine monitoring of heavy metals in seawater, sediments and biota. Monthly monitoring of seawater using DGTs. Fully contained conveyor system at the loading facility. Dust extractor and positive pressure differential in concentrate shed to minimise dust emissions. Watering roads to minimise dust kicked up by vehicles	4	3	7	M	Replace doors on the concentrate shed. Replace/fix dust extractor system in concentrate shed. Repair bitumen surface surrounding the Bing Bong Loading Facility
4.11	Bing Bong Loading Facility	Marine ecology	Dredging operations and regular passage of the MV Aburri barge	Dredging and regular passage of the MV Aburri stirs up contaminated and uncontaminated sediments at the Bing Bong Loading Facility and increases contamination, sedimentation and turbidity in the waters around the loading facility	Reduction in diversity, abundance and/or health of aquatic biota including species of conservation significance and potential health impacts for local fishers. Increased sedimentation smothers seagrass and/or increased turbidity reduces photosynthesis of seagrass, leading to a loss of seagrass coverage, density and/or diversity. This then impacts seagrass dependent communities, such a dugong	M	OM	Annual seagrass monitoring program with relevant control sites to determine the relative importance of impacts from MRM's operations and natural phenomena (e.g. cyclones). Annual marine monitoring of heavy metals in seawater, sediments and biota. Monthly monitoring of seawater using DGTs. Dredge spoil settled in ponds on land to minimise impacts of dredging on turbidity	3	3	6	M	Continue current monitoring and controls. Limit dredging to the dry season or do not dredge during rain events to ensure that particulate matter will have enough time to settle out before flowing out of the dredge spoil ponds
4.11	Sir Edward Pellew Islands and McArthur River estuary	Heavy metals	Mining operations adjacent to McArthur River and its tributaries.	Contaminants entering McArthur River travel downstream and settle in sediments around the McArthur River estuary and Sir Edward Pellew Islands.	Accumulation of metals in sediments and biota in vicinity of McArthur River estuary and Sir Edward Pellew Islands. Impacts on health, diversity, abundance of marine biota, effects on higher trophic species (including humans that eat fish caught in the area)	L	RI	Numerous controls at McArthur River Mine to minimise dust emissions, seepage and spills. Monitoring of contamination of soils, dust, fluvial sediments, surface water and groundwater around McArthur River Mine and contaminants in seawater, marine sediments and biota at Bing Bong Loading Facility and surrounds, McArthur River estuary and Sir Edward Pellew Islands	3	4	7	M	Continue current monitoring and controls. Eliminate sources of contamination along Barney Creek, including the Barney Creek haul road bridge and the ROM pad and sump
4.11	Transhipment area	Heavy metals	Transfer of concentrate from MV Aburri barge to larger vessel in the transhipment area	Load out from the MV Aburri to larger transport vessels causes dust emissions and spillage of concentrate, which contaminate the marine environment with lead and zinc	Reduction in diversity, abundance and/or health of aquatic biota including species of conservation significance and potential health impacts for local fishers	M	RI	Monitoring of metals and lead isotopes in sediments from the transhipment area, based on the location of anchoring points of bulk carriers. Compare these results with control sites outside the transhipment zones	3	4	7	L	Continue current monitoring and controls.
4.11	Bing Bong Loading Facility and Surrounding Marine Environment	Marine Ecology	Sinking or near sinking of the MV Aburri or transport vessel while loaded with concentrate and/or major oil or fuel spill	Large scale contamination of the marine environment with metals and oil/fuel	Reduction in diversity, abundance and/or health of aquatic biota including species of conservation significance and potential health impacts for local fishers	L	RI	Regular vessel maintenance and inspections, vessels kept in survey. MRM's formal process which specifically deals with managing and lowering the risk for possible sinking of the MV Aburri. Procedures include not deploying the vessel in adverse weather conditions and ensuring the vessel meets marine safety standards	2	4	6	M	Inherent risk of any port and shipping operations
4.11	Bing Bong Loading Facility and Surrounding Marine Environment	Marine Ecology	Minor operational oil or fuel spill from the MV Aburri or transport vessel	Release of oil or fuel to the marine environment	Reduction in diversity, abundance and/or health of aquatic biota including species of conservation significance and potential health impacts for local fishers	L	RI	Regular vessel maintenance and inspections, vessels kept in survey, leaks fixed promptly and reported as environmental incidents	4	4	8	L	No further controls recommended
4.12	Bing Bong Loading Facility	Soil and sediment monitoring	Lack of appropriate QA/QC for soil and sediment monitoring/analysis	Incomplete QA/QC may mean that data results are incorrect and exceedances may not be identified, or may be overestimated	Contamination of particular areas is not noticed	S	OM	Existing soils and fluvial sediment QA/QC includes relative percentage difference (RPD) of duplicate samples. Existing marine sediment QA/QC includes duplicate samples within the AMMP, trans-shipment area, and nearshore sediment sampling; method blanks within the AMMP, trans-shipment area sediment sampling only	4	4	8	L	· QA/QC control data for sample analyses, and subsequent discussion, should be presented in the next version of the MMP · There is room for improvement in QA/QC of soils and sediment monitoring reports – the QA/QC discussion for the surface water quality monitoring program in the current MMP provides a possible mode

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4.12	Bing Bong Loading Facility	Marine sediment management	Lack of appropriate marine sediment management and/or monitoring	Contamination of marine sediments in the nearshore and/or offshore environment due to poor quality surface runoff, concentrate spillage or dust deposition Insufficient spatial density and/or inappropriate control sites, application of inappropriate guidelines, and poor optimisation of analytes	Contamination of particular areas is not noticed Consequent impacts on marine environments and ecology, and potentially health of people consuming fish and shellfish	S	OM	Measures to manage marine sediment quality include dust management and surface water management Marine sediment program includes the AMMP, trans-shipment area and nearshore sediment monitoring programs	3	3	6	M	· Nearshore sediments – Zn exceedances in Zone 5 should be reviewed; if they continue to be elevated in 2018, the source should be investigated. · Nearshore sediments – The next nearshore sediment assessment report should advise the calculation method for interim criteria. · Marine sediments – the approach used in 2017 in both the AMMP and the TSA programs of quantifying the percentage contribution of the <63 µm sediment fraction to allow comparison between sites and to assess risk to biota should be continued in 2018. · The cause of exceedances of interim criteria for Tl within nearshore sediments at BBDDP should be investigated and the ecotoxicological implications of the data presented, with advice on required actions if Tl is found to be elevated due to MRM activities. This should include analysis of Tl within the dredge spoil ponds (potentially in 2019 as part of MRM's proposed geochemical investigation of the dredge spoil), and in swing basin sediments as part of the AMMP, in addition to fluvial sediments at the mine site as discussed · See also dust recommendations
4.12	Mine site and Bing Bong Loading Facility	Soil monitoring	Lack of appropriate soil monitoring	Insufficient spatial density and/or inappropriate control sites (or lack thereof), application of inappropriate guidelines, and poor optimisation of analytes	Contamination of particular areas is not noticed	L	L	Soil sampling program at mine site and Bing Bong Loading Facility	4	3	7	M	Monitoring of surface soil at control sites S10 (original location as per Q2 2017 and earlier) and S04 should be reinstated in 2018 · Ongoing reporting of exceedances via annual OPRs is a minimum requirement. Exceedances should not be treated as 'normal', but rather be reviewed and investigated as part of annual reporting. Where appropriate, new or revised management measures should be implemented to address the identified issues in the next period. MRM should review this matter with DPIR to reach an agreed position whereby legal requirements are met, an appropriate level of environmental protection is achieved, and bureaucratic burdens are minimised. A process such as a trigger action response plan may be appropriate to deal with ongoing exceedances, identifying under what circumstances certain actions should apply · A reconciliation/discussion of actual versus proposed/committed sampling events should be provided as part of all future soil and sediment reporting periods · The rationale for monitoring program changes should be considered and reported on a site-by-site basis. The range of potential contamination sources should be considered along with historical trends. If a site is known to have exceedances, the reasons should be assessed, and monitoring should continue at such a location unless there is a clearly stated reason to cease. Where it is necessary to move a monitoring site, a consistent and rational approach must be applied to site identification to minimise confusion and ensure that genuine comparison of results can be made across sampling periods
4.12	Mine site and surrounds	Fluvial sediment monitoring	Lack of appropriate fluvial sediment monitoring	Insufficient spatial density and/or inappropriate control sites, application of inappropriate guidelines, and poor optimisation of analytes	Contamination of particular areas is not noticed	M	OM	Fluvial sediment sampling program at creeks, rivers and diversion channels in and surrounding the mine site	3	3	6	M	· The next fluvial sediment report should explain the rationale for inclusion or exclusion of total sulfur as S, NAPP (ANC/MPA) and NAG in the program · Exceedance incident reporting: ongoing reporting of exceedances via annual OPRs is a minimum requirement. Exceedances should not be treated as 'normal', but rather be reviewed and investigated as part of annual reporting. Where appropriate, new or revised management measures should be implemented to address the identified issues in the next period. MRM should review this matter with DPIR to reach an agreed position whereby legal requirements are met, an appropriate level of environmental protection is achieved, and bureaucratic burdens are minimised. A process such as a trigger action response plan may be appropriate to deal with ongoing exceedances, identifying under what circumstances certain actions should apply · A reconciliation/discussion of actual versus proposed/committed sampling events should be provided as part of all future soil and sediment reporting periods · The rationale for monitoring program changes should be considered and reported on a site-by-site basis. The range of potential contamination sources should be considered along with historical trends. If a site is known to have exceedances, the reasons should be assessed, and monitoring should continue at such a location unless there is a clearly stated reason to cease. Where it is necessary to move a monitoring site, a consistent and rational approach must be applied to site identification to minimise confusion and ensure that genuine comparison of results can be made across sampling periods

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4.13	Bing Bong Loading Facility	Dust migration	Concentrate storage at Bing Bong Loading Facility	Emissions of dust from the Bing Bong Loading Facility concentrate storage shed, and from road vehicles at the facility, to the marine environment	Heavy metal contamination of seawater, marine sediments and potentially marine biota	M	WM	Dust monitoring program (DDG, DMV and TEOM) and dust mitigation measures including maintenance of a negative pressure differential and dust extractor system in the concentrate shed to reduce dust fugitive emissions	4	2	6	M	• The main doors of the Bing Bong Loading Facility concentrate shed should be replaced as soon as practicable, so that they can be closed except during truck access and egress; this is also important so that the dust extractor system in the concentrate shed can operate effectively. The vents of the dust extractor system in the concentrate shed should be replaced/made operable as soon as possible · The next air quality monitoring report should again present all of the available 24-hour average PM10, Pb and Zn concentrations recorded at DMV sites, from January 2012 to the end of the applicable reporting period, along with analysis/discussion of long-term trends (other than seasonality) and likely reasons
4.13	Bing Bong Loading Facility	Dust migration	Concentrate loading onto MV Aburri and from MV Aburri onto export vessels	Fugitive dust emissions to the marine environment	Heavy metal contamination of seawater, marine sediments and potentially marine biota	M	WM	Dust monitoring program (DDGs, DMVs, and TEOM) and dust mitigation measures including: · Covered, height-adjustable conveyor belts along with a funnel, to minimise fugitive dust emissions during loading of concentrate to the MV Aburri. · The vessel hold is sealed to prevent wind affects on dust. · The concrete apron (at the ship-loader) is washed down following completion of each ship-loading event (except when the next event is scheduled shortly afterwards). Contaminated wash-down water is directed to a sump.	4	3	7	M	NIL
4.13	Crushing plant and ROM	Dust emissions	Operation of ROM Pad, crushing plant and bulk concentrate stockpile at the mine site	Fugitive dust emissions from processing plant facilities	Heavy metal contamination of water and fluvial sediments in receiving waterways and diversion channels, and potential bioaccumulation in freshwater biota	M	L	Extensive dust monitoring program including: • HVAS and TEOM units at the mine site • DMV and DDG units at the mine site • duplicate and blank sampling as part of QA/QC Dust mitigation measures at crushing plant and ROM pad include: • Watering around the general area by water trucks. . • Double-layered skirting on horizontal rubber guarding. • A dust extraction system has been fitted to the secondary tertiary crusher building • At the bulk concentrate stockpile, a concrete base which is graded towards contaminated water drainage systems • A mini street-sweeper, used around the process plant to remove small spills • Enclosed facilities with internal water sprays at feeder, crusher, conveyor and transfer points. Water sprays, enclosures and windbreaks are used for crushers and screens. • Water sprays to minimise dust when unloading ROM to hopper, and manual implementation of water sprays and/or water cart around the general area during dusty periods. • Fitting all conveyors with appropriate cleaning and collection devices. Areas where spilt material can build up (e.g., under transfer chutes/conveyors) are regularly cleaned. • Slower tipping at ROM hopper during adverse weather conditions, and minimising drop heights when stacking. • Using visual triggers for implementation of further dust mitigation; visual surveillance of dust plumes during activity.	4	2	6	M	• The next air quality monitoring report should assess emissions trends recorded at the HVAS between periods, as well as exceedances recorded by TEOM units, with commentary on any operational aspects or weather patterns that may have influenced results • In addition to including long-term data, the next air quality monitoring report should include discussion and analysis of long-term trends (other than seasonality) and likely reasons (throughout the mine site) • The assessment of a rotary atomiser-based dust suppression system for the ROM bin primary crusher should be finalised and implemented, if appropriate, in the 2018-19 operational period

Report Section	Asset	Consideration	Hazard / Aspect	Incident / Event	Consequence / Impact	Potential duration of impact	Location of impact	Existing Controls/Monitoring and Assessment Undertaken	Consequence	Likelihood	Matrix Result	Risk Rating	Additional Controls, Monitoring, Assessment or Actions Required
4.13	Mine site	Dust emissions	Operation of the TSF, NOEF, WOEF, SOEF and haul roads	Dust emissions from exposed areas of facilities and haul roads	Heavy metal contamination of water and fluvial sediments in receiving waterways and diversion channels, and potential bioaccumulation in freshwater biota; deposition of dust on vegetation with potential uptake by terrestrial biota	M	L	Measures to control dust include: • Regular watering of haul roads, ore stockpiles, exposed construction areas and other exposed areas around the project site, subject to vehicle and machinery movements. Prevention of material being spilled on haul roads. • At the NOEF, operation of two water carts that spray the operating 'muck piles', roads and dumps. Compacted clay liners/advection layers assist in encapsulating potentially contaminated materials that could be mobilised via wind. Areas of OEFs are rehabilitated as soon as feasible. • At the TSF, tailings deposition rotation via the use of the spigots around the periphery to keep the exposed tailings surface damp, thereby reducing dust generation. • Capping of TSF Cell 1 with a clay layer to minimise generation of tailings dust. • Material extraction (mining)/unloading: application of water using dust suppression sprinklers on areas that are dusty prior to extraction/mining; water truck with water cannon to supply selective dust suppression when required. • Exposed areas and stockpiles: Regular watering of cleared or exposed areas and stockpiles, where appropriate; A concrete base at the mine site external concentrate storage area (bulk concentrate stockpile), which is graded towards contaminated water drainage systems. • Hauling on unsealed roads: Trafficable areas clearly marked and minimised, and vehicle movements restricted to these areas; speed limits on all roads. Trafficable areas and vehicle manoeuvring areas regularly maintained, and disused roads	4	2	6	M	• Future air quality monitoring reports should provide specific comment on DMV43/DDG43 trends, along with actions taken to minimise dust impacts in this area (and why they were or were not adequate to mitigate impacts), or further actions that are proposed to stabilise or improve results • The more noteworthy dust exceedances and long-term trends should not be treated as 'normal', but should be assessed and commented on in air quality monitoring reports, including specific comment on trends noted, any operational aspects or weather patterns that may have influenced these results, why (if applicable) existing dust controls may not have been adequate to mitigate impacts, or any further actions that are proposed to stabilise or improve results in accordance with the goals of the AQMP and TARP • The focus of the AQMP and the assessment framework and TARP therein should be expanded beyond a human health focus to reflect the dust monitoring program goals of the MMP and the OPR – i.e., including minimisation of air quality related impacts with respect to the environment and ensuring that the values of the surrounding environment are protected. Incident reporting should reflect this
4.13	Vehicular transport fleet	Dust emissions	Loading of concentrate onto transport vehicles at the mine site/transport of concentrate to Bing Bong Loading Facility Unloading concentrate from road trains, storage of concentrate and transfer of concentrate to MV Aburri barge leads to dust emissions at Bing Bong Loading Facility	Fugitive dust emissions during loading, unloading and transport	Heavy metal contamination of water and fluvial sediments in receiving waterways and diversion channels, with potential bioaccumulation in freshwater biota; deposition of dust on vegetation with potential uptake by terrestrial biota	M	WM	Extensive dust monitoring program and dust mitigation measures including: · covered dust generation points, watering for dust suppression around the mine site and NOEF by water trucks, dust extraction system fitted to the crusher building, washdown of all vehicles prior to leaving the mine site for Bing Bong Loading Facility and other destinations, maintenance of a dust extraction system and wet scrubber in the concentrate shed, and street sweeper used around the site and in particular the concentrator to remove dust which has settled to the ground, truck wheel-wash facilities and covers on concentrate transport vehicles · Loading/unloading of trucks inside concentrate sheds · Spraying roads with water at least once per day during the dry season · Sampling of concentrate and analysis/monitoring and management of the 'transportable moisture limit' (TML) of the product prior to transporting to Bing Bong Loading Facility and/or prior to loading of the MV Aburri or transfer to bulk carriers in the trans-shipment area	4	2	6	M	• The bitumen surface surrounding the Bing Bong Loading Facility should be repaired to avoid future soils, water and/or dust management issues • The main doors of the Bing Bong Loading Facility concentrate shed should be replaced as soon as practicable, so that they can be closed except during truck access and egress; this is also important so that the dust extractor system in the concentrate shed can operate effectively • The vents of the dust extractor system in the concentrate shed should be replaced/made operable as soon as possible

Appendix 2.
Gap Analysis

Report Section	Location	Aspect	Monitoring Area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	Water balance model documentation and reporting		x		It is recommended that more tables are used to improve clarity, understanding and error checking
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	OPR documentation and reporting		x		• There are numerous errors and inconsistencies which provide a misrepresentation of the status of on-site water management • Water balance model calibration charts that misrepresent the models predictive ability should not be used in the OPR
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	Water balance sensitivity analysis		x		Changes in climate The impact of climate change was modelled in the 2016-2017 mine site water balance report (WRM, 2016a) by increasing the model rainfall depths by 5%. This resulted in an additional 4% to 5% of 'rainfall runoff'. This result is of some concern because, in general, the change in runoff is greater than the change in rainfall (sometimes substantially). The model result tends to indicate that there may be something wrong with the rainfall-runoff model. The veracity of the rainfall-runoff model needs to be checked Changes in water chemistry The 2015-2016 water balance modelling report undertook this analysis by changing the controlled release dilution rate from 1 part mine water to 15 parts McArthur River water (1:15) to 1:50. The adopted change in site water quality needs to be justified with: • Current water quality monitoring data and/or predictions (e.g., pond water quality estimates, TSF/NOEF seepage estimates) • Input from professionals with expertise in geochemistry and water quality Runoff The 2016-2017 site water balance report showed the NOEF SEPROD and NOEF WPROD were highly sensitive to increases in runoff. This high sensitivity of changes to runoff volumes needs to be considered in all future water balance modelling
4.2	Mine Site	Water Balance	TSF Cell 2	The risk and impact of TSF Cell 2 spills contaminating water stored in the WMD, thereby making it unsuitable for off-site has not been assessed	x			The risk and impact needs to be assessed
4.2	Mine Site	Water Balance	TSF Cell 1	The MRM intent of improving TSF Cell 1 runoff quality is not reflected in current management of the cell's clay capping		x		The EIS proposes to combine TSF Cell 1 and Cell 2. If the Cells are combined, the problem of poor quality runoff from TSF Cell 1 will be addressed. However, the strategies proposed in the EIS are not currently approved
4.2	Mine Site	Water Balance	Mine Site	The resilience of the site water management system to address contingencies		x		While the current site water balance modelling shows that the probability of uncontrolled off-site releases is within the design criterion (less than 5%), the key modelling assumption is that model inputs are correct and the system performs as modelled. There is no allowance for unforeseen changes to the water balance estimates. That is, mine operations being different to those adopted in the model. MRM needs to develop the surface water management system to the point where there is sufficient resilience to accommodate the uncertainty in the model estimates
4.2	Mine Site	Water Balance	Mine Site	Water storage ponds and tailings storage facilities		x		• It is recommended that a plan is developed for de-sludging the NOEF PRODs used for lime treatment. • A new waste discharge point from the TSF WMD to the adjacent Barney Creek is proposed. The ecological impact of these releases when Barney Creek flow is affected by backwater from high McArthur River flows needs to be considered • The TSF Cell 1 east and west sumps overflows into the adjacent borrow pits. Changes to the sumps and/or pumps are required to. prevent further sump overflows • The TSF WMD currently has only a 39% (1:2.5) AEP flood immunity. It is recommended that the TSF WMD wall be modified to provide 1% AEP flood immunity • While the risk of TSF Cell 2 spills to the TSF Mini Dam has been modelled, the impact (on the site water balance) of contaminating water stored in the WMD, thereby making it unsuitable for off-site release, should be assessed
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	The uncertainty in model parameter estimation requires reduction		x		While this is implicit in all aspects of the water balance monitoring and modelling, high priority areas that need addressing are: • The amount of simultaneous calibration of multiple parameters needs to be reduced • Evaporation fan/sprinkler/fountain performance needs to be accurately quantified • Groundwater inflow rates need more accurate estimation • Seepage rates need more accurate estimation • Runoff rates need more accurate estimation • A strategy needs to be developed to reduce predictive uncertainty over time
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	Accurate quantification of water balance model uncertainty	x			It is recommended that a comparison of model water balance parameters from year to year be undertaken as a measure of reduction in parameter uncertainty over time.
4.3	Mine Site	Surface WQ	River monitoring	Installation of real time in situ monitoring capability at all relevant sites is yet to be completed		x		Issues associated with installing this capability at SW11 should be resolved. The IM understands that this is being addressed by MRM, with three EC/ temperature loggers also being installed across the riverbed at this site with data collection occurring after the wet season
4.3	Mine Site	Surface WQ	River monitoring	Validation of release calculator predictions		x		Sampling at SW11 concurrent with managed releases should be undertaken to validate the release calculator predictions, preferably at low dilution ratios (river flow: discharge) and assuming that safety concerns can be satisfactorily addressed
4.3	Mine Site	Surface WQ	River monitoring	No reporting of mine-derived and background loads			x	Mine-derived loads of contaminants reporting to the McArthur River should be reported on an annual basis, within the context of background loads in the river. Load calculations (and mine-site load balances) should take into account current and predicted natural and mine-derived loads, and seasonal variation. The results should be used to rank mine-associated contaminant sources and hence prioritise management and mitigation actions. The IM understands that loads will be reported in MRM's 2017 Operational Performance Report
4.3	Mine Site	Surface WQ	River monitoring	Additional data interpretation			x	Comparison of metal and metalloid results with ANZECC/ ARMCANZ (2000) values should include the 95th percentile values, expanding on the use of 95th percentile results to assign ASW monitoring locations to a specific water quality class
4.3	Mine Site	Surface WQ	River monitoring	Additional data interpretation			x	If SO_4 concentrations at SW11 reach 80% of the WDL trigger value (i.e., 273 mg/L), and SO_4 concentrations show an increasing trend prior to this value being reported, a risk assessment should be undertaken concerning possible implications associated with elevated SO_4 concentrations and conductivity levels at SW11 exceeding the respective SSTVs, likely causes and, if MRM operations are found to be a major contributing factor, mitigation measures commensurate with the level of risk
4.3	Mine Site	Surface WQ	River monitoring	Reinstatement of monitoring program component		x		Elemental scans should be reinstated at selected surface water monitoring sites (preferably during high flows). The IM understands that such scans will be added to the 2017/18 monitoring schedules, as indicated in MRM's 2017 Register of IM Recommendations spreadsheet
4.3	Mine Site	Surface WQ	River monitoring	Additional data interpretation			x	Further analysis is required concerning surface water TSS data and the risk posed by mine-derived suspended particulates on downstream beneficial uses, including consideration of TSS loads from the mine site over flood events and taking into account sediment basin overflows and particulate mineralisation

Report Section	Location	Aspect	Monitoring Area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
4.3	BBLF	Seawater quality	Surface water/ seawater monitoring	Additional data interpretation			x	Further analysis is required concerning surface water/seawater TSS data and the risk posed by BBLF-derived suspended particulates on nearby beneficial uses, including consideration of additional sampling sites if necessary and sampling of stormwater runoff during high rainfall events
4.3	BBLF	Seawater quality	Seawater monitoring	No current water quality monitoring in trans-shipment area	x			The IM understands that McArthur River Mining has collected DGT data at a site in the trans-shipment area as part of a 12-month investigation that will be addressed in next year's report
4.3	BBLF	Seawater quality	Seawater monitoring	Additional data interpretation			x	Consideration should be given to examining changes in DGT-labile metal concentrations that may have occurred since the program commenced
4.4	Mine Site	Hydraulics	McArthur River and Barney Creek Diversion Channel	Erosion identification and quantification		x		Ongoing monitoring of channel and bank erosion should be undertaken utilising the ALS surveys complimented by photograph monitoring, and visual inspection. No monitoring has been reported in the 2016-2017 or 2018 operational period
4.4	Diversion	Hydraulics	Diversions	Regular assessment of diversions by MRM staff	x			Establishing geomorphic monitoring locations to be regularly assessed by MRM personnel, based on methods outlined in ACARP (2002)
4.4	Diversion	Hydraulics	Diversions	Regular independent assessment of all waterways on the site	x			Regular (2-yearly) diversion assessments by a suitably qualified geomorphologist to establish a trajectory for the diversions and Surprise Creek. This should include the area just upstream of the McArthur River Diversion Channel.
4.5	Mine Site	Groundwater	Groundwater Resource	Assessment of impacts from groundwater production		x		An annual independent hydrogeological report should be prepared by suitably qualified hydrogeologist to evaluate effects of groundwater production on the groundwater and surface water environments
4.5	Mine Site	Groundwater	Groundwater Quality	Lack of site specific groundwater quality trigger levels	x			Groundwater quality trigger values are currently based upon guideline limits for livestock (ANZECC 1992). These should be updated to reflect the actual background water quality taking into consideration the surrounding ecosystems and environment in accordance with the approach presented in ANZECC 2000
4.5	Mine Site	Groundwater	Groundwater Environment	Assessment of groundwater models			x	There will be an increasing reliance on groundwater models to predict seepage impacts and identify suitable mitigation methods. It is important that all groundwater models are independently assessed by a modelling specialist to help ensure they are fit for purpose, adequately calibrated and the uncertainties are
4.5	Mine Site	Groundwater	Underground void/open cut	Surface water inflows to the pit should be monitored	x			Surface water inflows should be quantified to allow more reliable estimation of the groundwater inflow component of the dewatering rate
4.5	Mine Site and BBLF	Groundwater	Groundwater Environment	Statistical methods should be used to identify groundwater quality and level trends			x	Statistical assessment of trends assists in screening of monitoring data and identification of environmental impacts
4.5, 4.12 and 4.13	Mine Site /BBLF	Soil & sediment quality, dust and groundwater	Soil, fluvial sediment, marine sediment, dust and groundwater reporting	Addressing guideline exceedances			x	Exceedances of the various guideline levels for soils and sediments, dust and groundwater should be reported as environmental incidents, with subsequent investigation to address the reasons for exceedances and potential management measures
4.5	Mine Site	Groundwater	Groundwater numerical modelling	The numerical groundwater model developed for the mine site has not been calibrated to stream flow data		x		Stream flow data should be analysed to estimate baseflow contributions and the numerical groundwater model calibrated to this dataset
4.5	Mine Site and BBLF	Groundwater	Groundwater seepage	Seepage rates from dams and storages have not be assessed/reported	x			An assessment of the seepage rates from dams and storages should be undertaken using the site-wide water balances for the mine site and the Bing Bong Loading Facility to help identify sources of
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	External ICP testing (ALS) now carried out in preference to pXRF, but pXRF used from time to time when ALS at full capacity		x		Fully change to ICP analysis by progressing the on site ICP testing capacity or arranging back up external testing capability to avoid further contingency use of pXRF
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Criteria for PAF(RE) require more development to provide confident identification		x		Better demonstrate the validity of the PAF(RE) 10%S sulfur cut off
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Erosion modelling was carried out in relation to the proposed final outer NOEF cover, but assumptions require field confirmation		x		Progress field confirmation of erosion modelling predictions, as this could have significant implications for long-term cover system integrity and maintenance resources required
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Preliminary settlement modelling has been carried out, which indicated settlement was well within tolerances for the BGM option, but this needs to be verified		x		Carry out a more comprehensive settlement assessment for the NOEF in regard to potential effects on the proposed BGM layer, supported by site observation and settlement monitoring during dump construction
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Uncertain proportions of geochemical rock types in WOEF		x		Review/compile existing data and/or carry out a test programme to confirm the distribution of geochemical rock types at the WOEF and finalise closure options
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	The performance of the proposed outer OEF cover system has not been demonstrated		x		Proceed with trial cover designs of the new GSL cover system as planned to determine constructability and performance, and include physical and chemical testing of the proposed BGM as part of cover trials, with particular focus on UV and temperature sensitivity
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Some potential slope stability issues were identified in the cover system modelling carried out to date		x		The GSL cover system design should be independently reviewed in regards to saturation of the alluvium layer above the GSL and implications for slope stability
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Elevated SO_4 concentrations were detected in groundwater bores to the northeast of the NOEF near Emu Creek but the source is uncertain		x		Determine whether elevated SO_4 concentrations in groundwater bores to the northeast of the NOEF near Emu Creek are related to shallow seepage from the NOEF along natural drainage
4.6	Mine Site	Geochemistry	Tailings Geochemistry	Surface TSF sampling and water extract testing has been carried out, but some additional testing would assist interpretation and confirmation that oxidising tailings are not contributing significant acid.			x	Continue TSF surface sampling and water extract testing, and include targeted sampling of TSF surfaces that have been exposed for extended periods with strong salt generation, and record sample descriptions to assist interpretation of results
4.6	Mine Site	Geochemistry	Mine Site	Some testing was carried out of waste rock materials placed outside of the NOEF but it is incomplete	x			Carry out more extensive sampling at infrastructure sites tested to date to be confident in the relative proportions of geochemical rock types. Sampling should be extended to cover placed waste rock materials and excavated in situ sulfidic materials at the Barney Creek diversion channel and McArthur River diversion channel
4.6	BBLF	Geochemistry	Bing Bong Dredge Spoil	There is no acid sulfate soil assessment of the spoon drain around the dredge spoil ponds and other potential sources at Bing Bong Loading Facility	x			Carry out acid sulfate soil assessment of spoon drain and other potential sources at Bing Bong Loading Facility
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Treatment in progress in SPSD/SPROD/SEPROD, and may take a number of wet seasons to complete, and a clear treatment and water management schedule is required	x			Prepare treatment and water management schedule for acid water in NOEF SPSD/SPROD to ensure there is adequate storage to avoid uncontrolled release

Report Section	Location	Aspect	Monitoring Area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
4.6	Mine Site	Geochemistry	Open Pit	The open pit represents a major geochemical hazard for the site and current understanding of its long-term geochemical behaviour relies solely on the KCB pit water quality modelling		x		Verify the KCB pit void model predictions by an independent expert
4.7	Mine Site	Geotechnical	TSF Cell 1	Seepage monitoring		x		Continued investigations to improve extent and rate of seepage rates from Cell 1 towards Surprise Creek. Currently there is a strategy in place but uncertainty remains around how effective this system will be. Further studies and investigations are expected including additional pump tests.
4.7	Mine Site	Geotechnical	TSF Cell 1	Safe operating limits			x	Beach angles have been confirmed from the annual bathymetry survey (or other reliable means) to confirm maximum pond height to accommodate design storm event. Last survey was 5 June 2014
4.7	Mine Site	Geotechnical	NOEF	Closure modeling		x		Current closure modeling relies upon low confidence permeability estimates. Direct testing should be undertaken to conform these parameters and also their sensitivity checked more thoroughly. Progress on this issues is expected from EIS studies
4.7	BBLF	Geotechnical	Bing Bong Loading Facility dredge spoil ponds	Settlement monitoring		x		Survey monuments appear to have been installed but no evidence of monitoring has been provided to the IM. Survey points should be routinely interrogated particularly after the wet season and during dredging operations
4.7	BBLF	Geotechnical	Bing Bong Loading Facility dredge spoil ponds	Freeboard		x		Include a numerical assessment of the available freeboard in each monitoring report and check against design minimum
4.7	BBLF	Geotechnical	Bing Bong Loading Facility dredge spoil ponds	Monitoring reports and frequency			x	Schedule and document regular inspection of the storage ponds every 3 months outside of active dredging. The IM suggests monthly inspections during the wet season as a minimum
4.7	Mine Site	Geotechnical	TSF Cell 1	Monitoring			x	There is a lack of understanding as to how some piezometers may be impacted during flood events. Work needs to be done to properly understand how they are going to be impacted or prevent such impacts in future
4.7	Mine Site	Geotechnical	NOEF	Monitoring		x		Recent evidence suggests that revised design & construction methods re lowering in NOEF temperatures however there is little evidence to support this. Comparative monitoring should be undertaken in newer NOEF areas to allow more direct comparisons of old and new performance.
4.8	BBLF	Dredge spoil ponds	Closure costs	No closure costs for rehabilitation of dredge spoil ponds	x			Detailed closure costs be prepared for the Bing Bong Loading Facility and that these are presented as a separate domain from the mine closure costs
4.9	Mine Site	Terrestrial ecology	Rehabilitation	Insufficient quantitative assessment of the stability of the channel or erosion levels included in rehabilitation monitoring		x		It is recommended that a landscape function analysis method of assessing the rehabilitation of the diversions is investigated such as ephemeral drainage-line assessment particularly making use of quantitative methods of measuring erosion. This method allows the quantitative assessment of the stability of the channel, gives annual quantitative data of erosion change from year to year and guides remedial actions which need to be undertaken
4.9	Mine Site	Terrestrial ecology	Flora	Lack of synergistic weed management with upstream pastoral properties		x		Work in conjunction with pastoral properties upstream on the McArthur River on weed control, with the aim of decreasing the likelihood of the McArthur river diversion channel being repopulated with weeds from sources outside of the mine boundary. Will save costs in weed control and promote community
4.9	Mine Site	Terrestrial ecology	Flora	Lack of monitoring of flora at known areas of saline seepage such as Surprise Creek adjacent to the TSF and the Surprise/Barney Creek confluence to evaluate effect of seepage	x			Currently there is monitoring in the vicinity of the processing plant and PAF run-off dams, however, a site at Surprise Creek in the vicinity of the TSF and the Surprise/Barney Creek confluence, should be added to the program. Remote sensing study conducted in 2017 to detect saline seepage
4.9	BBLF	Terrestrial ecology	Fauna	There is insufficient comparison of migratory shorebird survey data to available long term data collect by Garnett and Chatto since 1987 in the gulf			x	Compare survey data to historical survey data for the region
4.9	BBLF	Terrestrial ecology	Flora	Trials for dredge spoil rehabilitation	x			Proposal sighted, but has not been undertaken as yet. Charkes Darwin University student failed to commence study
4.9	Mine Site	Terrestrial ecology	Rehabilitation	There is no specified completion date for the rehabilitation of the diversion channels		x		Include completion year in future MMPs
4.9	Mine Site	Terrestrial ecology	Rehabilitation	No revegetation monitoring site in the rocky gorge habitat along the diversion channel		x		Include a monitoring site in the rocky gorge area of the McArthur River diversion channel (downstream, below MRR6) along with a suitable control site and key species list, as this location will not rehabilitate in the same manner as other sites and data is required to ensure that it is also rehabilitated to an appropriate
4.9	BBLF	Terrestrial Ecology	Vegetation die-back	Insufficient inspection of Bing Bong dredge spoil and drain		x		Conduct monthly inspections of dredge spoil including examination of ponding, erosion, cracking and cattle damage
4.9	Mine Site	Terrestrial Ecology	Fauna	Insufficient mapping illustrating important Gouldian finch foraging habitat			x	Add mapped vegetation units that have been deemed important foraging habitats for the Gouldian finch to the current important habitat map figure
4.9	Mine Site	Terrestrial Ecology	Fauna	Inconsistent timing of early dry season riparian bird surveys		x		Standardise timing of riparian bird surveys to ensure results are comparable from year to year
4.9	Mine Site	Terrestrial Ecology	Flora	Lack of comparison of dust monitoring data with vegetation survey results in areas where reduced vegetation health has been recorded		x		Results from dust monitoring sites DMV25 and DMV23 should be assessed against foliage cover results from vegetation control sites BCC1 and BCC2 respectively, to identify whether airborne dust is a causal factor in decreasing foliage density
4.10	Mine Site	Freshwater ecology	Fauna	No assessment of how modelled drawdown of 0.7 m at Djirrinmini waterhole will impact freshwater fauna	x			While MRM advised that this will be considered in the water management plan, this is yet to be developed or sighted by the IM, as previously recommended, MRM should assess the ecological impacts of drawdown at Djirrinmini waterhole on freshwater fauna and assess how much habitat will be lost, especially for freshwater sawfish
4.10	Mine Site	Freshwater ecology	Movement of contaminated biota	Currently there is no assessment of the movement of contaminated biota and how long biota would need to spend at a site to uptake contaminants	x			A desktop review should use available literature to investigate likelihood and distance of dispersal of contaminated biota from McArthur River Mine, and how long biota would need to spend at a site to uptake measurable levels of metals, in particular Pb and Zn
4.10	Mine Site	Freshwater ecology	Fauna, flora, fluvial sediments and water quality	Little synthesis of entire monitoring program, each part (monitoring of water quality, contamination of fluvial sediments and diversity, abundance and contaminants in aquatic fauna) treated in isolation. In addition other monitoring programs, such as dust, soil and groundwater are not included in synthesis			x	An annual monitoring program report, which synthesises data, rather than just reproducing results, would help provide a better overall view of the impacts of mining operations on the freshwater environment. The report could then inform better management of watercourses around the mine, and aid in targeting sources of contamination

Report Section	Location	Aspect	Monitoring Area	Monitoring Gap	Gap Category			Recommendations/ Comments
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4.10	Mine Site	Freshwater ecology	Fauna	McArthur River Mining is planning to construct flow monitoring stations on McArthur River and Surprise or Barney Creek that would require a concrete weir-like structure. Any structure that acts as a barrier to fish movement has the potential to alter fish communities upstream of the structure	x			Prior to construction of these flow monitoring stations, the potential ecological impacts of such infrastructure should be assessed, and mitigation (e.g., fishways) planned and implemented if required
4.10	Mine Site	Freshwater ecology	Fauna	Finer scale movement data on migratory fish species (barramundi and sawfish) within the mine lease and the McArthur River diversion channel within and out of the McArthur River diversion channel		x		Install additional acoustic receivers between Upper Diversion and Cattle Yard and Lower Diversion and Hidden Pool monitoring sites and in the Glyde River
4.10	Mine Site	Freshwater ecology	Metals in fauna	The applicability of non-lethal sampling methods for measuring metal concentrations in biota		x		Continue to explore non-lethal sampling methods and conclude whether this is a suitable alternative to current practices
4.11	BBLF	Marine ecology	Flora/Fauna	No documentation regarding current practices involving ballast water from ships at Bing Bong Loading Facility e.g., ballast water source, dumping location	x			Desktop assessment of requirements and current practices with results documented, possibly in SDMMP if not stand-alone document
4.11	BBLF	Marine ecology	PbIRs for AMMP marine water quality sites	PbIRs to confirm sources of elevated Pb at BBW1 and BBW2 (and reference sites Pine Creek, Pine Reef, Rosie Creek)		x		Include PbIRs for annual marine monitoring program to provide better understanding of potential sources of elevated Pb recorded in 2017, particularly around BBW1 and BBW2 reference sites to the northwest
4.11	BBLF	Marine ecology	Metals in fauna	The applicability of non-lethal sampling methods for measuring metal concentrations in biota				Continue to explore non-lethal sampling methods and conclude whether this is a suitable alternative to current practices
4.11	BBLF	Marine ecology	Metals in fauna	Contaminant uptake pathways, timeframes and dispersal	x			Consider the use of an acoustic monitoring/tagging program as well as a desktop assessment to investigate how long biota would need to spend at a site to uptake measurable levels of metals, in particular Pb and Zn
4.12	Mine Site /BBLF	Soil & sediment quality	Soil, fluvial sediment, marine sediment reporting	Addressing guideline exceedances			x	• Ongoing reporting of exceedances via annual OPRs is a minimum requirement. Exceedances should not be treated as 'normal', but rather be reviewed and investigated as part of annual reporting. Where appropriate, new or revised management measures should be implemented to address the identified issues in the next period • MRM should review this matter with DPIR to reach an agreed position whereby legal requirements are met, an appropriate level of environmental protection is achieved, and bureaucratic burdens are minimised. A process such as a trigger action response plan may be appropriate to deal with ongoing exceedances, identifying under what circumstances certain actions should apply
4.13	Mine Site /BBLF	Dust	Dust reporting	Addressing guideline exceedances			x	• The more noteworthy dust exceedances and long-term trends should not be treated as 'normal', but should be assessed and commented on in air quality monitoring reports, including specific comment on trends noted, any operational aspects or weather patterns that may have influenced these results, why (if applicable) existing dust controls may not have been adequate to mitigate impacts, or any further actions that are proposed to stabilise or improve results in accordance with the goals of the AQMP and TARP • MRM should include commentary in air quality monitoring reports where particular operational activities are known or suspected as being sources of exceedances in certain areas
4.12	Mine Site	Soil & sediment quality	Soil	Inappropriate control site to be replaced		x		Monitoring of surface soil at control sites S10 (original location as per Q2 2017 and earlier) and S04 should be reinstated in 2018
4.12	Mine Site	Soil & sediment quality	Soil	Lack of site specific trigger levels; assessment framework			x	No site-specific trigger criteria have been derived for the mine site. Developing triggers and general assessment of soil monitoring data will need to take into account the revised version of NEPM (as amended, April 2013)
4.12	BBLF	Soil & sediment quality	Fluvial Sediments	No monitoring of sediments within the McArthur River Delta	x			McArthur River Delta sediments should be included in the fluvial sediment monitoring program. Suspended sediments have not been reanalysed and monitored for lead isotopes to compare with the settled sediments on the delta floor
4.12	Mine Site /BBLF	Soil & sediment quality	Soil, fluvial sediment and marine sediment reporting	Presentation of quality assurance data			x	• QA/QC control data for sample analyses, and subsequent discussion, should be presented in the next version of the MMP • While the IM notes that some discussion of QA/QC is now provided in all soil and sediment monitoring reports, this should be improved in the next operational period. The QA/QC discussion for the surface water quality monitoring program in the current MMP provides a possible model for the soil/sediment programs. QA/QC should include trip blanks, records of holding time compliance, and method blanks, laboratory control spikes and matrix spikes
4.13	Mine Site /BBLF	Dust	Dust monitoring	Review of long-term data required			x	In addition to including long-term data, the next air quality monitoring report should include discussion and analysis of long-term trends (other than seasonality) and likely reasons
4.12	BBLF	Soil & sediment quality	Nearshore sediment monitoring/ assessment	Derivation of assessment criteria			x	The next nearshore sediment assessment report should advise the calculation method for interim criteria
4.12 / 4.13	Mine Site /BBLF	Soil & sediment quality; Dust	Soil, fluvial sediment, marine sediment and dust monitoring	Reconciliation of sampling program changes			x	• A reconciliation/discussion of actual versus proposed/ committed sampling events should be provided as part of all future soil and sediment reporting periods • The rationale for monitoring program changes (including decommissioning/exclusion/replacement of sites) should be considered and reported on a site-by-site basis. The range of potential contamination sources should be considered along with historical trends. If a site is known to have exceedances, the reasons should be assessed, and monitoring should continue at such a location unless there is a clearly stated reason to cease. Where it is necessary to move a monitoring site, a consistent and rational approach must be applied to site identification to minimise confusion and ensure that genuine comparison of results can be made across sampling periods
4.13	Mine Site /BBLF	Dust	Dust monitoring and management	Addressing guideline exceedances		x		The focus of the AQMP and the assessment framework and TARP therein should be expanded beyond a human health focus to reflect the dust monitoring program goals of the MMP and the OPR – i.e., including minimisation of air quality related impacts with respect to the environment and ensuring that the values of the surrounding environment are protected. Incident reporting should reflect this
4.13	Mine Site	Dust	Dust monitoring and management	Dust issues at Barney Creek haul road bridge			x	Future air quality monitoring reports should provide specific comment on DMV43/DDG43 trends, along with actions taken to minimise dust impacts in this area (and why they were or were not adequate to mitigate impacts), or further actions that are proposed to stabilise or improve results
4.13	Mine Site /BBLF	Dust	Dust monitoring and assessment	HVAS and TEOM data reporting			x	The next air quality monitoring report should assess emissions trends recorded at the HVAS between periods, as well as exceedances recorded by TEOM units, with commentary on any operational aspects or weather patterns that may have influenced results

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4.13	Mine Site /BBLF	Dust	Dust monitoring and assessment	DDG reporting			x	With regards to DDG reporting in the next ambient air quality monitoring report: • Monthly DDG results (including deposited dust and metals results; from sampling or subsequent calculations) should be tabulated along with written interpretation of results in relation to criteria and/or background levels • Charts should be more clearly labelled • Natural dust deposition in the vicinity of the mine should be taken into account, thereby resulting in a standard for incremental deposited dust increase of 2.6 g/m2/month, expressed as an annual mean
4.13	Mine Site /BBLF	Dust	Dust monitoring and assessment	Dust criteria and action triggers		x		An update should be provided to the AQMP, addressing the following: • If possible, more specific relevant criteria should be adopted and/or developed for DDG sites (particularly for metals) to enable assessment of results beyond comparison with historical levels • Clarification of the TARP trigger for DMV sites (i.e., does it apply for a single Pb or Zn exceedance, or to be compared against historic data as stated in Section 10.1 of the AQMP)
4.13	Mine Site	Dust	Dust monitoring and assessment	Contribution of dust to contaminant loads		x		MRM should investigate dust/diffuse surface runoff contributions to contaminant loads reporting to surface drainages as part of the broader investigation into mine-derived loads

GAP CATEGORIES

Category	Description
1	Monitoring and/or modelling to mitigate potential associated environmental risk is not undertaken
2	Monitoring and/or modelling is undertaken, but monitoring is not sufficient in design (that is, frequency, location, type and so on), or the inputs to/assumptions of modelling are not validated, such that results are insufficient to identify or quantify potential environmental risks
3	Monitoring and/or modelling is undertaken and is appropriate, however data/output information is not adequately assessed, interpreted or managed to appropriately mitigate potential environmental risks

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