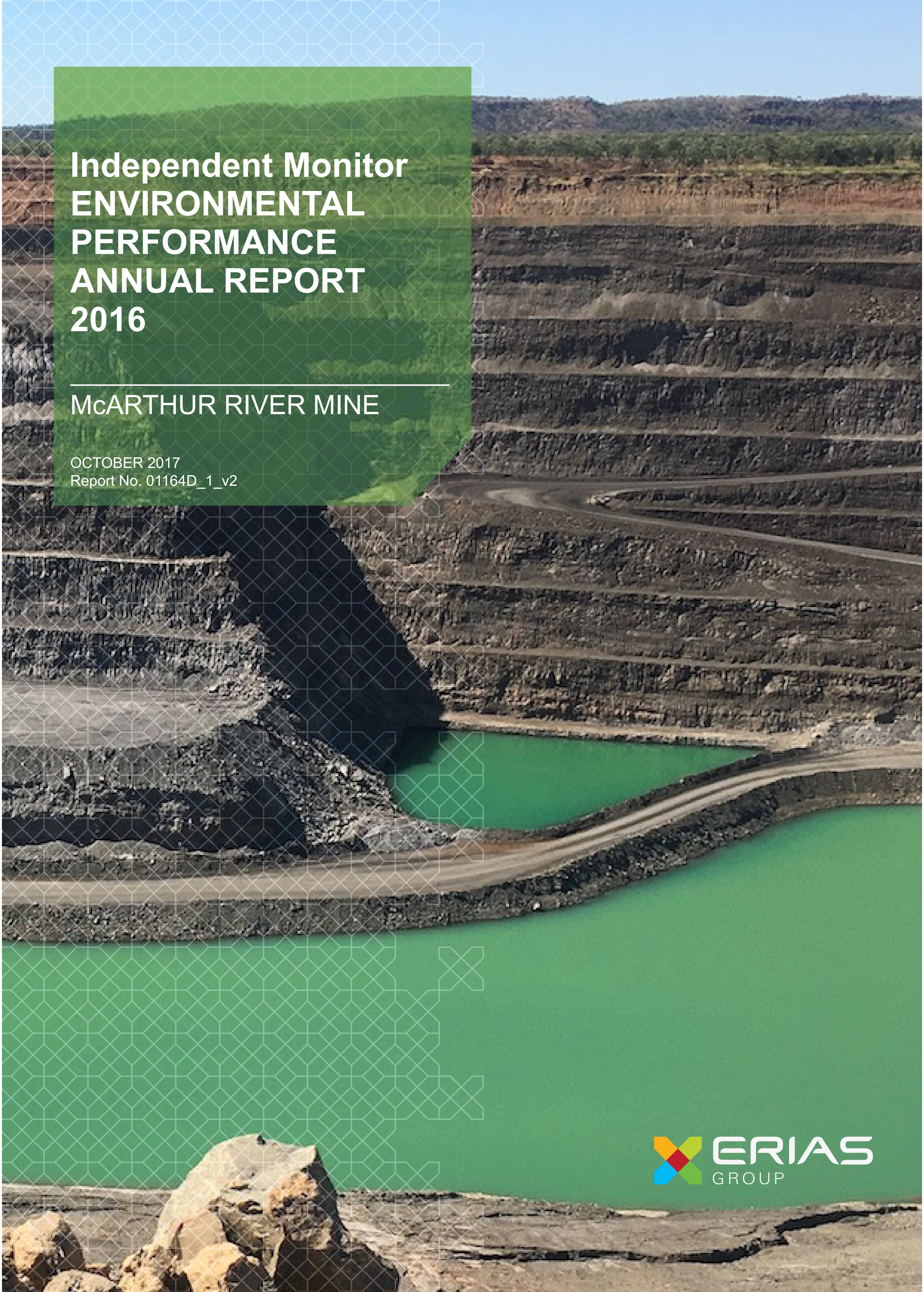

Independent Monitor ENVIRONMENTAL PERFORMANCE ANNUAL REPORT 2016

McARTHUR RIVER MINE

OCTOBER 2017
Report No. 01164D_1_v2

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 2016

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Executive Summary

This is the fourth 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 2015 to September 2016. Information obtained as a result of the IM site visit in June 2017 and information provided by both McArthur River Mining (MRM) and the Northern Territory Department of Primary Industry and Resources (DPIR) which is applicable to matters outside the reporting period has also been reviewed and incorporated into the report where relevant.

The reporting period has seen a significant number of technical reports completed which informed the Overburden Management Project draft environmental impact statement (Draft OMP EIS) which was released for public comment in March 2017. The IM undertook a review of the Draft OMP EIS and submitted comments to the Northern Territory Environment Protection Authority. The IM, in reviewing the performance of MRM over the reporting period, has made comment on the strategies outlined in the Draft OMP EIS.

McArthur River Mining has expended considerable effort on site geochemistry issues since the last IM report. Further studies and investigations have been carried out to better define the geochemical properties and risks of mine materials, and to provide more direction concerning the operational and long-term management required for problematic materials. Much of this was carried out in support of the recently submitted Draft OMP EIS. In addition, processes for identification, selective handling and management of geochemical waste rock types have been advanced.

Work carried out to date continues to confirm that McArthur River Mine materials are highly pyritic and a major potential source of acid[1], metalliferous and saline drainage (AMD). The risk of AMD generation, and the associated potential adverse impacts both on site and downstream, remains the most significant environmental issue at McArthur River Mine.

The northern overburden emplacement facility (NOEF), tailings storage facility (TSF) and open pit represent the key potential sources of AMD, and inadequate management of seepage/runoff during operations and/or failure of closure mitigation strategies could result in long-term impacts on groundwater and terrestrial and aquatic ecosystems. McArthur River Mining has recognised in the Draft OMP EIS that, with the implementation of strategies outlined in that document, the site will require ongoing monitoring and maintenance for an undetermined time (but likely to be in the hundreds of years).

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

[1] It should be noted that with the exception of acid drainage which was collected in SPROD as a result of water runoff from irrigation of a low-grade ore stockpile that was being reclaimed for processing, acid drainage has not been observed on the site.

October 2016 indicates that adverse impacts on downstream surface waters due to the mine are limited, although some effects are noticeable in watercourses within the mine lease boundaries (and this is not unexpected) and some non-compliance with WDL SSTVs at SW11 due to mine activities has occurred (but to a lesser extent than was noted in last year's IM report). Monitoring data suggests that adverse impacts on coastal waters near Bing Bong Loading Facility similarly remain limited. The IM also notes that MRM is starting to focus 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. The existing information indicates that mine-derived loads in Barney Creek, as measured at SW6 (which is located within the mining area), are significant, and the next steps are to fully quantify these loads and to determine the associated environmental risks, particularly in terms of downstream impacts.

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

- Completion of geochemical testing and investigations that have resulted in a comprehensive dataset using an appropriate suite of static and kinetic tests, so that the geochemical properties of overburden and tailings materials at the mine are well understood.
- Use of kinetic data to develop improved waste rock classification criteria.
- Improvements to block modelling, materials tracking and checks.
- Completion of a number of studies and assessments to address information gaps, including reconstruction of the NOEF waste rock composition, better definition of the composition of the southern overburden emplacement facility (SOEF) and western overburden emplacement facility (WOEF), cover design modelling and assessment, groundwater modelling to better understand seepage pathways for OEFs, erosion modelling to better understand potential impacts on long-term dump cover integrity, testing and assessment of tailings surface oxidation potential and lag times, and pit water quality modelling.
- Commissioning an independent consultant to investigate whether the placement and containment of mining waste at the NOEF is causing, or may cause, environmental harm to the receiving environment.
- Placement of newly-mined potentially acid-forming (high capacity)(PAF(HC)) and potentially acid-forming (reactive) (PAF(RE)) waste rock in paddock-dumped and traffic-compacted (2 m) lifts and placement of advection covers to help control rapid (convective) oxidation.
- Construction of a minimum 35-m wide metalliferous/saline-non acid forming (MS-NAF) halo zone around the west, south and east (in progress but almost complete) side of the older West Stage of the NOEF to help control convection/advection into PAF materials (and particularly end-tipped PAF materials) in this older zone.
- Establishment of a well-organised system of identification and stockpiling of materials suitable for the compacted clay liners (CCL) and advection barriers.
- Installation of additional monitoring equipment (flow meters and pond water level sensors).
- Continued effective management of the TSF pond size and cyclic deposition of tailings.

- Completion of a substantial area of the Central West NOEF liner system in preparation for receiving PAF.
- Reporting by the Independent Certified Engineer to document NOEF progress, testing and specification conformance.
- Improvement in the sensitivity analyses undertaken as part of the site water balance modelling.
- Completion of the geomorphological assessment of the McArthur River diversion channel.
- Development of updated conceptual geological and hydrogeological models for the mine site, based on extensive field investigations. This is considered by the IM to be a significant step forward in understanding the groundwater system across the site.
- Placement of a substantial amount of large woody debris (LWD) into the downstream end of the McArthur River diversion channel. Large woody debris is essential for the rehabilitation of the diversion channel as it provides important refuge habitat for fish species, helps to slow flow rates and acts as a sediment trap providing substrate for vegetation to grow in.
- Planting of over 25,000 tubestock during the 2016 operational year, including over 20,000 along the McArthur River diversion channel.
- Improved monitoring of metals in freshwater fauna to include more sites from Barney Creek and additional analytes.
- Declining levels of contamination in biota from SW19, likely due to controls implemented by MRM. For example, the mean concentration of Pb recorded in bony bream has declined more than six fold since 2014.
- Monitoring of metals in freshwater macrophytes for the first time, the results of which largely reflect the results of the metals in fauna program.
- Conducting a community survey of fish consumption patterns. The survey showed that the current monitoring program adequately targets commonly consumed fish and popular fishing spots. However, it also identified new fish and locations to include in the monitoring program.
- Establishing an acoustic tagging program to gather comprehensive data on fish movement in the McArthur River and diversion channel, particularly migratory freshwater sawfish and barramundi.

Issues that the IM has identified during the review of the 2016 operating year include the following, some of which have also been discussed in previous IM reports:

- Poor quality leachate, i.e., AMD, from waste rock in the NOEF is already reporting to groundwater and surface drainage due to inadequate management of seepage during operations. Future dump construction will better control seepage during operations, but infiltration through the NOEF will continue, and there is uncertainty concerning the fate of this seepage and whether the current ponds located around the NOEF will capture it all. Failure of the cover system post closure could continue to impact groundwater and terrestrial and aquatic ecosystems in perpetuity. McArthur River Mining has investigated the option of installing an interception trench and recovery bores to capture contaminated groundwater from the NOEF. Modelling indicates that this strategy would be effective in managing seepage from the NOEF. There is currently no timeframe on when such an interception system would be installed, with the consultant report indicating this would be based on groundwater monitoring results.

A major factor that contributes to this risk is historical end dumping of 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). This tends to promote rapid rates of sulfide oxidation and greater release of AMD. There is also potential for spontaneous combustion to affect the stability of the NOEF, and lead to breaches in the cover. Progress has been made in reducing convective oxidation in these older areas through construction of an MS-NAF halo on the western, southern and eastern faces of the West Stage, with advection covers placed over the halo on the western and west part of the southern faces. The advection covers currently being implemented are expected to assist control of rapid oxidation in newer areas of the NOEF where PAF materials are placed in small lifts, but the effectiveness of these advection covers on a large, heterogeneous and actively convecting system will require monitoring to demonstrate its effectiveness.

- Improvements in CCL construction and reporting have improved confidence in the ability of the CWNOEF facility to safely store non-benign waste. The IM has reviewed the proposed cover design outlined in the Draft OMP EIS and provided comment to the Northern Territory Environment Protection Authority; the IM understands its comments will be addressed in the EIS Supplement, which is currently being prepared by MRM.

- Declining groundwater quality is being observed south of the SEPROD, although seepage rates from the dam are estimated to be minimal. The source of the contamination should be identified and mitigation measures implemented.

- Seepage through the TSF Cell 2 embankment has been an ongoing issue at the TSF. The main cause of the seepage was the use of a rockfill mattress as part of the Stage 3 raising works to facilitate using upstream construction methods. More recently, seepage levels have again increased and this will be discussed in next year's report.

  These increases in collected seepage and continued elevated piezometric levels within the embankment have occurred despite the adoption of a number of good water and tailings management practices. The higher piezometric levels are also at odds with seepage modelling that suggests much lower piezometric levels. McArthur River Mining should undertake further investigation of the causes of this continued seepage as this may have implications for future TSF management.

- Poor quality leachate from the TSF is also already reporting to groundwater and surface drainage due to inadequate management of seepage during operations. Process water appears to be the key source of contamination rather than oxidising pyrite in the tailings. For the existing TSF designs and configurations, the current minimisation of water storage and planned seepage recovery seem to be the only viable options to control direct impacts on receiving creeks from ongoing and historical process water. For closure, the IM strongly supports the re-processing and in-pit disposal option proposed in the Draft OMP EIS, which would ensure that the tailings remain inundated in the long term, thereby preventing further sulfide oxidation and providing a much more secure closure outcome than would be achieved for a TSF with a cover system.

- McArthur River Mining is starting to focus 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. The existing information indicates that mine-derived loads in Barney Creek are significant, and the next steps are to fully quantify these loads within the context of background loads and to determine the associated environmental risks, particularly in terms of downstream impacts.
- The geomorphological study identified an active channel avulsion (wholesale shift in channel position) immediately upstream of McArthur River diversion channel off-take, 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 rehabilitation of the McArthur River diversion channel has continued with the planting of tens of thousands of seedlings in recent years. It is expected that the redesigned revegetation monitoring program will aid in increasing the success of revegetation by helping to identify where the significant problems lie and how these problems can be addressed in the coming years.

The IM has also reviewed DPIR's performance in regulating the McArthur River Mine. During the 2016 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.

The IM commends the DPIR on continuing these site visits and the comprehensive reports that are provided. While major issues observed during site inspections were addressed through the issuing of an instruction, the IM notes that there is no tracking of issues which do not warrant an instruction. The IM believes that this is a gap in DPIR's inspection process.

During the operational period (October 2015 to September 2016), the DPIR issued a series of instructions to MRM. A number of these related to requesting additional information to assist in the assessment of MMP amendments or as a result of site inspections or incidents that occurred at the operation. In reviewing the incidents which MRM reported to DPIR, there appears to be confusion regarding what incidents are required to be reported. The IM was advised by DPIR that all environmental incidents must be reported to the department in accordance with Section 29 of the Northern Territory *Mining Management Act*. Previously DPIR issued a guideline to operators with regard to incident reporting which has subsequently been withdrawn. It would not appear practical for all environmental incidents at operations throughout the Northern Territory to be reported to the department. Many of the incidents reported on a mine site are likely to be minor in nature and result in no or negligible environmental impact and reporting of these is likely to add to the administrative burden of the department without any impact on performance at operations. An incident reporting system based on the impact of the incident and potential risk would reduce the number of incidents being reported to a manageable level, which would enable the department to direct its resources to those incidents with a high environmental impact or potential impact. There also appears to be inconsistency regarding incident classification.

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 has been slow and the IM would like to see DPIR place a higher priority on appropriate action.

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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[2] (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 (0059-02[3]), where Schedule 2 (independent monitoring assessment conditions) states that:

> 3.1 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.
>
> 3.2 The Department will engage an Independent Monitor to undertake the independent monitoring assessment.

1.2 Scope of the Assessment

Clause 4.1(a) of the independent monitoring assessment conditions states that the IM is required to monitor the environmental performance of the mine[4] 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 2015 to September 2016[5] and is referred to as the 2016 operational period[6].

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[2] During the 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 for consistency.
[3] On 1 June 2017, MRM were issued with a Variation of Authorisation that combines Authorisations 0059-01 and 0059-02.
[4] Includes Bing Bong Loading Facility.
[5] Note that monitoring data has been assessed primarily for the period of July to June, i.e., July 2015 to June 2016. Some additional monitoring data from July 2016 to September 2016 has also been reviewed and discussed where available and relevant.
[6] 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

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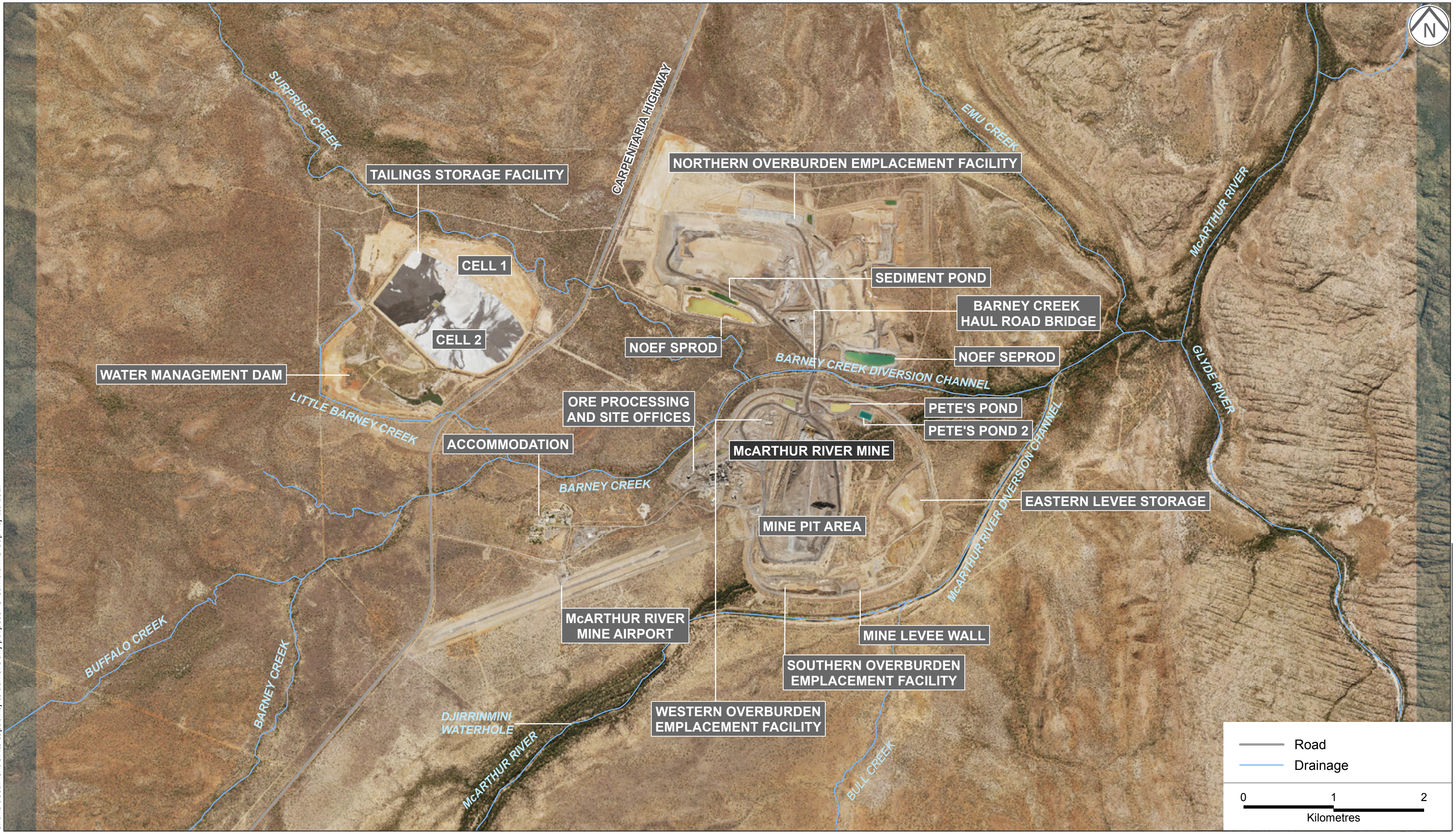
McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 1.2



BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 1.3

The scope of the assessment included the following:

- An inception meeting with DPIR prior to travelling to the mine site.
- An inception meeting with MRM on site.
- Reviewing environmental assessments, monitoring activities and reviews undertaken by both MRM and DPIR.
- 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 2016 operational period.
- Undertaking a site visit and discussions with MRM personnel and MRM consultants.
- 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.

The scope of subsequent assessments will be similar to that described above and defined in the associated environmental performance annual report.

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 nine chapters:

- 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 chapter, 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 NT. 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 the DPIR in December 2015. A number of amendments to the MMP have been approved since December 2015.

During the review period, two waste discharge licences[7] (WDL 174-07 and WDL 174-08) issued under the *Water Act* applied to the discharge of wastewater into the McArthur River and 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).
- Licences and agreements.
- 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 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

[7] Note that WDL 174-07 applied until 17 March 2016 when WDL 174-08 became effective.

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 that following further testwork of waste rock 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 is currently reviewing the public comments and preparing a response. The IM reviewed the Draft OMP EIS and submitted comments to the EPA (ERIAS Group, 2017).

Ore from the zinc/lead/silver deposit is extracted and processed to produce a high-grade bulk zinc/lead/silver concentrate. 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 and 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 potentially acid-forming (PAF) sediment dam (SPSD)	Runoff from OEF (waste rock) (contaminated)
NOEF southern PAF runoff dam (SPROD)	Runoff from OEF and SPD overflow (contaminated)
NOEF southeast PAF runoff dam (SEPROD)	Runoff from southeast area of NOEF (contaminated)
NOEF western PAF runoff dam (WPROD) - under construction	Runoff from western area of NOEF (contaminated)
NOEF eastern PAF 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
Tailings Storage Facility	
TSF Cell 1 west storm water collection sump	Runoff from TSF Cell 1 (potentially contaminated)
TSF Cell 1 east storm water collection sump	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
Bing Bong Loading Facility	
Bing Bong surface runoff pond 1	Contaminated runoff from sumps, washdown and infrastructure areas

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

Pond/Dam	Description of Water Stored
Bing Bong Loading Facility (cont'd)	
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. Contains sediment.

2.3 Previous Independent Monitor Reviews

The first IM review of MRM's environmental performance was for the period October 2006 to September 2007 or 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 and 2015. 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 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	♦ Some improvements since the 2007 review
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	♦ A number of issues identified in the previous reviews addressed; however, there were a number of ongoing, and additional, issues

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

Review Year	Key Findings/Recommendations	Environmental Performance Over Time
2009 (cont'd)	♦ 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	
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
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

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

Review Year	Key Findings/Recommendations	Environmental Performance Over Time
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 ♦ DME to improve the timeliness of issuing audit reports ♦ DME 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: – 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	♦ 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 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

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

Review Year	Key Findings/Recommendations	Environmental Performance Over Time
2014 (cont'd)		♦ 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

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 (DLPE)	Environment groups
Department of Infrastructure, Planning and Logistics	Other interested parties
Department of Tourism and Culture	
Northern Territory Environment Protection Authority	
Department of Health	
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.

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
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; aquatic ecology; marine ecology
Nicola Hanrahan	Low Ecological Services	Terrestrial flora and fauna
Matt Le Feuvre	Low Ecological Services	Aquatic ecology; marine ecology (including the annual marine monitoring program, seagrass and *Vibrio* assessment)
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 informs how the mine will be operated and describes the controls that will be implemented to manage and monitor environmental risks (see Section 2.1). The currently-approved MMP is the 2013-2015 MMP (MRM, 2015a), which was approved by the DPIR in December 2015. Three documents form the MMP assessed by DPIR, their relevance being as follows:
  - Sustainable Development Mining Management Plan 2013-2015. Volume 1 (March 2015). This document addresses proposed management and monitoring for the period October 2013 to September 2015 (MRM, 2015a).
  - Interim Mining Management Plan 2013-2015. Volume 2: Environmental Monitoring Report (January 2015). The report reviews environmental monitoring data collected over the period July 2013 to June 2014 (MRM, 2015b).
  - Supplementary Environmental Monitoring Report 2014 (February 2015). The report was requested by DME and covers monitoring activities over the period July to November 2014 (MRM, 2015c).

  In addition, MRM submitted a number of MMP amendments to DPIR for approval.
- Operational performance report. The report covers monitoring activities over the period 1 February 2015 to 1 July 2016 (MRM, 2016).
- 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, 2011):

> An unplanned or unwanted event with the potential to harm personnel, the environment, equipment or the community.

Incidents are managed according to the MRM Incident Management Procedure (GEN-SD-PRO-6040-0015) 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

Ranking	Environmental Impact
1	No or very low environmental impact. Impact confined to small area. Site impact only
2	Low environmental impact. Rapid clean up by site staff and/or contractors. Impact controlled to area currently impacted by operations
3	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	Major environmental impact. Considerable clean up effort using site and external resources. Impact may extend beyond lease boundaries
5	Severe environmental impact. Local species destruction and likely long recovery period. Extensive clean up involving external resources. Impact on regional scale

There was a discrepancy in the number of incidents provided to the IM during the reporting period. The IM was provided with incident reports from MRM and DPIR, with MRM also providing two databases. The incidents reported were as follows:

- Four incident reports were provided by MRM covering a hydraulic hose failure, TSF pipeline leak, tailings spill and exceedances at BBDPP – dredge spoil drain.
- Five incident reports were provided by DPIR covering an hydraulic hose failure, PAF dumped on the SOEF, APP suction line leak, SO_2 detection on the SOEF and NOEF dust emissions.
- Twenty two incidents were reported in the MRM Monthly HSEC Summary spreadsheet over the period February 2016 to September 2016.
- Twenty nine incidents were reported in the MRM Site Safe spreadsheet over the period February 2016 to September 2016.

In reviewing documentation provided to the IM, it is clear that there is some misunderstanding/ confusion regarding incident reporting. The IM sought clarification from DPIR regarding incident reporting and was advised that under the *Mining Management Act* operators are required to report all incidents.

A number of instances occurred during the operational period where the IM considered an event to be an incident, even though MRM did not report these in accordance with their incident management procedure. These events have been identified within the relevant technical area of the report.

Compliance was assessed in two areas:

- Compliance with the waste discharge licence (WDL 174-07 and WDL 174-08) that specifies trigger values that must not be exceeded for two authorised discharge points (SW11 and BBDDP – dredge spoil drain).
- Compliance with relevant criteria, standards and guidelines.

Issues of compliance are discussed is each discipline section.

2. Progress and new issues

The recommendations from the previous (2016) 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 (Section 3.2.4), 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. A full list of files used in the assessment is provided in Appendix 1.

3.4 Site Inspection

The IM team that visited the site consisted of David Browne, Michael Jones, Rob Garnham, Michael Cheetham, Warwick Stewart, Gareth Swarbrick, Michelle Clark and Nicola Hanrahan. The site visit was conducted on 14 and 15 June 2017 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 2016 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 16 June 2017, the IM team members attending the site visit met with the DPIR to discuss with DPIR personnel the following:

- Progress with completion of IM recommendations from the 2015 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

Following review of documentation (and in particular the update provided by MRM on actions to address issues in the risk assessment) and the site visit, IM team members reviewed the previous risk assessment and completed the following:

- Updated information regarding the description of the risk where additional information is known.
- Reviewed the consequence and likelihood rating.
- Updated the existing controls.
- Provided comment on whether additional controls are required.

This updated the previous risk assessment (completed in 2016) 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).

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

3.5.3 Outcomes

The updated risk register is provided in Appendix 2. A total of 74 risks were assessed. A comparison of the risk assessment results with the previous four assessments is provided in Table 3.7.

Table 3.7 – Comparison of Risk Assessment Results

Risk Rating	2011 IM Risk Assessment	2014 IM Risk Assessment	2015 IM Risk Assessment	2016 IM Risk Assessment	2017 IM Risk Assessment
Extreme	2	1	2	2	3
High	13	31	25	24	27
Moderate	36	29	38	40	35
Low	19	7	12	9	9
Total	**70**	**68**	**78***	**75**	**74**

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

Key risks are discussed in each technical area of the report, with all risks detailed in Appendix 2.

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 3.8).

Table 3.8 – 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 81 gaps were identified, 3 less than in the 2015 operating year:

- 22 Category 1 gaps.
- 37 Category 2 gaps.

- 22 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.
- Instructions and investigations initiated by DPIR.
- Independent Monitor recommendations tracking.
- Previous IM recommendations regarding DPIR performance.

It should also be noted that no DPIR audits were undertaken in 2016. The only check monitoring data that was available for IM review related to surface water and groundwater samples taken in November 2015; however, no report or details regarding the purpose of this check sampling were provided.

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. 2011. Incident Management Procedure. GEN-SD-PRO-6040-0015. McArthur River Mining Pty Ltd, Winnellie, 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. 2015c. Supplementary Environmental Monitoring Report 2014. February 2015. Reference Number GEN-HSE-RPT-6040-002, Issue Number: 1, Revision Number: 1. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2016. Mining Management Plan 2013-2015, Operational Performance Report 2016 Reference Number MRM-HSE-RPT-6040-0014, Issue Number: 1, Revision Number: 0. McArthur River Mining Pty Ltd, Winnellie, NT.

MRM. 2017. Overburden Management Project Draft Environmental Impact Statement. 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.

4. Results

4.1 Approach and Key Risks

The IM has reviewed and updated the risk register presented in the 2016 IM report (for the 2015 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.
- New risks as a result of the IM's document review and site inspection have been included.

Review of the risk register has resulted in the number of risks identified by the IM decreasing from 75 to 74. Table 4.1 provides a summary of the risks from the 2012, 2014, 2015, 2016 and 2017 risk assessments undertaken by the IM.

Table 4.1 – Summary of Risks Identified by the IM in 2012, 2014, 2015, 2016 and 2017

Report Year	2012	2014	2015	2016	2017
Operational Year/s	2011	2012-2013	2014	2015	2016
Extreme risk	2	1	2	2	3
High risk	13	31	25	24	27
Moderate risk	36	29	38	40	35
Low risk	19	7	12	9	9
TOTAL	**70**	**68**	**78***	**75**	**74**

* In 2015, there was one risk for which it was not possible to assign a risk rating, as this item related to closure.

Risks identified in the 2017 review of the risk register that are considered by the IM to be key risks include (those marked with an asterisk are new for the reporting period):

- Potential failure of the NOEF final cover as a result of erosion, slumping, differential movement, and cracking/heaving due to convective oxidation, leading to exposure of highly pyritic waste rock to oxidation and infiltration. The consequence of this event is acid, metalliferous and/or saline drainage impacts on groundwater quality, and terrestrial and aquatic ecosystems.
- Potential failure of the TSF cover as a result of erosion, slumping or embankment failure, leading to the exposure of highly pyritic tailings to oxidation and infiltration. The consequence of this event is acid, metalliferous and/or saline drainage impacts on groundwater quality, and terrestrial and aquatic ecosystems.
- * Under-estimation of long-term post-closure monitoring and maintenance costs, which have been based on a period of 25 years following closure. The Draft OMP EIS states that post-closure monitoring and maintenance costs are likely to be incurred for several hundred years. The consequence is that, based on current information, the costs for post-closure

monitoring and maintenance are not sufficient and in the scenario where MRM were to leave the site the NT government would be required to fund the shortfall.

- * Active avulsion upstream directing McArthur River flow into the old river channel and towards the mine levee wall, resulting in sediment laden water (as a result of erosion of mine levee wall) discharging into the McArthur River diversion channel, potential breach of the mine levee wall, erosion of the SOEF and discharge of water and sediment into the pit.
- Seepage of tailings water impacting on groundwater quality, and aquatic and terrestrial ecosystems where groundwater is discharged to creeks or the surface.
- Seepage from the NOEF impacting on groundwater quality, and aquatic and terrestrial ecosystems where groundwater is discharged to creeks or the surface.
- Deterioration in mine site seepage and/or runoff water quality beyond current estimates resulting in changed conditions and the requirement to manage larger volumes of contaminated water.
- Revegetation of the McArthur River diversion channel is insufficient in preventing erosion of areas of the diversion channel, and lack of suitable habitat for terrestrial and aquatic flora and fauna.
- Existing mine closure costs are based on a strategy that cannot be implemented. It is likely that any revised strategy will involve additional costs both in terms of construction and post-closure monitoring and maintenance. These additional costs are currently unknown and therefore are not included in the existing security bond.
- Erosion along the mine levee wall leading to failure of the levee wall during a flood event resulting in flooding of the open pit and potential downstream impacts to terrestrial and aquatic ecosystems.

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

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 (as listed in Appendix 1), with particular reference to the following:
  - The 2013-2015 MMP (MRM, 2015a).
  - Operational performance report 2016 (MRM, 2016).
  - Site water balances for the McArthur River Mine and Bing Bong Loading Facility, for 2015-2016 (WRM, 2015) and 2016-2017 (WRM, 2016a).
  - 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.

4.2.2 Key Risks

The risk of the site water balance not performing as predicted is the delivery 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 and 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 assessment (Appendix 2) 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 allow for any contingency. 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 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 the WPROD by the 2016-17 wet season, the additional contaminated water in the NOEF SPROD as at mid 2017).

- Incorporation of water balance model results into on-ground mine site water management. The modelling results indicate that, in general, the model is providing a reasonable representation of mine site water behaviour. However, it does not appear that full advantage of the model's capabilities is being applied to the on-ground site water management.

- The open pit development is continually advancing into the underground void, which will eventually be engulfed by the open pit. This poses two problems: the loss of the underground void storage (3,915 ML as at 1 July 2016) (WRM, 2016a) from the water balance and the need to remove the existing water in the underground void to allow for the mine development. The lead-time to modify the site water balance to account for these changes (e.g., design and build more storages and/or design and build a water treatment plant, change the site water balance configuration to allow for increased controlled releases) will be a number of years. Inadequate lead time to adapt to the loss of the underground void as a storage may result in one or more on-site storages being too small to hold the available water. This could lead to uncontrolled off-site releases of contaminated water.

  The Draft OMP EIS addresses the loss of the UG&OP as a water storage.

- Changes in mine site runoff/seepage water quality. There is a chance 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 the addition of a water treatment plant) 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[8] 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.

[8] Note that one control employed in previous operational periods was not implemented in the 2016 operational period. See Section 4.2.4.2 for discussion.

- 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. The results of this assessment were used in risk management.
- Continual investment in equipment used to monitor the water balance (e.g., pond levels and pump rates). This greatly assists in the parameterisation of the water balance model which, in turn, reduces model prediction uncertainty.

4.2.3.2 New Controls – Implemented and Planned

The following controls have been implemented during the reporting period:

- The operational performance report 2016 (MRM, 2016) contains:
  - A reconciliation of knowledge gaps listed in the 2013-2015 MMP (MRM, 2015a).
  - A table of current key water-related knowledge gaps.
- Installation of additional monitoring equipment to measure pond water level and water transfer between ponds (ongoing).
- Improved water balance modelling reporting (ongoing).
- Runoff investigations of the NOEF and SOEF (ongoing).
- The installation of pipes to allow bi-directional water transfers between NOEF SPROD, NOEF SEPROD, NOEF WPROD and OP PP.
- The installation of pipes to allow water transfer of TSF Cell1 runoff from TSF C1SA and TSF C1SB to the Mill CRP instead of the TSF Mini Dam.
- The installation of pipes to transfer unwanted HMP slimes from the HMP plant to the TSF Cell2 instead of the UG&OP.

The following controls are planned for the next 12 months:

- Lining of the NOEF SPROD to reduce seepage.
- The commissioning of the West PAF Runoff Dam (NOEF WPROD).
- Installation of additional monitoring equipment to measure pond water level and water transfer between ponds. This is an ongoing commitment by MRM.
- Commissioning of the water treatment plant between August and September 2017.
- Evaporation measurements/investigations of the NOEF PAF dams and TSF Cell 2.
- Runoff investigations of the NOEF and SOEF (ongoing).
- Incorporation of manual valve change logs (in the pipe network) into the digital records.

4.2.4 Review of Environmental Performance

4.2.4.1 Incidents and Non-compliances

Incidents

McArthur River Mining did not report any incidents affecting the site water balance during the 2016 operational period.

Non-compliances

A number of water balance commitments made in the 2013-2015 MMP (MRM, 2015a) have not been met. However, the operational performance report 2016 (MRM, 2016) tracks the non-compliance and shows that progress has been made. The report also provides revised timeframes. The IM considers this progress acceptable.

4.2.4.2 Progress and New Issues

Controls

A site water inventory tracking tool was developed by MRM and implemented during the 2015 operational period. The tool collated monitored pond water levels and pumping rates in a database, in real time, with a user-friendly interface. 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, gaps and ongoing problems. During the 2015 operational period site visit the IM was advised that the tracking tool would be a central part of the water management system going forward. Further, MRM made a commitment to continual development of the tool.

It has been advised by MRM that the tool was used in a reduced capacity during the 2016 operational period and was not used during the 2017 operational period. The tool is currently replaced with a system of spreadsheets that are updated manually. The IM considers this to be a backwards step from a site water management perspective. It is recommended that the site water inventory tracking tool be reinstated.

The following controls planned for the 2016 operational period were not implemented/achieved:

- Commissioning of the water treatment plant by January 2016 (2015-2016 water balance model report; WRM, 2015).
- Lining of the NOEF SPROD to reduce seepage.
- The commissioning of the West PAF Runoff Dam (NOEF WPROD).
- Incorporating manual valve change logs (in the pipe network) into the digital records.
- Setting up weather stations (i.e., to measure rainfall and evaporation) on selected ponds.
- Lining of the eastern levee storage (ELS) to reduce seepage.
- Evaporation measurements/investigations of the NOEF PAF dams and TSF Cell 2.
- Revision of the waste discharge licence to include additional discharge locations.

Documentation and Reporting

MMP Operational Performance Report 2016

The IM report for the 2014 operational period (ERIAS Group, 2015) listed a number of reporting limitations in the surface water management section of the 2013-2015 MMP (MRM, 2015a). The overarching limitations are:

- It does not accurately reflect current surface water management on site. This is because the adaptive nature of site water management makes the MMP surface water management section out of date almost as soon as it is finalised.
- It does not provide a process to allow for the adaptive management of surface water on site.

The 2014 operational period IM report made a number of recommendations to address these limitations. The recommendations can be summarised as improving the water management gap analysis, updating it regularly (e.g., every 6 or 12 months) and producing it as a separate document, outside of the MMP. Many of these recommendations have been addressed in the operational performance report 2016 (MRM, 2016) with tables listing:

- A reconciliation of knowledge gaps listed in the MMP.
- Current key water-related knowledge gaps.

The IM acknowledges and commends this. Notwithstanding this, a number of the previous recommendations have not been adopted. These can be addressed with additional columns in the gap analyses detailing the following:

- Specific and measureable actions.
- Estimated commencement times (completion times are currently given).
- An 'effectiveness ranking' (e.g., 1 to 5) of the impact the task will have on the site water balance.
- Tracking of the progress on the tasks identified in the previous gap analysis.

Progress tracking is important because failure to meet a target does not necessarily constitute a problem. What is important is that performance is monitored. This is a fundamental risk management principle. For example, the ‘evaporation rates from dams and tailings beaches’ knowledge gap in the MMP operational performance report 2016 (MRM, 2016) has a completion date of ‘Q4 2018’. The issue of pond evaporation uncertainty has been ongoing since the IM report for the 2012-2013 operational periods (ERIAS Group, 2014). There has been no reduction in the evaporation estimate uncertainty since then. Further, there was a commitment to undertake pond evaporation studies during 2016-2017; this has not happened. The continual postponement of the ‘improving evaporation estimates’ knowledge gap continues to compromise the accuracy of the site water balance modelling. In terms of the ‘effectiveness ranking’ this would be considered a high priority as the volume of water ‘lost’ to evaporation in the water balance is substantial; with a high level of uncertainty.

Trigger Action Response Plan (TARP) Modelling

The Trigger Action Response Plan (TARP) is an MRM management tool which is updated each year, and directs the operation on how to operate/manage its mine water storages during the next wet season. The TARP water balance modelling report (WRM, 2016b) has the following limitations:

- There is substantial repetition of material from the annual water balance report (WRM. 2016a), in particular, model description.
- The model used in the TARP does not appear to represent the most up-to-date estimate of the site water balance configuration for the wet season. For example, the WPROD is included in both the annual and TARP water balance models. However, the WPROD was still not commissioned at the time of the most recent IM site inspection (14 to 15 June 2017). Given the lead time to undertake the annual water balance report it is understandable that a number of adopted modelling assumptions may be different to the actual on-site operations at the commencement of the wet season. However, it is difficult to understand how in late 2016 it would not have been apparent that the WPROD was not going to be commissioned by the wet season. The WPROD has a storage capacity of 1.3 GL, which should have a substantial impact upon the water balance.
- In Chapter 4: TARP Recommendations (Tables 4.1 to 4.12), in many cases, there is no difference in the recommended pond management actions regardless of rainfall trigger level, with management primarily relating to pond water level. As such, the rainfall trigger levels appear to be of limited value.
- There is a large amount of modelling and reporting undertaken, however, it is most likely that the recommended management actions are simply a reflection of the transfer rules imbedded in the model. These rules may be able to be tabulated without the need for any modelling.

The TARP needs to provide clear, simple and robust directions for managing the site water management system. The directions need to be understood by MRM personnel who do not necessarily have a background in the complexities of the site water management and/or modelling. Less time spent on modelling and reporting would allow more time to be spent on ensuring the TARP modelling includes the most up-to-date estimates of site layout during the wet season. 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 next wet season.
- Simplifying the TARP action plan tables (removing the different rainfall groups is an obvious first step).

- Using the rules embedded in the water balance model to develop the TARP recommendations.

Annual Water Balance Modelling

The quality of reporting in the water balance modelling reports has continued to improve, as reflected in the 2016-2017 report (WRM, 2016a). 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 2016-2017 annual water balance report (WRM, 2016a) to assist in the preparation of future water balance reports.

Table 4.2 – Specific Recommendations to Improve Water Balance Model Reporting

WRM (2016a) Reference	Recommendation
Table 5.1 MRM water storage capacities and stored volumes on 1 July 2016	While Table 5.1 is dated 1 July 2016 and the stored volumes presented are as at that date, this table is in Chapter 5 (2015/16 water management) and the storage capacities, liner details and expected water classes could be considered to be (actual) model inputs for that period. It would be useful if information were presented in Chapter 6 (proposed 2016/17 water management) indicating any changes from Table 5.1 for 2016/17
Section 9.9 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 ♦ What is being done to remove each assumption/reduce each uncertainty ♦ A priority/ranking for the removal/reduction of each assumption/ uncertainty and a due date for completion
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 ♦ What is being done to remove each assumption/reduce each uncertainty ♦ A priority/ranking for the removal/reduction of each assumption/uncertainty

Water Balance Sensitivity Testing

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 undertaken in the 2015-2016 (WRM, 2015) and 2016-2017 (WRM, 2016a) site water balance reports at the request of the IM are:

- Pump or pipe failure.
- Deterioration in mine site water quality.

- Climate change impacts (increased rainfall).
- Increased runoff.

The IM agrees with the finding from WRM (2016a) that uncontrolled off-site releases show low sensitivity to the combinations of the pump failures assessed. However, the IM considers further assessment is required of the changes in water quality, climate change impacts and increased runoff. Details are provided in the following sections.

Deterioration in Mine Site Water Quality

An assessment of changes to mine site water quality was undertaken for the 2015 to 2016 site water balance report (WRM, 2015). The controlled release dilution rate was changed 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 and water quality.

Climate Change Impacts

The impact of climate change on the site water balance was assessed for the 2016-2017 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 to the IM because the relationship between rainfall and runoff is non-linear. That is, in general, the change in runoff is greater than the change in rainfall (sometimes substantially). For example, a 10% increase in rainfall will produce (say) a 12 to 15% increase in runoff and a 10% decrease in rainfall will produce (say) a 12 to 15% decrease in runoff (these are not actual figures but are used for illustrative purposes only). Therefore, a 5% increase in rainfall producing a 4% to 5% increase in 'rainfall runoff' tends to indicate that there may be something wrong with the rainfall-runoff model. For clarity, the 'rainfall runoff' reduction shown in the modelling is independent of the complexity of the site water balance (e.g., evaporation from different pond water levels). Rainfall and runoff in the model should be independent of other site water fluxes.

This anomaly in the rainfall-runoff model needs addressing.

Runoff

The impact of the site receiving greater runoff than that currently estimated by the model was assessed for the 2016-2017 water balance report (WRM, 2016a). This was done by applying the runoff characteristics of the disturbed/compacted areas to the waste rock areas, together with reducing the model soil moisture store for all areas. The water balance model report states that the increased risk of overflow from the NOEF dams under this high runoff scenario is 'not significant'. However, the report shows that the increase in spills are:

- NOEF SEPROD: base case = 4%, increased runoff case = 5% (a 25% increase).
- NOEF WPROD: base case = 2%, increased runoff case = 3% (a 50% increase).

It is unknown how runoff increases of this magnitude can be classified as 'not significant', regardless of the probability of spills being ≤5%. These increases indicate very high model sensitivity to changes in runoff. The purpose of a sensitivity analysis is to determine the sensitivity of model results to particular model parameters, variables and assumptions. Any area of high sensitivity needs to be considered in the application of model results (e.g., in risk management).

This high sensitivity of changes to runoff volumes needs to be considered in all future water balance modelling.

Using the Water Balance Model in Mine Site Management

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 indicates that, in general, the model is providing a reasonable representation of mine site water behaviour. For example:

- Over recent years there have been no uncontrolled off-site releases.
- Over recent years 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.
- The actual site water balance for the 2015-2016 operational period (from the 2016-2017 water balance report: WRM, 2016a) is generally similar to that predicted in the 2015-2016 water balance report (WRM, 2015) for a similar rainfall total.
- There was approximately 1,100 mm of rain recorded at the MRM Airport rain gauge during the 2016-2017 wet season. This is approximately equivalent to the 10% exceedance probability 'wet' year (WRM, 2016a). The 2016-2017 water balance report (WRM, 2016a) estimated that if this rainfall depth occurred during 2016-2017 it would result in approximately 1.6 GL of water stored above ground in the open pit. Further, the modelling showed that the open pit would not be free of water prior to the onset of the 2017-2018 wet season. During the IM site inspection (14 to 15 June 2017) MRM staff advised that there was currently approximately 2 GL stored above ground in the open pit and that it was likely that the open pit may hold water at the beginning of the next wet season (in order to maintain adequate freeboard in the site runoff ponds).

Unfortunately, it does not appear that MRM is taking full advantage of the water balance model's capabilities. The two areas where the model could be better utilised are risk management and options analysis. These are discussed in the following sections.

Using the Water Balance Model for Risk Assessment

Examples where the model could have been used for risk assessment are:

- Assessing the impact of water in the open pit. The IM understands that the water currently in the open pit is cause of considerable concern for MRM. However, the water balance model predicted this situation with reasonable accuracy.
- Assessing the impact of unexpected changes to the water balance. For example, the large volume of low-quality water currently in the NOEF SPROD as a result of runoff from the low

grade ore stockpile during reclamation is treated by MRM as unexpected. However, the model could have been used to assess the impact of (say) an unexpected additional 1 GL of poor quality water somewhere on-site. Measures may then have been implemented to mitigate the risk and the low-quality water currently in the NOEF SOEF may not be a problem. A quantitative assessment of water balance model predictive uncertainty recommended in a later section of this report will greatly assist MRM in risk management.

Using the Water Balance Model for Options Analysis

Possible options that could be analysed easily in the model (with minimal effort and cost) are:

- Increased controlled release capacity (e.g., larger pumps, greater ability to transfer water to the discharge ponds.
- Doubling the pump rate between ponds. Of note, an assessment of doubling the pump rate between Pete's pond and the NOEF SPROD showed a substantial reduction in open pit inundation risk (from 42% to 32%) (WRM, 2016a).

It is recommended that MRM use the water balance model more in mine site water management planning.

Risk Management of the Site Water Balance

Use of the Underground Void/Open Pit for Water Storage

The current site water balance configuration (pumps, pipes, storages and their interconnections) is sized so that excess mine site water is stored in the UG&OP. That is, the probability of uncontrolled off-site releases of contaminated water is kept within the design criterion (less than 5% probability) by using the UG&OP as a system buffer. This approach is of concern because it may impact upon mine operations, making them uneconomic (jeopardising closure planning) and/or may necessitate the release of additional water off-site (putting pressure on the regulator to licence these discharges). The following is of note:

- The issue of storing excess water in the UG&OP has been raised in the 2012-2013, 2014, 2015 operational period IM reports. Discussions with MRM during the site inspections for these operational periods revealed that MRM is concerned about the impact upon mining of ponding in the open pit.
- During the 2016 operational period IM site inspection (14 to 15 June 2017) there was approximately 2GL of water stored in the open pit. Further, MRM staff advised that it was likely that the open pit may hold water at the beginning of the next wet season in order to maintain adequate freeboard in the site runoff ponds. This was of considerable concern to MRM.
- The Draft OMP EIS addresses the use of the UG&OP as a water storage by building additional storages on the mine site. In particular, a process water dam with a capacity of approximately 4 GL, in the general location of the current TSF Mini Dam, will hold water pumped from the UG&OP. However, the strategies proposed in the Draft OMP EIS are not currently approved.

Tailings Storage Facility 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.

Accurate Quantification of Water Balance Processes

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 and 2015 operational period IM reports. 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 in the amount of surface water monitoring undertaken at the mine site.
- Undertaking targeted short-term runoff, evaporation and seepage trials.

The 2016-2017 water balance report period shows some successes with this approach (e.g., identification of an 820 ML error between recorded inflows and outflows from Pete's Pond during 2015-2016). 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/Sprinkler/Fountain Performance

There is substantial uncertainty in the fan/sprinkler and fountain evaporation estimates. For example, from the 2016-2017 site water balance report (WRM, 2016a):

- The estimated OP fan evaporation rates vary between:
  - An adopted rate (for modelling) of 39%, based upon 'MRM advice'.
  - MRM adopts 60% for operational purposes.
  - The fan supplier estimated evaporation rate is 57%.
  - A PAE Holmes (2011) study of evaporation and spray drift from proposed evaporation fans on the TSF Cell 2 calculated an annual average evaporation rate of 38%.
- The adopted NOEF SPROD and NOEF SPSD (South PAF Sediment Dam) sprinkler evaporation efficiency is 13%. These are based upon MRM evaporation trials (MRM, 2015b and 2015c), which are acknowledged by MRM to be flawed as they used adopted SILO Data Drill (Queensland Government, 2017) daily evaporation estimates to calculate pond evaporation (rather than site specific data). Further, the adopted efficiency is justified (in

WRM, 2016a) because it is consistent with that estimated from the NOEF SEPROD in the 2014-2015 water balance report (WRM, 2014). However, WRM (2014) states that the estimate is based upon the WRM (2013) estimate of a 66% sprinkler loss rate (the reason for the transformation from 66% to 13% is unreported). This uncertainty is a good example of the problems with simultaneous calibration of parameters. In this case, seepage, evaporation, sprinkler efficiency and mill demand (see section on Simultaneous Calibration of Multiple Parameters).

Pond evaporation and seepage investigations were planned for 2016-2017. These did not occur. The finish date on the current commitment to better define evaporation from 'dams and tailings beaches' is between October and December 2018 (MRM, 2016). The issue of fan/sprinkler and fountain evaporation uncertainty 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. 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.

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.

This uncertainty in seepage estimates has been ongoing since the 2012-2013 operational period IM report. With the exception of NOEF SPROD, there has been minimal reduction in seepage uncertainty since the 2012-2013 operational period IM report. Notwithstanding this, uncertainty in pond inflows/outflows is incrementally reducing (through additional monitoring). It is likely that seepage may be the last parameter to show improved accuracy, i.e., since it is calculated by difference, it requires all other inflows/outflows for a pond to be defined first.

Runoff

Runoff trials are currently in place (with more planned) for the NOEF and the SOEF (e.g., SMI, 2016). 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.

Estimation of Model Predictive Uncertainty

There is no estimation of model predicative uncertainty. That is, the primary purpose of the water balance model is to estimate (or predict) future mine site water balance behaviour. Quantification of the uncertainty in this prediction would assist mine site risk management. For example, if a pond containing contaminated water has a 5% chance of uncontrolled off-site release, does this prediction have an uncertainty of ±5% or ±50%? Applying these uncertainties to the prediction would result in a probability of spilling of between 4.75% and 5.25% (probably acceptable) or between 2.5% and 7.5% (probably unacceptable as 7.5% is substantially greater than the MRM uncontrolled release commitment of <5%).

Currently the water balance modelling addresses climate uncertainty by running the model multiple times (for the one or two-year period of interest) with different historical rainfall and evaporation data. The results are then statistically analysed. Another large uncertainty in the model is mine operations being different to those adopted in the model. This uncertainty is not assessed. Examples of recent differences between model and mine site water management configuration are:

- Changes to the water treatment plant commissioning date.
- Changes in the process mill throughput.
- Contaminated runoff water entered the NOEF SPROD during 2016-2017 during the reclamation of the low grade ore stockpile.

Modelling all the possible variations (and combinations of possible variations) in mine site operations would be close to impossible. Further, not all changes can be foreseen (e.g., the additional contaminated runoff into the NOEF SPROD in 2016-2017).

A readily available way to estimate predictive uncertainty of the McArthur River Mine water balance model 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). For example, the 2015-2016 water balance predictions from the 2015-2016 report (WRM, 2015) compared with the 'actual' 2015-2016 site water balance from the 2016-2017 report (WRM, 2016a). The comparison should be undertaken against a range of water balance metrics (e.g., total inflow/outflow, evaporation, seepage, change in water inventory).

The results of the model predictive uncertainty analysis can be used for risk management and prioritisation of site water management and water balance model development. Further, comparison of the uncertainty analyses across years will show any trend over time, or a change in trend (e.g., if the Draft OMP EIS recommendations are adopted). Undertaking the uncertainty analysis is a simple task. All the data is available and minimal (if any) additional modelling is required.

Surface Water Monitoring at Bing Bong Loading Facility

No monitoring of pond water levels and transfers was undertaken at the Bing Bong Loading Facility during the 2016 operational period. It is recommended that the water monitoring program at the facility be reinstated.

McArthur River Mining's performance against previous IM review recommendations relating to mine site water balance is outlined in Table 4.3.

Table 4.3 – Mine Site Water Balance Recommendations from Previous IM Reviews

<table>
<tr><th>Subject</th><th>Recommendation</th><th>IM Comment</th></tr>
<tr><td colspan="3">2015 Operational Period</td></tr>
<tr><td rowspan="2">Documentation and reporting</td><td>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</td><td>Ongoing. Partially addressed in the gap analyses in the MMP 2013-2015 operational performance report 2016 (MRM, 2016). Additional columns are required in the gap analyses listing the following:
♦ Specific and measureable actions
♦ Estimated commencement times
♦ An 'effectiveness ranking' (e.g., 1 to 5) of the impact the task will have on the site water balance
♦ Progress tracking from previous gap analyses</td></tr>
<tr><td>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</td><td>Ongoing. Improved. Some modification to tables recommended to aid clarity</td></tr>
<tr><td>Water balance sensitivity testing</td><td>Pump or pipe failure:
♦ An assessment of the impact of pump or pipe failure should be undertaken</td><td>Completed</td></tr>
<tr><td rowspan="2">Water storage ponds and tailings storage facilities</td><td rowspan="2">♦ The risk of spills from the TSF Mini Dam to the WMD, thereby making it unsuitable for off-site release, needs to 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 needs to be resolved</td><td>Outstanding. No change has been made to the TSF Cell 1 capping. However, it is proposed to combine TSF Cell 1 and Cell 2 as part of the Draft OMP EIS. The issue will be resolved if the TSF cells are combined</td></tr>
<tr><td>Completed. TSF Cell 1 runoff collected in the TSF Cell 1 sumps is now transferred to the CRP</td></tr>
<tr><td>Risk management of the site water balance</td><td>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</td><td>Outstanding. The Draft OMP EIS addresses the use of the UG&OP as a water storage. However, the strategies proposed in the Draft OMP EIS are not currently approved</td></tr>
</table>

Table 4.3 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2015 Operational Period (cont'd)		
Accurate quantification of water balance processes	Surface water monitoring at Bing Bong Loading Facility needs to be resumed	IM has been advised that daily monitoring of pond water levels has recommenced
2014 Operational Period		
Documentation and 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 – 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	Outstanding. The current MMP is the same as that reviewed last year. Therefore no change
Water balance scenario testing	Changes in climate: ♦ The possible impact of climate change on the site water balance needs to be addressed	Outstanding. 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). This result indicates that there may be something wrong with the model. This question of the veracity of the rainfall-runoff model needs addressing

Table 4.3 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Water balance 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	Outstanding. 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
	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)	Completed: ♦ Assessment of two consecutive years adopted in the 2015-2016 water balance modelling
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	Outstanding. The risk of spill from the TSF Cell 2 to the WMD has been modelled. However, the impact of the spill on the site water balance (by contamination of WMD water) has not been undertaken. This IM recommendation has not been adopted
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	Outstanding
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	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

Table 4.3 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Accurate quantification of water balance processes (cont'd)	♦ 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	
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	Outstanding. The Draft OMP EIS addresses this. However, the strategies proposed in the Draft OMP EIS are not currently approved
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
2012 and 2013 Operational Periods		
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	Ongoing. Mostly completed. Some modification to tables recommended to aid clarity
Changes in climate	The possible impact of climate change on the site water balance needs to be addressed	Outstanding. This item has been superseded by a 2014 recommendation (see above)

Table 4.3 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (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	Ongoing: ♦ Undertaken in the 2015-2016 and 2016-17 site water balance reports ♦ Additional reporting is required
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	Outstanding. 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)	Completed: ♦ Multiple year recommendations were adopted in the 2015-2016 water balance modelling. During discussions with MRM staff as part of the 2016 IM site inspection, it was agreed to model 3 consecutive years in future studies ♦ Only 2 consecutive years were modelled in the 2016-17 water balance modelling due to substantial mine site water management changes as part of the overburden management project, which is due to start in 2018 subject to approval

Table 4.3 – Mine Site Water Balance Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2011 Operational Period		
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 and up to the time of the IM site inspection (14 to 15 June 2017) 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.

4.2.5 Conclusion

The 2016 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.

Notwithstanding this, there remains substantial uncertainty in the water balance modelling and the isolation of key elements 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

Two areas of mine site water management that can be greatly improved (with the current level of knowledge) are:

- The water balance model's capabilities should be better utilised. In particular, in the areas of risk assessment and options analysis.

- Mine site water management needs to be more resilient to unforeseen/unpredicted changes in the system.

At the time of the 2015 operational period IM site inspection (May 2016), MRM were collating monitored pond water levels and pumping rates in a database, in real time. This database was suspended in 2016/2017 due to an upgrade of to the SCADA water management monitoring system and replaced with a system of manually updated spreadsheets. The IM supports the reinstated of this database as soon as the upgrade is completed.

Ongoing and new IM recommendations related to mine site water balance issues are provided in Table 4.4.

Table 4.4 – New and Ongoing Mine Site Water Balance Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Documentation and reporting	MMP ♦ 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) – 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	Medium
	Site water balance report ♦ This report needs to demonstrate ongoing model refinement, increased process understanding and a reduction in model parameter/calibration uncertainty ♦ 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 MMP operational performance report ♦ Additional columns are required in the gap analyses listing the following: – Specific and measureable actions – Estimated commencement times – An 'effectiveness ranking' (e.g., 1 to 5) of the impact the task will have on the site water balance – Progress tracking from previous gap analyses	

Table 4.4 – 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	<u>Changes in climate</u> ♦ 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 <u>Changes in water chemistry</u> ♦ 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 <u>Runoff</u> ♦ The 2016/17 site water balance report (WRM, 2016a) showed the NOEF SEPROD and NOEF WPROD were runoff highly sensitivity to increases in runoff. This high sensitivity of changes to runoff volumes needs to be considered in all future water balance modelling <u>Annual Review</u> ♦ 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	Medium
Water storage ponds and tailings storage facilities	♦ While the risk of TSF Cell 2 spills to the WMD 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
Risk management of the site water balance	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 Use of the UG&OP for water storage: ♦ McArthur River Mining should provide a medium- to long-term plan which resolves the conflict between mine operations and using the UG&OP as a water storage	Medium

Table 4.4 – 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 – A strategy should be developed to reduce predictive uncertainty over time Bing Bong Loading Facility surface water monitoring: ♦ Surface water monitoring at Bing Bong Loading Facility should be resumed	Medium
New Items		
Documentation and reporting	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	Medium
Site water balance database	At the time of the 2015 operational period IM site inspection (May 2016). McArthur River Mining were 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	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
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 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	Medium

4.2.6 References

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WRM. 2013. 2013/2014 Site Water Balances McArthur River Mine and Bing Bong Port Facility. Report No. 0790-10-E_DRAFT, dated 23 October 2013. Prepared by WRM Water and Environment for McArthur River Mining Pty Ltd, Winnellie, NT.

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WRM. 2016a. 2016/17 Site Water Balances for the McArthur River Mine and Bing Bong Loading Facility. Report No 0790-28-E3, Revision No. 3, 7 November 2016. Prepared by WRM Water and Environment for McArthur River Mining, Winnellie, NT.

WRM. 2016b. Water balance modelling in support of the 2016/17 TARP. Report No. 0790-31-B1, dated 22 December 2016. 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.
- Various reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to the operational performance report 2016 (OPR) (MRM, 2016a), mining management plan (MRM, 2015a), surface water monitoring report (KCB, 2016), artificial surface water monitoring report (WRM, 2016a) and WDL monitoring report (MRM, 2016b).
- The Excel files provided by MRM that contain:
  - Collated laboratory and in situ water quality data for the operational period and historical data.
  - Event-based water quality data for selected sites.
  - Discharge records.
  - Flow versus SO_4 data for selected sites.
  - Water monitoring schedule.
- Laboratory documents including sample receipt notification, chemical analysis reports and quality control data.
- Various MRM forms and similar documents such as chain of custody forms, survey results, incident notification letters, and correspondence between MRM and other parties.
- Aerial and other photographs of the MRM mine site provided by MRM.
- 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 2), 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. 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[9].

  – Saline seepage from areas such as the OP ELS potentially reporting directly to McArthur River (although this risk has been reduced with the OP ELS no longer being used as an evaporation pond for water pumped from the open pit and underground workings).

  – 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 consideration.

- Poor quality surface runoff due to soil contamination from depositional dust generated by mining and processing operations, primarily from the TSF, ROM pad, crushing circuit and external concentrate storage area, 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).

A key closure-related risk concerns the final pit lake water quality and the potential for poor quality water to reach nearby watercourses, with adverse impacts as noted above. This is discussed further in Section 4.8. 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.

[9] As noted elsewhere in this report, the waste rock classification was amended in 2013 to include rock that potentially produces a metalliferous and saline runoff/leachate, as well as acidic runoff/leachate.

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 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 OPR (MRM, 2016a), where key elements include:

- Classifying mine water into six water classes, as follows (and these were described as 'new controls' in last year's IM report) (WRM, 2016a):

  – Class 1 – diverted water. This is typically sourced from upstream catchments that are unaffected by mining. Wherever possible, this water is diverted away from mining activities.

  – Class 2 – surface water. This is typically sourced from cleared areas and clay/stockpile areas. This runoff requires treatment through a sediment trap prior to release either passively across the sediment-trap spillway or via dewatering.

- Class 3 – treated water. This is permeate from the water treatment plant (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–acid-forming (NAF) material. 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 water. This is typically seepage from the TSF and NOEF, runoff from areas with exposed potentially acid-forming (PAF) material, and underground void water. This water class is contained within the mine water management system and is not released off site.
- Class 6 – process water. This is typically used within the mill and TSF as well as other process streams. As with Class 5 water, this water class is contained within the mine water management system and is not released off site.

The adoption of this classification scheme should assist MRM with surface water management, given that it represents a move towards increasing focus on water quality rather than water source.

It is also worth noting that this classification has subsequently been further refined for MRM's 2016/17 reporting period (which commences 1 July 2016 and overlaps the IM 2015/16 reporting period of October 2015 to September 2016), as further discussed in the following section.

- Establishing the following operational objectives (MRM, 2016a):
  - Protect the integrity of local and regional surface water resources within and downstream of the mine lease boundary.
  - Maintain separation between 'diverted' water and water that is generated from mine-affected areas.
  - Provide a reliable source of water for mining and concentrator mill processing while minimising raw water consumption by maximising reuse of mine-affected water.
  - Manage the operational risk of open pit inundation to ensure an uninterrupted ore supply to the concentrator mill.
  - Operate in accordance with the requirements of the 2013-15 MMP and WDL conditions.
- Achieving these objectives by implementing measures (which have been refined compared with those described previously) such as:
  - Separating mine-affected waters stored on site according to the water classification systems as much as possible.

- Minimising raw water use for mine water demands by using reclaimed process water from the TSF, brine water from the water treatment plant and dewatered poor quality water from underground voids where possible.
- Intercepting as much surface water and groundwater from around the pit before it contacts the waste rock.
- Using sprinklers and evaporation fans as much as possible to enhance evaporation losses from poor quality and process water site inventories.
- Minimising the poor quality stored water inventory on site by treating excess underground void water in a water treatment plant.
- Storing treated and managed release waters in dedicated storages until they can be discharged in the wet season under the conditions of the WDL.
- Ensuring that the TSF has a tailings beach around the perimeter of the dam against the walls in all but extreme rainfall events.
- Maintaining poor quality and process water storages at their target operating levels to maximise evaporation and minimise the risk of uncontrolled spills.
- Installing permanent pumping infrastructure to allow transfer of poor quality and process runoff between storages as required to minimise the potential for uncontrolled overflows.
- Where possible, using the open pit as the ultimate fall-back position for water storage to avoid unplanned discharges into the receiving environment.

For the purposes of this report, performance of the surface water management system is assessed largely in terms of adherence to the WDL conditions, the OPR (MRM, 2016a) 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 surface water monitoring report (KCB, 2016), the artificial surface water monitoring report (WRM, 2016a), and the WDL monitoring report (MRM, 2016b) for the reporting period, supplemented by review of the data provided by MRM in separate spreadsheets.

During the IM reporting period (i.e., 1 October 2015 to 30 September 2016), MRM operated under two WDLs, with the conditions of WDL 174-07 being applicable from 16 January 2015 until WDL 174-08 became effective on 17 March 2016. The expiry date for WDL 174-08 was notionally 30 September 2016, although WDL 174-08 didn't become effective until 28 October 2016, i.e., after the current IM reporting period. Licence WDL 174-07 provided conditional approval for the discharge of water from (Figure 4.1):

- OP NC1A, with discharges being limited to rain water collecting in the old McArthur River channel inside the mine levee, groundwater from dewatering bores around the open pit and collected in Pond 2 (OP P2), and groundwater from dewatering bores around the open pit and mixed with water in the water management dam (TSF WMD) and then discharged from

WASTE DISCHARGE LICENCE AUTHORISED DISCHARGE POINTS

McArthur River Mine Project

FIGURE 4.1

OP P2. Water discharged at OP NC1A was pumped over the mine levee wall and flowed into the old McArthur River channel upstream of the McArthur River and Glyde River confluence.

- South Eastern Levee spillway (NOEF SEL1- S), where discharges could only occur when floodwaters were at the base of the levee wall.

Licence WDL 174-08 provided conditional approval for the discharge of water from (see Figure 4.1):

- Mine Levee Discharge Point (OP MLDP), which is analogous to the previous OP NC1A mine levee pumping outlets and included discharge of water from OP NC1A inside the mine levee, OP P2 and the TSF WMD, which included water from various sources around the open pit including groundwater intercepted by bores and sumps, and surface runoff from within the mine levee wall.

- South East Levee 1 Discharge Point (NOEF SEL1 DP), which was located in the Barney Creek diversion channel where water could be pumped via pipeline from NOEF SEL1, and allowed for discharge of water from various sources around the NOEF. A flow rate cut-off of 20 m^3/s in McArthur River at the downstream gauging station was also applied to discharges from the NOEF SEL1 DP.

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. While a simple approach, this is likely to be an effective management tool. As noted in previous IM reports, this would benefit from verification by actual measurements at SW11 during the discharge event. Also, as discussed later in this report, there may be merit in (cautiously) examining if additional opportunity exists for discharge of more water from the site, while still protecting downstream environmental values.

A key aspect of MRM's management plan, as referred to above, is an environmental monitoring system. The stated aims and objectives of the surface water monitoring program remain as described in last year's IM report and include the following (KCB, 2016):

- Measure the water quality in McArthur River, Barney Creek, Surprise Creek, Emu Creek and Glyde River.
- Compare the measured water quality in McArthur River with site-specific trigger values (SSTVs).
- Compare water quality from downstream monitoring sites with upstream control sites to help identify possible contamination of surface water.
- Identify the potential sources of any contamination measured in McArthur River or the local tributaries.
- Determine the efficacy of the controls implemented by MRM to prevent contamination of surface waters.

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 (WRM, 2016a):

- Determining water class.
- Determining suitability of water for off-site discharge.
- Determining suitability of water for different storage and transfer options.
- Determining suitability of water for end uses such as milling ore, dust suppression, water treatment, potable use and clay conditioning.
- Identifying trends in relation to key analytes to help identify possible sources of catchment contamination.

As has been noted in previous IM reports, MRM devotes considerable effort to this monitoring program. Key elements of the program include:

- Natural surface waters – sampling sites are shown in Figure 4.2, including SW11 that is used to determine compliance with MRM's WDL. McArthur River, Barney Creek, Surprise Creek, Emu Creek and Glyde River monitoring sites are sampled weekly, but only if flow is evident at the individual sampling sites, i.e., no sample is taken if no flow is observed, regardless of flow at upper catchment control sites. Site SW08 on the downstream McArthur River is located at the Burketown Causeway at Borroloola (about 60 km downstream from the mine site) and is sampled on a monthly basis, as is Site SW32 (a new site for 2016/17) that is located about 6 km upstream of the Burketown Causeway.

  Both in situ (e.g., pH, temperature, dissolved oxygen (DO), EC, turbidity, oxidation-reduction potential (ORP)) and laboratory (e.g., pH, EC, total dissolved solids (TDS), total suspended

SURFACE WATER MONITORING SITES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.2

Source: KCB, 2016.

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solids (TSS), major ions, nitrate and filtered (<0.45 µm) trace metals (including Ni since January 2015) analysis is undertaken. Selected data from upstream (SW21) and downstream (SW11) sites is statistically compared using a 0.05 level of significance.

Additional laboratory analysis (e.g., total metals, total petroleum hydrocarbons (TPH) and benzene/toluene/ethylbenzene/xylenes/naphthalene (BTEXN)) is undertaken for selected samples. The analytical program was expanded in July 2016 to include parameters such as total N, total P and additional metals, as recommended in Ecometrix (2016).

It is worth noting that MRM has revised the nomenclature that applies to surface water monitoring sites such that the artificial surface water sites are now clearly differentiated from the sites in McArthur River, Barney Creek, Surprise Creek, Emu Creek and Glyde River.

- Artificial surface water – all sampling sites are shown in Figure 4.3, with the previous 'committed' and 'non-committed' sites (where the latter were used by MRM for internal purposes) no longer being routinely distinguished by MRM in the surface water monitoring reports. Sampling is generally on a monthly basis, although some sites (e.g., NOEF SEL1, OP P2) are sampled on a weekly basis while others (e.g., BC NWST, OP DSD) have event-based sampling. Both in situ (e.g., pH, temperature, DO, EC, ORP) and laboratory (pH, EC, TDS, TSS, major ions and filtered (<0.45 µm) trace metals analysis is undertaken. Additional laboratory analysis (e.g., total metals, total petroleum hydrocarbons (TPH) and benzene/ toluene/ethylbenzene/xylenes/naphthalene (BTEXN)) is undertaken for selected samples. The analytical program was expanded in July 2016 to include parameters such as total N, total P and additional metals, as recommended in Ecometrix (2016).

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 last year's IM report, 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 4.4):

- 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.
- 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 dredge spoil drain to the tidal mud flats east of the Bing Bong Loading Facility area (Figure 4.5). No dredging was undertaken in the swing basin or navigation

ARTIFICIAL SURFACE WATER MONITORING SITES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.3

ARTIFICIAL SURFACE WATER MONITORING SITES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.4

Source: WRM, 2016.

SURFACE WATER MONITORING SITES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.5

Source: KCB, 2016.

channel over the 2015-2016 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 remain as described in last year's IM report and include:

- 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.
- 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 marine 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. The specific objectives of the DSEA surface water monitoring program are to (KCB, 2016):

- Measure the water quality in the dredge spoil perimeter drain and at the dredge spoil discharge point.
- Compare the measured water quality at the discharge point with site-specific trigger values.
- Identify the potential source of any contamination measured at the sample points.

The objectives of the artificial surface water monitoring program are as described previously, although these appear to be more applicable to the mine site; no objectives that are specific to Bing Bong Loading Facility are contained in WRM (2016a).

As in previous years, a series of specialist projects addressed seawater quality (using DGTs[10]), as well as nearshore sediment quality, seagrass surveys and trans-shipment area sediment quality (including lead 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 November 2015 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.

From a surface water perspective, key elements of the monitoring program include:

- Marine waters – DGTs were deployed at six sites (Figure 4.6) for the 2015-2016 monitoring period (14 August 2015 to 14 June 2016), with the specific objective of determining if MRM's operations at the Bing Bong Loading Facility were having a negative impact on the marine environment in the Gulf of Carpentaria (MRM, 2016a). Subsequent

[10] The 'diffusive gradients in thin films' (DGT) technique provides in situ determination of thermodynamically and kinetically labile metal species in aquatic systems (Tsang, 2016).

DGT MONITORING SITES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.6

ERIAS GROUP

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analysis of the retrieved DGTs was for trace metals and Pb isotope ratios. Deployments were undertaken on a monthly basis, with each deployment typically being for four or five days. DGT-labile Zn, Pb, Cd, Co, Cu, Ni, Mn and Fe were determined, as were 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 in July, August and September 2016 has also been included in the assessment presented herein to address the IM reporting period of 1 October 2015 to 30 September 2016.

- Surface waters (DSEA) – sampling sites are shown in Figure 4.5, i.e., four sites along the dredge spoil perimeter drain (DSD) plus BBDDP, which is the authorised discharge point specified in the WDL. Monthly observations and samples are collected, although hydrocarbons are determined on a biannual (twice per year) basis. Both in situ (e.g., pH, temperature, DO, EC, turbidity) and laboratory (e.g., TSS, filtered (<0.45 µm) trace metals) analysis is undertaken.
- Artificial surface waters – sampling sites are shown in Figure 4.4 (three runoff ponds). Sampling is generally as for the surface waters (DSEA) sites, although additional clarity about the sampling program could be provided in future artificial surface water monitoring reports.

4.3.3.2 New Controls – Implemented and Planned

Water Classification

Further to the use of a revised water classification system for the mine site as described in the preceding section, the system has been further refined for MRM's 2016/17 reporting period (the start of which, i.e., 1 July 2016, overlaps with the end of the IM 2015/16 reporting period, i.e., 30 September 2016). Trigger values for SO_4/EC and all other CoCs are now included, with other changes including a reduction in the minimum trigger value for Class 5 (poor quality) water from 100 to 50 times the WDL trigger value (as summarised in Table 4.5). 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 clarified for stakeholders' consideration, using mechanisms such as a decision tree or similar.

Table 4.5 – MRM Water Quality Classification

Class	Class Description	Typical Sources	Water Quality – Number of Times Above WDL Trigger Values#		Typical Limiting CoCs	Typical Range of Release Rate per 100 ML/d at SW11 (ML/d)	Proposed Minimum River Flow Trigger
			SO_4 and EC	All Other CoCs			
1	Diverted water	See Section 4.3.3.1	<1	<1	Nil	Unrestricted	n/a
2	Surface water	See Section 4.3.3.1	<1	<1	Sediment	Unrestricted	n/a

Table 4.5 – MRM Water Quality Classification (cont'd)

Class	Class Description	Typical Sources	Water Quality – Number of Times Above WDL Trigger Values#		Typical Limiting CoCs	Typical Range of Release Rate per 100 ML/d at SW11 (ML/d)	Proposed Minimum River Flow Trigger
			SO_4 and EC	All Other CoCs			
3	Treated water	See Section 4.3.3.1	<1	<1	Nil	Unrestricted	10x the managed release rate
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	Range between 5 to 25 and 100 depending on limiting contaminant	10x the managed release rate
4b	♦ Good quality	See Section 4.3.3.1	3 to 5	4 to 20	SO_4/EC, Al, NO_3, Zn, Cd	Range between 1 to 25 and 5 to 25 depending on limiting contaminant	20 m^3/s (1,728 ML/d) at SW11
4c	♦ Medium quality	See Section 4.3.3.1	5 to 10	20 to 50	SO_4/EC, Zn, Cd	Range between 0.1 to 0.5 and 1 to 5 depending on limiting contaminant	20 m^3/s (1,728 ML/d) at SW11
5	Poor quality water	See Section 4.3.3.1	10 to 30	50 to 1,000	Zn, Cd	n/a	n/a
6	Process water	See Section 4.3.3.1	>30	>1,000	Metals, pH	n/a	n/a

pH, DO, TPH and BTEXN are excluded from the classification.

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. However, 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. For example, KCB (2016) reported that 97.37 ML was discharged over the 2015/16 wet season, corresponding to 0.15% of the total river flow for that wet season. This percentage of total river flow is equivalent to an annual river flow was 64,913 ML. Assuming that a maximum dilution of 50 was required to allow Class 4 water to meet WDL trigger values (as shown for Class 4c water in Table 4.5), this very simplistic analysis suggests that 1,298 ML could theoretically have been discharged (and this also assumes that this volume of Class 4 water was actually available for discharge, and that such a discharge would be beneficial in terms of overall water management on the mine site). This analysis is supported by examination of the dilution calculations undertaken by MRM prior to managed releases in the 2015/16 wet season, where dilution ratios (SW11 flow:pumped discharge) range from 86:1 up to 11,500:1. However, consideration of increased discharge volumes would also need to take into account factors such as the delays between obtaining water quality data for both SW11 and the discharge stream, and the actual release period (with the associated changes in water quality that might occur) and the already naturally elevated (in some instances) levels of parameters such as filterable Al, filterable Fe and nitrate. This may also require monitoring of water quality at both the discharge sources and SW11 that is closer to real-time monitoring than currently occurs.

Water Treatment Plant

As noted in last year's IM report, a major item of infrastructure that is planned for the mine site but has yet to be constructed is a water treatment plant that is proposed to treat poorer quality mine water (Class 5 and/or 6) to help manage the volume of stored process water. The plant will involve precipitation and filtration pre-treatment prior to reverse osmosis (RO) and pH correction. End uses for the permeate are proposed to include (MRM, 2016a):

- 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.
- Mine water demands (such as raw water make supply to the mill and dust suppression).

Water will reportedly be treated to a quality that will be better than the WDL trigger values. Feed water to the treatment plant will be sourced from Pete’s Pond, which stores mainly water sourced from the underground workings 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 either used in the mill (Class 6 water) or contained in the poor quality water circuit (Class 5).

The plant is currently scheduled to be operational in Q3 2017 (MRM, 2016a). Inspection of the plant site during the IM's site visit in June 2017 showed that plant construction had commenced.

Site-specific Investigations

A number of site-specific water quality investigations were undertaken during the reporting period, including the following:

- Storm event runoff water quality from the NOEF SEPROD catchment during the 2015/16 reporting period. The results indicated that improved management of surface water runoff from the NOEF could potentially allow more water to be managed in the Class 2 and Class 4 water circuits, as long as it is separated from other water sources to prevent adverse impacts on water quality.
- Storm event runoff water quality from the TSF C1SA and TSF C1SB catchments during the 2015/16 reporting period. The results showed that large spikes in key contaminant concentrations occur after rain events.
- Potential changes to void (underground) water quality due to transfers from TSF Cell 2. The results showed that OP VDD (Van Duncan's Dam) transfers to OP VR300 (vent raise) may be impacting underground void water quality.

Information/Knowledge Gaps

A number of key water-related knowledge gaps have been identified by MRM (MRM, 2016a), and those directly relating to surface water quality are shown in Table 4.6.

Table 4.6 – Key Surface Water Quality-related Knowledge Gaps Identified by MRM

Knowledge Gap	MRM Priority	MRM Accountability	MRM Completion Date
TARPs (trigger action response plans) for surface water quality	High	Manager ESP	Q4 2016
Mine-derived loads in surface water	High	Manager ESP	Q3 2017
Waste discharge monitoring	High	Manager Mining	Q4 2016
Interaction of OP ELS and diversion	Medium	Manager ESP	No date
Dredge Spoil Emplacement Area LOM (life of mine) Plan	Medium	Manager Metallurgy	Q4 2017
Continuous surface water quality monitoring	Medium	Manager ESP	Q4 2016
Definition of the current transhipment zone	Low	Manager ESP	Q4 2016
Transhipment water quality	Low	Manager ESP	Q3 2016
Water management system monitoring and automation	Low	Manager Mining	2018

The IM commends the identification of these gaps and the programs that MRM has implemented to address them. 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 (2016a) and revised completion dates if warranted, together with supporting explanations concerning the revised dates.

Other knowledge gaps identified by MRM include those concerning water management/ hydrology, hydrogeology, OEF design/seepage/capping and biota/sediment monitoring.

Other Controls

Other new controls that have been implemented or planned in relation to matters such as the TSF, OEFs and open pit (including closure scenarios) and which can influence the extent of adverse impacts on McArthur River 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.

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 174-07 and WDL 174-08) 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 2015-2016 monitoring period (1 July 2015 to 30 June 2016), with these exceedances primarily involving:

- Elevated concentrations of filterable Al in the wet season (nine occurrences in December 2015, January 2016, February 2016 and March 2016), and, to a lesser degree, filterable Fe (once in January 2016 and once in March 2016). As in previous years, these values were attributed to surface run-off from the upper catchments rather than to mining-related activity. while exceedances of Fe at SW11 'could be attributed to the influence of the Glyde River' (KCB, 2016). The IM agrees that these elevated levels of filterable Al and filterable Fe at SW11 are likely to be due to factors other than mine-related activities, but recommends that MRM obtains further certainty about these findings.

- Dissolved oxygen levels that were both lower than, and greater than, the WDL trigger levels, although KCB (2016) notes that DO values for all sites along McArthur River varied above and below this trigger range. The IM supports the conclusion that DO values are unlikely to be related to mine activities.

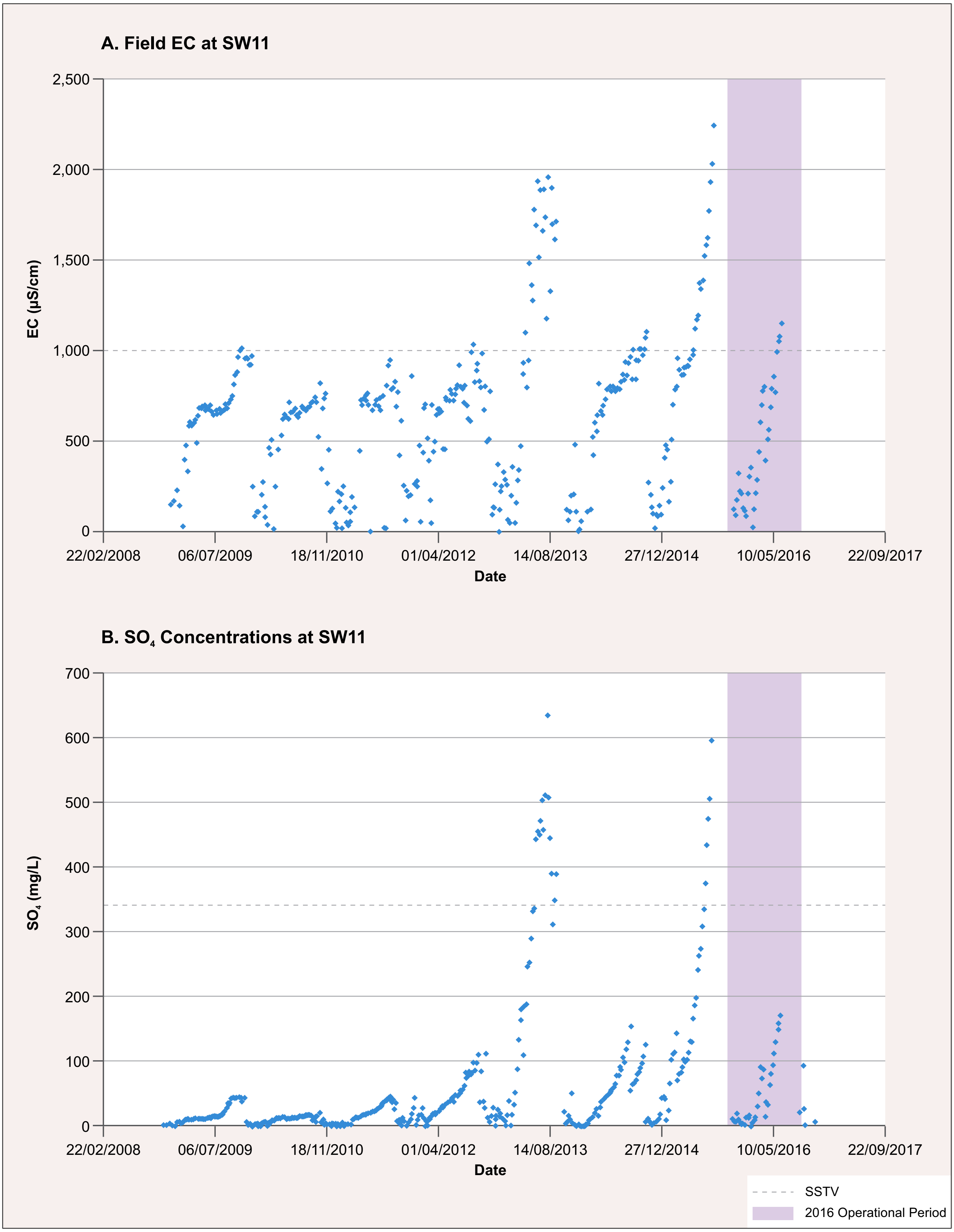
- Elevated EC values, primarily at the end of the dry season. The EC trigger value was exceeded twelve times over the 1 July 2015 to 30 June 2016 period (Figure 4.7A) – all in the period from July 2015 to September 2015, which is within the previous IM reporting period – and KCB (2016) notes the previously-reported areas of mineralisation along the McArthur River diversion channel and that 'surface water passing these exposed zones of mineralisation could be responsible for the increased EC in the McArthur River, in addition to groundwater upstream which is likely to contribute load to the system'. It is further noted that 'With the dec[r]easing flow in the diversion channel the influence of groundwater seepage on the concatenations (sic) of EC have a greater influence in water quality' (KCB, 2016), and Figure 4.8A shows the increase in EC levels that occur at SW16 and SW17. The IM notes the reference in the MRM's table of knowledge gaps to an OP ELS seepage investigation (Table 4.6), and encourages the inclusion of the OP ELS in source load calculations if appropriate, and further definition of the relative influence of groundwater inputs versus those from surface water passing through mineralised zones, with subsequent identification of mitigation measures commensurate with the risk posed by these changes in EC.

  Further review of the data for the months beyond those reported in KCB (2016) shows that the elevated conductivity values that occurred in the latter months of the 2015 dry season, where a maximum of 2,240 µS/cm on 22 September was reported before substantially decreasing (presumably due to the onset of the wet season), was repeated to a considerably lesser extent in 2016, with only the last three values recorded – 1,054, 1083 and 1,150 µS/cm in July 2016 – exceeding the SSTV of 1,000 µS/cm (Figure 4.7A). These

EC LEVELS AND SO_4 CONCENTRATIONS AT SW11

McArthur River Mine Project

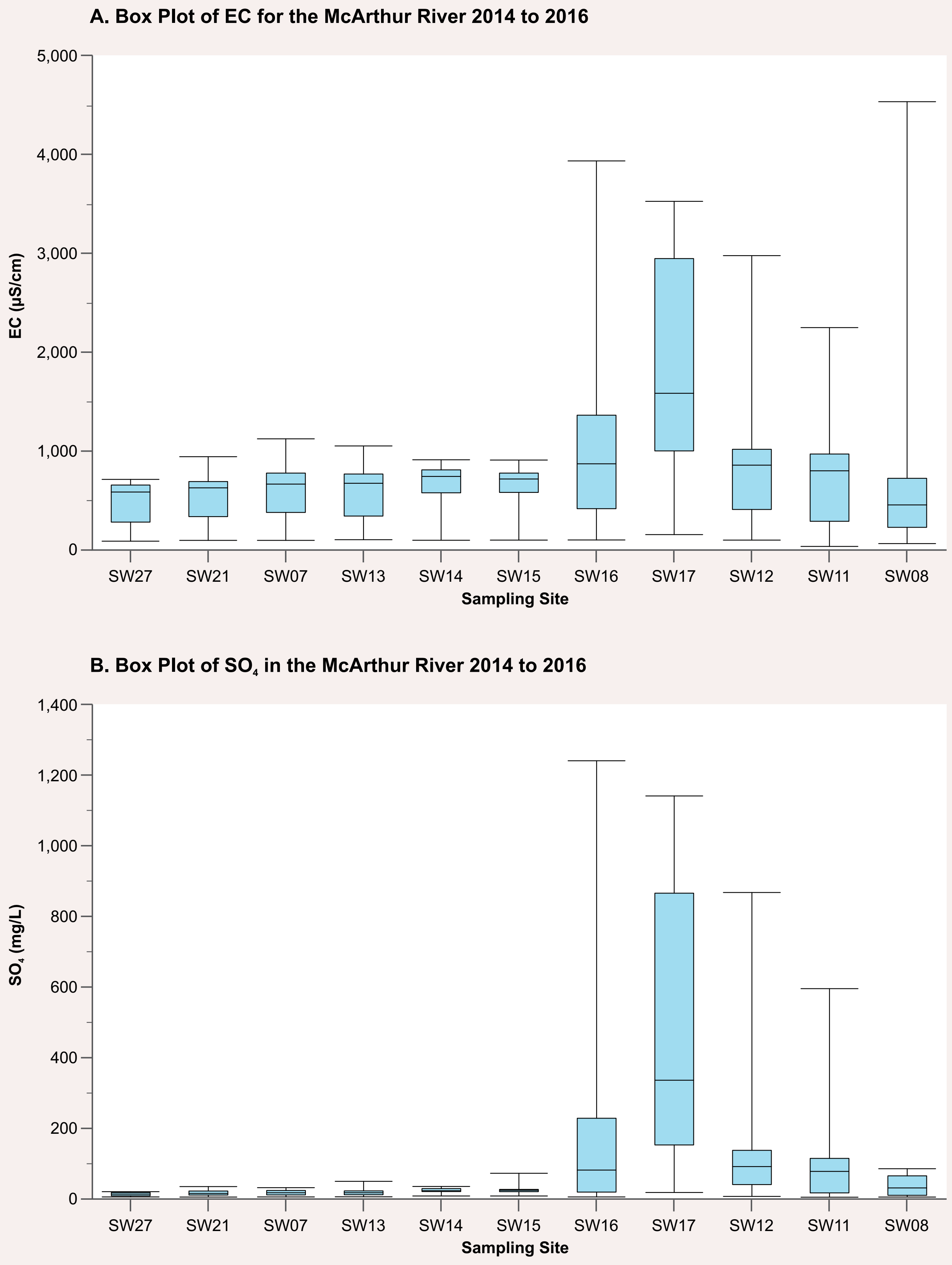
FIGURE 4.7



BOX PLOTS OF EC LEVELS AND SO_4 CONCENTRATIONS IN McARTHUR RIVER FOR THE PERIOD 2014 TO 2016

McArthur River Mine Project

FIGURE 4.8



smaller increases at SW11 relative to the previous year are attributed by MRM to a reduced SO_4 influence along the McArthur River diversion channel, which in turn is attributed (by MRM) to the wetter 2015/16 wet season (compared with the 2014/15 wet season) and associated higher flow in McArthur River. The IM acknowledges that this is a reasonable explanation, but recommends that MRM re-visits this explanation in light of the very wet 2016/17 wet season and the subsequent surface water monitoring data that will be available. The IM also notes that these three EC exceedances do not seem to have been recorded as incidents or reported to DPIR at the time.

- The in situ pH at SW11 on 3 August 2015 was 8.53, which is marginally outside the SSTV range of 6.0 to 8.5. The IM notes that this value is the same as the upper SSTV value when two significant places are used (as in the WDL).
- Elevated concentrations of NO_3, which occurred on four occasions in December 2015, January 2016, April 2016 and May 2016, where the maximum was 1,439 µg/L compared with the WDL value of 700 µg/L. Possible reasons for these exceedances 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). Examination of data for the months beyond those reported in KCB (2016) shows levels that are less than the WDL value.

The results for SO_4 concentrations at SW11 are shown in Figure 4.7B for the period from December 2008 to December 2016, which encompasses the IM reporting period of 1 October 2015 to 30 September 2016 (as shown in the figure). During the 1 July 2015 to 30 June 2016 period, the SSTV for SO_4 at SW11 of 341 mg/L was exceeded five times, all in August and September 2015 which is within the previous IM reporting period, with the maximum value being 593 mg/L on 22 September 2015 before substantially decreasing with the onset of the wet season. Non-compliances were not apparent in the additional results for the months of July to September 2016. The elevated levels in the 2015 late dry season were attributed to inputs from the McArthur River diversion channel, as shown in Figure 4.8B for the 2014 to 2016 period, although the relative contributions of groundwater seepage versus surface water passing through mineralised rock is not known (KCB, 2016), as is the case with EC values at SW11 discussed above (and where EC is closely correlated with SO_4).

A further point to note is that the data for SW11 shows a significant decrease in SO_4 levels in May 2016 before they increase again as the dry season progresses. Similar decreases in previous years reflect MRM's use of a pump in Barney Creek at the haul road bridge 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. McArthur River Mining has advised that dewatering of Barney Creek at SW19 did not occur in the 2016 dry season, and there was no flow at SW19 during the period when the decrease was recorded at SW11. However, similar decreases in SO_4 concentrations were noted at SW16 on the McArthur River diversion channel. These changes were not specifically addressed in KCB (2016).

From the perspective of additional incidents that could have direct adverse impacts on surface water quality at the mine site and surrounds, the file 'SiteSafe 2015-2016.xlxs' provided by MRM lists some 41 environmental incidents for the IM reporting period of 1 October 2015 to 30 September 2016, with additional detail for those incidents up to 30 June 2016 being described in the OPR (MRM, 2016a). While a number of these relate to exceeding WDL trigger values, as discussed above, others relate to matters such as minor leaks or spills, misallocation of waste rock or similar (and the IM notes that the 'SiteSafe' spreadsheet did not contain all of the descriptive text, i.e., the detailed description was truncated for a number of the incidents). Three of these were assigned an impact category of 2 – minor, the rest being 1 – low or 0 – near miss. The IM has no reason to disagree with these findings or the corrective and preventative actions, and notes that MRM submitted formal notification to DPIR concerning a number of incidents including a tailings slurry release of about 5 m^3 on 2 August 2016 (category 1) that stopped short of entering Barney Creek, and an oil leak from an excavator. However, the IM recommends that the descriptions in the OPR for spills and/or leaks include volumes and fate of the material, i.e., where it ended up (this is not always described).

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.

It is also worth noting that significant gully erosion was observed during the site visit near the walking track leading to NOEF SEL1 DP, and this should be addressed prior to the next wet season. Similarly, the potential for erosion at the actual pipe outlet (near Barney Creek) should also be evaluated and addressed as required.

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 update presented in MRM (2016a) indicates 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.

From a surface water quality perspective, the IM encourages MRM to adopt the recommendations contained in KCB (2016), where these include:

- 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 the previous surface water monitoring report (MRM, 2015b) concerning mitigation of elevated concentrations of metals and major ions in Surprise and Barney Creek, 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). 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) (and the IM acknowledges that this is beyond the reporting period but uses this to demonstrate the particular matter):

> 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 OPR (MRM, 2016a) provides a list of commitments from the following documents:

- 2013-2015 MMP (MRM, 2015a).
- MMP information requests.
- MMP amendments.
- MMP conditional approvals.

A small number of these commitments relate directly to surface water quality, e.g., investigating water treatment plants and conduct EC gradient monitoring along Barney and Surprise creeks, although a considerably larger number relate to aspects of the operation that indirectly affect surface water quality, e.g., compaction trials for reactive PAF and constructing toe drains. The IM found that the commitments related directly to surface water quality had generally been, or are planned to be, implemented.

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. However, dry conditions during the reporting period meant that there was only limited flow and connection observed at the Bing Bong sample points (MRM, 2016b). Sampling from the BBDDP occurred on three occasions over the reporting period, with SSTV exceedances summarised in Table 4.7.

Table 4.7 – SSTV Exceedances at BBDDP for 2015/16

Date of Sample	Field pH	Al (f) (µg/L)	Cu (f) (µg/L)	Pb (f) (µg/L)	Mn (f) (µg/L)	Zn (f) (µg/L)
SSTV	8.0 to 8.4	0.5	1.3	4.4	80	15
12/01/2016	7.79	39.1	2.45	--	--	19.6
14/03/2016	7.82	27.4	6.03	--	298	--
12/04/2016	7.84	17.1	--	22.2	--	35.5
n	3	3	2	1	1	2

Investigation into the elevated metal concentrations by MRM indicated that the source was the perimeter drain in the vicinity of DSD2 (see Figure 4.5), with the elevated concentration being correlated with the wet season months and increased rainfall intensity in the area (MRM, 2016b). It was further suggested by MRM that direct rainfall onto the DSEA infiltrated through to the base of the cells and resulted in seepage that was intercepted by the perimeter drain, and that the risk posed to the receiving environment was minor with flows in most case being less than 1L/s and DGT-labile metal concentrations in the adjacent marine waters being low (MRM, 2016b). However, and notwithstanding the likely validity of this interpretation of the data, this is indicative of a potential issue that could be problematic in the future and the IM recommends that this matter be addressed prior to future placement of dredge spoil in the DSEA.

From the perspective of 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, MRM reported that bulk concentrate dust residue covered the deck of MV Santa Barbara during loading on 2 January 2016, with a subsequent low impact. The IM has no reason to disagree with this impact classification and notes the reported implementation of appropriate actions, i.e., spraying product that is being loaded and has low moisture content with liquid dust suppressant.

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 4.8, excluding those that have been flagged in earlier IM reports as being completed or superseded. While additional comment to that provided in the table is not required for most matters, an exception concerns the recommendation 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'. This has been a high priority recommendation in the last two IM reports, and it is pleasing to note that MRM has made some progress. As noted in last year's IM report, the need to determine loads is based largely on two considerations:

- Reliance on filterable metal concentrations does not take into account downstream effects that might be associated with the long-term biogeochemical cycling of metals, including metals associated with suspended particulates, and hence total (unfiltered) metals also need to be considered. This includes establishing background and mine-derived loads of key metals such that the increments due to the mine can be placed into the appropriate context, taking into account downstream depositional (including coastal) environments.

- Determination of loads from various sources within the mine site and subsequent prioritisation of current and potential inputs will allow appropriate focus to be placed on management and mitigation measures such that the downstream environmental values can be maintained both now and in the future.

Table 4.8 – Estimated Mine-derived Loads for 2014/15 at SW06

	Zn (f) (kg)	Zn (t) (kg)	TDS (kg)	SO_4 (kg)	Pb (f) (kg)	Pb (t) (kg)
Total load for 2014/15	15.8	68.1	2,659,202	1,233,620	3.13	16.7
Mine-derived load for 2014/15	11.7	65.8	1,437,842	1,218,249	2.76	13.3
Mine-derived as % of total	74	97	54	99	88	80
Mine-derived:upstream	2.9:1	28:1	1.2:1	79:1	7.3:1	3.9:1

Note 1: Load estimates are sourced from KCB (2016).
Note 2: (f) = filtered; (t) = total.

Given that significant loads of both soluble and particulate material are transported during flood events, and taking into account the relationships between water quality and river flow reported in WRM (2016b), sampling over individual flood events should be considered to ensure that the resulting load estimates are robust and to complement the data from the current weekly sampling program. This could include sampling during managed releases if this is logistically feasible and can be undertaken in a safe manner.

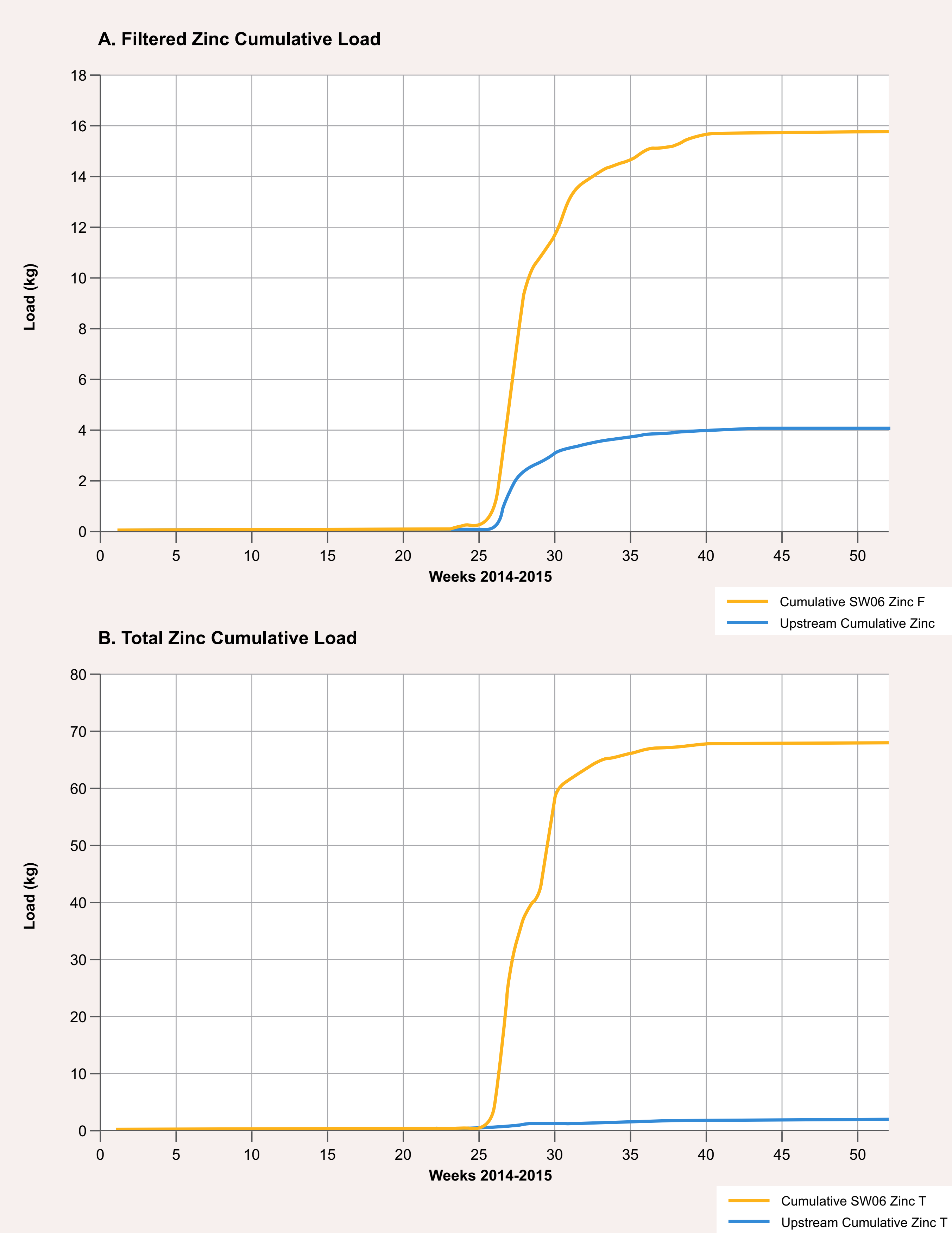
Such a focus on determining contaminant loads is consistent with both RGC (2015), where it is noted that the absence of information concerning contaminant loads to or from the local groundwater system or to McArthur River or its tributaries is a significant data gap, and MRM's own surface water monitoring report from last year (MRM, 2015b). More recently, Ecometrix (2017) has recommended that loads along Surprise Creek and Barney Creek diversion channel should be estimated so as to differentiate NOEF inputs from TSF inputs.

As noted above, some progress has been made in this area. From a qualitative perspective, the surface water monitoring report (KCB, 2016) contains a number of figures that conceptually illustrate the sources of various contaminant loads to McArthur River, Barney Creek and Surprise Creek. This is a commendable expansion on previous reporting, with the next step being to quantify these inputs. Initial estimates of Pb, Zn and SO_4 loads contributed to McArthur River during MRM discharge events in the 2015/16 wet season are also included in KCB (2016), as are mine-derived loads for these contaminants (including total and filterable Pb and Zn) as a percentage of total loads for Barney Creek at SW06 (which is downstream of the mine but upstream of the confluence with McArthur River diversion channel (see Figure 4.2)). The results (Table 4.8) show that MRM activities at the mine site are responsible for 74 to 99% of the total load of each contaminant at this site (and 54% of the TDS load). Of possibly greater significance is that the mine-derived loads are between 2.9 and 79 times the upstream (background) loads, excluding TDS (and the difference in ratios for TDS and SO_4 warrants further consideration by MRM). This is shown graphically in Figure 4.9, which clearly shows the significant mine-derived

CUMULATIVE TOTAL AND FILTERED ZN LOADS AT SW06 IN 2014/15

McArthur River Mine Project

FIGURE 4.9



contribution relative to the upstream inputs for total and filterable Zn at SW06. Although the loads in McArthur River itself have not been determined by MRM, the estimates presented in this table demonstrate the importance of load calculations and the need to adopt an approach that reflects the entire mine site and the upstream catchment.

The IM's view therefore remains 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. The IM strongly endorses MRM's commitment to determine mine-derived loads in surface water as a high priority (Table 4.9), and MRM has advised that a comparison of mine-derived loads and McArthur River background loads will be completed for the 2016/17 wet season data and presented in the 2017 OPR. 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 both background, current mine-derived and predicted mine-derived loads, and seasonal variation (including loads that are transported during flood events). Loads from Glyde River should also be estimated (although this is a lower priority).

Some progress has also been made in relation to suspended sediment from MRM's operations. The assessment provided in KCB (2016) reported that the mean TSS value at SW11 was not significantly different from that at the upstream control site (SW21). However, mineralised suspended material reporting to McArthur River during flood events remains a possible pathway for downstream impacts to occur (as noted above), and downstream impacts might therefore be attributable to the suspended solids themselves or their mineralised nature (or both). The IM therefore recommends that this issue be closed out via an assessment that includes TSS loads from the mine site, including over flood events and taking into account sediment basin overflows. As noted in ERIAS Group (2017), the absence of this information prevents stakeholders from forming an overall view of the project's impacts. In this context, a finding that, for example, particulate-associated metals would have no material impact on the downstream beneficial uses, including those associated with the estuarine reaches or coastal waters into which McArthur River discharges, would be useful information. This assessment should also include TSS from the operations at the Bing Bong Loading Facility reporting to surface (including coastal) waters.

Table 4.9 – Surface Water Quality Management Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2015 Operational Period		
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 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	There has been no progress in terms of developing a formal procedure that addresses this issue, and MRM has advised the IM that changes completed as part of the annual review are undocumented other than the annual update to the formal monitoring schedule. However, MRM has further advised that changes to future monitoring schedules will be documented as part of the review

Table 4.9 – Surface Water Quality Management Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2015 Operational Period (cont'd)		
McArthur River/SW11/ other surface water sites	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	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
Monitoring	Real-time in situ monitoring at SW11 should be implemented with the issues observed during the 2015-2016 wet season (i.e., burial of the probe) being appropriately addressed	Multi-probes for real-time monitoring have been installed at a number of sites. The probe at SW11 was damaged by sedimentation and MRM intends to install a new probe that determines pH, EC, DO, temperature and turbidity. Three EC/temperature loggers will also be installed across the riverbed at this site with data collection occurring after the wet season
	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	There has been some progress in this area but Zn and Al blank levels remain at around 1 to 2 µg/L (sometimes significantly higher) and examination of the water quality data spreadsheet shows that some reported filterable Zn concentrations are higher than total Zn levels (at low levels), which is theoretically not possible. Occasional poor precision for the DGTs remains an issue that requires continued attention, and the IM notes that Tsang (2016) reports that 'the reasons for imprecise duplicate concentrations of DGT-labile metals on some occasions are unknown'. The IM also supports the inclusion of DGT field blanks in the program
	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	Partially completed. This and other changes are described in the monitoring reports but some anomalies remain in the database, e.g., there is still reference to 'ASW BBDDP' rather than just 'BBDDP'

Table 4.9 – Surface Water Quality Management Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2015 Operational Period (cont'd)		
Monitoring (cont'd)	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 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 Creek, Surprise Creek and Emu Creek (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	There has been some progress on this item. See accompanying text in Section 4.3.4.2
	Results of the release calculator should be validated by concurrent water quality measurements at SW11	No information was reviewed that indicates that such a validation exercise has been completed
	Elemental scans should be reinstated at selected surface water monitoring sites (preferably during high flows)	The IM understands that the variables determined as part of the surface water monitoring program have been expanded following the NIRB review. However, the IM is still of the view that selected multi-element scans would benefit the overall program and allow assessment of contaminants that might otherwise be missed. The IM also notes that such scans will reportedly be added to the 2017/18 monitoring schedules, as indicated in MRM's 2017 Register of IM Recommendations spreadsheet
	The feasibility of deploying DGTs to monitor seawater quality in the trans-shipment area during transfer of the concentrate should be determined	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

Table 4.9 – Surface Water Quality Management Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2015 Operational Period (cont'd)		
Water management system	Specific surface water quality management objectives should be formalised for Bing Bong Loading Facility and incorporated into relevant MRM documents	Partially completed. Specific objectives for the DSEA surface water monitoring program are provided in KCB (2016), but not for the artificial surface water monitoring program
	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	There has been some progress; however, further clarity is required as to how the ASW monitoring data assists water management on a daily or weekly basis
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	Partial progress has been achieved in terms of comparing upstream and downstream TSS concentrations, but further assessment is required that includes consideration of TSS loads from the mine site over flood events and taking into account sediment basin overflows and particulate mineralisation
2014 Operational Period		
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 sufficient early warning is provided concerning potential impacts on surface water quality from NOEF and TSF leachates and runoff (or other potential failures of these project infrastructure components). This should include implementing a formal procedure whereby the review process, outcomes and required actions are documented and available for IM review	This has been superseded by a subsequent recommendation
McArthur River/SW11	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 (i) possible implications (if this trend were to continue in the dry season), (ii) likely causes, and, if MRM operations are found to be a major contributing factor, (iii) mitigation measures commensurate with the level of risk	This has been superseded by a subsequent recommendation
Monitoring	Elevated trip blank Zn and Al levels, implementing an inter-laboratory program, using only NATA-accredited laboratories, and occasional poor precision for DGT analyses should be investigated	This has been superseded by a subsequent recommendation
Water management system	Specific surface water quality management objectives should be formalised for Bing Bong Loading Facility	This has been superseded by a subsequent

Table 4.9 – Surface Water Quality Management Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Water management system (cont'd)	Additional information about the use of water quality monitoring data from the ASW program should be provided for IM review	This has been superseded by a subsequent recommendation
General data interpretation and reporting	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. If additional stream gauging data is required, a plan for obtaining such data should be developed and implemented as a priority	This has been superseded by a subsequent recommendation
	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; a reconciliation of actual versus proposed sampling is yet to be demonstrated
2012 and 2013 Operational Periods		
Monitoring	The feasibility of real-time in situ monitoring at the stream gauging stations on McArthur River, Surprise Creek, Barney Creek and Glyde River should be determined and, if found to be feasible, this capability should be installed so as to be consistent with leading industry practice. The parameters for which the feasibility of real-time in situ monitoring should be investigated include pH, temperature, DO, EC (first priority) and turbidity (second priority)	This has been superseded by a subsequent recommendation
General data interpretation and reporting	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. Additional discussion about water quality changes in relation to flow and mine-derived influences is evident. The IM also commends the preparation of two separate reports, one for each of the surface water monitoring program (KCB, 2016) and the artificial surface water monitoring program (WRM, 2016a). 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 material was reviewed that indicated that this has occurred, although WRM (2016a) reports the use of 95^{th} percentile results to assign ASW monitoring locations to a specific water quality class
	Figures in the MMP that show sampling sites should show ALL sampling sites, including control sites	Completed. Presentation of sampling sites in relevant report figures is satisfactory

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).
- 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.

As described in previous IM reports, 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 mine-affected areas had a negative influence on the surface water quality of these two 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, as discussed in earlier sections. Given these impacts, the IM recommends that stakeholders 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 the case for the previous IM reporting period, both versions of the WDL that applied during the monitoring period state that water quality at SW11 and BBDDP 'must not exceed the trigger values specified' in the licence, 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 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 4.10. Three controlled discharges were undertaken during the reporting period, with one of these originating from SEL1 and two from Pond 2. Discharge dates and volumes are shown in Table 4.11.

Table 4.10 – Comparison of MRM Monitoring Data for SW11 with WDL Requirements

WDL 174-07 and WDL 174-08[1]			MRM Monitoring Data (SW11)[2]
Parameter	**Units**	**Site-specific Trigger Value (SSTV) for SW11**	**Oct 2015 – Sep 2016[3] (Minimum – Maximum)**
pH (in situ)	pH units	6.0 – 8.5	6.4 – 8.5
EC (in situ)	µS/cm	1,000	25 – **1,150**
DO (in situ)	% saturation	85 – 120	**78** – **147**
Al (filtered 0.45 µm[4])	µg/L	55	2.4 – **238**
As (filtered 0.45 µm)	µg/L	24	0.2 – 1.6
Cd (filtered 0.45 µm)	µg/L	1.73	<0.02 – 0.04
Cu (filtered 0.45 µm)	µg/L	10.97	0.52 – 4.26
Fe (filtered 0.45 µm)	µg/L	300	14 – **382**
Pb (filtered 0.45 µm)	µg/L	16.6	<0.01 – 0.48
Mn (filtered 0.45 µm)	µg/L	1,900	0.42 – 611
Hg (filtered 0.45 µm)	µg/L	0.6	<0.02 – 0.02
Ni (filtered 0.45 µm)	µg/L	11	0.04 – 1.18
Zn (filtered 0.45 µm)	µg/L	62.68	0.3 – 5.2
TPH fraction C6-C9 (filtered 0.45 µm)	µg/L	N/A	N/A
Benzene (filtered 0.45 µm)	µg/L	950	All values <2
TPH fraction C10-C14 (filtered 0.45 µm)	µg/L	600	<50 – 280
C15-C28 (filtered 0.45 µm)			
C29-C36 (filtered 0.45 µm)			
SO_4 (filtered 0.45 µm)	mg/L	341	0.9 – 171
NO_3 (filtered 0.45 µm)	µg/L	700	<22 – **1,439**

1. WDL174-07 was applicable until 17 March 2016, after which WDL 174-08 was applicable; 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. The licence actually refers to 'Total and filtered (0.45 µg/l)' for metals and metalloids.

Table 4.11 – Discharges During the 2015-2016 Reporting Period

Date	Location	Discharge Volume (ML)[1]
20 to 22 December 2015	Pond 2	53
30 December 2015 to 1 January 2016	SEL1	16
2 to 3 February 2016	Pond 2	28
TOTAL		97

1. KCB (2016).

The surface water monitoring report (KCB, 2016) notes the following in relation to filterable metal concentrations at SW11 for the 2015-2016 monitoring period (with additional comment being provided as required by the IM to take into account the IM's reporting period):

- Most of the results showed water quality at SW11 that complied with the WDL SSTVs. For example, all pH (in situ) values at SW11 complied with the WDL trigger limits of 6.0 and 8.5. Almost all benzene and TPH results were less than the respective detection limits and SSTVs, the exceptions being two 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 (four) 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 475 µS/cm. Only three EC results from this site were above the trigger value, and these were obtained well into the dry season but before the river had stopped flowing. This has been further discussed in terms of non-compliance (Section 4.3.4.1).

- Individual dissolved oxygen values at SW11 ranged from 78 to 147% saturation compared with the trigger values of 85 to 120%, with the average value over the reporting period being 99%. According to KCB (2016), DO at all sites along McArthur River, including the upstream control sites, routinely fall outside the range of trigger values, with no trends found to be related to any mine activities (as previously discussed).

- In relation to metals and metalloids:

  - All results for filtered metals and metalloids other than Al, Fe and Cu (i.e., As, Cd, Pb, Mn, Ni, Hg, Zn) 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 trend associated with elevated filtered Al and upper catchment rainfall 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 twice 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), the single exceptions being one value that was reported as 4.26 µg/L. However, the corresponding total Cu value was 0.52 µg/L, which indicates that the filtered Cu concentration was incorrect.

- When evaluated against hardness modified trigger values (HMTVs) calculated using the hardness of each sample from SW11, MRM (2016b) reported only two exceedances, these being for Zn and Cu on 15 March 2016 where the measured values of 4.5 and 0.92 µg/L exceeded the corresponding HMTVs of 1.83 and 0.32 µg/L, respectively. This was attributed by MRM (2015b) to the very low hardness of 5.3 mg/L (as $CaCO_3$). The toxicological implications of these low-level exceedances are unlikely to be significant. Further assessment of the data for the period 1 July to 30 September 2016 shows that no exceedances were evident, with the single Cu value that exceeded the unmodified ANZECC/ ARMCANZ (2000) trigger value being less than the corresponding HMTV (notwithstanding its likely contamination).

A final parameter that warrants discussion is SO_4. As noted in previous IM reports, elevated SO_4 concentrations at SW11 in the latter part of the dry season have been a potential concern in previous years, although this was not evident in the current IM reporting period. From a 'success' perspective, MRM's use of a dewatering pump in the downstream section of Barney Creek diversion channel late in the 2014 dry season and again in the 2015 dry season remains a useful control measure, although SO_4 from the McArthur River diversion channel remains a concern (as discussed above).

With respect to the artificial surface water monitoring program, the overall objective is to assist the facilitation of sustainable management of water on site (WRM, 2016). The monitoring data reported by MRM indicates that the program provides a suitable basis for this objective to be achieved, and can also flag potential issues of concern.

The role of the program in classifying various water sources is appropriately described in WRM (2016). However, the extent to which this data is actively used to assist water management on site on a day-to-day basis remains unclear.

Reporting of the QA/QC data for surface water monitoring continues to show improvement, although continued effort is required to address Zn and, to a lesser extent, Al blank values. The water quality data presented in the spreadsheet shows that blank values for Zn are routinely reported to be 1 to 2 µg/L, which are similar to the actual values reported for samples (where the range at SW11 is 0.3 to 5.2 µg/L) (and some blank values are considerably higher). Continued effort is also needed to address the sometimes poor precision obtained from analysing duplicate samples.

Also worth noting is MRM's modification of the sampling system whereby surface water monitoring sites are only sampled if flow is present at the individual sample site.

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).

In particular, SO_4 and EC values at SW11 were lower compared with the previous IM reporting period, which can be attributed to a reduced influence of the McArthur River diversion channel that, in turn, reflects lower flows in the river and (possibly) reduced influence of seepage from the ELS, 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 (although this risk would be reduced by placing the tailings in the final pit void for subaqueous storage, which is MRM's preferred (but not approved) option). The impact of the mine in terms of loads of contaminants (as opposed to concentrations) is yet to be fully determined by MRM.

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.

The results from the monitoring program that employed DGTs around the Bing Bong Loading Facility demonstrate a relatively high level of success in terms of being less than the SSTVs specified in the WDL, as summarised in Table 4.12.

Table 4.12 – Comparison of MRM DGT Monitoring Data for Bing Bong Loading Facility with WDL Requirements

WDL 174-07 and WDL 174-08				MRM Monitoring Data[1]
Parameter	Units	Site-specific Trigger Value (SSTV) for BBDDP[2]	ANZECC/ARMCANZ (2000) 95% (99%)[3]	Oct 2015 – Sept 2016[4,5]
Mn	µg/L	80	Insufficient data	0.60 – 26.6
Fe	µg/L	N/A	Insufficient data	0.30 – 279
Cd	µg/L	5.5	5.5 (<u>0.7</u>)	0.004 – 0.090

Table 4.12 – Comparison of MRM DGT Monitoring Data for Bing Bong Loading Facility with WDL Requirements (cont'd)

WDL 174-07 and WDL 174-08				MRM Monitoring Data[1]
Parameter	Units	Site-specific Trigger Value (SSTV) for BBDDP[2]	ANZECC/ARMCANZ (2000) 95% (99%)[3]	Oct 2015 – Sept 2016[4,5]
Cu	µg/L	1.3	1.3 (0.3)	0.08 – **2.73**
Co	µg/L	N/A	1.0 (0.005)	0.006 – 0.216
Ni	µg/L	70	70 (7)	0.05 – 2.14
Pb	µg/L	4.4	4.4 (2.2)	<0.01 – 2.74
Zn	µg/L	15	15 (7)	0.11 – **45.6**

1. Values for ranges were extracted from Tsang (2016) and monthly reports generated by Charles Darwin University for AIMS.
2. Values refer to filtered concentrations, although the licence actually refers to 'Total and filtered (0.45 µg/l)' for metals and metalloids.
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.
5. Some values were reported by the laboratory as being less than the detection limit, where this was greater than the minimum values in this column.

Tsang (2016) reports that, during the 2015-2016 monitoring period, the concentrations of DGT-labile Co, Ni, Cu, Zn, Cd and Pb at the monitoring sites within the swing basin, i.e., DGT3 and DGT4, 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 4.12 shows that this means the values were also below the SSTVs. This was also the case for most results for July to September 2016[11] (which were not included in Tsang 2016 and hence were evaluated separately by the IM), apart from two Cu and one Zn values.

Concentrations of DGT-labile Zn, Pb, Cd and Ni 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. These findings generally also applied to results for July to September 2016, apart from a number of Cu and Zn values that exceeded the 99% protection guideline.

The DGT-labile Zn, Pb, Cd, Co, Cu and Ni concentrations at monitoring sites outside the swing basin, i.e., DGT1, DGT2, DGT5 and DGT6, were less than their ANZECC/ARMCANZ (2000) 95% protection levels (as were results for July to September 2016). 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 July to September 2016 generally reflected these findings.

[11] The data spreadsheets provided by MRM that contained the July to September 2016 results also contained data for DGT-7 and DGT-8, which are additional sites that will be discussed in the next IM report.

General comments relating to the results are as follows (and are based on the discussion in Tsang (2016)):

- Higher concentrations of DGT-labile Mn and/or Fe were measured in Sep-15 (DGT4), Oct-15 (DGT6), Jan-16 (DGT3, DGT5), Feb-16 (DGT3–6), Mar-16 (DGT4, DGT6) and Jun-16 (DGT4), with these values being attributed to exposure to sediment pore water, or to the DGT samplers themselves containing particles.
- The average concentrations of DGT-labile Zn and Pb were generally higher at the swing basin monitoring sites (DGT3, DGT4), particularly DGT3, than the channel (DGT1, DGT2) and coastal (DGT5, DGT6) sites (and this was also evident for the July to September 2016 data). 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.
- The relationship between DGT-labile Zn and DGT-labile Pb at DGT3 and DGT4 indicates that the metals were derived from the same source, where this is likely to be the Bing Bong Loading Facility.
- Determination of Pb isotope ratios 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 (2016) also offers an alternative reason for the elevated Pb 208/206 values at coastal sites, this being that natural weathering of Pb outliers removed from the orebody mined by MRM may impart a regional signature with the same Pb 208/206 ratio as MRM concentrate. However, this hypothesis has not been investigated.

In addition to the low levels of metals obtained at all sites, a related success is the continued implementation of the DGT method instead of grab water samples for marine monitoring. The IM endorses this approach but notes that the poor reproducibility of some results, as shown by imprecise duplicate concentrations on some occasions (which was also noted in previous IM report), requires further investigation and resolution. Tsang (2016) notes that ' Although some samples appeared to be contaminated in the 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.
- Contact between the DGT units and bed sediments.
- Interaction between the DGT units and benthic marine organisms.
- Biofouling of the DGT units.
- Application to a limited number of metals/metalloids.

The IM notes the development of new HDPE DGT holders (and the subsequent reduction in Ni values that resulted from the previously-used stainless steel holders) and the inclusion of field blanks in the sampling procedure, and encourages further development of the use of DGTs to improve the precision of the data. The IM also recommends that consideration be given to examining changes in DGT-labile metal concentrations that may have occurred since the program commenced.

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 in Section 4.3.4.1.

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. It is also worth noting that the water classification approach implemented for the mine site has also been used for the Bing Bong Loading Facility, notwithstanding the different SSTVs at the two locations. Using the same method as used at the mine site of comparing measured concentrations to SSTVs, BB SRP1 and BB SRP3 would be classified as Class 6 (process) water, while BB SRP2 would be classified as Class 5 (poor quality) water. This is consistent with the presence and handling of concentrated metal products at the loading facility (WRM, 2016a). The IM endorses the application of this approach to the Bing Bong Loading Facility.

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 October 2016 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) and some non-compliance with WDL SSTVs at SW11 due to mine activities has occurred (but to a lesser extent than was noted in last year's IM report). Available data suggests that adverse impacts on coastal waters near Bing Bong similarly remain limited. The IM also notes that MRM is starting to focus 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. The existing information suggests that mine-derived loads may be significant, and the next steps are to fully quantify these loads and to determine the associated environmental risks, particularly in terms of downstream impacts.

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.

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 4.13.

Table 4.13 – 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 and available for IM review	High
McArthur River/ SW11/other surface water sites	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, e.g., McArthur River diversion channel, Surprise Creek and Barney Creek diversion channel), within the context of the environmental values that require protection (see new recommendation below) ♦ 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
	An assessment that validates (or otherwise) MRM's assertion about the low risk associated with mine-derived TSS should be completed, taking into account changes in TSS loads during flood events, sediment basin overflows and the mineralised nature of mine-derived particulates. 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 the 2015-2016 wet season (i.e., burial of the probe) 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
	The alternative labeling of natural surface water sampling sites that has been adopted by MRM should be carried through into all formats that report this data	Low

Table 4.13 – New and Ongoing Surface Water Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Monitoring (cont'd)	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 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 Creek, Surprise Creek and Emu Creek (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	High
	Results of the release calculator should be validated by concurrent water quality measurements at SW11	Low
	Elemental scans should be reinstated at selected surface water monitoring sites (preferably during high flows)	Low
	The feasibility of deploying DGTs to monitor seawater quality in the trans-shipment area during transfer of the concentrate should be determined	Medium
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	Low
	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	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 (natural and artificial), as well as additional details about the sampling programs, e.g., sampling frequency and parameters, that more fully reflects MRM's water monitoring schedule spreadsheet	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
New Items		
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	High

Table 4.13 – New and Ongoing Surface Water Recommendations (cont'd)

Subject	Recommendation	Priority
New Items (cont'd)		
Water management (cont'd)	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	High
	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	Low
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
	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	High
	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 2016/17 water quality data	Medium
	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	Low
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	Medium
Monitoring	The recommendations in KCB (2016) should be fully implemented	High
General data interpretation and reporting	Descriptions of spills and/or leaks in the OPR should include volumes and fate of the material, i.e., where it ended up	Low
	Consideration should be given to examining changes in DGT-labile metal concentrations that may have occurred since the program commenced	Low
	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	Low

4.3.6 References

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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:

- Observations from the site visit.
- Aerial and other photographs of the mine site provided by MRM.
- Mine levee wall inspection notes and photographs.
- Discussions with MRM staff.
- Geomorphological assessment of the McArthur River and Barney Creek diversion channels (Hydrobiology, 2016).
- McArthur River Mine levee wall assessment (Mining One, 2016).
- Other documents such as DPIR field inspection reports and mine levee wall inspection reports.

4.4.2 Key Risks

The key risks to diversion channel hydraulics as described in the risk assessment (Appendix 2) are:

- Flooding within the open pit in a rarer than 0.2% AEP[12] 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.
- Rainfall runoff erosion of the mine levee wall potentially impacting integrity in the long term (Mining One, 2016).
- 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.
- 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.

[12] 1 in 500 year event – 0.2% chance of occurring in any one year.

- 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 its 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 4.14.

Table 4.14 – Existing Control Measures in Place for Risks Associated with Diversion Channel Hydraulics

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 2009-2010 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
Ponding of water between channel diversion and mine bund	♦ Not identified in Hydrobiology (2016) report; not observed during any site inspection ♦ Independent inspection carried out by Mining One Consultants in October 2016 did not identify ponding at the toe of the mine levee wall (Mining One, 2016) ♦ This is no longer considered a risk and will be removed from the risk register
Ongoing erosion in McArthur River diversion channel	♦ 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 or 2016 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 ♦ Large woody debris (LWD) placement operation are ongoing with new plans to create a 'permanent' access ramp into the 'gorge' section to allow placement in currently inaccessible areas
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
Sourcing of appropriate materials	♦ Systematic planning for sourcing of LWD timber has been conducted with timber sources identified for the next 10 years (ending 2027)

4.4.3.2 New Controls – Implemented and Planned

The following new controls were implemented in the 2016 operational period:

Implemented Controls

- Ongoing erosion in McArthur River diversion channel:
  - Revegetation operations have been planned and are soon to be carried out, which will address another 800-m section of the McArthur River diversion channel.
  - Large woody debris (LWD) placement operations are ongoing with new plans to create a permanent access ramp into the 'gorge' section of the diversion channel to allow placement in currently inaccessible areas.
- Integrity of mine level wall:
  - Independent inspection undertaken (Mining One, 2016).
  - Regular inspections being carried and documented.
- Sourcing of appropriate materials (rock and wood):
  - Systematic planning for sourcing of LWD timber has been conducted with timber sources identified for the next 10 years.

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 currently being considered, including:
  - Revision of the existing hydraulic model to incorporate the present-day topography (the IM has been advised that this is 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.
  - 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 currently 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 2016 operational period relating to diversion channel hydraulics.

Non-compliances

The IM has not identified any non-compliances in the 2016 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 stability, timber sourcing and mine levee wall integrity.

Progress

Revegetation operations have been planned and are soon to be carried out on the McArthur River diversion channel, which will address another 800-m section of the right bank immediately downstream of the previous works. Revegetation plans are discussed in detail in Section 4.9 and include an additional irrigation sled with drip lines to the 800-m bank section, additional woody vegetation and a refocus on grasses for ground cover and bank stabilisation. It is also understood that a rehabilitation management plan is to be developed soon (2017) which will identify appropriate vegetation, soil remediation and landform slopes for rehabilitation of the diversion.

Placement of LWD is ongoing with the addition of LWD in 2016 to a ~500-m section of the McArthur River diversion channel and its downstream extent. Additionally, plans are in place to create a permanent access ramp into the gorge section of the McArthur River diversion channel. This will allow LWD placement in areas currently inaccessible to heavy vehicles. Monitoring activities are well documented with the creation of maps indicating where LWD has been placed and dumped. Additionally, systematic planning for sourcing of LWD timber has been conducted with timber sources identified for the next 10 years (ending 2027). This is a significant improvement to the LWD placement program. 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.

Other plans for diversion stability improvements were discussed with MRM staff during the site visit. The gorge section of the McArthur River diversion channel was discussed in detail with reference to its impact on hydraulics. This 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. Although not formalised, plans are being discussed to counter this effect including potentially battering the banks back at this location to reduce the constriction.

Independent inspections have been carried out on the diversion channels (Hydrobiology, 2016) and mine levee wall (Mining One, 2016). Notably, no signs of water ponding at the toe of the levee wall were identified in the Mining One (2016) or Hydrobiology (2016) reports. Nor has this been identified by the IM during any site visit. As this area has not been identified it is no longer considered a risk and will be removed from the risk register.

The investigations into the diversion channels and the mine levee wall were recommended in the last IM Report (ERIAS Group, 2016) and as such, their completion addresses those recommendations. However, the investigations have also identified new issues, discussed below.

New Issues

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 and summarised below:

- 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:
  - Revision of the existing hydraulic model to incorporate the present-day topography (the IM has been advised that this is 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.
- 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. As discussed above, informal plans for diversion stability improvements were discussed with MRM staff during the site visit.
- Barney Creek diversion channel instabilities: The report recommends an investigation into the alignment of the confluence of Surprise Creek and the old Surprise Creek path. 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.
- 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.

- 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 (Plates 4.1 and 4.2). 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.

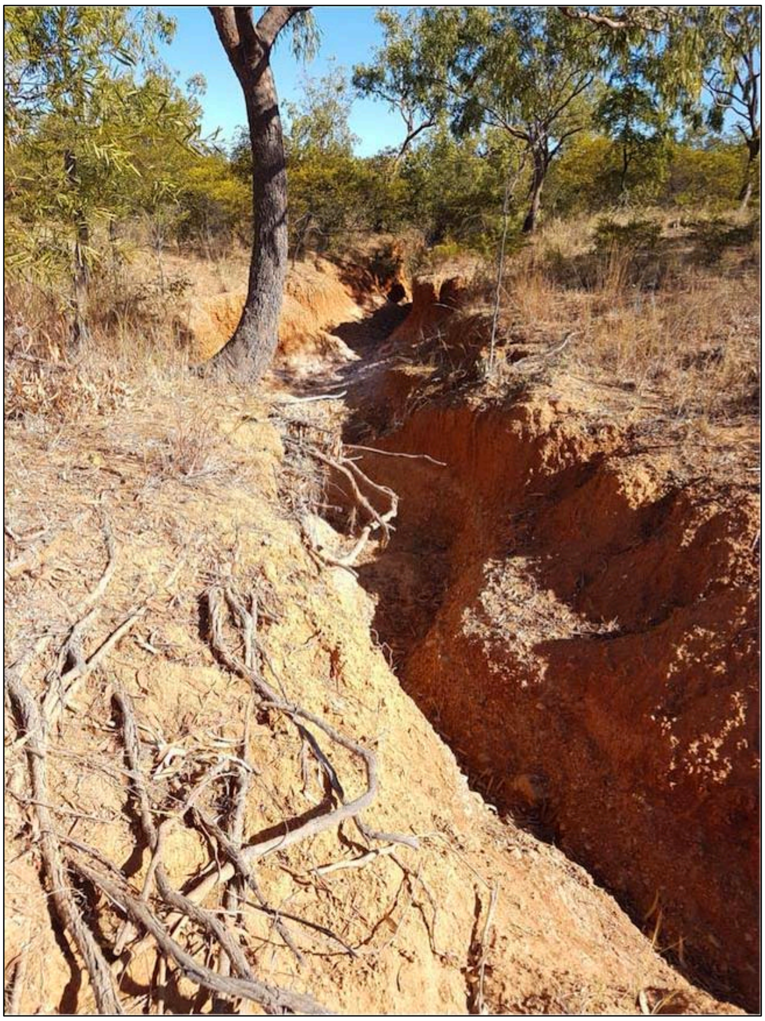
Plate 4.1 – Location of Erosion Gullies on Surprise Creek Southwest of the NOEF SPROD

- 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. The report recommends:
  - 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 Hardie and Lucas (2002).

Plate 4.2 – Erosion Gully at Southwest Corner of SPROD



An independent inspection of the mine levee wall was undertaken in October 2016 (Mining One, 2016). The inspection found several areas where the mine levee wall is experiencing erosion due to local surface run off and identified areas of sparse vegetation and limited rock armouring. Recommendations are made in the report to address these areas. The inspection found no indication that the identified erosion is presently impacting the integrity of the mine levee wall, however, acknowledged that until preventative measures were taken (rock armouring and revegetation), heavy rain will continue to erode the embankment and possibly cause instability in the long term. The report identified one area where due to sparse vegetation and a lack of rock armouring, erosion may be exacerbated rapidly during heavy rain (area between Access 2 and Access 3, Figure 4.10), and recommended placing rock fill over this area. Whereas no indication

AREA OF MINE LEVEE WALL RECOMMENDED FOR ROCK PROTECTION

McArthur River Mine Project

FIGURE 4.10

Source: Mining One, 2016

was given for the amount of rock required, the area indicated for rock placement is large. This is likely to increases the demand for ‘clean’ rock significantly and highlights the need for a plan for sourcing rock. Regular inspections of the mine levee wall are being carried out and documented by MRM staff.

The Mining One (2016) report also pointed out that previous instabilities or major erosion damage has occurred during the life of the mine levee wall that have since been remediated. The report recommended that documentation and photographs of the remediation works be kept in the future.

McArthur River Mining’s performance against previous IM review recommendations relating to diversion channel hydraulics is outlined in Table 4.15.

Table 4.15 – Diversion Channel Hydraulics Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2015 Operational Period		
There were no new recommendations in the 2015 operational period		
2014 Operational Period		
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 ♦ 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 for the next 10 years (ending 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 2016 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)	Geomorphic assessment undertaken in 2016 (Hydrobiology, 2016). Issues associated with an avulsion upstream of the diversion identified. A mitigation options analysis was recommended
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	Not identified as a risk in the Hydrobiology (2016) report. Inspections are being carried out annually but not reported on

Table 4.15 – Diversion Channel Hydraulics Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Ponding of water	The site referred to in the 2011 IM Report (EES, 2012) as 'ponding of water between the diversion channel and mine bund' has yet to be inspected. The 2011 IM Report (EES, 2012) recommended re-contouring the section to provide adequate drainage. It is recommended that the location of this site be identified and that the status of the recommended actions be reported	Completed. No signs of water ponding at the toe of the levee wall were identified in the Mining One (2016) or the Hydrobiology (2016) reports. Nor has this been identified by the IM during any site visit
2012 and 2013 Operational Periods		
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 results of the Phase 3 Development Project Surface Water Assessment (WRM, 2012a) and the Review of the 'As-Designed' and 'As-Constructed' McArthur River and Barney Creek diversion channels (WRM, 2012b) ♦ 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 4.16
Erosion	Ongoing monitoring of diversion channel and bank erosion should continue using airborne laser scanning complemented by photograph monitoring, and visual inspection. It is recommended that an annual report on observed erosion should then be completed. These reports should detail: ♦ The observed erosion ♦ The existing mitigation measure (if any) ♦ The planned mitigation measures ♦ The status of implementation of the planned mitigation measure	♦ The Hydrobiology (2016) report was a thorough assessment of diversion channel and bank erosion ♦ No reporting on erosion monitoring was sighted other than the Hydrobiology (2016) report

4.4.4.3 Successes

The completion of the geomorphological assessment (Hydrobiology, 2016) and the independent mine levee wall inspection (Mining One, 2016) represent significant steps forward. These reports highlight issues at the site and assist in planning related to diversion rehabilitation and mine levee wall integrity.

Plans in place to create a permanent access ramp into the gorge section of the McArthur River diversion channel to allow LWD placement are commendable. This will allow LWD placement in areas previously inaccessible to heavy vehicles.

The planning for sourcing of LWD timber has been conducted with timber sources identified for the next 10 years (ending 2027). This is a significant improvement to the LWD placement program.

4.4.5 Conclusion

Progress has been made in various areas relating to the diversion hydraulics and mine levee wall integrity in the 2016 operational period. These include:

- Revegetation operations.
- Large woody debris (LWD) placement.
- Sourcing of LWD timber.
- Diversion stability improvements.
- Inspections of the mine levee wall.

The investigations into the diversion channels and the mine levee wall were recommended in the last IM Report (ERIAS Group, 2016) and as such, their completion addresses those recommendations. However, the investigations have also identified new issues as listed in Table 4.16. The observations and recommendations in the reports are endorsed by the IM.

The potential for erosion of the mine levee wall at the McArthur River offtake as identified in the Hydrobiology (2016) report is a serious risk with potentially catastrophic consequences, and is exacerbated by the active avulsion upstream. This is considered a priority for investigation for the next reporting period.

The lateral migration of Surprise Creek is also a concern and should be monitored. It is understood that a measure proposed in the Draft OMP EIS is to remove the TSF at closure and pump the tailings to the pit. Even if this measure is approved, there are still many years before the TSF is completely removed. Surprise Creek should therefore be monitored regularly, particularly after large rainfall events.

Table 4.16 – New and Ongoing Diversion Channel Hydraulics Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Erosion	♦ Ongoing monitoring of diversion channel and bank erosion should continue using ALS complemented by photograph monitoring and visual inspection. It is recommended that an annual report on observed erosion should then be completed ♦ It is recommended that this 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	The independent inspection report by Mining One (2016) recommends 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
New Items		
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	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
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

ERIAS Group. 2016. Independent Monitor Environmental Performance Annual Report 2015, McArthur River Mine. Report No. 01164C_1_v2. October. Report prepared by ERIAS Group Pty Ltd for the Northern Territory Department of Mines and Energy, Darwin, NT.

Hardie, R and Lucas, R. 2002. Bowen Basin River Diversions Design and Rehabilitation Criteria. Project C9068, July 2002. Report prepared by Fisher Stewart Ltd for the Australian Coal Association Research Program (ACARP), Brisbane, Queensland.

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.

Mining One. 2016. Memorandum – McArthur River Mine Levee Wall Assessment. 21 October 2016. Prepared by Harley Greaves of Mining One Pty Ltd for McArthur River Mining, Winnellie, NT.

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 (as listed in Appendix 1), which includes:
  - The approved current mining management plan volumes 1 and 2 (MRM, 2015a and 2015b).
  - The 2013-2015 operational performance report (OPR) (MRM, 2016a).
  - The 2014-2016 groundwater monitoring report (KCB, 2016a).
  - The Overburden Management Project draft environmental impact statement (Draft OMP EIS) (MRM, 2017a).
  - Quarterly and annual reports relating to the remediation of the 2011 diesel spill (MRM, 2016b; 2016c; 2017b).
  - Other reports and documents relating to the McArthur River mine, TSF, OEFs, PAF runoff dams, pit and underground, and the Bing Bong Loading Facility.
- Various Excel workbooks provided by MRM that contain collated water quality data for 2015 and 2016 (MRM, 2017c), and water monitoring and monitoring bore schedules for 2016 and 2017 (MRM, 2017d).
- 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 2), 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.

From an operation phase perspective, key risks are as follows:

- 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 aquatic and terrestrial 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 aquatic and terrestrial ecosystems where groundwater discharges to creeks/rivers or to the surface.
- Poor quality seepage from water storages, including the PAF runoff dams and the dams and ponds used to manage dirty and contaminated water, impacting groundwater quality and aquatic and terrestrial 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 aquatic and terrestrial 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 aquatic and terrestrial ecosystems where groundwater discharges to creeks/rivers or to the surface.

In terms of the post-mining closure phase, the key risks are:

- Poor quality seepage from the pit lake reporting to the groundwater system after mine closure, impacting groundwater quality and aquatic and terrestrial ecosystems where pit lake water discharges to creeks/rivers.
- 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 aquatic and terrestrial 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 aquatic and terrestrial ecosystems where groundwater discharges to creeks/rivers or to the surface[13].

[13] MRM's preferred strategy, as described in the Draft OMP EIS, is to retreat the tailings and place them into the final pit void at closure, which, if adopted, will minimise the post-closure risks associated with the TSF.

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 PAF 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

Groundwater monitoring data is collected by MRM at both the McArthur River Mine and Bing Bong Loading Facility. Monitoring bores at the mine site were previously divided into two groups:

- Committed monitoring bores which MRM was required to monitor under the water management plan.
- Non-committed monitoring bores at the mine site which were used intermittently by MRM for internal assessments.

This division has been revised and all bores are now included in the annual reporting[14].

A summary of the monitoring bores at the mine site and Bing Bong Loading Facility is provided in Table 4.17.

Table 4.17 – Monitoring Bore Summary

Facility	Number of Monitoring Bores
TSF (includes Cells 1 and 2, the WMD and tailings pipeline corridor)	90
NOEF (includes the SPROD, SEPROD, WPROD and Emu Creek)	88
Processing Plant area	6
McArthur River pit and underground	39
Bing Bong Loading Facility	27
Diesel spill area	28

[14] All the monitoring bores at the Bing Bong Loading Facility have historically been classified as committed bores.

Groundwater monitoring data is assessed annually either as part of the MMP or for the operation's groundwater review. 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 requested DPIR to allow a reduction in the frequency of the sampling and reporting for the diesel spill remediation (MRM, 2017e).

McArthur River Mining's groundwater monitoring schedule is summarised in Table 4.18 and the monitoring bore locations are shown in Figures 4.11 (TSF area), 4.12 (NOEF area), 4.13 (processing plant, and McArthur River Mine pit and underground area), 4.14 (Bing Bong Loading Facility) and 4.15 (vicinity of the 2011 diesel spill).

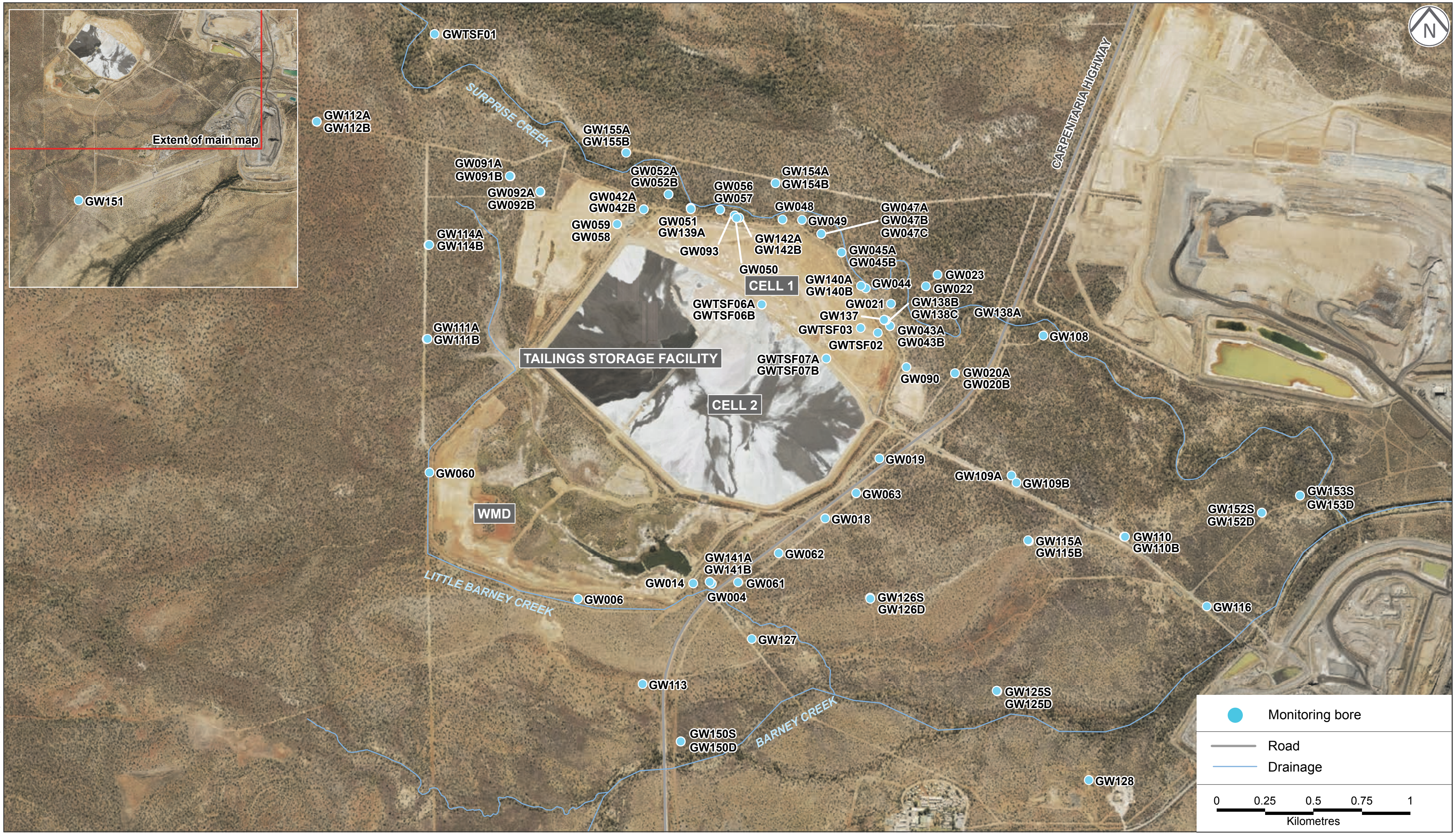
Table 4.18 – Groundwater Monitoring Schedule Summary

Location	Parameters	Frequency
TSF	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 3 (pH, EC, TSS, 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, Fe^{2+}, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg)	Quarterly (35 bores), bi-annually (42 bores), annually (13 bores)
	Organics Suite 1 (TPH and BTEXN)	Bi-annually (4 bores)
NOEF	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 3 (pH, EC, TSS, 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, Fe^{2+}, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg)	Monthly (16 bores), quarterly (68 bores), bi-annually (4 bores)
Plant area	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 3 (pH, EC, TSS, 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, Fe^{2+}, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg)	Quarterly (all bores)
	Organics Suite 1 (TPH and BTEXN)	Bi-annually (all bores)
McArthur River pit and underground	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 3 (pH, EC, TSS, 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, Fe^{2+}, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg)	Quarterly (15 bores), bi-annually (10 bores), annually (14 bores)
Bing Bong Loading Facility	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 3 (pH, EC, TSS, 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, Fe^{2+}, Mn, Mo, Ni, Pb, Se, Sb, Tl, U, V, Zn & Hg)	Monthly (5 bores), quarterly (9 bores), bi-annually (13 bores)
	Organics Suite 1 (TPH and BTEXN)	Bi-annually (4 bores)
Diesel spill area	Field Suite 1 (Field pH, Temp, DO, EC, Turb, ORP, Obs and SWL) & Laboratory Suite 6 (pH, EC, TSS, TDS, Ca, Mg, Na, K, hardness, Cl, SO_4, F, alkalinity, alkalinity, ionic balance, filtered Hg and Mn, TPH and BTEXN, sulfide, salinity)	Quarterly (all bores)
	Field Suite 6 (water/diesel interface)	Fortnightly (all bores)

GROUNDWATER MONITORING BORES - TSF

McArthur River Mine Project

FIGURE 4.11



GROUNDWATER MONITORING BORES - NOEF

McArthur River Mine Project

FIGURE 4.12

ERIAS Group | 01164D_1_F4-12_v1.pdf

GROUNDWATER MONITORING BORES - McARTHUR RIVER MINE PIT AND PROCESSING PLANT

McArthur River Mine Project

FIGURE 4.13

ERIAS Group | 01164D_1_F4-13_v1.pdf

GROUNDWATER MONITORING BORES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.14

GROUNDWATER MONITORING BORES - VICINITY OF 2011 DIESEL SPILL

McArthur River Mine Project

FIGURE 4.15

A number of monitoring bores were installed at the NOEF as part of a hydrogeological and geochemical investigation completed by MRM (MRM, 2016d). These comprise 16 bores located at six sites across the facility, with the bores being screened within the mine waste, at the natural ground surface and within the underlying alluvium and bedrock. The bores were monitored monthly to assess hydrogeological conditions within the NOEF and seepage impacts on the underlying groundwater system.

Higher frequency monitoring will also be carried out around dredge spoil ponds at the Bing Bong Loading Facility before and three months after any dredging operations. The data collected will be used to investigate impacts on the groundwater system from deposition of the slurry discharge.

Six monitoring bores near the NOEF, which have shown evidence of seepage impacts, have been equipped with water pressure and EC loggers to capture short-term trends in groundwater level and salinity. In addition, 92 monitoring bores across the mine site, including the majority of the recently-completed NOEF bores, have been equipped with water pressure loggers. The instrumented bores should provide an improved insight into seepage and groundwater recharge processes.

Groundwater trigger values are used at the mine site and at the Bing Bong Loading Facility to help identify impacts on groundwater quality, as stated in the 2013-2015 operational performance report (MRM, 2016a). The trigger values are based upon the water quality limits for livestock in ANZECC/ ARMCANZ (2000) guidelines.

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 the 2014 IM reporting period around SPROD, SEPROD and the proposed EPROD.

The surveys around the TSF show both shallow and deep areas of higher EC at two locations on the northern side of TSF Cell 1, at the southeast corner of TSF Cell 2, and on the eastern side of TSF Cell 3 WMD coincidental with the old Little Barney Creek channel. The results for the SPROD show a broad front of higher EC extending south and west of the dam towards Surprise Creek.

A review of the program by MRM indicated that the results were strongly influenced by the groundwater depth. However, the surveys do appear to 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.

Development of Conceptual Geological and Hydrogeological Models

Considerable effort has been made to further develop geological and hydrogeological models for the mine site. This work 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 by URS (2012) for the Phase 3 EIS.
- Site-wide studies and more targeted studies in the TSF and NOEF areas completed by KCB (2015d; 2016b).

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 groundwater flow models have previously been developed for the mine site. These include:

- A two-dimensional (2-D) model of pit developed by Golder Associates (Golder) to estimate inflows via the McArthur River channel alluvium (Golder, 2004).
- A three-dimensional (3-D) MODFLOW-SURFACT model developed by URS to investigate seepage from the TSF (URS, 2006).
- A 2-D model of TSF Cell 1 (Golder, 2011).
- A preliminary site-wide 3-D model developed by URS for the Phase 3 EIS to estimate both dewatering rates from the pit and underground, and drawdown impacts from pumping (URS, 2012).
- Refinement of the URS Phase 3 EIS model by RPS on two occasions to investigate seepage impacts from the proposed EPROD and SEPROD (RPS, 2013; 2012).
- Various 2-D models of the NOEF and proposed WPROD developed by KCB during the previous reporting period (KCB, 2014; 2015a; 2015b; 2015c).
- A 3-D model developed by GHD for the area around the TSF, incorporating saturated and unsaturated flow, which was based on earlier site-wide modelling completed by URS (GHD 2016a; 2016b). The model was used to investigate various seepage mitigation design options.

Further modelling has been undertaken during the current reporting period by KCB as part of the Draft OMP EIS, as 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.

The IM notes that MRM's preferred option for the final pit void, as outlined in the Draft OMP EIS, is based on a flow-through system. This allows for the diversion of a proportion of the 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 in below (see Pit Void Lake Water and Solute Balance Model) based on a limnology model developed for the Draft OMP EIS (Tropical Water Solutions, 2016).

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. The palaeochannel is thought to trend through the pit and provide a conduit to the McArthur River.

As for the seepage recovery systems (discussed above), there is some uncertainty regarding the effectiveness of the existing geopolymer barriers. Assessments reported in KCB (2015d) 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 4.16.

Lining of Water Storages

A number of storages are operated by MRM to manage potential release water, poor quality water and process water (Classes 4, 5 and 6 (WRM, 2015)). 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.

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. 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 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 either completed or were proposed during the review period. The majority of the completed studies were associated with the Draft OMP EIS.

TAILINGS STORAGE FACILITY GEOPOLYMER BARRIER AND TRENCH LOCATION PLAN

McArthur River Mine Project

FIGURE 4.16

Various new controls were also applied to limit impacts upon the groundwater environment. The recent (or recently proposed) studies and controls include:

- Collation of the available historical geological and hydrogeological data of the mine site, and updating of the geological and hydrogeological model.
- Development of a groundwater flow and solute transport model for the area around the TSF.
- Development of a site-wide groundwater flow and transport model for the mine site.
- Development of a water and solute balance for the post-closure pit void lake.
- Implementation of a number of field programs at various sites including the TSF, NOEF and Bing Bong Loading Facility.
- Installation of new bores into the underground mine to allow future mine dewatering.
- Lining of the SPROD using a synthetic liner.
- Suspending use of the ELS.
- Development of site-specific trigger values for groundwater quality.
- Diesel spill remediation (ongoing assessment).

These studies are described in more detail in the following sections.

Conceptual Geological and Hydrogeological Model Update

McArthur River Mining and its consultants have undertaken a major review of the available geological and hydrogeological information, including historical data collected during project development. This information is being used to revise the geological and hydrogeological conceptual models for the sites, including:

- Improved delineation of geological and hydrogeological units and characterisation of their hydraulic properties.
- Improved delineation of geological faults and characterisation of their hydraulic properties.
- Better identification of hydrogeological units (e.g., aquifers and aquitards) across the mine site.
- Assessment of possible higher permeability zones.
- Identification of naturally mineralised areas that may impact on nearby groundwater quality.

The updated conceptual models will assist in implementation of field investigations and further development of the various groundwater flow and transport models developed or planned to be developed for the mine site. This approach is considered essential under MRM's proposed adaptive management approach for the operation.

TSF Groundwater Flow Modelling

A 3D groundwater flow and transport model was developed for the area around the TSF by KCB as part of the Draft OMP EIS (KCB, 2017; Appendix 1). The model was developed mainly to assess the effectiveness of two seepage mitigation strategies against a 'do-nothing' base case. Outputs included estimates of TSF seepage rates, impacts on surrounding groundwater levels, SO_4 loads leaving the TSF and entering nearby creeks, and SO_4 concentrations in the surrounding groundwater.

The model was based on the updated geological and hydrogeological models (described above) and calibrated against groundwater level data and, less successfully, against recorded SO_4 concentrations and baseflow estimates in Surprise and Barney creeks. The simulated TSF seepage flux was also compared against the results of earlier modelling studies.

The seepage mitigation strategies simulated in the model comprised two options to excavate an interception trench between TSF Cell 1 and Surprise Creek. These options involved a shallow trench extending 1 m below the base of Surprise Creek and a deeper trench excavated 2 m below the base of Surprise Creek. The model was not used to assess the benefits of primary source controls (e.g., decant pond management, treatment of decant water and mud farming) or active measures to control deeper seepage (e.g., recovery bores).

The TSF modelling results are summarised in Table 4.19.

Table 4.19 – Summary of TSF Modelling Results

Scenario	Outcomes	Predictions
Base case: no new seepage mitigation measures	TSF seepage outflows	TSF seepage varies from 10-13 L/s (current) to 23-24 L/s (2037). Seepage inflows to Surprise Creek and Barney Creek remain consistent over the model run, inflows range seasonally from 5-15 L/s and 2-3 L/s respectively
	Tailings and bedrock groundwater levels	Mounding underneath the TSF reaches about 50 mAHD and extends south and east of the facility. Mounding to the north is controlled by seepage to Surprise Creek. Local lowering of groundwater levels occurs adjacent to Barney Creek. Water levels in the deposited tailings at the end of operations reach about 70 mAHD
	Sulfate loads	Sulfate loads from the TSF increase over the period of operation reaching about 3,500 kg/day by 2037, consistent with the rising seepage rate. A similar rising trend is predicted in the load to Surprise Creek (1,000 kg/day up to 3,000 kg/day in 2037). Loads in Barney Creek remain around 700 kg/day)
	Groundwater SO_4 concentrations	Sulfate concentrations in the groundwater are consistent with predicted groundwater levels, with near background concentrations north of Surprise Creek, which acts as an interception drain
Scenario 1: shallow interception trench between TSF Cell 1 and Surprise Creek	TSF seepage outflows	Similar seepage rates from the TSF and to Barney Creek over the life of mine (compared to the base case). Seepage rates to the interception trench and Surprise Creek are steady at about 4-6 L/s and 5-10 L/s respectively. The combined flows to the interception trench and Surprise Creek are slightly higher than the seepage to Surprise Creek under the base case

Table 4.19 – Summary of TSF Modelling Results (cont'd)

Scenario	Outcomes	Predictions
Scenario 1: shallow interception trench between TSF Cell 1 and Surprise Creek (cont'd)	Tailings and bedrock groundwater levels	Similar to the base case
	Sulfate loads	Sulfate loads from the TSF are slightly higher than those predicted for the base case. Loads to the interception trench rise from about 700 kg/day to 4,000 kg/day in 2037. Loads to Surprise Creek increase modestly over the life of mine from 700 kg/day to 1,500 kg/day, i.e., roughly half the load predicted for the base case. Loads to Barney Creek are similar to the base case
	Groundwater SO_4 concentrations	Sulfate concentrations are predicted to fall north of Surprise Creek, because of capture of previously contaminated water by the trench. Away from this area the predicted SO_4 concentrations are similar to the base case
Scenario 2: deep interception trench between TSF Cell 1 and Surprise Creek	TSF seepage outflows	Similar seepage rates from the TSF and to Barney Creek over the life of mine (compared to the base case and Scenario 1). Seepage rates to the interception trench higher and comparable with rates to Surprise Creek at about 5 to 10 L/s. This equates to an increase in the combined flow compared to Scenario 1
	Tailings and bedrock groundwater levels	No information provided
	Sulfate loads	Loads to the interception trench increase compared to Scenario 1, ranging from 1,800 kg/day to 5,000 kg/day by 2037. There is a corresponding drop in the Surprise Creek loads, which range from 600 kg/day to 1,100 kg/day by 2037. This represents a 10-15% reduction in the loads to Surprise Creek. Loads to Barney Creek are similar to those predicted for the base case and Scenario 1
	Groundwater SO_4 concentrations	No information provided

The modelling results suggest that Surprise Creek acts as a natural interception feature for TSF seepage to the north, which is consistent with measured creek water quality. Construction of an interception trench extending 1 or 2 m below the invert level (base) of the creek bed would be expected to capture most of the seepage emanating from the TSF and nearby previously contaminated water. A deeper trench would likely increase the effectiveness of the recovery system.

The effectiveness of the Surprise Creek interception trench will be localised and could increase total seepage from the TSF because of the increased hydraulic gradient between the decant pond and the creek/trench. The lowering of the groundwater level around the trench will also induce seepage from the creek to the trench and reduce creek flows. Even with the deeper trench option (excavated 2 m below the creek invert), loads in Surprise Creek at the end of operations in 2037 are predicted to be similar to the current loads. However, the IM judges that a deeper trench is likely the most appropriate means of managing contaminant loads through the overburden aquifer. Additional measures (e.g., seepage recovery bores) are likely to be required to manage contamination via deeper flow paths. The longer-term predictions should be assessed as part of

MRM's adaptive management approach and an assessment made of the acceptability of the predicted future loads entering Surprise Creek.

The TSF model was also used to assess the changes in seepage rates and SO_4 concentrations for the closure option that involves reprocessing the tailings. The results show that flow rates are maintained in Surprise Creek after closure and SO_4 concentrations falling. Sulfate concentrations in Barney Creek are predicted to fall more slowly as the contaminant plume migrates to the south and east of the TSF. These are positive outcomes for the preferred TSF closure option.

The IM considers the use of groundwater models appropriate in assessing impacts from operation of the TSF and evaluating options to mitigate these impacts. However, the IM also recognises that the current model includes a number of significant gaps. These include groundwater flow paths associated with the deeper aquifers and the seepage rates from reactivation of TSF Cell 1. The available information suggests that Cell 1 had high seepage rates when it was previously operated. These gaps should be addressed as part of MRM's proposed approach of adaptive management, which will require further field investigations in the TSF area.

Site-wide Groundwater Flow Modelling

A site-wide 3D groundwater flow and transport model was developed by KCB as part of the Draft OMP EIS (KCB, 2017) in parallel with the TSF groundwater model (described in the previous section). The model was developed to assess:

- Changes to groundwater flow regimes due to seepage from the NOEF, PRODs and TSF.
- Physical stresses from mining operations, e.g., dewatering, groundwater mounding at the TSF and drawdown from the borefields.
- The fate of contaminants from mining, processing and waste management on surface water receptors.
- The effectiveness of mitigation strategies.
- The influence of mine dewatering and post-closure pit lake development on the groundwater environment.

The model was constructed using the updated geological and hydrogeological conceptual models described above, and regional geological interpretation from public sources. Results from a number of other models developed for the Draft OMP EIS were adopted in the groundwater model, including:

- Seepage estimates for the NOEF that were generated using two models, i.e., the DumpSim model, which estimated infiltration through the cover system, and a model developed in TOUGH2 which calculated the subsequent flow to the underlying groundwater system through the compacted clay liner beneath the mine waste.
- Seepage estimates for the PRODs and other water storages which were generated using the site water balance model.

- Seepage estimates for the TSF which were sourced from the TSF groundwater flow model (described in the preceding section).
- The post-closure pit lake water levels estimated by KCB's water and solute pit lake water balance.

The model was calibrated against groundwater level data and recorded SO_4 concentrations. The model was not calibrated to surface water baseflows, which are available at a number of sites on McArthur River, McArthur River diversion channel, and Barney and Surprise creeks, or to metals concentrations that have generally remained below or close to detection limits due to attenuation in the soil and rock.

One predictive transient simulation was completed covering the operating period from 2015 to 2037, and post-closure period from 2037 to 2167; a subsequent long-term post-closure period was then simulated in quasi steady state. McArthur River Mining's preferred closure options were adopted for the simulation, i.e., reprocessing of 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 module included SO_4, 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, 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.

The site-wide modelling results are summarised in Table 4.20.

Table 4.20 – Summary of Site-wide Modelling Results

Model Stage	Outcome	Prediction
Life of mine	Changes to the groundwater flow regime	Groundwater flows up until 2023 are predicted to remain generally from west to east, with radial flow towards the pit due to dewatering. After 2023, groundwater flows from the north towards the pit become more apparent, when the high permeability zone associated with the Western fault is intersected during mining. This results in drawdowns propagating northward beneath the Barney Creek diversion channel
	Physical stresses from mining	Baseflows to McArthur River and Barney Creek diversion channel are predicted to decrease significantly in response to dewatering. The baseflows to the lower reaches of Surprise Creek decrease with the reduction in seepage from SPROD
		Dewatering rates from the underground are consistent over the life of mine. Groundwater inflows from the palaeochannel reduce as dewatering progresses and inflows from the upper bedrock increase as mining progresses. Inflows from the lower bedrock remain low
	Fate of contaminants	Downgradient SO_4 plumes develop from the TSF and NOEF in the bedrock which report to Surprise Creek and Barney Creek. Sulfate plumes from the EOEF and SOEF, and most of the plume from the WOEF, are captured in the drawdown cone around the mine
		Metals do not migrate far beyond their source over the life of mine due to attenuation by soil and rock
		Particle tracking shows seepage from the OEFs reports to the pit at the end of mining, while seepage from the TSF migrates to Surprise and Barney creeks

Table 4.20 – Summary of Site-wide Modelling Results (cont'd)

Model Stage	Outcome	Prediction
Life of mine (cont'd)	Impacts of dewatering on groundwater	A maximum drawdown of about 0.4 m is predicted at Djirrinimini water hole. Similar drawdowns are predicted for the palaeochannel aquifer
Post closure	Physical stresses post mining	Baseflows to McArthur River, Barney Creek and the Barney Creek diversion channel increase as the pit lake develops and groundwater levels recover. Baseflows to Surprise Creek fall with relocation of the tailings to the pit void
	Fate of contaminants	The SO_4 plume from the TSF disperses after closure, because of flushing from groundwater recharge. A minor SO_4 plume develops downgradient of the WOEF, which reports to Barney Creek and the Barney Creek diversion channel. A long-term plume develops south and southeast of the NOEF, which reports to Surprise Creek and the Barney Creek diversion channel
		Sulfate loads to the Barney Creek diversion channel primarily from the NOEF increase after closure as groundwater levels recover and baseflow interaction resumes
		Metal plumes show a slow migration away from the sources after closure
		Particle tracking shows seepage from the NOEF reports to the Barney Creek diversion channel once groundwater levels around the pit have recovered. Seepage from the WOEF still reports primarily to the pit and the residual seepage from the TSF continues to report to Surprise and Barney creeks
	Impacts of the pit void lake on groundwater	Groundwater levels at both the palaeochannel aquifer and Djirrinimini water hole recover within about 5 years

The IM considers the development of the site-wide groundwater 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, as for the TSF model, there are a number of significant gaps, 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).
- Identification of groundwater flow paths associated with the deeper aquifers, particularly faults, which have a major impact on the model predictions and are currently assumed to be associated with a uniform corridor of higher permeability.
- The seepage rates from the NOEF, especially after closure.
- The locations of naturally mineralised zones, which have been inferred from anomalous monitoring results.
- The attenuation of metals, which does not allow for flow via discrete pathways and has a major impact on the results from the solute transport modelling.

- Interaction between the groundwater system and pit lake after closure, which has a major impact on the post-closure results and implications for MRM's preferred pit lake management option.

These gaps will require ongoing field investigations to improve MRM's understanding of the groundwater system at the mine site.

As noted above, the model was not calibrated against surface water baseflows. It is recommended that this calibration be carried out, which should provide significantly more confidence in the simulation of key model parameter including recharge, evapotranspiration and groundwater-surface water interaction. The IM also notes that MRM is planning to install a number of new flow gauging stations to improve the collection of baseflow data, which should provide an excellent dataset going forward.

Pit Void Lake Water and Solute Balance Model

A pit lake water and solute balance model was developed by KCB (KCB, 2016b), which was revised as part of the Draft OMP EIS (KCB, 2017; Appendix IV). The model was used to assess the likely pit lake quality after closure, as well as the pit lake's impact upon the surrounding environment and its compatibility with MRM's preferred closure option to flood the pit and allow seasonal inflows and outflows to McArthur River.

As for the TSF and site-wide groundwater models, the pit lake water and solute balance provides a good preliminary assessment of the preferred pit closure option. The IM has provided a detailed technical review as part of its review of the Draft OMP EIS which has identified gaps to be addressed in the Supplementary EIS. The IM recognises that some of the gaps cannot be adequately addressed until after closure, when monitoring of the pit lake conditions will allow the various models to be adequately calibrated.

Field Investigations

A significant number of ongoing field investigations have also been undertaken to support the revised conceptual models at the mine site (discussed above), with the aim of:

- Improving the delineation of geological and hydrogeological units and characterisation of their hydraulic properties.
- Further characterising the deeper groundwater system within the fresh bedrock.
- Better identifying geological faults and characterisation of their hydraulic properties, e.g., the Bald Hills, Emu, Woyzbun and Mt Stubbs faults.
- Assessing other features that may have enhanced hydraulic conductivity, e.g., the higher permeability zones between the NOEF and Emu fault.
- Identifying groundwater flow paths in areas such as north-east of the mine levee and near the downstream part of the McArthur River diversion channel.
- Improving the understanding of the interaction between the TSF and groundwater system.

Numerous bores were drilled as part of the Draft OMP EIS and the comprehensive program of hydraulic testing that was completed. These comprised four pumping tests, 96 slug tests and 29 packer tests. Field programs are ongoing. These include installation and testing of production bores north of TSF Cell 1 which was underway during the 2017 IM site visit.

Field investigations were conducted at the CWNOEF to investigate an anomaly identified from aerial photography. The investigation comprised the drilling of three drill-holes and construction of one monitoring bore. The three drill-holes were airlifted to estimate yields, which were low (i.e., less than 0.3 L/s).

Collection of field data to reduce key uncertainties in the conceptual and numerical groundwater flow models is considered essential. The main knowledge gaps identified by the IM are provided in the TSF and site-wide modelling sections above.

Field investigations were also conducted at the Bing Bong Loading Facility. These comprised the installation of nested monitoring bores at BBGW09A and B, and BBGW10A and B, and the slug testing of all the monitoring bores at the facility. The results were used to improve the conceptual hydrogeological model for the area.

Installation of New Underground Mine Bores

The dewatering of the mine includes pumping from the old underground workings, which produces between 90 L/s and 200 L/s (KCB, 2016a). The pumping system is currently centred around the original eastern vent rise (Evasee). Mining is now encroaching on this area and MRM has installed new pumping bores into the underground workings adjacent to pond P2. The new location should be suitable for the life of mine.

McArthur River Mining intends to relocate the Evasee pumps to the new bores in 2017.

Lining of the SPROD

McArthur River Mining plans to minimise seepage from the SPROD with installation of a synthetic liner. This follows on from work completed in 2016 when the original clay liner was reworked to reduce high seepage rates of around 4,000 m^3/d.

The installation of a synthetic liner has been approved by the DPIR and was originally planned for 2016, but has been delayed with the onset of the 2016/17 wet season and subsequent impoundment of contaminated runoff from the low-grade stockpile. It is now likely that the dam will not be lined until 2018.

Decommissioning of the ELS

High SO_4 concentrations have been recorded at five monitoring bores located south and east of the ELS (GW129S, GW129D, GW130, GW145S and GW145D), which are judged to be impacted by seepage from the storage. To mitigate potential seepage impacts, MRM elected to discontinue operation of the ELS, until further investigations and/or upgrading of the storage was completed.

Development of Site-specific Trigger Values

McArthur River Mining recognises that the use of a uniform groundwater quality limit across the mine site and Bing Bong Loading Facility is inappropriate, because of the natural groundwater variation across the sites. Therefore, the current limit, which is based on the ANZECC/ ARMCANZ (2000) guideline limit for livestock, will be replaced with site-specific trigger values.

Baseline groundwater quality ranges will be established for areas across the mine site and Bing Bong Loading Facility using the extensive monitoring record and the method provided in ANZECC/ARMCANZ (2000). This approach has been previously recommended by the IM and other reviewers. The IM notes that a number of the areas have already been contaminated and hence it may be necessary to define reference conditions using analogous areas.

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 the 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, 2011).

The results from the remediation program presented in the 2014-2016 OPR update (MRM, 2016a) 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 extent of migration to the west 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), although the IM notes that the monitoring bore coverage to the east and northeast of the impacted area is minimal, particularly with the loss of bore URS17. Consideration should be given to installing replacement bores at URS17 and URS23 (both destroyed during the review period) and bore URS03 (previously destroyed).

The plume extents have been influenced by fracture flow rather than radial flow. Total product recovery as of 1 July 2016 was 3,324 L, which represents around 12.01% of the spill volume (MRM, 2016c). Natural attenuation appears to be active in the area of contamination, although there are large temporal variations in measured concentrations of indicator parameters (e.g., SO_4, alkalinity, NO_3, ferrous Fe and Mn). 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.

4.5.4 Review of Environmental Performance

4.5.4.1 Incidents and Non-compliances

Incidents

No groundwater-related incidents were recorded over the review period.

Non-compliances

Non-compliances during the review period included the following:

- A number of monitoring bores were not sampled in accordance with the schedule provided in Table 4.18. It is understood that this was due to access constraints.
- Samples collected from a number of monitoring bores exceeded the livestock limits for total dissolved solids (TDS), SO_4, Ca, B, Cu, F, Pb, Mo, Ni and Se. The groundwater quality exceedances are summarised in Table 4.21 and the locations of bores with unacceptably high SO_4 and TDS concentrations (based on groundwater trigger values) are shown in Figure 4.17 for the mine site, and Figure 4.18 for Bing Bong Loading Facility.

Table 4.21 – Groundwater Quality Exceedances

Parameter	Stock Limit (mg/L)	Bores Where Groundwater Quality Exceeded Trigger Values
TDS	5,000	Mine Site - GWSS6-1, GW004, GW014, GW018, GW019, GW020A, GW020B, GW021, GW042A, GW043A, GW043B, GW044, GW045B, GW047B, GW047C, GW048, GW049, GW050, GW051, GW052A, GW052B, GW056, GW057, GW062, GW063, GW064D, GW064S, GW065D, GW065S, GW090, GW092A, GW093, GW095D, GW095S, GW096D, GW096S, GW097, GW100, GW105, GW109B, GW110, GW110B, GW115B, GW116, GW125D, GW128, GW129D, GW132, GW138A, GW140A, GW140B, GW141A, GW141B, GW142A, GW142B, GW145S
		Bing Bong Loading Facility - GWBB009A, GWBB009B, GWBB010A, GWBB010B, GWBB01A, GWBB01B, GWBB02, GWBB03A, GWBB03B, GWBB04A, GWBB04B, GWBB05A, GWBB05B, GWBB05C, GWBB06C, GWBB07B, GWBB08A, GWBB08B, GWBB08C
Calcium	1,000	Bing Bong - GWBB009B, GWBB05C, GWBB06C, GWBB08C
Sulfate	1,000	Mine site - DRPURS01, DRPURS02, DRPURS14, DRPURS15, DRPURS18, GWSS6-1, GWSS6-2, GW003A, GW004, GW014, GW016, GW018, GW019, GW020A, GW020B, GW021, GW042B, GW043A, GW043B, GW044, GW045B, GW047B, GW047C, GW048, GW049, GW050, GW051, GW052A, GW052B, GW056, GW057, GW058, GW059, GW061, GW062, GW063, GW064D, GW064S, GW065D, GW065S, GW087D, GW087S2, GW090, GW092A, GW093, GW094D, GW095D, GW095S, GW096D, GW096S, GW097, GW100, GW102, GW103D, GW103S, GW104D, GW104S, GW105, GW109, GW109B, GW110, GW110B, GW115B, GW116, GW125D, GW125S, GW126D, GW126S, GW128, GW129D, GW132, GW134, GW136, GW137, GW138A, GW138B, GW138C, GW139, GW140A, GW140B, GW141B, GW142A, GW142B, GW143D, GW143S, GW144D, GW145D, GW145S, GW149D, GW149S, GW150S, GW152D, GW152S, GW153D, GW153S, GW154B
		Bing Bong Loading Facility - GWBB009A, GWBB009B, GWBB010A, GWBB010B, GWBB01A, GWBB01B, GWBB02, GWBB03A, GWBB03B, GWBB04A, GWBB04B, GWBB05A, GWBB05B, GWBB05C, GWBB06B, GWBB06C, GWBB07B, GWBB08A, GWBB08B, GWBB08C
Boron	5	Mine site - GW132
Copper	0.5	Mine Site - GW064D, GW072, GW074, GW075, GW076, GW077

Table 4.21 – Groundwater Quality Exceedances (cont'd)

Parameter	Stock Limit (mg/L)	Bores Where Groundwater Quality Exceeded Trigger Values
Fluoride	2	Mine Site - GW004, GW006, GW014, GW015, GW018, GW044, GW061, GW062, GW063, GW096S, GW099D, GW099S, GW100, GW105, GW106, GW115B, GW119D, GW119S, GW126S, GW128, GW131
		Bing Bong Loading Facility - GWBB03A
Lead	0.1	Mine Site - GW015
Molybdenum	0.15	Bing Bong Loading Facility - GWBB009A
Nickel	1	GWBB04B
Selenium	0.02	Bing Bong Loading Facility - GWBB010B

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 last reporting period (see Section 4.5.3.1).

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 concentrations of salt where groundwater levels lie close to surface immediately south 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 be developed (see Table 4.22).

4.5.4.2 Progress and New Issues

One new issue was identified during the review, which relates to the declining groundwater quality south of the SEPROD, especially at GW102 where SO_4 concentrations have risen from less than 1,000 mg/L to nearly 4,000 mg/L. The source of the contamination has not been identified. However, water balance estimates suggest there is minimal seepage from the SEPROD. The IM recommends that the source of the contamination is investigated and suitable mitigation strategies implemented.

A significant amount of progress was made over the review period, much of it associated with the work undertaken for the Draft OMP EIS. This included:

- Advancement in the understanding of the groundwater system at the mine site, which is related to extensive field investigations, review of existing geological and hydrogeological information, further development of the conceptual models for the mine site and development of groundwater models (discussed in Section 4.5.3.2).
- Mitigation of potential seepage impacts from the ELS by decommissioning the storage, which was previously used to store underground water.
- Continued remediation of the diesel spill with further product recovery and no evidence of offsite impacts.

GROUNDWATER TOTAL DISSOLVED SOLIDS AND SULFATE EXCEEDANCES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.17

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

McArthur River Mine Project

FIGURE 4.18

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 4.22.

Table 4.22 – Groundwater Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2015 Operational Period		
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	A significant amount of progress was made during the review period. However, this work needs to be ongoing with a focus on targeting the main uncertainties in MRM's understanding of the groundwater system (e.g., the presence of deep aquifer flow paths (including aquifers associated with faults), mechanisms affecting seepage from TSF Cell 1, groundwater flow paths to the underground mine and the presence and influence of naturally mineralised zones)
Groundwater model review	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: ♦ The 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	There has been no progress on this item

Table 4.22 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period		
Trigger limits	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)	McArthur River Mining proposes to develop site-specific trigger values for all monitoring bores, based on up-gradient water quality and historic ranges (KCB, 2016a)
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 the 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	McArthur River Mining has started investigations into groundwater pathways linking the McArthur River diversion channel to the pit and underground as part of the development of a site-wide conceptual model. The investigations have been based upon a review of existing data, as recommended. However, no groundwater exploration drilling has been undertaken During the IM site visit, MRM staff also identified possible pathways between the lower reaches of Barney Creek (which commonly floods during the wet season) and the northern part of the underground mine. A pathway at this location is consistent with results from site investigations completed for the Barney Creek channel diversion in 2009 which identified near-surface karst development Updated recommendations for managing inflows to the pit and underground are provided in Table 4.23
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	There has been no progress on this item

Table 4.22 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods		
OEF	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	At least one new monitoring bore was installed at the NOEF (GWTP54) and one bore decommissioned (GW107 located at the WPROD) since the 2016 IM review. However, no information was sighted showing the locations of future monitoring bores. The IM acknowledges that the outcomes from the Draft OMP EIS will determine future dump development. Revised recommendations for the NOEF are provided in Table 4.23 A synthetic liner for the SPROD is planned to be installed most likely in 2018, which should eliminate most of the seepage from the dam
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	A number of studies have been completed around the TSF, including development of a conceptual hydrogeological model and a groundwater model as part of the Draft OMP EIS. The conceptual model has identified deep groundwater pathways under the TSF, and provided estimates of hydraulic properties for the various aquifer units and further evidence of the ineffectiveness of existing controls. Groundwater modelling results indicate a deep trench excavated 2 m below the invert of the Surprise Creek channel should intercept most of the SO_4 loads currently reporting to the creek. However, an assessment of possible deeper pathways is ongoing. The IM considers it unlikely that a trench will be effective in mitigating seepage via deeper pathways, which are likely to require seepage recovery bores.

Table 4.22 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
TSF (cont'd)	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 dirty water 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	This option should be assessed by MRM based on field investigations (including investigative drilling) and further groundwater modelling No evidence of studies into the management of seepage from the southeastern perimeter of the TSF Cell 3 WMD or southeastern corner of TSF Cell 2 were sighted The IM notes that MRM is no longer storing contaminated water in the active TSF Cell 2 and has implemented improved management strategies for the TSF including management of the decant pond. These actions have assisted in reducing seepage Revised recommendations for the TSF are provided in Table 4.23
Open pit	See recommendation in Section 4.8.4.2	A number of studies have been completed on the management of the pit void lake after closure as part of the Draft OMP EIS. McArthur River Mining's preferred option is to flood the pit and allow seasonal inflows and outflows to McArthur River, although a number of other options are still being considered.
General data interpretation and reporting	An annual independent review of the impacts from groundwater abstraction, including both groundwater supply from borefields and dewatering, should be undertaken by a suitably qualified hydrogeologist. The review should assess drawdown impacts on the groundwater and surface water systems and impacts on groundwater quality	Completed. McArthur River Mining has committed to preparation of a groundwater monitoring report, which will be submitted as part of the operational performance report. The first monitoring report was prepared for the 2014-2016 period
	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	A listing of MRM's groundwater monitoring commitments was provided in Excel format (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 (ID 352)

Table 4.22 – Groundwater Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
General data interpretation and reporting (cont'd)	McArthur River Mining should commit to reporting all breaches of their groundwater commitments to the DME. 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 2017
Analytical suite	A comprehensive groundwater monitoring schedule should be presented in the MMP and annual OPR, which lists the committed monitoring bores and details the monitoring requirements, i.e., parameter, detection limit and frequency	Completed The 2014-2016 monitoring report includes a monitoring bore schedule and description of MRM's monitoring requirements
2011 Operational Period		
Borefields	Constructing hydrographs of pressure levels in all borefield abstraction bores and nearby observation bores, including rainfall and abstraction volumes and rates	No production or observation bore hydrographs were identified. These should be provided in future groundwater monitoring reports
	Assessing data such as recovery rates following cessation of pumping and drawdown rates during constant discharge	No assessment of the drawdown or recovery rates was identified. These should be provided in future groundwater monitoring reports
TSF	The tailings stored in TSF Cell 1 should be removed for re-processing	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 is satisfied
	A limestone or calcium-rich cover should be installed on the TSF	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	No kinetic test data were sighted, although 11 soil samples from around the TSF were tested to estimate the distribution coefficient and provide an indication of their attenuation potential. This recommendation should be actioned
General data interpretation and reporting	Comparison of the actual groundwater contours and the modelled groundwater level contours	Completed Calibration of groundwater models for the TSF area and across the mine site was completed as part of the overburden management
	Groundwater quality criteria should be based upon the potential environmental receptors to groundwater discharge or use	This recommendation has been superseded by more recent recommendations

4.5.4.3 Successes

Significant progress was made on many issues during the review period (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:

- Updated conceptual geological and hydrogeological models were developed for the mine site, based on extensive field investigations. This is considered a significant step forward in understanding the groundwater system across the site. However, further field investigations and model development are necessary to address knowledge gaps, which include:
  - The presence of deep aquifer flow paths (including aquifers associated with faults).
  - Mechanisms affecting seepage from TSF Cell 1.
  - Groundwater flow paths to the underground workings.
  - The presence and influence of naturally mineralised zones.
- A calibrated groundwater flow model was developed for the area around the TSF. The model was used to:
  - Assess the effectiveness of design options for a seepage interception trench between TSF Cell 1 and Surprise Creek.
  - Assess flow rates and contaminant concentrations for MRM’s preferred TSF closure option (reprocessing and in pit storage).

  The IM considers the option to install a deep trench between Cell 1 and Surprise Creek appropriate in managing contaminant loads to the creek via the overburden aquifer. However, additional measures will likely be required to manage contamination via deeper flow paths.

  The model predicts flow rates in Surprise and Barney creeks will be maintained after closure, based on MRM’s preferred options (i.e., retreating tailings and subsequent storage in pit, flooding of the mine pit and capping of the NOEF). Sulfate concentrations are predicted to fall in both creeks, although the fall in Barney Creek is more gradual. These are considered positive outcomes with respect to MRM’s preferred closure option.
- A calibrated site-wide groundwater model was developed for the mine site, which incorporated the results from the TSF groundwater model. The site-wide model was used to assess seepage impacts from potential contaminant sources, physical stresses from mining (including the influence of dewatering), and the fate of contaminants and effectiveness of mitigation strategies. The IM considers the use of the site-wide groundwater model appropriate and the results from the recent study (completed for the Draft OMP EIS) useful in assessing impacts from operations and mitigation strategies. Further investigations are

required to address knowledge gaps, consistent with those identified in the conceptual models (listed above).

- A numerical water and solute balance model was developed for the post-closure pit void lake to investigate the pit lake development, and its impacts on the environment and the suitability of the preferred pit closure option. The pit lake modelling is considered preliminary because of the knowledge gaps associated with the system. However, the results provide some insight into post-closure conditions and the IM recommends that the model be used to simulate all closure options being considered by MRM.
- New bores into the underground mine have been installed to replace the Evasee system, which will be mined out during forthcoming pit cutbacks. The dewatering infrastructure will be relocated to the new bores in 2017.
- The ELS, which was used to store water from underground, has been decommissioned to prevent seepage impacts observed in monitoring bores located between the storage and the McArthur river diversion.
- McArthur River Mining plans to develop site-specific trigger values for groundwater to identify impacts from the operation. This has been a long-standing recommendation from the IM.
- Monitoring of the area around the 2011 diesel spill indicates that the impacts have stabilised and that the plume is not expanding. Unacceptable impacts on local water courses are considered unlikely.
- Declining groundwater quality is being observed south of the SEPROD, although seepage rates from the dam are estimated to be minimal. The source of the contamination should be identified and mitigation measures implemented.

Ongoing and new IM recommendations related to groundwater issues are provided in Table 4.23.

Table 4.23 – 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 McArthur River palaeochannel aquifer) and estimate their properties. 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 pit and underground should be updated to include the field program results ♦ Numerical models should be updated to identify effective controls, which may include installation of production bores to intercept groundwater flows towards the pit or underground	High

Table 4.23 – New and Ongoing Groundwater Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
OEF	The following revised recommendations are made regarding the assessment of seepage impacts around the NOEF to confirm the effectiveness of the PAF containment system, once the future development of the facility is approved: ♦ A schedule should be developed for the installation and testing of monitoring bores in areas planned for future NOEF expansion. The schedule should allow for the adequate collection of background data ♦ Electromagnetic surveys should be carried out in areas planned for future NOEF expansion to identify background responses. The timing of surveys should take into consideration seasonal changes in groundwater level ♦ Monitoring of all new NOEF bores should be included in MRM's list of commitments ♦ Field investigations should be undertaken to identify groundwater pathways in the vicinity of the NOEF and estimate their hydraulic properties. 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 outcomes from field investigations and ongoing monitoring should be used to routinely update the conceptual and numerical hydrogeological models for the NOEF. The updated numerical model should be used to assess future impacts from the facility and, where these impacts are judged to be unacceptable, identify effective controls	High
SPROD	The following revised recommendations are made regarding the SPROD: ♦ A synthetic liner should be installed as a long-term seepage control ♦ The site-wide water balance developed by WRM should be used to confirm that seepage rates from the SPROD are acceptable	High
TSF	The following revised recommendations are made regarding the assessment of seepage impacts around the TSF: ♦ Field investigations should be undertaken to better identify groundwater pathways in the vicinity of the TSF and estimate their hydraulic properties. 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

Table 4.23 – New and Ongoing Groundwater Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Open pit closure	The site-wide groundwater flow model and pit lake water and solute balance model should be used to assess all the pit void closure options under consideration by MRM. Both models should be revised and the closure scenarios re-run when the mine site conceptual hydrogeological model is updated. This is consistent with the adaptive management approach proposed by MRM in the Draft OMP EIS	High
Diesel spill	Monitoring bores URS03, URS17 and URS23 should be replaced and an additional monitoring bore installed east or northeast of bore URS17 to increase the coverage to the east and northeast of the plume	Medium
General data interpretation and reporting	A comprehensive interpretation of the groundwater monitoring data should be carried out as part of future groundwater monitoring reports. These should aim at identifying processes responsible for unacceptable groundwater impacts	Medium
	A summary of all groundwater commitments should be presented in future MMPs and annual groundwater reviews	Low
	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
	Hydrographs of pressure levels in all borefield abstraction bores and nearby observation bores should be constructed, including rainfall and abstraction volumes and rates, and included in future groundwater monitoring reports	Low
	Data such as recovery rates following cessation of pumping and drawdown rates during constant discharge should be assessed	Low
	Kinetic tests should be carried out to estimate the attenuation characteristics of the alluvium underlying the TSF	Medium
New Items		
Groundwater impacts south of the SEPROD	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	High
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 the storages. These estimates should be included in the groundwater monitoring report prepared as part of the operational performance report. Further investigations should be carried out where high seepage rates are estimated	High
General 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	Medium

4.5.6 References

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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) is the most significant environmental issue for the site. Preventing adverse impacts on the receiving groundwater and surface water environments, and ensuring rehabilitation success, requires a thorough understanding of the acid, metalliferous and saline drainage (AMD) potential of mine materials (including waste rock, tailings, open cut walls/void and stockpiles) and development of appropriate management strategies to mitigate current mining impacts, and future impacts during operations and closure.

In addition, some materials have spontaneous combustion potential where there is abundant fine-grained pyrite and organic carbon.

There was a major change in the understanding of site geochemistry following the McArthur River Mine Phase 3 EIS approval, when further investigations highlighted the highly sulfidic nature and high AMD potential of much of the waste rock, ore and tailings, with consequent implications for the key mine components, including OEFs, TSF and open pit. This changed appreciation of AMD potential has required MRM to revaluate the environmental risks from mine materials, instigate numerous studies and investigations to better understand those risks, and develop new approaches to mine materials management. These changes were also the main trigger for the requirement of the recently submitted Overburden Management Project Draft EIS (referred to hereafter as the Draft OMP EIS).

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 its consultants (as listed in Appendix 1), with particular reference to geochemical investigations carried out as part of the Draft OMP EIS (MRM, 2017a), operational performance reports (MRM, 2016c; 2017h) and other consultant reports (Earth Systems, 2016a; 2016b; 2017) (ITRB, 2015).
- Excel spreadsheets provided by MRM that contain collated laboratory and in situ data.
- Various MRM documents such as procedures and manuals (MRM, 2016a; 2016b; 2017l; 2017c; 2017d; 2017e; 2017f; 2017i), incident registers, and correspondence between MRM, regulators and third parties.

4.6.2 Key Risks

As in previous years, MRM has expended considerable effort on site geochemistry issues since the last IM report. Further studies and investigations have been carried out to better define the geochemical properties and risks of mine materials, and to provide more direction concerning the operational and long-term management required for problematic materials. Much of this was carried out in support of the recently submitted Draft OMP EIS. In addition, processes for identification, selective handling and management of geochemical waste rock types have been advanced.

The OMP EIS assessment process is ongoing, and management strategies have yet to be finalised, but the work carried out to date continues to confirm that McArthur River Mine materials are highly pyritic and a major potential source of AMD. The risk of AMD generation, and the associated potential adverse impacts both on site and downstream, remains the most significant environmental issue at McArthur River Mine, and the key geochemistry risks identified in 2016 remain the same.

The NOEF, TSF and open pit represent the key potential sources of AMD, and inadequate management of seepage/run off during operations and/or failure 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 of the cover system post closure leading to AMD from waste rock reporting to groundwater and surface drainage, potentially impacting groundwater and terrestrial and aquatic ecosystems. Key uncertainties include performance of the cover design, ability to construct a low infiltration clay layer over the entire dump surface, the effects of erosion and differential settlement on the integrity of the cover, and the resources/equipment and duration required for maintenance.

- A major factor that contributes to the above risk is historic end-dumping of 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. There is also potential for spontaneous combustion to affect the stability of the NOEF, and lead to breaches in the cover.

TSF

- Inadequate management of seepage during operations and failure of long-term mitigation measures post closure leading 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.

Open Pit

- The open pit lake could become strongly acid and/or saline and metalliferous after closure due to oxidation of exposed pyritic PAF and NAF materials in pit walls, 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 regards to prediction, classification, monitoring, investigations/reviews and management of mine materials.

4.6.3.1 Previously Reported Controls

Last year's IM review identified considerable progress in geochemical prediction, classification and monitoring of mine materials, including:

- Completion of a new waste rock block model that accounted for the acid neutralising capacity (ANC), allowing classification based on neutralisation potential ratio (NPR) rather than just total S, and improving longer-term planning.
- Integration of the waste rock classification system into grade control and dispatch systems, which were formalised in a number of technical work instructions manuals.
- Continued sampling and testing of OEFs, with results showing general consistency with expected properties of placed materials types, although the number of low salinity non–acid-forming (high capacity) (LS-NAF) samples collected appeared disproportionate to the importance of this unit for waste rock management.
- Continued operation of kinetic leaching field barrels, humidity cells and leach columns to provide information concerning leaching characteristics of key mine materials to compare against assumed AMD potential.
- Additional geochemical characterisation of waste rock to support the Draft OMP EIS.
- Drilling of the NOEF to better understand the geochemical and hydrological processes occurring in the dump.
- Review of spontaneous combustion, air quality monitoring and assessment of SO_2 emissions, and trial of chemical sealants for control of spontaneous combustion.
- Sealant trial pads to assess alternate infiltration controls on the NOEF.
- Cover design modelling and assessment, including review of alternate infiltration control layers.
- Drilling of hanging wall sediments to identify additional reserves of LS-NAF from the Upper Breccia unit (UpX) outside the pit.
- Additional geochemical testing (static and kinetic) of tailings and review of historic data, significantly improving the understanding of tailings geochemical variation.

Management controls instigated in the previous IM reporting period and described in last year's IM report (Section 4.6.3) include:

- Updated waste rock handling recommendations based on additional static and kinetic test work and improved understanding of geochemical properties.

- Improved materials handling and dump construction.
- Improved control of convective/advective oxidation and spontaneous combustion, including re-handling and compaction of waste rock zones with high combustion potential.
- 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 has carried out numerous investigations to better understand the geochemical issues on site and to support the recently submitted Draft OMP EIS. Management of mine materials has also substantially progressed since the last IM review. 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 include the following:

- Revision 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.

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

<u>Hanging wall:</u>

- Alluvium (Quaternary).
- Cooley Dolomite.
- Upper Breccia.
- Upper Dolomitic Shale.

- Upper Pyritic Shale.
- Black Bituminous Shale.
- Lower Pyritic Shale.

<u>Orebody:</u>

- Here's Your Chance Mineralised Shales (Mineralised Interval).

<u>Foot wall:</u>

- Lower Dolomitic Shale.
- W-Fold Shale.
- Teena Dolomite.

Figure 4.19 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 is only occurs south of the Woyzbun Fault, restricted to southeast of the pit.

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

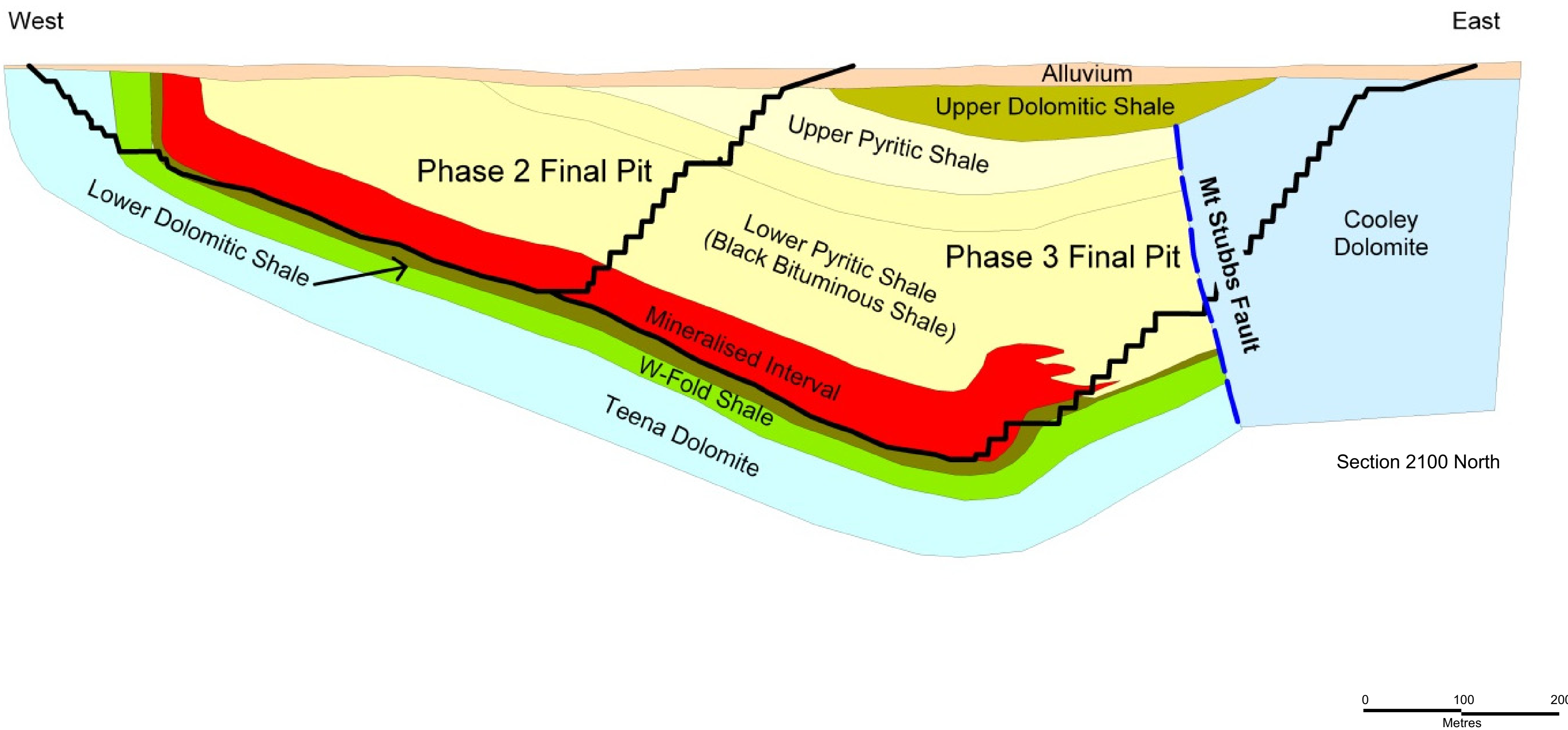
- Low salinity non–acid-forming (high capacity) (LS-NAF(HC)).
- Metalliferous saline non–acid-forming (high capacity) (MS-NAF(HC)).
- Metalliferous saline non–acid-forming (low capacity) (MS-NAF(LC)).
- Potentially acid-forming (high capacity) (PAF(HC)).
- Potentially acid-forming (reactive) (PAF(RE)).

A proposed modified geochemical waste rock classification scheme was presented in the Draft OMP EIS (MRM, 2017a) based on review of previous static and kinetic geochemistry results and additional testing arranged by KCB (KCB, 2015a; 2017a). The new classification scheme is shown in Table 4.24. The classes remain the same as presented in last year's IM report, but with modified criteria again based on a combination of NPR, S and key metal/metalloid contents. The S and NPR cut off values for each class are similar to those of the previous criteria, but with some changes 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 parameter for the PAF(RE) class.

CROSS-SECTION SHOWING WASTE ROCK TYPES AND OPEN PIT LIMITS

McArthur River Mine Project

FIGURE 4.19



Source: MRM, 2012

Table 4.24 – Proposed Waste Rock Classification Criteria

Class	Description	Criteria
LS-NAF(HC)	**Low Salinity High Capacity NAF**. Considered low risk of generating AMD. Generally characterised by a high acid consumption capacity Suitable for placement in environmentally sensitive areas such as the OEF outer cover	NPR ≥ 2 and S < 1% and Zn < 0.12% and Pb < 0.04% and As < 40 ppm and Cd < 10 ppm
MS-NAF(HC)	**Metalliferous Saline High Capacity NAF**. 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 This material is not considered environmentally benign and requires some form of encapsulation and water management strategy	NPR ≥ 2 and S ≥ 1% or Zn ≥ 0.12% or Pb ≥ 0.04% or As ≥ 40 ppm or Cd ≥ 10 ppm
MS-NAF(LC)	**Metalliferous Saline Low Capacity NAF**. 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 This material is not considered environmentally benign and requires some form of encapsulation and water management strategy	1 ≤ NPR < 2
PAF(HC)	**High Capacity PAF**. Considered higher risk of generating AD, and is likely to have a significant capacity to do so This material is not considered environmentally benign and requires some form of encapsulation and water management strategy	NPR < 1 and S < 10% **OR** NPR < 1 and S ≥ 10% and not Black Bituminous Shale
PAF(RE)	**Reactive PAF**. Reactive PAF Material considered high risk of generating AD, and high risk of self-heating which may progress into spontaneous combustion This material is not considered environmentally benign. It requires encapsulation and is likely to require specific additional handling strategies to prevent the onset of spontaneous combustion	NPR < 1, S ≥ 10%, and Black Bituminous Shale

Source: MRM, 2017a.

Waste rock that is classified as LS-NAF is the only material considered benign on site, and hence reliably identifying this material is key to much of the site AMD management approach. The current LS-NAF criteria use metal/metalloid cut off values for Zn, Pb and Cu. McArthur River Mining proposes that this be changed to Zn, Pb, As and Cd based on results of kinetic testing, which indicated that the Zn cut off may not be sufficiently conservative, and that As and Cd may be more relevant than Cu. The revised criteria appear justified and conservative based on results presented.

Identifying PAF(RE) waste rock is also key, since this material requires special handling to prevent self heating (spontaneous combustion). The current criteria distinguish PAF(RE) from PAF(HC) for NPR < 1 materials based only on a total S cut-off value of 10%S. McArthur River Mining proposes revised criteria for PAF(RE), which restricts the PAF(RE) to PAF materials with S ≥ 10% and within the Black Bituminous Shale, so that PAF materials with S ≥ 10% but not hosted by Black Bituminous Shale would be classified PAF(HC). The IM considers that limiting the PAF(RE) class to Black Bituminous Shale is appropriate, since the organic carbon component is a crucial contributor to the spontaneous combustion reaction. However, the reason for selection of the 10%S cut off is not given, and this requires further justification.

Note that although the PAF(HC) material is not as prone to spontaneous combustion as PAF(RE), it is still prone to self heating and will tend to form convective cells with rapid rates of oxidation if not appropriately managed.

There is also an additional PAF class referred to as PAF hanging wall (PAF(HW)) in the Draft OMP EIS. McArthur River Mining personnel advised that the PAF(HW) class is restricted to a specific stratigraphically-controlled unit within the lower part of the Lower Pyritic Shale, which is defined as having 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. The IM recommends that the PAF(HW) material be added to the proposed waste rock classes since it would be handled differently from other materials.

An update report on kinetic testing for humidity cells, leach columns and field barrels was prepared for MRM in 2017 (KCB, 2017a) for the Draft OMP EIS, which included kinetic data for waste rock up to November 2016. The sulfate trends from kinetic testing to date are consistent with the geochemical leaching characteristics expected from the various material types, with LS-NAF samples producing the lowest SO_4 concentrations and PAF(RE) showing the highest. All NAF samples produced circum-neutral pH leachates, supporting the classification. Most of the PAF samples also typically produced circum-neutral pH leachates (apart from one PAF(RE) sample), reflecting a lag period due to high ANC contents. The kinetic testing results support the classification system in general, but long lag times in the order of years to decades can be expected for many of these materials, and long-term operation of the kinetic tests would be required to confirm the criteria. The kinetic results were also presented in the Draft OMP EIS (MRM, 2017a) to support the proposed changes in classification as described above.

No new results for the barrel tests were provided to the IM from the last report.

Tables 4.25 and 4.26 compare typical acid-base compositions of waste rock classes (from KCB, 2017a) with those loaded into humidity cells and leach columns (also from KCB, 2017a), and field barrel tests (from MRM, 2017b). The tables show that the range of materials selected for kinetic testing appear to cover the range of expected compositions of the various classes, and also represent the higher S compositions, which will help assessment of worst case conditions.

The geochemical testing and investigations carried out for overburden materials include a comprehensive dataset with an appropriate suite of static and kinetic tests. The IM considers that the geochemical properties of overburden materials at the mine are now well understood, and that the classification system is generally well justified and is expected to be reliable. The main exception is that the validity of the PAF(RE) cut-off value of 10%S should be better demonstrated.

Updated technical work instruction manuals provided by MRM describe how the waste rock classification system is integrated into waste rock block modelling, grade control and dispatch systems (MRM, 2016a; 2016b; 2017l; 2017c; 2017d; 2017e; 2017f).

Table 4.25 – Comparison of Humidity Cell and Leach Column Sample Compositions with Typical Values for Waste Rock Classes

Waste Type	Lithology	Sample ID	Humidity Cell	Column Leach Test	Typical (Median) ABA				Actual ABA			
					Total S (%)	ANC (H_2SO_4/t)	NAPP (H_2SO_4/t)	ANC/MPA	Total S (%)	ANC (H_2SO_4/t)	NAPP (H_2SO_4/t)	ANC/MPA
LS- NAF (HC)	Upper Dolomitic Shale	44060	X		0.22	696	-689	103.39	0.89	598	-571	21.96
LS- NAF (HC)	Upper Breccia	44016	X		0.22	696	-689	103.39	0.35	825	-814	77.03
LS- NAF (HC)	Upper Breccia	44007	X	X	0.22	696	-689	103.39	0.24	694	-687	94.50
LS- NAF (HC)	W Fold Shale	KWFS- 06	X	X	0.22	696	-689	103.39	0.09	188	-185	68.26
MS- NAF (HC)	Cooley Dolomite	44284	X	X	1.30	555	-515	13.95	1.32	819	-779	20.28
MS- NAF (HC)	Cooley Dolomite	44288	X		1.30	555	-515	13.95	0.71	855	-833	39.35
MS- NAF (HC)	W Fold Shale	KWFS- 03	X		1.30	555	-515	13.95	0.59	173	-155	9.58
MS- NAF (HC)	Lower Dolomitic Shale	KLDH- 04	X		1.30	555	-515	13.95	1.86	195	-138	3.43
MS- NAF (HC)	Siltstone	44004	X		1.30	555	-515	13.95	2.92	185	-96	2.07
MS- NAF (LC)	Upper Pyritic Shale	44106	X		5.90	231	-50	1.28	7.76	242	-5	1.02
MS- NAF (LC)	Black Bituminous Shale	44084	X		5.90	231	-50	1.28	7.09	317	-100	1.46
MS- NAF (LC)	Lower Pyritic Shale	44127	X		5.90	231	-50	1.28	5.45	219	-52	1.31
MS- NAF (LC)	Upper Dolomitic Shale	44057	X	X	5.90	231	-50	1.28	6.44	231	-34	1.17
PAF (HC)	Lower Pyritic Shale	44093	X	X	8.49	214	46	0.82	9.66	223	73	0.75
PAF (HC)	Lower Dolomitic Shale	KLDH- 11	X	X	8.49	214	46	0.82	5.06	124	31	0.80
PAF (R)	Upper Pyritic Shale	44072	X	X	13.58	199	217	0.48	20.56	204	425	0.32
PAF (R)	Upper Pyritic Shale	44065	X	X	13.58	199	217	0.48	16.97	167	352	0.32
PAF (R)	Black Bituminous Shale	44079	X	X	13.58	199	217	0.48	12.36	192	186	0.51

Table 4.26 – Comparison of Field Barrel Sample Compositions with Typical Values for Waste Rock Classes

Waste Type	Lithology	Sample ID	Typical (Median) ABA				Actual ABA			
			Total S (%)	ANC (H_2SO_4/t)	NAPP (H_2SO_4/t)	ANC/MPA	Total S (%)	ANC (H_2SO_4/t)	NAPP (H_2SO_4/t)	ANC/MPA
LS-NAF(HC)	WFS	8	0.22	696	-689	103.39	0.08	131	-129	53.51
LS-NAF(HC)	Quartz	10	0.22	696	-689	103.39	0.04	6	-5	5.23
LS-NAF(HC)	LpHbx1	11	0.22	696	-689	103.39	0.45	666	-652	48.37
MS-NAF(HC)	LpH_c	3	1.30	555	-515	13.95	4.88	490	-341	3.28
MS-NAF(HC)	LpH_c	4	1.30	555	-515	13.95	4.95	461	-310	3.04
MS-NAF(LC)	LpH_b	2	5.90	231	-50	1.28	4.40	254	-119	1.89
MS-NAF(LC)	UpH	5	5.90	231	-50	1.28	6.81	224	-16	1.07
MS-NAF(LC)	LpH_a	6	5.90	231	-50	1.28	6.34	252	-58	1.30
MS-NAF(LC)	BbH	12	5.90	231	-50	1.28	3.03	111	-18	1.20
PAF(HC)	#6-8	7	8.49	214	46	0.82	8.92	266	7	0.97
PAF(RE)	BbH	1	13.58	199	217	0.48	12.70	130	259	0.33
PAF(RE)	LpH_d	9	13.58	199	217	0.48	12.20	184	189	0.49
PAF(RE)	BbH	13	13.58	199	217	0.48	17.30	210	319	0.40
PAF(RE)	LpH_c	14	13.58	199	217	0.48	10.70	253	74	0.77
PAF(RE)	LdH_Upper	15	13.58	199	217	0.48	10.80	142	188	0.43

Planning and segregation of waste rock types at the mine have a number of levels (i.e., resource model, reserve model, grade control model, and truck tracking of actuals), all of which use full criteria based on S, NPR and metals rather than the S proxies that were used prior to 2016. The grade control model is key to short-term identification of waste rock classes in the field for selective handling, and this has been refined and improved since the last IM review as follows (MRM, 2017d):

- Introduction of estimation domains, which constrains modelling within geological domains to account for the strong lithostratigraphic controls on the distribution of sulfide and carbonate, and avoid smearing between distinct units, particularly benign (LS-NAF) units.
- Refinement of modelling ellipsoids to differentiate between steep- and shallow-dipping stratigraphy to better represent spatial distribution of waste classes.
- Use of ICP analysis, and phasing out of portable XRF (pXRF) analysis, for S, Ca, Mg and metals/metalloids to assign waste rock classes.

The in-pit grade control results are used to produce a map of overburden classes for production plans. The overburden class descriptions in the Draft OMP EIS provide clarification on how the lithostratigraphy is used to refine the boundaries of the different classes, with a degree of conservatism applied so that only those units known to be consistently benign (based on geology and test work) are mined as LS-NAF(HC), comprising Quaternary Alluvium, Upper Breccia, W-Fold Shale and Teena Dolomite. The plans are used to mark up waste rock classes and ore in the field, and site personnel advised the IM that shovels also have access to GPS guided boundaries, so that in most cases there are two controls on correct selective mining of waste rock classes.

The ANC is estimated from Ca and Mg contents to allow calculation of an NPR. Figures 6-40 and 6-41 from the Draft OMP EIS (MRM, 2017a) show strong linear relationships between Ca+Mg and ANC for ICP data, supporting the validity of this approach. A review of the pXRF correlation with ICP data was provided in an internal MRM report (MRM, 2017i) based on over 400 samples. Correlations of pXRF Ca with ICP Ca show a reasonable linear relationship, but S shows significant scatter, and Mg has a very poor correlation. The pXRF correction factors described in the report are therefore deliberately conservative, but results strongly support the need to fully change to ICP analysis.

The IM was advised that ICP analysis is currently carried out off site (ALS) due to current limitations of the on-site facility. During the IM site visit, the external laboratory was unable to provide required turn-around times due to high sample loads, and pXRF analysis was carried out instead. Progressing the on site ICP testing capacity or arranging back up external testing capability should be considered to avoid further use of pXRF.

A GPS fleet management system referred to as APS is used to track placement of waste rock. The process of capturing and generating screenshots of material movements on a day-to-day basis are described in a technical work instructions manual (MRM, 2017l). The data capture and reporting aspects are leading practice, but it is less clear what actions are taken (and in what situations) if materials are misplaced. McArthur River Mining provided a PowerPoint presentation (MRM, 2017j) that included more details on actions. The presentation indicates that the APS is a tracking tool used in conjunction with morning and afternoon dump inspections to assist identification of misplaced loads on the waste dump, and that identified misplaced loads are logged as an incident and the non-conforming waste is rehandled. This is supported by a recorded incident on 21 January 2017 and 6 February 2017 (MRM, 2017k), in which an APS check and a separate OEF inspection identified MS-NAF placed in a LS-NAF area, and materials were rehandled. There is mention in the Draft OMP EIS that PAF(RE) material was misplaced in the SOEF during 2015, which did not appear to be detected until obvious signs of spontaneous combustions were observed (DME, 2016a). This would have occurred before implementation of the APS and procedures, and the new system is expected to avoid similar undetected occurrences. The IM was not able to directly review the waste rock placement tracking system in operation during the site visit, and the supplied procedures do not provide guidelines as to how the information is used on a day-to-day basis. Elaboration on the review and decision-making process in the technical work instructions manuals, with examples, would assist the IM assessment in the next reporting period.

McArthur River Mining geologists carried out a reconciliation of tonnes of waste rock classes mined versus the 2015 grade control model and reserve model for 2016 (MRM, 2017h). Table 4.27 combines these results with the updated GC model produced in 2017 for the 2016 mine period (MRM, 2017d). The total tonnes actually mined in 2016 were 10% greater than modelled, but there were much larger differences between mined versus modelled with respect to individual classes. In particular, LS-NAF materials mined were approximately 25% less than that planned, PAF(HC) were 145% more, and PAF(RE) were 85% more. This significant overestimation (by modelling) of LS-NAF and underestimation of PAF(HC)/ PAF(RE) was explained by MRM as being due to:

- A conservative mining approach (i.e., bias towards non-benign materials) in the first seven months of 2016.
- Limitations in obtaining grade control samples in some areas so that materials had to be treated conservatively.
- Mining being carried out in some areas prior to grade control results becoming available so that materials were again treated conservatively.

Table 4.27 – Comparison of Reconciled Waste Tonnes Mined with Predictions from the 2017 GC Model and Reserve Model

Class	Reconciled Mined (t)	GC Model 2017 (t)	Reserve (t)	GC Difference	Reserve Difference
Alluvium	197,829	483,806	483,828	-59%	-59%
LS-NAF(HC)	943,201	1,017,761	743,909	-7%	27%
MS-NAF(HC)	3,359,417	2,695,177	2,158,827	25%	56%
MS-NAF(LC)	1,114,645	1,383,585	2,103,950	-19%	-47%
PAF(HC)	702,648	286,480	381,720	145%	84%
PAF(RE)	292,587	157,945	152,519	85%	92%
TOTAL	6,610,327	6,024,754	6,024,753	10%	10%

Source: MRM (2017d and 2017h).

McArthur River Mining personnel appear well aware of the issues, based on the IM review of the relevant documents and discussion with personnel on site. However, the water management issues and restricted access to dumping space could make resolving these issues a challenge in 2017. Approval of the Draft OMP EIS would significantly improve flexibility and performance of materials handling and management.

Quality control checks of OEFs are described in the Draft OMP EIS (MRM, 2017a), and an updated draft OEF sampling procedure was provided to the IM (MRM, 2017g). The Draft OMP EIS indicates that sampling is carried out monthly, comprising around 250 samples a year, with the sampling density proportional to the amount of material moved based on international guidelines. While use of guidelines is a reasonable starting point, sampling densities need to consider site-specific geological variation and key concerns. The draft OEF sampling procedure increases the sample density of LS-NAF samples from one sample every 100,000 t to one sample every 50,000 t. During the site visit the IM was advised that this higher LS-NAF sample density had been implemented, addressing the IM recommendation in 2016 that, given the importance of LS-NAF to the overall mitigation strategies for the NOEF, more focus should be given to sampling dumped LS-NAF. The OEF sampling results provided in this reporting period did not significantly update the previous IM review, and will be reviewed in detail in the next IM report.

A recorded incident on 4 October outlines an occurrence in August 2016 in which OEF sampling detected MS-NAF in an area where only LS-NAF should have been placed (MRM, 2017k). The action was to re-handle the materials. It is uncertain why there was a two-month gap between sampling and the incident being reported.

The instructions for OEF sampling in the draft manual are general. To avoid sample bias and ensure consistency, more detailed instruction should be included in the OEF sampling procedure, including photos showing typical sampling. Representative sampling of dumped waste rock can be problematic due to the large range in particle sizes and the high very coarse fraction, as noted by the IM at an LS-NAF dump site on the north side of the NOEF (Plate 4.3). The following are recommended to assist collection of more representative samples:

- Omit clasts greater than 100 mm.
- Collect of 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.

Investigations were undertaken as part of the Draft OMP EIS to better understand the geochemistry and distribution of overburden classes in the existing NOEF (MRM, 2016d) which has greatly assisted understanding the AMD hazards of the NOEF. The investigations involved:

- Using historical survey records, mining production data, and a geological block model to reconstruct the placement of overburden classes in the NOEF as a block model.

- Drilling into the NOEF to obtain in situ geological and geochemical information to calibrate the NOEF block model and provide a visual measure of the degree of oxidation in overburden materials.
- Measuring temperature and gas compositions in drill holes to better understand internal dump oxidation conditions and reactions.
- Installing groundwater monitoring bores to better understand NOEF hydrology and groundwater quality below the NOEF.

Plate 4.3 – Example LS-NAF Dumping Zone on North Side of the NOEF

Results of the NOEF block model reconstruction indicate that PAF(HC) makes up 13% of the NOEF and PAF(RE) 5%, both of which are lower than expected based on historical volumes reported, which is due to past conservatism in PAF classification. Results also confirm that the NOEF NAF base has both LS-NAF and MS-NAF, but is dominated by MS-NAF at 60%. Gas and temperature monitoring confirmed that advective oxidation is occurring. There is a comment in the report (MRM, 2016d) that the low oxygen measured in the NOEF means that oxygen is limited in the interior, resulting in control of oxidation rates and preventing run-away self-heating and combustion of the PAF. While the low oxygen concentrations do show that the rate of oxidation exceeds oxygen supply, the results alone confirm nothing about air movement or oxidation rates, and any assumptions about limited oxidation in the dump interior and controls on spontaneous combustion require other evidence. The temperature profiles discussed in the report show high temperatures at various depths, indicating rapid and convective oxidation within at least portions of the interior of the dump. Note also that the while background temperatures of 65°C do not indicate spontaneous combustion, they are indicative of convective oxidation and rapid AMD generation rates. The elevated temperatures measured throughout the PAF cells indicate high rates of oxidation, and do not support the concept of limited oxygen in the dump interior.

The SOEF is described in the Draft OMP EIS (MRM, 2017a) as comprising a base of alluvial materials mined from the open pit and placed between 2010 and 2011, with mixed MS-NAF and LS-NAF (prior to revised classification) placed in 2013, and mainly MS-NAF from 2015. A small portion of PAF(RE) material was also accidentally dumped there in 2015. The composition of the SOEF appears to be well defined and the overall assumption by MRM that the SOEF is MS-NAF is appropriate, with the main geochemical hazard being the leaching of pH-neutral saline and metalliferous drainage. Groundwater monitoring has confirmed this, with elevated SO_4 and Zn concentrations measured below the SOEF (MRM, 2017a).

There has been no advancement in defining the distribution of geochemical rock types placed in the WOEF since the last IM report, but it is described in a general sense in the Draft OMP EIS (MRM, 2017a), presumably based on historic records and results from one hole drilled in 2015 (Table 20, MRM, 2016c). The WOEF was developed in 2005 to 2008 at the start of open pit mining, and is described as comprising a NAF base (mixed LS-NAF and MS-NAF), with a PAF cell (presumably mixed PAF(HC) and PAF(RE)) encapsulated in clay, and with more NAF placed on the outside. The PAF appears to have been mainly end tipped in two lifts to 20 m high. McArthur River Mining plans to undertake further drilling and definition of waste rock in the WOEF, together with review of production records to better understand the distribution and structure of the dump (MRM, 2016c).

The site-wide groundwater system at McArthur River Mine was modelled and assessed as part of the Draft OMP EIS based on an extensive hydrogeological field programme. The Draft OMP EIS (MRM, 2017a) and KCB (2017b) discuss the main pathways for seepage and water flow for the NOEF, and identify the key migration pathways of any seepage, with the main receptors being Surprise Creek to the southeast and Barney Creek diversion channel to the south and southeast. The same documents also discuss groundwater modelling for the SOEF and WOEF, which indicate that seepage from those OEFs will tend to flow towards the open pit, with a small portion potentially draining north from the WOEF to the Barney Creek diversion channel. The approach taken to better define the primary seepage/flow pathways of the existing OEFs has improved the understanding and prediction of key potential impacts, which will assist optimising management approaches.

A cover system and landform design for the NOEF was carried out by O'Kane Consultants (2016a) in support of the Draft OMP EIS, with modelling used to predict performance of a multi-layered final cover system in controlling infiltration and oxygen flux, and to finalise the design. The modelling was an update of that reviewed in the last IM report (O'Kane Consultants, 2016b), and focused on performance of the compacted clay layer (CCL) in limiting infiltration and oxygen diffusion. The modelling included a 125-year simulation to assess the effects of climate (including wet and dry years) on cover performance. Results indicated that a final cover system comprising 1.5 m of alluvium sandy clay overlaying a CCL and/or 2 m of breccia overlaying a CCL would provide the required controls of infiltration to less than 5% of annual rainfall and oxidation rates to less than 5 mol O_2/m^2/year. The IM considers that the modelling was a valid approach to assessing and selecting cover options for the OEFs. Trial covers would be required to confirm the modelling results.

A conceptual model for air and water movement through the NOEF is presented in the Draft OMP EIS (MRM, 2017a), which forms the basis of predicting seepage quality from the NOEF. The relevant section is a summary of DumpSim modelling work carried out O'Kane Consultants (2016c) for the Draft OMP EIS. The DumpSim model is a one-dimensional analytical model and an O'Kane Consultants proprietary tool that comprises a number of modules to model heat generation, gas flux, water flux, AMD load generation and pore water quality. The main model inputs include the overburden class distribution (existing and over the LOM), physical/hydrological properties of the various materials, climatic data, temperature profiles, and results of kinetic test work. The key water quality outputs produced by the modelling were SO_4, Zn, Pb, Cd, As concentrations, and pH and redox potential. The IM considers that the approach used by O'Kane Consultants appears appropriate.

Erosion modelling was carried out by O'Kane Consultants (OKC) as part of the Draft OMP EIS (O'Kane Consultants, 2016a), with focus on the dump cover integrity. Samples of key rock types that could be present on the OEF surface were tested in an erosion flume apparatus (and rainfall simulator) as input into the model. The Water Erosion Prediction Project (WEPP) and SIBERIA models were used to model a variety of landform configurations under varying rainfall conditions, including storm events. The approach appears to be a valid way of comparing options and helping to select optimal landform configurations. The modelling indicated that erosion can be reduced to rates that will be manageable with maintenance and repair, with an assumption that vegetation will stabilise the landform at some point in the future. The IM was advised by site personnel that the erosion trials operating in the last reporting period were discontinued as the results did not provide any conclusive data due to the coarse nature of the materials and the short slopes. It is understood that erosion measuring would recommence when a suitable high slope becomes available, but that topsoil erosion monitoring would be included in small scale cover trials that are planned for this year, i.e., 2017. Field confirmation of erosion modelling predictions is strongly supported by the IM, as this could have significant implications for long-term cover system integrity and maintenance resources required.

Waste Rock Materials - Management

Although the final cover system outlined in the Draft OMP EIS is not yet approved, MRM's current waste rock management activities at the NOEF have to account for the potential implementation of the proposed design. Work is currently focused on the Central West (CW) portion of the NOEF, which is maintaining consistency with the Phase 3 approvals while also making allowance for the proposed final dump design. The NOEF cover system design focuses on two key aspects: the control of advective oxygen transport to PAF(RE) and PAF(HC) materials to reduce pyrite oxidation rates and generation of AMD, and limit spontaneous combustion from PAF(RE) materials; and control of net percolation to reduce seepage rates and contaminant loadings. The design concept is outlined in the Draft OMP EIS (MRM, 2017a) as follows:

- Base Layer – at CW, as per Phase 3 approvals, this will comprise an LS-NAF base constructed in maximum 5-m lifts to the 1:100 flood level zone at the western end, but sloping upwards as a wedge to encourage seepage into the NOEF WPROD, with a CCL above and below. For the remainder of the NOEF, MRM plans to change this approach to an approximately 5-m MS-NAF base layer, with a CCL only at the base. Seepage from the CCL foundation will be collected and pumped to the PRODs.

- Core zone – containing PAF(HC), and excess MS-NAF and PAF(RE) materials:
  - PAF(HC) placed in thin paddock-dumped lifts of 2-m thickness or less and/or 7.5 m high with 0.1 m of alluvium each 7.5 m.
  - PAF(RE) placed in 2-m paddock-dumped lifts with heavy compaction, and 0.1 m of alluvium each 2 m. Prior to each wet season, an advection cover layer comprising alluvium 1.2 m thick would be placed to help reduce convective oxidation, followed by a 1.5-m thick MS-NAF erosion protection layer. Scheduling will attempt to limit mining of PAF(RE) during the wet season to reduce the occurrence of spontaneous combustion.
  - Each inter-stage face that will be exposed for over six months will incorporate advection covers comprising alluvium 0.5 to 1.2 m thick (thinner in flat zones and thicker in batter zones), followed by MS-NAF 0.2 to 1.5 m thick (thinner in flat zones and thicker in batter zones) to help maintain control of rapid oxidation of PAF materials in the core.
- Halo Zone – constructed with MS-NAF materials (or better) in maximum 7.5-m lifts with true thickness between 5 to 20 m (thinner in plateau zone) to provide a buffer between the outer cover zone and PAF core.
- Cover Zone – multi-layered cover constructed with compacted clay, LS-NAF, alluvium and topsoil to restrict oxygen ingress, store water to promote plant growth, and shed excess water down purpose-built drains in higher intensity rain events while resisting erosion. The plateau and batter zones would be constructed differently:
  - Plateau Zone Cover - 0.5-m thick CCL, 0.5-m coarse LS-NAF drainage layer, 1.5-m thick alluvium growth medium layer and 0.1 m of topsoil.
  - Batter Zone Cover - 0.5-m thick CCL, 2-m thick coarse LS-NAF growth medium layer and 0.1 m of topsoil.

A key to the proposed NOEF management is successfully identifying and segregating sufficient resources of LS-NAF for base layers and outer cover zones, clay for CCLs, and silty sandy clay alluvium for advection barriers. Table 3-11 of the Draft OMP EIS (MRM, 2017a) indicates that sufficient LS-NAF resources are available for the proposed life of mine outlined in the Draft OMP EIS with development of the Woyzbun Quarry. Pre-stripping as part of operational activities would also produce excess clay and silty sandy clay alluvium, with the possibility of sourcing further material from borrow pits if required.

The existing NOEF has been used for overburden placement since 2008, and was largely constructed prior to the change in classification and appreciation of the extent of site geochemical issues. The dump comprises an undifferentiated NAF base to the 100-year flood level, undifferentiated PAF cells end tipped in 15-m lifts, a 20-m thick undifferentiated NAF overburden outer zone, and interim clay layers between PAF and NAF materials. This design did not account for the presence of MS-NAF materials in the NAF zone, and that end-tip placement encourages rapid oxidation of PAF(HC) and PAF(RE) materials, with spontaneous combustion effects readily observed from the facility. Re-handling and re-shaping of the older NOEF materials has been ongoing to meet revised management requirements. Figure 4.20 shows the historic and current stages of the NOEF. Site personnel provided clarification as to how the existing stages were constructed and planned continuation:

- West (A, B, C, D) stage:
  - In situ clay foundation constructed with just the topsoil stripped.
  - NAF base under the PAF cells constructed in 2- to 3-m lifts.
  - PAF in West A and B was end tipped in 15-m lifts, and includes some PAF(RE).
  - MS-NAF halo on east and north side of West A and B was end-tipped in 5-m lifts between 2015 and 2017.
  - PAF in West C was end tipped in a 15-m lift for the first lift, and then end tipped in approximately 5-m lifts.
  - PAF in West D was paddock dumped, with batters flattened concurrently.
  - MS-NAF halo at least 35-m wide was constructed around the west, south and east faces in 2016 and is almost complete. It was constructed in paddock-dumped lifts, and progressively flattened to 1:4.
  - Advection covers are planned to be placed over the MS-NAF halo. The eastern face would comprise 0.5 m of alluvium with 1.5 m of MS-NAF. Alluvium advection covers (0.5 m) have started on the western face and west part of the southern face, since these are at final limits ready for the final outer cover. An MS-NAF protection cover is not suitable for the western and southern faces as construction of a CCL (as part of proposed final cover) on MS-NAF would be problematic. Erosion protection options for the alluvium advection covers on the western and southern faces are being developed.
- East stage:
  - NAF was placed in 15-m lifts over in situ clay.
- Central West (Charlie, Bravo 2, Alpha-Bravo 1) stage:
  - Basal CCL is currently being constructed using Lucas contractors with scrapers, stabiliser and compactors, and placed in 2 x 300-mm lifts. Cleared area moistened before placement of the clay. Clay layer is watered daily until it is covered over, with a maximum of 10 days before being covered.
  - LS-NAF base/wedge is being built in paddock dumps (nominally 2 m high), with dozer and truck compaction, and with the last lift below the CCL reduced to 1 m thick. The wedge is designed to slope downwards to the NOEF WPROD to encourage drainage towards the dam.

HISTORIC AND CURRENT NOEF STAGES

McArthur River Mine Project

FIGURE 4.20

Source: MRM, 2016d.

- PAF cells are being paddock dumped and/or in 2-m lifts, with dozer and truck compaction. 100-mm thick alluvium covers will be placed where PAF(RE) is tipped, and advection covers will be placed on outer batters. The 7.5-m PAF(HC) lifts proposed in the Draft OMP EIS have not yet been constructed. Flattening of the western portion of the north face is complete, and flattening of the eastern portion in progress (Plate 4.4). The north face is planned to have 0.5 m of alluvium and 1.5 m of MS-NAF armouring as an internal advection cover prior to CW PAF cell construction.
- Additional inter-stage internal advection cover is planned on the north and east side as the dump progresses, with 10 m (minimum) MS-NAF between the PAF and advection cover to better isolate the PAF materials.
- Western side MS-NAF halo is to be constructed in paddock dumps at the same time as the PAF cells, but with the option of end tipping in 5-m lifts to keep up with the PAF cell placement.

Plate 4.4 – Northern Face of the NOEF Showing Flattened Western Portion Ready for Advection Barrier and Eastern Portion Still to be Flattened

The base of the existing NOEF comprises undifferentiated NAF material and was designed to keep overlying PAF and low-grade stockpiles above the 1:100 flood level. Block modelling of the existing NOEF NAF base showed that this layer is mainly (60%) comprised of MS-NAF materials. The current base layer construction at Central West will ensure that LS-NAF is placed in a wedge above the 100-year flood level, as per approved designs. As discussed in the previous IM report, MRM considers this to be an inefficient use of LS-NAF since the company does not believe that the wedge will be effective in directing drainage/seepage (presentation by MRM to DME on 27 April 2016).

The proposed NAF base layer detailed in the Draft OMP EIS will mainly comprise MS-NAF (consistent with the older NOEF base layer areas), with LS-NAF materials reserved for the outer cover zone. This departs from the previous design concept of only benign materials being placed in this layer, but is justified in the Draft OMP EIS on the basis of the planned implementation of additional flood protection measures, including encapsulation of the entire base zone in the cover system and 100-year flood protection barriers keyed into the basal clay layer. This reasoning is supported by the IM, particularly since the principal impacts from the NOEF are likely to be due to seepage from PAF materials.

In newly-developed areas of the NOEF, the foundation layer for the NAF base layer will be compacted to direct any seepage passing through the NOEF towards an appropriate PROD. The foundations under much of the existing NOEF do not have a basal compacted layer, but do have in situ clay. Figure 4.21 is a plan showing contours of the approximate thickness of the in situ clay (i.e., clay suitable for construction, not the entire thickness of alluvium) at the base of the NOEF. It is understood that very little clay was excavated from the NOEF footprint, as clay was used from the pit clearing areas during this timeframe. The figure indicates that even where active compaction was not carried out in the West and East stages, the in situ clays have a thickness ranging from 1.5 m in the west to 12 m in the east. McArthur River Mining personnel expressed the opinion during the site visit that any seepage from the NOEF will tend to drain along the clay layer and is likely to mainly report to surrounding PRODs. While the presence of relatively thick in situ clay appears to support this, further investigation would be required for confirmation. Figure 8-11 of the Draft OMP EIS (MRM, 2017a) shows clear evidence of high SO_4 concentrations in groundwater below the footprint of the NOEF, and elevated EC (primarily controlled by SO_4) continues to be reported from Surprise Creek and Barney Creek (KCB, 2016b). Much of this could be from previous contributions from the NOEF SPROD and NOEF SPSD when they were inadequately lined (both now have a better-constructed compacted clay lining), but the contribution from NOEF direct seepage is uncertain.

Elevated SO_4 concentrations in groundwater to the northeast of the NOEF near Emu Creek (particularly bore GW105) were discussed in the previous IM report. Groundwater assessment by KCB (2016a) indicates mixed groundwater sources of high salinity background and possibly NOEF-derived seepage. The report states that this is being further investigated with electrical resistivity and hydrogeological investigations.

The IM considers the proposed NOEF cover system design outlined in the Draft OMP EIS (MRM, 2017a) and by O'Kane Consultants (2016a) to be generally consistent with best practice. The IM has provided specific technical comment on the NOEF cover design in its review of the Draft OMP EIS which was submitted to the Northern Territory Environment Protection Authority.

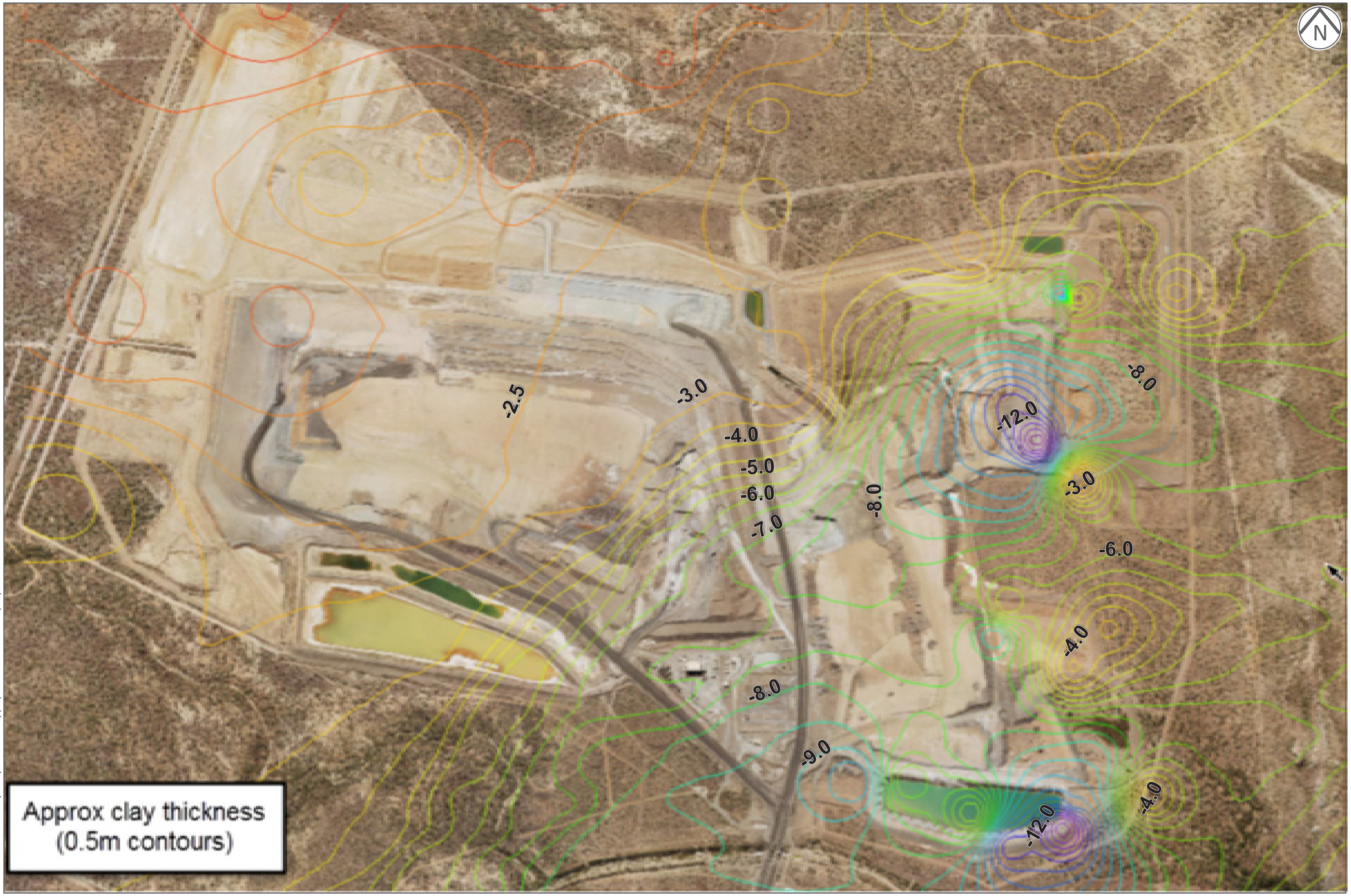
The key proposed advection controls for PAF material involve dumping in short lifts, paddock dumping, traffic compaction, and use of alluvium advection covers. The MS-NAF in the halo zone is sulfidic and hence will also assist somewhat through consumption of oxygen. While on site, the IM was advised that even with paddock dumping and compaction, some PAF zones on the southwest corner of the NOEF were showing spontaneous combustion. This appeared to be managed through placement of an alluvium cover layer, but the occurrence emphasises the high reactivity of these PAF materials, and supports the need to review the 7.5-m option for PAF dumping in the core zone, and how advection layers on paddock-dumped materials are placed and at what stages.

The IM observed the placement of advection control layers on the western (Plate 4.5) and southern faces for the NOEF over the MS-NAF halo. The IM was advised that alluvium was spread down the dump face to form 0.5-m layers and track-rolled vertically, with no moisture

APPROXIMATE THICKNESS OF IN SITU CLAY BELOW THE NOEF

McArthur River Mine Project

FIGURE 4.21



conditioning. Inspection of the advection control layer indicated even coverage, and the fine-grained nature appeared to be suitable for advection control, but this would need to be confirmed. These faces are at the limit of the dump, and are ready for final cover placement once the design is approved. It is not planned to cover the alluvium covers with a fresh rock erosion protection CCL (as part of the final outer cover) on a rock layer. These advection control layers are therefore at risk of erosion until approvals, and MRM is planning to use other options to minimise erosion before the next wet season:

- Placement of a traffic-compacted layer of weathered rock (from excavation of NOEF WPROD) to help protect the advection layer from erosion. There is only sufficient weathered rock for either a 1.4-m cover on the western face or a 1.2-m cover on the southern face.
- Install rock drains down slope on the face without a weathered rock cover to help control water flow rather than allow random gullying, with maintenance of the 0.5-m barrier layer through the wet season.
- Possible use of cobbly alluvium to help minimise erosion, either alone or in conjunction with the rock drains. The performance of these materials in erosion protection is not known.

Plate 4.5 – Advection Control Layer on Western Face of NOEF

While the described concepts and design of the NOEF PAF cells and advection controls are an appropriate approach, field trials must be carefully designed and executed to test the proposed control measures and confirm that advection can be successfully managed. Failure of the advective barriers would lead to continued high oxidation rates and contaminant release during operations, and high temperatures in the NOEF. This is particularly important for the existing end-tipped PAF portions of the NOEF in which convective oxidation is already occurring. The effectiveness of these advection covers on a large, heterogeneous and actively convecting system has not been demonstrated by investigations carried out to date. Advection covers are expected to perform best in the more recent areas of the NOEF (i.e., West D and Central West Stages) where PAF materials have been or will be placed in small lifts and are subjected to greater traffic compaction.

It is noted that the advection barriers are not designed to limit infiltration, but are focused on limiting bulk air transfer into the dump. Investigations carried out by Sustainable Minerals Institute (2016) as part of the interim cover trials reported in the last IM period indicated that infiltration through alluvium barriers may be reduced by around 50% to approximately 1.6 x 10^{-5} m/s compared to uncovered waste rock, which is four orders of magnitude higher than the target infiltration of 1 x 10^{-9} m/s for the final CCL barrier. Active portions of the dump would not have interim advection covers due to the difficulties in working on this material during the wet season, and would have higher infiltration rates. Significant infiltration into the NOEF can therefore be expected during operations.

The general concepts and principles employed for the design of the NOEF outer cover zone are considered to be well conceived and consistent with best practice, in that they integrate the mechanisms of i) water shedding, ii) store and release, and iii) infiltration/oxygen barrier.

The integrity of the proposed cover system is obviously key to long-term performance, which relies heavily on a relatively thin 0.5-m CCL to control infiltration.

Erosion is a major factor that could influence the cover integrity, which is acknowledged by MRM, and the proposed cover system includes a number measures to reduce this risk, including:

- A growth-medium layer designed to encourage revegetation for surface stability and act as a layer for storage and evapotranspiration of incident rainfall.
- Inclusion of a 0.5-m drainage layer in the cover on the plateau.
- Use of trilinear concave batters.

The erosion modelling mentioned previously appears to show that erosion can be reduced to rates that will be manageable with maintenance and repair. It is understood that MRM plans to carry out small-scale cover trials this year, which is strongly supported by the IM to help demonstrate the validity of the proposed approach as soon as possible.

During the site visit it was apparent that the identification and stockpiling of materials suitable for the CCLs and advection barriers was well organised. The alluvium materials are sourced from open pit pre-stripping areas. Operators are trained to recognise the different materials types, with clear boundaries between clay suitable for CCLs and silty sandy clay suitable for advection barriers (Plate 4.6). Because the alluvium materials are excavated early in the mine life, a system of storage and rehandling is required, and the IM observed well-organised stockpiles close to the CW construction works, with testing carried out to confirm the suitability of materials for CCL and advection layer purposes.

Plate 4.6 – Pre-Stripping Area Showing In Situ Clay and Silty Sandy Clay Materials

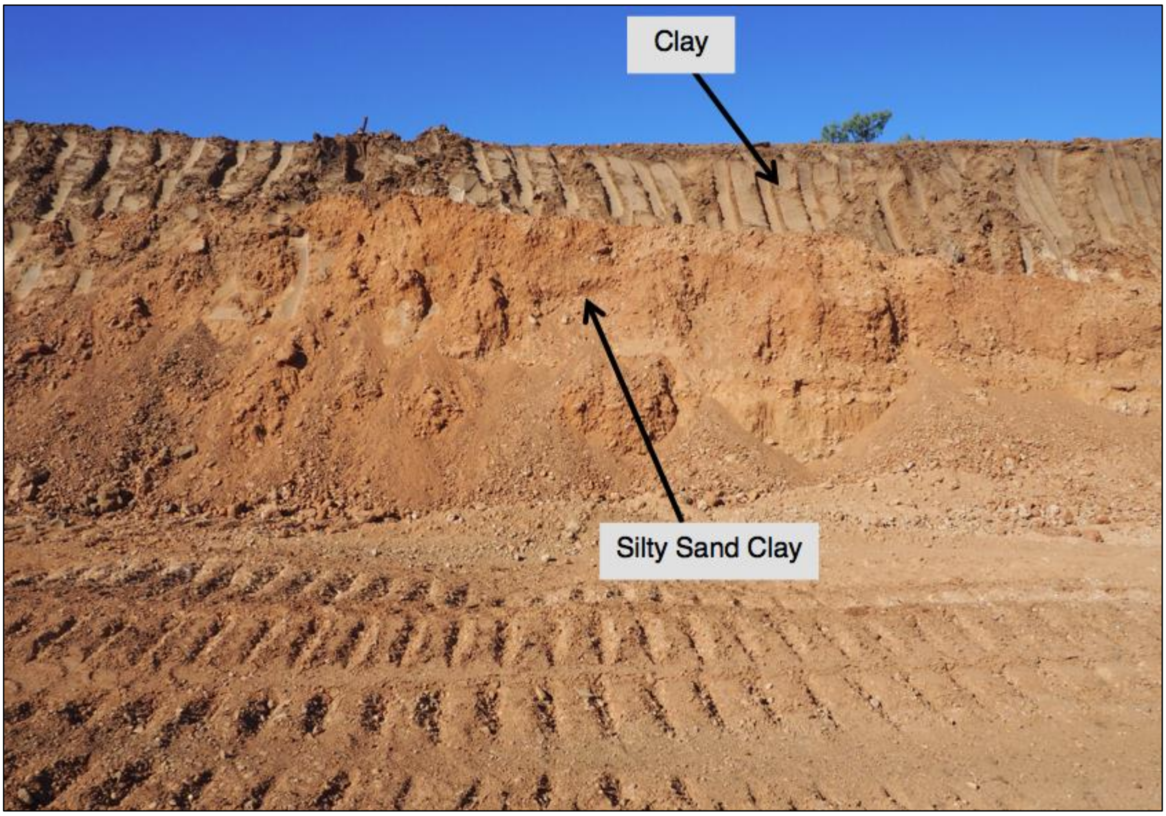
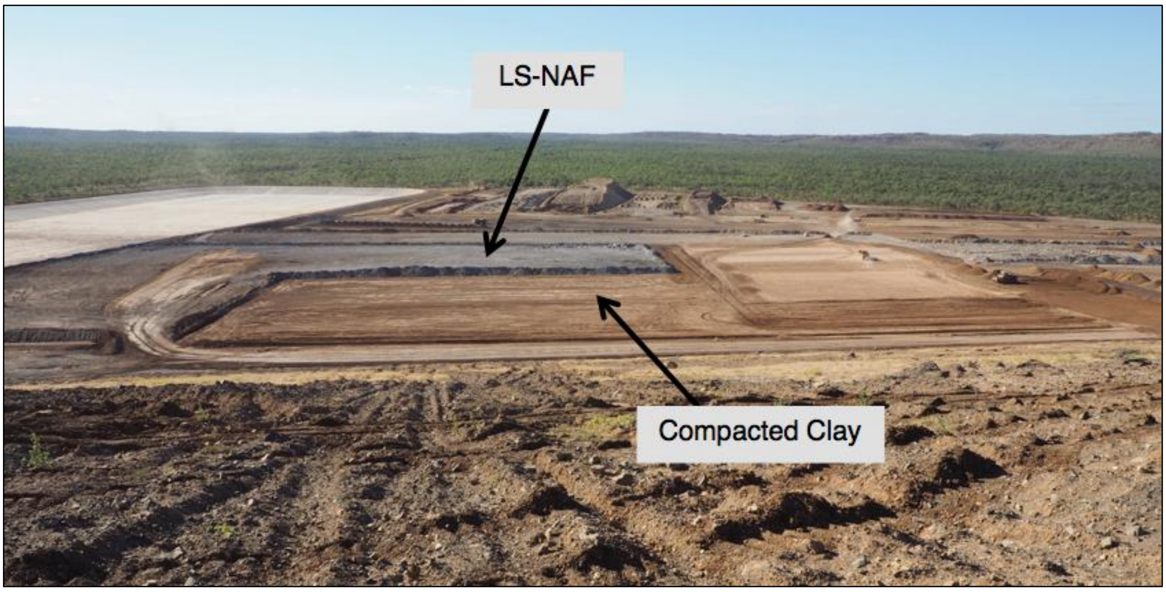


Plate 4.7 shows preparation of the basal layer in the Central West stage, with LS-NAF being placed over a CCL. The placement and conditioning of the basal layers was likewise well organised.

Plate 4.7 – Northern Portion of Central West Showing Placement of the CCL and LS-NAF Base Layer



It is understood that in July 2016 during low grade ore (LGO) recovery on the NOEF, DPIR issued an instruction to MRM to cease work until a dust management plan had been submitted and approved by the DPIR (DME, 2016b). The LGO stockpiles were a known source of high temperatures and a spontaneous combustion hazard (MRM, 2016d), and it is understood from MRM that the combustion degraded the materials so that when disturbed they tended to readily liberate dust. McArthur River Mining personnel advised the IM that the dust issue was mitigated by application of water during mining of the LGO, but that this caused increased oxidation of the LGO and transport of stored oxidation products, resulting in acidic (pH less than 4) leachate reporting to the NOEF SPSD. During the site visit, the acid water was being held in the NOEF SPSD and NOEF SPROD, and a combined hydrated lime/limestone product was being used to try and neutralise the water and reduce the metal content by precipitation. The incident highlights the potential for generation of highly acidic leachate from these strongly pyritic PAF materials if advection processes are not controlled. Continued treatment of the acid water is encouraged by the IM to reduce the potential for uncontrolled release. The acid leachate generation appeared to be unexpected, and although captured, such events should be avoided in future.

During operations, management of seepage and run off from the NOEF will be key to minimising continued AMD impacts on the receiving groundwater and surface water systems. Minimising impacts through oxidation control and reducing the generation of AMD will be less effective during operations with the current management and configuration of the dump. Although the interim advection barriers may help limit advection, it is unlikely that oxidation rates and AMD generation rates would significantly reduce until the final cover is installed. Managing the transport of AMD from the NOEF relies on seepage and run off reporting to the surrounding PRODs. Direction of surface run off to the PRODs is straightforward, but infiltration is expected to be substantial for the NOEF given there will be no active infiltration control during operations. The fate of the subsequent NOEF seepage is uncertain, with the foundations of a large portion of the existing NOEF comprising uncompacted in situ clayey alluvium. There will be limited infiltration controls on the NOEF until final cover placement, and it is recommended that the potential seepage contribution from the NOEF to the groundwater system during operations be better defined.

The potential for seepage from the PRODs has been much reduced, with the NOEF SPSD and NOEF SPROD now clay lined and consistent with the NOEF SEPROD. Note that a HDPE lining was proposed for the NOEF SPROD, but this dam is being used to store acidic leachate from the LGO stockpile irrigation event. The acidic water would need to be removed from the NOEF SPROD before installation of a HDPE liner could be carried out, and the IM was advised that the capacity to remove the acidic water would require approval of the expanded water management system outlined in the Draft OMP EIS, including construction of the NOEF EPROD, expansion of the water treatment plant, and Cell 3 water management structures.

No new material was placed in the SOEF since the last IM report, but a small portion of PAF(RE) material was accidentally dumped there in 2015. This was not recognised until 2016 during a DPIR inspection, in which a sulfurous odour was noted, and heat cracks, elevated temperatures, and elevated SO_2 were noted in a follow up inspection (DME, 2016a). The identified hot spots of PAF(RE) were tracked back to 2015 by MRM and, although they represent a hazard requiring separate management for control of temperature and gas issues, are unlikely to greatly affect the overall leaching characteristics of the SOEF during operations.

Some minor dumping of MS-NAF waste rock (160,000 t) occurred at the WOEF on the ROM pad to improve access, stockpile configurations and drainage (MRM 2016c). McArthur River Mining plans to manage this dump at closure in the same way as the NOEF, with an outer cover system similar to that proposed for the NOEF but without the MS-NAF halo zone (MRM, 2017a).

Tailings Materials - Geochemical Prediction and Monitoring

The following additional geochemical testing and investigations of tailings was carried out in the current reporting period:

- Continued routine 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.

Tailings S and ANC results from May 2007 to August 2016 are shown in Figure 4.22. Results from the current IM review period are consistent with those previously reviewed, with the tailings expected to be 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. Total sulfur contents are also similar to previous results and very high relative to typical base metal mine tailings, varying from approximately 10 to 18%S.

The ANC data in Figure 4.22B continues to show the vast bulk of the tailings samples have high ANC values greater than 150 kg H_2SO_4/t. In the 2015 IM report, it was noted that the ANC results for tailings collected in December 2014 to March 2015 showed lower ANC values than expected, ranging from 60 to 95 kg H_2SO_4/t compared to median values of approximately 180 kg H_2SO_4/t. Repeat testing indicated the anomalous values were related to laboratory issues, and continued testing demonstrates that these low values were anomalous.

No new geochemical assessment was carried out since the last IM report, but results are summarised in the Draft OMP EIS (MRM, 2017a), which also refers to humidity cell testing of two tailings samples. This testing indicates that As, Cu, Pb, SO_4, Cd, Co and Zn may be mobilised in significant concentrations at neutral pH conditions. Kinetic results were not provided to the IM, and the Draft OMP EIS did not elaborate on what concentrations can be expected from oxidising tailings.

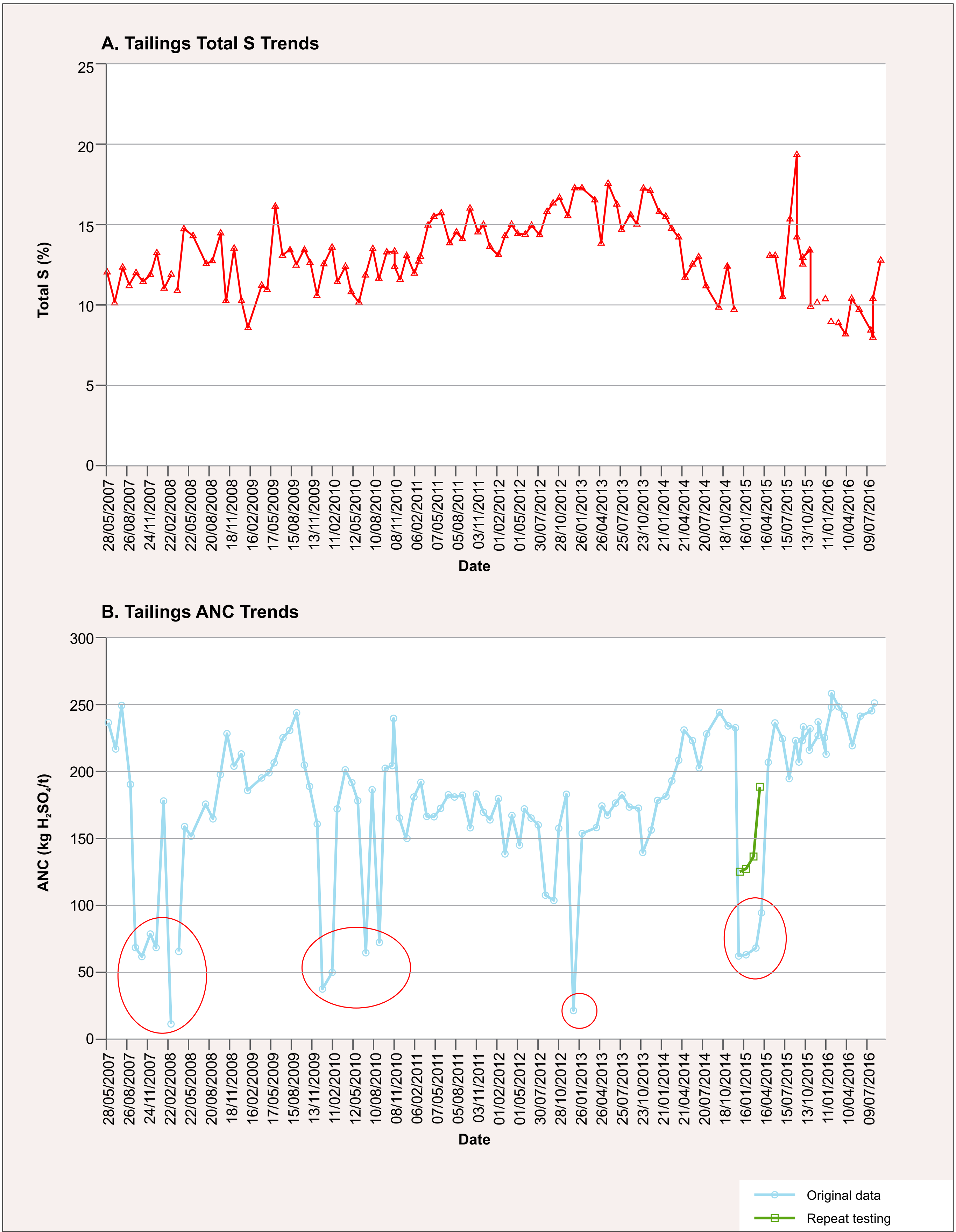
Earth Systems (2016a; 2016b; 2017) reviewed kinetic test data and MRM process data, and carried out geochemical and oxygen penetration test (OPT) work to better assess contributions of tailings oxidation, PBOX effluent and process water to TSF chemistry. The investigations help address a number of uncertainties from the last IM report. The main findings were:

- Mass balance calculations confirm that the acidic PBOX effluent was the most likely source of the early 2015 decrease in tailings supernatant pH noted in the previous IM report, and that thiosalts and ferrous ions are likely to have very minor influence on any supernatant acidification.

TAILINGS TOTAL S AND ANC TRENDS (2008 TO 2016)

McArthur River Mine Project

FIGURE 4.22



- The PBOX process is likely to be a major source of elevated SO_4 and metal concentrations in the supernatant, with Zn concentrations (for example) increasing from less than 50 mg/L to over 200 mg/L, and peaking at over 1,000 mg/L in the first half of 2015. The concentrations dropped from October 2015, which appears to be due to only sporadic PBOX operation (MRM, 2016c).
- The acidity input from the PBOX effluent is unlikely to have a major impact on lowering the ANC of the tailings.
- Acid conditions are unlikely to develop within tailings pore water or supernatant water during operations in which only partial surface drying of tailings occurs due to spigot cycling, and maintenance of 80 to 90% saturation. However, the oxidation is likely to contribute some SO_4 and dissolved metals, particularly Zn.
- If operations cease, tailings saturation will drop, and significantly higher rates of acid and associated metal/metalloid generation would occur, with an estimated 2 months before acid conditions develop in the upper 20 mm of the tailings.
- Control of oxidation would be required at closure to prevent ARD being generated in the long term (assuming these tailings are not re-processed).

The test work, mass balance calculations and approach taken by Earth Systems appears reasonable, and the conclusions are consistent with IM's expectations.

Supernatant water quality data reviewed by KCB (2015b) and Earth Systems (2016b) shows that the process water has high EC (over 10 dS/m) and is dominated by Ca, Cl, K, Mg, Na and SO_4. Concentrations of SO_4 range from around 5,000 to 11,000 mg/L, with an increasing trend noted by Earth Systems (2016b) being due to PBOX input (as alluded to above). During the IM site visit, the surface of the tailings showed considerably more white salt crusting than in the previous year (Plate 4.8), indicating drier surface conditions. McArthur River Mining processing personnel commented that the crusting was most likely due to drying of process water. While the drying out of the tailings is undoubtedly causing oxidation of the highly pyritic and strongly reactive tailings, the IM agrees that the very high EC and SO_4 in the process water is likely to be the dominant contributor.

The results of the Earth Systems investigations indicate that while tailings oxidation is a potential long-term issue for acid drainage and high SO_4 and metals/metalloids concentrations, during operations the saturation of the tailings is likely to be generally at 80 to 90% with limited oxidation depths and acid/SO_4 loadings, and hence the process water on active Cell 2 is likely to be the dominant influence on seepage water quality. It is also evident that the PBOX effluent is a major contributor to SO_4 and metals/metalloids concentrations, and that controlling this process stream could potentially significantly reduce downstream seepage impacts during operations. GHD (2017a) makes reference to MRM changing management of the PBOX stream so that most of the water is recycled rather than discharged, which may address the issue, but no further details were evident in the information provided. There is no mention of recycling the PBOX stream in the OPR (MRM, 2016c), or whether this will continue.

Plate 4.8 – Salt Crusting on TSF Surface

Investigations and assessment was carried out by the ITRB (2015) on Cell 1, which included excavation of a test pit through the clay cap. The results showed limited oxidation to a depth of 50 to 100 mm and moist tailings below this depth, indicating that despite the lack of activity on Cell 1 since 2007, oxidation was limited and that the process water pore water chemistry would dominate the water quality of seepage from Cell 1.

The ITRB and Earth Systems assessments highlight that infiltration control and controlling/treating the PBOX process stream are the key to controlling impacts on receiving waters during operations, and that surface tailings oxidation effects are unlikely to be significant until after tailings disposal ceases. Routine surface sampling of dry tailings and 1:2 water extraction testing (or equivalent) should be carried out to check for any acid generation from oxidising tailings and confirm the assumed lack of operational impacts.

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). The Draft OMP EIS discusses the planned LOM management of the TSF (MRM, 2017a), which involves combining Cell 1 and Cell 2 into one large cell and hydraulic mining and re-processing once mining operations cease. Cell 2 tailings disposal will continue until 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 significantly from the last IM report.

Management of seepage from Cell 1 still 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.

The current management of Cell 2 (GHD, 2017b) 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 CRP for use in the processing plant. This can be expected to significantly reduce the rate and volume of poor water quality reporting to the groundwater system compared to operations prior to 2015, in which high volumes of water were stored in Cell 2.

As mentioned above, various investigations by the ITRB and Earth Systems strongly suggest that process water is the main source of salts reporting to groundwater and downgradient surface drainage at Surprise Creek. The recycling of the PBOX water mentioned by GHD (2017a) would also significantly reduce the ongoing loadings of SO_4 and metals/metalloids. However, the process water contained in the pore water within the TSF and that portion already reporting to groundwater will continue to drain and migrate to surface drainage receptors. McArthur River Mining proposes to manage the ongoing seepage of tailings water through seepage recovery, primarily through the use of interception trenches (GHD, 2017a and 2017b). The efficacy of this approach is discussed elsewhere in this report (e.g., Section 4.5).

The current and proposed TSF management strategies are considered appropriate for the operation period, and likely to minimise both seepage and oxidation. Results of investigations to date indicate that sulfide oxidation processes do not require further management during operations beyond what is already occurring, and that mitigation efforts need to focus on managing process water infiltration and migration. For the existing TSF designs and configurations, minimising water storage and seepage recovery seem to be the only viable options to control direct impacts on receiving drainage from process water.

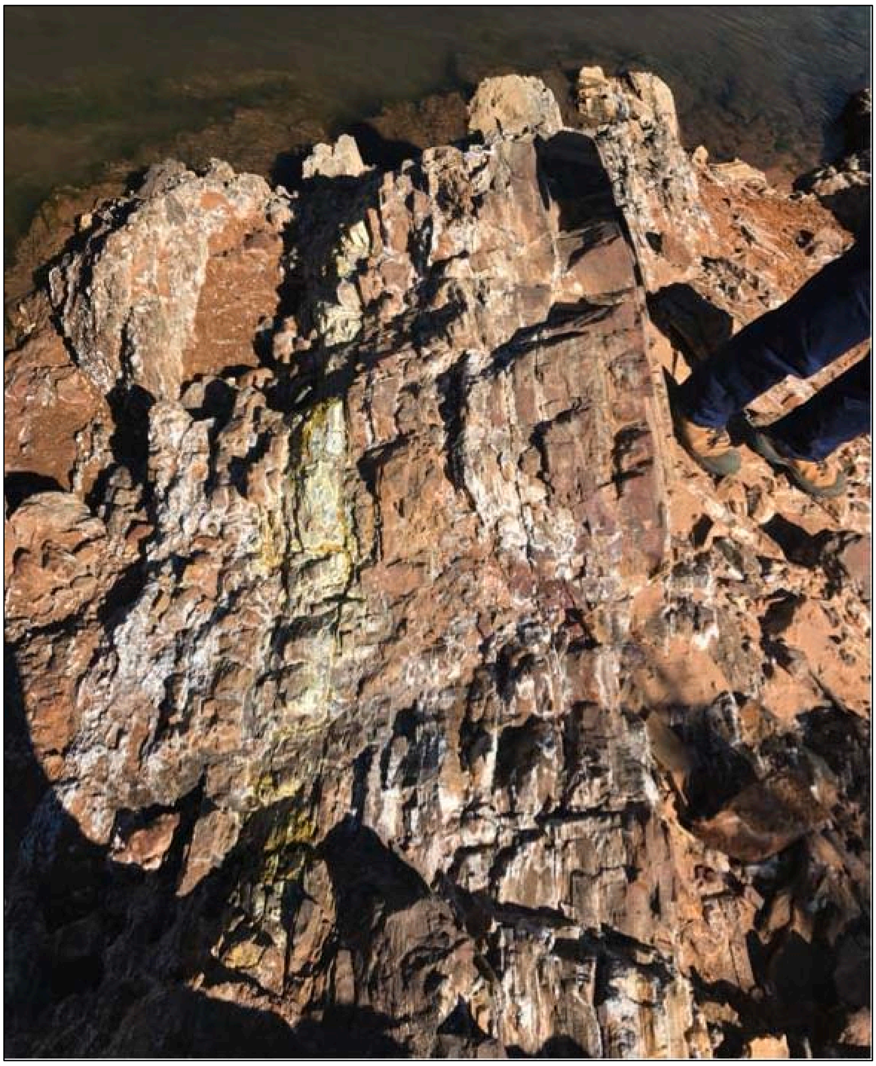
In relation to closure, the IM strongly supports the re-processing and pit disposal option. Placement of the tailings in the pit would have the benefit of consolidating potential sources of AMD, and the tailings would remain inundated thereby preventing further sulfide oxidation and providing a much more secure closure outcome than would be achieved for a TSF with a cover system.

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. Progress was made on pit water quality modelling for the Draft OMP EIS (Appendix VI, KCB, 2017b). Although the modelling relates to a specific closure scenario which has not yet been approved whereby tailings and waste rock are submerged in the final pit, the results indicate that acceptable pit water quality could be achieved over the long term. Although not evident in KCB (2017b), KCB personnel advised during the site visit that the recovery water level in the pit would inundate most of the pyritic materials in the pit shell so that sulfide oxidation would largely cease, with only small amounts of MS-NAF exposed to contribute ongoing AMD loadings.

In the last IM report, reference was made to elevated EC values (that were related to SO_4 concentrations) observed in the McArthur River diversion channel from monitoring point SW16 downstream through SW17. Geological inspection identified zones of mineralisation along the diversion, which MRM believed may be the source. The IM inspected the diversion channel during the site visit, and observed that the oxidation profile extended down to around 3 to 5 m depth, but the lower parts of the diversion excavation continued below the oxidation zone. In some areas (close to the Western Fault) the diversion channel excavation has exposed highly sulfidic units, with frequent to abundant salt coatings and crustings (Plate 4.9 and 4.10), and the IM agrees that this is likely to be the main source of sulfate salt under low flow conditions. The exposed sulfidic rock in the excavated banks are likely to continue to cause long-term local impacts on water quality, and will affect revegetation success on the lower parts of the diversion banks. These effects will need to be put into context of other water quality impacts from other parts of the mine.

Plate 4.9 – Salt Crusting on Pyritic Units Exposed in the McArthur River Diversion Channel Between SW15 and SW16



The OP ELS is reasonably close to SW16 and was also a potential contamination source when it was used for storing water pumped from the old underground workings, but that ceased during the 2015 dry period. Groundwater assessment by KCB (2016a) indicated a potential influence of the OP ELS on groundwater quality in bores to the east between the OP ELS and diversion, supporting a possible influence on the diversion water quality when it was active. Now the OP ELS only collects runoff from the SOEF area, and the future influence on diversion water quality is likely to be minor.

Plate 4.10 – Intense Salt Crusting on Pyritic Units Exposed in the McArthur River Diversion Channel Between SW15 and SW16

4.6.4 Review of Environmental Performance

4.6.4.1 Incidents and Non-compliances

Incidents

Most incidents related to geochemistry are discussed in Section 4.6.3.2, including:

- Three Category 1 incidents on 4 October 2016, 21January 2017 and 6 February 2017 (MRM, 2017k) related to misplacement of materials and correction through rehandling.
- Misplacement of a small portion of PAF(RE) material at the SOEF in 2015.
- Release of acidic leachate from the LGO stockpiled on the NOEF in mid-2016 as a result of irrigation for dust control, although this was not recorded as an incident in the documents reviewed. Such events should be avoided and actions required for future situations documented.

Additional incidents relating to water quality have been discussed in Section 4.3.4.1.

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 4.28. Those recommendations already completed or combined into subsequent years' recommendations have been omitted.

Table 4.28 – Geochemistry Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2015 Operational Period		
NOEF	Installation and maintenance of complex cover systems on the NOEF will be challenging. Performance criteria should be developed, and a cover system designed that is robust enough to be installed on the NOEF and provide satisfactory long-term performance Allowance should be made for long-term monitoring and ongoing maintenance of the NOEF cover system post closure	Performance criteria have been developed, and design updated, as part of the Draft OMP EIS, but there are still uncertainties in regard to the performance of advective oxygen control and infiltration control, and long-term (1,000 years) sustainability Long-term maintenance and monitoring has been allowed for in the Draft OMP EIS, but requires further details on costings and review of assumptions. Updates should await outcomes of the Draft OMP EIS assessment
	Develop a new approach to wet season infiltration control given the apparent ineffectiveness of a clay cover	Completed. Infiltration control with surface covers is no longer deemed practical by MRM. Seepage management now relies on the foundation layer directing any seepage to PRODs
	Improve control of convective/advective oxidation and spontaneous combustion. Advances have been made, but these processes are still occurring	Improvements have been made and advection covers are being placed, but performance remains uncertain, particularly for the older actively convecting portions of the dump
	Undertake further investigation and analysis of monitoring data to better understand the extent and impact of groundwater contamination from the NOEF	Some work has been carried out, but the direct seepage contribution from the NOEF to the groundwater system is uncertain
	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. Knowing the rock type composition and distribution will help MRM predict contaminant loadings being generated	Block model generated and it is understood additional drilling is planned in 2018
	Increase the frequency of check sampling of dumped materials, particularly for LS-NAF. Only 102 check samples of LS-NAF cells were collected over the 2014 to 2016 period	Procedures have changed and frequency increased, but the changes won't be apparent until the next reporting period

Table 4.28 – Geochemistry Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2015 Operational Period (cont'd)		
NOEF (cont'd)	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	Part of investigations planned for the next IM reporting period
In-pit waste rock grade control	Progress use of on-site ICP testing to replace pXRF	External ICP testing (ALS) now carried out in preference to pXRF, but pXRF used from time to time when ALS is at full capacity
Waste rock criteria	Maintain NPR cut offs for PAF(HC) materials at 1 unless there is compelling geochemical evidence to justify a reduction	Completed. New criteria in Draft OMP EIS maintains NPR cut off at 1
Waste rock kinetic testing	Include results from all kinetic testing in future kinetic test reports, including barrel leach, humidity cells, leach columns, and for waste rock and tailings materials Provide a table of the S, ANC, ABA and key metal/metalloid compositions of samples used in kinetic testing and compare with ranges expected (based on static testing) in each waste rock class and tailings	Completed. Addressed in latest kinetic report as part of Draft OMP EIS (KCB, 2017a)
	Repair barrel tests before the next wet season	Repairs were carried out and all fully functioning before the wet season. Maintenance of seals and sample containers likely to be required annually
	Consider continuing LS-NAF humidity cells/columns to demonstrate longer-term low rates of contaminant release	These have continued into the current review period
TSF	Progress the in-pit disposal and flooded option for tailings, which will provide the most secure closure outcome	Included as part of the Draft OMP EIS as MRM's preferred option
	Install a more robust cover on Cell 1 before the next wet season that will withstand erosion and control infiltration, and progress the Cell 1 dewatering bores. The previous interim clay covers installed did not appear adequate to control seepage and impacts on Surprise Creek	Infiltration control not considered practical by MRM and management will rely on seepage interception and collection
	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 measurements of surface tailings	Not yet carried out
	Continue kinetic leach 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	Continuing

Table 4.28 – Geochemistry Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2015 Operational Period (cont'd)		
TSF (cont'd)	Maintain moisture in drier and less active areas of Cell 2 to minimise sulfide oxidation and dust. This may include spraying water onto the surface	Results of recent investigations by Earth Systems (2016a; 2016b; 2017) suggest a limited oxidation depth and that the tailings are unlikely to develop acid conditions during operations, and hence acid/sulfate loadings are likely to be minor, and requirement for addition of moisture to surface unnecessary Requires confirmation with surface sampling
	Variation in ANC values was detected between different laboratories. Further checks should be carried out to determine which results best reflect the available ANC in the tailings, with inclusion of ABCC testing	Completed. No longer relevant. Continued monitoring of tailings highlights the anomalous nature of the lower ANC values and investigations show that the ANC will be more than sufficient to maintain circum-neutral pH during operations
Mine site	Progress investigations into the eastern levee storage (ELS) and potential for saline seepage to McArthur River diversion channel	ELS no longer used KCB (2016a) indicated a potential influence of the OP ELS on groundwater quality in bores between the OP ELS and McArthur River diversion channel, supporting a possible influence on the diversion water quality when it was active
2014 Operational Period		
NOEF	Continue paddock dumping and roller compacting PAF(HC) materials, which are still highly pyritic, to maximise stability and minimise oxidation and infiltration	Currently, PAF(HC) materials are being paddock dumped together with PAF(RE) in the NOEF due to dump space limitations Note that materials are traffic-compacted rather than roller-compacted The Draft OMP EIS describes options for 7.5-m PAF(HC) lifts, which require further investigation
	Maintain a 100-m set back for PAF(HC&RE) materials, particularly in older 15-m end-tipped dump zones, to control convection	Current cover system design will not include a 100-m setback. Advection cover layers are proposed to achieve this, but performance requires confirmation Recommendation no longer relevant
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	Not yet carried out, but a general understanding of the distribution has been provided in the Draft OMP EIS along with a general closure plan to complete cover system similar to NOEF
SOEF	Review kinetic test results and assess potential impacts on receiving drainage during operations, and finalise closure options	Completed. Kinetic testing continuing and groundwater monitoring confirms impacts, but modelling suggests seepage towards open pit Closure plan in Draft OMP EIS involved re-handling to pit

Table 4.28 – Geochemistry Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Resource waste block model	Reconcile the block model predicted tonnages by waste rock type against tonnages actually mined, and adjust the block model if required. The amount of materials classified PAF(HC) in 2014 was significantly higher at 34% of waste rock moved than the 15% predicted by the block model	Improvements made but issues still to be resolved and included in new recommendations (Table 4.29)
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	Not carried out
In-pit waste rock grade control	Check calibration of hand-held XRF with new ICP check data	Further calibration completed, and MRM is moving towards ICP instead
Waste rock criteria	Identification of PAF(RE) is currently based on S criteria only. Continue investigations into spontaneous combustion potential and develop criteria that provide more confident identification of PAF(RE). In particular, confirm whether the current 10%S cut off is too high and needs to be lowered to 8.5%S	The current 10%S cut off is still used but not yet justified
TSF	Make financial allowance for long-term monitoring and ongoing maintenance of any TSF cover system post closure	May not be relevant pending approval of in-pit disposal proposed in Draft OMP EIS
	Assess the potential effects of pyrite oxidation and salt generation on the overall stability of the TSF embankment if compacted tailings are used in embankment construction	May not be relevant pending approval of in-pit disposal proposed in Draft OMP EIS
	Continue ongoing geochemical monitoring of discharged tailings and carry out geochemical characterisation of tailings collected as part of TSF drilling to obtain information on historic variation through the tailings profile	Routine testing is being carried out. Fate of TSF samples from the drilling is unknown, but may not be relevant pending approval of in-pit disposal proposed in Draft OMP EIS
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 and McArthur River diversion	Not yet carried out
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	No specific acid sulfate soil assessment of the spoon drain at Bing Bong Loading Facility was provided

4.6.4.3 Successes

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

- Completion of geochemical testing and investigations that have resulted in a comprehensive dataset with an appropriate suite of static and kinetic tests, so that the geochemical properties of overburden and tailings materials at the mine are well understood.
- Use of kinetic data to develop improved waste rock classification criteria.
- 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 classes.
- Completion of a number of studies and assessments to address information gaps, including reconstruction of the NOEF waste rock composition, better definition of the composition of the SOEF and WOEF, cover design modelling and assessment, groundwater modelling to better understand seepage pathways for OEFs, erosion modelling to better understand potential impacts on long-term dump cover integrity, testing and assessment of tailings surface oxidation potential and lag times, and pit water quality modelling.
- 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.
- Construction of a minimum 35-m wide MS-NAF halo zone around the west, south and east (in progress but almost complete) side of the older West Stage of the NOEF to help control convection/advection into PAF materials (and particularly end-tipped PAF materials) in this older zone.
- Set up of a well-organised system of identification and stockpiling of materials suitable for the CCLs and advection barriers.
- Clay lining the NOEF SPROD, thereby greatly reducing the potential for seepage of AMD.

4.6.5 Conclusion

As with previous years, considerable efforts have been carried out by MRM in regards 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. Assessment of the Draft OMP EIS is ongoing, and management strategies have yet to be finalised, but the work carried out to date continues to confirm that McArthur River Mine materials are highly pyritic and a major potential source of AMD. The risk of AMD generation and the associated potential adverse impacts both on site and downstream remains the most significant environmental issue at the mine. The NOEF, TSF and open pit represent the key potential sources of AMD.

Poor quality leachate, i.e., AMD, from waste rock in the NOEF is already reporting to groundwater and surface drainage due to inadequate management of seepage during operations. Future dump construction will better control seepage during operations, but infiltration through the NOEF will continue, and there is uncertainty concerning the fate of this seepage and whether the current PRODs will capture it all.

A major factor that contributes to the above risk is historical end dumping of 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). This tends to promote rapid rates of sulfide oxidation and greater release of AMD. Progress has been made in reducing convective oxidation in these older areas through construction of an MS-NAF halo on the western, southern and eastern faces of the West Stage, with advection covers placed over the halo on the western and west part of the southern faces. The advection covers currently being implemented are expected to assist control of rapid oxidation in newer areas of the NOEF where PAF materials are placed in small lifts, but the effectiveness of these advection covers on a large, heterogeneous and actively convecting system is uncertain.

Poor quality leachate from the TSF is also already reporting to groundwater and surface drainage due to inadequate management of seepage during operations. Process water appears to be the key source of contamination rather than oxidising pyrite in the tailings. For the existing TSF designs and configurations, the current minimisation of water storage and planned seepage recovery seem to be the only viable options to control direct impacts on receiving drainage from ongoing and historical process water. For closure, the IM strongly supports the re-processing and in-pit disposal option proposed in the Draft OMP EIS, which would ensure that the tailings remain inundated in the long term, thereby preventing further sulfide oxidation and providing a much more secure closure outcome than would be achieved for a TSF with a cover system.

Management of open pit water has not changed since the last IM report, with the discontinuation of pit water storage in the OP ELS removing a potential contamination source.

The IM supports MRM's belief that the exposed sulfidic rock in the excavated banks of the McArthur River diversion channel is likely to be the main source of sulfate salt under low flow conditions. These banks are likely to continue to cause long-term local impacts on water quality, and will affect revegetation success on the lower parts of the diversion.

New IM recommendations related to geochemistry issues have been consolidated in Table 4.29, with updated recommendations from previous IM reviews also being included.

Table 4.29 – New and Ongoing Geochemistry Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
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	High
	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	Medium
	Carry out further investigations to determine the direct seepage contribution from the NOEF to the groundwater system	High

Table 4.29 – New and Ongoing Geochemistry Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
NOEF (cont'd)	Review the frequency of check sampling of dumped materials, particularly for LS-NAF	Medium
	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
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 ICP testing capacity or arranging back up external testing capability to avoid further contingency use of pXRF	Medium
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
Waste rock criteria	Better demonstrate the validity of the PAF(RE) 10%S cut off	Medium
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	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
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
New Items		
NOEF	Proceed with trial cover designs in 2017 as planned	High
	Carry out field trials and monitoring of the end-tipped dump portions of the NOEF to confirm effectiveness of advection covers	High
	Progress field confirmation of erosion modelling predictions, as erosion could have significant implications for long-term cover system integrity and maintenance resources required	High
	Complete treatment of acid water in NOEF SPSD/SPROD before the next wet season to avoid uncontrolled release	High
	Document procedures to avoid generation of AMD from highly pyritic PAF materials in older end-tipped parts of the NOEF	High
Waste rock criteria	Add PAF(HW) to the proposed waste rock classes since it would be handled differently from other materials	Medium

Table 4.29 – New and Ongoing Geochemistry Recommendations (cont'd)

Subject	Recommendation	Priority
New Items (cont'd)		
Waste rock segregation, handling and checks	Resolve discrepancies between mined and modelled waste rock classes	High
	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	Medium
	Include more detailed instructions on sampling methods in the OEF sampling procedure, including photos showing typical sampling	Medium
	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.	Low
Tailings kinetic testing	Prepare a tailings kinetic test report for the next IM reporting period	Medium
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

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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 (as listed in Appendix 1), with particular reference to MRM's mining management plan (MRM, 2015) and the Operation Performance Report (MRM 2016).
- Design reports for the TSF.
- Incidents reports.
- Measured piezometric levels and survey data.
- As constructed report for the Cell 2 raise to RL 10055 m (55 mAHD (10055 m Mine Datum).
- Monthly TSF Cell 2 Communication Reports.
- Inspection reports and compliance audits undertaken by DPIR.
- Reports on the known seepage at the southwest corner of Cell 2 and at the Cell 2 spillway.
- A Life of Mine (LoM) review undertaken by the ITRB (2016).
- Aerial and other photographs of the MRM mine site provided by MRM.
- Topographic (ALS) data of the MRM mine site 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 assessment (Appendix 2), are:

- Embankment failure (loss of containment): embankment slope failure or excessive deformation due to static, seismic or pore pressure loading resulting in 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 4.23 where applicable, and include:

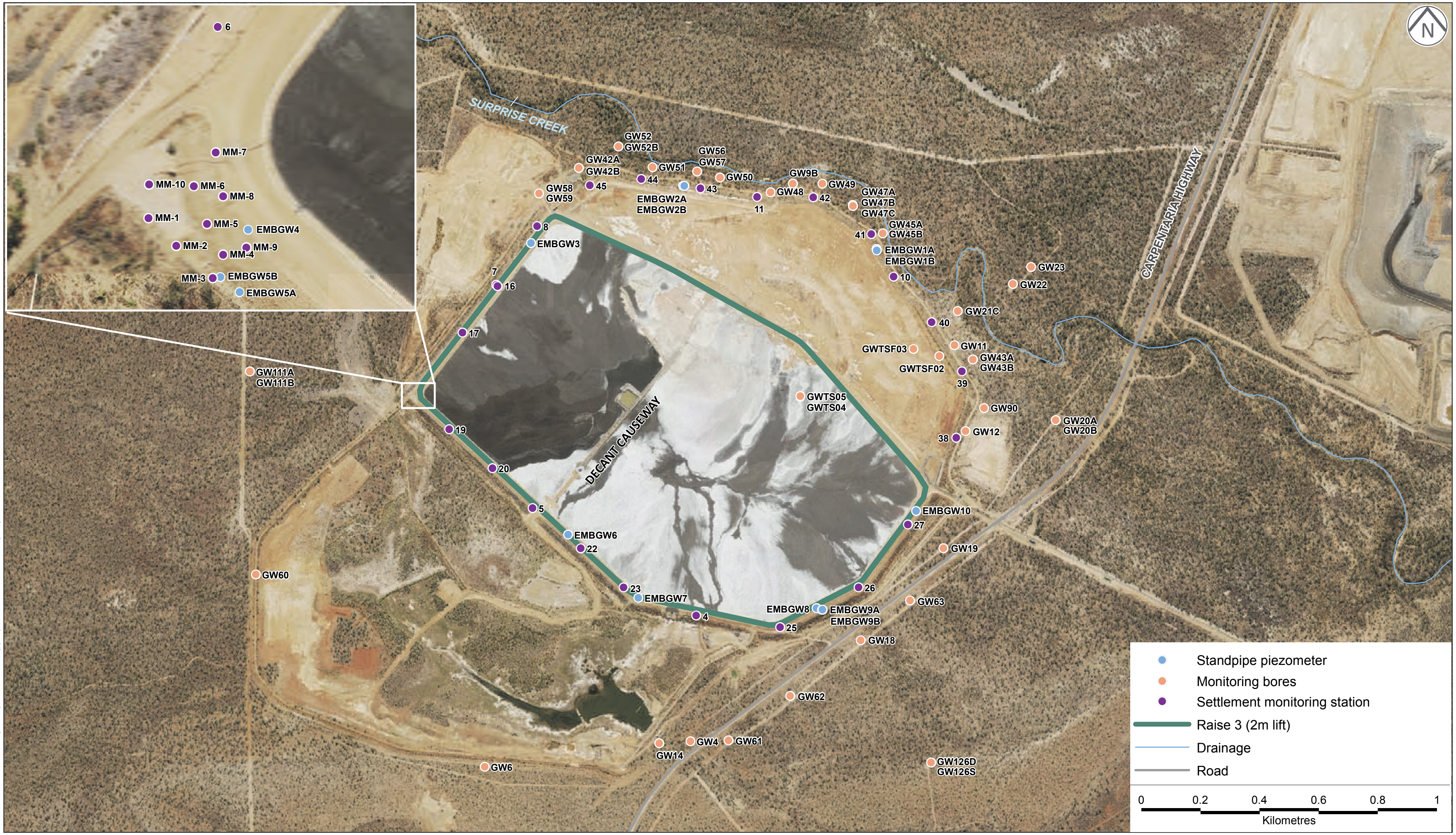
- Design and analysis of future TSF works to meet ANCOLD (2012a) guidelines for a 'High C' dam failure consequence and a 'Significant' dam spill consequence.
- Supervision during construction, and certification that the TSF has been constructed in accordance with design and is fit for purpose under the expected operating conditions.
- 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.
- 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.
- Monthly site inspections of the TSF recording climate, water levels, deposition quantities, construction or maintenance activities and observed impacts such as seepage and erosion.
- Nominally monthly hydrographic surveys of the TSF pond aerial extent. The last survey of this type provided to the IM was undertaken in February 2016. It is unclear whether these surveys are continuing.
- Quarterly level surveys of 23 monuments[15] (expanded from 11 in 2015) within and around the TSF Cell 1 and TSF Cell 2 embankments.

[15] Survey stations used to measure any movement in the embankment wall.

OVERVIEW OF TSF SHOWING MONITORING LOCATIONS

McArthur River Mine Project

FIGURE 4.23



- 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.
- Regular pipeline inspections and monitoring of wall thickness to identify potential pipeline breakage, or limit the impacts should such breaks occur (The IM is not aware of any such inspections or monitoring having taken place for the current reporting period).
- 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.

In addition to the above, the DPIR undertake regular inspections. In the current reporting period the DPIR undertook inspections of the TSF in October, November and December 2015 and January, April, May, June and July 2016.

New Controls – Implemented and Planned

New controls implemented within the reporting period include:

- Completion of the Stage 3 raising of Cell 2 to RL 55 m (completed November 2015).
- Construction of a new Cell 2 spillway to RL 53 mAHD to replace the original and to facilitate safe discharge for the Stage 3 raise (completed November 2015).
- Construction of a bentonite cut-off wall at the southern end of the decant access wall to limit TSF water into the rockfill platform (completed November 2015).
- Strength testing of the surface using a vane shear. Results have not been provided to the IM but use of this type of testing and the indicative results was discussed with MRM during the site inspection.
- Additional investigations and assessments as part of TSF LoM studies (GHD, 2016a). This included:
  - Cone Penetration Testing including pore pressure measurement (CPTu).
  - Undisturbed sampling.
  - Measurement of the thickness of the rock mattress using CPTu testing.
  - Laboratory testing including Atterburg limits, moisture content, particle sizing, oedometer compression testing and cyclic simple shear for liquefaction assessment.

- Updated stability assessment based on the results of new site investigations and measured piezometric levels (GHD, 2016a).
- An annual dam safety inspection by the TSF designer (undertaken December 2015).
- Updated water balance modelling to account for TSF Cell 2 Raise 3, pond water reclamation, revisions to TSF Cell 1 surface water management and changes to WMD operation.

Planned controls include:

- Nineteen new nested vibrating wire piezometers installed in pairs and triplets at 10 locations around the Cell 1 and Cell 2 embankments (installed November 2016).
- Thirty five new survey monuments installed on the newly raised Cell 2 crest (installed November 2016).
- An updated TSF Operations, Maintenance and Surveillance Manual (GHD, 2017). Updates include:
  - References to updated MRM guidelines.
  - New organisation chart and roles and responsibilities.
  - Other changes related to the Stage 3 lift.
- Additional investigations to further define the extent of faulting below the TSF.
- Capping of TSF Cell 1 contingent on the choice of future TSF management and expansion.

Installation of new or extension of existing monitoring was largely due to the newly raised embankment.

4.7.1.4 Review of Environmental Performance

Incidents and Non-compliances

Incidents

Several incidents were reported during the reporting period, these being:

- A tailings pipeline failure was noted in the MRM Monthly Health, Safety, Environment and Community (HSEC) Management System Register (MRM, 2017a) as having occurred on 2 July 2016 ‘near the first environmental containment pond on the TSF side of Barney Creek’. The following action is reported in MRM (2017a):

  > Inspected & tightened flange bolts at the point of the leak. Tested the tension of several other flanges in that area. Removed the spillage and disposed of it in the tailings dam.

  This incident was noted in MRM (2017a) as having no submission of formal notification and no incident number, report or photographic evidence has been provided by MRM or noted by the DPIR.

- A tailings pipeline failure was noted in MRM (2017a) as having occurred on 2 August 2016 and reported as the following:

  Tailings slurry was released due to a flange failure on the tailings pipeline that delivers tailings from the mill to the TSF. The tailings sprayed onto the adjacent road and vegetation. The tailings ran via a natural drainage feature towards Barney Creek. The tailings spillage stream stopped about 5 metres short of entering Barney Creek. No tailings entered Barney Creek. The quantity of tailings slurry released is estimated at 5m^3.

  Corrective measures are reported in MRM (2017a) as:

  Tailings pumps and tailings disposal pumps were shut down immediately on identification of leak. The plant was shut down. Dry NAF gravel was transported to site to contain and control the spill. The tailings pipeline was temporarily repaired by tightening bolts and wrapping filter cloth around flange. The tailings pipeline was flushed to lined containment ponds. Leaks were directed to the lined pond.

  Formal notification of this incident is noted as having occurred in MRM (2017a) given however no incident number, report or photographs have been provided by MRM or noted by the DPIR.

- A tailings pipeline failure was noted in MRM (2017a) as having occurred on 7 August 2016 and reported as the following:

  18:20 night shift supervisor noticed slurry leaking from tailings disposal pipe work from a flange, 18:24 tailings disposal pumps shut down.

  Corrective measures are reported in MRM (2017a) as:

  The leaking flange was removed, redesigned and reinstalled. The structural support of the flange & pipe has been improved. The contaminated area has been cleaned up & all contamination taken to the tails dam.

  No formal notification of this incident is noted in MRM (2017a) given and no incident number or report has been provided by MRM or noted by the DPIR. Photographic evidence has been provided by the DPIR.

- A tailings pipeline failure was noted in MRM (2017a) as having occurred on 26 August 2016 and reported as the following:

  Tailings leak from pipeline at TSF. On entering the TSF for morning inspection the worker noticed tailings spray near base of N.E ramp. On closer inspection they found spool flanges leaking and notified control and had tails line shut down.

  Corrective measures are reported in MRM (2017a) simply as: ‘clean up completed’.

  No formal notification of this incident is noted in MRM (2017a) and an incident number is reported (Incident Number: 32903). No incident report has been provided by MRM or noted by the DPIR. Two photographs of the incident were provided by the DPIR.

- Two other incidents of breaks in the tailing pipeline are reported in MRM (2017a) around the perimeter of the TSF for December 2016.

No other incidents were reported or noted for the reporting period.

Spills of this nature may happen from time to time due to pipe wear or coupling failure. McArthur River Mining employ a number of techniques to minimise the likelihood of pipe burst or the extent of flow if this occurs. These methods are:

- Thermal tomography is used on sections of steel pipeline situated near the process plant and extending to the TSF to check for pipe wear.
- Small earth ponds have been constructed along the pipeline at coupling points (about every 500 m) to capture and hold leaks. Two additional capture ponds were constructed in this reporting period.
- On the TSF itself, MRM employ regular pipeline inspections to detect such leaks as soon as possible and implement spill procedures to contain and remove spills when required.

Notwithstanding the above, examination of MRM (2017a) reveals that flanges on the tailings pipeline have failed at least four times within the reporting period. It also reveals a lack of consistency in documenting, reporting and remediating such incidents. Such spills are also difficult to effectively remediate given the tailings and ability to spread quickly and it’s relatively high environmental impacts.

The frequency and similarity of these failures suggests a possibility of a systemic failure in some of the pipeline couplings. The IM recommends an inspection of the entire tailings pipeline including checking flange bolts to confirm correct assembly to prevent or at least limit similar occurrences.

Non-compliances

There are no non-compliance issues known to the IM to report however further clarification is required from the DPIR regarding breaches of the tailings delivery pipeline.

Progress and New Issues

Progress in the last reporting period includes:

- Completion of Cell 2 Stage 3 construction in compliance with the design specification.
- Construction of a separation plug between the decant bund ‘finger’ and the rock mattress used in the previous construction raise along the southern wall of Cell 2.
- Continued MRM monthly inspections and reporting.
- Routine (usually monthly) inspections of the TSF by the DPIR.
- Development of a LoM strategy for ultimate TSF management.

New issues include:

- Errors in reported piezometric levels
- Continued seepage in the southwest corner of the Cell 2 embankment and at the spillway.
- Concerns raised by the DPIR over the validity of piezometric levels used in stability analyses.

These issues all relate to seepage and piezometric levels within the tailings. Each is expanded separately below.

No significant issues were raised by the ITRB in their review of options and life-of-mine tailings management (ITRB 2016).

Errors in Calculated Piezometric Levels

The IM have been provided with the recorded depths to water levels for the 14 piezometers installed around the TSF perimeter that has been stored in a spreadsheet (MRM, 2017b). These piezometers are denoted EMBG1A, 1B, 2A, 2B, 3, 4, 5A, 5B, 6, 7, 8, 9A, 9B and 10. The latest readings provided to the IM are 30 May 2017 and records commenced on 18 December 2014.

Over time these piezometers have been extended and then cut due to embankment raising construction activity. The provided records indicate that extensions to piezometers EMBGW3, 4, 6, 7, 8 and 10 occurred on or around 8 March 2016 (denoted 'Extension #1 (8/3/2016)'). These same piezometers have been trimmed shortly thereafter on or around 21 March 2016 (denoted 'Trim (21/3/2016)'). The IMs interpretation of this record is that recorded values of 'm bTOC' represent the measurement taken on site of the distance in metres below top of casing to the water surface – 'metres below Top Of Casing'. Therefore these measurements need to be subtracted from the reduced level of the top of the casing to calculate the water level as an RL. This appears to have been undertaken correctly for EMBGW7 only. For other extended or trimmed piezometers EMBGW3, 4, 6, 8 and 10 water level calculations have used the same original casing RL level throughput the entire time series record. This potentially represents actual water levels around 2 m higher than that calculated in MRM (2017) for affected piezometers. All affected piezometers are within the rock mattress.

Water levels for piezometers that have not been extended or trimmed (EMBG1A, 1B, 2A, 2B, 5A, 5B, 9A and 9B) appear to have been calculated correctly.

Normally an abrupt change in piezometric levels can indicate whether there has been in error in calculations due to this type of change in the measurement datum. However, none of the affected piezometers was read in the four months before or four months after the date of extension and trimming as they were all recorded as being dry. The first affected readings were recorded at the beginning of the wet season in November 2016 and therefore outside of the reporting period.

The IM have made McArthur River Mining aware of this issue. McArthur River Mining has, in turn, contacted GHD, the TSF designer, who were apparently aware of this issue but had not communicated this to McArthur River Mining. The IM have been provided with more recent plots of piezometric levels prepared by GHD that do appear to show corrected piezometric levels.

These corrected piezometric levels indicate the following:

- Water levels across the TSF embankment are at RL 43.94 mAHD on average.
- Water levels within the rock mattress are around RL 48.7 to 49 mAHD on average.
- Water pressures in the rock mattress gradually rose to a peak of RL 52.95 mAHD in EMBGW4 in the southwest wall on 19 February 2017.

- Water pressures in the rock mattress spiked to RL 52.94 mAHD in EMBGW10 in the east wall on 20 February 2017.

These trends show significantly higher water levels in the rock mattress compared to those reported in MRM monthly reports. They also indicate that water pressures within the rock mattress have not significantly reduced since they rose during filling the Cell 2 Stage 2 lift in 2014 and resulted in seepage through the embankment walls. These sustained piezometric levels strongly correlate with recent observations in increased seepage collection at the southwest corner of the Cell 2 embankment and at the spillway. This is discussed further below.

Correct measurement and interpretation of piezometric levels is vital for the assessment of embankment stability and potential seepage. The IM recommends use of Vibrating Wire Piezometers (VWPs) in piezometer holes to avoid such misinterpretation in the future. Use of VWPs also allows two alternate forms of measurement to be taken to further reduce the possibility of such errors; one being a simple measurement to the water level and the other being an electrical sensor. VWPs have the added benefit of being readily logged.

The IM understand that there may be a reluctance to use VWPs in holes that become dry. This can be readily managed by temporary removal of VWPs during the dry season and using the depth measurement method. VWPs can then be re-established once sufficient water returns.

Continued Seepage Through the Cell 2 Embankment

Seepage through the Cell 2 embankment has been an ongoing issue at the TSF. The main cause of the seepage was the use of a rockfill mattress as part of the Stage 3 raising works to facilitate using upstream construction methods.

Since seepage was first detected, a number of measures have been employed to stop or limit this seepage including:

- Appointment of a new TSF designer, GHD.
- A change to operational procedures to keep the decant pond at least 50 m away from embankment walls.
- Extension of the tailings pipeline to facilitate discharge from the full Cell 2 perimeter.
- Relocation of the decant point away from the Cell 2 southern wall.
- Installation of permanent sump and pump systems at the southwest corner and spillway to collect and discharge water back to the TSF.
- Installation of piezometers and surface monitoring points.
- Changes to management of surface water at the mine generally to limit water storage at the TSF.
- Regular inspections (initially fortnightly) of the affected areas and direct reporting to the DPIR.
- The appointment of the IRTB and ICE.

Over time collected seepage has reduced from highs of 900 kL/day at the southwest corner and 90 kL/day at the spillway (first recorded in May 2015) dropping to zero in both areas in September 2015. During the reporting period seepage levels at the spillway have steadily increased and are consistently around 40 kL/month by November 2016 peaking at 113 kL/month in August 2016. Total recorded seepage for the spillway in 2015 was 193 ML while in 2016 it has risen more than two-fold to 647 ML.

Seepage at both the spillway and the southwest corner of Cell 2 was noted by the IM during the June 2017 inspection.

These increases in collected seepage and the higher than reported piezometric levels described above show continued elevated piezometric levels within the embankment despite the adoption of a number of good water management practices. These higher piezometric levels are also at odds with seepage modelling that suggests much lower piezometric levels. McArthur River Mining should undertake further investigation of the causes of this continued seepage as this may have implications for future TSF management.

Concerns Over the Validity of Piezometric Levels used in Stability Analyses

On 4 April 2016, MRM submitted a LoM plan to the DPIR (GHD, 2016a) that contained results and testing in support of combining cells 1 and 2 for longer term tailings storage. The DPIR subsequently queried the shape of some of the phreatic surfaces used in stability modelling of the embankment. Specifically the DPIR were concerned with a reversal in the shape of the phreatic surface where the simulated pond intersected the surface. This was described by the DPIR as the 'phreatic surface with an inward curvature on the left side of the figures' which was postulated as being 'unlikely that such a profile would exist in practice'.

The DPIR subsequently requested MRM undertake comprehensive review of the stability analysis and provide an analysis on how anistotropy would affect the flow net. MRM commissioned GHD to undertake this review. Initial findings were reported to MRM in a letter dated 2 May 2016 (GHD, 2016b) which found that the seepage modelling undertaken to produce the phreatic surfaces was not in error.

The DPIR raised further concerns with MRM on the shape of the phreatic in a letter dated 3 June 2016. This letter requested MRM undertake a number of additional investigations, these being:

1. Seepage modelling reports from GHD including discussion and visualisation of flow boundary conditions.
2. Plots of the flow nets showing both flowlines and equipotentials for key conditions (as-is and as may be with future tailings deposition).
3. Quantification of the seepage quantities:
    a. From the pond.
    b. Through the embankment.
    c. Down to the alluvium.
    d. More or less horizontally through the alluvium.
    e. Into and through the bedrock.
4. Consideration of the influence of pool size on seepage quantities it appears that the pool may be bigger at times than assumed in some of the seepage models).

5 Consideration of the seepage patterns when the pool approaches the embankment crest in extreme conditions.
6 Sensitivity analyses for the likely range of material hydraulic conductivities, including increased permeability of the foundations, anisotropy of the tailings, location of the pool, duration of the pool in extreme conditions (near the embankment crest) etc.
7 A reconciliation of the backward trending phreatic lines as shown in the slope stability plots which differ from traditional literature plots for similar conditions.
8 Plans for monitoring seepage conditions in the future and contingency plans for implementation if water pressures develop that could impact embankment stability.
9 An update of the risk register to consider the risks associated with varying seepage conditions, and possible mitigation actions that may be appropriate.

These studies were undertaken by GHD and reported to the DPIR in July 2016 (GHD, 2016c). It was found that the shape of the phreatic surfaces was due to the use of anisotropic values for hydraulic permeability. They also undertook a number of sensitivity analyses to assess the impact on stability including:

- Variations in horizontal permeability in the bedrock, tailings and embankment.
- Transient infiltration under temporary extended pond conditions.

No significant change in embankment stability was identified by GHD as a consequence of changes in these material properties or boundary conditions.

On 12 August 2016 the DPIR requested further information to demonstrate a comparison between measured piezometric surfaces and that predicted by seepage modelling and how specific boundary conditions were implemented. This prompted further analyses and assessments undertaken by GHD (2016d) and reported to the DPIR on the 9 September 2016.

The IM has reviewed the testing and stability modelling undertaken by GHD (2016a) for the LoM studies and the additional studies undertaken in response to DPIR queries. This assessment considered the appropriateness of material properties and piezometric surfaces (including boundary conditions and associated hydraulic properties). The IM undertook similar seepage and stability analyses to those presented by GHD. Our assessment noted the following:

- The phreatic surfaces presented by GHD (2016a) are significantly lower than that measured to date.
- The general level of the phreatic surface is mainly the result of the choice of tailings permeability used in their seepage predictions.
- The abrupt reversal of the predicted phreatic surface at the edge of the pond is due to use of anisotropic values for the permeability.
- The CPT dissipation testing used to estimate permeability (GHD, 2016a) is not able to determine this parameter directly or estimate the degree of anisotropy.
- The assumption by GHD that layering of material during deposition creates anisotropy is logical but cannot be definitively proven with the available data. It is possible that such

layering has not resulted in continuous lenses of material and therefore horizontal permeability over large distances may not be significantly different to vertical permeability. GHD have assumed horizontal permeability is ten times greater than that of the vertical.

- The design value of vertical permeability has varied significantly over time from a high of 1 x 10^{-6} m/s in GHD (2015) to 2 x 10^{-8} m/s in GHD (2017); a change of two orders of magnitude. In recent LoM sensitivity studies, GHD (2016c) used a fixed value of vertical permeability of 1 x 10^{-8} m/s and varied horizontal permeability only. In most cases these analyses did not significantly increase the piezometric levels to match that recorded by piezometers within the rock mattress.
- The IM agrees with the use of undrained shear strengths for tailings stability analyses.
- The IM agrees with the tailings undrained strength/overburden stress ratios derived from CPTu testing but note that these are derived from empirical relationships.
- The IM notes that the density used in stability modelling has been derived from interpolation of oedometer test results. The IMs experience with tailings density profiles suggests that in-situ densities may not be as high as 1.87 t/m^3 as adopted in GHD (2016a) and may be closer to 1.6 t/m^3. Additionally Section 4.2 and Table 7 of GHD (2016a) has a maximum dry density of only 1.75 t/m^3. Any reduction in density affects stability factors of safety calculations due to a corresponding reduction in calculated tailings strength (as this is based on a proportion of effective stress, this being in turn dependent on density), and tailings load (being derived directly from density). The IMs assessment of this potential has found that the net effect of any reduction in assumed density is likely to slightly increase factors of safety rather than reduce them.
- Provision was made by GHD (2016a) for density reconciliation based on deposition records and survey in accordance with ANCOLD (2012b) recommendations. This type of reconciliation would provide an accurate estimate of the tailings density for comparison with other estimates. The IM is not aware of this type of reconciliation having taken place at any time for the TSF and recommend this take place.
- More generally there are a number of discrepancies within GHD (2016a); particularly Table 3 vs. Table 7. Discrepancies include the particle density (3.2 vs. 2.8), production rate (3.3 vs. 3.2) and maximum dry density.

Despite these potential shortcomings, the IM noted that updates to stability analyses undertaken in response to DPIR requests used piezometric surfaces that were much closer to those measured (including corrections to the rock mattress piezometric levels noted above). These updated stability assessments did not show any significant reduction in calculated factors of safety.

McArthur River Mining's performance against previous IM review recommendations relating to geotechnical issues at the TSF is outlined in Table 4.30.

Table 4.30 – Geotechnical (TSF) Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2015 Operational Period		
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	Largely completed. It is now easier to differentiate between these roles based on the documentation provided
TSF construction	The DPIR should seek a formal commitment from MRM as to the type and timing of construction quality records that need to be provided to the DPIR	Complete Comprehensive records have been provided of the Cell 2 Stage 3 lift
TSF surface water management	There are discrepancies between GHD and WRM on the capacity and efficacy of the Cell 1 western sump. GHD states the capacity as 6 ML and inadequate for the catchment area (GHD, 2017) while WRM (2015) 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	These discrepancies remain
2014 Operational Period		
TSF design	The 2013-2015 MMP refers to a preliminary design for Cell 2 Phase 3. The IM recommends that the final design be checked for the following: ♦ Compliance with ANCOLD (2012a) Guidelines on the Consequence Categories for Dams ♦ Compliance with ANCOLD (2012b) Guidelines on Tailings Dams - Planning, Design, Construction, Operation and Closure	Complete Cell 2 - Raise 3 Detailed Design Report Revision 2 (GHD, 2015) has been submitted to and accepted by the DPIR. A review of this report by the IM found it complies with the ANCOLD 2012a and 2012b guidelines
	Ensure the Cell 1 drainage and detention system can accommodate a 1 in 100 year storm event through assessment and modification as required	Ongoing Complete for TSF Cell 1 eastern sump only
TSF operation	Confirm assumed average tailings beach gradient from survey	Complete
TSF seepage	The efficacy of the systems put in place to limit seepage to Surprise Creek need to be assessed, namely: ♦ 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 recommend 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	Ongoing Klohn Crippen Berger has investigated hydrogeological conditions in the vicinity of TSF Cell 1 and Surprise Creek, GHD has undertaken preliminary groundwater modelling of seepage from the TSF and more recently investigations including pump testing has ben initiated

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

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
TSF monitoring	The IM recommends that inspections be improved and standardised through (but not restricted to) the following actions: ♦ Staff training (if not undertaken already) at specialist courses such as the annual course on tailings dam inspections run by NSW Dam Safety, or training by the TSF designer or another provider ♦ Update the infrastructure inspection and operating reports to a single report that includes a proforma for all relevant operational information (discharge quantities, piezometric levels, survey levels, pond extent, water levels, rate of water reclamation) plotted over time, records of the inspected areas, current discharge, items in the TSF operating guidelines not listed here and any other features or activities indicated on a plan, photographs of pertinent areas (pond, discharge, embankment likely seep points) and a comparison of measured performance to safe operating limits. These reports should be forwarded to the designer	Complete MRM has revised their inspection protocols and now produce TSF Communications reports which meet these recommendations
TSF monitoring	All monthly reports including summaries of monitoring data to be provided to the IM to demonstrate compliance with MRM commitments	Complete
Commitments	McArthur River Mining provide a definitive list of commitments	Partially completed in the 2016 Operational Performance Report (MRM, 2016)
2012 and 2013 Operational Periods		
TSF design	McArthur River Mining to provide a better assessment of their TSF risk of release by estimating the rainfall return periods that would result in: ♦ Exceeding the Cell 1 stormwater capacity resulting in overtopping and potentially catastrophic failure of the embankment ♦ Exceeding the Cell 2 stormwater capacity (including spillway capacity) resulting in overtopping and potentially catastrophic failure of the embankment ♦ Exceeding the Cell 3 WMD stormwater capacity resulting in overtopping and potentially catastrophic failure of the embankment	Complete
	For MRM to confirm if the concrete works on the downstream channel of the emergency spillway have been completed	Complete
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	Complete for the Cell 2 Stage 3 lift

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

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
TSF operation	For MRM and TSF designer to provide design evidence and clear operating guidelines under which the TSF embankments are proven to be effective with respect to stability, seepage, erosion control, piping and any other action that may lead to an uncontrolled release of tailings or water. This should include limits on the depth and extent of the surface water pond	Complete
	The discharge lines should be extended to facilitate deposition around the entire Cell 2 perimeter. This will significantly improve control of the location and extent of the surface pond water	Complete This has now occurred and the pond location and extent is better controlled as expected
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 Further drilling and model has been initiated
	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	Complete McArthur River Mining has ceased operation of recovery bores at Cell 1
TSF monitoring	For MRM to fulfil their 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	Complete Fourteen piezometers installed in the TSF continue to be read every fortnight. Piezometers are scheduled for extension during embankment raises and most have already been reinstated
	Provide graphs in the MMP that clearly show groundwater levels (in RL), tailings pond surface water levels and maximum pond depth. These plots should also clearly show the monitoring locations in plan	Complete
	McArthur River Mining to provide a monitoring report which includes assessment by the relevant designer as to the implications of monitored piezometric levels, embankment settlements, pipeline wear, pond levels and any other TSF monitoring data with respect to design. This would essentially expand the Annual Regulated Dam Safety Reports that currently do not make any comment on these issues	Complete The new TSF Cell 2 Communications reports meet these recommendations

Successes

The most significant success for the TSF in this reporting period is continued effective management of the pond, cyclic deposition, strength gain and monitoring.

Specific successes include:

- Completion of the 2-m raise[16] of TSF Cell 2 to RL 55 mAHD based on a successful field trial and subsequent approval by the DPIR.
- Raising of the Cell 2 spillway to accommodate storage to RL 55 mAHD.
- Favourable reviews on the LoM plan by the ITRB.
- Updated operating guidelines, operating limits, triggers and actions.
- Ongoing monitoring of piezometric levels, settlement, pond levels, reclaim volumes and beach angles.
- Extensive investigations by CPTu that inform estimates of density, permeability and liquefaction potential.
- New laboratory testing that improves overall understanding and provides specific testing for assessing liquefaction potential.
- Exceeding surface strength targets (as measured by vane shear testing) required for future upstream raises.

4.7.1.5 Conclusion

Overall, the TSF has been well managed in terms of operation, inspections and external review for the current reporting period. Some concerns have been raised over the pipeline delivery system that warrant further investigation.

Many of the concerns raised by the DPIR over stability analyses concerning the shape of piezometric surfaces and material properties have been found by the IM to not be likely to have a significant impact on calculated factors of safety themselves. However concerns over factors of safety remain due to concerns over the piezometric levels used in stability analyses in light of:

- Possible errors in the calculation of water pressures recorded by several piezometers in the TSF embankment. These errors, if confirmed, represent an increase in measured levels within the rock mattress zone of the embankment of 2 m in most instances. However the IM has confirmed that the TSF designer, GHD, used corrected piezometric levels in their stability analyses.
- Measured increases in collected seepage in the southwest and spillway of Cell 2.

Ongoing and new IM recommendations related to TSF geotechnical issues are provided in Table 4.31.

[16] Noting that this raise was only 80% complete (see ' TSF Cell 2 Raise 3 Construction' in 'Progress and New Issues').

Table 4.31 – New and Ongoing Geotechnical (TSF) Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
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	Medium
TSF seepage	The origin and veracity of fault mapping in the vicinity of the TSF need to be investigated 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 permeability of the tailings needs to be reviewed and appropriate testing (such as low pressure oedometer or Rowe cell testing) be undertaken to reduce uncertainty in this parameter 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	High
	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	High
TSF construction	Provide all records to the DPIR of earthworks testing or other construction certification for TSF Cell 2 Raise 3. The IM notes that this same request was given to MRM by DPIR on 27 August 2015	High
TSF operation	Confirm assumed average tailings beach gradient from survey	Medium
New Items		
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	High
TSF Piezometers	Use VWPs to record water levels	High
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 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	Low
TSF Density	Undertake a reconciliation of deposited mass and surveyed volume to estimate in-situ density	Medium
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	High
TSF Operations Manual	Reconcile a number of discrepancies within the Operations Manual	Low

4.7.1.6 References

ANCOLD. 2012a. Guidelines on the Consequence Categories for Dams. October. Australian National Committee on Large Dams Incorporated. Hobart, Tasmania.

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

GHD. 2015. Cell 2 – Raise 3 Detailed Design Report, Revision 2, Reference 32/17476, April 2015.

GHD. 2016a. MRM TSF – Stability Analysis for Life of Mine, Preliminary Design, Job 32/17476, Letter from Josh Kline to Tyrone Blyth, 8 March 2016.

GHD. 2016b. TSF Life of Mine Design – Stability Model, DME Request for Information (RFI), Letter from Ben Hanslow to Karen Hazlewood, Reference 32/17476-64752, May 2016.

GHD. 2016c. MRM TSF Life of Mine Study Response to DME Comments Dated 3 June 2016, Letter from Ben Hanslow to Karen Hazlewood, Reference 32/17476-64992, 11 July 2016.

GHD. 2016d. MRM TSF Life of Mine Study, Response to DME Request Dated 12 August 2016. Letter from Ben Hanslow to Karen Hazlewood, 7 September 2016.

GHD. 2017. Tailings Storage Facility (TSF) Cell 2 Operations, Maintenance and Surveillance Manual, Reference 32/17476, February 2017.

ITRB. 2016. Independent Technical Review Board, Review of Options and Life-of-Mine Tailings Management Proposal for Tailings Storage Facility at McArthur River Mine, UniQuest Project No. C02562, 9 May 2016.

MRM. 2015. Sustainable Development Mining Management Plan 2013-2015, McArthur River Mining. GEN-HSE-PLN-6040-0003, November 2013.

MRM. 2016. Mining Management Plan 2013 – 2015 – Operational Performance Report, McArthur River Mining. MRM-HSE-RPT-6040-0014, 22 September 2016.

MRM. 2017a. Health, Safety, Environment and Community (HSEC) Management System Register, Spreadsheet: MRM_Monthly HSEC Report 2016-2017.xlsx, Author S Donovan, last modified 12 May 2017.

MRM. 2017b. TSF Piezometer Readings and Calculations, Spreadsheet: TSF Embankment Piezometers.xlsx, Author K Hazlewood, last modified 26 June 2017.

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 (as listed in Appendix 1), with particular reference to MRM's mining management plan (MRM, 2015 and the Operation Performance Report (MRM, 2016a).
- Inspection reports undertaken 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 September to October 2015, November to December 2015, January to March 2016, July 2016, August 2016 and September 2016.
- Review of Excel spreadsheets provided by MRM that contain collated laboratory and in situ data.
- Review of various MRM forms survey results, incident notification letters, and correspondence between MRM, regulators and third parties.
- Aerial and other photographs of the MRM mine site provided by MRM. No updated aerial photography was provided for the OEFs for the current reporting period.
- Airborne laser scanning (ALS) (topographic) data of the mine site provided by MRM.

4.7.2.2 Key Risks

The key risks to management of geotechnical issues at the OEFs, as described in the risk assessment (Appendix 2), 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 of the liner due to drying and hence cracking of the liner, with a resulting increase in its permeability to air and water.
  - Construction quality control issues with liner placement, resulting in the liner not achieving the required permeability.
  - Differential settlement of waste rock leading to excessive strain and cracking of the liner.

- Slope instability or excessive displacement of the PAF 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).
- Operational Performance Report (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).

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 (2015a).
- CWNOEF Design, Construction and Operations Manual (MRM, 2015b).
- Operational Performance Report (MRM, 2016a) and subsequent amendments to the MMP.

The CWNOEF design has undergone a number of revisions. Version 2.0 of the Design, Construction and Operations Manual (MRM, 2015b) was accepted by the DPIR as part of the approved 2013 to 2015 MMP.

In the current reporting period MRM subsequently sought an amendment to the MMP to modify the waste dumping program, reprocess low-grade stockpiles placed in NOEF areas West A and West B stages and place PAF in NOEF area West D. Approval for this amendment was granted by the DPIR on 18 March 2016.

The approved amendment allows MRM to continue construction of the Alpha and Bravo stages of the CWNOEF for future storage of non-benign material.

Version 2.1 of the CWNOEF Design, Construction and Operations Manual (MRM, 2015c) 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 +5 to +3% of optimum.
  - A minimum dry density ratio to 98% of maximum dry density (standard).
  - A maximum loose layer thickness from 300 to 200 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 .
  - Hydraulic conductivity testing at 1 in 10,000 m^3 for placed CCL material.
  - Dispersion testing (Emerson Class & pinhole dispersion) at a rate of 1 per 20,000 m^3
- 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.

There are a number of planned controls specified in MRM (2015c). These are:

- Ongoing investigations of alluvial materials to examine their suitability for use in CWNOEF construction.
- Testing of waste rock density and permeability.

- A drilling investigation to identify and quantify the extent of possible faults or paleochannels beneath CWNOEF.
- Lysimeters are still planned to measure infiltration.

4.7.2.4 Review of Environmental Performance

Incidents and Non-compliances

Incidents

There are ongoing issues with the management of material in the SOEF. Site inspections by the DPIR have reported a number of issues including:

- DME concerns regarding ponding and movement of surface water identified by areas of decolourisation and/or appearance of salts (DME site inspection reports 9 December 2015 and 19 January 2016).
- DME concerns in the legitimacy and suitability of MRM's current management of surface water through the use of the area anecdotally referred to as the 'rice paddy area'.
- Uncertainties regarding rates of infiltration currently being studied by University of Queensland to address 'knowledge gaps regarding infiltration and runoff' (DME site inspection report 19 January 2016).
- The lack of a suitable continuous clay cap to limit infiltration.
- Elevated SO_2 concentrations as evidenced by noticeable odour and personal gas monitors showing 'concentrations of up to 10 ppm and an average of approximately 5 ppm' (DME site inspection report 14 July 2016 and subsequent DME file note dated 20 July 2016).
- Evidence of different types of vegetation and the presence of damp and historically waterlogged soils noted in the areas identified by the IM in our previous report, this being on the southern edge of the mine levy adjacent to the SOEF (DME site inspection report 14 July 2016).
- The presence of potential smokers/fumaroles.
- Settlement or 'heat' cracks exhibiting high temperatures as measured by DPIR representatives.

Many of the issues identified for the SOEF were noted during the routine DPIR inspection on 16 July 2016. These observations triggered a follow-up visit by the DPIR on 20 July 2016 and subsequent investigation. Subsequently DPIR instructed MRM to investigate the cause and extent of the problem, provide a remediation plan and outline steps to prevent this reoccurring.

An investigation was subsequently undertaken by MRM (2016a). This investigation found that:

- 63 truckloads loads of PAF had been placed at the SOEF.
- There were three areas where PAF impacts were visible at the surface.

- All loads were associated with one event that occurred around mid to late May 2015.
- The error was caused by the application of an incorrect naming convention to a block of material within the mine grade control model.
- The PAF was likely to have been placed within the top 10 m of the existing SOEF surface.

Actions arising from this incident undertaken by MRM included:

- Reporting the emissions of SO_2 under Section 29 of the *Mining Management Act*.
- Revising MRM procedures for blast block naming (procedures MIN-TEC-CKL-1000-0009 and MIN-TEC-PRO-1000-0042) and survey control for identification of remnant material (MRM_TWI_Grade_Control_Markup_SJW_20161814_v2).
- Preparing an SOEF Remediation Instruction (MRM, 2016c) and dig plan (MIN-TEC-WI-SOEF-160727-SOEF PAF DIG) showing relocation of 236,000 m^3 of potential PAF waste from the SOEF to the West AB cell of the NOEF.

The original Notification of Environmental Incident by MRM (20 July 2016) stated that 11 truckloads of PAF had been incorrectly placed in the SOEF. This was updated to 63 truckloads in the incident report prepared by MRM (2016a).

The DPIR approved the SOEF Remediation Instruction, including a request to defer the works until the dry season of 2017, on 4 November 2016.

The only other incidences of note are ongoing fumaroles and areas of spontaneous combustion along the northern edge of the NOEF. McArthur River Mining are aware of this issue and continue to manage these areas on a case-by-case basis. They expect this type of occurrence to cease once these areas have been properly capped and consequently implemented basic management controls such as localised placement of benign cover material.

Non-compliances

Placement of PAF in the SOEF is considered a non-compliance and has been discussed above.

Progress and New Issues

CWNOEF

The CWNOEF has seen substantial progress with large areas of the foundation for Alpha and Bravo stages nearing completion. Examination of the testing records indicates that during the reporting period the following material and compaction testing was undertaken:

- Around 270 material tests particle size, Atterburg, pinhole dispersion, Emerson dispersion and moisture content) on Basal CCL borrow areas including Cation Exchange Capacity (CEC) and X-ray Flourescence (XRF) testing across 9 lots.
- Around 1386 compaction, moisture and density tests on placed Basal CCL material across all ten lots.
- Around 15 permeability tests on placed Basal CCL across 5 lots.

- Around 636 material tests (particle size, Atterburg, pinhole dispersion, Emerson dispersion and moisture content) on other borrow areas.
- A limited number of permeability tests on the subgrade.

All results have been checked against the MRM (2015b) specification.

The current testing database shows that substantial material, compaction and permeability testing has been recently undertaken on the Wedge (PAF cell) CCL.

The IM has been provided with ICE construction reports for September to October 2015, November to December 2015, January to March 2016, July 2016, August 2016 and September 2016. The ICE reports indicate the following:

- Testing frequency is in accordance with the approved CWNOEF design.
- Incidents of CCL placement prior to subgrade inspection – rectified by removal of placed CCL, inspection then reapplication.
- Incidents of placement of incorrect material – rectified by removal and reapplication.
- Documentation of failed test areas being replaced and or reworked to meet the specification.
- Issue 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.
- A relatively high failure rate (~40%) of compaction testing in late 2015 reducing to a relatively low failure rate (<5%) in 2016. This reduction was largely due to the change from traditional moisture conditioning to the use of a moisture stabiliser.

There are no known specific issues related to the construction of the CWNOEF.

McArthur River Mining's performance against previous IM review recommendations relating to geotechnical issues at the OEFs is outlined in Table 4.32.

Table 4.32 – Geotechnical (OEFs) Recommendations from Previous IM Reviews

Area	Recommendation	IM Comment
2015 Operational Period		
CWNOEF Construction	There are a number of recommended minor corrections and updates to the CWNOEF design report as described elsewhere	No update to the manual has been released at the time of the IM's visit
CWNOEF Closure	MRM should undertake direct testing of candidate materials likely to be used for the NOEF final cover. MRM should also expand the limited sensitivity studies on the CCL saturated conductivity to examine how differences in the hydraulic conductivity contrast may affect net percolation	The IM is aware of testing being undertaken on some candidate materials and further testing will be completed as materials become available

Table 4.32 – Geotechnical (OEFs) Recommendations from Previous IM Reviews (cont'd)

Area	Recommendation	IM Comment
2014 Operational Period		
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	The IM is aware of some progress on this issue having been undertaken as part of the Draft OMP EIS. We expect this will be incorporated in a revised MMP
2012 and 2013 Operational Periods		
QA/QC assessment	The IM has found many instances where material in violation of the construction specification is being accepted for dumping of PAF waste (e.g., memo dated 19/9/2013). The IM has also found that the specification pass/fail criteria are being incorrectly applied. In light of these the IM recommends: ♦ McArthur River Mining review all test data to properly assess locations and approximate volumes of placed materials that have not met the reviewed specification including testing frequency ♦ The OEF designer(s) conduct a review of the above to ascertain whether the placed materials meet design requirements. If not, the OEF designer(s) should recommend remedial action that would be required such that OEF can function as per the approved design and therefore its intended purpose A revised encapsulation design may be required to accommodate these shortcomings depending on the severity and extent of test failures	Complete
General	Detailed plans and cross sections of the OEFs should be prepared and made available to the IM such that the construction of the OEF can be verified. This should include, where relevant, a system to identify the QA/QC testing lots for the relevant materials	Complete

Successes

There have been a number of successes this reporting period, namely:

- Agreement between DPIR and MRM on the CWNOEF design and subsequent approval.
- Completion of a substantial area of the CWNOEF liner system in preparation for receiving PAF.
- Continued use of a compaction stabilising equipment to improve CCL compaction consistency and overall construction efficiency.
- Reporting by the ICE to document progress, testing and specification conformance.

There are a number of other successes as a consequence of preparing the Draft OMP EIS. These include but are not limited to:

- The delineation of sufficient volumes of benign material for construction of the NOEF and WOEF to meet the revised design requirements.
- Site wide testing of materials for suitability in construction of CCLs, the benign wedge and other purposes.

4.7.2.5 Conclusion

This reporting period largely consisted of a period of reduced overburden generation, reprocessing of some low-grade material within the original NOEF footprint, construction of the new CWNOEF facility and continued intermittent use of the SOEF for non-benign material.

Significant progress has been made on the design and construction and verification of the CWNOEF facility in preparation of receiving non-benign material.

Improvements in CCL construction and reporting have improved confidence in the ability of the CWNOEF facility to safely store non-benign waste.

Ongoing and new IM recommendations related to OEFs geotechnical issues are provided in Table 4.33.

Table 4.33 – New and Ongoing Geotechnical (OEFs) Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
NOEF design	McArthur River Mining should provide a clear timetable of outstanding activities required to finalise OEF cover design 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	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
New Items		
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	High

4.7.2.6 References

MET Serve. 2012. Overburden Emplacement Facility Management Plan. January 2012.

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MRM. 2012a. MRM Technical Services, Clay Liner Quality Control and Construction at the NOEF, MIN-TEC-PRO-1000-0026, Rev 1 4/4/2012.

MRM. 2012b. MRM Mining Department, EOM NOEF Sampling Procedure, MIN-TEC-PRO-1000-0015, Rev 4, 13/12/2012.

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OKC. 2014. Rehabilitation of North Overburden Emplacement Facility, West A-B Cells, Draft Report No. 750/11-01, April 2014.

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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 site inspection.
- Review of various reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to MRM's current mining management plan (MRM, 2015) and Operational Performance Report (MRM, 2016).
- Aerial and other photographs of the MRM mine site 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. There are additional risks associated with excessive seepage of saline water.

The risk of wall failure is related to:

- The minimalist approach to engineering due to lesser containment requirements when compared to other storages, such as the TSF.
- The rapid flooding of the ponds when dredge operations are being undertaken.
- Elevated water levels during extreme rainfall events.

The IM recognises that at the Bing Bong Loading Facility, the approach taken to date is minimal design requirements given the height of embankments, the more benign nature of materials and water 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.

Recently large rainfall events were experienced during the 2016-2017 wet season. Examination of the Bureau of Meteorology rainfall data for Bing Bong Port (BoM ID 14729) shows these notable events:

- A highest single-day rainfall of 176 mm on 20 February 2017.
- A combined three-day rainfall around this date of 267 mm.
- A continuous period of rainy days from 2 to 22 February 2017 (21 days) with a combined rainfall of 724.8 mm.

These records emphasise the potential for significant rainfalls over extended periods and therefore the need to properly monitor and maintain the Bing Bong Loading Facility dredge spoil storages.

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 (none have been provided for the current reporting period).
- Surface water quality, air quality and dust monitoring.
- Groundwater quality and levels.

The IM notes that no readings have been provided to the IM for the new groundwater wells installed in the dredged pond embankments. It is also noted that while groundwater levels were recorded for Bing Bong Loading Facility wells (GWBB series) these levels were not reported in the 2014-16 groundwater monitoring report (KCB, 2016).

The IM notes that there are no records of monthly inspections having taken place during the reporting period or thereafter. It is unclear, therefore, whether these inspections are being undertaken.

New Controls – Implemented and Planned

New controls undertaken within the reporting period are:

- A dam safety inspection of the storage ponds undertaken on 18 November 2016 (GHD, 2017).
- An updated water balance report for 2015-2016 (WRM, 2015).

The GHD (2017) inspection report is dated outside the reporting period but has been included here as the inspection date is close the end of the reporting period. The previous annual report was included in last years IM report.

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 are not aware of any geotechnically related non-compliances at Bing Bong Loading Facility for the reporting period.

Progress and New Issues

There was effectively no progress on previous issues during the reporting period. More recently, however, MRM have commenced implementation of the recommendations made in the annual inspection report (GHD, 2017). These recommendations include:

1. Regrade the crest to provide minimum 3% fall towards the upstream side of the crest.
2. Use the excess spoil from regrading to patch the eroded areas of the embankments.
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 of 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.

Items 1 to 4 of these recommendations were confirmed as having been completed by the IM during its site inspection.

Currently the water monitoring schedule implies that the new piezometers installed in the embankment in 2015 (BBEMB series) do not need to be read outside of dredging activity. Correspondingly, there appears to be no measurement records of these piezometers within the reporting period. Additionally these piezometers do not appear in the Operational Performance Report (MRM, 2016).

The IM understands that for much of the time these piezometers are likely to be dry and therefore recording a water level is not possible. However, no inspection records have been provided to the IM to substantiate anecdotal water levels or the condition of the ponds generally.

Rainfall during the recent wet season rainfall was the highest since construction and the dredging campaign in 2006. Groundwater levels during the recent wet season have not been provided to the IM and will be reviewed as part of our next report, however analysis of previous data shows that relatively large (greater than 1 m) changes in groundwater levels can occur over a relatively short time at Bing Bong Loading Facility. These changes in combination with elevated groundwater levels everywhere could result in elevated piezometric levels within the storage pond embankments.

Given the severity of recent rainfall and the likelihood of similar events in the future the IM recommends that the ponds be inspected at periodic intervals to document their condition and record embankment water levels; dry or otherwise. Ongoing erosion could leave some areas of the storage prone to overtopping leading to the release of contaminated sediment during intensive rainfall periods.

The IM has not been provided with any information that demonstrates that the storage ponds were inspected during the reporting period. An annual inspection was undertaken by GHD in December 2016 just outside the reporting period.

Previously MRM have undertaken inspections and provided these to the IM. It is unclear whether these inspections are taking place and if so, whether they are being documented. The IM recommends this omission be redressed.

New issues are summarised in Table 4.34.

Table 4.34 – Recommendations for Bing Bong Loading Facility Dredge Spoil Area

Recommendation	Priority
Set a frequency of sampling and water level measurement for new piezometers (BBEMB series) outside of active dredging. Suggested frequency is at least every 3 months and more frequently after periods of heavy rainfall	Medium
Schedule and document regular inspection of the storage ponds outside of active dredging. The IM suggests every month during the wet season	High

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 4.35.

Table 4.35 – Geotechnical (Bing Bong Loading Facility Dredge Spoil Area) Recommendations from Previous IM Reviews

Area	Recommendation	IM Comment
2015 Operational Period		
Bing Bong Loading Facility dredge spoil – embankments	Item: ♦ Repair severely eroded areas ♦ Remove trees ♦ 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: ♦ Completed ♦ Completed ♦ Ongoing ♦ Incomplete ♦ Incomplete
Bing Bong Loading Facility dredge spoil – drainage	Item: ♦ Review of 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
2014 Operational Period		
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	Unknown

Table 4.35 – Geotechnical (Bing Bong Loading Facility Dredge Spoil Area) Recommendations from Previous IM Reviews (cont'd)

Area	Recommendation	IM Comment
2012 and 2013 Operational Periods		
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 by GHD (2016)

Successes

Successes include repairs to the embankment external walls and the development of a life of mine concept design for storage of future dredging.

However, the new embankment repairs have been completed with no effective compaction. These repairs are likely to be impacted by surface water erosion during the next wet season. This emphasizes the need to regular inspections outside of active dredging and after periods of intensive rainfall.

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, the annual inspection by GHD (GHD, 2017) has 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. The IM recommends that these actions be undertaken at least three months before any dredging activity or the next wet season, whichever comes first.

Recent repairs to the storage pond embankments have lessened the likelihood of instability or breach of contained surface water. However these repairs do not appear to have been compacted. Therefore ongoing erosion of the storage ponds could leave some areas of the storage prone to overtopping leading to the release of contaminated sediment during intensive rainfall periods. The IM has not been provided with any information that demonstrates that the storage ponds are undergoing regular inspection that would detect and therefore prevent this possibility. Such inspections have occurred in the past and it is unclear if or why they have stopped.

A summary of new and ongoing IM recommendations is provided in Table 4.36.

Table 4.36 – New and Ongoing Geotechnical (Bing Bong Loading Facility Dredge Spoil Area) Recommendations

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 measure performance against measurement, such as settlement and pore pressures	High
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	Medium to high depending on planned dredging
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	High
New Items		
Monitoring	Set a frequency of sampling and water level measurement for new piezometers (BBEMB series) outside of active dredging. Suggested frequency is at least every 3 months and more frequently after periods of heavy rainfall	High
Monitoring	Schedule and document regular inspection of the storage ponds outside of active dredging. The IM suggests monthly inspections during the wet season.	High

4.7.3.6 References

AWA. 2012. McArthur River Mine Hazardous Dams Stability Assessment, Project 111351-07-r001-b, December 2012.

EcOZ. 2012. Dredging and Spoil Disposal Management Plan, EcOz, EZ12019-C0301-EIA-R001, Rev 1, 26/9/2012.

GHD. 2016. Dredge Spoil Ponds Long-term Strategy, 32/17476, 14 December 2016.

GHD. 2017. McArthur River Mining – Bing Bong Dredge Ponds 2016 Annual Inspection, 32/17476, DRAFT, January 2017.

KCB. 2016. Groundwater Monitoring Report 2014-16 Final, Klohn Crippen Berger, D09814A18, 30 August 2016.

MRM. 2015. Sustainable Development Mining Management Plan 2013-2015, McArthur River Mining. GEN-HSE-PLN-6040-0003, November 2013.

MRM. 2016. Mining Management Plan 2013-2015 – Operational Performance Report, McArthur River Mining. MRM-HSE-RPT-6040-0014, 22 September 2016.

WRM. 2015. 2015/16 Site Water Balances for the McArthur River Mine and Bing Bong Loading Facility, WRM Water + Environment, 0790-21-B1, 3 December 2015.

4.8 Closure Planning

4.8.1 Introduction

The operation is at an important juncture with regard to mine closure. The approved mine closure plan was prepared by MET Serve (2012) as part of the Phase 3 Environmental Impact Statement. Since the development of that mine closure plan, significant changes to the geochemistry of the waste rock have been reported which resulted in MRM being required to prepare a new EIS (the Draft OMP EIS). The Draft OMP EIS (MRM, 2017a) was submitted for public comment in late March 2017 and included the Overburden Management Project Conceptual Mine Closure Plan (referred hereafter as the 'EIS Conceptual Mine Closure Plan') (MRM, 2017b) which was reviewed by the IM (ERIAS Group, 2017).

The Draft OMP EIS conceptual mine closure plan is significantly different 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.
- Various reports prepared by MRM and its consultants as part of the Draft OMP EIS.
- Excel spreadsheets provided by MRM that contain mine closure costs (MRM, 2015a).

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 outlined in the 2016 IM report have not changed – the management of mine wastes (tailings and waste rock) and the final pit lake water quality remain the key risks relating to mine closure. These are outlined in Appendix 2 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 Draft OMP EIS.

- Availability of suitable NAF materials to construct the cover for the NOEF. The reclassification of waste has highlighted that the availability of NAF material may be insufficient to implement the cover design outlined in the approved closure plan. Investigations into the identification of additional quantities of NAF material that can be used in cover construction have been completed as part of the Draft OMP EIS. As a result, the Woyzbun Quarry has been identified as a source of NAF material to supplement existing supplies for use in cover construction.

- 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 current proposed 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. However, this is currently minimised by the regular application of tailings that prevents the complete drying out of the tailings and therefore oxidation (with the neutralising capacity in the tailings providing additional mitigation). 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.

- 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 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 which if approved would replace the existing mine closure plan prepared as part of the Phase 3 EIS (Met Serve, 2012). The EIS conceptual mine closure plan has proposed closure strategies for the three key risk areas, i.e., TSF, OEF and open pit that contain some significant differences from the currently approved mine closure plan.

4.8.3.2 New Controls – Implemented and Planned

As outlined above an EIS conceptual mine closure plan has been prepared as part of the Draft OMP EIS. At the time of the IM review the Draft OMP EIS had not been approved.

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 report (OPR) (MRM, 2016) provides a list of commitments from the following documents:

- The 2013-2015 MMP (MRM, 2015b).
- MMP information requests.

- MMP amendments.
- MMP conditional approvals.

A number of these commitments contained a closure-related aspect in that the commitment formed part of a larger piece of work. For example, MRM has established erosion trials to gather information on the susceptibility of particular waste rock types to erosion. This information will be used as part of the overall project of developing a landform design for the NOEF and WOEF landforms.

The IM has found that the commitments related to mine closure have generally been implemented, exceptions being due to lower mining rates and subsequent reduced availability of materials.

4.8.4.2 Progress and New Issues

Overburden Emplacement Facility

Risk Assessment

A number of risk assessments have been undertaken during the review period which were used to support the Draft OMP EIS. The IM reviewed these risk assessments (ERIAS Group, 2017) and recommended that a review of the risk assessment method was required, in particular the following:

- Review and revise the hazard so that the risk is clear.
- Review and revise the impact to clearly articulate the consequence.
- Assess likelihood in accordance with Standards Australia 2009 and 2012.

NOEF Erosion Trials

No data on the NOEF erosion trials was available for review.

NOEF Cover Design

An update on MRM's further investigations with regard to a cover design for the NOEF is outlined in Section 4.6.3.2.

TSF Closure

The Draft OMP EIS conceptual mine closure plan outlines a new strategy for the closure of the TSF involving the retreatment of tailings following the completion of mining and placement of this material back into the open pit. The IM believes that this strategy is a considerable improvement on the currently-approved strategy of the tailings remaining in situ with a cover system being implemented over the TSF.

Pit Lake Modelling

Numerical modelling has been undertaken to predict the water quality of the pit lake after mine closure. Initial modelling was conducted by URS as part of the Phase 3 EIS (URS, 2012), using outputs from their 3D groundwater model. The strategy, which was approved as part of the

Phase 3 EIS, was for the open pit to remain closed to any external surface water inflows and to slowly fill over an estimated period of 300 to 400 years. Further modelling undertaken as part of the Draft OMP EIS has proposed a change in strategy which involves the following:

- Backfilling the open pit with tailings.
- Accelerated flooding of the open pit over a period of five years with water from McArthur River.
- Monitoring of pit water quality and, when acceptable, removal of sections of the mine levee wall to allow McArthur River at high flows to enter the pit. This will initially be undertaken at the downstream end and then, if further monitoring indicates that water quality is acceptable, removal of a portion of the mine levee wall upstream to allow river to flow through the pit during high flows.

McArthur River Mining outlined in the Draft OMP EIS that the feasibility of the revised strategy will require further data collection and modelling and an extended period of monitoring before the option of opening up the pit to flows from McArthur River could be considered.

Mine Closure Plan

Mine Closure Criteria

The EIS conceptual mine closure plan outlines a closure framework consisting of the following:

- **Goals** – these are the closure goals for the site, developed from the ecologically sustainable development (ESD) policy framework, in particular the National Strategy for Ecologically Sustainable Development (ESDSC, 1992).
- **Objectives** – a clear set of statements relating to environmental and social aspects of mine closure that describe the intent of the mine closure strategy.
- **Indicators** – these may be either an agreed value that is measurable and is regarded as the minimum that must be achieved, or a certification that specific closure activities comply with an agreed plan for those activities.
- **Criteria** – these describe specific elements that can be measured or certified to have occurred and that are considered to be critical to achieving the objectives. Each objective may have more than one criterion, and a criterion may apply to more than one objective.

The IM has reviewed the draft indicators and completion criteria (ERIAS Group, 2017) and found that the framework provides a logical progression from high-level goals to specific criteria which are used to demonstrate achievement of the goals. Further work is required, however, to clearly link each relevant component. For example, the definition of criteria is not linked to indicators but rather to objectives and the definition for indicators does not specifically relate to objectives. The criteria need to specify how the achievement of the indicator will be demonstrated and subsequently how achievement of the indicator demonstrates achievement of the objective.

Mine Closure Costs

The IM was provided with mine closure costs which were last updated in 2015 (MRM, 2015b). Should the Draft OMP EIS be approved, a substantial update to the mine closure costs is expected with revised costs for construction of OEF covers, water treatment and an extended period of post-closure monitoring and maintenance.

McArthur River Mining's performance against previous IM review recommendations relating to closure planning issues, excluding those that have been flagged in previous IM reports as being completed, is outlined in Table 4.37.

Table 4.37 – Closure Planning Recommendations from Previous IM Reviews

Subject	Recommendation	Status
2015 Operational Period		
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 outlined in the Draft OMP EIS conceptual mine closure plan
Open pit	Extend pit void quality modelling to a longer period and assess the possibility of the pit lake ultimately acidifying under different assumptions	Completed. Updated pit lake water quality modelling undertaken as part of the Draft OMP EIS
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
2014 Operational Period		
NOEF	A Failure Mode Effects Analysis (FMEA) should be undertaken on the preferred cover and landform design. The FMEA should clearly outline how likelihood and consequence are determined and the mitigation strategies in place. Where the confidence levels are low or medium, actions to improved confidence should be detailed	Completed. A FMEA was undertaken and details included in the Draft OMP EIS
Materials balance	A comprehensive materials balance should be prepared following finalisation of the cover and landform design to identify potential shortfall in materials and: ♦ Confirmation that LS-NAF(HC) material can be selectively mined to make up this shortfall ♦ Costs (drill, blast and haul) associated with the selective mining of LS-NAF(HC) is included in the revised mine closure cost estimate	Ongoing: ♦ Material balance detailed in the Draft OMP EIS. Completed ♦ If the Draft OMP EIS is approved the IM would expect to see costs for drill, blast and haul itemised separately rather than included in the item 'source, cart and spread suitable cover material' in the revised mine closure costs
Mine closure commitments	As part of the review of the mine closure plan, the IM recommends that MRM review all previous rehabilitation and closure commitments which have been made since the project commenced as an underground mining operation	Ongoing. The Draft OMP EIS conceptual mine closure plan contains a list of commitments, although those relating to the 1992 EIS are not listed

Table 4.37 – Closure Planning Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	Status
2014 Operational Period (cont'd)		
Mine closure commitments (cont'd)	All commitments should be upgraded to reflect the current status of the operation, community expectations and industry practice	If these commitments are considered superseded, then this needs to be stated and agreed with regulators
Mine closure costs	A comprehensive review is required of the closure costs. The IM understands that this will occur as part 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 Draft OMP EIS process
2012 and 2013 Operational Periods		
NOEF	Review the current dump design in relation to the sustainability and performance of the 0.6-m compacted clay infiltration/oxidation control layer. Test the sensitivities of the cover design to: ♦ Changes in material properties ♦ Changes in depth of NAF cover as a result of erosion ♦ Changes in climate	Completed. A new cover design strategy was outlined in the Draft OMP EIS
	Undertake erosion and sediment transport modelling of the proposed NOEF landform to identify depth of NAF cover material required to ensure the functionality of the cover for 100, 500 and 1,000 years. The IM supports MRM's decision to evaluate alternative landform designs which eliminate the need for engineered structures	Completed. Erosion trials established but no data available for review. Modelling of NOEF landform detailed in the Draft OMP EIS
	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 Draft OMP EIS. Trial to commence following completion of the Draft OMP EIS process
	Evaluate the potential for differential settlement of the NOEF to compromise the cover design. In particular, the potential implications for highly reactive PAF material to settle faster than other waste rock contained in the NOEF	Ongoing. Differential settlement was considered during risk assessments, but the IM believes that further investigation is required to determine if differential settlement could impact on the performance of the cover

Table 4.37 – Closure Planning Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	Status
2012 and 2013 Operational Periods (cont'd)		
Open pit	The seepage of contaminated water from the pit lake after closure should be assessed. This would best be carried out using a water and solute balance model for the pit void lake, which would include inflows, outflows, storage volumes, effects of salinity on lake evaporation rates and geochemical process associated with interaction between lake water and the pit wall rocks Under the 2015 West Australian mine closure guidelines (DMP, 2015) (revision of the 2011 guidelines), which MRM has adopted for closure planning purposes, an assessment of the pit lake condition is required to identify whether a groundwater sink or flow through will develop after closure	Completed. A revised strategy for the management of the open pit has been outlined in the Draft OMP EIS. The final strategy, however, will not be known until further modelling has been completed and monitoring of the pit lake following closure
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 Draft OMP EIS process and also proposed amalgamation of Cells 1 and 2 to form one TSF
	Undertake erosion and sediment transport modelling of the proposed TSF landform to identify depth of NAF cover material required to ensure the functionality of the cover for 100, 500 and 1,000 years	See above

4.8.4.3 Successes

The release of the Draft OMP EIS in March 2017 was the culmination of a number of studies which were focused on the closure of the operation. The completion of these studies has increased the knowledge and understanding of closure issues and, importantly, highlighted gaps in knowledge. Additional studies are proposed by MRM to address these gaps. The strategies proposed are currently being assessed as part of the EIS process.

4.8.5 Conclusion

Planning for closure of the McArthur River Mine has advanced significantly in the past four years. Numerous studies have been completed which have improved the understanding of the key mine components (NOEF, TSF and open pit) and their inter-relationships.

At the time of preparing this report, the status of the proposed revised closure strategies outlined in the EIS conceptual mine closure plan is uncertain pending the conclusion of the Draft OMP EIS review process by the regulatory authorities and other stakeholders. No new recommendations regarding closure planning have been made following review of the 2016 performance year. Ongoing closure planning recommendations are outlined in Table 4.38.

Table 4.38 – 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 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 2016 (MRM, 2016a) and MRM's Draft OMP EIS (MET Serve, 2017).
- Monitoring reports prepared by 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 June 2017.
- Discussions with MRM personnel and consultants during the IM site visit in June 2017.

4.9.2 Key Risks

The key risks to terrestrial ecology, as described in the risk assessment (Appendix 2), are unchanged from the previous IM report (ERIAS Group, 2016) 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, redistributing and/or preventing retention of soils, and removal of planted tubestock.
  - 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 homologous 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 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 spoil 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.

- Failure of vegetation to establish 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:

- Annual revegetation monitoring program along the Barney Creek and McArthur River diversion channels (EcOz, 2017).
- Bi-annual riparian bird monitoring program along McArthur River and Barney Creek diversion channels (EMS, 2016a; 2017a).
- Annual vegetation condition monitoring of the Barney Creek diversion channel and Surprise Creek to monitor impacts of saline and metal contamination (EcOz, 2016a).
- Annual Gouldian finch (*Erythrura gouldiae*) monitoring program conducted in suitable habitat in the project area (EMS, 2017b).
- 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, 2016b; 2016c).
- Weeds controlled in liaison with Weeds District Officer and maintenance of weed management logs and weed spraying register (MRM, 2016b; 2016c).
- 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, 2016b).
- Targeted planting along the McArthur River and Barney Creek diversion channels of tubestock grown in the MRM nursery and/or sourced from suppliers (MRM, 2016d; Darwin Plant Wholesalers, 2016).
- Placement of large woody debris (LWD) in the river bed of the McArthur River diversion channel.
- Dust monitoring at 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, 2016).
- Livestock management, including cattle exclusion fences surrounding mine site and diversion channels and the Bing Bong Loading Facility dredge spoil ponds, and livestock mustering and culling (MRM, 2017a; 2016e; 2016f).
- Inspection and maintenance of dredge spoil ponds and perimeter drain surrounding dredge spoil ponds at Bing Bong Loading Facility to facilitate the flow of saltwater out to sea (GHD, 2017).

Rehabilitation of the Diversion Channels

A range of controls are in place to encourage successful rehabilitation of the McArthur River and Barney Creek diversion channels. These include:

- Vegetation monitoring: In accordance with the Rechannel Vegetation Monitoring Procedure (MRM, 2012), annual monitoring assesses revegetation sites along the diversion channels and control sites along the natural channels of Barney Creek and McArthur River (EcOz, 2016a). During the 2016 operational period, 13 revegetation sites and 5 control sites were assessed, including slope and batter plots (Figure 4.24). The program monitors foliage and ground cover, vegetation structure and composition, and disturbance from erosion, weeds and feral herbivores. The monitoring program aims to:
  - Assess the success of rehabilitation of riparian habitat along the diversion channels in comparison to undisturbed sites on Barney Creek and McArthur River.
  - Enable revegetation works to be targeted at locations requiring further work and methods to be reassessed if required.
- Riparian bird monitoring: The riparian bird assemblage is an indicator of habitat health, and as such is relevant to rehabilitation of the diversion channels. Bi-annual surveys (early and late dry season) are conducted along McArthur River and Barney Creek (diversion and natural channels) to record bird species using revegetation and control sites (EMS, 2016a; 2017a), as shown in Figure 4.25. All bird species are recorded, but the purple-crowned fairy wren (PCFW) (*Malurus coronatus*) and buff-sided robin (BSR) (*Poecilodryas cerviniventris*) are targeted, as they are riparian health indicator species. Habitat condition data is also recorded, and its relationship to the species recorded is assessed.
- Revegetation: Tubestock of desirable flora species are planted along the diversion channels where soil pockets are present (MRM, 2016d). Targeted areas are watered using irrigation sleds that source water from the diversion channels, supplying it to vegetation on channel batters and banks. Most tubestock is grown in MRM nurseries located on site, with supplementary tubestock purchased from local suppliers.
- Livestock management: Livestock can impact diversion channel rehabilitation by trampling or grazing on riparian vegetation, causing erosion, and facilitating the spread of weeds. Livestock controls include 47 km of fencing surrounding the mine site, diversion channels and the TSF, with 8 km of electric fencing along the far bank of the McArthur River diversion channel (MRM, 2017a). McArthur River Mining's Cattle Management Plan (MRM, 2017a) details livestock exclusion activities including daily fence checks, and six-weekly mustering and/or culling within the exclusion fence in collaboration with the Department of Primary Industries and Resources (MRM, 2016e).
- Large woody debris placement: LWD piles are placed into the McArthur River diversion channel to create variable habitat for fish and macroinvertebrates, trap sediment and decrease flow rates during the wet season. The debris is sourced from areas that are cleared for mine expansion; logs are partially buried in the diversion channel bed to ensure that they remain secure during the wet season.

REVEGETATION MONITORING AND CONTROL SITES ON THE BARNEY CREEK AND McARTHUR RIVER DIVERSION CHANNELS

McArthur River Mine Project

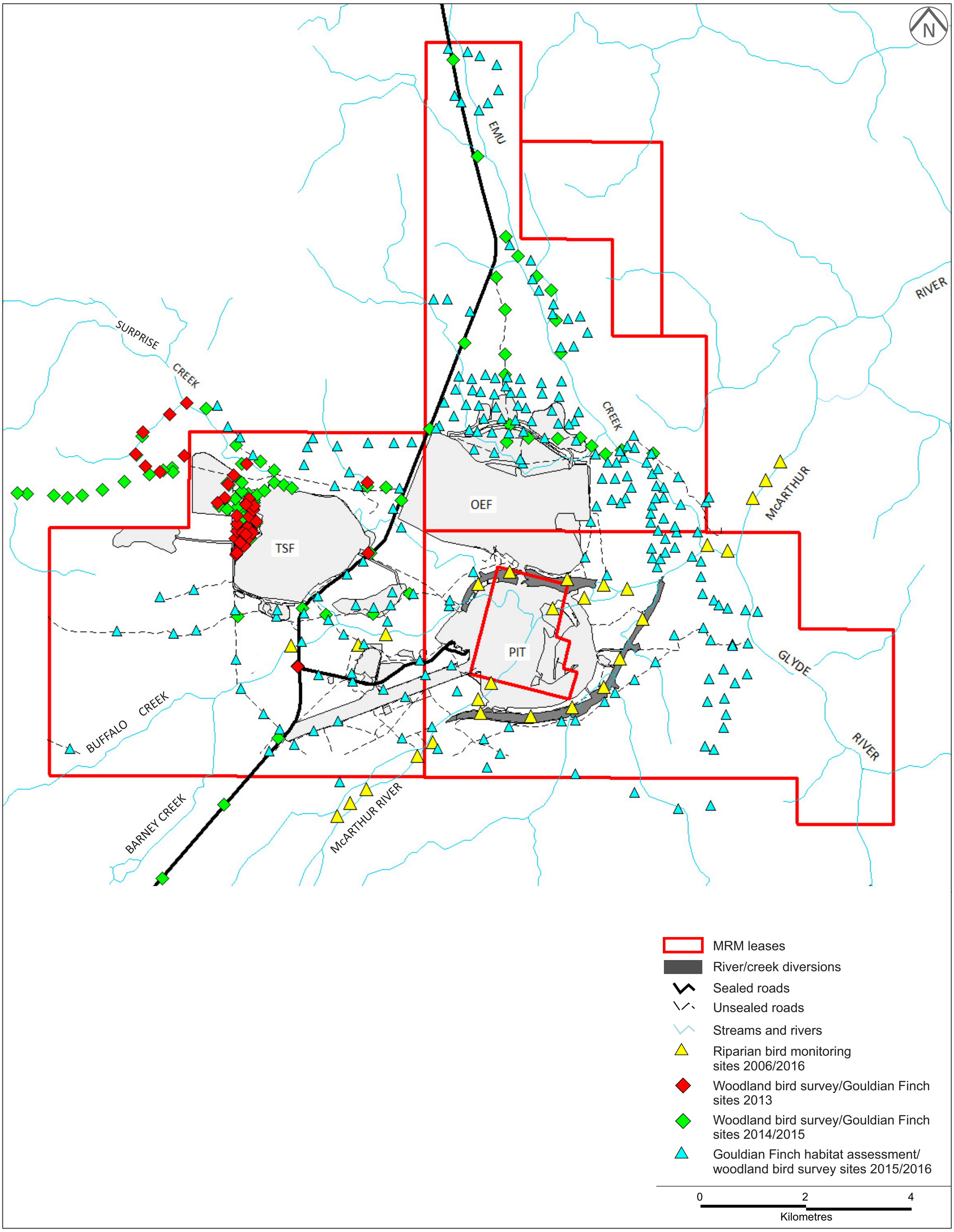
FIGURE 4.24

Source: EcOz, 2015a.

GOULDIAN FINCH AND RIPARIAN BIRD STUDY SITES

McArthur River Mine Project

FIGURE 4.25



Source: EMS, 2017b.

Impact of Saline Seepage on Vegetation

The potential impact of saline seepage on vegetation along the Barney Creek diversion channel and Surprise Creek is monitored in areas in the vicinity of potential sources of saline seepage and/or contamination including the TSF and PAF runoff dams, dust from the processing plant and haul roads, and runoff from the Barney Creek haul road bridge (EcOz, 2016a). Impact monitoring is undertaken within 18 plots across three locations near the processing plant, the southeast PAF runoff dam, and the southern PAF runoff dam (Figure 4.26). Impact site conditions are compared to two control sites located on upstream Barney Creek and upstream Surprise Creek.

Impact on the Gouldian Finch

Regular surveys targeting the Gouldian finch were implemented as a result of the species being observed within the mine lease in 2013. The Gouldian finch is listed as endangered under the *Environment Protection and Biodiversity Conservation Act 1999*. The annual Gouldian finch monitoring program was conducted in November-December 2015 and July-August 2016 in the vicinity of the mine, Carpentaria Highway and NOEF expansion areas (EMS, 2017b), as shown in Figure 4.25.

Impact on Migratory Birds

As a condition of Commonwealth government approval, MRM is required to undertake migratory bird surveys twice per year (EMS, 2016b; 2016c) due to concerns that operations at Bing Bong Loading Facility may result in dust migration or concentrate spillage leading to heavy metal bioaccumulation in Port McArthur flora and fauna. The survey uses shorebird counts to assess if migratory bird populations are being affected. Migratory bird monitoring is completed during the austral summer (January) and northern staging period (April) using aerial transects and on-ground check sites (Figure 4.27). Sediment sampling is completed as part of this program at important feeding areas to assess the concentrations of metals, which may be transferred to the shorebirds while feeding.

Weed Management

Controls in places at McArthur River Mine for the exclusion and eradication of weeds include:

- A weed management plan outlining targets and recommended actions for weeds known from the mine site and surrounds (MRM, 2013).
- Weed control record sheets which provides a description of weeds recorded and actions taken (MRM, 2016b).
- Spraying and/or removal of weeds as appropriate (MRM, 2016c).
- Exclusion of cattle to reduce the disturbance of native vegetation and spread of weed seeds.
- Wash down pad for vehicles moving to and from the mine site. The main purpose of this equipment is to reduce the amount of mine-derived dust being transported from the processing area, although it has a secondary function of removing seed matter.

MONITORING SITES FOR ASSESSMENT OF SALINE SEEPAGE IMPACT ON VEGETATION NEAR BARNEY AND SURPRISE CREEKS

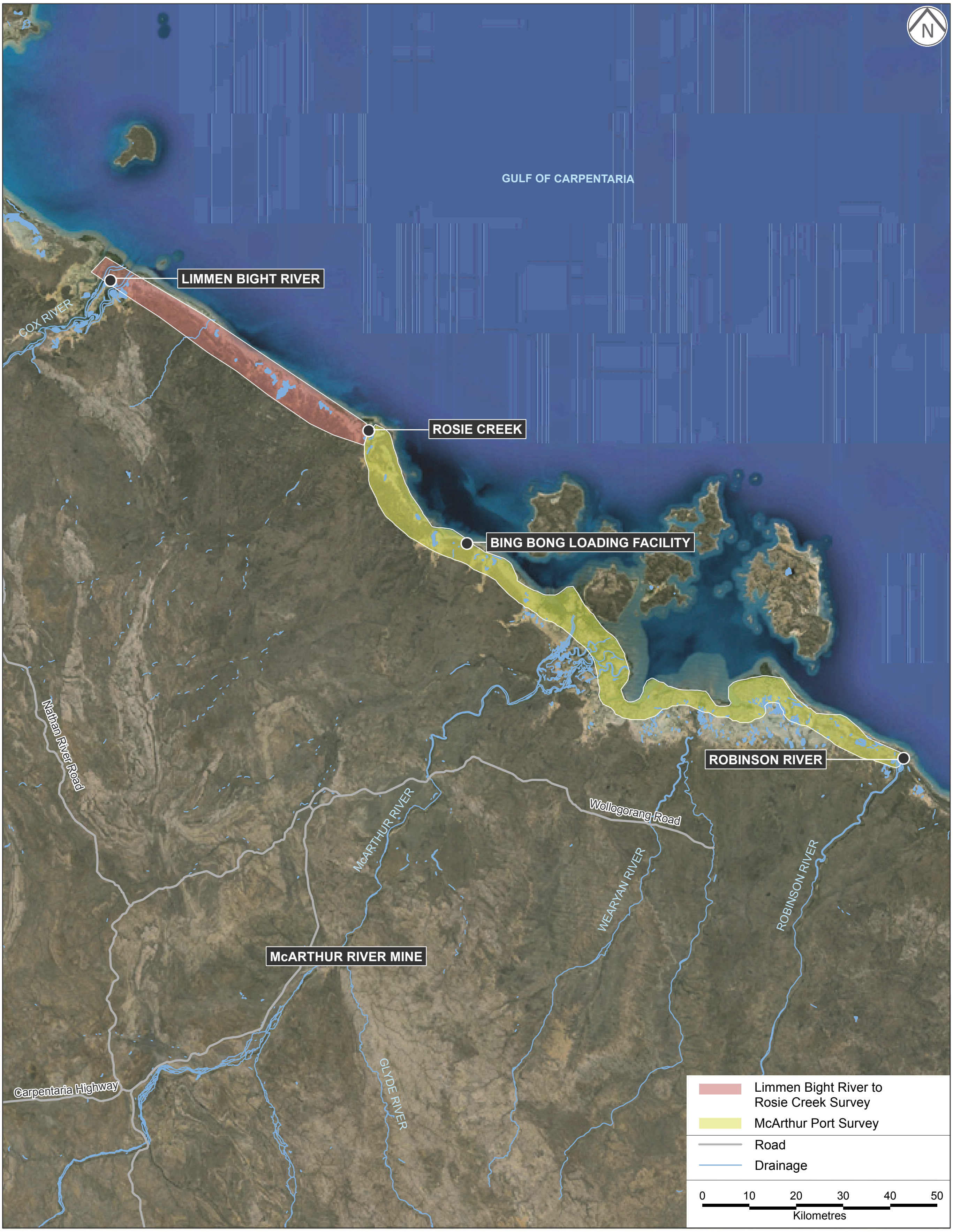
McArthur River Mine Project

FIGURE 4.26

MIGRATORY BIRD SURVEY AREAS FOR THE 2016 OPERATIONAL PERIOD

McArthur River Mine Project

FIGURE 4.27



Source: Google Image 2005

ERIAS Group | 01164D_1_F4-27_v1.pdf

Dredge Spoil Vegetation Monitoring Program

Vegetation monitoring at the Bing Bong Loading Facility dredge spoil ponds surveys vegetation within and surrounding the dredge ponds for the purpose of:

- Monitoring vegetation survival and growth within the dredge spoil ponds.
- Monitoring the condition of vegetation surrounding the dredge spoil ponds that has experienced vegetation dieback as a result of saline water leaching from the dredge spoil ponds and/or prolonged tidal pooling.

Transects (Figure 4.28) are surveyed annually and compared with previous data (EcOz, 2016b). Transects are located within salt-affected areas and in un-impacted reference sites. Surface soil samples are taken at each site to assess salt (EC) levels and to ascertain if changes in vegetation corresponded to changing salt levels in soil.

4.9.3.2 New Controls – Implemented and Planned

No new controls were implemented or planned during the 2016 operational period.

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 2016 operational period.

Non-compliances

The 2013-2015 MMP does not contain a definitive list of commitments against which to assess non-compliances. Despite this, MRM have provided the MRM Compliance Register (MRM, 2017b), which outlines MRMs commitments including recommendations from the IM report. As these recommendations are dealt with in detail below they will not be repeated here.

Through the review of this document, it was determined that the majority of commitments had been met. Several commitments were made in early September 2016 and as this report is examining compliance between October 2015 and September 2016, it is not expected that these commitments would be completed within the review period. These items will be assessed in the next IM report.

One commitment from 2006 does not appear to have been met- Assessment of potential to impact White-browed Robin with measures to minimise impacts. It is unclear what this assessment was in relation to.

4.9.4.2 Progress and New Issues

Reviews and Investigations Conducted During the 2016 Operational Period

- Gouldian finch habitat mapping- In the 2016 IM report (ERIAS Group, 2016), it was recommended that MRM conduct a review of suitable nesting and foraging habitat for Gouldian finches within and in the vicinity of the mine. This information would form the basis

VEGETATION MONITORING SITES AT THE BING BONG LOADING FACILITY DREDGE SPOIL EMPLACEMENT AREA

McArthur River Mine Project

FIGURE 4.28

ERIAS GROUP

Source: EcOz, 2015.

for decisions related to land clearing and disturbance. In response to this, MRM commissioned EMS in 2016 to update vegetation mapping within the mine lease based on field check sites, aerial mapping and existing vegetation mapping, to determine the vegetation mapping units that represented suitable Gouldian finch nesting and foraging habitat (EMS, 2017b). This review is discussed in more detail below.

- Key and primary flora review- As a result of reviewing the 2012 and 2013 operational periods, the IM recommended that MRM reassess the list of key and primary species to which revegetation on the diversion channels was compared to and/or reassess control site selection. The IM also recommended that MRM investigate whether separate key and primary species lists for McArthur River and Barney Creek were needed. These recommendations were made as revegetation monitoring had shown that even analogue sites were failing to meet completion criteria in relation to the number of key and primary species present. In response, MRM commissioned EcOz to conduct a review of the species list and its suitability for use in the completion criteria (EcOz, 2015).

- Investigation into metals in forage grasses- To assess the risk of the accumulation of mine-derived metals in cattle through the consumption of vegetation, Indo-Pacific Environmental investigated metals levels in common forage species (Indo-Pacific Environmental, 2017). The species *Vachellia farnesiana* (shrub), *Heteropogon contortus* (grass) and *Panicum decompositum* (grass) and attached soil were tested for Pb, Co, As and Cd. Samples were taken from eleven sites surrounding the mine site and in the vicinity of the Carpentaria Highway (Figure 4.29). This investigation is discussed further below.

- Revegetation monitoring program redesign- In early 2017, MRM put out a request for tender for redesign of the revegetation monitoring program including the rechannel revegetation and the saline impact monitoring. In the request for tender document, MRM outlined the IM recommendations in relation to revegetation monitoring and requested that the successful consultant design the monitoring program with these in mind. MRM's commitment to ensuring the revegetation monitoring program is designed to aid in the revegetation and monitoring of sensitive areas of the lease, is encouraging. Recommendations for the redesign of the monitoring plan are included below.

Rehabilitation of the Diversion Channels

The McArthur River diversion channel continues to remain largely unrehabilitated with little change in coverage since the previous IM period. This is reflected in both the results from the riparian bird monitoring program and revegetation monitoring program (EMS, 2017a; EcOz, 2017). Neither of the riparian indicator species (the purple-crowned fairy wren or the buff-sided robin) were detected within the diversion channel during the 2016 surveys (EMS, 2017a).

The upstream end of the diversion channel (next to the lookout) has areas of good coverage with some areas showing continuing maturity of trees and shrubs and an understorey of grasses with good diversity aided by irrigation sleds set up at the top of the bank. Despite planting in other locations along the diversion channel, much of the tubestock has been washed out during the wet season, although some tubestock survival has been seen next to LWD piles where sediment has collected and is shielded from high flows. In 2017, MRM plan to change their focus to planting grasses rather than trees and shrubs. Native grasses including *Chrysopogon elongatus* will be

STUDY SITES USED TO INVESTIGATE Pb, Co, As AND Cd ANALYTE LEVELS IN FORAGE SPECIES

McArthur River Mine Project

FIGURE 4.29

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Source: Indo-Pacific Environmental, 2017.

planted in the first year to stabilise the bank, followed by flora that are more susceptible to flooding including the key habitat grass, cane grass (*Chionachne cyathopoda*), and mid and upper storey species. An additional 400 m irrigation sled will be installed and modified from the previous design to include irrigation 'fingers' every 50 m that will run down the bank and ensure tubestock lower down on the bank are watered sufficiently during the wet season (Jones, pers. com., 13 June 2017). The new proposed measures are a logical progression from lessons learned from previous years' revegetation efforts and are likely to increase success in stabilising the diversion channel banks.

The current revegetation monitoring program is considered insufficient for aiding rehabilitation beyond determining the presence of vegetation and noting the qualitative impact from disturbances such as erosion and feral herbivores. Stability of the diversion channels is of utmost importance if the diversion channel banks are to be revegetated and the current program fails to address the underlying issue that causes revegetation to fail, which is the loss and reduced quality of soil substrate as a result of high flow rates and bank instability and the removal of planted tubestock as a result of high flow rates. McArthur River Mining are aware of this problem and are in the process of redesigning the revegetation monitoring program to allow progress to be quantitatively monitored and success and failures to be determined, allowing management actions to be informed for the following year. The revised monitoring program is due to commence in September 2017. The IM recommends that the revegetation monitoring program is encapsulated within a Rehabilitation Plan that includes the following:

- Incorporate recommendations outlined in the geomorphological assessment of the diversion channels (Hydrobiology, 2016) when planning future management actions for addressing high flow rates and bank stability remediation.
- A review of rehabilitation works to date including total tubestock 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.
- Projected detailed milestones to determine if revegetation is on track and facilitate planning for the next year.
- A timeline outlining when the rehabilitation of the McArthur River and Barney Creek diversion channels are expected to be completed, broken down into measurable stages. Results from each year should be used to revaluate this timeline in conjunction with projected milestones and the timeline updated, if required.
- Revised completion criteria that take into account the variability in habitats along the diversion channels and a broader treatment of key and primary species (as discussed in Section 4.9.3.2).
- An outline of the revegetation process including soil treatment, planting methods targeted planting and watering methods.

The following should be included in the revised revegetation monitoring program:

- A monitoring method that is based on the currently accepted practice of ecosystem function assessment such as Ephemeral Drainage Line Assessment (Tongway and Ludwig, 2011). This method is based upon the assessment of erosion gullies on hillslopes that ephemerally contain runoff water and therefore would require some modification to be used for assessing the stability of the diversion channels.
- Quantitative measurements of success such as a count of tubestock survival.
- Reference back to the rehabilitation plan as to performance against projected milestones and timeline.

Saline Seepage at the Mine Site

Saline seepage is occurring as is evident from SO_4 deposition observed at the Barney/Surprise Creek confluence and at Surprise Creek next to the TSF during the IM visit (Plate 4.11). Vegetation monitoring is conducted to assess the impact of saline seepage in the vicinity of high risk areas (refer to Section 4.9.3.1 for details). The saline seepage monitoring program found little difference between vegetation condition at the impact sites compared to the control sites. Currently impact sites are located in areas that have the potential to be impacted by saline seepage rather than in areas that have already experienced salt deposition. The current monitoring sites are useful as they will aid in the detection of a seepage event at these sites if one occurs, but in addition it is recommended that sites be installed in locations where impacts are already evident. This will enable monitoring of recovery or decline of condition at these sites over time, and assist in determining if points of seepage have been contained sufficiently.

Plate 4.11 – Salt Deposition at the Barney Creek-Surprise Creek Confluence During the 2017 IM Visit

McArthur River Mining plans to trial aerial filming (via drone) as a method of detecting vegetation dieback due to saline seepage. As it is unclear at this stage if it will be possible to adequately detect impacts and change over time by reviewing aerial footage, it is recommended that the monitoring program continue as described above until this is confirmed.

Old Fencing

McArthur River Mining have put great effort and expense into excluding cattle and donkeys from the mine and rehabilitation areas. During the site visit, the cattle exclusion fencing was found to be in good condition. While signs of cattle were observed and a donkey was seen inside the fenced area, the IM understands that that it is an ongoing task to restrict feral herbivores and MRM's efforts are to be commended. Of concern during the 2017 IM visit was the observation of old fencing, rusted and partially buried in the McArthur River bank. Concealed barbed wire presents a hazard to native and feral. It must be ensured that decommissioned fencing is removed.

McArthur River Mining conduct daily inspections of the cattle exclusion fencing to inspect for damage; results of these inspections also include observations of feral herbivores. Barbed wire is a key threat to small mammals and birds due to the risk of entanglement. Observations of fauna entanglements during fence inspections should be added to the routine notes taken. If hot spots for entanglement are observed, the issue can be greatly reduced by the addition of polytape to the top barbed wire strand allowing animals to more easily see the fence.

Gouldian Finch

The review of vegetation types within the mine leases determined that there are ten vegetation mapping units (VMUs) present within the MRM mining lease, of which two (VMU4a and VMU4b) contain suitable Gouldian finch nesting habitat. Gouldian finch nesting habitat in the Gulf of Carpentaria is snappy gum (*Eucalyptus leucophloia*) woodland. This habitat covers approximately 422 ha of the leases, predominantly in the eastern portion of the leases running in a band from north to south (Figure 4.30). Gouldian finch sightings are not restricted to these nesting VMUs and it is likely these sightings were in foraging habitat and/or close to watering points.

While EMS (2017b) discusses important foraging grasses for this species, and states that 'suitable foraging habitats occur across broad areas of the MRM lease and grasses that Gouldian finch are known to feed on are common in a range of lease VMUs', important foraging VMUs are not specified and are not mapped. It is recommended that using the existing information, foraging areas are mapped to the same detailed that nesting areas have been.

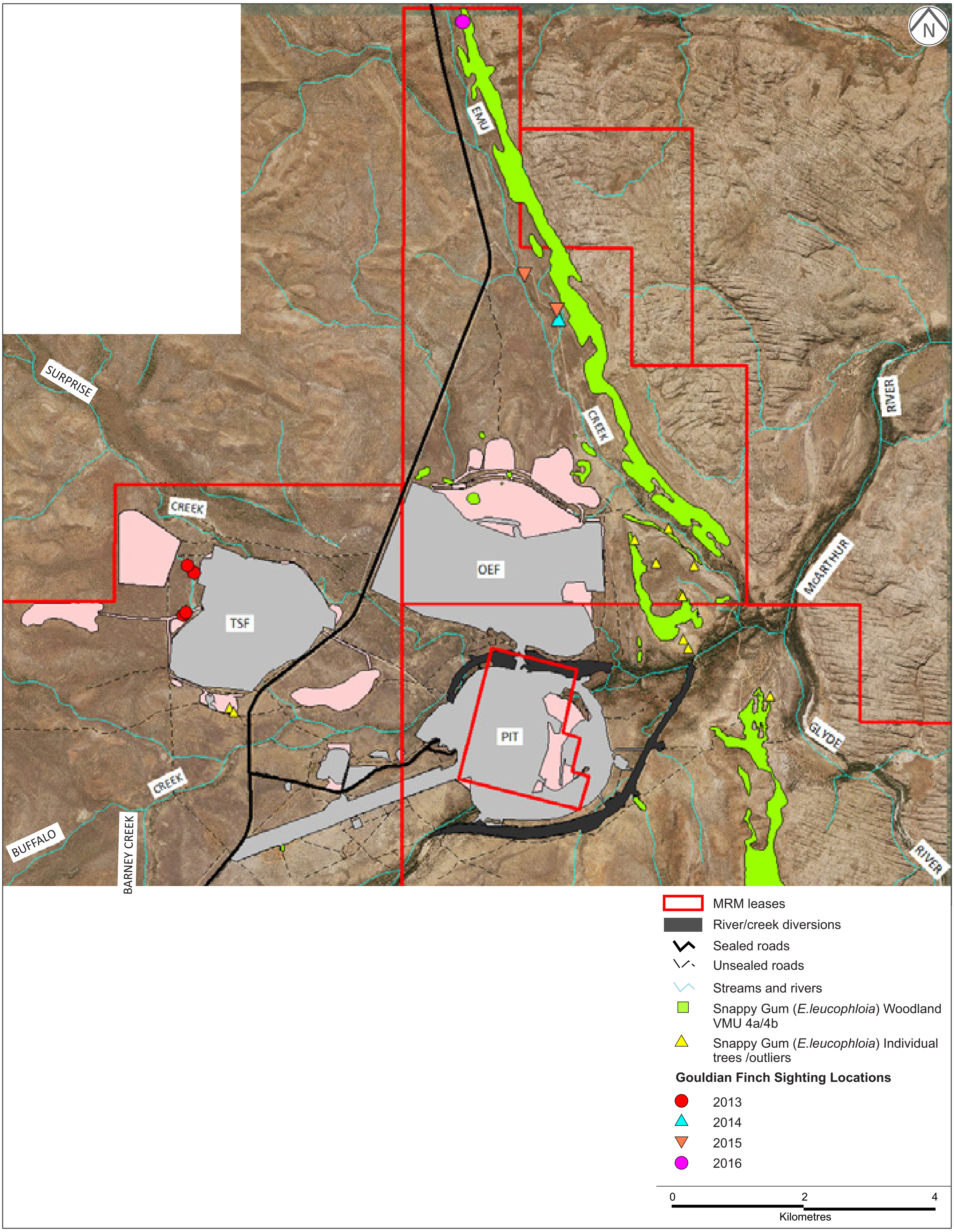
Key and Primary Species

As a result of the review of key and primary species, EcOz (2015) recommended that MRM should 'broaden the list of key and primary species to include all long lived woody native species in the region'. The IM agrees that this would make completion criteria more achievable while ensuring that the habitat at revegetation sites is consistent with undisturbed habitat in the region. The current diversity completion criteria should be retained to prevent homologous vegetation communities from forming. Despite the broadening of the criteria, revegetation will still need to include targeted planting and/or seeding of species that are suitable for the slope, soil and bank position.

GOULDIAN FINCH NESTING HABITAT AND SIGHTINGS WITHIN THE MRM LEASES

McArthur River Mine Project

FIGURE 4.30



Source: EMS, 2017b.

Metals in Foraging Grasses

Highly elevated levels of Pb were recorded in all species at Site 1, with As and Cd also highly elevated in *Vachellia farnesiana* and *Panicum decompositum* (Table 4.39). Site 1, located next to the mill, was found to pose a high risk to cattle when theoretical blood Pb levels in cattle were calculated (see Figure 4.29). Indo-Pacific Environmental (2017) states that:

> Although Site 1 falls within the cattle exclusion zone, if cattle were to enter the area they could potentially exceed the MRL after consuming just over half of their daily dry matter intake which would require them to be placed under quarantine or destroyed. Additionally if cattle were to breach primary fencing and graze in areas closer to recognised sources of contamination such as the mill they would likely reach or exceed the MRL within a shorter grazing period.

Table 4.39 – Mean Pb, Cu, Cd and As Concentrations of *Vachellia farnesiana, Heteropogon contortus* and *Panicum decompositum*

Site	Distance from Mill (km)	*Vachellia farnesiana*				*Heteropogon contortus*				*Panicum decompositum*			
		Pb	Cu	As	Cd	Pb	Co	As	Cd	Pb	Cu	As	Cd
1	0.58	90.33	9.33	2.93	0.45	133.33	9.37	2.77	0.78	22.67	4.5	0.99	0.18
2	1.53	15.2	3.47	0.88	0.07	5.9	2.37	0.33	0.13	13.77	4.4	0.79	0.13
3	2.21	2.4	2.7	0.19	0.01	0.76	2.17	0.05	0.06	0.86	3.47	0.07	0.03
4	2.26	2.73	3.4	0.2	0.02					3.83	3.4	0.2	0.04
5	2.63	11.23	4.53	0.52	0.05					12.87	4.43	0.58	0.15
6	2.70	2.33	4.47	0.12	0.02					7.13	3.7	0.44	0.06
7	2.94	1.08	2.73	0.07	0.01	3.33	3.27	0.19	0.08	1.57	3.1	0.09	0.03
8	3.07	12.67	3.17	0.93	0.05	9.93	3.23	0.93	0.15				
9	3.73	4.2	3.6	0.19	0.03	5.63	2.1	0.2	0.1				
10	5.00	2.2	3.33	0.14	0.01	1.3	2.3	0.07	0.03	2.2	3.37	0.15	0.02
11	9.16	3.8	1.97	0.25	0.02	5.07	2.53	0.18	0.07	1.87	3.17	0.15	0.03

Red: highly elevated. Orange: moderately elevated. Yellow: slightly elevated. Green: lowest value recorded.

Sites 2, 5 and 8 posed a limited risk to cattle while Sites 3, 4, 6 and 7, 10 and 11 were found to pose a low risk to cattle. Of concern is Site 9, located next to the Carpentaria Highway. This site was found to have the highest soil analyte concentrations for Pb (208 mg/kg), which exceeds the MLC for Pb outlined by ANZECC (1992). Indo-Pacific Environmental suggested that the source of Pb is likely from passing haul road trucks with water runoff from the road transferring Pb to the soil (Indo-Pacific Environmental, 2017). While Site 1 is somewhat protected from cattle in that it within the cattle exclusion fence, Site 9 is along the Carpentaria Highway, with cattle having access to the entire road corridor. As recommended in the report, further investigation into metal analyte concentrations along the Carpentaria Highway should be conducted to determine if additional fencing is required to restrict cattle from the corridor.

Higher metal concentrations were found in forage species at sites closer to the mine, and particularly, the mill. High Pb levels in all species were recorded at Site 1, the closest site to the mill, implying that metal contamination may be as a result of dust from the mill. Results showed that areas of highest risk were located within the cattle exclusion fence indicating that the fence is currently well placed. The region surrounding the TSF was not included in the recent investigation and it is recommended that an investigation into metal analyte concentrations in forage species and soil be conducted in this area. This study provides useful information for planning the location of fencing and has the potential to save costs associated with mustering/culling or with fence length and placement (Indo-Pacific Environmental, 2017).

McArthur River Mining's performance against previous IM review recommendations relating to terrestrial ecology issues is outlined in Table 4.40.

Table 4.40 – Terrestrial Ecology Recommendations from Previous IM Reviews

Subject	Recommendation	Status
2015 Operational Period		
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
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. McArthur River Mining commissioned EMS to update vegetation mapping across the mining lease and assess the suitability of VMUs for Gouldian finch nesting habitat (EMS 2017b). While foraging habitat is discussed briefly, no details have been supplied as to the specific VMUs that are suitable for foraging and where these are located in relation to the mine
Bing Bong Loading Facility	Investigate ponding of seawater against bund wall and cause of damage to the surrounding drain at the Bing Bong Loading Facility dredge spoil ponds	Not completed
2014 Operational Period		
Rehabilitation	Include new revegetation sites MRR7 and MRR8 in the analysis of data with other sites. This will assist to better indicate how channel revegetation is progressing	Completed. Results for MRR7 and MRR8 were reported alongside the other sites. This gives a better whole-of-channel view of the success of the 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	Not completed. Currently the saline seepage impact program assesses six plots downstream of the Barney Creek haul road bridge, one of which is included in the revegetation monitoring program. Including data from the other plots would require little additional effort as the methods used in each program are the same and would increase the programs' coverage of the Barney Creek diversion channel
	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	Not completed. The IM recommends that MRM includes an additional site to represent all habitat types along the McArthur River diversion channel

Table 4.40 – Terrestrial Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	Status
2014 Operational Period (cont'd)		
Rehabilitation (cont'd)	unlikely that areas such as this would meet completion criteria set out for more sloped sites	
Flora	Control sites need to be found for comparison with impact monitoring sites as part of the saline seepage impact monitoring program. Investigate whether control sites used for the diversion channel revegetation monitoring program can also be used in this case	Completed. Two control sites were included in the 2015 saline seepage monitoring program. One of these sites (BCC1) is used as a control site as part of the revegetation monitoring program, while the second (SCC1) is a new site. The suitability of BCC1 as a control site should be investigated, as vegetation on slopes and batters at this location is experiencing a downward trend in the density of foliage from 2012 to 2015
	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	Not completed. While vegetation monitoring has been established in Surprise Creek sites potentially affected by saline seepage from the NOEF, as well as control sites upstream of the TSF, it is still recommended that additional site/s be placed along Surprise Creek to the northeast of the TSF, where previous seepage has occurred. The health of the vegetation in this area should be monitored to determine if the long-term saline seepage impact issue has been rectified
Bing Bong Loading Facility dredge spoil ponds	Fix fencing surrounding the Bing Bong Loading Facility dredge spoil ponds to ensure that cattle and donkeys are excluded from the ponds and drains, ensuring that their integrity is protected	Completed. During the site inspection, fencing was observed to be in good condition and no signs of cattle were seen inside the fenced area
2012 and 2013 Operational Periods		
Rehabilitation monitoring	Revise revegetation monitoring program to include sites on the Barney Creek diversion channel downstream of the Barney Creek haul road bridge, and additional sites in the downstream half of the McArthur River diversion channel. Monitoring of diversion channel revegetation control sites every year rather than every three years	Completed. Two additional sites were added in 2014 in the downstream half of the McArthur River diversion channel and data was included in the analysis for the first time in 2015. In 2015, a site was added downstream of the Barney Creek haul road bridge
	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	Not completed. Erosion assessment has been improved by measuring the distance of terracing from the site start marker, with the aim of monitoring change over time. A landscape function-based monitoring program has not been researched to date, however, the geomorphological study of the diversion channels will help to assess and inform mitigation of erosion issues

Table 4.40 – Terrestrial Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	Status
2012 and 2013 Operational Periods (cont'd)		
Cattle exclusion	Redesign current cattle fencing surrounding McArthur River diversion channel to increase flood-proofing and ensure that cattle exclusion fences are monitored for damage	Completed. McArthur River Mining has developed a cattle management plan (MRM, 2017a), which addresses fencing
Rehabilitation	Conduct a review of rehabilitation works to date including total tubestock 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	Partially completed. McArthur River Mining keeps a detailed register of available tubestock, amount of seed used and areas planted. This needs to be compared to some measure of revegetation success to allow determination of a reasonable expected completion date
Bing Bong Loading Facility dredge spoil ponds	Establish reference sites for dredge spoil transects which do not currently have controls. If this is not possible, it is recommended that additional sites be selected in the same habitats sufficient to provide statistically significant assessment of changes occurring within bands of vegetation in the landscape	Completed. Previously unpaired sites have been matched with controls that have similar vegetation assemblage and structure as the monitoring sites
Fauna	Continue migratory bird monitoring bird program for one additional year with comparison of survey data to older data collected for the gulf by Garnett and Chatto. Reassess need to continue surveys based on trend of fluctuations compared to historical data	Partially completed. 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
Flora	Conduct bi-annual vegetation monitoring at Surprise Creek to evaluate effects of tailings seepage	See 2014 recommendation
Rehabilitation monitoring	Reassess the list of key and primary species to which revegetation on the diversion channels is compared to and/or reassess control site selection, as many of those listed are not recorded at current control sites	Completed. Although it is unclear if recommendations included in the review were taken into consideration during the 2016 operational period
	Investigate separate key and primary species lists for McArthur River and Barney Creek as vegetation assemblages at the control sites show different assemblages	Completed. See comment above
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	No evidence sighted

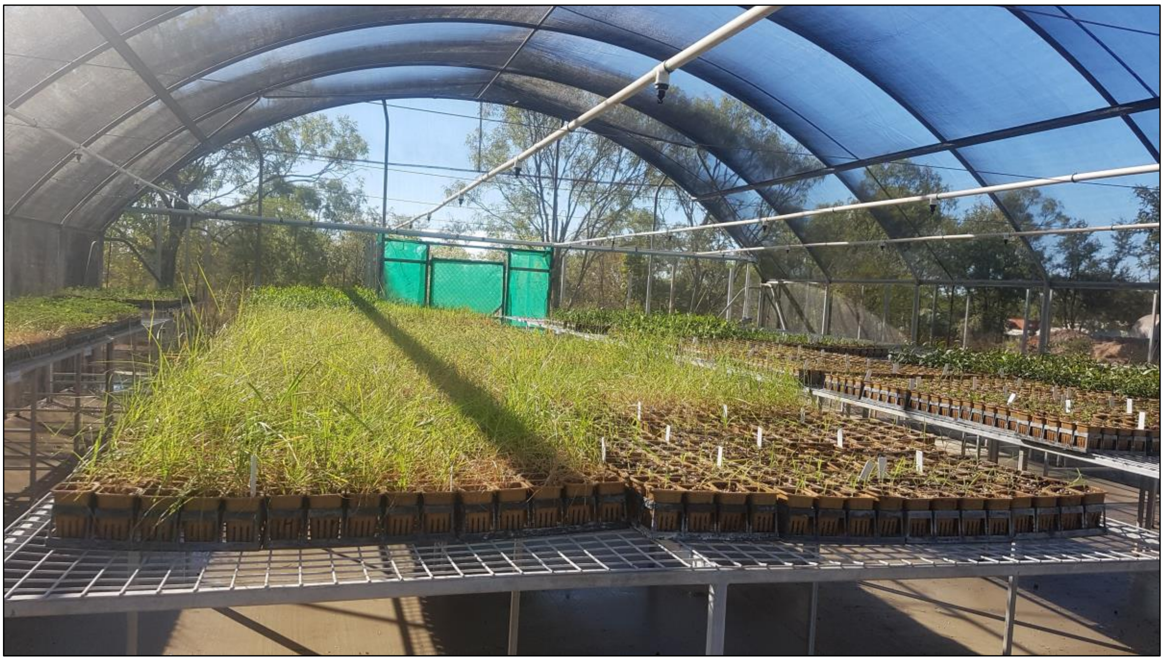
4.9.4.3 Successes

In the 2016 operational period, successes relating to terrestrial ecology have included:

- The placement of a large amount of LWD into the downstream end of the McArthur River diversion channel. Large woody debris is essential for the rehabilitation of the diversion channel as it provides important refuge habitat for fish species, helps to slow flow rates and acts as a sediment trap providing substrate for vegetation to grow in.

- Over 25,000 tubestock were planted during the 2016 operational year including over 20,000 along the McArthur River diversion channel (MRM, 2016d).
- McArthur River Mining have upgraded their on-site nursery to allow increasing numbers of tubestock to be propagated by dedicated nursery staff (Plate 4.12).

Plate 4.12 – Thousands of Tubestock Growing in the Refurbished Nursery at McArthur River Mine



4.9.5 Conclusion

McArthur Riving Mining have progressed a number of the IM recommendations during the 2016 operational period. Of note is the move to address issues with the revegetation monitoring program by releasing a request for tender for the redesign of this program. Additionally, MRM have commissioned consultants to map important Gouldian finch habitat and address concerns regarding the key and primary species used in revegetation completion criteria.

The rehabilitation of the McArthur River diversion channel remains a concern, with very little change observed since the previous IM visit despite the planting of tens of thousands of seedlings in recent years. It is hoped that the redesigned revegetation monitoring program will aid in increasing the success of revegetation by helping to identify where the significant problems lie and how these problems can be overcome in the coming years.

Ongoing and new IM recommendations related to terrestrial ecology issues are provided in Table 4.41.

Table 4.41– 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
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 and rectify recent ponding of seawater against the bund wall and damage to the surrounding drain at Bing Bong Loading Facility dredge spoil ponds	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	Medium
Fauna	Add information on VMU's that are important foraging habitats to the Gouldian finch habitat map	Medium
Rehabilitation monitoring	Revised- Encapsulate the revegetation monitoring program within a Rehabilitation Plan that includes the following: ♦ Incorporate recommendations outlined in the geomorphological assessment of the diversion channels (Hydrobiology, 2016) when planning future management actions for addressing high flow rates and bank stability remediation. ♦ A review of rehabilitation works to date including total tubestock 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 ♦ Projected detailed milestones that will allow it to be determined if revegetation is on track and facilitate planning for the next year ♦ A timeline outlining when the McArthur River and Barney Creek diversion channels are expected to be completed, broken down into measurable stages. Results from each year should be used to revaluate this timeline in conjunction with projected milestones and the timeline updated, if required ♦ Revised completion criteria that take into account the variability in habitats along the diversion channels and a more broader treatment of key and primary species (as discussed in Section 4.9.3.2) ♦ An outline of the revegetation process including soil treatment, planting methods targeted planting and watering methods	High
	Revised- The following should be included in the revised revegetation monitoring program: ♦ Based on ecosystem function assessment such as Ephemeral Drainage Line Assessment (Tongway and Ludwig, 2011)	High

Table 4.41– New and Ongoing Terrestrial Ecology Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Rehabilitation monitoring (cont'd)	♦ Quantitative measurements of success such as tubestock survival ♦ Reference back to the rehabilitation plan as to performance against projected milestones and timeline	
New Items		
Flora	♦ Conduct testing for metal analyte concentrations in common forage species at sites surround the TSF ♦ Measure the survival rate of seedlings being planted to enable an assessment of whether the current strategy of planting seedlings is successful	Medium
Fencing	Remove decommissioned fencing to avoid causing injury to fauna and/or mine personnel and animals	High

4.9.6 References

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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 (Indo-Pacific Environmental, 2016a, 2017a).
  - Metals and As concentrations and Pb isotope ratios (PbIRs) in freshwater fauna (Indo-Pacific Environmental, 2016b) and macrophytes (Indo-Pacific Environmental, 2016c).
  - Freshwater macroinvertebrates (Barden, 2016).
- Additional monitoring and other reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to MRM's mining management plan (MRM, 2015), operational performance report (MRM, 2016), and monitoring of surface water (KCB, 2016a), dust (Todoroski Air Sciences, 2016) and fluvial sediments (KCB, 2016b).
- 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 assessment (Appendix 2) 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 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, Barney Creek, Little Barney Creek, Surprise Creek and/or Emu Creek. This could lead to 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 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

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*) (Indo-Pacific Environmental, 2016a; 2017a).
- Freshwater macroinvertebrate diversity and abundance (Barden, 2016).
- Metals and Pb isotopes in freshwater fauna (Indo-Pacific Environmental, 2016b) and macrophytes (Indo-Pacific Environmental 2016c).
- Riparian revegetation program along the diversion channels (EcOz, 2016).

Large woody debris (LWD) is also added to the McArthur River diversion channel to provide in-stream habitat.

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 the 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

Freshwater fauna were surveyed in the early and late dry season (April and October 2016, respectively) by Indo-Pacific Environmental (Indo-Pacific Environmental, 2016a; 2017a). Freshwater 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 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 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 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.

Less sites were surveyed in 2016 compared to 2015 due to a combination of factors including equipment failure, safety and low water levels following a below average wet season. However, due to the early dry season survey occurring earlier in 2016, an additional five sites were surveyed on Barney Creek above the Barney Creek diversion channel, so the performance of the diversion channel can be better assessed. Survey locations are shown in Figure 4.31.

Freshwater Macroinvertebrates

Freshwater macroinvertebrates are surveyed annually, four to six weeks after the last major wet season flood (generally April to June) by Ecological Management Services (Barden, 2016). As the 2015 to 2016 wet season was below average, surveys were conducted in April and many minor drainage line sites normally surveyed could not be sampled due to a lack of water. 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. Twenty-six sites were surveyed for macroinvertebrates in 2016, 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 4.32 shows the macroinvertebrate sampling sites around the McArthur River Mine.

Where possible, macroinvertebrates were sampled along river edges and in riffles at each site. However, at nine sites there was no flow during the survey period, so riffle habitats were not present. 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).

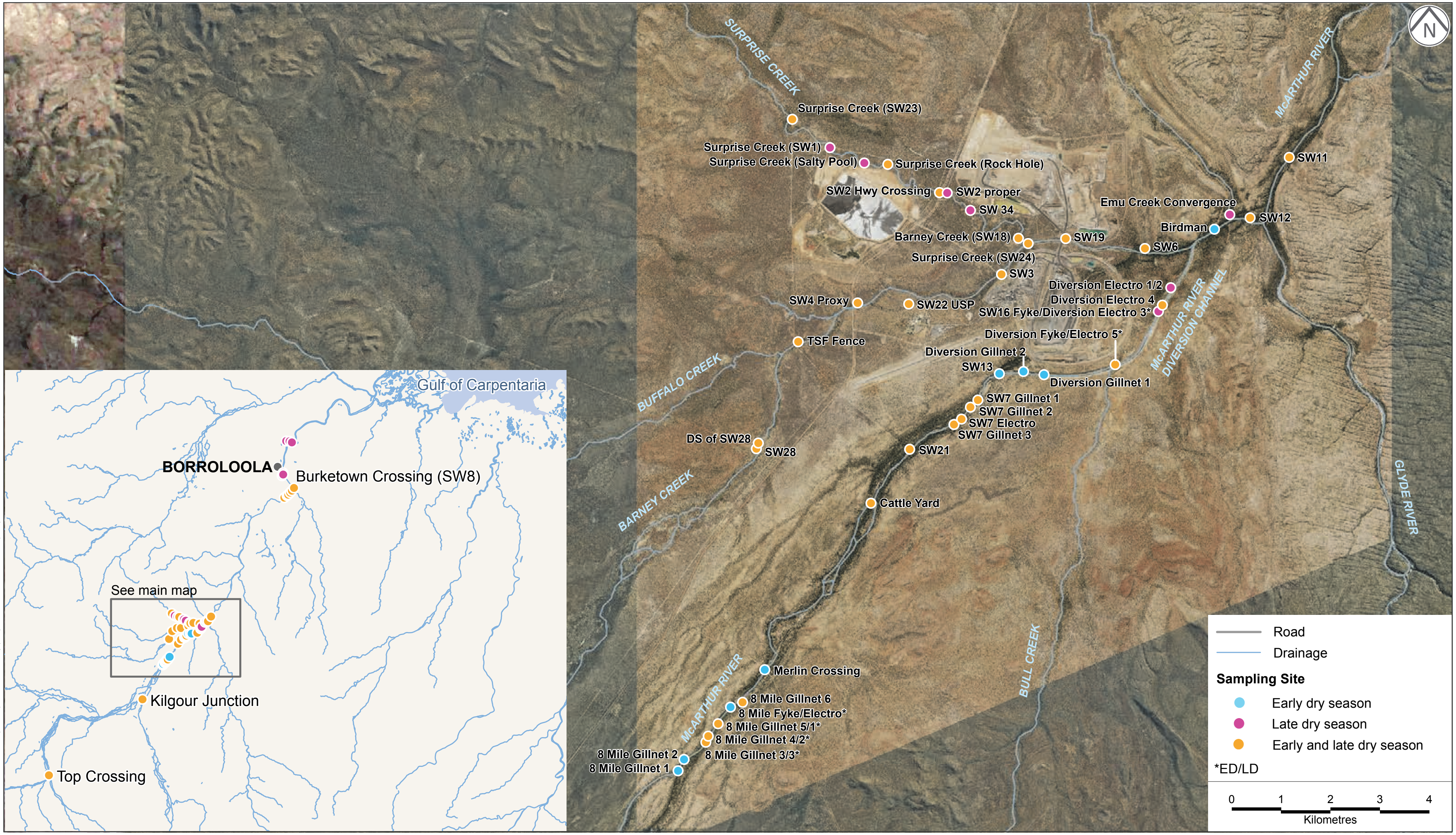
Metals and Lead Isotope Ratios in Freshwater Fauna

The metals and lead isotope ratios 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 were assessed in April 2016 (Indo-Pacific Environmental, 2016b). Six species of fish (sooty grunter [*Hephaestus fuliginosus*], barramundi [*Lates calcarifer*], bony bream [*Nematalosa erebi*], chequered rainbowfish [*Melanotaenia splendida*] and spangled grunter [*Leiopotherapon unicolor*]), one crustacean species (freshwater prawn, *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 4.33.

SAMPLING LOCATIONS OF FRESHWATER FISH, CRUSTACEANS AND OYSTERS IN THE VICINITY OF McARTHUR RIVER IN 2016

McArthur River Mine Project

FIGURE 4.31



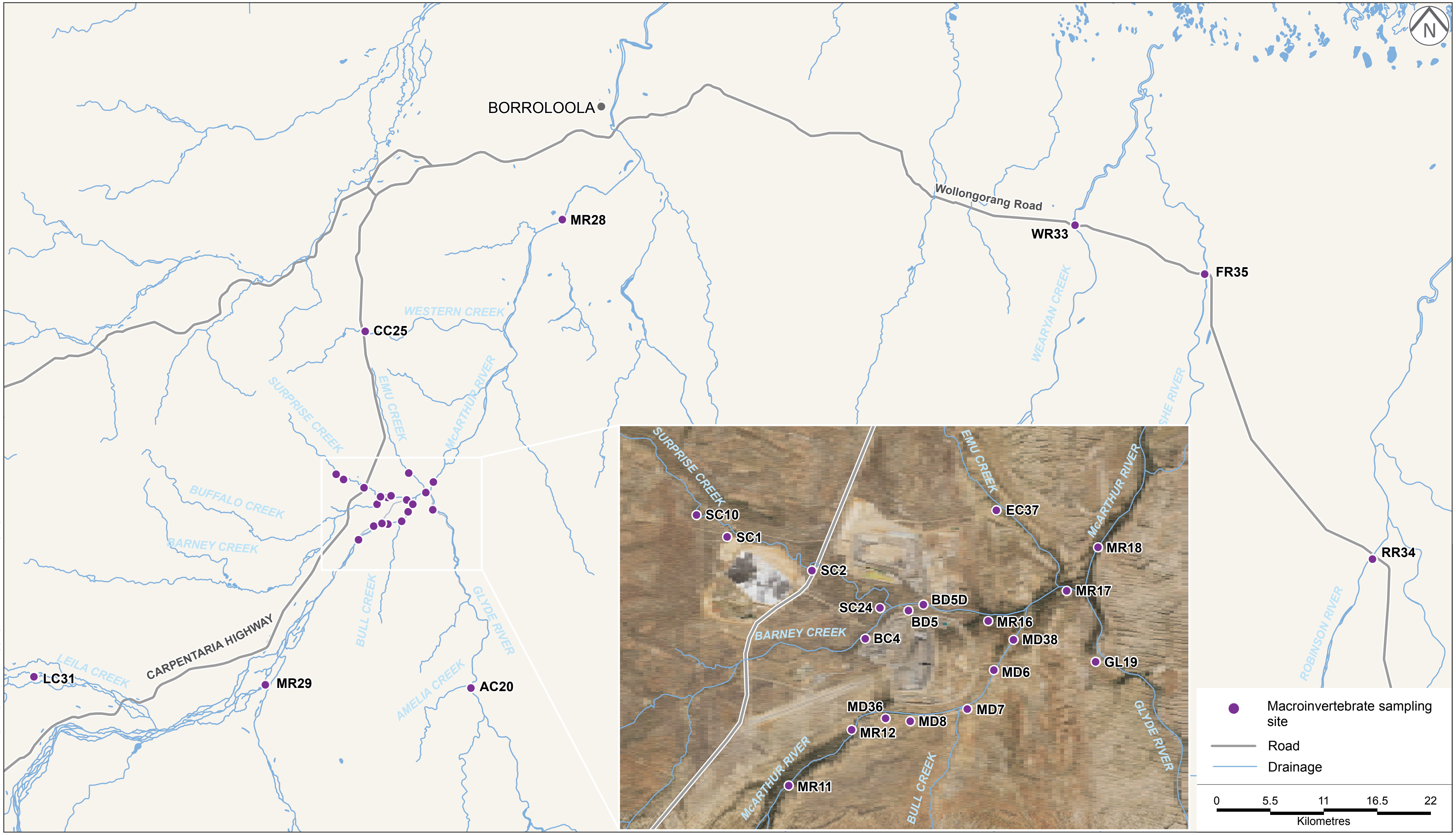
Source: Thorburn, 2016a; 2017a

MACROINVERTEBRATE SAMPLING SITES IN 2016

McArthur River Mine Project

FIGURE 4.32

ERIAS GROUP

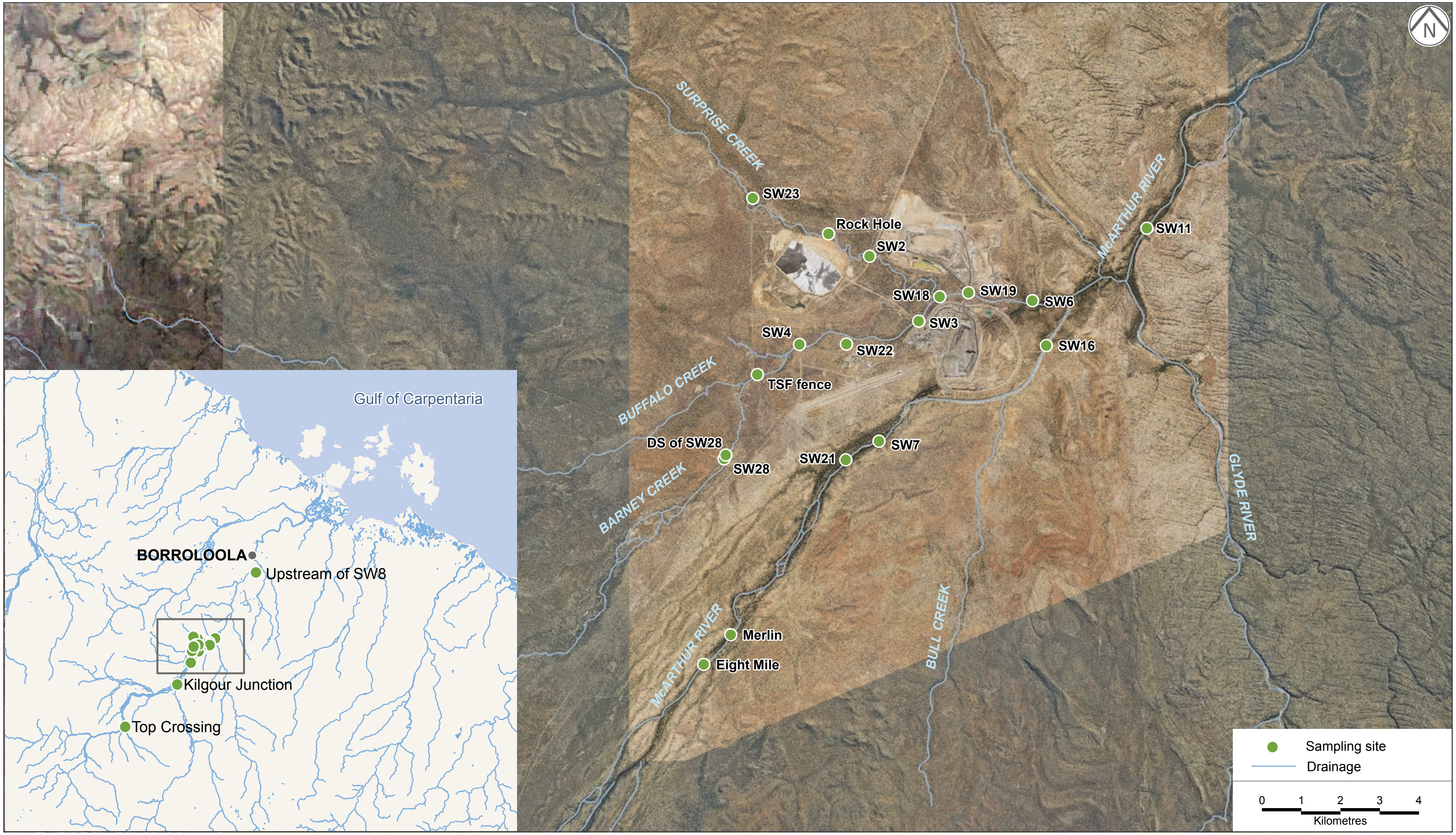


Source: Barden, 2016.

LOCATIONS SAMPLED FOR FRESHWATER BIOTA AS PART OF THE METAL AND LEAD ISOTOPE RATIOS MONITORING PROGRAM IN 2016

McArthur River Mine Project

FIGURE 4.33



Source: Thorburn, 2016b

Tissues were analysed using inductively coupled plasma mass spectrometry for 20 metals (9 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 Pb isotopic ratios 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.

Prior to 2016, samples were collected annually in the early dry season. However, since 2016 sampling occurs in the early and late dry season. The 2016 late dry season monitoring of metals in freshwater biota fell outside the 2016 operational period and is not discussed in this report.

Monitoring 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).

4.10.3.2 New Controls – Implemented and Planned

Additional Monitoring Sites

Five new sites were added along Barney Creek upstream of the Barney Creek diversion channel and ROM pad to assess whether contaminants are present upstream of SW3, and if present, the extent of that contamination. These additional sites may help determine whether elevated concentrations of Pb at SW3 were due to naturally elevated concentrations or MRM's operations.

Late Dry Season Monitoring of Metals in Biota

McArthur River Mining has added late dry season (generally October or November) monitoring of metals in freshwater biota. The first round of late dry season monitoring fell outside the 2016 operational period. As freshwater fauna will generally be constrained to isolated pools for roughly six months longer than the early dry season survey, monitoring in the late dry season may provide an indication of the maximum concentrations of metals in fauna. In addition, this may identify seasonal variation in metal concentrations.

Annual Sampling of Regional Reference Sites

From 2017, MRM will sample regional references sites biannually as part of the metals in freshwater biota monitoring program. This will capture annual variation in background concentrations of metals in freshwater fauna due to natural processes (such as the amount of wet season rainfall) and provide a more robust natural reference point for the monitoring program.

Monitoring Metals in Freshwater Vegetation

During the 2016 operational period, concentrations of four metals in terrestrial and freshwater vegetation were measured for the first time to determine whether plants could be used as simple, cost effective and non-destructive means for monitoring the introduction of metals into the environment (Indo-Pacific Environmental 2016c). Macrophytes (*Chara* sp.) were collected from 12 sites in the diversion channels, McArthur River and Barney and Surprise creeks and concentrations of metals and PbIRs analysed. Sites within and outside the mine site were surveyed. Zinc concentrations could not be meaningfully measured in this study, as Zn is essential for plant growth and as a result is actively regulated by plants.

Fish Consumption Survey

In 2016, Indo-Pacific Environmental conducted a survey of local community members to determine local fish consumption patterns (Indo-Pacific Environmental, 2016d). The fishing and fish consumption habits of at least 10% of the population of Borroloola were surveyed.

Acoustic Tagging of Migratory Species

Due to the expansion of the monitoring of metal in the 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 (Indo-Pacific Environmental, 2017b) 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 diversion and nine fish were tagged. As part of ongoing monitoring programs, MRM will opportunistically tag additional fish and download data three times per year. The monitoring program will be run in partnership with the Ii-Anthawirriyarra Sea Rangers and MRM will erect signage and posters to inform the community of the monitoring program. In addition, acoustic tagging will improve the resolution of the monitoring of fish movement in the McArthur River, rather than relying on recapture of visually tagged individuals.

Installation of Large Woody Debris

During the 2016 dry season, MRM installed roughly 100 Moxy loads of LWD at the downstream end of the McArthur River diversion channel. New LWD is a welcome addition to the diversion channels, as the provision of LWD creates complex habitats that have a rapid, positive effect on the abundance and diversity of freshwater fauna. Unfortunately, during the June 2017 site visit, MRM personnel reported that the above average 2016 to 2017 wet season washed much of the LWD downstream.

4.10.4 Review of Environmental Performance

4.10.4.1 Incidents and Non-compliances

Incidents

Unhealthy Barramundi in the McArthur River Diversion Channel

On 6 August 2016, the environmental team noted four unhealthy barramundi at the upstream end of the McArthur River diversion channel. As a result, MRM issued a site-wide communication regarding treatment of injured animals. No further detail was provided in the written report. However, the IM was informed that the fish were translocated from SW19 into the McArthur River diversion channel by mining staff, without the knowledge of MRM environmental personnel, when SW19 was being pumped dry. The mining personnel who translocated the fish were unaware of the rules regarding the translocation of fish or the correct handling and translocation techniques for fish. The poor condition of these fish was likely due to incorrect transport and handling techniques.

In future, MRM should ensure that environmental staff are involved in handling and translocation of animals whenever possible, and proper handling and transportation techniques are used. As SW19 is drained annually prior to the onset of the wet season and other sites have been pumped dry historically, MRM should establish a policy for either translocating or humanely killing aquatic biota stranded at sites prior to pumping them dry.

Non-compliances

The 2013-2015 MMP does not contain a definitive list of commitments against which to assess non-compliances, however, a summary of the exceedances for metals in freshwater biota during the 2016 operational period are outlined below.

Waste Discharge License Exceedances

Water quality exceedances near the mine site during the operational period (see Section 4.3) were unlikely to have any effect on freshwater biota, as biota in northern Australia is relatively well adapted to peaks in salinity and low oxygen levels at the end of the dry season. Data from the late dry season survey indicates that elevated salinities during the reporting period did not affect fish communities at SW16.

4.10.4.2 Progress and New Issues

Freshwater Fauna Surveys

Table 4.42 outlines the results of the early and late dry season freshwater surveys (Indo-Pacific Environmental, 2016a, 2017a). Two juvenile sawfish were caught in the diversion in the early dry season. These individuals likely entered the McArthur River in the 2014/2015 wet season and were only able to migrate a short distance upstream that year due to the contracted wet season, and then continued upstream in the 2015/2016 wet season. This is consistent with data from previous years in the McArthur River and other rivers of northern Australia, which indicates that sawfish recruitment is positively correlated with the intensity and duration of the wet season. In the late dry season survey, a large sawfish (2.75 m in length) was caught in the McArthur River downstream of Borroloola. Based on the size of this individual, it was thought to have entered the river in the 2011/2012 wet season, and was preparing to navigate back downstream to the sea. This indicates that the McArthur River supports juvenile sawfish for several years until they grow large enough to return to sea.

Table 4.42 – Number of Species of Bony Fish and Elasmobranchs and Abundance of Fish Caught During Freshwater Fauna Surveys at All Sites from 2012 to 2016

	2012		2013		2014		2015		2016	
	ED	LD	ED	LD	ED	LD	ED	LD	ED	LD
Number of species of bony fish	30	23	31	28	28	30	27	17	23	19
Number of species of elasmobranch	2	2	1	2	2	2	2	2	1	2
Total number of fish caught	1,596	1,954	2,194	5,152	2,214	4,933	2,953	2,858	3,306	3,147

Table 4.42 – Number of Species of Bony Fish and Elasmobranchs and Abundance of Fish Caught During Freshwater Fauna Surveys at All Sites from 2012 to 2016 (cont'd)

	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
	ED	LD	ED	LD	ED	ED	LD	ED	LD	ED
Number of sawfish caught	3	1	0	1	3	2	0	2	2	1

Notes: ED – early dry season survey. LD – late dry season survey.

Consistent with previous years, during the 2016 surveys marine-dependent fish were caught within and above the diversion channels, indicating that these species are able to traverse the diversion channels. Anglers recaptured three tagged barramundi, one of which traversed downstream through the diversion since being tagged.

Diversity and late dry season abundances of freshwater fishes in the McArthur River catchment declined in 2016 compared to previous years, likely due to two below average wet seasons in a row (see Table 4.42). Consistent with survey data since 2009, in 2016 the freshwater communities of the McArthur River diversion channel continue to be impaired compared with the original channel, likely due to the absence of suitable habitat. During the 2016 early dry season survey, catches of fish in the McArthur River diversion channel using standardised fyke netting were 8.22 fish per net per night, compared to 39.0 fish for sites downstream of the diversion and 30.78 for sites upstream (Table 4.43).

Table 4.43 – Fyke Net Catch in the Vicinity of the McArthur River Diversion Channel (Early Dry Season Surveys, 2014 to 2016)

	Upstream			McArthur River Diversion Channel				Downstream		
	2014	2015	2016	2008*	2014	2015	2016	2014	2015	2016
Number of fish per net per night	3.17	16.78	30.78	47.4	2.00	3.67	8.22	3.83	7.67	39.0
Diversity (species)	7	10	12	16	9	9	18	10	7	15
Macrobrachium per net per night	8.00	6.11	17.0	NA	1.33	5.56	3.89	22.0	9.67	17.0

* Catch in the original McArthur River channel prior to the diversion

Between 2015 and 2016, the number of species and individuals caught in the fyke nets in the McArthur River diversion channel increased (see Table 4.43). Fyke net diversity and abundances are above those recorded between 2009 and 2015 (an average 6.05 fish per net per night and 13.29 species recorded in the channel). As fyke net catches tend to be lower during below average wet seasons such as the 2015 to 2016 wet season, this increase is somewhat surprising. However, while rainfall was below average it fell over an extended period, which may have increased the window of opportunity for spawning and migration. Abundances remain well below those recorded in the original McArthur River prior to diversion. The most numerous species before the diversion (gobies [*Glossogobius* spp.], giant gudgeon [*Oxyeleotris selheimi*] and chequered rainbowfish [*Melanotaenia splendida*]) have declined in abundance in the McArthur River diversion channel, and are no longer the most abundant species. Due to very low water levels, fyke nets were not used in the late dry season 2016 survey.

Macrobrachium spp. abundances in the McArthur River diversion channel declined compared to the previous year, which is surprising as abundances outside the diversion roughly doubled (see Table 4.43).

In 2015, MRM introduced a new approach for electrofishing surveys that separated complex and simple habitats within, upstream and downstream of the diversion channel where possible. This new approach was adopted as the availability of complex habitat is thought to be the most important factor inhibiting fish abundances and diversity in the diversion channel. However, due to low water levels and safety concerns, no bare bank sites outside of the McArthur River diversion channel were surveyed in 2016.

In the early and late dry season, fish abundance and diversity were slightly lower at bare bank habitats within the diversion channel compared to complex habitats. Complex habitats supported relatively similarly diverse and abundant fish communities within and upstream/downstream of the diversion channel (Table 4.44). However, Analysis of Similarity (ANOSIM) on both early and late dry season data indicate that sites within and outside the diversion channel on complex and bare bank sites were not significantly different to each other. However, this lack of significance may be due to the treatment of the data, as data may need to be transformed to improve normality due to the high variability in abundance between species. While not statistically significant, analyses indicate that bare bank sites within the McArthur River diversion channel support less fish than complex habitats within the diversion. Complex habitats within the diversion channel are generally more similar to natural habitats upstream and downstream of the diversion channel than they are to bare banks within the diversion channel. No crustaceans were caught at bare banks sites, indicating the importance of complex habitat for these taxa. The electrofishing surveys further highlight the importance of complex habitats for fish communities. Large-scale additions of long, continuous patches of LWD to the diversion channels should continue as such additions greatly improve the availability of complex habitats in the diversion channels with major benefits to freshwater fauna.

Table 4.44 – Electrofishing Catch in the Vicinity of the McArthur River Diversion Channel During the 2015 and 2016 Freshwater Surveys

Section	Upstream		McArthur River Diversion Channel				Downstream		
Habitat	Complex Habitat		Bare Bank		Complex Habitat		Bare Bank	Complex Habitat	
Season	ED	LD	ED	LD	ED	LD	ED	ED	LD
2015									
Density of fish (per m^2)	2.59	6.81	1.16	0.51	2.37	6.55	0.40	3.13	4.16
Diversity (species)	13	9	9	8	10	8	4	10	7
Density of crustaceans (per m^2)	1.01	0.67	0.32	0.44	0.40	0.23	0.03	0.72	0.12
2016									
Density of fish (per m^2)	3.08	4.25	1.35	2.86	2.27	3.29	NA	1.68	8.92
Diversity (species)	10	9	9	7	10	8	NA	11	12
Density of crustaceans (per m^2)	0.48	0.058	0	0	0.12	0.007	NA	0.13	0

Notes: ED – early dry season survey. LD – late dry season survey.

The availability of habitat and the types of habitats present hamper comparisons between Surprise Creek, Barney Creek and the Barney Creek diversion channel. Shallow ephemeral pools are the only natural habitat present in Barney Creek, whereas Surprise Creek and the Barney Creek diversion channel also contain deeper, more permanent pools. Barney Creek cannot support species that require larger pools and, as a result, diversity in Barney Creek was lower (8 species) than the Barney Creek diversion channel and Surprise Creek (14 and 16 species, respectively) during early dry season surveys. However, abundance was highest in Barney Creek (1.81 fish per m^2) compared to Surprise Creek and Barney Creek diversion channel (1.24 and 1.16 fish per m^2, respectively). The high numbers of chequered rainbowfish present in Barney Creek drove the difference between sites, rather than any impairment in Surprise Creek or the Barney Creek diversion channel. Analysis of Similarity indicated that fish communities in Surprise Creek, Barney Creek and the Barney Creek diversion channel were no different to each other in terms of abundance and diversity, indicating that the Barney Creek diversion channel is performing acceptably.

Overall, these results indicate that McArthur River and its tributaries continue to support a diverse and regionally representative freshwater fish community. Outside the diversion channels, MRM's operations do not appear to be having an impact on fish communities. Within the McArthur River diversion channel, where complex habitat is provided, fish communities and *Macrobrachium* abundances are similar to natural areas outside the diversion channel. However, throughout the majority of the McArthur River diversion channel there is little or no complex habitat and, as a result, freshwater communities continue to be impaired. This indicates that the McArthur River diversion channel is still in the early stages of rehabilitation. The high number of predators and low levels of cover in the diversion channel suggests that predation is likely high and lack of habitat is restricting fish communities. Results show marine vagrants and migrants, such as barramundi, are able to traverse the McArthur River diversion channel. However, it is unclear whether they can only traverse the diversion channel while the floodplain is inundated, and if smaller fish can traverse the diversion channel at all. The new acoustic tagging program (see section 4.10.3.2) will provide further insight into fish passage through the diversion.

Macroinvertebrate Surveys

Surface Water and Fluvial Sediments

Multi-dimensional scaling (MDS, a visualisation of the degree of similarity between sites) of surface water and fluvial sediment data in 2016 divided survey sites into four main groups with similar water and fluvial sediment chemistry and a single outlier, roughly equating to:

- Regional reference sites on Caranbirini and Amelia creeks and SC10 (equivalent to SW23 surface water monitoring point) on Surprise Creek upstream of the TSF.
- Remaining major river sites including reference sites, the McArthur River and the McArthur River diversion channel, Surprise Creek above the TSF (SC1 [SW01] and SC10 [SW26]) and Leila Creek.
- Sites on the Barney Creek diversion channel (SC24 [SW24] and BD5 [SW18]), as well as MR16 [SW06] below the Barney Creek diversion channel.
- Site BD5D (SW19) downstream of the Barney Creek haul road bridge.

- Site BC4 (SW03) adjacent to the ROM pad was an outlier.

These results indicate that the chemistry of surface water and fluvial sediment from sites in the McArthur River diversion channel and reference sites was similar. Pairwise tests confirm that there were no statistically significant differences between the McArthur River diversion channel and reference sites in water chemistry. However, consistent with 2015, salt-related parameters (e.g., EC and SO_4) are elevated in the McArthur River at sites between MD6 (SW16) and MR18 (SW11). Barden (2016) indicates that this is possibly due to inflows of groundwater into the mid to downstream end of the diversion channel near mineralised sub-surface geology. However, this also correlates with the location of potential seepage pathways from the former ELS dam.

In Barney and Surprise creeks, PERMANOVA analyses found a statistically significant difference between minor drainage line regional reference sites and the sites within and below the TSF, NOEF and the ROM pad and associated ore stockpiles. Consistent with the previous operational period, SO_4 is particularly elevated at sites below the ELS, TSF and SPROD (MR16, SC24, BD5, BD5D and SC2 [SW02]). Sites affected by dust emissions from the Barney Creek haul road bridge (BD5 and BD5D) and the ROM pad and associated stockpiles (BC4, SC24) had elevated levels of Zn and Pb. Site BC4 is an outlier as it has the highest concentrations of Pb and elevated Zn, but very low concentrations of SO_4 as it is away from the influence of the TSF and SPROD. It is surprising that concentrations of Zn were highest at SC24, as it is further from known sources of contamination than BD5, BD5D and BC4. Overall these results are consistent with previous years showing that salts and metals are elevated at sites downstream from the TSF and crushing plant.

Edge Macroinvertebrates

Multi-dimensional scaling plots for edge macroinvertebrates revealed three distinct communities and four separate outliers:

- A group encompassing all major drainage lines, Leila Creek and the McArthur River diversion channel except site MD7 (SW15).
- Within the above group, another group encompassing all McArthur River diversion channel sites and some major drainage line reference sites (MR18, MR28, MR29, WR33, FR35) and Leila Creek.
- Most sites on Surprise Creek and Barney Creek below the TSF (SC1, SC2, BD5, BD5D) and MR16 in the old McArthur River channel.
- Four separate outliers (SC24, BC4, CC25, SC10).

Within the McArthur River/McArthur River diversion channel and large order reference sites, there were three distinct groups of edge macroinvertebrate communities. These equated to:

1. The middle McArthur River diversion channel (MD6 and MD7).
2. The upstream end of the diversion channel (MD36 [(SW13]) and the authorised monitoring point (MR18 [SW11]).
3. The remaining reference sites and two sites in the diversion (MD8 [SW14] and MD38 [SW17]).

The separation between the middle diversion (MD6 and MD7) and upper (MD36, MD8) and lower sites (MD38) may be indicative of improvement of edge habitat at the ends of the diversion due to waterline planting at upstream sites and the provision of LWD at lower sites. However, PERMANOVA pair wise tests still show a statistically significant difference between diversion channel sites and both McArthur River reference sites and all major reference sites. The differences are likely due to the absence of riparian vegetation, low sinuosity and atypical bank structure in the diversion compared to reference sites. Compared to 2015, macroinvertebrate communities did not appear to be impaired at MR12. It is likely that the impaired edge macroinvertebrate community at MR12 in 2015 was related to edge habitats being impacted by bed erosion initiated at the diversion inlet. The below average 2015 to 2016 wet season may have resulted in less erosion at this site in 2016.

PERMANOVA analyses found a statistically significant difference between edge macroinvertebrate communities in the reference minor drainage lines and exposed/diversion channel sites on Barney and Surprise creeks. These patterns are likely due to reduced water quality related to increased concentrations of soluble salts, As and Cd and modified habitats on Surprise and Barney creeks below the TSF and ROM pad. These patterns are consistent with previous years. In addition, two minor drainage line reference sites (CC25 and SC10) supported abnormal edge macroinvertebrate communities, probably due to low flow conditions.

Overall, edge macroinvertebrate diversity increased between 2015 and 2016.

Riffle Macroinvertebrates

A reduced number of sites were sampled for riffle macroinvertebrates due to low flows associated with the below average wet season. Multi-dimensional scaling plots for riffle invertebrates again reveal two distinct communities and three outliers:

- Reference sites and the McArthur River diversion channel.
- The two sites surveyed on Barney Creek diversion channel below the TSF (BD5 and BD5D).
- Three separate outliers (MD8, LC31 and CC25).

The results of PERMANOVA indicate that riffle macroinvertebrate communities are not significantly different between the McArthur River diversion channel and major drainage line reference sites on all surveyed rivers and major drainage line reference sites on the McArthur River. This indicates that riffle macroinvertebrate communities in the McArthur River diversion channel are similar to natural riffle communities. This is consistent with long-term data which indicates that, while the riffle macroinvertebrates in the McArthur River diversion channel normally resemble those found in reference sites, communities within the McArthur River diversion channel tend to be less resilient in years of high and low flow.

Consistent with previous years, riffle macroinvertebrate communities were impaired in the Barney Creek diversion channel, likely due to reduced surface water quality (primarily Zn, Ag, Pb, dissolved oxygen, pH and soluble salt parameters), impaired habitats and a silt that covered riffle habitats at this site. The riffle macroinvertebrate communities at the two minor drainage line regional reference sites surveyed (LC31 and CC25) were different in 2016 compared to previous years, probably due to two below average wet seasons in a row.

Riffle macroinvertebrate taxa diversity declined at almost all sites in 2016 compared to 2015, potentially due to the below average wet season. Sites with the lowest riffle macroinvertebrate taxa diversity were located on the mid and upper McArthur River diversion channel (MD6, MD7 and MD8). Riffle macroinvertebrate abundance scores were lowest sites on the Barney Creek diversion channel (BD5, BD5D) and McArthur River diversion channel (MD36, MD7).

Macroinvertebrate Survey Conclusions

The IM agrees with the conclusions of Barden (2016) that along the McArthur River diversion channel, the diversity of edge macroinvertebrate communities is impaired due to a lack of suitable habitat, and riffle macroinvertebrate diversity is less resilient to environmental perturbations in years of high and low flows. Edge habitats within the McArthur River diversion channel are distinct and tend to support macroinvertebrate communities more typical of riffle habitats. This is likely due to the absence of natural edge habitat in the diversion channel (e.g., overhanging vegetation, root mats, plant litter). However, the 2016 survey found that at sites at the upstream and downstream ends of the diversion channel, where rehabilitation efforts have been extensive, communities are approaching reference sites for the first time. This shows that programs to create more natural edge habitats through revegetating the riparian zone and adding large and small woody debris are having a positive effect and should continue. In the middle of the McArthur River diversion channel where negligible rehabilitation has occurred, edge macroinvertebrate communities remain impaired.

Consistent with the conclusions of Barden (2016), the IM believes that the reduced diversity of macroinvertebrate communities at sites adjacent to and below the ROM pad on Barney Creek, the Barney Creek diversion channel and Surprise Creek adjacent to the TSF, are likely due to the effects of impaired water quality. Sites between the TSF and the junction of the Barney Creek and McArthur River diversion channels have elevated levels of SO_4, potentially due to seepage from the TSF and SPROD. Sites BC4, SC24, BD5, BD5D and MR16 had elevated concentrations of Zn and Pb, which may relate to dust emissions and/or contaminated runoff from the ROM pad and/or Barney Creek haul road bridge (Barden, 2016, KCB, 2016a).

As noted by Barden (2015 and 2016), poor surface water quality may have negatively impacted macroinvertebrate edge assemblages at site MR16 in the old McArthur River channel, downstream from the Barney Creek haul road bridge but upstream from the confluence with the McArthur River diversion channel. Other influences at this location are likely to include changes to stream flow and channel structure since construction of the McArthur River diversion channel, and sediment deposition. This indicates that metal contaminants are likely travelling downstream from points of contamination where they may enter the trophic cycle, potentially impacting larger fauna (e.g., *Macrobrachium* and fish).

Dust emissions and/or associated contaminated runoff from the vicinity of the ROM pad may contribute to reduced diversity of macroinvertebrate communities at site BC4. Metal concentrations are elevated at BD5 and BD5D, potentially due to dust emissions and/or runoff near the Barney Creek haul road bridge. SC24 may be impacted by dust emissions from the ROM pad, as well as contaminants migrating down Barney and Surprise creeks. The SPROD and TSF have been identified as major sources of seepage (see Section 4.5), which may have increased salt-related parameters at sites SC24, BD5, BD5D and MR16. Controls at these sites have reduced salt-related parameters at these sites. Controls at the Barney Creek haul road bridge appear to be reducing contamination at BD5 and BD5D. However, as it appears the ROM pad is the likely source of contamination at sites BC4 and SC24, further work is required to minimise potential dust emissions and/or contaminated runoff from the vicinity of this site.

As few minor drainage line reference sites were visited in 2016, inferences drawn regarding macroinvertebrate communities in Surprise and Barney creeks and the Barney Creek diversion channel should be interpreted with caution. However, the results of the macroinvertebrate surveys from Barney and Surprise creeks and the Barney Creek diversion channel are consistent with those recorded in previous years when communities below the TSF and ROM pad were likely impaired due to MRM's operations. This indicates that, during the 2016 survey, macroinvertebrate communities at exposed sites on these watercourses are likely similarly affected by operations.

Metals in Freshwater Biota

This report section refers to exposed sites, i.e., sites that may be exposed to contaminants in the immediate vicinity of McArthur River Mine (sites adjacent to or downstream of the TSF and ROM pad [Rock hole, SW02, SW03, SW06, SW18 and SW19] and SW16 on the McArthur River diversion channel). Other sites are further from mining activities and will be referred to as reference sites.

Lead in Freshwater Biota

Concentrations of Pb were elevated in biota from six exposed sites (Table 4.45). The ten highest concentrations of Pb were all from exposed sites. If freshwater mussels from references sites are excluded, as they naturally accumulate higher concentrations of metals than other biota, the highest 23 Pb concentrations were from exposed sites.

The maximum permitted concentration (MPC) for Pb was exceeded at SW19 (adjacent to Barney Creek haul road bridge) in two of three muscle tissue samples for bony bream, and three out of five trunk samples from chequered rainbowfish. The MPC for Pb was not exceeded in liver and muscle samples from sooty grunters and barramundi or muscle samples from spangled grunter. Lead isotope ratios in biota were elevated at SW19, indicating that mine-derived Pb is the likely cause of contamination at this location. Concentrations of Pb in organisms at SW19 have generally dropped yearly since 2012 (Table 4.46). However, concentrations of Pb in chequered rainbowfish trunks did not decline between 2015 and 2016. The overall decline in Pb concentrations at SW19 is likely due to controls implemented by MRM, including:

- Sediment traps installed at the Barney Creek haul road bridge to capture contaminated runoff and sediments that are washed off the haul road during rain events and by water trucks spraying roads to suppress dust.
- Excavating sediments from the creek bed at SW19 at the end of the dry season to remove contaminants that may be deposited at the site. The pool at SW19 effectively operates as a natural sediment trap where contaminated sediments may settle out of the water column, as the creek gets slightly wider and deeper at this point, and flow rates slow.
- Installing a bund at SW19 and pumping water captured in the bund to the WMS.
- Efforts by MRM to reduce seepage from the TSF and the SPROD.

Table 4.45 – Sites and Biota with Elevated Concentrations of Metals in 2016 with Data from 2013-2015 (mg/kg)

Metal and MPC#	Site	Organism	2016				2015			2014			2013		
			All Values from Site	Mean	Med.	Species Mean*	Mean	Med.	Max.	Mean	Med.	Max.	Mean	Med.	Max.
Pb Fish – 0.5, Molluscs – 2.0	SW19	*H. fuliginosus*	0.011, 0.009, 0.008, 0.003	0.008	0.009	0.004** (0.002)	0.004	0.005	0.005	NA	NA	NA	NA	NA	NA
		H. fuliginosus (liver)	0.2, 0.19	0.2	0.2	0.041 (0.01)	0.78	0.79	1.2	NA	NA	NA	NA	NA	NA
		L. calcarifer (liver)	0.15, 0.045	0.098	0.098	0.022** (0.004)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		M. splendida	**1.0, 0.54, 0.5,** 0.48, 0.37	0.58	0.5	0.16 (0.07)	0.39	0.36	0.59	0.68	0.62	0.9	2.16	1.4	4.7
		N. erebi	**0.93, 0.57,** 0.31	0.60	0.57	0.09** (0.02)	2.0	1.8	2.4	3.84	2.7	8.9	NA	NA	NA
	SW18	*M. splendida*	0.23, 0.23, 0.2, 0.14	0.2	0.22	0.16 (0.07)	0.43	0.41	0.51	NA	NA	NA	NA	NA	NA
		N. erebi	0.41, 0.4, .013	0.31	0.4	0.09** (0.02)	0.25	0.27	0.36	NA	NA	NA	NA	NA	NA
	SW03	*H. fuliginosus*	0.021, 0.009, 0.006, 0.004, 0.004	0.009	0.006	0.004** (0.002)	0.002	0.002	0.002	NA	NA	NA	NA	NA	NA
		L. unicolor	0.028, 0.021, 0.021	0.023	0.021	0.007** (0.006)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Macrobrachium	0.28, 0.24, 0.14, 0.04	0.17	0.19	0.023** (0.004)	0.03	0.012	0.073	NA	NA	NA	NA	NA	NA
		M. splendida	**0.79, 0.67, 0.67, 0.63, 0.61**	0.67	0.67	0.16 (0.07)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		V. angasi	**9, 7.4, 7**	7.8	7.4	1.1 (0.23)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW16	*N. erebi*	0.39, 0.13, 0.039, 0.009, 0.005	0.11	0.039	0.09** (0.02)	0.017	0.017	0.024	0.016	0.016	0.018	0.18	0.051	0.63

Table 4.45 – Sites and Biota with Elevated Concentrations of Metals in 2016 with Data from 2013-2015 (mg/kg) (cont'd)

Metal and MPC#	Site	Organism	2016				2015			2014			2013		
			All Values from Site	Mean	Med.	Species Mean*	Mean	Med.	Max.	Mean	Med.	Max.	Mean	Med.	Max.
Pb Fish – 0.5, Molluscs – 2.0 (cont'd)	SW02	*H. fuliginosus*	0.021, 0.009, 0.006, 0.004, 0.004	0.009	0.006	0.004** (0.002)	0.002	0.002	0.002	NA	NA	NA	NA	NA	NA
		L. unicolor	0.014, 0.007	0.011	0.011	0.007** (0.006)	NA	NA	NA	0.009	0.008	0.013	0.052	0.054	0.099
		V. angasi	**2.7**			1.1 (0.23)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Surprise Ck RH†	*M. splendida*	0.2, 0.18, 0.17, 0.11, 0.1	0.15	0.17	0.16 (0.07)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW04	*L. unicolor*	0.018			0.007** (0.006)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		M. splendida	0.23, 0.2, 0.18	0.2	0.2	0.16 (0.07)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW07	*L. unicolor*	0.037, 0.02, 0.012, 0.011, 0.003	0.017	0.012	0.007** (0.006)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW22	*L. unicolor*	0.018			0.007** (0.006)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		M. splendida	0.19, 0.18, 0.15	0.17	0.18	0.16 (0.07)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	DS SW28	*L. unicolor*	0.024, 0.003, <0.002	0.010	0.003	0.007** (0.006)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	TSF Fence	*L. unicolor*	0.015, 0.004	0.01	0.01	0.007** (0.006)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zn (no MPCs apply)	SW19	*L. calcarifer*	3.3, 3	3.15	3.15	2.82 (2.75)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		M. splendida	25, 24, 23, 22, 17	22.2	23	19.6 (19.1)	23.5	23.5	24	24.6	25	29	29.6	29	35
		N. erebi	6.3, 6.6, 5	6.0	6.3	4.47 (4.04)	8.0	7.5	9.1	14.6	13	23	NA	NA	NA
	SW18	*M. splendida*	29, 20, 19, 18	21.5	19.5	19.6 (19.1)	24.2	24	28	NA	NA	NA	NA	NA	NA
		N. erebi	7.2, 6.5, 5.1	6.3	6.5	4.47 (4.04)	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4.45 – Sites and Biota with Elevated Concentrations of Metals in 2016 with Data from 2013-2015 (mg/kg) (cont'd)

Metal and MPC#	Site	Organism	2016				2015			2014			2013		
			All Values from Site	Mean	Med.	Species Mean*	Mean	Med.	Max.	Mean	Med.	Max.	Mean	Med.	Max.
Zn (no MPCs apply) (cont'd)	SW03	*Macrobrachium*	17, 16, 16, 14	15.8	16	14.24 (14.25)	12.4	13	13	NA	NA	NA	NA	NA	NA
		N. erebi	7, 6.9, 5.6, 5.1, 4.8	5.9	5.6	4.47 (4.04)	7.6	8.6	8.6	NA	NA	NA	NA	NA	NA
		V. angasi	110, 94, 72	92	94	36.3 (28.4)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW02	*V. angasi*	50			36.3 (28.4)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW16	*H. fuliginosus (liver)*	31, 21, 18	23.3	21	18.9 (18.1)	21.5	21.5	25	NA	NA	NA	NA	NA	NA
	Rockhole	*M. splendida*	25, 25, 24, 19, 19	22.4	24	19.6 (19.1)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW04	*N. erebi*	6, 5.4, 5.3	5.6	5.4	4.47 (4.04)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW22	*N. erebi*	6.9, 6.8, 6.6	6.76	6.8	4.47 (4.04)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	TSF Fence	*N. erebi*	5.7			4.47 (4.04)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ag	SW19	*N. erebi*	0.005, 0.004, 0.003	0.004	0.004	0.001** (0.001)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW03	*M. splendida*	0.006, 0.004, 0.004, 0.002, 0.002	0.004	0.004	0.001** (0.001)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Al (no MPCs apply)	SW03	*Macrobrachium*	16, 3.7, 1.3, 0.7	5.4	2.5	1.3** (0.8)	1.94	0.8	4.3	NA	NA	NA	NA	NA	NA

Table 4.45 – Sites and Biota with Elevated Concentrations of Metals in 2016 with Data from 2013-2015 (mg/kg) (cont'd)

Metal and MPC#	Site	Organism	2016				2015			2014			2013		
			All Values from Site	Mean	Med.	Species Mean*	Mean	Med.	Max.	Mean	Med.	Max.	Mean	Med.	Max.
As (MPC cannot be applied##)	SW19	*L. calcarifer*	0.023, 0.023	0.023	0.023	0.016 (0.013)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		L. calcarifer (liver)	0.24, 0.15	0.195	0.195	0.18 (0.18)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW16	*L. calcarifer*	0.021, 0.018, 0.016, 0.014, 0.013	0.016	0.016	0.016 (0.013)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		L. calcarifer (liver)	0.26, 0.22, 0.14, 0.14, 0.12	0.176	0.14	0.18 (0.18)	0.11	0.063	0.24	NA	NA	NA	NA	NA	NA
	SW04	*L. unicolor*	0.045			0.015** (0.016)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW22	*L. unicolor*	0.042			0.015** (0.016)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		M. splendida	0.11, 0.11, 0.1	0.0107	0.11	0.029 (0.027)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		N. erebi	0.28, 0.28, 0.28	0.28	0.28	0.1 (0.11)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cd	SW19	*M. splendida*	0.006, 0.006, 0.005, 0.004, 0.004	0.005	0.005	0.003** (0.002)	0.006	0.007	0.007	0.001	0.001	0.001	0.011	0.005	0.034
	SW18	*N. erebi*	0.008, 0.007, 0.004	0.006	0.007	0.002** (0.002)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW03	*L. unicolor*	0.009, 0.004, 0.003	0.005	0.004	0.002** (0.002)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		M. splendida	0.013, 0.011, 0.01, 0.008, 0.008	0.01	0.01	0.003** (0.002)	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4.45 – Sites and Biota with Elevated Concentrations of Metals in 2016 with Data from 2013-2015 (mg/kg) (cont'd)

Metal and MPC#	Site	Organism	2016				2015			2014			2013		
			All Values from Site	Mean	Med.	Species Mean*	Mean	Med.	Max.	Mean	Med.	Max.	Mean	Med.	Max.
Cd (cont'd)	SW03 (cont'd)	*N. erebi*	0.007, 0.004, 0.003, 0.002, 0.002	0.004	0.003	0.002** (0.002)	0.003	0.003	0.005	NA	NA	NA	NA	NA	NA
	SW04	*L. unicolor*	0.005			0.002** (0.002)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		M. splendida	0.004, 0.004, 0.004	0.004	0.004	0.003** (0.002)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW22	*L. unicolor*	0.006			0.002** (0.002)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		M. splendida	0.007, 0.006, 0.005	0.006	0.006	0.003** (0.002)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	TSF Fence	*M. splendida*	0.005, 0.005, 0.004, 0.004	0.005	0.005	0.003** (0.002)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	US of SW08	*H. fuliginosus (liver)*	0.35, 0.12, 0.043	0.171	0.12	0.079 (0.095)	0.12	0.12	0.17	NA	NA	NA	NA	NA	NA
Cu (no MPCs apply)	SW03	*M. splendida*	1.3, 0.98, 0.95, 0.83, 0.81	0.97	0.95	0.50 (0.51)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW16	*H. fuliginosus (liver)*	8, 3.8, 2.8	4.87	3.8	3.26 (3.02)	3.2	3.15	4.4	NA	NA	NA	NA	NA	NA
	SW04	*L. unicolor*	0.44			0.26 (0.29)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW21	*H. fuliginosus*	0.38, 0.2, 0.17, 0.17, 0.15	0.21	0.17	0.15 (0.16)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		V. angasi	3, 2.4, 2, 2, 2	2.28	2	1.51 (1.61)	1.28	1.28	1.8	NA	NA	NA	NA	NA	NA
	SW22	*N. erebi*	0.81, 0.7, 0.64	0.717	0.7	0.308 (0.29)	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4.45 – Sites and Biota with Elevated Concentrations of Metals in 2016 with Data from 2013-2015 (mg/kg) (cont'd)

Metal and MPC#	Site	Organism	2016				2015			2014			2013		
			All Values from Site	Mean	Med.	Species Mean*	Mean	Med.	Max.	Mean	Med.	Max.	Mean	Med.	Max.
Fe	SW03	*Macrobrachium*	22, 6.9, 2.1, 1.4	8.1	4.5	2.26 (1.67)	2.12	1.8	4.3	NA	NA	NA	NA	NA	NA
		N. erebi	9.6, 7.1, 6, 5.8, 5.5	6.7	6	3.7 (3.3)	5.4	5.5	7.1	NA	NA	NA	NA	NA	NA
	SW04	*L. unicolor*	6.8			3.6 (4.06)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		M. splendida	44, 22, 12	26	22	7.4 (8.5)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW22	*M. splendida*	21, 20, 18	19.7	20	7.4 (8.5)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		N. erebi	7.9, 7, 5.5	6.8	7	3.7 (3.3)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	8 Mile	*L. calcarifer (liver)*	1100, 720	910	910	495 (610)	719	700	880	NA	NA	NA	NA	NA	NA
	Kilgour	*V. angasi*	1300, 660	980	980	495 (543)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Top Crossing	*Macrobrachium*	7.4, 6.7	7.05	7.05	2.26 (1.67)	1.74	1.1	3.2	NA	NA	NA	10.4	15	15
Mo	SW04	*M. splendida*	0.014, 0.012, 0.012	0.013	0.012	0.006** (0.006)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mn	SW18	*M. splendida*	43, 35, 32, 30	35	33.5	13 (12)	29.8	29	36	NA	NA	NA	NA	NA	NA
		N. erebi	5.8, 2.4, 2	3.4	2.4	2.0 (1.9)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW03	*Macrobrachium*	4.8, 1.8, 1, 0.64	2.06	1.4	1.3 (1.0)	0.55	0.06	0.06	NA	NA	NA	NA	NA	NA
		N. erebi	5, 4.8, 4.1, 1.2, 0.64	3.1	4.1	2.0 (1.9)	1.5	1.3	2.1	NA	NA	NA	NA	NA	NA
		V. angasi	1600, 1300, 930	1276	1300	532 (446)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW02	*Macrobrachium*	3.1, 2.6, 1.5, 0.53	1.93	2.05	1.3 (1.0)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW04	*N. erebi*	7.1, 6.6, 3.3	5.7	6.6	2.0 (1.9)	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4.45 – Sites and Biota with Elevated Concentrations of Metals in 2016 with Data from 2013-2015 (mg/kg) (cont'd)

Metal and MPC#	Site	Organism	2016				2015			2014			2013		
			All Values from Site	Mean	Med.	Species Mean*	Mean	Med.	Max.	Mean	Med.	Max.	Mean	Med.	Max.
Mn (cont'd)	SW16	*L. calcarifer (liver)*	0.99, 0.88, 0.8, 0.66, 0.59	0.78	0.8	0.68 (0.65)	0.6	0.6	0.8	NA	NA	NA	NA	NA	NA
	SW22	*N. erebi*	5.4, 4.5, 3.8	4.6	4.5	2.0 (1.9)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	8 Mile	*H. fuliginosus (liver)*	9.4, 4.9, 1.1	5.1	4.9	2.8 (4.9)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	US of SW08	*H. fuliginosus (liver)*	22, 9.9, 5.9	12.6	9.9	2.8 (4.9)	10.85	7.4	26	NA	NA	NA	NA	NA	NA
		L. calcarifer (liver)	0.76, 0.57	0.67	0.67	0.68 (0.65)	0.8	0.8	0.8	NA	NA	NA	NA	NA	NA
Ni	SW18	*M. splendida*	0.07, 0.07, 0.07, 0.07	0.07	0.07	0.028** (0.028)	0.06	0.06	0.08	NA	NA	NA	NA	NA	NA
		N. erebi	0.08, 0.06, 0.04	0.06	0.06	0.026** (0.025)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW04	*M. splendida*	0.07, 0.06, 0005	0.06	0.06	0.028** (0.028)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW21	*M. splendida*	0.13, 0.02, <0.02, <0.02, <0.02	0.042	<0.02	0.028** (0.028)	0.025	0.025	0.03	0.03	<0.03	0.03	NA	NA	NA
	SW28	*L. unicolor*	0.26, <0.02, <0.02	0.1	<0.02	0.025** (0.028)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ti	SW19	*M. splendida*	0.055, 0.046, 0.042, 0.039, 0.036	0.044	0.042	0.015 (0.008)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		N. erebi	0.023, 0.021, 0.019	0.021	0.021	0.006** (0.003)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	SW18	*N. erebi*	0.033, 0.025, 0.017	0.025	0.025	0.006** (0.003)	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4.45 – Sites and Biota with Elevated Concentrations of Metals in 2016 with Data from 2013-2015 (mg/kg) (cont'd)

Metal and MPC#	Site	Organism	2016				2015			2014			2013		
			All Values from Site	Mean	Med.	Species Mean*	Mean	Med.	Max.	Mean	Med.	Max.	Mean	Med.	Max.
Ti (cont'd)	SW16	*L. unicolor*	0.019, 0.012, 0.006, 0.004, 0.004	0.009	0.006	0.004** (0.002)	NA	NA	NA	NA	NA	NA	NA	NA	NA
		M. splendida	0.072, 0.049, 0.043, 0.032	0.049	0.046	0.015 (0.008)	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: Concentrations are taken from muscle tissue unless stated, except in the case of *M. splendida* where concentrations are taken from the whole trunk of the animal. **Bold** values indicate concentrations exceed the MPC. Shaded cells are in the immediate vicinity of McArthur River Mine, and as a result may be exposed to higher levels of contamination.
MPC = Maximum permitted concentration value for fish, crustaceans and molluscs. FSANZ (2015) does not include MPCs for Cu or Zn.
* Mean value concentration for this species for the entire 2016 survey. Values in parentheses represent the mean concentration from all reference sites, that is, sites away from the influence of the mine.
† RH = rock hole; US = upstream; DS = downstream.
MPC for As is for inorganic As only; results for As are for Total As, as such MPC cannot be applied.
** Concentrations were below detection limits in some instances. To determine the mean, these individuals were conservatively given the value of the detection limit, even though concentrations may well have been lower.
NA – data not available for that year, as either the site was not surveyed or the species was not collected from that site.

Table 4.46 – Exceedances of Pb MPCs in Freshwater Fauna at SW19 (2012 to 2016)

Organism	Year	Number Exceeding MPC*	Concentration (mg/kg)		
			Exceedance Values	Mean	Median
M. splendida (trunk)	2012	2 of 4 caught	1.3, 0.6	0.6	0.8
	2013	5 of 5 caught	4.7, 2.1, 1.4, 1.4, 1.2	2.2	1.4
	2014	4 of 5 caught	0.9, 0.9, 0.6, 0.6	0.7	0.6
	2015	1 of 5 caught	0.6	0.4	0.4
	2016	3 of 5 caught	1.0, 0.54, 0.5	0.58	0.5
L. unicolor (muscle and trunk)	2013	4 of 5 caught	1.8, 1.5, 0.6, 0.5	1.0	0.6
L. unicolor (liver)	2014	1 of 1 caught	0.5	0.5	0.5
N. erebi (muscle)	2014	5 of 5 caught	8.9, 2.8, 2.7, 2.6, 2.2	3.8	2.7
	2015	5 of 5 caught	2.4, 2.3, 1.8, 1.7, 1.7	2.0	1.8
	2016	2 of 3 caught	0.93, 0.57	0.60	0.57
Macrobrachium spp.	2012	1 of 1 caught	2.9	2.9	2.9
H. fuliginosus (liver)	2015	3 of 4 caught	1.2, 0.9, 0.7, 0.4	0.8	0.8

For the first time, biota exceeded MPCs for Pb at SW02 and SW03. All five chequered rainbowfish and three freshwater mussels caught at SW03 exceeded MPCs for Pb, as did the single freshwater mussel from SW02. This was the first time rainbowfish have been caught at SW03 and the only time mussels have been caught in Surprise and Barney creeks as part of the monitoring program. Other biota also had elevated concentrations of Pb at these sites (Table 4.45).

Lead isotope ratios at SW02 and SW03 were also very close to that of the ore body, indicating that mine-derived Pb is the likely source of contamination at these sites. It is likely that dust, seepage and/or runoff from the ROM pad and/or the TSF are contaminating these locations.

Although concentrations of Pb were elevated in chequered rainbowfish and bony bream caught at SW18 in 2016, the MPC for Pb was not exceeded at this site (compared to 2015 when a single chequered rainbowfish exceeded the MPC for Pb). Sites SW18 and SW19 are in close proximity, and Indo-Pacific Environmental (2015) considered it possible that contaminated fish including *M. splendida* may be actively moving upstream from SW19. However, as concentrations of Pb and Zn are elevated in surface waters (KCB, 2016a) and fluvial sediments (KCB, 2016b) at SW18, contaminant loads may have accumulated at this site alone. Lead isotope ratios were elevated at SW18, indicating that mine-derived Pb is the source of the elevated concentrations of Pb.

Lead concentrations were also elevated in some biota from SW04, SW07, SW22, Surprise Creek rock hole, downstream of SW28 and the TSF fence (Table 4.45). For the majority of individuals from these sites there was no evidence of elevated PbIRs. However, individuals with the highest Pb concentrations at SW07 and Surprise Creek rock hole had elevated PbIRs. This may indicate that for most individuals from these sites, Pb concentrations are due to natural enrichment, however a few individuals may have been enriched with mine-derived Pb at either the site where they were captured or other exposed site(s).

Indo-Pacific Environmental (2015) raised the possibility that natural mineralisation of Barney and Surprise creeks and the surrounding catchment may cause contamination of biota in this watercourse. There are exposed areas of galena, a natural mineral form of lead sulfide, in Surprise and Barney creeks. There are unconfirmed anecdotes of prospectors collecting Pb nuggets from Surprise Creek to make bullets back in the 1950s. Additional survey sites in Barney Creek above the diversion channel in the 2016 monitoring program tested this hypothesis. Monitoring in 2016 suggests that elevated Pb concentrations are widespread in this catchment. Concentrations of Pb in sites adjacent to and downstream of the ROM pad are likely enriched via dust, runoff and/or seepage from MRM's operations. However, elevated concentrations of Pb in biota in sites upstream of the ROM pad (SW4, SW22, downstream of SW28 and the TSF fence) may not be due to MRM's activities, as PbIRs do not indicate mine-derived Pb to be the source of contamination at these sites. Therefore, elevated Pb at exposed sites may partially be enriched by naturally elevated Pb in Barney Creek. However, dust emissions may enrich these sites.

Indo-Pacific Environmental (2015) raised the possibility that rainbowfish were being enriched with mine-derived Pb at SW19 and then moving to SW18. However, with further sampling at SW18 and throughout Surprise and Barney Creeks, and the large number of enriched individuals at exposed sites around the mine, it is more likely that individuals are being enriched with mine-derived Pb in situ. However, there is evidence to suggest that some individuals are being enriched with Pb at exposed sites and then moving to unimpacted sites. As discussed in the previous IM report (ERIAS Group, 2016), the IM supports including measures in the monitoring program to account for the high mobility of species and a desktop study of the movement of contaminated biota and exposure times for the uptake of metals.

While metals in biota exceeded MPCs for human consumption on occasion, there was no evidence of elevated concentrations causing any potential health effects in the biota.

Although there is evidence of contamination in the vicinity of the mine site, the majority of biota collected had concentrations of Pb and other metals well below their respective MPCs. Fish with the highest concentrations of Pb in their muscle tissues were either very small (chequered rainbowfish, generally less than 5 g) or generally small and very unpalatable (bony bream). Freshwater mussels are rarely recorded at exposed sites, and when present they are at very low abundances. In Surprise and Barney creeks, palatable fish are only present in low abundance. Therefore the potential risks to human health are negligible.

Zinc in Biota

Concentrations of Zn showed similar patterns to Pb, with concentrations elevated in biota from exposed sites (Table 4.45). This indicates that MRM's activities may be contaminating biota with Zn at sites on Barney and Surprise creeks adjacent to and downstream of the TSF, SPROD and ROM pad. In addition, bony bream caught in Barney Creek at sites upstream of SW3 had elevated concentrations of Zn. The source of this contamination could either be elevated background concentrations in this creek, dust emissions from the mine and/or migration of individuals from contaminated sites downstream. A single sooty grunter liver from SW16 had elevated concentrations of Zn and may have migrated to this site from an exposed site.

Other Metals in Freshwater Biota

Concentrations of other metals showed similar patterns, with concentrations of metals often slightly elevated in Barney Creek, and Surprise Creek below the TSF. Where metals were elevated in the McArthur River, they were away from the influence of the mine and not due to MRM's operations.

Metals in Freshwater Biota Conclusions

Exposed sites on Surprise and Barney creeks have the highest concentrations of Pb and Zn, and other metals are elevated in these sites. Metal concentrations, including Pb and Zn, in biota are also elevated in sites upstream of the mine on Barney Creek; however, it is unclear whether these elevated concentrations are due to dust emissions from MRM's activities, naturally elevated concentrations, movement of contaminated biota or a combination of these factors.

The potential for human health impacts from the elevated concentrations of metal in biota from Barney and Surprise creeks are negligible due to:

- The large amounts of flesh that would need to be consumed to exceed guidelines.
- The unpalatability of the most abundant species.
- The low population size of palatable species in exposed waterways.
- Difficulty accessing waterways in the immediate vicinity of the mine site.

There is no evidence of contamination of biota in the McArthur River near the mine site. Overall, evidence suggests that contamination of biota as a result of MRM's operations is limited to the mine site and specifically Surprise Creek below the TSF and Barney Creek adjacent to and downstream of the ROM pad.

Monitoring Metals in Freshwater Vegetation

Mean concentrations of Cu were elevated at SW02 and SW19 (8.4 and 6.2 mg/kg, respectively) compared to sites away from the mine (mean of 4.5 mg/kg). Mean concentrations of As were elevated at SW23, SW02, SW19 and SW16 (9.8, 14.0, 7.2 and 6.5 mg/kg) compared to sites away from the mine (4.0 mg/kg). Mean concentrations of Cd were elevated at SW02 and SW19 (0.28 and 1.0 mg/kg) compared to sites away from the mine (0.05 mg/kg). Mean Cd in macrophytes was also elevated at SW11 (0.12 mg/kg) compared to sites upstream of the confluence with Barney Creek, indicating that Cd may be being washed down Barney Creek diversion channel to the McArthur River and enriching macrophytes at this site. The Glyde River could also be a source of elevated Cd at SW11. Finally, mean concentrations of Pb are elevated at SW23, SW02 and SW19 (8.6, 51.7 and 69 mg/kg) compared to sites outside the mine site (3.7 mg/kg). Lead isotope ratios at SW02 and SW19 were very close to that of the ore body and somewhat elevated at SW23 and SW16.

Concentrations of Cd and, to a lesser extent, Pb in macrophytes were closely correlated with concentrations in sediment, and somewhat correlated with surface water concentrations. The stronger correlation with concentrations in sediments is likely as result of plants absorbing the majority of their nutrients through their roots (Indo-Pacific Environmental 2016c).

The IM agrees with the conclusion made by Indo-Pacific Environmental (2016c) that, similarly to freshwater fauna, MRM's operations are enriching concentrations of metals in macrophytes at sites in Surprise and Barney creeks downstream of and adjacent to the TSF and ROM pad.

Fish Consumption Survey

Most people (81.4% of respondents) fished at least once a month, and 43.2% fished one or more times a week. Most people fished throughout the year. The most frequently visited fishing sites were on McArthur River (43.5%). Creek sites accounted for 23.9% and ocean sites 15.2% of visits. Fish was the primary source of protein for 10.1% of respondents and a main source for another 35.4%. The four most commonly caught fish were sooty grunter, barramundi, catfish (*Neoarius* spp.) and sevenspot archerfish (*Toxotoes chatareus*).

While the current metals in biota monitoring program covers most of the species commonly consumed and sites commonly fished, the monitoring program will be adapted slightly to reflect the results of this program. Specifically, in future the monitoring program will:

- Include sevenspot archerfish.
- Collect samples in the early and late dry season.
- Collect samples from Limmen Bight and Robinson River biannually to act as control sites.
- Add key fishing sites on the McArthur River, including Ryans Bend.
- Investigate the potential of obtaining freshwater turtle tissue samples from members of the community, as turtles were consumed by nearly 5% of respondents.
- Investigate the potential to use a biopsy punch to non-lethally sample muscle tissue.

Monitoring of Large Woody Debris

McArthur River Mining has not measured the persistence of LWD in the McArthur River diversion since 2013. The monitoring of LWD is a relatively short and simple process and should be included in the annual monitoring program.

Diversion Channel Revegetation

Healthy riparian vegetation is essential for 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, 2016, 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 fully rehabilitate the diversion channels. 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.

Erosion Upstream of the McArthur River Diversion Channel

There is considerable bed erosion immediately upstream of the McArthur River diversion channel (Site SW07), and there is considerable risk of ongoing erosion at this site (Hydrobiology, 2016b). However, in contrast to 2015, there was no impairment of edge macroinvertebrates at this site. This was potentially due to the below average 2015 to 2016 wet season limiting the amount of erosion at this site. Mitigation measures should be implemented to reduce erosion above the diversion (see Section 4.4 and Hydrobiology 2016b).

Baseflow Measurement Structures

In the Operational Performance Review Report, MRM (2016) discusses establishing permanent concrete weir-like structures to measure flow rates in the 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 the 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 4.47. It should be noted that the 2016 monitoring of metals in freshwater biota, the macroinvertebrate surveys and early dry season fish surveys took place before the release of the 2016 IM report which addressed the 2015 operational period. As a result, many of the IM's recommendations could not be incorporated into the monitoring undertaken in the current reporting period and may have already been addressed in the 2017 operational period.

Table 4.47 – Freshwater Ecology Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2015 Operational Period		
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	Not addressed in the 2016 operational period
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	Not addressed in the 2016 operational period. However, there are plans to review and redesign the spray system on the ore crushing plant to reduce dust emissions in Q2 2017

Table 4.47 – Freshwater Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2015 Operational Period (cont'd)		
Contamination at end of dry season	The current elevated concentrations of metals in biota are measured in the early dry season, when sites would have recently been flushed with freshwater and sediments and biota may have recently arrived from uncontaminated sites. By the end of the dry season, biota would have persisted for roughly six or more months in increasingly contaminated areas and, as a result, the contamination of biota would likely have increased. Monitoring of metals in conjunction with the late dry season survey would provide useful information on the potential elevated concentrations at the end of the dry season, just before fish may disperse away from the mine site in wet season floodwaters. It would also provide a better indication of the maximum contaminant loads taken up by biota	Completed. Late dry season monitoring of metals in freshwater fauna has been added to the monitoring program, however the results fell outside the 2016 operational period and therefore were not provided to the IM
Erosion in McArthur River	There is evidence of erosion moving upstream from the southern end of the McArthur River diversion channel, potentially as a result of increased flow velocities at the start of the diversion. In the 2015 surveys, macroinvertebrate edge communities were impaired at MR7, likely due to reduced habitat quality as a result of this erosion. McArthur River Mining should investigate the causes of this erosion and potential mitigation measures if required. This should be covered in the upcoming geomorphological assessment of the McArthur River and Barney Creek diversion channels	Completed. Geomorphological assessment conducted by Hydrobiology (2016b), and is discussed in more detail in Section 4.4 (this recommendation is superseded by those in Section 4.4)
Contamination at SW16	McArthur River Mining should investigate the sources of contamination entering the McArthur River diversion channel just upstream of SW16. McArthur River Mining should determine the relative contribution of groundwater flows through natural mineralisation and seepage from mining infrastructure, particularly the ELS	This recommendation is superseded by those in Sections 4.3 and 4.6
Visit reference sites annually	Hydrobiology (2016b) raised the issue of including more regional reference material in the annual assessment of metals in biota. Analysis of collections made in 2010-2011 from the Limmen Bight and Wearyan rivers indicate naturally elevated Pb, but the amount of Pb taken up will depend on the strength and duration of the wet season. To account for this variation, reference material should be collected annually	Completed. In future operational periods, regional reference sites will be visited annually
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	Not addressed in the 2016 operational period (note, this recommendation was in response to a fish kill observed in the SEL in February 2015)

Table 4.47 – Freshwater Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period		
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	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)
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	As additional sites along Barney and Surprise creeks were added to the 2015 and 2016 monitoring programs, this recommendation has largely been addressed. An additional site should be added to the program between SW19 and SW06 The adaptive monitoring program should be maintained to maximise the likelihood of being able to collect freshwater biota in these creek lines in dry years, and monitoring programs should start as early as possible following the wet season to maximise the number of sites visited
Dam at SW19	The dam constructed to extract water and trap sediment at SW19 is likely having an impact on the freshwater ecosystem downstream of SW19 on Barney Creek diversion channel. It may also be having an impact on the main McArthur River, due to reduced inflows. If the dam remains in place, then the effects on sites downstream should be formally investigated, and potential mitigation strategies, such as pumping water from the water management dam to below the dam at SW19, could be considered	The dam remains in place and MRM has not investigated the impacts on sites downstream of SW19. However, MRM contends that Surprise and Barney creeks continue to flow into the dry season largely due to seepage from the TSF and SPROD. As a result the potentially contaminated water needs to be captured. In addition, sites below SW19 would not naturally receive surface flows far into the dry season. The IM considers that this recommendation is no longer valid and will be removed from future reports
Monitoring of freshwater fauna in Barney Creek	Additional monitoring of freshwater fauna in natural sites along Barney Creek or equivalent reference sites and multiple sites in the Barney Creek diversion channel should be included, so the performance of the diversion can be properly assessed	Completed

Table 4.47 – Freshwater Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
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 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	No monitoring of LWD took place during the current monitoring program, MRM should monitor the locations of LWD in the diversion annually. MRM should identify which pieces remain in place and how they are anchored to inform and improve future LWD additions
2012 and 2013 Operational Periods		
Contamination of biota	The IM recommends additional freshwater fauna abundance, diversity and metal concentration monitoring along Barney, Little Barney and Surprise creeks to identify potential sources of contamination. This should include sites SW4, SW22, SW3, SW18, SW6 and SW28 until sources of contamination are determined. This monitoring can also be used to assess the effectiveness of the diversion channel rehabilitation	Completed
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	Not addressed. A more relevant background ratio could be established by taking the average ratio from sites along McArthur River upstream of the mine, tributaries downstream of the mine site and regional reference sites

4.10.4.3 Successes

The monitoring of the freshwater ecosystem around McArthur River Mine continues to improve yearly. The most positive developments in the current reporting period include:

- An improved monitoring of metals in freshwater fauna program to include more sites from Barney Creek and additional analytes.
- Declining levels of contamination in biota from SW19 likely due to controls implemented by MRM. For example, the mean concentration of Pb recorded in bony bream has declined more than six fold since 2014.
- Monitoring of metals in freshwater macrophytes for the first time, the results of which largely mimic the results of the metals in fauna program.

- Conducting a community survey of fish consumption patterns. The survey showed that the current monitoring program adequately targets commonly consumed fish and popular fishing spots. However, it also identified new fish and locations to include in the monitoring program.
- Establishing an acoustic tagging program to gather comprehensive data on fish movement in the McArthur River and diversion channel, particularly migratory freshwater sawfish and barramundi.
- Installing large amounts of LWD at the downstream end of the McArthur River diversion channel.

4.10.5 Conclusion

Monitoring of freshwater biota at McArthur River Mine continues to improve. Surveys of local fishing habitats and fish consumption indicate that, for the most part, monitoring of metals in freshwater fauna is well targeted. The McArthur River diversion channel is performing better as more habitat is provided. Contamination at SW19 is declining. However, monitoring of exposed sites on Barney Creek and the Barney Creek diversion channel adjacent to and downstream of the ROM pad indicates that mine-derived Pb contamination is more widespread in this system than previously recognised.

Ongoing and new IM recommendations related to freshwater ecology issues are provided in Table 4.48.

Table 4.48 – New and Ongoing Freshwater Ecology Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
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
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
Identify potential sources of contamination in Barney Creek diversion channel	McArthur River Mining should conduct a full review and synthesis of the monitoring programs at McArthur River Mine, including metals in freshwater fauna, macroinvertebrates, surface water, groundwater, fluvial sediments, dust and soil to identify additional sources of contamination at the mine site. Using a conceptual site model could be a useful approach to integrate monitoring programs (NTEPA, 2013). The crushing plant has been identified as a potential source of dust emissions, but other sources may include dust emissions from the haul road and ore 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	Medium

Table 4.48 – New and Ongoing Freshwater Ecology Recommendations (cont'd)

Subject	Recommendation	Subject
Items Brought Forward (Including Revised Recommendations) (cont'd)		
LWD	The IM recommends continuing to add LWD in the McArthur River diversion channel, particularly along poorly revegetated sections, to improve continuity of habitat along the diversion channel. Annual monitoring of LWD is recommended to enable continuous improvement of the program McArthur River Mining should continue to add small woody debris and leaf litter to the diversion channels at the end of the wet season to provide habitat and detritus for small fish and invertebrates 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.	Medium
New background Pb isotope ratio	Monitoring would benefit from the establishment of a more regionally relevant background level for Pb isotopes. Establishing a regionally relevant background isotope ratio would be better for determining whether mine-derived Pb is entering freshwater fauna	Low
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, or whether it should be modified so it better fulfils its role either as flood protection or for capturing and containing contaminated water	Low
New Items		
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

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 annual marine monitoring program (AMMP), which covers the monitoring of water, sediment 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) (Thorburn, 2016a).
- The annual seagrass surveys, which assess the extent and species composition of seagrass meadows around Bing Bong Loading Facility, and whether seagrass meadows are expanding or contracting (Thorburn, 2016b).
- 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 4.3 and 4.12 of this report.

4.11.2 Key Risks

The key risks to marine ecosystems as outlined in the risk assessment (Appendix 2) 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 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, 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 site may lead to contaminated water and sediments washing down McArthur River, resulting in the accumulation of metals in sediments and marine 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

McArthur River Mining has monitoring and controls in place to minimise the risk to marine biota. These controls remain largely unchanged from last year and include:

- Covered conveyor belts at the Bing Bong Loading Facility to reduce dust emissions while loading the MV Aburri.
- A dust extraction system on the concentrate storage shed, although not all of the duct pipes or shed doors are currently operational (see Section 4.11.3.2).
- Vehicle wash-down facility at Bing Bong Loading Facility to reduce dust emissions from vehicles.
- Covers on concentrate transport vehicles to prevent dust blowing from concentrate loads.
- 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 (Thorburn, 2016a) and annual seagrass surveys (Thorburn, 2016b). 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 lead isotope ratios of seafloor sediments in the McArthur River Mine trans-shipment area (Thorburn, 2016c and 2017a).
- Annual assessment of metal contaminants in nearshore sediments to meet the requirements of the waste discharge licence (Thorburn, 2017b).
- Monthly monitoring of seawater contaminants by diffusive gradients in thin films (DGTs) (Tsang, 2016).

These monitoring programs are discussed further in sections 4.3 and 4.12.

Annual Marine Monitoring Program

The AMMP was established to ensure MRM is meeting its commitments to monitor the environment and operations are not contaminating 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, McArthur River estuary and SEPI.
- Quantify impacts to sediment and seawater quality as a result of MRM's operations.

- Determine whether there is any contamination of biota as a result of MRM's activities within the vicinity of Bing Bong Loading Facility.

The AMMP sampling was carried out in November 2015 by Indo-Pacific Environmental (Thorburn, 2016a).

Twenty one sites were sampled in the 2015 monitoring program (Figure 4.34), twenty of which were consistent with the 2014 program. A new site was added at East Creek, approximately 2.4 km east of Bing Bong Loading Facility, to further understand the movement of contaminants close to the facility. Sites at SEPI provide baseline data for the monitoring program. Marine sediments were sampled at an additional ten sites within the swing basin and shipping channel (Figure 4.34).

Annual Seagrass Monitoring

Seagrass is monitored annually to ensure that seagrass communities are not being impacted as a result of activities at Bing Bong Loading Facility, which could then affect 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 Bing Bong Loading Facility.
- Identify and categorise the relative cover and/or abundance of seagrass.
- 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 Bing Bong Loading Facility and implications for future management of the site.
- Provide recommendations for future monitoring events (Thorburn, 2016b).

Monitoring of seagrass includes control sites (Figure 4.35) so that the underlying causes of seagrass community dynamics can be better understood (i.e., natural variation or operations at Bing Bong Loading Facility). The control sites are between 7 and 14 km from the Bing Bong Loading Facility.

4.11.3.2 New Controls – Implemented and Planned

One new site, East Creek, was added to the AMMP in 2015. This site was added to provide better insight to the movement of contaminants in the immediate vicinity of Bing Bong Loading Facility and to complement the two sites (Bing Bong West 1 and 2) added immediately west of the Bing Bong Loading Facility in 2014.

McArthur River Mining has recently 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

SURVEY SITES FOR THE 2015 ANNUAL MARINE MONITORING PROGRAM

McArthur River Mine Project

FIGURE 4.34

Source: Google image 2005; Thorburn, 2016a.

SEAGRASS SURVEY AREAS IN 2016

McArthur River Mine Project

FIGURE 4.35

Source: Google, 2005; Thorburn, 2016b.

be noted that the IM was advised that the roller doors would be replaced soon during the 2015 and 2016 site visits.

Finally, 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.

4.11.4 Review of Environmental Performance

4.11.4.1 Incidents and Non-compliances

Incidents

During the 2016 operational period, there was a single reported incident at the Bing Bong Loading Facility with potential to impact marine biota. Several site-specific trigger values (SSTVs) for pH and filtered Al, Cu, Pb, Mn and Zn in seawater outlined in the waste discharge license were exceeded at the Bing Bong dredge discharge point (BBDDP) in January, March and April 2016 (Table 4.49). An investigation revealed that contaminants were also present in higher concentrations in water samples taken from the dredge spoil perimeter drain at the same time, potentially due to wet season rains causing seepage from the dredge spoil. While these exceedances are unlikely to have impacted marine biota, they occurred after the 2015 AMMP (Thorburn, 2016a), so the IM has not sighted evidence to empirically assess the impact. Other monitoring programs at the Bing Bong Loading Facility do not indicate any widespread impacts.

Table 4.49 – SSTVs Exceeded at BBDDP During the Current Reporting Period

Date	pH – field	Al (µg/L)	Cu (µg/L)	Pb (µg/L)	Mn (µg/L)	Zn (µg/L)
SSTV	8.0 to 8.4	0.50	1.30	4.40	80.0	15.0
12/01/2016	**7.79**	**39.1**	**2.45**	1.07	1.26	**19.6**
14/03/2016	**7.82**	**27.4**	**6.03**	<1	**298**	<10
12/04/2016	**7.84**	**17.1**	<1	**22.2**	6.54	**35.5**

Note: Metal concentrations were for filtered samples. Exceedances are in bold.

Despite seawater monitoring from the swing basin recording spikes in Zn concentrations in February, March and April 2016, including the only exceedance of the ANZECC/ARMCANZ (2000) 99% protection levels for marine water, there were no increases in other metals (Tsang, 2016). While there were increases in concentrations of all of the metals exceeded during nearshore sediment monitoring, these increases were not greater than those recorded at other sites in the region, indicating that they were likely due to natural variations in concentrations of metals (Thorburn, 2017b).

The exceedances of sediment quality guideline values (SQGV) (Simpson et al., 2013) and maximum permitted concentrations (MPCs) (FSANZ 2009 and 2015) in biota from the Bing Bong Loading Facility shipping channel and immediate area as part of the AMMP (see below) constitute unreported incidents. Any exceedances should be reported to the DPIR as soon as possible in future years.

There were no reported incidents related to marine biota during the 2016 operational period. However, the IM believes that the following should also have been reported as incidents:

- Seven exceedances of SQGVs for As in sediment as outlined in Simpson et al. (2013).
- Five exceedances of SQGVs-high and four exceedances of SQGVs for Zn in sediment as outlined in Simpson et al. (2013).
- Two exceedances of SQGVs-high and eight exceedances of SQGVs for Pb in sediment as outlined in Simpson et al. (2013).
- Elevated Pb and Zn concentrations in biota from the Bing Bong Loading Facility.

Refer to discussion in Section 4.11.4.2 for further details.

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, seawater and sediments as part of the AMMP is provided below.

4.11.4.2 Progress and New Issues

Monitoring of Marine Environment

Seawater Monitoring

The majority of metal concentrations in filtered and unfiltered seawater collected during the AMMP were consistent across monitoring sites. At all sites, Cu concentrations were above trigger values set by ANZECC/ARMCANZ (2000) guidelines for marine water quality for 99% species protection. The trigger values for Co were exceeded at 20 of 21 sites for unfiltered seawater and 12 of 21 sites for filtered seawater. It is likely that trigger values for Co were exceeded at all sites, but the detection limit (<0.05 µg/L) is above the trigger value (0.005 µg/L). Most sites had Co concentrations close to the detection limit. This is consistent with results from 2010 to 2014 and background levels across the marine waters of northern Australia. Due to their widespread occurrence, it is unlikely that exceedances of Co and Cu are due to MRM's operations.

During the 2014 AMMP, concentrations of Pb and Zn in unfiltered seawater at Bing Bong West 1 (BBW1) were three and four times higher, respectively, than the next highest recorded concentrations. Zinc concentrations at BBW1 were above the ANZECC/ARMCANZ (2000) trigger values for 99% species protection. Concentrations of Pb at this site were just below the trigger value (Thorburn, 2015). However, during the current AMMP, concentrations of Pb and Zn at BBW1 were not elevated compared to other sites (Table 4.50). Concentrations of Co, Cu, Mn and Ni were elevated in filtered seawater from BBW1 compared to other sites (Table 4.50).

Last year, the AMMP emphasised that the construction of the Western Desert Resources (WDR) wharf from mid-2013 and increased boat traffic from the transport of iron ore likely stirred up contaminated sediments which had been buried by naturally-deposited benign sediments. Similarly this year, the AMMP argued that the decline in concentrations of Zn and Pb in seawater was due to the halting of operations at WDR. While this may be the case, little can be inferred from a single data point, and further annual monitoring will help clarify the cause of elevated Zn and Pb in seawater during the 2014 AMMP.

Table 4.50 – Metals in Seawater Elevated at BBW1 Compared to Other Survey Sites in the Vicinity of Bing Bong Loading Facility (µg/L)

Metal/Trigger Values*	Sample Type	Concentration at BBW1		Highest Concentration from Other Survey Sites in 2015	Overall Mean 2015
		2014	2015		
Zn – 7	Filtered	3.0	<1	1 (Sites 107 and 117)	<1#
	Unfiltered	**9.0**	<1	3 (Site 117)	<1.29#
Pb – 2.2	Filtered	0.3	0.2	0.6 (Site 104)	<0.17#
	Unfiltered	1.8	<0.3	0.5 (CDC)	<0.3#
Fe – ntv†	Filtered	5.0	6.0	6 (Pine Creek)	<1.86#
	Unfiltered	750	65	310 (CDC)	91.14
Al – ntv†	Filtered	<5	<5	<5 (all sites)	<5#
	Unfiltered	300	35	330 (CDC)	71.67
Mn – ntv†	Filtered	33	14	8.7 (East Creek)	3.94
	Unfiltered	59	17	20 (CDC)	9.38
Co – 0.005	Filtered	**0.23**	**0.22**	**0.15** (East Creek)	**<0.08#**
	Unfiltered	**0.54**	**0.25**	**0.28** (CDC)	**<0.13#**
Ni – 7	Filtered	0.5	0.5	0.4 (SEPI 11)	<0.31#
	Unfiltered	0.8	0.5	0.6 (SEPI 10)	<0.43#
As – ntv†	Filtered	2.8	2.4	2.4 (East Creek)	1.60
	Unfiltered	3.2	2.5	2.6 (East Creek)	1.82
Cu – 0.3	Filtered	**0.5**	**1.0**	**0.6** (CDC)	**0.44**
	Unfiltered	**1.1**	**1.0**	**0.8** (CDC)	**0.49**

Bold results indicate concentrations exceed the trigger values.
*Trigger values are ANZECC/ARMCANZ (2000) for 99% species protection in marine waters.
#Many values below detection limit.
†ntv = no trigger value.

Immediately adjacent to the Bing Bong Loading Facility, Pb and Zn in nearshore sediments have continued to rise in 2015 and 2016 (Thorburn, 2016d and 2017b). The increase in contaminants may relate to dust emissions from MRM's operations. Currently, there is inadequate evidence to suggest whether or not elevated concentrations of Pb, Zn and other metals are due to WDR or MRM operations. However, the contaminated sediments are likely to be a legacy of MRM's historic operations, and may be resuspended in future as a result of dredging by MRM.

The Fe concentration at BBW1 was elevated in filtered seawater compared to all but one site (Pine Creek), potentially due to residual iron ore dust from the WDR facility.

Lead isotope ratios from DGT monitoring (Tsang, 2016; see Section 4.3) indicate that concentrate-derived Pb is entering marine waters and is traceable at reference sites roughly 7 km in both directions from Bing Bong Loading Facility, but at background concentrations. This is consistent with DGT monitoring since 2013.

Marine Sediment Monitoring

Sediment samples were analysed in two ways. The first involved using the whole sediment sample (<2 mm particle size to remove large particles such as shells) and second involved the <63 µm fraction. The latter analysis was included as it may provide a closer indication of what contaminants are available to biota and adheres more closely to sediment quality guideline values (SQGV) outlined in Simpson *et al.* (2013). These guidelines are provided as values and upper guideline values (SQGV-high); values indicate that there is unlikely to be an effect on local biota, but further investigation is required. Sediment quality guideline values-high indicate that there may well be adverse effects on organisms.

For sites outside the swing basin and shipping channel, there were only three exceedances of SQGVs; all were for As at sites GB, 117 and 8 (48, 48 and 34 mg/L respectively). Concentrations of Zn and Pb were not elevated in the <2 mm fraction at BBW1 or BBW2. In the <2mm fraction, concentrations of Pb were highest at the three offshore sites closest to the Bing Bong Loading Facility (Sites GB, 8 and 117) but Pb isotope ratios (PbIR) from these sites indicate that Pb at these sites is not mine-derived. For the <63 µm fraction, As, Cd, Fe, Mn, Pb, and Zn were elevated at one or both of the Bing Bong West sites (Table 4.51). Lead isotope ratios indicate that Pb at BBW1 and, to a lesser extent, BBW2 is enriched with mine-derived ore compared to other sites in the vicinity of the Bing Bong Loading Facility.

Table 4.51 – Metals in Sediments Elevated at BBW1 and BBW2 Compared to Other Survey Sites in the Vicinity of Bing Bong Loading Facility (mg/kg)

Metal and SQGV /SQGV-High	Sample Fraction	Concentration at		Highest Concentration from Other Survey Sites	Overall	
		BBW1	BBW2		Mean	Median
As – 20/70	<2mm	7.2	16	**48** (GB and 117)	14.7	9.60
	<63 µm	8.0	7.1	8 (Rosie Creek)	4.80	3.95
Cd – 1.5/10	<2mm	0.2	<0.2	0.4 (SEPI 10)	0.028*	0.03*
	<63 µm	0.17	0.08	0.06 (Pine Creek)	0.048*	0.04*
Fe – ntv[†]	<2mm	6,500	16,000	120,000 (GB)	29,675	15,500
	<63 µm	7,400	11,000	11,000 (East Creek)	8,455	8,450
Mn – ntv[†]	<2mm	320	230	450 (SEPI 11)	236.8	220
	<63 µm	440	290	350 (SEPI 11)	235	215
Pb – 50/220	<2mm	4.9	4.9	26 (GB)	8.45	4.85
	<63 µm	21	21	22 (GB)	12.39	11.0
Zn – 200/410	<2mm	10	9.0	30 (SEPI 11)	8.05	5.00
	<63 µm	92	31	9.3 (East Creek)	12.86	8.00

Bold results indicate concentrations exceed the trigger values.
* Many values below detection limit. [†]ntv = no trigger value.

At BBW1, Fe concentrations in the <2 mm fraction dropped considerably between 2014 and 2015, declining from 69,000 mg/kg to 6,500 mg/kg, while in the <63 µm fraction concentrations remained consistent (7,800 mg/kg to 7,400 mg/kg). At BBW2 concentrations of Fe increased considerably in the <2 mm fraction (5,300 mg/kg to 16,000 mg/kg) and remained constant in the <63 µm fraction (11,000 mg/kg both years). Concentrations of Fe have also increased at sites offshore from Bing Bong Loading Facility (Sites 8, 117 and GB). These patterns may indicate that the localised effects of past operations at the WDR loading facility are becoming diluted as iron ore dust is washed offshore and in a westward direction.

Concentrations of metals including Ag, As, Cd, Cu, Fe, Pb and Zn remain elevated within the swing basin compared to the surrounding area (Table 4.52). With the exception of As at a single site (MS1B), concentrations of metals in sediments in the shipping channel increased at sites closer to the Bing Bong Loading Facility. Within the swing basin, concentrations were highest at leeward, westerly sites (MS5A, MS6A, MS7A). For the <2mm fraction of sediments in the swing basin, SQGVs-high were exceeded at four sites for Zn and one sites for Pb and SQGVs were exceeded for Pb, As and Cd at three sites each and Zn for one site. For the <63 µm fraction of sediments, SQGVs-high were exceeded at one site for Zn and Pb and SQGVs were exceeded for Pb at five sites and Zn at three sites.

Table 4.52 – Metals in Sediments Elevated in the Swing Basin and Shipping Channel Compared to Other Sites Surveyed During the AMMP (mg/kg)

Metal and ISQG Low/High	Sample Type	Inside Swing Basin and Shipping Channel			Outside Swing Basin and Shipping Channel		
		Mean	Median	Maximum	Mean	Median	Maximum
Ag – 1/4	<2mm	0.15*	0.08[1]	0.39	<0.02[#]	<0.02[#]	<0.02[#]
	<63 µm	0.056*	0.06[1]	0.08	0.026[†]	0.03[†]	0.04
As – 20/70	<2mm	**20.1**	18.0	**41**	14.76	9.6	**48**
	<63 µm	4.67	4.8	6.3	4.82	3.95	8.0
Cd – 1.5/10	<2mm	1.07*	0.56*	**3.0**	0.275[†]	0.03[†]	0.04
	<63 µm	0.38	0.28	1.0	0.048[†]	0.04[†]	0.17
Cu – 65/270	<2mm	23.3	16.5	51	5.59	2.75	16
	<63 µm	17.43	17.0	33	5.20	5.2	7.7
Fe - ntv**	<2mm	47,400	42,000	110,000	29675	15500	120,000
	<63 µm	11,190	12,000	13,000	8455	8450	11,000
Pb – 50/220	<2mm	**80.5**	46.5	**230**	8.45	4.85	26
	<63 µm	**98.3**	**81.0**	**260**	12.39	11	22
Zn – 200/410	<2mm	**432.4**	190	**1400**	8.05	5.0	30
	<63 µm	156.4	112.5	**430**	12.86	8.0	92

Bold results indicate concentrations exceed the trigger values. **ntv = no trigger value.
* A single value below detection limits. [#] All values below detection limit. [†] Many values below detection limit.

Lead isotope ratios increase in sediments closer to the swing basin and in sediments with increased concentrations of Pb, indicating that mine-derived Pb is entering the marine environment. As SQGVs-high are exceeded for both Pb and Zn in the swing basin, MRM's operations may be having adverse effects on marine organisms in this localised area and no health impacts to marine biota have been noted. However, while these very high concentrations of Pb and Zn are concerning, they are not altogether surprising as one would expect some level of contamination within the swing basin and this is consistent with previous sampling. Consistent with monitoring since 2011, regional sampling indicates that the impacts are localised to the swing basin, shipping channel and tidal flats immediately west of Bing Bong Loading Facility.

Of some concern is the large increase in concentrations of Zn and Pb in sediments from the swing basin since 2013. On average, concentrations of Pb from sites MS5A, MS6A and MS7A have increased from roughly 52 mg/kg in 2013 and 105 mg/kg in 2014 to 177 mg/kg in 2015. At the same three sites, concentrations of Zn have increased from roughly 211 mg/kg in 2013 and 476mg/kg in 2014 to 1063 mg/kg in 2015. At MS7A where contamination is highest, concentrations of Pb and Zn have increased from roughly 73 mg/kg and 299 mg/kg, respectively, in 2013 to 230 mg/kg and 1400 mg/kg in 2015. Nearshore sediments immediately west also show increases in Zn and Pb concentrations between 2013 and 2016. While some of these increases may be due to operations at WDR re-suspending contaminated sediments, as concentrations have continued to rise since WDR stopped operating, MRM's operations are likely contributing to contamination. Every effort should be made to minimise dust emissions from Bing Bong Loading Facility and identify potential unrecognised sources of contamination. In addition, MRM should endeavour to be more responsive to reducing known sources of contamination at Bing Bong Loading Facility; for example at the concentrate shed it took at least a year to repair the dust extractor system, two years to replace the smaller roller doors, and replacement of the large roller doors is still pending after more than two years. However, it should be noted that these exceedances are restricted to the swing basin.

Marine Biota

The biota assessed for levels of 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*).

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*).

In the AMMP report (Thorburn, 2016a), exceedances of the MPCs set by the Australia New Zealand Food Standards Code (FSANZ, 2009) were reported in relation to Pb, inorganic As and Cd. The maximum permitted levels of these metals in fish and molluscs are unchanged in the current version of the Food Standards Code (FSANZ, 2015). No criteria are currently set for Zn and Cu.

There were four exceedances of MPCs for biota in the 2015 AMMP. The concentration of Pb in the muscle of a single mullet from Mule Creek was 0.72 mg/kg, above an MPC of 0.5 mg/kg. While all other individuals from this site were well below the MPC (0.008 to 0.037 mg/kg), the site had the highest mean (0.157 mg/kg) and median (0.011 mg/kg) concentrations of Pb for all sites (2015 mean and median for mullet 0.028 mg/kg and 0.006 mg/kg, respectively). However, the

PbIR for individuals from Mule Creek indicate that the Pb was not mine-derived. The MPC for Cd (2 mg/kg) was exceeded in one oyster from three sites, 107 (2.5 mg/kg), SEPI 9 (2.3 mg/kg) and SEPI 8 (2.0 mg/kg). Due to the distance between these sites and the Bing Bong Loading Facility, it is unlikely that these exceedances were due to MRM's operations.

Table 4.53 shows which metals were elevated in the immediate vicinity of the Bing Bong Loading Facility (the shipping channel and BBW1).

Concentrations of As, Cd, Mn, Ni, Pb and Zn were elevated in the vicinity of the Bing Bong Loading Facility when compared to results from other sites in the monitoring program. Specifically:

- Total As concentrations in *Terebralia* were elevated in the shipping channel and at BBW1. All *Terebralia* collected at BBW1 had concentrations of As above the next highest recordings. Mean and median values for As were elevated in the shipping channel and were the third highest after BBW1 and Site 104. In contrast to the 2014 AMMP, concentrations of As in *Telescopium* was not elevated in the shipping channel or BBW1. Arsenic speciation analysis of oysters, mud crabs and seagrass indicates that concentrations were largely consistent between sites, and no MPCs for inorganic As were exceeded.
- Cadmium concentrations were elevated in *Telescopium, Terebralia* and mullet from BBW1. While the concentration of Cd was elevated in the two species of gastropod, these were not the highest concentrations recorded, indicating that MRM's operations were not the source of this contamination. In the mullet, Cd concentrations at BBW1 (0.006 mg/kg) were on average double those at the next highest site (0.003 mg/kg).
- Concentrations of Mn in *Terebralia* from the shipping channel were elevated compared to the mean and median values for the 2015 AMMP, including the highest concentration of Mn for an individual *Terebralia.* However, mean and median values were below those for 3 and 4 other sites respectively, so elevated Mn is likely due to natural variation in background levels.

Table 4.53 – Elevated Metals in Biota in the Shipping Channel or BBW1 Compared to Regional Sites (mg/kg)

Metal	Taxonomic Group (and MPC Where Applicable)	Species/ Genus	BBLF/BBW1 Concentration	Next Highest Concentration, excluding BBLF and BBW1	BBLF/BBW1 Mean/Median	BBLF/BBW1 Mean/Median/ Maximum in 2014	Next Highest Site Mean/ Median	AMMP Mean/Median
Bing Bong Loading Facility Shipping Channel (BBLF)								
As	Mollusc	*Terebralia*	3.5, 3.5, 3.1, 2.6, 2.6	4.7, 4, 2.8 (104)	3.2/3.1	4.9/4.9/5.2	3.8/4	2.3/1.9
Mn	Mollusc	*Terebralia*	39, 7.9, 7.2, 4.1, 3.6	35, 25, 16, 13, 4.7 (CDC)	12.36/7.2	18.5/10/43	18.74/16	7.9/4.1
Pb	Mollusc (MPC: 2 mg/kg))	Oyster	0.34, 0.3, 0.3, 0.28, 0.14	0.12, 0.0042, 0.016, 0.016, 0.015 (SEPI 8)	0.27/0.3	0.16/0.12/0.29	0.048/0.042 (SEPI 11)	0.048/0.03
		Telescopium	0.46, 0.25, 0.2, 0.16, 0.12	0.33, 0.31, 0.25, 0.24, 0.11 (CDC)	0.24/0.2	0.1/0.05/0.25	0.25/0.25	0.08/0.038
		Terebralia	0.8, 0.63, 0.63, 0.24, 0.22	0.29, 0.22, 0.22, 0.1, 0.035 (CDC)	0.5/0.63	0.68/0.82/1.1	0.178/0.24 (104)	0.12/0.045
	Crustacean	Mud crab	0.066, 0.02, 0.014, 0.01, 0.006	0.016, 0.007, 0.005 (107)	0.023/0.014	0.014/<0.004/ 0.052	0.009/0.007	0.009/0.006
Zn	Mollusc	Oyster	1400, 890, 880, 670, 540	210, 160, 110, 110, 94 (CDC)	876/880	550/550/650	137/110	140.1/77
		Terebralia	65, 14, 11, 11, 10	12, 11, 10, 9.9, 8.9 (SEPI 12)	22/11	13.2/13/16	10.8/11 (Mule Creek)	10.4/9.3
	Fish	Mullet	5.2, 5.1, 5.1, 4.9, 4.3	5.8, 5.1, 4.7, 4.6, 3.8 (Mule Creek)	4.9/4.3/	4.7/4.3/6.5	4.8/4.7 (Mule Creek)	4.7/4.6
Bing Bong West 1 (BBW1)								
As	Mollusc	*Terebralia*	7.5, 5.9, 5.4, 5.2, 4.8	4.7, 4, 2.8 (104)	5.8/5.4	6.6/6.7/7.8	3.8/4	2.3/1.9
	Fish	Mullet	1.5, 1.2, 1.2, 1.1, 1	0.93, 0.77, 0.76, 0.61, 0.58 (Mule Creek)	1.18/1.2	N/A	0.88/0.79 (107)	0.72/0.76

Table 4.53 – Elevated Metals in Biota in the Shipping Channel or BBW1 Compared to Regional Sites (mg/kg) (cont'd)

Metal	Taxonomic Group (and MPC Where Applicable)	Species/ Genus	BBLF/BBW1 Concentration	Next Highest Concentration, excluding BBLF and BBW1	BBLF/BBW1 Mean/Median	BBLF/BBW1 Mean/Median/ Maximum in 2014	Next Highest Site Mean/ Median	AMMP Mean/Median
Bing Bong West 1 (BBW1) (cont'd)								
Cd	Mollusc (MPC: 2 mg/kg)	*Telescopium*	0.079, 0.075, 0.075, 0.07, 0.061	0.093, 0.074, 0.069, 0.066, 0.061 (BBHC)	0.072/0.075	N/A	0.073 (BBHC) /0.074 (SEPI 8)	0.051/0.049
		Terebralia	0.39, 0.25, 0.17, 0.17, 0.17	0.34, 0.26, 0.26, 0.23, 0.12 (Pine Creek)	0.23/0.17	0.22/0.18/0.29	0.24/0.26	0.14/0.13
	Fish	Mullet	0.008, 0.006, 0.006, 0.005, 0.004	0.005, 0.003, 0.003, 0.002 (104)	0.006/0.006	N/A	0.003/0.003	0.003*/0.001
Pb	Mollusc (MPC: 2 mg/kg)	*Terebralia*	0.45, 0.27, 0.11, 0.1, 0.088	0.29, 0.22, 0.22, 0.1, 0.035 (CDC)	0.2/0.11	0.59/0.38/1.2	0.178/0.24 (104)	0.12/0.045
Zn	Mollusc	*Terebralia*	12, 11, 10, 9.3, 8.9	12, 11, 10, 9.9, 8.9 (SEPI 12)	10.2/10	10.4/10/13	10.8/11 (Mule Creek)	10.4/9.3
	Fish	Mullet	6.6, 6.4, 6.1, 5.4, 4.9	5.8, 5.1, 4.7, 4.6, 3.8 (Mule Creek)	5.9/6.1	N/A	4.8/4.7 (Mule Creek)	4.7/4.6

MPC – maximum permitted concentration. Unless otherwise stated, the site with the next highest mean/median value is the same as the location of the next highest concentration.
* Indicates organisms collected from Bing Bong West 1. All other records are from biota collected from the shipping channel.
# Although an MPC is specified for inorganic As, this does not apply to the presented total As results.

- Lead was elevated in biota from the shipping channel. The highest concentrations of Pb in oysters, *Terebralia*, *Telescopium* and mud crabs all came from the Bing Bong Loading Facility shipping channel, but maximum values were at least 2.5 times below the MPC for Pb. The mean and median Pb concentrations for these species were also well above the average values collected for the monitoring program and the next highest site. It is somewhat concerning that for the last two years, mud crabs at Bing Bong Loading Facility have elevated concentrations of Pb, as historically it was thought that these more mobile species would not spend sufficient time in the swing basin to receive elevated doses of metals. However, the health risk assessment methodology outlined by FSANZ indicates that an adult male could safely eat 3.4 kg and a child 2.7 kg of mud crab meat from BBLF per day. Unfortunately, no barramundi or queenfish were caught in the shipping channel during the 2015 AMMP.

  For oysters, *Telescopium* and *Terebralia,* PbIRs in individuals from the shipping channel were very close to that of the ore body compared to other sites. For *Telescopium* and *Terebralia*, PbIRs were consistently elevated for individuals from BBW1. The PbIRs for mud crab from the shipping channel were elevated, and the highest recorded isotope ratio for mud crabs was from an individual from the shipping channel. However, the highest mean isotopic ratio for mud crab was from SEPI 8. It is unclear why PbIRs were elevated in mud crab at SEPI 8, but concentrations of Pb were not elevated at this site. PbIRs were also elevated for mullet from the shipping channel and BBW1, but well below the isotope ratio recorded at site 104. Finally PbIRs were elevated in the two barramundi and single giant queenfish caught at Mule Creek, indicating they may have spent time in the shipping channel before migrating to Mule Creek, which is 4 km away. Concentrations of Pb are very low in these individuals. However, these results should be treated with caution due to the low numbers of barramundi and giant queenfish collected. Overall, PbIRs from the swing basin and BBW1 were elevated, particularly in sessile species, indicating that mine-derived Pb is entering the environment at concentrations well below MPCs.

- Zinc was elevated in oysters collected from the shipping channel. Mean, median and maximum values (876, 880 and 1,400 mg/kg, respectively) were well above those for all oysters collected during the monitoring program (140.1, 77.0 and 210 mg/kg, respectively). Concentrations of Zn in oysters from the shipping channel have been consistently elevated since the AMMP began in 2012. Oysters are well known bioaccumulators of metals and can live at least five years, so this result is unsurprising based on long-term evidence of elevated Zn levels in sediments and biota from the shipping channel. To put these results in the context of moderately disturbed ecosystems, oysters collected from around Darwin also had elevated Zn; individuals taken from Rapid Creek had concentrations 488 to 787 mg/kg and from East Point 180 to 305 mg/kg (Peerzada and Dickinson 1989). Commercially produced Sydney rock oysters often have Zn concentrations comparable to those recorded at Bing Bong Loading Facility (Mackay et al., 1975, Hardiman and Pearson, 1995).

  Maximum, mean and median Zn concentrations were elevated in *Terebralia* and mullet from the shipping channel and BBW1, indicating that contaminants are spreading westward from Bing Bong Loading Facility due to the prevailing winds and currents. Overall, results indicate that contamination is restricted to the shipping channel and immediate surrounds.

In contrast to 2014, concentrations of Al, Co, Cu and Fe were not elevated in any biota in the shipping channel or BBW1.

Concentrations of metals in seagrass (*Halodule uninervis*) were consistent across all sites. No metals were elevated.

Zinc and Pb have been consistently elevated in molluscs and crustacean collected from the shipping channel since 2011 (Table 4.54). Zinc concentrations in oysters collected from the shipping channel have remained well above the regional average since 2012 and there is no indication of a decline in concentrations. Lead has remained elevated in molluscs and mud crabs caught in the shipping channel compared to regional sites. Of particular concern, mean, median and maximum concentrations of Zn in oysters and Pb in oysters, *Telescopium* and mud crabs all increased in 2015. McArthur River Mining should ensure that best practice is being implemented at the Bing Bong Loading Facility, and that dust controls are being maintained and kept operational. If concentrations of metals remain high with best practice procedures being implemented, MRM should investigate additional management options to reduce contamination.

Table 4.54 – Elevated Zn and Pb in Biota from the Shipping Channel Since 2011 (mg/kg)

Organism		Oyster	Oyster	*Telescopium*	*Terebralia*	Mud Crab
Metal: MPC*		*Zn: N/A*	*Pb: 2.0*			*Pb: N/A*
Mean	2011	-	-	0.91#	0.871#	-
	2012	553	0.069	0.64	0.82	0.014
	2013	480	0.32	0.078	0.32	0.006
	2014	550	0.16	0.1	0.68	0.014
	2015	876	0.27	0.24	0.5	0.023
	2015 Prog†	79.8	0.03	0.064	0.076	0.006
Median	2014	550	0.12	0.05	0.82	<0.004
	2015	880	0.3	0.2	0.63	0.014
	2015 Prog†	69	0.029	0.026	0.033	0.005
Maximum	2014	650	0.29	0.25	1.2	0.052
	2015	1400	0.34	0.46	0.8	0.066
	2015 Prog†	210	0.12	0.33	0.29	0.016

*MPC – maximum permitted concentration (mg/kg), where applicable. Under FSANZ (2015) there is currently no MPC for Zn or for Pb in crustaceans.
#In 2011 *Telescopium* and *Terebralia* were collected from a slightly different location in the shipping channel compared to subsequent years.
†2015 Prog – mean, median and maximum values (excluding Bing Bong Loading Facility sites) from the entire AMMP.

Annual Marine Monitoring Program Conclusion

The AMMP 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 animals and sediments from sites within 700 m of the loading facility, beyond which there is no measureable impact on the environment. Concentrations of Zn in oysters in 2015 were the highest recorded since sampling began, and concentration of Pb were elevated in oysters, *Telescopium* and mud crab compared to 2014. It is unclear whether these elevated concentrations were due to MRM's or WDR's operations. In addition, more mobile species (mud crab and mullet) have elevated PbIRs in the vicinity of Bing Bong Loading Facility, as these species may be accumulating contaminants over a short time. It is unfortunate that more barramundi could not be caught as part of the AMMP, as a result elevated Pb concentrations and PbIRs in individuals from Mule Creek could not be further investigated. Without additional samples from other sites, it is not possible to know whether these elevated concentrations and isotope ratios are due to MRM's activities.

Seagrass Monitoring Program

Qualitative analysis indicates seagrass coverage remained very high in 2016, with seagrass present at 99% of monitoring sites at the Bing Bong Loading Facility (Table 4.55). Seagrass coverage at control sites at Sectors 3, 5 and 6 also remained high, with seagrass present at 86%, 100% and 97% of sites, respectively. At all sites, there has been a slight decline in the density of seagrass cover, likely caused by the successional change to seagrass species dominance to species that form less dense meadows (see below) and the increase in macroalgal cover inhibiting seagrass growth and reducing survey efficiency. Macroalgae cover was quantified at Bing Bong Loading Facility and Sector 6, where cover increased from 17.1% to 42% and 4.1% to 14.6% respectively from 2015 to 2016.

The quantitative approach shows similar results (Table 4.56), with coverage increasing at all sites since records began. However, between 2015 and 2016 seagrass cover decreased by an average of 4% at Bing Bong Loading Facility, remained stable in Sector 3 and increased by 23% and 9% in Sectors 5 and 6 respectively. The small decrease in seagrass coverage at the Bing Bong Loading Facility is likely caused by the increase in macroalgae. Seagrass diversity continues to increase; for the first time, *Syringodium isoetifolium* was the dominant seagrass species at Bing Bong Loading Facility and Sectors 5 and 6. Consistent with previous years *Halophila ovalis* and *Halodule uninervis* dominate Sector 3 (Table 4.57). The coverage, density and dominance of other species continue to increase.

Seagrass cover, density and diversity largely 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). With the establishment of suitable controls and qualitative and quantitative approaches, the seagrass monitoring program effectively quantifies spatial and temporal variation in seagrass communities, and effectively separates between natural variability and the potential impacts from operations at the Bing Bong Loading Facility. Operations at the Bing Bong Loading Facility are not having a measurable impact on seagrass communities.

The increase in macroalgae requires further investigation. A desktop study should be conducted to ensure that the increase in macroalgae cover is due to natural variation (such as successional changes) rather than anthropogenic causes such as increased nutrient loads. In addition, macroalgal cover should be quantified at all sites, rather than just Bing Bong Loading Facility and Sector 6.

Table 4.55 – Seagrass Coverage Adjacent to Bing Bong Loading Facility (2011 to 2016) and at Control Sites (2012 to 2016) (%)

Seagrass Coverage	2011	2012	2013	2014	2015	2016
Bing Bong Loading Facility						
Bare substrate	1	1	3	1	1	1
Very sparse	0	0	5	2	5	16
Sparse	12	52	44	21	23	29
Moderate	54	44	51	55	53	47
Dense	27	3	8	17	13	4
Very dense	6	0	0	4	4	2
Sites with seagrass	99	99	97	99	99	99
Sector 3*						
Bare substrate	-	57	26	14	27	14
Very sparse	-	0	33	31	15	22
Sparse	-	6.	10	28	15	42
Moderate	-	17	31	28	37	19
Dense	-	13	0	0	7	3
Very dense	-	6	0	0	0	0
Sites with seagrass	-	43	74	86	73	86
Sector 4*						
Bare substrate	-	43	26	-	-	-
Very sparse	-	0	13	-	-	-
Sparse	-	23	22	-	-	-
Moderate	-	34	26	-	-	-
Dense	-	0	13	-	-	-
Very dense	-	0	0	-	-	-
Sites with seagrass	-	57	74	-	-	-
Sector 5*						
Bare substrate	-	-	-	0	0	0
Very sparse	-	-	-	11	11	6
Sparse	-	-	-	6	22	6
Moderate	-	-	-	58	31	53
Dense	-	-	-	25	25	36
Very dense	-	-	-	0	11	0
Sites with seagrass	-	-	-	100	100	100
Sector 6*						
Bare substrate	-	-	-	-	0	3
Very sparse	-	-	-	-	19	8
Sparse	-	-	-	-	6	22
Moderate	-	-	-	-	50	58
Dense	-	-	-	-	25	8
Very dense	-	-	-		0	0
Sites with seagrass	-	-	-		100	97

*Control sites. Data from sectors 3 and 4 was first collected in 2012, from sector 5 in 2014 and sector 6 in 2015. Due to its unsuitability as a control site, data collection from sector 4 stopped following the 2013 survey.

Table 4.56 – Percentage Cover of Seagrass and Change in Cover at Bing Bong Loading Facility and Control Sites from 2013 to 2016 (%)

Transect	Percentage Cover of Seagrass				Percentage Change in Cover	
	2013	2014	2015	2016	2013-2016	2015-2016
Bing Bong Loading Facility						
1	45	43	61	42	-3	-19
2	24	38	68	29	5	-39
3	28	42	17	29	1	12
4	39	58	35	43	4	8
5	50	55	56	56	6	0
6	27	63	82	57	30	-25
7	40	82	43	58	18	15
8	34	63	47	60	26	13
9	54	68	44	49	-5	5
10	43	55	55	36	-7	-19
11	31	63	60	40	9	-20
12	42	48	43	57	15	14
Average	38	57	51	47	9	-4
Sector 3†*						
2	32	38	57	47	15	-10
3	43	53	71	73	30	2
4	16	18	24	33	17	9
5	19	30	41	37	18	-4
6	17	5	22	12	-5	-10
7	0	28	17	37	37	20
Average	22	28	40	40	18	0
*Sector 5**						
1	-	64	24	47	-17#	23
2	-	67	31	67	0#	36
3	-	60	47	85	25#	38
4	-	48	65	84	36#	19
5	-	43	76	71	28#	-5
6	-	39	61	91	52#	30
Average	-	53	51	74	21#	23
*Sector 6**						
1	-	-	47	69	-	22
2	-	-	44	57	-	13
3	-	-	53	53	-	0
4	-	-	46	55	-	9
5	-	-	45	64	-	19
6	-	-	63	55	-	-8
Average	-	-	50	59	-	9

* Control sites. # Comparison between 2014 and 2016, not 2013 and 2016.
† Two transects could not be sampled in Sector 3 due to the presence of a mobile sandbar

Table 4.57 – Percentage of Sites Where Seagrass Species Were Recorded in the Shipping Channel and Control Sectors (%)

Seagrass Species	2011	2012	2013	2014	2015	2016
Bing Bong Loading Facility						
Halophila ovalis	68	60	83	99	78	38
Halodule uninervis	92	94	92	97	89	78
Cymodocea serrulata	5	6	10	22	13	27
Syringodium isoetifolium	31	16	24	45	56	92
Thalassia hemprichii	4	0	0	0	0	0
Sector 3*						
Halophila ovalis	-	36	46	67	61	64
Halodule uninervis	-	34	56	42	37	78
Cymodocea serrulata	-	0	8	17	10	31
Syringodium isoetifolium	-	15	26	22	22	53
Sector 4*						
Halophila ovalis	-	36	61	-	-	-
Halodule uninervis	-	45	65	-	-	-
Cymodocea serrulata	-	0	7	-	-	-
Syringodium isoetifolium	-	43	65	-	-	-
Thalassia hemprichii	-	6	0	-	-	-
Sector 5*						
Halophila ovalis	-	-	-	100	78	25
Halodule uninervis	-	-	-	81	92	67
Cymodocea serrulata	-	-	-	11	22	39
Syringodium isoetifolium	-	-	-	33	78	92
Sector 6*						
Halophila ovalis	-	-	-	-	81	58
Halodule uninervis	-	-	-	-	94	69
Cymodocea serrulata	-	-	-	-	22	44
Syringodium isoetifolium	-	-	-	-	42	86
Halophila spinulosa	-	-	-	-	14	25

*Control sites. Data from Sectors 3 and 4 was first collected in 2012, from Sector 5 in 2014 and sector 6 in 2015. Due to its unsuitability as a control site, data collection from Sector 4 stopped following the 2013 survey.

Progress

McArthur River Mining's performance against previous IM review recommendations relating to marine ecology issues is outlined in Table 4.58.

Table 4.58 – Marine Ecology Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2015 Operational Period		
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	Not addressed in the 2015 AMMP. This recommendation should have been addressed in the 2016 AMMP
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	Not included in the 2015 to 2016 DGT monitoring program, and not mentioned as one of the new sites to be added in the 2016 to 2017 monitoring program
Monitoring of *Vibrio* bacteria	The last monitoring of *Vibrio* bacteria in the vicinity of McArthur River was carried out in 2013. In the 2014 report, the IM suggested a final *Vibrio* survey in 2015, which was not undertaken. A final *Vibrio* survey should be undertaken to confirm that *Vibrio* bacteria abundances are not increasing as a result of MRM's activities	MRM (2017) notes that the 2013 Vibrio report (Streten-Joyce, 2013 concluded that Vibrios are consistently higher at Vanderlin Island, which has the lowest dissolved Zn concentrations, and that there was no correlation between Zn and *Vibrio* occurrence. The IM notes that this reflects results found in 2011 and 2012 (Streten-Joyce, 2012). On this basis, MRM (2017) states that 'given no correlation between Zn concentration and *Vibrio* occurrence was observed in the last study, further investigation and expenditure is considered unwarranted'. The IM concurs with this conclusion

Table 4.58 – Marine Ecology Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012, 2013 and 2014 Operational Periods		
Inclusion of long-term datasets in reports	As the AMMP, the seagrass, DGT and nearshore sediment monitoring programs have now been running for several years, long-term datasets should be included in the reports so consistent patterns and inconsistencies can be more easily identified	Long-term datasets were included in the most recent AMMP, seagrass and nearshore sediment monitoring programs. The DGT report continues to focus on the most recent findings, without presenting data from previous years
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	No dredging was undertaken during the reviewed reporting period

4.11.4.3 Successes

As the marine monitoring program was improved and expanded significantly in 2014 and 2015, it now comprehensively and adequately monitors the marine environment, and the 2015 to 2016 monitoring period was a period of consolidation. One new site was added to the east of the Bing Bong Loading Facility to the AMMP during the operational period, to ensure that contaminants are not spreading in an easterly direction.

4.11.5 Conclusion

Overall, impacts to the marine environment at the Bing Bong Loading Facility are almost exclusively restricted to the shipping channel and the area immediately west of the facility. Where metal concentrations were detected in biota, they fell well below applicable MPCs in all but one instance, and the one exceedance did not appear to be due to MRM's operations. However, concentrations of Zn and Pb in biota from the swing basin increased in 2015 compared to previous years, which is of concern. Unfortunately very few barramundi were caught in the 2015 AMMP, so the impacts of operations on barramundi could not be quantified.

Ongoing and new IM recommendations related to marine ecology issues are provided in Table 4.59.

Table 4.59 – New and Ongoing Marine Ecology Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
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 ♦ (Long-term data was included in the AMMP, seagrass and nearshore sediment monitoring program in the 2016 operational period, and this recommendation is closed out with regards to those programs)	Low
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 4.59 – 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 barramundi with elevated, mine-derived Pb were caught in the Bing Bong Loading Facility shipping channel in 2014, 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	Medium
New DGT monitoring sites	As seawater from BBW1 had elevated levels of contaminants, the IM suggests establishing DGT monitoring stations at BBW1 and 2, if feasible, to determine fine-scale patterns of contamination at these sites	Medium
New Items		
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	Low
Include 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	Low
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	Low

4.11.6 References

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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.
- Various reports prepared by MRM and its consultants (as listed in Appendix 1), with particular reference to MRM's MMP 2013-2015 operational performance report (MRM, 2016), along with reports addressing part or all of the 2016 operational period with regards to soil monitoring (TAS, 2016), fluvial sediment monitoring (KCB, 2016a), annual marine monitoring, nearshore sediment and trans-shipment sediment (Indo-Pacific, 2016a, 2017, and 2016b, respectively).
- Responses by MRM to recommendations raised in the previous IM report.
- Laboratory analysis results and/or spreadsheets provided by MRM that contain collated laboratory analysis data.

4.12.2 Key Risks

The risk assessment undertaken to support the review identified a number of key risks concerning soils, fluvial sediments[17] and marine sediments (see Appendix 2). These remain largely as described in last year's IM report and are summarised below.

Soils

The two 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[18].
- Soil contamination as a result of groundwater seepage 'daylighting' on the ground surface.

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.

[17] Fluvial sediments are those associated with McArthur River and its tributary streams.
[18] No dredging occurred during the 2014, 2015 or 2016 operational periods.

- 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 the McArthur River. The environmental impacts are as described in relation to surface water quality at McArthur River Mine (Section 4.3). This type of risk also includes impacts such as those that might be associated with TSF embankment failure (in which case the tailings solids themselves would also present a significant hazard) and the TSF overtopping, neutral or saline leachates from waste rock[19], and saline seepage from areas such as the ELS potentially reporting directly to McArthur River. 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.

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[19] As noted elsewhere in this report, the waste rock classification was amended in 2013 to include rock that potentially produces acid, saline and/or metalliferous drainage.

- 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 report for the mine and loading facility (TAS, 2016) describes the aim of the program more narrowly, as being:

> …to measure the concentration of contaminants in the soil surrounding the operational areas of McArthur River Mine and the Bing Bong Loading Facility and determine the effectiveness of the current dust controls utilised at the operations.

The key elements of the surface soil monitoring program include:

- Sampling sites as shown in Figure 4.36 (McArthur River Mine) and Figure 4.37 (Bing Bong Loading Facility) for the 2016 operational period:

SOIL MONITORING SITES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.36

Source: TAS, 2016.

ERIAS Group | 01164D_1_F4-36_v1.pdf

SOIL MONITORING SITES - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.37

ERIAS GROUP

Source: TAS, 2016.

ERIAS Group | 01164D_1_F4-37_v1.pdf

  - Sampling sites at the mine site have previously (MRM, 2015a) been grouped according to an identified point source of potential dust generation in operation, e.g., control sites and potential impact sites associated with each of the ore crushing plant/ROM pad, NOEF and TSF. For the purposes of TAS (2016), they have been grouped simply as control sites, 'west group' and 'east group', however data is still presented graphically in terms of distance from main dust point sources.
  - Sampling at Bing Bong Loading Facility included sampling of surface soil from two sites (BBS03 and BBS04) in the dredge spoil emplacement area, as well as sites near the Bing Bong Loading Facility concentrate shed/loading conveyor and swing basin.
- Sampling soils from the 40 to 50 cm depth range, and from the surface (1 to 10 cm depth).
- Sampling soils on an annual basis in the middle of the dry season. In most instances, soil monitoring sites correspond to dust monitoring sites, which are sampled via a separate program (Section 4.13).
- 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[20]). 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.

Monitoring site S43 near Barney Creek haul road bridge was not sampled as part of the 2015 program as its original location was in a heavily modified area, and results were thought to reflect the waste rock used to build up this location rather than identifying contamination from depositional dust (Dobson, 2016). The site was reinstated as part of the 2016 program in response to an IM recommendation, but in a different location further to the west.

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).

[20] The original NEPM (NEPC, 1999) has been revised, with the updated version becoming effective in 2013. Although the updated document is still officially called the 'The National Environment Protection (Assessment of Site Contamination) Measure 1999', we have cited it as 'NEPC, 2013' in this report to avoid confusion.

As indicated in Figure 4.38, additional controls that are specific to fluvial sediments (and reducing input of contaminated sediment) near Barney Creek haul road bridge include:

- Northwest of the bridge (northern side of Barney Creek diversion channel, on the western side of the bridge) – a permanent settlement sump/sediment basin system to intercept surface water runoff reporting to this area (see also Section 4.12.3.2).
- Southeast of the bridge – a permanent 'Type F' sediment basin[21] (MRM, 2015b), along with a series of minor silt traps in the drainage channel between this basin and the Barney Creek diversion channel.
- Southwest of the bridge – a minor silt trap.
- Northeast of the bridge – a berm along the eastern side of the haul road that is maintained during the wet season 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.
- 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).

The IM was advised by MRM during the most recent site visit that sediment captured within these control structures is cleared out annually during the dry season, if required.

Monitoring Program

As noted in MRM (2015a), the purpose of the fluvial sediment monitoring program is to assess potential sediment-associated pollutant fluxes in the McArthur River and its tributaries in proximity 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 KCB (2016a) as being to:

- Identify sediments where contaminant concentrations are likely to result in adverse effects on sediment ecological health.

[21] 'Type F' soils contain a significant proportion of fine-grained particles and require extended settlement periods to achieve settlement. A Type F sediment basin is a wet basin (i.e., not free-draining), which is designed for settling out fine sediment before draining of the clarified water.

SEDIMENT CONTROL STRUCTURES NEAR BARNEY CREEK HAUL ROAD BRIDGE

McArthur River Mine Project

FIGURE 4.38

- 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.
- 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 4.39 for the 2016 operational period. These are, for the most part, in the same locations as the natural surface water sampling sites (see Figure 4.1).
- Sampling annually in the early to mid dry season (in the 2016 operational period, this occurred in April 2016).
- Laboratory testing including pH and EC (paste), particle size distribution, major ions, Pb isotope ratios, and trace metals in the <63 µm fraction (analysed separately after weak acid (1M HCl) digestion and after strong acid (HNO_3/$HClO_4$/HF/HCl) digestion).

Assessment of the data obtained from fluvial sediment sampling in the 2016 operational period primarily involved comparison with the ANZECC/ARMCANZ (2000) sediment quality guidelines. The SQGV value 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. The sediment quality aspects of the ANZECC/ARMCANZ guidelines have been updated by Simpson et al. (2013), but the guideline values applicable to parameters monitored by MRM have not changed. Nonetheless, as recommended in last year's IM report, the next version of MRM's MMP, as well as future fluvial sediment monitoring reports, should reference Simpson et al. (2013).

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

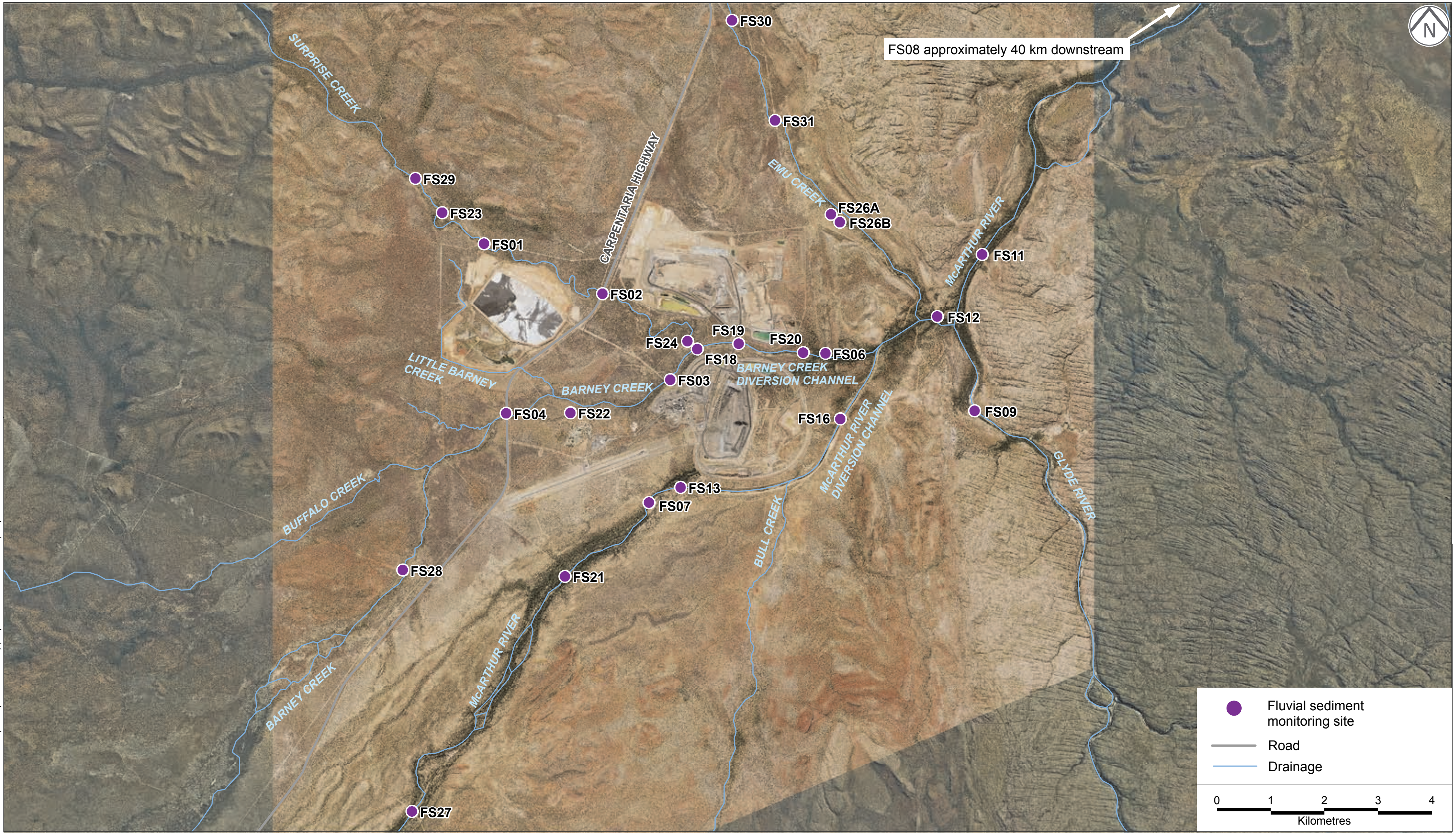
The aim of the marine sediment monitoring program is to assess impacts and manage risks of activities at Bing Bong Loading Facility with regards to the local marine environment. The specific objectives of the program are to (MRM, 2015a):

- 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.

FLUVIAL SEDIMENT MONITORING SITES - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.39



Source: KCB, 2016.

ERIAS Group | 01164D_1_F4-39_v1.pdf

- 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 2016 operational period, as part of:
  - The annual marine monitoring program (AMMP) undertaken in November 2015, with sampling sites as shown in Figure 4.34.
  - The nearshore sediment assessment undertaken in August 2016, with sampling sites as shown in Figure 4.40.
  - The trans-shipment area seafloor sediment assessment, undertaken in November 2015, with sampling sites as per Figure 4.41.
- Lead isotope ratios (in the AMMP and trans-shipment area assessments). Trace metals in marine sediments were analysed for the three programs as follows:
  - The AMMP analysed trace metals 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).
  - The nearshore sediment assessment analysed trace metals in the <63 µm fraction (after weak acid (1M HCl) digestion).
  - The trans-shipment area seafloor sediment assessment analysed trace metals in the <2 mm and <63 µm fraction (after strong acid (HCl/HNO_3) digestion).

Data obtained from the three marine sediment sampling programs during the 2016 operational period has been assessed against the Simpson et al. (2013) sediment quality guidelines, as opposed to ANZECC/ARMCANZ (2000) which was used in previous years. The IM commends this change.

4.12.3.2 New Controls – Implemented and Planned

New soil and sediment controls in the 2016 operational period are as follows:

- At the mine site, in response to IM recommendations, two additional surface soil monitoring sites have been established between S31 and S47 (see Figure 4.36):
  - Site S32 (south of the mine pit, approximately 200 m southwest of the SOEF, between the mine bund wall and the McArthur River diversion channel). A new dust monitoring site, DMV32, was established in a similar location.
  - Site S38 (south of the mine pit, approximately 200 m southeast of the SOEF, between the mine bund wall and the McArthur River diversion channel). A new dust monitoring site, DMV33, was established in a similar location.

NEARSHORE SEDIMENT ASSESSMENT SAMPLING SITES

McArthur River Mine Project

FIGURE 4.40

Source: Indo-Pacific, 2017.

ERIAS Group | 01164D_1_F4-40_v1.pdf

TRANS-SHIPMENT AREA SAMPLING SITES

McArthur River Mine Project

FIGURE 4.41

Note: trans-shipment area sampling for the 2016 operational period was undertaken in November 2015.

Source: Google Image 2015 and Indo-Pacific, 2016b.

- In relation to fluvial sediment management at the mine site:
  - To the northwest of FS19, the MIA (Mine Infrastructure Area) sump (see Figure 4.38) was under construction during the recent IM site visit. This new sump is designed to capture sediment and contaminated runoff from adjacent haul roads, and is expected to reduce inputs to the existing sediment sump northwest of the haul road bridge.
  - While not new controls as such, fluvial sediment sampling was reinstated at sites FS08 and FS20 (see Section 4.12.4.3 Successes).
  - Analysis as part of the 2015 and 2016 programs also included total sulfur as S, net acid producing potential (NAPP (ANC/MPA)) and net acid generation (NAG).
- For marine sediment management, new controls were confined to the AMMP, which in 2016 included sampling from an additional site to the immediate east of the Bing Bong Loading Facility shipping channel (East Creek) (see Figure 4.34) (Indo-Pacific, 2016a).

4.12.4 Review of Environmental Performance

4.12.4.1 Incidents and Non-compliances

Incidents

There were no reported incidents related to soil or sediment associated with the McArthur River Mine or Bing Bong Loading Facility during the 2016 operational period. A dust incident reported at the NOEF on 23 July 2016 occurred after the June 2016 soil sampling program; potential impacts of this incident on soils in the vicinity will be addressed in the next IM report.

The IM believes that the following should also have been reported as incidents:

- Exceedances of soil HILs for Pb within 1 km of the processing plant, and exceedances of EILs for other metals throughout the mine site and at Bing Bong Loading Facility.
- Exceedances of ANZECC/ARMCANZ (2000) interim sediment quality guideline trigger values in fluvial sediments at the mine site, including exceedances of SQG-high for Pb and Zn in the Barney Creek diversion channel at the haul road bridge.
- Exceedances of Simpson et al. (2013) interim sediment quality guideline trigger values within:
  - Marine sediments in the Bing Bong Loading Facility shipping channel and immediate area, including exceedances of SQG-high for Zn at a number of sites, and for both Zn and Pb in the bioavailable fraction at MS7A.
  - Nearshore sediments in Zone 2 to the immediate west of the loading facility (Pb only).

These are discussed under non-compliances below.

Non-compliances

The 2013-2015 MMP (MRM, 2015b) does not contain a definitive list of commitments against which to assess non-compliances (see Section 3.2.4). However, the IM has reviewed MRM's compliance register (environment) (MRM, 2017a), and discussion and recommendations within this chapter are consistent with that source. A summary of the soil and sediment guideline exceedances at the mine site and at or near Bing Bong Loading Facility are provided in the following sections.

Soils

During the 2016 operational period, a soil monitoring report was prepared (TAS, 2016) covering the period July 2014 to June 2016, and that report forms the basis of this review.

Table 4.60 summarises those soil analysis results for metals in the <2 mm fraction that exceeded NEPM (NEPC, 2013) guideline levels – yellow cells indicate exceedances of EIL criteria, while pink cells indicate exceedances of HIL(D) criteria (where 'D' relates to industrial sites). Blank cells relate to sites and sample depths for which no exceedance was recorded for the specified metal. Note that the NEPC (2013) criteria have changed from those in the original NEPM (NEPC, 1999), which MRM applied until 2015. As such, exceedances identified the 2016 operational period are not readily comparable to those in the previous period.

Table 4.60 – Soil Metal Results From June 2016 Exceeding NEPM (NEPC, 2013) Criteria

Group	Site No.	Sample Depth	Concentration (mg/kg) (Dry Weight) (Total Fraction)			
			As	Cu	Pb	Zn
Ore crushing plant/ROM pad <1 km group	S23	0 to 10 cm				474
	S23	40 to 50 cm				45
	S24	0 to 10 cm		103	1,600	3,220
	S24	40 to 50 cm				315
	S27	0 to 10 cm				208
	S27	40 to 50 cm				66
	S28	0 to 10 cm	267	259	5,720	10,000
	S28	40 to 50 cm		71.5	1,380	1,440
	S44	0 to 10 cm				311
	S44	40 to 50 cm	382	353	12,100	8,190
Ore crushing plant/ROM pad 1 to 2 km group	S08	0 to 10 cm				846
	S08	40 to 50 cm				1,150
	S25	0 to 10 cm				183
	S32*	0 to 10 cm				74.5
	S38*	0 to 10 cm				76.5
NOEF <2 km	S43	0 to 10 cm				124
	S43	40 to 50 cm				56.5
	S45	0 to 10 cm				53.0
	S45	40 to 50 cm				46.5

Table 4.60 – Soil Metal Results From June 2016 Exceeding NEPM (NEPC, 2013) Criteria (cont'd)

Group	Site No.	Sample Depth	Concentration (mg/kg) (Dry Weight) (Total Fraction)			
			As	Cu	Pb	Zn
TSF <2 km	S07	0 to 10 cm				252
	S07	40 to 50 cm				106
	S12	0 to 10 cm				46.0
	S15	0 to 10 cm				47.5
	S42	0 to 10 cm				548
Bing Bong Loading Facility	BBS02	0 to 10 cm				818
	BBS05	0 to 10 cm				106
	BBS07	0 to 10 cm				444
HIL (D) criteria#			3,000	240,000	1,500	400,000
EIL criteria#			80	45	440	45

* New soil monitoring sites in the 2016 operational period.
# HIL (D): commercial/industrial. EIL criteria are for 'fresh' contaminants, which have been in the soil for <2 years.

Exceedances of the HIL (D) criteria only occurred within 1 km of the processing plant, for Pb at sites S24, S28 and S44. Deeper soils at S28 exceeded the EIL, but not the HIL. Lead concentrations were particularly high at sites S28 and S44, with nearly four times the HIL in surface soils at the former, and eight times the HIL at depth at the latter. This may be indicative of mineralised soils in the area or, alternatively, may indicate that soils at this location contain significant amounts of introduced or mine-derived materials. The soil report (TAS, 2016) presents metals data for 2014 to 2016 – while this shows that Pb results in the low thousands of mg/kg are not uncommon at the most impacted sites (and results of nearly 6,000 mg/kg were also recorded in 2015 at S28), the result of 12,100 mg/kg at S44 is unusually high.

Only sites within 1 km of the ore crushing plant had exceedances of the EIL criteria for As and Cu. There were no exceedances of Mn or Cd HIL criteria; EILs do not apply for these metals under NEPC (2013).

Exceedances of the EIL criterion for Zn occurred at a number of sites within 2 km of key mine infrastructure, in both surface (0 to 10 cm) and deeper (40 to 50 cm) soil profiles. The highest results (>1,000 mg/kg) were primarily at sites within 1 km of the ore crushing plant, as well as S08 slightly further to the west and in the path of prevailing winds. Elsewhere at the mine site, exceedances of the EILs for Zn were relatively minor.

At Bing Bong Loading Facility, surface exceedances of the Zn EIL occurred at the three sites to the west of the concentrate shed – BBS02, BBS05 and BBS07. The highest result (818 mg/kg) was at the closest site to that facility, BBS02.

While the 2016 soil report (TAS, 2016) provided data for reference site S01, no results were presented for reference sites S04, S05 or S10 (nor a replacement for S05, as previously recommended by the IM). Additionally, results were not presented for sites S13, S17 or S19 near the TSF, or for site S31 on the southern side of the McArthur River diversion channel. 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.

Fluvial Sediments

Fluvial sediment monitoring sites with elevated concentrations of Pb and/or Zn (in the 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 (KCB, 2016a) are shown in Table 4.61. Yellow cells indicate exceedances of ANZECC/ARMCANZ (2000) SQGV, while pink cells indicate exceedances of SQG-high.

Table 4.61 – Fluvial Sediment Results from 2016 Showing Elevated EC and/or Elevated Concentrations of Metals in the <63 µm Fraction (by Acid Digestion Method)

Monitoring Site		EC (µS/cm)	Concentration (mg/kg) (Dry Weight)			
Number	Location		Pb		Zn	
			WA*	SA*	WA	SA
Surprise Creek						
FS02	Surprise Creek, downstream of the TSF at Carpentaria Highway	295	85.2	94.2	191	276
FS24[#]	Surprise Creek, upstream of FS18	4,520	27.3	42.2	33.3	86.5
Barney Creek						
FS22	Barney Creek near Little Barney Creek junction	145	73.9	-	32.1	-
FS03	Barney Creek diversion channel next to crushing plant	280	71.5	98.6	163	269
FS18	Barney Creek diversion channel/Surprise Creek confluence	2,660	104	141	225	367
FS19	Barney Creek haul road bridge (diversion channel)	3,380	241	273	495	749
FS20	Barney Creek diversion channel between FS19 and FS06	915	95.8	114	233	280
FS06	Barney Creek diversion channel/ unnamed creek confluence	400	51.1	65	106	146
SQG-high values*			220		410	
SQGV values*			50		200	

*WA = weak acid digestion. SA = strong acid digestion. [#] FS24 is included due to high EC results, despite no exceedances of metals criteria. *Criteria are as per ANZECC/ARMCANZ, 2000. Source: KCB, 2016a.

Results from FS03 (near the old PACRIM ROM pad and crushing plant) have improved since 2015, only exceeding SQGV for Pb and Zn; results at FS06 also improved somewhat. Results from FS19 (Barney Creek haul road bridge) were similar to last year, exceeding the SQG-high for Pb and Zn.

Only FS19 had exceedances for other metals/metalloids. Specifically, strong acid results returned minor exceedances of SQGV for As (30 mg/kg versus a value of 20 mg/kg) and Cd (1.55 mg/kg versus a value of 1.5 mg/kg) at this site. Results after weak acid digestion (bioavailable fraction) were well below relevant values.

All sites were well below the SQGV for As (20 mg/kg) after weak acid digestion (i.e., the bioavailable fraction). Strong acid digestion results for FS19 (at Barney Creek haul road bridge) continue to be above this level (30 mg/kg), although comparable to last year. Long-term average results from the Barney Creek reference site (FS28) indicate that this watercourse may have naturally higher As levels than others in the vicinity; however, the average results within the mine site remain nearly three times higher.

No sites exceeded the SQGV for Cd (1.5 mg/kg) in the bioavailable fraction, although after strong acid digestion, the result from FS19 was 1.55 mg/kg.

As shown in Table 4.61, results from strong acid digestion were consistently higher than those from weak acid digestion (representing the bioavailable fraction), as expected. Exceedances for Pb were only slightly higher under strong acid digestion, and as such, exceedances (i.e., SQGV versus SQG-high) were the same regardless of digestion method. Results for Zn were again notably higher after strong acid digestion, exceeding the SQGV at FS02 and FS03. The differences between results for strong acid versus 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.

While FS24 had no metals exceedances, this site returned a higher EC result than any other site (including diversion channel sites FS18 and FS19), and as such is included in Table 4.61 for comparison. It is noted by KCB (2016a) that FS24 was not flowing at the time of sampling and that EC results may have been influenced by evapo-concentration.

Marine Sediments

Within sediments sampled as part of the AMMP, analysis of the bioavailable fraction (<63 µm using a weak acid digestion) showed no exceedances of Simpson et al. (2013) criteria for As or Cd, and no exceedances of SQG-high values except at site MS7A, in the southwest of the swing basin. In this fraction, exceedances of SQGV for Pb and Zn were confined to the swing basin, as shown in Table 4.62, with concentrations of these metals being significantly higher at the swing basin sites than at other sites. Results for As outside the swing basin to the east (GB and 117) have improved in the 2016 operational period, while As, Pb and Zn results within the swing basin itself have deteriorated.

As shown in Table 4.62, Pb results 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. 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. 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. Analysis of the <2 mm fraction after strong acid digestion showed exceedances of SQGV for As outside the swing basin, at sites MS1B, 8, GB and 117, as well as along the western flank of the swing basin itself.

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) values for Zn, As or Cd. There were two exceedances of the SQGV values for Pb (50 mg/kg) in Zone 2, immediately to the west of the swing basin (see Figure 4.40).

Table 4.62 – AMMP Results from 2016 Showing Elevated Concentrations of Metals in Marine Sediment (by Size Fraction and Acid Digestion Method)

Monitoring Site		Concentration (mg/kg) (Dry Weight)							
		As		Cd		Pb		Zn	
Name	Location	WA*	SA*	WA	SA	WA	SA	WA	SA
8	Northwest of BBLF	7.4	34	0.05	0.03	15	18	8.5	5.0
GB	Northeast of BBLF	6.5	48	0.04	<0.02	22	26	8.0	6.0
117	East of BBLF	5.5	48	0.04	<0.02	15	24	6.7	5.0
MS1B	Northeast of BBLF	4.1	41	0.04	<0.02	11	23	19	6.0
MS5A	Swing basin NW	6.3	22	0.69	1.9	170	140	280	850
MS5B	Swing basin NE	5.1	18	0.59	1.3	130	99	230	580
MS6A	Swing basin W	4.5	23	0.34	2.1	110	160	140	940
MS6B	Swing basin E	5.6	12	0.71	0.56	180	49	280	220
MS7A	Swing basin SW	6.2	23	1.00	3.0	260	230	430	1,400
MS7B	Swing basin SE	2.6	14	0.21	0.38	52	44	85	160
SQG-high values*		70		10		220		410	
SQGV values*		20		1.5		50		200	

Data source: Indo-Pacific. 2016a. *WA = weak acid digestion, performed on the <63 µm sediment fraction. SA = strong acid digestion, performed on the <2 mm fraction.

For metals that do not have SQG value, Indo-Pacific Environmental (2017) calculated interim criteria based on concentrations in control zones. A number of individual exceedances of these interim criteria occurred in 2016, however, no analytes in potential impact zones were atypical of concentrations recorded from the wider survey area, and sediments within the immediate vicinity of the BBLF are considered to be of low risk (Indo-Pacific Environmental, 2017). Mean results (by zone) which exceeded the interim criteria included B in Zone 2, and Ba, Mn, Tl and U from BBDDP. Indo-Pacific Environmental (2017) recommends investigation of the potential sources of Tl in the vicinity of the BBDDP, given the high concentration of Tl in sediment at this location (2.7 mg/kg), and its potential toxicity.

Within the trans-shipment area sediment results (for both the <2 mm size fraction after strong acid digestion and the <63 µm size fraction after weak acid digestion), there were no exceedances of Simpson et al. (2013) values during the 2016 operational period, and results within the trans-shipment area continued to be generally lower than those in the control area (Indo-Pacific Environmental, 2016b).

4.12.4.2 Progress and New Issues

Progress

McArthur River Mining's progress and performance against previous IM review recommendations relating to soil and sediment issues is summarised in Table 4.63.

Table 4.63 – Soil and Sediment Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2015 Operational Period		
Gaps in monitoring programs	A gap in soil monitoring remains between S47 and S31, i.e., between the mine levee wall and the McArthur River diversion channel, to the southeast of the mine pit and potentially influenced by activities at the SOEF. McArthur River Mining should consider installing a soil monitoring site in this area during the 2016 operational year	Completed. Two new soil monitoring sites were established in this vicinity in 2016 – S32 and S38. These sites had minor exceedances of EILs for Zn (approx. 75 mg/kg versus EIL of 45 mg/kg), but these levels are no higher than those at sites at similar distances from mine infrastructure in the eastern half of the site
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	Ongoing. McArthur River Mining (2017b) comments that 'the long term trends for S28 and S44 will be presented in the 2017 Soil Report'
Surface soil EIL exceedances	The next soil monitoring report to be prepared by MRM should review long-term trends in Mn results across the mine site to assess the likely cause of widespread Mn EIL exceedances	Completed. McArthur River Mining (2017b) notes that 'there is no EIL for Mn in the latest version of the NEPM (NEPC, 2013). All Mn results recorded were well below the HIL for industrial / commercial areas'. The IM acknowledges this; this recommendation related to the previous version of the NEPM (NEPC, 1999) which had a much lower EIL that MRM applied/reported prior to 2016
EC results at FS04	The cause of high EC results at FS04 should be investigated during the 2016 operational year	Completed. The high EC results recorded at FS04 in April 2015 (along with associated high Na, Cl and K concentrations) were addressed by KCB (2016a), who suggest that sediments collected at this site may have contained a significant evaporative signature, with salts that had formed from evaporation rather than being indicative of the fluvial sediments themselves or a new source of major ions in the vicinity. Results in 2016 had returned to well within the normal range (130 µS/cm)
Fluvial sediment monitoring at FS08	Fluvial sediment monitoring at FS08 should be reinstated in the 2016 operational period	Completed. Site FS08 was reinstated in 2016
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	♦ McArthur River Mining (2017b) comments that this action has not been completed, but that 'exceedances will be recorded and investigated accordingly. If the exceedance is determined to be mine derived the exceedance will be raised as an incident'

Table 4.63 – Soil and Sediment Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2015 Operational Period (cont'd)		
Incident reporting (cont'd)		♦ No soil or sediment incidents were reported in the 2016 operational period, although exceedances were recorded for soils, fluvial sediments, nearshore sediments and marine sediments in the AMMP program ♦ This recommendation should be addressed in 2017
2014 Operational Period		
Surface soil contamination near Barney Creek haul road bridge	Given the surface soil Pb HIL(F) exceedances at S43 (correlating with dust exceedances at site D43), MRM should investigate the main sources of this issue and develop a formal plan for dust minimisation in the vicinity A replacement site for S43 should be established in the vicinity of Barney Creek haul road bridge, but situated on an area of natural (in situ) soils	Completed. S43 was reinstated in 2016 (after not being sampled in 2015) and was moved further to the west. Results from S43 are within a similar range to nearby sites. This item is closed from a soils perspective. Investigation of dust issues at DMV43 is discussed in Section 4.13 of this report
Fluvial sediment contamination at Barney Creek haul road bridge	Given ongoing contamination issues at FS19, MRM should close the remaining open drain holes in Barney Creek haul road bridge, with runoff directed into silt traps on either side of the bridge	Completed. McArthur River Mining (2017b) states that 'the Barney Creek [haul road] bridge drains have been managed to direct runoff into suitably built sediment traps'
	McArthur River Mining should continue the ongoing monitoring of water quality in silt traps at Barney Creek haul road bridge during the wet season, along with dewatering of poor quality water in the southeast and northwest traps to Pete's Pond/SPSD/SPROD	Completed. Water sampling was undertaken at the northwest and southeast silt traps (BC NWST and BC SEST) in 2015/16 (WRM, 2016). McArthur River Mining (2017b) reports that silt traps were dewatered over the 2015/16 and 2016/17 wet seasons
	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 As well as being cleaned out annually after the wet season, silt traps at Barney Creek haul road bridge should be inspected periodically and cleaned out as required at other times of the year, e.g., in the early wet season/ before significant floods are experienced (taking into account logistical constraints)	Completed. Silt traps at this location are cleaned out annually during the dry season, if required, however the IM has been advised that it is not logistically practical to clean these out once the wet season has commenced (Dobson and Hatfield, 2017) Construction of the new MIA sump is commended as an action to reduce inputs to existing sediment traps

Table 4.63 – Soil and Sediment Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Nearshore sediment monitoring	The Eastern Control group should be modified (moved slightly to the west) to reduce possible impacts/influences of outputs from Mule Creek and thereby be a more useful control group	Completed. The Eastern Control location was moved approximately 1 km westwards in the 2016 operational year (Indo-Pacific. 2017), which was reflected in lower Mn and Co results than last year (i.e., this should now be a more useful control group, more accurately reflect background levels of contaminants)
Surface soil contamination north/ northeast of the TSF	Results from soil site S42 in 2014 showed exceedances of the Pb HIL correlating with dust results. Results from August 2015 were well below Pb HILs and EILs; dust Pb and PM_{10} results at DMV42 in July and September 2015 were also low. If the next sampling event shows an increase in Pb at S42, MRM should investigate the reason for these temporal fluctuations at this site	Completed. Results at S42 for Pb were again below EILs in 2016
Surface soil monitoring	Soil site S05 should be removed from the surface soil sampling program, as it is neither an appropriate control site (being in the immediate vicinity of an ex-quarry) nor an appropriate impact site (as the impacts are more likely to be related to past quarry operations than to recent/ current mine operations)	Completed. No results were provided in the soil report (TAS, 2016) for S05. McArthur River Mining (2017b) notes that S05 was removed from the program
	A reference site to replace S05 will be required away from the quarry in a more 'natural' location	A replacement for S05 was not established in 2016. Within the 2017 operational year, S05 should be replaced with a new reference site that is not in the immediate vicinity of the 1970s quarry
2012 and 2013 Operational Periods		
Soil monitoring data – assessment	All future soil monitoring reports should evaluate soil monitoring data within the context of the revised NEPM (NEPC, 2013)	Completed. This latest soil report (TAS, 2016; covering both 2014-2015 and 2015-2016) applies the current NEPM (NEPC, 2013)
Fluvial and marine 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)	Data obtained in the three marine sediments programs during the 2016 operational period has been assessed against Simpson et al. (2013). The IM commends this change The fluvial sediment assessment (KCB, 2016a) has continued to reference ANZECC/ARMCANZ (2000). Although the guideline values applicable to MRM have not changed, the next version of MRM's MMP, as well as future fluvial sediment monitoring reports, should reference Simpson et al. (2013)

Table 4.63 – Soil and Sediment Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2012 and 2013 Operational Periods (cont'd)		
Fluvial sediments – monitoring results and responses	♦ Particular focus should be placed on site FS20 (elevated Zn and Pb in 2012/2013; not sampled in 2014 or 2015). Where required, mitigation implementation measures should be designed and implemented ♦ Data for reinstated fluvial sediment site FS20 should be reported in the 2016 operational year (Recommendations relating to FS06, FS18, FS22 and FS25 were closed out in the IM report for the 2015 operational period)	Completed. Site FS20 was reinstated and sampled during the 2016 operational year. Results exceeded SQGV values for Zn and Pb, although they were less than half that of the next site upstream on Barney Creek diversion channel (FS19)
General data interpretation and reporting	A reconciliation/discussion of actual versus proposed/committed sampling events should be provided	McArthur River Mining (2017b) notes that this task is 'underway but not yet completed as the 2016/17 monitoring period concludes 30 June 2017' No information was sighted for the 2014, 2015 or 2016 operational periods. The IM recommends this be done as part of 2017 reporting
Soil, fluvial sediment and marine sediment monitoring program – reporting	Quality assurance/quality control 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 2016 operational year	♦ The soils report (TAS, 2016) and the various reports addressing marine sediments (Indo-Pacific Environmental, 2016a; 2016b; 2017) provide no QA/QC data or discussion ♦ Some discussion of QA/QC is provided in the fluvial sediment monitoring report (KCB, 2016a), including relative percentage difference of duplicate samples. However, this could be improved ♦ The discussion provided for the surface water quality monitoring program within the current MMP (MRM, 2015a) provides a possible model for all aspects of the soil/sediment program

*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).

New Issues

Monitoring of surface soil control sites S04, S05 (or a replacement site as previously recommended) and S10 did not occur in the 2016 operational period. This should be recommenced in the 2017 period, as ongoing monitoring of control sites is necessary to provide a baseline/comparison for potentially impacted sites.

Reporting of soils results (TAS, 2016) is not clear as to which size fraction results relate to. For example, results Table A-1 (pages 68 to 73) is titled 'for <63µm fraction of soil', although some of the 2015 results in this table were identified in the previous IM review (ERIAS Group, 2016) as relating to the <2 mm fraction. Furthermore, page 10 of TAS (2016) states that 'analysis of contaminants of the <63µm fraction was only conducted in 2014'. This confusion should be resolved in the next soils report.

The unusually high EC results at FS24 in Surprise Creek (twice that of 2015 results, 15 times higher than at the next site upstream (FS02), and 1.7 times higher than the nearby downstream site (FS18)) may reflect evapo-concentration, and/or a potential new or increased source(s) of major ions in this vicinity. Surface water quality results at this location also showed high EC results, and the 2015 EC profile presented in KCB (2016b) implies that there may be a source of major ions to Surprise Creek to the south of the NOEF SPROD. This should be investigated during the 2017 operational year.

In relation to the nearshore sediment program, Indo-Pacific Environmental (2017) recommends investigation of the potential sources of Tl in the vicinity of the BBDDP, given the high concentration of Tl in sediments at this location (2.743 mg/kg), and its potential toxicity.

Recommendations to address these new issues are included in Table 4.64, which also includes recommendations that are ongoing (and in some cases have been modified).

4.12.4.3 Successes

Soils

In the 2016 operational period, successes relating to surface soils have included:

- The addition of surface soil monitoring sites S32 and S38 (and associated dust site DMV32 and DMV33). This has improved the soil monitoring program by addressing a gap in knowledge regarding potential impacts on soils from the recently constructed SOEF, between the mine levee wall and the McArthur River diversion channel, to the south of the open pit. Results from these sites in 2016, while showing exceedances of the EIL for Zn, are not elevated compared to similar sites.
- Exceedances of HILs again being confined to Pb results from sites within 1 km to the west and south of the ore crushing plant/ROM pad.
- Application of the current NEPM (NEPC, 2013) criteria in the 2016 soil monitoring report (TAS, 2016), as opposed to the original NEPM (NEPC, 1999) which were used in previous soil reports as well as in Volume 2 of the 2013-2015 MMP (MRM, 2015a).

Fluvial Sediments

In the 2016 operational period, successes relating to fluvial sediments have included:

- Reinstatement of fluvial sediment monitoring at FS20 (downstream extent of Barney Creek diversion channel) and FS08 (Burketown Crossing in Borroloola) in the 2016 operational period, in response to IM recommendations.
- To the northwest of FS19, construction of the MIA sump (see Figure 4.38) during 2017. This sump is designed to capture sediment and contaminated runoff from adjacent haul roads, and is expected to reduce inputs to the existing sediment sump northwest of the haul road bridge, which may also reduce impacts on fluvial sediments at FS19.

- Improved results from FS03 since 2015, exceeding only SQGV for Pb and Zn rather than SQG-high values.
- Relatively minor exceedances of SQG-high values, with these being confined to FS19 at the haul road bridge, within Barney Creek diversion channel. Results for this site were very similar to the previous operational period, implying that current MRM management actions have stabilised the issues at this location. The IM commends MRM on the improvements to date.

Marine Sediments

In the 2016 operational period, successes relating to marine sediments have included:

- In the nearshore sediment program, relocation of the 'Eastern Control' zone approximately 1 km westward in an attempt to reduce the influence of sediment flowing out of Mule Creek (Indo-Pacific, 2017).
- Assessment of data obtained from the three marine sediment sampling programs during the 2016 operational period against the Simpson et al. (2013) sediment quality guidelines, as opposed to ANZECC/ARMCANZ (2000) which was used in previous years.
- The addition of a new marine sediment site in the AMMP east of the Bing Bong Loading Facility shipping channel (East Creek). This site fills a monitoring gap between GB and 117, and should provide increased understanding of the movement of potential contaminants in this vicinity (Indo-Pacific Environmental, 2016a).
- Trans-shipment area sediment results demonstrating continued low risk, as shown by being below SQV values.

4.12.5 Conclusion

The 2016 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. Monitoring programs as well as management practices continue to improve.

Ongoing and new IM recommendations related to soil and sediment issues are provided in Table 4.64. These recommendations have been categorised as either high, medium or low. High priority recommendations focus on the need to report and manage soil and sediment exceedances as incidents, and utilise current assessment frameworks for soil and sediment monitoring data (i.e., Simpson et al. (2013) as replacement for ANZECC/ARMCANZ (2000)), along with new issues of high EC at FS24, Tl exceedances at BBDDP, and the need to reinstate soil control sites.

Table 4.64 – New and Ongoing Soil and Sediment Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
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	High

Table 4.64 – New and Ongoing Soil and Sediment Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
Fluvial and marine sediment monitoring data – assessment	The next version of the MMP, as well as future fluvial sediment monitoring reports, should reference Simpson et al. (2013) which has superseded ANZECC/ARMCANZ (2000)	High
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	Medium
Surface soil monitoring	Within the 2017 operational year, S05 should be replaced with a new reference site that is not in the immediate vicinity of the 1970s quarry, i.e., in a more 'natural' location	Medium
Soil, fluvial sediment and marine sediment monitoring program – reporting	Quality assurance/quality control 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 quality monitoring program within the current MMP (MRM, 2015a) provides a possible model for all aspects of the soil/sediment program	Medium
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	Low
New Items		
Surface soil monitoring	Monitoring of surface soil control sites S04 and S10 should be recommenced in the 2017 period	High
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)	Medium
EC results at FS24	The cause of high EC results at FS24 should be investigated during the 2017 operational year	High
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	High

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.
- Various reports prepared by MRM and its consultants (as listed in Appendix 1).
- Responses by MRM to recommendations raised in the previous IM report, as well as responses to comments raised by DPIR.
- Excel spreadsheets provided by MRM that contain collated laboratory analysis data.

4.13.2 Key Risks

The key risks associated with dust as described in the risk assessment (Appendix 2) 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 of 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 road vehicles to the marine environment, which may result in heavy metal contamination of seawater, marine sediments and marine biota.
- 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 offshore transport zone, which may lead to contamination of seawater and marine sediments, and bioaccumulation in marine biota.

4.13.3 Controls

4.13.3.1 Previously Reported Controls

Monitoring Program

As noted in MRM (2015a), the MRM dust monitoring program aims to:

- Assess the concentration of particulate contaminants in the 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 key elements of the dust monitoring program include:

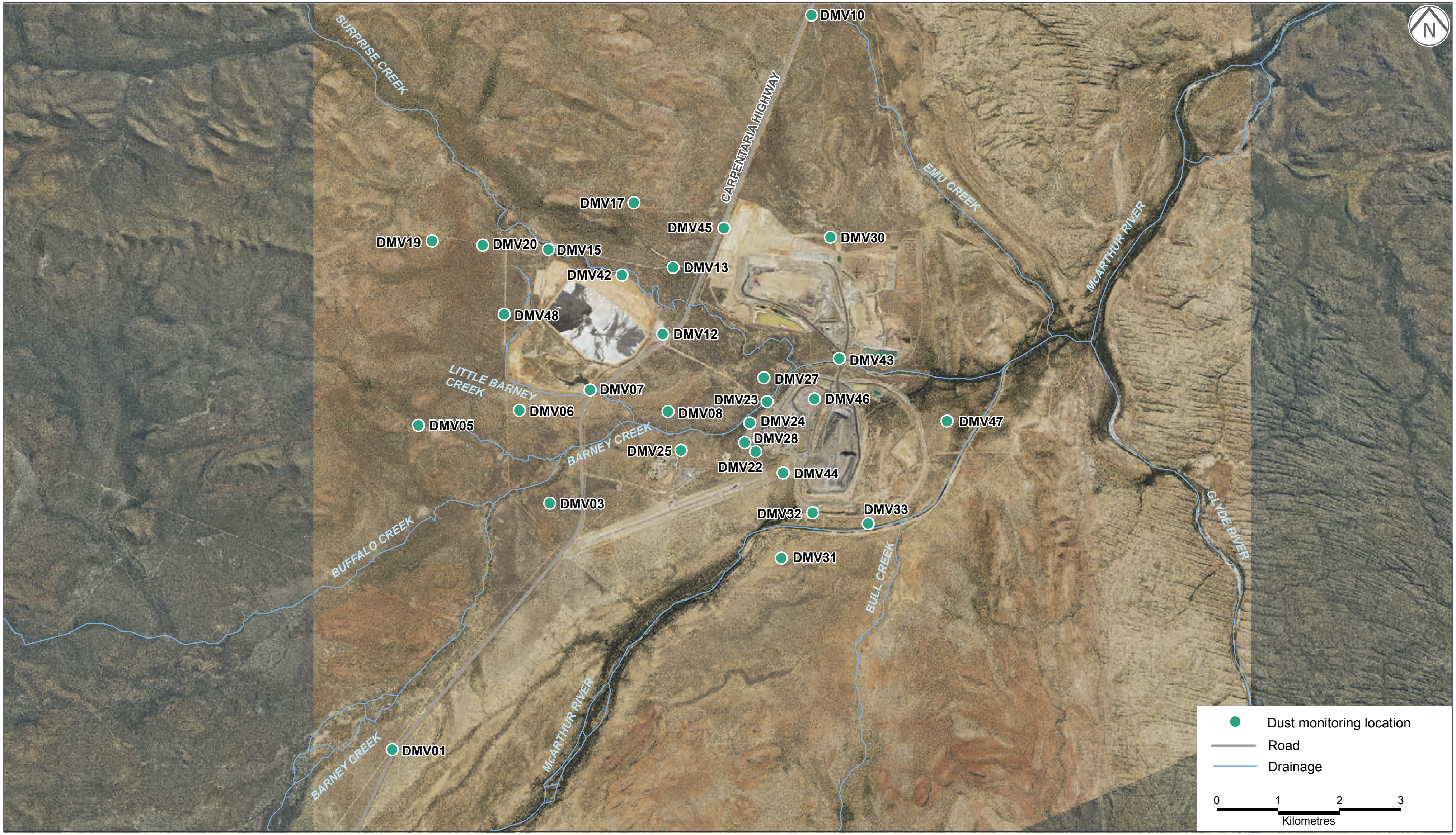
- An extensive network of dust monitoring sites. Within and near the mine site, 30 sites were sampled during the 2016 operational year, as shown in Figure 4.42. Monitoring locations have been selected on the basis of the prevailing wind directions and potential sources of fugitive dust emissions. Key dust sources at the mine site include:
  - The processing plant, ore crushing circuit and run of mine (ROM) pad.
  - Overburden emplacement facilities: NOEF, WOEF and SOEF.
  - Haul roads.
  - The TSF.
- At Bing Bong Loading Facility, six sites were sampled during the operational year, as shown in Figure 4.43. Key dust sources in the vicinity of the loading facility include:
  - The MRM concentrate shed and loading conveyor.
  - The dredge spoil ponds located to the south of the loading facility.
  - External to MRM's operations, adjacent to the northwest of Bing Bong Loading Facility, the Western Desert Resources (WDR) iron ore stockpile and loading conveyor. This facility ceased operations during 2014. Limited rehabilitation activities have occurred.
- Throughout the 2016 operational year, low-volume portable air samplers (referred to as 'Dust MiniVol' (DMV) samplers[22]) were deployed at all 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 (≤PM_{10}).
- Samples were analysed for parameters associated with airborne particulate matter, including:
  - Total suspended particulates (PM_{10}).
  - Particulate base metals: As, Cd, Cu, Pb, Mn and Zn.

[22] The low-volume dust samplers used are Airmetric MiniVol Tactical Air Samplers.

DUST MONITORING LOCATIONS - McARTHUR RIVER MINE

McArthur River Mine Project

FIGURE 4.42



DUST MONITORING LOCATIONS - BING BONG LOADING FACILITY

McArthur River Mine Project

FIGURE 4.43

- Quality assurance/quality control at the mine site:
  - Duplicate sampling was undertaken at 11 of the 30 mine site dust monitoring sites sampled between July 2015 and June 2016 (TAS, 2016).
  - Field blank sampling was initiated at the mine site and Bing Bong Loading Facility during 2015, and nine blank samples were recorded between October 2015 and June 2016

General Controls

Measures to control dust at the mine site include:

- Regular watering or other dust suppression treatment of haul roads, ore stockpiles and other exposed areas around the mine site subject to vehicle and machinery movements (MRM, 2015c).
- At the NOEF, dust is managed through the 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.
- At the TSF:
  - Capping of TSF Cell 1 with a clay layer to minimise generation of tailings dust.
  - Tailings deposition via 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.
- A concrete base at the mine site external concentrate storage area (bulk concentrate stockpile), which is graded towards contaminated water drainage systems.
- At the processing plant:
  - Covered dust generation points, including transfer points between conveyors and at the base and top of the secondary crusher.
  - Water addition point to the head drum of the stockpile feed conveyor.
  - A booster pump and spray bar for the head drum to improve suppression of dust as the crushed material falls to the stockpile surface.
  - Watering around the general area by water trucks.
  - Use of water sprays in the primary crushing plant and conveyors.
  - Double-layered skirting on horizontal rubber guarding.
  - A dust extraction system fitted to the secondary tertiary crusher building.
- A vehicle washdown facility for all vehicles prior to leaving the mine site for Bing Bong Loading Facility and other destinations.

- A dust extraction system in the concentrate shed at the mine site (consisting of an extraction fan and a wet scrubber) to reduce particulate emissions from the shed.
- A mini street-sweeper, which is used around the process plant to remove small spills.

Measures to control dust at the Bing Bong Loading Facility include:

- Doors on the concentrate shed to reduce fugitive emissions (during the 2014, 2015, 2016 and 2017 site visits, the IM was informed that at least some of the doors were not operational and remained open at all times (Plate 4.13) – this ongoing issue is discussed in Section 4.13.4).

Plate 4.13 – Replaced Side Doors at Bing Bong Loading Facility Concentrate Shed

June, 2017.

- A system designed to maintain a negative pressure differential in the concentrate shed, with dust extraction around the main entry and exit point, 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).
- Covered conveyor belts at the loading facility to minimise fugitive dust emissions during loading of concentrate to the MV Aburri.
- Covers on concentrate transport vehicles to minimise dust.
- The concrete apron (at the ship-loader) is washed down following completion of every ship-loading event.
- A truck wheel wash to minimise dust emissions from heavy vehicles leaving the facility.

4.13.3.2 New Controls in the Reporting Period

Existing

New dust controls[23] implemented in the 2016 operational period are as follows:

- At the mine site, two additional low-volume dust monitoring sites were established (see Figure 4.42): sites DMV32 and DMV33, both between the mine bund wall and the McArthur River diversion channel (south and southeast, respectively, of the mine pit and SOEF). These sites commenced operation in December 2015. New soil sites S32 and S38 were established in similar locations. These sites fill a previous gap in the monitoring program coverage.
- Quality assurance/quality control (QA/QC) initiated at Bing Bong Loading Facility (TAS, 2016): duplicate sampling commenced in November/December 2015 and was undertaken at two of the six dust sites sampled during the operational period.
- Preparation of gradient contour maps based on interpolation of ambient dust data, including average annual and 24-hour maximum PM_{10} concentration, and 24-hour maximum Pb and Zn concentrations (TAS, 2016). These show graphically an estimation of results in relation to adopted guidelines across the mine site and as far north and south as control sites DMV01 and DMV10.
- During January/February 2016, two tapered element oscillating microbalance (TEOM) units were established – one at Bing Bong Loading Facility near the camp, and one at McArthur River Mine near the mine site accommodation. These units continuously record PM_{10} and are fitted with weather monitoring equipment. In addition to the new TEOM units, MRM has installed a high-volume air sampler (HVAS) at the mine site, between the primary crusher and Barney Creek, to increase the frequency, duration and accuracy of dust monitoring in this area. This unit is operating for 24 hours every 6 days as per Australian Standards (MRM, 2016a). Raw data for the 2016 operational period has been supplied to the IM for these sites, but analysis has not been undertaken/provided as yet. McArthur River Mining (2016a; 2017a) notes that this data will be reported in the 2016 to 2017 air monitoring report. It will also be discussed in the next IM report.
- A dust management plan and improved controls were developed specifically for the reclamation of low grade ore and waste rock from the NOEF West A during Q3 of 2016 in response to a dust incident (see Section 4.13.4.1 for more detail).

Controls Planned for or Implemented After the 2016 Operational Year

The following dust controls were planned during the 2016 operational year, and have been or are intended to be implemented during 2017 or later operational years. They will be addressed in future IM reports as appropriate:

[23] While MRM has initiated various new aspects of monitoring, modeling and reporting with regards to SO_2 (including a site-wide management plan) during the 2016 operational period, SO_2 emissions relate to human health and amenity, and as such are outside the scope of the IM review.

- As stated in MRM (2015b), in addition to those measures already initiated, MRM intends to develop formal dust mitigation plans for both the Bing Bong Loading Facility and the mine site, targeting the most impacted areas as identified by dust monitoring. This intention evolved during the 2016 operational period to be a formal and comprehensive Air Quality Management Plan (AQMP) to be developed by an independent air quality specialist (Todoroski Air Sciences (TAS)). The IM was informed during the 2017 site visit that this AQMP was in preparation and will include review of options to increase sample frequency and/or duration at monitoring sites. The AQMP is intended to provide overarching support, analysis and evaluation for management of air quality at the mine site and Bing Bong Loading Facility. Performance in accordance with this document will be reviewed and reported annually (MRM, 2016i).

- The DME (now DPIR) issued an instruction to MRM in March 2016 requiring an independent third party consultant to investigate whether the placement and containment of mining waste at the NOEF is causing, or may cause, environmental harm to the receiving environment. In response to this requirement, MRM engaged EcoMetrix (2017) to prepare an investigation report, which includes, among other matters, discussion of air quality impacts including dust. As this report was prepared towards the end of the 2017 operational period, relevant findings will be discussed in next year's IM report.

4.13.4 Review of Environmental Performance

4.13.4.1 Incidents and Non-compliances

Incidents

July 2016 NOEF Dust Incident

There was one reported incident related to dust at the McArthur River Mine during the 2016 operational period. On 23 July 2016, significant dust plumes were observed in the vicinity of the NOEF, and a DME (at the time, now DPIR) mining officer undertook an inspection of the site (DME, 2016a). It was identified that reclamation and cartage of low grade ore and waste rock from the NOEF was generating significant quantities of dust. The DME considered this to be a reportable environmental incident on the basis of environmental harm/likely nuisance. McArthur River Mining was instructed (DME, 2016b) to immediately cease these operations and not to recommence until a dust management plan for the operations had been submitted to the DME. The DME required that a written incident report be submitted by 9 August 2016 including (DME, 2016a):

- A determination of the cause of the incident.

- Information about remediation action taken or to be taken (including identification of the extent and nature of the environmental harm associated with the underlying issue).

- Recommendations for the prevention of further similar incidents.

McArthur River Mining complied with the above instructions and a notice of environmental incident (MRM, 2016b) was submitted to the DME by MRM on 29 July 2016, along with a letter (MRM 2016c) committing to complete the above-described report as instructed.

The incident report along with a letter (MRM, 2016d) was submitted by MRM on 9 August 2016, advising that ‘mining the NOEF with insufficient dust suppression available caused visible dust from the mining activity’, and that dust mitigation measures associated with the activity were included in the dust management plan. This incident investigation report (MRM, 2016e) noted that:

- Existing MRM dust suppression techniques (water carts and sprinkler system) are effective when in use. The incident was the result of insufficient dust suppression being applied.
- Remediation and corrective/preventative actions involved:
  - Re-establishing a water line from SEPROD to the NOEF to enable effective dust suppression via a sprinkler system, prior to recommencement of activities.
  - Reviewing the current MRM dust management plan.
  - Developing a detailed risk assessment/job safety analysis (JSA) for dust mitigation with regards to recommencement (provided to DME).
  - Developing/implementing a dust trigger action response plan (TARP) (provided to DME).

A follow up letter from MRM to DME on 17 August confirmed that sprinklers had been re-established on the NOEF, monitoring data had been provided to the DME to demonstrate effectiveness of dust suppression systems, additional budget had been allocated to water cart requirements, and the above-mentioned JSA and TARP had been provided (MRM, 2016f).

The NOEF West A Reclamation Dust Management Plan (MRM, 2016g) was duly submitted to DME on 31 August 2016. A response from DME on 2 September indicated that the plan required further detail, including assessment of receptors and exposure pathways, sampling design and analysis QA/QC, and justification for standards used (DME, 2016c).

An updated report (MRM, 2016h) with further detail was submitted to DME along with a letter (MRM, 2016i) on 19 September, addressing each of the DME’s requests as per DME (2016c). The letter also noted that MRM had committed to engaging an independent third party to develop an AQMP encompassing all operational areas of the mine site (see Section 4.13.3.2). The AQMP will address DME’s information requests in more detail.

A response from DME on 27 September 2016 welcomed the commitment to develop an AQMP, and confirmed that MRM had satisfied instructions in relation to the incident and that ore reclamation activities could recommence at NOEF West A (DME, 2016d). Due to DME’s concerns regarding the adequacy of the existing dust monitoring program at the mine site, recommencement of these activities was conditional on supervision of DME officers to ensure operational controls are effective at managing dust.

Reclamation operations at NOEF West A were completed between 5 October and 23 November 2016, and a final report was submitted to the DME on 16 December (MRM, 2016j), including dust monitoring data, and information on operations and controls, incidents and exceedances. This report concluded that the mitigation measures and control strategies implemented as per the

NOEF West A Reclamation Dust Management Plan (MRM, 2016h) had been successful in minimising the dust levels from the NOEF during this period. Results showed that reclamation activities did not discernibly increase the emissions of dust around site. However, the results highlight the requirement for further dust mitigations in the vicinity of Barney Creek haul road bridge. Initiatives for dust suppression in this area will be elaborated upon within the AQMP mentioned above (being developed during 2017).

Other Incidents

There were no other reported or unreported incidents recorded during the reporting period.

Non-compliances

The 2013-2015 MMP (MRM, 2015c) does not contain a definitive list of commitments against which to assess non-compliances (see Section 3.2.4). However, the IM has reviewed MRM's compliance register (environment) (MRM, 2017b), and discussion and recommendations within this chapter are consistent with that source. Some general observations are listed below, along with a review of air quality guideline exceedances at or near the mine site and Bing Bong Loading Facility during the operational period. Air quality standards as shown in Table 4.65 have been adopted by MRM (TAS, 2016).

Table 4.65 – Adopted Air Quality Standards

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)
Pb	24 hours	0.5 µg/m^3	-	Ontario MOE (2012)
	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})$^\#$	-	Ontario MOE (2012)

* The 2016 dust report (TAS, 2016; Table 4-1) cites NEPC (2016) as the source for the Pb annual criterion, and Ontario MOE (2012) as the source for the Cd 24-hour criterion. However, it leaves the respective maximum concentrations blank for these parameters on the basis of limits of reporting. This is discussed further below. †Cd criterion is below LOR.
\# 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'.

Todoroski Air Sciences (2016) states that 'the NEPM[24] Ambient Air Quality Measure goal for annual average Pb is 0.05 µg/m³', and on this basis argues that MRM Pb data cannot be compared to this goal, due to a limit of reporting (LOR) of 0.07 µg/m³. This statement is incorrect – the NEPC (2016) annual criterion for Pb is 0.05 µg/m³, which is well above the LOR. The next dust report should correct this statement and include the NEPC (2016) maximum annual average concentration for Pb in the table of adopted standards.

[24] 'The NEPM' is the Australian National Environment Protection (Ambient Air Quality) Measure (NEPC, 2016).

The revised NEPM (NEPC, 2016) has dispensed with allowable maximum days of 24-hour exceedances for PM_{10} and adopted a maximum annual average criterion (25 µg/m^3) in addition to the 24-hour one (50 µg/m^3). Individual exceedances at the mine site and loading facility (within a single 24-hour period) of the maximum allowable concentration of PM_{10} for a one-year averaging period do not exceed that standard.

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 exceedences of the standard are reported. Dust monitoring is currently conducted monthly for a 24-hour period at each DMV site, however due to site constraints, sites cannot always be sampled each month (TAS, 2016). As such, some statistical calculations based on daily data that are less than 75% complete in each calendar quarter (NEPC, 2002) cannot be made strictly in accordance with the NEPM. Individual (24-hour) exceedances of the specified maximum concentrations have been 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.

A summary of the individual 24-hour air quality exceedances at the mine site and Bing Bong Loading Facility during the operational period is provided in Table 4.66. The ambient dust monitoring report (TAS, 2016) covers the first nine months of the operational period (October 2015 to June 2016); the IM has sighted data for the remainder of the operational period.

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 2016 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)	Days/Total*	Results (Month)
McArthur River Mine Site					
<1 km from processing plant	DMV22#	3/12	56.67 (Oct), 77.08 (Nov), 105.97 (May)	4/10	0.74 (Oct), 1.67 (Nov), 0.67 (Mar), 1.33 (May)
	DMV23#	1/12	51.81 (May)	-	-
	DMV24#	-	-	1/12	0.57 (Jun)
	DMV28#	2/12	68.47 (May), 101.94 (Jun)	3/12	0.60 (Oct), 0.68 (May), 1.29 (Jun)
1-3 km from processing plant	DMV31#	2/10	52.78 (Oct), 64.17 (Aug)	-	-
	DMV33	1/10	82.50 (Aug)	-	-

Table 4.66 – 24-hour Air Quality Exceedances in the 2016 Operational Period (cont'd)

Monitoring Group	Site	Exceedances of the Mean Maximum Concentration Within a 24-hour Monitoring Period			
		$PM_{10} \geq 50$ µg/m^3		Pb ≥0.5 µg/m^3	
		Days/Total*	Results (Month)	Days/Total*	Results (Month)
McArthur River Mine Site (cont'd)					
<2 km from NOEF	DMV43#	3/11	54.03 (May), 73.47 (Jul), 73.89 (Aug)	-	-
	DMV30#	-	-	-	-
<2 km from TSF	DMV42#	1/12	75.28 (Oct)	-	-
	DMV48#	1/11	81.25 (Nov)	-	-
	DMV12#	-	-	-	-
Bing Bong Loading Facility					
Bing Bong Loading Facility	BBDMV02#	-	-	1/11	0.83 (May)
	BBDMV03	1/12	77.36 (Jul)	-	-
	BBDMV04#	1/11	62.78 (Sep)	-	-
	BBDMV07#	-	-	1/10	0.56 (May)

*Represents number of days of exceedances out of total sampling events in the period, e.g., for DMV22, there were 3 PM_{10} exceedances and 12 sampling events in total during the 2016 operational year.
Sites which exceeded the annual average criterion (25 µg/m^3) between July 2015 and June 2016; sites DMV12 and DMV30 exceeded the annual criterion but not the 24-hour criterion.

McArthur River Mine

Within the 2016 operational 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:

- As expected, the majority of individual exceedances (six) occurred within 1 km of the processing plant. Site DMV22 had the highest PM_{10} results at the mine site in May 2016, and nearby site DMV28 had a similar result in June. As in the previous two operational periods, site DMV22 (southwest of the processing facility) had the most exceedances of any site in this group.

- Three exceedances occurred within 2 km of the NOEF, all at site DMV43 near the haul road bridge. There were also two exceedances within 2 km of the TSF, one to the north near Surprise Creek (DMV42) and one to the west (DMV48). Three exceedances also occurred within 1 to 3 km of the processing plant – two at DMV31, on the far side of the McArthur River diversion channel, and one at new site DMV33, southeast of the SOEF.

In terms of annual averages, TAS (2016) reports that between July 2015 and June 2016, 10 of the mine site monitoring sites (with sufficient data for an annual average calculation) exceeded the annual PM_{10} criterion (see note to Table 4.66). These were in the same groups as the 24-hour exceedances. The highest annual average recorded within that period was at DMV22, with average PM_{10} of 49.2 µg/m^3.

At the mine site, exceedances of the standard for Pb as PM_{10} during the 2016 operational period were as follows:

- The maximum Pb concentration standard of 0.5 µg/m^3 was exceeded during individual 24-hour periods (noting that the NEPC (2016) averaging period is one year) at three mine site monitoring locations (DMV22, 24 and 28) (see Table 4.66). These sites are all within 1 km to the west or southwest of the processing plant (see Figure 4.42), and ore/ concentrate materials processed by the facilities in this vicinity are likely to be the source of these dust exceedances. The highest individual Pb result was 1.67 µg/m^3 at DMV22 in November 2015.
- While daily Pb results illustrate the air quality of the site, NEPC (2016) specifies that the Pb standard of 0.5 µg/m^3 is in relation to a one-year averaging period. Exceedances of annual averages for Pb were not reported by TAS (2016). However, from the raw data provided to the IM, the average of Pb results collected during the operational period gives a result of 0.54 µg/m^3 for DMV22. No other site exceeded the annual criteria.
- As per the previous operational period, there were no exceedances of Pb criteria in other monitoring groups at the mine site. Again, there were no Pb exceedances (or other metals exceedances) at site DMV43, which had metals results well below that of the monitoring group within 1 km of the processing plant. This supports the assertion proposed in the 2014 operational year that dust issues at DMV43 derive from lower grade waste rock being hauled to the NOEF.

There were no exceedances of other metals criteria (Zn, Mn, As or Cu) at the mine site during the 2016 operational period.

Bing Bong Loading Facility

Within the 2016 operational period, particulates as PM_{10} exceeded the maximum concentration standard of 50 µg/m^3 during single 24-hour averaging periods once at each of the two dust monitoring sites within the Bing Bong Loading Facility dredge spoil ponds (BBDMV03 and BBDMV04), both within the 2016 dry season (see Table 4.66). No PM_{10} exceedances were recorded at the loading facility sites.

In terms of annual averages, TAS (2016) reports that between July 2015 and June 2016, three of the Bing Bong Loading Facility monitoring sites (with sufficient data for an annual average calculation) exceeded the annual PM_{10} criterion (see note to Table 4.66). The highest annual average recorded within the July to June period was at BBDMV04 with average PM_{10} of 29.1 µg/m^3 (this site also exceeds the criterion when reviewing data for the operational period of October 2015 to September 2016).

At Bing Bong Loading Facility, exceedances of criteria for Pb as PM_{10} during the operational period were as follows:

- The maximum Pb concentration standard of 0.5 µg/m^3 was exceeded during individual 24-hour periods once at each of two monitoring locations (BBDMV02 and BBDMV007), during May 2016 (see Table 4.66). These sites are both to the west of the ship loader and to the northwest of the concentrate shed (see Figure 4.43), in the path of prevailing winds from these facilities. The highest Pb result from loading facility sites was 0.83 µg/m^3 at the closer of the two sites, BBDMV02.

- While daily Pb results illustrate the air quality of the site, NEPC (2016) specifies that the Pb standard of 0.5 µg/m^3 is in relation to a one-year averaging period. Exceedances of annual averages for Pb at Bing Bong Loading Facility were not reported by TAS (2016). The IM has reviewed the raw data provided and notes that during the 2016 operational period, no sites exceeded the average annual criteria for Pb.
- There were no exceedances of Pb criteria in the dredge spoil ponds monitoring group.

There were no exceedances of other metals criteria (Zn, Mn, As or Cu) at the Bing Bong Loading Facility during the 2016 operational period.

4.13.4.2 Progress and New Issues

Progress

McArthur River Mining's progress and performance against previous IM review recommendations relating to dust issues is outlined in Table 4.67.

Table 4.67 – Dust Recommendations from Previous IM Reviews

Subject	Recommendation	IM Comment
2015 Operational Period		
Dust management planning – Bing Bong Loading Facility	McArthur River Mining should develop a formal dust mitigation plan for Bing Bong Loading Facility, targeting the most impacted areas as identified by dust monitoring (i.e., BBDMV02 and BBDMV07)	No formal plan for dust minimisation at Bing Bong Loading Facility has been developed to date. McArthur River Mining (2017a) states that this is underway and will be covered by the AQMP and TARP. This should be completed during the 2017 operational period
Dust monitoring and analysis	McArthur River Mining should implement duplicate sampling and field blank sampling as part of the Bing Bong Loading Facility dust monitoring program to assist with quality assurance/quality control	♦ Duplicate sampling was initiated in late 2015 and undertaken at two of the six Bing Bong Loading Facility dust sites sampled during the 2016 operational period ♦ According to TAS (2016), field blank sampling was undertaken at the loading facility during the 2015 operational period. It is unclear whether the field blank results reported for December 2015 to April 2016 relate to the mine site or the loading facility. No comment is provided in TAS (2016) regarding these blank samples ♦ Dust reporting for 2017 should include separate field blank samples for the mine site and loading facility, with comment on the results
	McArthur River Mining should calculate gradient contours based on ambient dust data from the mine site, so that adopted guidelines can be applied at the mine lease boundaries and at nearby public and recreational areas	♦ Gradient contour maps based on interpolation of ambient dust data were provided in TAS (2016), including average annual and 24-hour maximum PM_{10} concentration, and 24-hour maximum Pb and Zn concentration. This effort is commended ♦ While it is noted that this is interpolated (rather than modelled) data, in the 2017 dust report MRM should add a comment as to the low

Table 4.67 – Dust Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2015 Operational Period (cont'd)		
Dust monitoring and analysis (cont'd)		potential for dust impacts at the mine lease boundaries and nearest sensitive receptors, as demonstrated by previous modelling (it is noted that the air quality impact assessment report provided as an appendix to MRM's 2017 EIS (MRM, 2017c) included modelling/assessment of likely levels at relevant sensitive receptors)
	The IM recommends that the frequency of monitoring for PM_{10} and Pb be temporarily increased at two high impact sites (DMV22 or 23, and DMV43) and one reference site (DMV01 or DMV10), to be sampled once every six (6) days for a one-year period, in order to determine whether the current monthly monitoring approach is statistically valid	♦ This data was not presented for the 2016 operational period ♦ McArthur River Mining (2017a) states that the revised monitoring program in the AQMP will cover increased frequency and analysis of Pb at key locations for both DMV samplers and dust deposition; this will include 24-hour sampling with low-volume air samplers every 12 days. The findings of this monitoring should be reported during 2017
	The IM recommends that MRM reviews and presents all available long-term dust data (in particular, PM_{10} and Pb results) for the mine site and Bing Bong Loading Facility, to inform understanding and management of dust issues at each site	♦ Dust data from July 2014 was presented in TAS (2016). McArthur River Mining (2017a) states that all long-term low volume air sampler data is to be included in the 2017 ambient dust monitoring report ♦ In addition to including long-term data, the 2017 dust report should also review/discuss long-term trends in relation to dust
Dust management – TSF	An area immediately east of the decant wall on the TSF Cell 2 north wall is not being covered by tailings during the current deposition cycle. Discharge pipelines should be extended to this area to reduce dust emissions from this area	♦ McArthur River Mining (2017a) states that this action (extension of discharge pipelines) is completed, but that deposition here is an issue due to embankment height, and dust may need to be managed through irrigation until the embankment raise is completed. No comment is provided by MRM on whether irrigation has been/is being undertaken at this location in the interim ♦ Action (irrigation and/or completion of the embankment raise with associated tailings deposition) should be completed and reported during 2017
Incident reporting/ management of exceedances	Exceedances of dust guideline levels should be reported as environmental incidents, with subsequent investigation to address the reasons for exceedances and potential management measures	♦ Dust guideline exceedances were not reported as environmental incidents during the 2016 operational period ♦ McArthur River Mining (2017a) states that this approach has been adopted for inclusion in the 2017 MRM AQMP. Subsequent correspondence from MRM (2017d) has indicated that the AQMP lists compliance sites where the NEPM standards are considered 'reasonably applicable', and exceedances of the criteria adopted at these sites would be reported as incidents

Table 4.67 – Dust Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2015 Operational Period (cont'd)		
Incident reporting/ management of exceedances (cont'd)		♦ The IM accepts that given the intent of the NEPM (NEPC, 2016), exceedances of these criteria within the mine site and Bing Bong Loading Facility need not be reported as incidents. However, it is appropriate that exceedances 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 NEPM exceedances on the mine site and Bing Bong Loading Facility. If the NEPM criteria are considered inappropriate, an alternative assessment framework should be considered (e.g., more appropriate criteria with triggers for management actions)
2014 Operational Period		
Dust monitoring	Install high-volume air samplers in the area adjacent to the WOEF ROM Pad and at the Bing Bong Loading Facility, to improve the overall quality and type of data collected. Target completion date: 30 November 2015	♦ Raw data for the TEOM units (at Bing Bong Loading Facility and near the mine site accommodation) and the HVAS unit (installed at the mine site between the primary crusher and Barney Creek) was provided to the IM for the 2016 operational period, but this data was not discussed by TAS (2016). McArthur River Mining (2016a; 2017a) notes that this data is to be included in the 2016-17 Air Monitoring Report ♦ Data from the TEOM and HVAS units should be reported/analysed and discussed during the 2017 operational period
Dust management at McArthur River Mine	McArthur River Mining should develop a formal plan for dust minimisation in the vicinity of DMV43. This may be part of a formal dust mitigation plan for the mine site as a whole, targeting the most impacted areas as identified by dust monitoring	♦ Results from the 2016 operational period show that there are ongoing PM_{10} exceedances at DMV43 ♦ As noted in ERIAS Group (2016), the cause of dust issues at this location has been identified as heavy equipment movements along the entrance ramps to the haul road bridge and dust from haul trucks travelling from the open pit to the NOEF; PM_{10} concentrations are strongly correlated with volume of waste rock haulage, outside of 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 ♦ No formal plan for dust minimisation at DMV43 has been developed to date. McArthur River Mining (2017a) states that this is underway and will be covered by the AQMP and TARP. This should be completed during the 2017 operational period

Table 4.67 – Dust Recommendations from Previous IM Reviews (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
Dust management at Bing Bong Loading Facility	The doors of the Bing Bong Loading Facility concentrate shed should be repaired or replaced as soon as practicable. Once doors are operational, they should be kept closed as often as possible	♦ During the June 2017 site visit, the IM observed that the two smaller flanking roller doors on either side of the central/main door (on each side of the concentrate shed) have now been repaired or replaced (see Plate 4.13). This action by MRM is commended ♦ As per the past two years, the larger central/ main concentrate shed doors were still not operational. McArthur River Mining advised that replacement of these doors was imminent in June 2017 ♦ 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 (e.g., May 2016 Pb exceedances at BBDMV02 and BBDMV07)
	The dust extractor system in the concentrate shed should be repaired to an operational condition	♦ 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 ♦ During the 2017 site visit, it was apparent that the vents associated with the dust system were damaged and required replacing (Plate 4.14). The IM was advised by MRM that replacement was planned ♦ 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
	The bitumen surface surrounding the Bing Bong Loading Facility is failing in a number of areas, with formation of potholes apparent. These should be repaired to avoid future soils, water and/or dust management issues	♦ During the June 2017 site visit: – The IM observed that the bitumen surface was in worse repair than during the previous two site visits – McArthur River Mining advised last year that repairs were due to start by June 2016, 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 June 2017 ♦ McArthur River Mining (2017a) states that these works will be combined with a roadworks project planned for 2018. Recommendation ongoing until these roadworks are completed

Plate 4.14 – Dust Vent at Bing Bong Loading Facility Concentrate Shed

June, 2017.

The IM notes that DMV05 was still part of the 2016 dust monitoring program (though S05 was excluded from the soil program in response to an IM recommendation). As noted in previous years (ERIAS Group, 2015; 2016), the IM contends that DMV05 is not an appropriate control site, as it is in the immediate vicinity of a quarry that operated in the 1970s, and is also near currently active dirt tracks. In response to an IM recommendation to remove this site from the monitoring program (ERIAS Group, 2015), MRM removed the site from the dust control/reference monitoring groups in the 2015 operational period. However, dust monitoring data from DMV05 has instead been reported as a non-control site (i.e., a monitoring site impacted by mine operations), in both 2015 (MRM, 2015b) and 2016 (TAS, 2016). This was not part of the previous IM recommendation (ERIAS Group, 2015; 2016) and is not appropriate, as site DMV05 is unlikely to be an impact site in terms of current/ongoing mine operations dust impacts, but instead is more likely to be impacted by dust from nearby tracks. The IM recommends that for the 2017 ambient dust monitoring report, data from this site should be provided with a caveat reflecting the above or, alternatively, excluded from the report. In addition, this site should be replaced with a new control site that is not in the immediate vicinity of the 1970s quarry or currently active dirt tracks.

New Issues

Most dust issues identified in the current IM review are ongoing aspects of previously identified issues, and are detailed in Table 4.67, and Table 4.68 where the issue is ongoing.

The ‘adopted standards’ section of the latest dust report (TAS, 2016) requires clarification. The next dust report should correct the discussion of the annual criterion for Pb (versus the LOR) and include the NEPC (2016) maximum annual average concentration for Pb in the table of adopted standards.

Although TAS (2016) reported exceedances of the maximum annual average PM_{10} criterion, exceedances of the maximum annual average criterion for Pb were not reported for the 2016 operational period. This should be undertaken during the 2017 operational period to assess compliance against the adopted NEPC (2016) guideline, for both the mine site and Bing Bong Loading Facility.

4.13.4.3 Successes

In the 2016 operational period, successes relating to dust have included:

- The addition of sites DMV32 and DMV33 has improved the dust monitoring program by filling a gap in knowledge regarding potential dust impacts between the mine bund wall and the McArthur River diversion channel to the south of the mine pit and SOEF.
- Initiation of duplicate sampling at Bing Bong Loading Facility is commended as an improvement to QA/QC of the dust monitoring program.
- Preparation of interpolated gradient contour maps for PM_{10}, Pb and Zn at the mine site assists in understanding of dust impacts as a result of mining activities.
- The installation and commencement of operations of TEOM units at Bing Bong Loading Facility and McArthur River Mine, along with a new HVAS at the mine site, will assist in collection of more detailed dust data for each site.
- The IM also commends the initiative to prepare an AQMP for the mine site and loading facility.

- Fewer exceedances were recorded during the 2016 operational year than in the previous year. For example:
  - Compared to the 2015 operational period, there was half the number of Pb exceedances at the mine site, and the highest of these (at DMV22 in both years) was 40% of the highest in the previous period.
  - The maximum annual average criterion for Pb was only exceeded at DMV22 in the current period (as opposed to at three sites in the previous period).
- The total number of PM_{10} exceedances within 1 km of the processing plant have again reduced – from 25 in the 2014 operational period to 17 in the 2015 period, to only 6 in the 2016 operational period. This may again reflect limited mining during the operational period.
- The smaller four doors in the Bing Bong Loading Facility concentrate shed were replaced by the time of the IM's June 2017 visit. This will assist in reducing fugitive dust emissions from the shed.
- During the June 2017 site visit, the IM again observed that Bing Bong Loading Facility and the MV Aburri (which was in dock at the time) were 'clean', considering the nature of the concentrate product which is stored/transported therein.
- Despite the continually increased potential for dust emissions from the TSF as water retained at this facility has been reduced, dust results from monitoring sites within 2 km of the TSF show that there were fewer individual (24-hour) PM_{10} exceedances during the 2016 operational period, i.e., only two, compared to seven in each of the previous two operational periods. The maximum PM_{10} results in this monitoring group are also slightly reduced. The stable or reducing dust impact from the TSF, despite reduced water storage, is commended. The IM notes that the current practice of an approximate 40-day spigot cycle around the TSF continues to appear to be adequate to keep the surface sufficiently damp and resistant to wind erosion.

4.13.5 Conclusion

The IM review has found that while there are ongoing issues relating to dust at the mine site and in the vicinity of Bing Bong Loading Facility, results are generally stable or improving. Monitoring programs as well as management practices continue to improve. The key ongoing dust concerns relate to dust management near Barney Creek haul road bridge, and the inoperability of the main concentrate shed doors at Bing Bong Loading Facility.

Ongoing and new IM recommendations related to dust issues are provided in Table 4.68.

Table 4.68 – New and Ongoing Dust Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
Dust management planning	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	High
	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	High
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 framework (e.g., more appropriate criteria with triggers for management actions)	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 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	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	High
	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	High
	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	Medium
	The revised monitoring program in the AQMP will cover increased frequency and analysis of Pb at key locations for both DMV samplers and dust deposition; this will include 24-hour sampling with low-volume air samplers every 12 days. The findings of this monitoring should be reported during 2017	Medium
	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	Medium
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	Medium

Table 4.68 – New and Ongoing Dust Recommendations (cont'd)

Subject	Recommendation	Priority
New Items		
Adopted criteria	The 'adopted standards' section of the next dust report should correct the discussion of the annual criterion for Pb (versus the LOR), include the NEPC (2016) maximum annual average concentration for Pb	Medium
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	High

4.13.6 References

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MRM. 2016d. Letter. Re: Northern Overburden Emplacement Facility (NOEF) Issue. Steven Rooney, Acting General Manager. 9 August 2016. Submitted to the Department of Mines and Energy by McArthur River Mining, Winnellie, NT.

MRM. 2016e. McArthur River Mining Incident Investigation Report – Dust NOEF. Sitesafe Incident Number 32844. 9 August 2016. McArthur River Mining, Winnellie, NT.

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MRM.2016g. NOEF West A Reclamation Dust Management Plan. Reference No. MIN-TEC-PLN-1000-0008. Issue No. 1. Revision No. 0. 31 August 2016. McArthur River Mining, Winnellie, NT.

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MRM. 2017d. MRM Comments on Second Draft IM Report. McArthur River Mining, Winnellie, NT.

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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), Goenet Consulting).
  - Instructions (e.g., in relation to placement of PAF material on the SOEF).
  - 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.
- Instructions and investigations initiated by DPIR.
- Independent Monitor recommendations tracking.
- Previous IM recommendations regarding DPIR performance.

It should also be noted that no DPIR audits were undertaken during the 2016 operational year. One sampling event was undertaken consisting of one surface water and one groundwater in November 2015.

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 outlined in Section 4.14.2.2.

4.14.2.2 Site Visits

During the reporting period DPIR undertook eight site inspections. An additional site inspection occurred as a result of DPIR personnel travelling past the mine site and observing dust emissions resulting from reclaiming low grade ore from the NOEF.

As stated in last year's IM report (ERIAS Group, 2016) the IM commends DPIR on undertaking these site visits. For each site visit DPIR prepared a comprehensive site visit report detailing the areas inspected and observations with supporting photographs.

The IM has reviewed the site inspection reports and found a number of instances where the site inspection had identified an issue, however it was unclear what, if any, action was taken by DPIR as a result of identifying the issue. Examples include the following:

- During the site inspection of 9 September 2016, DPIR personnel observed that the height of the Cell 3 spillway had been increased but that DPIR had not been provided with the GHD dam safety report in which this action had been recommended nor had DPIR assessed or approved the works.
- While inspecting works at CWNOEF, MRM advised that they were using version 2.3 of the CWNOEF Operations Manual yet DPIR had only approved version 1.3.
- During a site inspection on 23 June 2016, DPIR observed that waste rock had been placed over a road which prevented seepage from the NOEF entering the central west sump, and noted that ponding of seepage water may result in contamination of groundwater. On a subsequent site inspection on 14 July 2016, DPIR observed that the issue had not been rectified.

In the last IM report 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. The IM has not been provided with any evidence that documentation of issues arising from site inspections (as outlined above) is being complied into a register to enable tracking of progress. The IM notes, however, that where DPIR has identified issues that are considered serious DPIR has issued instructions to MRM. This action was taken with regard to the following issues which were observed by DPIR personnel during a site inspection and as a result of travelling past the operation:

- Placement of PAF waste rock on the SOEF.
- Dust emissions from reclaiming low grade ore from the NOEF.

Further discussion regarding instructions issued during the reporting period is outlined in Section 4.14.4.1.

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 resulting 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 three amendments during the review period covering the following:

- Development of the NOEF Central West Alpha and Bravo stages.
- Lining of SPROD.
- Transfer water from P2 to WMD.

An amendment to the 2013-2015 MMP was submitted to DPIR on 5 February 2016 to address changes to mining activities and NOEF CW Alpha and Bravo stages. Specifically, the amendment involved the following:

- A revision in the mining schedule and staging with ore processing being reduced from 5.5 Mtpa to 2.5-3.5 Mtpa.
- The development of the NOEF CW Alpha and Bravo stages in accordance with previously approved designs and Phase 3 EIS commitments.

Following the receipt of the request to amend the MMP, considerable correspondence and a number of meetings occurred between DPIR and MRM with DPIR requesting additional information to assist its review of the MMP amendment. Approval of the MMP amendment was provided on 21 March 2016. An instruction was included as part of the approval and this is detailed in Section 4.14.4.1.

The second amendment to the 2013-2015 MMP was submitted to DPIR on 17 August 2016 requesting approval to line SPROD with HDPE. Further information was requested by DPIR on 9 September to assist its review of the amendment, with MRM providing the additional information on 3 October 2016. Following review of this additional information, DPIR approved the MMP amendment on 4 November 2016.

A request to transfer water from P2 to the WMD was made on 28 September 2016. Approval by DPIR to the request was provided on 1 October 2016.

In reviewing the process of approval of these MMP amendments, the IM found that the level of technical review was appropriate and that requests by DPIR for additional information were detailed. The timeframes from receipt of MRM's request for an amendment to the MMP and subsequent approval were also appropriate and review of the documentation indicated that DPIR provided timely responses in terms of initial review and requests for additional information.

4.14.4 Review of Instructions, Investigations and Incidents

4.14.4.1 Instructions

During the operational period (1 October 2015 to 30 September 2016), the DPIR issued a series of instructions to MRM. A number of these related to requesting additional information to assist the assessment of MMP amendments or were as a result of issues identified during site inspections. Instructions issued by DPIR to MRM during the operational period are summarised in Table 4.69.

Table 4.69 – Key Instructions Issued to MRM by the DPIR

Date	Instruction
1 October 2015	♦ Department of Primary Industry and Resources approve MRM request to transfer water from P2 to the TSF WMD for use in construction of Cell 2 embankment raise. An instruction was issued which detailed conditions of this approval, and specifically concerning: – A maximum of 35ML could be transferred – Approval provided as a one off event – MRM to continue to monitor water quality in the WMD before, during and after the transfer from P2 to WMD with results submitted to DPIR within 14 days – Independent Certifying Engineer to review the quality of the water and approve its use in construction of the embankment raise
8 January 2016	♦ Department of Primary Industry and Resources request for information regarding depth, volume, construction material and ongoing management for the Central West C sediment trap and Southwest sediment trap and finalised design report for the water treatment plant, including how brine will be managed and disposed of
18 January 2016	♦ Department of Primary Industry and Resources request for MRM to prepare an Operational Performance Report and detailing the information which DPIR requires to be included and date to be submitted
10 February 2016	♦ Department of Primary Industry and Resources reviewed the MMP amendment relating to mining activities and NOEF CW Alpha and Brava stages and requested that MRM provide additional information to assist DPIR in its assessment of the MMP amendment
4 March 2016	♦ Department of Primary Industry and Resources advised MRM that the report 'Bioaccumulation of heavy metals in McArthur River and tributaries – Investigation and assessment of potential impacts – January 2016' had been received by DPIR. As a result of the findings of this report, DPIR issued an instruction to MRM requiring the following: – Proposed amendments and revisions of the environmental monitoring program which addresses the recommendations identified within the report – Following approval of the amended monitoring program, to implement these changes
21 March 2016	♦ Department of Primary Industry and Resources approved an amended MMP submitted by MRM on 5 February 2016. As part of the approval, DPIR issued an instruction requiring that MRM appoint an independent consultant to conduct an investigation which would: – Identify groundwater aquifer that may be impacted by the NOEF – Review monitoring programs (groundwater, surface water and air quality) – Assess contamination to the environment, including assessment of options to address contamination, and costs and likely timeframe to implement remedial works

Table 4.69 – Key Instructions Issued to MRM by the DPIR (cont'd)

Date	Instruction
14 April 2016	♦ Department of Primary Industry and Resources following review of the life of mine tailings plan provided to DPIR on 4 April 2016 requested further information, specifically regarding: – Closure of the TSF – Stability modelling outputs – Status of ITRB review of the life of mine tailings plan
23 May 2016	♦ Department of Primary Industry and Resources following review of March and April monthly TSF reports issued an instruction requesting further information and specifically: – Additional interpretation of data and the causes of the trends – Discussion regarding how monuments were damaged and when they will be repaired – Actions to be taken to enable monitoring of piezometer which is inaccessible due to being buried
3 June 2016	♦ Department of Primary Industry and Resources following review of additional information provided by MRM concerning stability analyses regarding the life of mine tailings plan requested additional information. The requested information sought information on seepage modelling, sensitivity analyse, reconciliation of phreatic lines and updating of the risk register
21 July 2016	♦ Department of Primary Industry and Resources issued an instruction to MRM as a result of site visits on 16 and 20 July to investigate the possible placement of potentially acid-forming material on the SOEF
23 July 2016	♦ Department of Primary Industry and Resources following an inspection of the NOEF where low grade ore was being reclaimed issued an instruction to MRM to: – Cease all mining activities associated with reclaiming low grade ore and waste rock from the NOEF – Not recommence reclaiming of low grade ore until MRM submitted a dust management plan to DPIR and MRM received approval of this plan from DPIR
12 August 2016	♦ Following receipt of additional information requested in the instruction dated 3 June 2016, DPIR requested further information to assist its review of the life of mine tailings plan
9 September 2016	♦ Department of Primary Industry and Resources requested additional information with regard to a proposed modification to the Southern PAF Runoff Dam, and specifically concerning: – Clearly stated objectives for the project – An assessment of dam failure risk – Anticipated storage capacity of SPROD after allowing for storage required to prevent liner uplift

As noted in last year's IM report, the IM commends DPIR on the level of detail provided in various comments and responses attached to the various instructions, and the engagement of external specialists to assist in the review of technical reports provided by MRM.

The IM recommended last year 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 recommendation has not been adopted by DPIR.

4.14.4.2 Incidents

The DPIR provided documentation for five incidents, two of which were the same. The incidents included the following:

- A leak in a suction hose at the anti pollution pond (17 November 2015).
- An hydraulic oil spill from an excavator (9 February 2016).
- Placement of PAF waste rock on the SOEF (16 July 2016).
- Emissions of SO_2 from the SOEF (20 July 2016) – this incident was related to the incident above.
- Dust emissions from the NOEF as a result of reclaiming low grade ore for processing (23 July 2016).

The number of incidents reported to DPIR and the number of incidents recorded in the MRM incident database differs substantially. In review of correspondence between MRM and DPIR, there appears to be some confusion regarding when an incident should be reported to the latter. The IM sought clarification from DPIR who advised that in accordance with Section 29 of the *Mining Management Act* all environmental incidents must be reported to the department. Under the *Mining Management Act* an environmental incident is defined as:

- An incident on a mining site that causes environmental harm.

Environmental harm is defined as:

- Any harm to or adverse effect on the environment; or
- Any potential harm (including the risk of harm and future harm) to or potential adverse effect on the environment.

It is evident from review of the MRM incident database that not all incidents are being reported; however, the IM would question whether reporting all environmental incidents is practical. The IM also notes that the classification of incidents varied, with DPIR and MRM classifying the same incident at different levels. In clarifying the reporting of incidents, it would also be opportune to clarify the classification of incidents.

4.14.5 Review of Expert Advice

4.14.5.1 Independent Tailings Review Board

The Independent Tailings Review Board (ITRB) was appointed in September 2015. The key activity undertaken by the ITRB during the operational year was the review of the life-of-mine TSF design. The ITRB prepared a report (ITRB, 2016) detailing its review findings. No significant issues were raised by the ITRB in their review of options and life-of-mine tailings management.

4.14.5.2 Robertson Geoconsultants and Geonet Consulting

During the operational year DPIR engaged two consulting companies to provide expert advice as follows:

- Robertson Geoconsultants were engaged to provide a review of the life-of-mine TSF design.
- Geonet Consulting were engaged to undertake a review of the NOEF (Central West Phase), Design, Construction and Operations Manual.

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) collected one opportunistic groundwater sample and one surface water sample during the operational year. It is unclear how DPIR used this information. In the last IM report, the IM recommended that a schedule for EMU's check monitoring be developed together with objectives of the check monitoring and criteria for assessment of performance. The IM has not been provided with any information to indicate that this recommendation has been implemented.

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 4.70.

Table 4.70 – Recommendations from Previous IM Reviews Concerning DPIR Performance

Subject	Recommendation	IM Comment
2015 Operational Period		
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	IM was advised that no documents were available to demonstrate progress towards completing IM recommendations
Site visits	The DPIR should: ♦ Continue the regular site visits that were undertaken in the second half of 2015 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	Ongoing. Regular site inspections continued during the reporting period with a consistent approach to site inspection reports. Recommendations and required actions are not detailed (unless an instruction is issued)
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	No progress

Table 4.70 – Recommendations from Previous IM Reviews Concerning DPIR Performance (cont'd)

Subject	Recommendation	IM Comment
2015 Operational Period (cont'd)		
Documentation (cont'd)	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	No progress
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	No progress
2014 Operational Period		
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 operational performance report submitted by MRM contained a list of commitments and progress towards achieving these commitments. Further 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)	Completed. Correspondence reviewed by the IM indicated that reference to correspondence was consistently using the date of the document.
	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	No documentation provided which indicates that DPIR has reviewed the assessment process for the 2013-2015 MMP. DPIR did not provide comment on the OPR DPIR when referring the 2013-2015 MMP to EPA also provided an additional report prepared by Geonet Consulting which provided independent review on the proposed design for NOEF central west

Table 4.70 – Recommendations from Previous IM Reviews Concerning DPIR Performance (cont'd)

Subject	Recommendation	IM Comment
2014 Operational Period (cont'd)		
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	No progress
	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)	No progress
2012 and 2013 Operational Periods		
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	No audits were conducted during the reporting period
	The DPIR should define and document 'best practice' for specific areas of the operation and include this as part of the DPIR audit protocol	No progress
	The DPIR should establish a goal that audit reports are finalised within six weeks of the audit being conducted	No audit was conducted during the reporting period
IM review findings	The DPIR should request that MRM submits: ♦ An action plan detailing how the high priority recommendations will be addressed, including a timeline ♦ Quarterly updates on progress towards implementing the high priority recommendations	McArthur River Mining provided to the IM a commitments register detailing all commitments including recommendations of the IM. The register does not identify who is responsible for completing the recommendation nor a completion date

4.14.7.2 New Issues

During the 2016 operational year, DPIR continued undertaking regular site visits while also finalising the approval of the 2013-2015 MMP, and approved a number of amendments to the MMP. Progress towards implementing previous IM recommendations has been limited. After reviewing the performance of DPIR in regulating MRM, the IM has made one new recommendations but strongly encourages DPIR to progress recommendations from previous IM reports. Table 4.71 outlines recommendations brought forward and/or modified from previous IM reports.

Table 4.71 – Ongoing DPIR Performance Recommendations

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations)		
IM review findings	The DPIR should prepare: ♦ An action plan detailing how DPIR high priority recommendations will be addressed, including a timeline ♦ Quarterly updates on progress towards implementing the high priority recommendations	High
	The DPIR should request that MRM submits: ♦ An action plan detailing how the high priority recommendations will be addressed, including a timeline ♦ Quarterly updates on progress towards implementing the high priority recommendations	High
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	Medium
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	High
	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
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)	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 4.71 – Ongoing DPIR Performance Recommendations (cont'd)

Subject	Recommendation	Priority
Items Brought Forward (Including Revised Recommendations) (cont'd)		
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	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
	The DPIR should define and document 'best practice' for specific areas of the operation and include this as part of the DPIR audit protocol	Medium
	The DPIR should establish a goal that audit reports are finalised within six weeks of the audit being conducted	Medium
New Recommendations		
Incident reporting	DPIR should clarify with MRM incident reporting requirements, process and incident ranking	Medium

4.14.8 References

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.

ITRB. 2016. Review of Options and Life of Mine Tailings Management Proposal for Tailings Storage Facility at McArthur River Mine. Report prepared by Independent Tailings Review Board, UniQuest Project No: C02562, May 2016.

5. Summary of Recommendations

5.1 2016 Recommendations

New IM recommendations are provided in Table 5.1. These have been grouped by topic and categorised as either high, medium or low. High recommendations are considered a priority and relate to the more significant risks and information deficiencies.

Table 5.1 – New Recommendations

Subject	Recommendation	Priority
Mine Site Water Balance		
Documentation and reporting	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	Medium
Site water balance database	At the time of the 2015 operational period IM site inspection (May 2016). MRM were 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	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
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 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	Medium
Surface Water Quality		
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.	High

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Surface Water Quality (cont'd)		
Water management (cont'd)	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	High
	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	Low
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
	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	High
	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 2016/17 water quality data	Medium
	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	Low
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	Medium
Monitoring	The recommendations in KCB (2016) should be fully implemented	High
General data interpretation and reporting	Descriptions of spills and/or leaks in the OPR should include volumes and fate of the material, i.e., where it ended up	Low
	Consideration should be given to examining changes in DGT-labile metal concentrations that may have occurred since the program commenced	Low
	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	Low
Diversion Channel Hydraulics Management		
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	High

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Diversion Channel Hydraulics Management (cont'd)		
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
Diversion Channel Hydraulics Management	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
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 White (2000)	Medium
Groundwater		
Groundwater impacts south of the SEPROD	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	High
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 the storages. These estimates should be included in the groundwater monitoring report prepared as part of the operational performance report. Further investigations should be carried out where high seepage rates are estimated	High
NOEF	The Overburden Management Project EIS included an assessment of the seepage impacts from the NOEF based on expected performance of the NOEF cover. This assessment should be expanded to estimate the seepage impacts should the cover partially fail or the NOEF be partially inundated	High
Site-wide groundwater model	The site-wide groundwater model developed for the Overburden Management Project EIS was not calibrated against recorded surface water baseflows. It is recommended this be undertaken	High

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Groundwater (cont'd)		
General 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	Medium
Geochemistry		
NOEF	Proceed with trial cover designs in 2017 as planned	High
	Carry out field trials and monitoring of the end-tipped dump portions of the NOEF to confirm effectiveness of advection covers	High
	Progress field confirmation of erosion modelling predictions, as erosion could have significant implications for long-term cover system integrity and maintenance resources required	High
	Complete treatment of acid water in NOEF SPSD/SPROD before the next wet season to avoid uncontrolled release	High
	Document procedures to avoid generation of AMD from highly pyritic PAF materials in older end-tipped parts of the NOEF	High
Waste rock criteria	Add PAF(HW) to the proposed waste rock classes since it would be handled differently from other materials	Medium
Waste rock segregation, handling and checks	Resolve discrepancies between mined and modelled waste rock classes	High
	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	Medium
	Include more detailed instructions on sampling methods in the OEF sampling procedure, including photos showing typical sampling	Medium
	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.	Low
Tailings kinetic testing	Prepare a tailings kinetic test report for the next IM reporting period	Medium
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
Geotechnical		
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	High
TSF Piezometers	Use VWPs to record water levels	High

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Geotechnical (cont'd)		
TSF Piezometers (cont'd)	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 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	Low
TSF Density	Undertake a reconciliation of deposited mass and surveyed volume to estimate in-situ density	Medium
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	High
TSF Operations Manual	Reconcile a number of discrepancies within the Operations Manual	Low
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 Overburden Management Project EIS	High
Bing Bong Loading Facility Dredge Spoil Area Monitoring	Set a frequency of sampling and water level measurement for new piezometers (BBEMB series) outside of active dredging. Suggested frequency is at least every 3 months and more frequently after periods of heavy rainfall	High
Bing Bong Loading Facility Dredge Spoil Area Monitoring	Schedule and document regular inspection of the storage ponds outside of active dredging. The IM suggests monthly inspections during the wet season	High
Closure Planning		
NONE		
Terrestrial Ecology		
Flora	♦ Conduct testing for metal analyte concentrations in common forage species at sites surround the TSF ♦ Measure the survival rate of seedlings being planted to enable an assessment of whether the current strategy of planting seedlings is successful	Medium
Fencing	Remove decommissioned fencing to avoid causing injury to fauna and/or mine personnel and animals	High
Aquatic Ecology		
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

Table 5.1 – New Recommendations (cont'd)

Subject	Recommendation	Priority
Marine Ecology		
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	Low
Include 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	Low
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	Low
Soil and Sediment Quality		
Surface soil monitoring	Monitoring of surface soil control sites S04 and S10 should be recommenced in the 2017 period	High
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)	Medium
EC results at FS24	The cause of high EC results at FS24 should be investigated during the 2017 operational year	High
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	High
Dust		
Adopted criteria	The 'adopted standards' section of the next dust report should correct the discussion of the annual criterion for Pb (versus the LOR), include the NEPC (2016) maximum annual average concentration for Pb	Medium
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	High

5.2 Ongoing Recommendations

In addition to the new recommendations summarised in Table 5.1, there are a number of recommendations that 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.

Table 5.2 – Ongoing Recommendations

Subject	Recommendation	Priority
Mine Site Water Balance		
Documentation and reporting	MMP ♦ 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	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

<table>
<tr><th>Subject</th><th>Recommendation</th><th>Priority</th></tr>
<tr><td colspan="3">Mine Site Water Balance (cont'd)</td></tr>
<tr><td rowspan="3">Documentation and reporting (cont'd)</td><td>– 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)
– 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</td><td rowspan="3">Medium</td></tr>
<tr><td><u>Site water balance report</u>
♦ This report needs to demonstrate ongoing model refinement, increased process understanding and a reduction in model parameter/calibration uncertainty
♦ 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</td></tr>
<tr><td><u>The MMP operational performance report</u>
♦ Additional columns are required in the gap analyses listing the following:
– Specific and measureable actions
– Estimated commencement times
– An 'effectiveness ranking' (e.g., 1 to 5) of the impact the task will have on the site water balance
– Progress tracking from previous gap analyses</td></tr>
<tr><td rowspan="2">Water balance sensitivity analysis</td><td><u>Changes in climate</u>
♦ 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</td><td rowspan="2">Medium</td></tr>
<tr><td><u>Changes in water chemistry</u>
♦ 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</td></tr>
</table>

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Mine Site Water Balance (cont'd)		
Water balance sensitivity analysis (cont'd)	Runoff ♦ The 2016/17 site water balance report (WRM, 2016a) showed the NOEF SEPROD and NOEF WPROD were runoff 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	
Water storage ponds and tailings storage facilities	♦ While the risk of TSF Cell 2 spills to the WMD 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
Risk management of the site water balance	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. 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 Use of the UG&OP for water storage: ♦ MRM should provide a medium- to long-term plan which resolves the conflict between mine operations and using the UG&OP as a water storage	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 – A strategy should be developed to reduce predictive uncertainty over time Bing Bong Loading Facility surface water monitoring: ♦ Surface water monitoring at Bing Bong Loading Facility should be resumed	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Surface Water Quality		
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 and available for IM review	High
McArthur River/ SW11/other surface water sites	A risk assessment should be undertaken concerning: ♦ Possible implications associated with elevated sulfate concentrations and conductivity levels at SW11 (and 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) exceeding the respective SSTVs ♦ 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
	An assessment that validates (or otherwise) MRM's assertion about the low risk associated with mine-derived TSS should be completed, taking into account changes in TSS loads during flood events, sediment basin overflows and the mineralised nature of mine-derived particulates. 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 the 2015-2016 wet season (i.e., burial of the probe) 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
	The alternative labeling of natural surface water sampling sites that has been adopted by MRM should be carried through into all formats that report this data	Low
	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 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	High

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Surface Water Quality (cont'd)		
Monitoring (cont'd)	• 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 • 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
	Results of the release calculator should be validated by concurrent water quality measurements at SW11	Low
	Elemental scans should be reinstated at selected surface water monitoring sites (preferably during high flows)	Low
	The feasibility of deploying DGTs to monitor seawater quality in the trans-shipment area during transfer of the concentrate should be determined	Medium
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	Low
	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	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 (natural and artificial), as well as additional details about the sampling programs, e.g., sampling frequency and parameters, that more fully reflects MRM's water monitoring schedule spreadsheet	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
Diversion Channel Hydraulics Management		
Erosion	• Ongoing monitoring of diversion channel and bank erosion should continue using ALS complemented by photograph monitoring and visual inspection. It is recommended that an annual report on observed erosion should then be completed • It is recommended that this 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 White (2000) as described by Hydrobiology (2016)	Medium
Integrity of the mine levee wall	The independent inspection report by Mining One (2016) recommends 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

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Groundwater		
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 McArthur River palaeochannel aquifer) and estimate their properties. 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 pit and underground should be updated to include the field program results ♦ Numerical models should be updated to identify effective controls, which may include installation of production bores to intercept groundwater flows towards the pit or underground	High
OEF	The following revised recommendations are made regarding the assessment of seepage impacts around the NOEF to confirm the effectiveness of the PAF containment system, once the future development of the facility is approved: ♦ A schedule should be developed for the installation and testing of monitoring bores in areas planned for future NOEF expansion. The schedule should allow for the adequate collection of background data ♦ Electromagnetic surveys should be carried out in areas planned for future NOEF expansion to identify background responses. The timing of surveys should take into consideration seasonal changes in groundwater level ♦ Monitoring of all new NOEF bores should be included in MRM's list of commitments ♦ Field investigations should be undertaken to identify groundwater pathways in the vicinity of the NOEF and estimate their hydraulic properties. 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 outcomes from field investigations and ongoing monitoring should be used to routinely update the conceptual and numerical hydrogeological models for the NOEF. The updated numerical model should be used to assess future impacts from the facility and, where these impacts are judged to be unacceptable, identify effective controls	High
SPROD	The following revised recommendations are made regarding the SPROD: ♦ A synthetic liner should be installed as a long-term seepage control ♦ The site-wide water balance developed by WRM should be used to confirm that seepage rates from the SPROD are acceptable	High

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Groundwater (cont'd)		
TSF	The following revised recommendations are made regarding the assessment of seepage impacts around the TSF: ♦ Field investigations should be undertaken to better identify groundwater pathways in the vicinity of the TSF and estimate their hydraulic properties. 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
Open pit closure	The site-wide groundwater flow model and pit lake water and solute balance model should be used to assess all the pit void closure options under consideration by MRM. Both models should be revised and the closure scenarios re-run when the mine site conceptual hydrogeological model is updated. This is consistent with the adaptive management approach proposed by MRM in the Overburden Management Project EIS	High
Diesel spill	Monitoring bores URS03, URS17 and URS23 should be replaced and an additional monitoring bore installed east or northeast of bore URS17 to increase the coverage to the east and northeast of the plume	Medium
General data interpretation and reporting	A comprehensive interpretation of the groundwater monitoring data should be carried out as part of future groundwater monitoring reports. These should aim at identifying processes responsible for unacceptable groundwater impacts	Medium
	A summary of all groundwater commitments should be presented in future MMPs and annual groundwater reviews	Low
	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 SO4 and salinity in areas previously affected by seepage do not warrant reporting	Low
	Hydrographs of pressure levels in all borefield abstraction bores and nearby observation bores should be constructed, including rainfall and abstraction volumes and rates, and included in future groundwater monitoring reports	Low
	Data such as recovery rates following cessation of pumping and drawdown rates during constant discharge should be assessed	Low
	Kinetic tests should be carried out to estimate the attenuation characteristics of the alluvium underlying the TSF	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Geochemical		
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	High
	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	Medium
	Carry out further investigations to determine the direct seepage contribution from the NOEF to the groundwater system	High
	Review the frequency of check sampling of dumped materials, particularly for LS-NAF	Medium
	Determine whether elevated SO4 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
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 ICP testing capacity or arranging back up external testing capability to avoid further contingency use of pXRF	Medium
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
Waste rock criteria	Better demonstrate the validity of the PAF(RE) 10%S cut off	Medium
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	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
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
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	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Geochemical (cont'd)		
TSF seepage	The origin and veracity of fault mapping in the vicinity of the TSF need to be investigated 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 permeability of the tailings needs to be reviewed and appropriate testing (such as low pressure oedometer or Rowe cell testing) be undertaken to reduce uncertainty in this parameter 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	High
	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	High
TSF construction	Provide all records to the DPIR of earthworks testing or other construction certification for TSF Cell 2 Raise 3. The IM notes that this same request was given to MRM by DPIR on 27 August 2015	High
TSF operation	Confirm assumed average tailings beach gradient from survey	Medium
NOEF design	McArthur River Mining should provide a clear timetable of outstanding activities required to finalise OEF cover design 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 Overburden Management Project EIS has been finalised	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
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

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Geochemical (cont'd)		
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	Medium to high depending on planned dredging
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	High
Closure Planning		
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 prevent seepage for the design period of 1,000 years. 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 (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		
Rehabilitation	Add known saline and/or SO4 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 and rectify recent ponding of seawater against the bund wall and damage to the surrounding drain at Bing Bong Loading Facility dredge spoil ponds	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	Medium
Fauna	Add information on VMU's that are important foraging habitats to the Gouldian finch habitat map	Medium

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Terrestrial Ecology (cont'd)		
Rehabilitation Monitoring	Revised- Encapsulate the revegetation monitoring program within a Rehabilitation Plan that includes the following: ♦ Incorporate recommendations outlined in the geomorphological assessment of the diversion channels (Hydrobiology, 2016) when planning future management actions for addressing high flow rates and bank stability remediation. ♦ A review of rehabilitation works to date including total tubestock 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 ♦ Projected detailed milestones that will allow it to be determined if revegetation is on track and facilitate planning for the next year ♦ A timeline outlining when the McArthur River and Barney Creek diversion channels are expected to be completed, broken down into measurable stages. Results from each year should be used to revaluate this timeline in conjunction with projected milestones and the timeline updated, if required ♦ Revised completion criteria that take into account the variability in habitats along the diversion channels and a more broader treatment of key and primary species (as discussed in Section 4.9.3.2) ♦ An outline of the revegetation process including soil treatment, planting methods targeted planting and watering methods	High
	Revised- The following should be included in the revised revegetation monitoring program: ♦ Based on ecosystem function assessment such as Ephemeral Drainage Line Assessment (Tongway and Ludwig, 2011) ♦ Quantitative measurements of success such as tubestock survival ♦ Reference back to the rehabilitation plan as to performance against projected milestones and timeline	High
Aquatic Ecology		
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
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 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Aquatic Ecology (cont'd)		
Identify potential sources of contamination in Barney Creek diversion channel	McArthur River Mining should conduct a full review and synthesis of the monitoring programs at McArthur River Mine, including metals in freshwater fauna, macroinvertebrates, surface water, groundwater, fluvial sediments, dust and soil to identify additional sources of contamination at the mine site. Using a conceptual site model could be a useful approach to integrate monitoring programs (NTEPA, 2013). The crushing plant has been identified as a potential source of dust emissions, but other sources may include dust emissions from the haul road and ore 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	Medium
LWD	The IM recommends continuing to add LWD in the McArthur River diversion channel, particularly along poorly revegetated sections, to improve continuity of habitat along the diversion channel. Annual monitoring of LWD is recommended to enable continuous improvement of the program McArthur River Mining should continue to add small woody debris and leaf litter to the diversion channels at the end of the wet season to provide habitat and detritus for small fish and invertebrates 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
New background Pb isotope ratio	Monitoring would benefit from the establishment of a more regionally relevant background level for Pb isotopes. Establishing a regionally relevant background isotope ratio would be better for determining whether mine-derived Pb is entering freshwater fauna	Low
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, or whether it should be modified so it better fulfils its role either as flood protection or for capturing and containing contaminated water	Low
Marine Ecology		
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 reports so consistent patterns and inconsistencies can be more easily identified ♦ (Long-term data was included in the AMMP, seagrass and nearshore sediment monitoring program in the 2016 operational period, and this recommendation is closed out with regards to those programs)	Low
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 (cont'd)		
Contaminant uptake and dispersal in biota	As barramundi with elevated, mine-derived Pb were caught in the Bing Bong Loading Facility shipping channel in 2014, 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	Medium
New DGT monitoring sites	As seawater from BBW1 had elevated levels of contaminants, the IM suggests establishing DGT monitoring stations at BBW1 and 2, if feasible, to determine fine-scale patterns of contamination at these sites	Medium
Soil and Sediment Quality		
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	High
Fluvial and marine sediment monitoring data – assessment	The next version of the MMP, as well as future fluvial sediment monitoring reports, should reference Simpson et al. (2013) which has superseded ANZECC/ARMCANZ (2000)	High
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	Medium
Surface soil monitoring	Within the 2017 operational year, S05 should be replaced with a new reference site that is not in the immediate vicinity of the 1970s quarry, i.e., in a more 'natural' location	Medium
Soil, fluvial sediment and marine sediment monitoring program – reporting	Quality assurance/quality control 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 quality monitoring program within the current MMP (MRM, 2015a) provides a possible model for all aspects of the soil/sediment program	Medium
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	Low

Table 5.2 – Ongoing Recommendations (cont'd)

Subject	Recommendation	Priority
Dust		
Dust management planning	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	High
	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	High
Incident reporting	Exceedances of dust guideline levels should be reported as environmental incidents, with subsequent investigation to address the reasons for exceedances and potential management measures	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 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	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	High
	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	High
	In the next dust report, MRM should again prepare gradient contours maps based on ambient dust data from the mine site. The scope of these maps should be expanded to include mine lease boundaries and nearest sensitive receptors, and/or add commentary in the report as to estimated concentrations at those locations	Medium
	The revised monitoring program in the AQMP will cover increased frequency and analysis of Pb at key locations for both DMV samplers and dust deposition; this will include 24-hour sampling with low-volume air samplers every 12 days. The findings of this monitoring should be reported during 2017	Medium
	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	Medium
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	Medium

6. Conclusions

The 2016 operating year saw the culmination of a number of technical studies that were initiated over the past two years. These studies formed the basis for the development of new closure strategies that were outlined in the Draft OMP EIS that was released for public comment in March 2017.

Further studies and investigations have been carried out to better define the geochemical properties and risks of mine materials, and to provide more direction concerning the operational and long-term management required for problematic materials. Work carried out to date continues to confirm that McArthur River Mine materials are highly pyritic and a major potential source of acid, metalliferous and saline drainage (AMD). The IM has stated in the last three IM reports that the risk of AMD generation, and the associated potential adverse impacts both on site and downstream, remains the most significant environmental issue at McArthur River Mine and the IM's view after reviewing monitoring data and technical reports for the 2016 operating year remains unchanged.

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 October 2016 indicates that adverse impacts on downstream surface waters due to the mine are limited, although some effects are noticeable in watercourses within the mine lease boundaries (and this is not unexpected) and some non-compliance with WDL SSTVs at SW11 due to mine activities has occurred (but to a lesser extent than was noted in last year's IM report). Monitoring data suggests that adverse impacts on coastal waters near Bing Bong Loading Facility similarly remain limited. The IM also notes that MRM is starting to focus 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. The existing information indicates that mine-derived loads in Barney Creek as measured at SW8 (which is located within the mining area) are significant, and the next steps are to fully quantify these loads and to determine the associated environmental risks, particularly in terms of downstream impacts.

The northern overburden emplacement facility (NOEF), tailings storage facility (TSF) and open pit represent the key potential sources of AMD, and inadequate management of seepage/runoff during operations and/or failure of closure mitigation strategies could result in long-term impacts on groundwater and terrestrial and aquatic ecosystems.

Poor quality leachate, i.e., AMD, from waste rock in the NOEF is already reporting to groundwater and surface drainage due to inadequate management of seepage during operations. Future dump construction will better control seepage during operations, but infiltration through the NOEF will continue, and there is uncertainty concerning the fate of this seepage and whether the current ponds located around the NOEF will capture it all. Failure of the cover system post closure could continue to impact groundwater and terrestrial and aquatic ecosystems in perpetuity. McArthur River Mining has investigated the option of installing an interception trench and recovery bores to capture contaminated groundwater from the NOEF. Modelling indicates that this strategy would be effective in preventing contaminated groundwater entering Barney Creek. There is currently no timeframe on when such an interception system would be installed with the consultant report indicating this would be based on groundwater monitoring results.

Seepage through the TSF Cell 2 embankment has been an ongoing issue at the TSF. The main cause of the seepage was the use of a rockfill mattress as part of the Stage 3 raising works to facilitate using upstream construction methods. More recently, seepage levels have again increased and this will be discussed in next years report.

These increases in collected seepage and continued elevated piezometric levels within the embankment have occurred despite the adoption of a number of good water and tailings management practices. The higher piezometric levels are also at odds with seepage modelling that suggests much lower piezometric levels.

The geomorphological study identified an active channel avulsion (wholesale shift in channel position) immediately upstream of McArthur River diversion channel off-take, 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 rehabilitation of the McArthur River diversion channel has continued with the planting of tens of thousands of seedlings in recent years. It is expected that the redesigned revegetation monitoring program will aid in increasing the success of revegetation by helping to identify where the significant problems lie and how these problems can be addressed in the coming years.

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 AMD. 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.

Notwithstanding the above, MRM has taken some significant steps forward during the 2016 operating year, including the following:

- Completion of geochemical testing and investigations that have resulted in a comprehensive dataset using an appropriate suite of static and kinetic tests, so that the geochemical properties of overburden and tailings materials at the mine are well understood.

- Completion of a number of studies and assessments to address information gaps, including reconstruction of the NOEF waste rock composition, better definition of the composition of the southern overburden emplacement facility (SOEF) and western overburden emplacement facility (WOEF), cover design modelling and assessment, groundwater modelling to better understand seepage pathways for OEFs, erosion modelling to better understand potential impacts on long-term dump cover integrity, testing and assessment of tailings surface oxidation potential and lag times, and pit water quality modelling.

- Commissioning an independent consultant to investigate whether the placement and containment of mining waste at the NOEF is causing, or may cause environmental harm to the receiving environment.
- Continued improvement in the operation of the TSF with effective pond management being evident and a subaerial tailings beach of at least 50 m being maintained. Process water is efficiently reclaimed and safe operating levels have been established.
- Development of updated conceptual geological and hydrogeological models for the mine site, based on extensive field investigations. This is considered by the IM a significant step forward in understanding the groundwater system across the site.
- Placement of a substantial amount of large woody debris (LWD) into the downstream end of the McArthur River diversion channel. Large woody debris is essential for the rehabilitation of the diversion channel as it provides important refuge habitat for fish species, helps to slow flow rates and acts as a sediment trap providing substrate for vegetation to grow in.
- Declining levels of contamination in biota from SW19, likely due to controls implemented by MRM. For example, the mean concentration of Pb recorded in bony bream has declined more than six fold since 2014.
- Conducting a community survey of fish consumption patterns. The survey showed that the current monitoring program adequately targets commonly consumed fish and popular fishing spots.

The IM has also reviewed DPIR's performance in regulating the McArthur River Mine. During the 2016 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. While major issues observed during site inspections were addressed through the issuing of an instruction, the IM notes that there is no tracking of issues which do not warrant an instruction. The IM believes that this is a gap in DPIR's inspection process.

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 has been slow and the IM would like to see DPIR place a higher priority on appropriate action.

References

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.

7. Limitations

7.1 Introduction

The following statements remain the same as those included in previous IM reports and 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 mining Authorisation Number 0059-02, and in particular Schedule 2 – McArthur River Mine Independent Monitoring Assessment Conditions (IMACs).
- The specific scope of services set out in the Request for Tender issued by the 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 cannot be used to assess the effect of 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.

As noted in last year's IM report, the Overburden Management Project EIS, and related studies, is in progress and, as such, assumptions and findings contained in this report 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, is not entirely consistent with the IM review period (i.e., 1 October to 30 September). 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

µg/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
EPROD	east PAF runoff dam
GDE	groundwater dependent ecosystem
IM	Independent Monitor
ISSTV	interim site-specific trigger value
ISQG	interim sediment quality guideline
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
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
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 PAF sediment dam
SPROD	southern PAF runoff dam
SEPROD	southeast PAF 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 PAF 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 minesite 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.
List of Files

Table 1 – MRM-Supplied Files Used in the Assessment

MRM-Supplied Files as Provided to ERIAS Group
02 Incident Reports and Complaints/Complaints/Complaints August 2015 to August 2016.docx
02 Incident Reports and Complaints/Incidents/160614 Hydraulic Hose failure Water Cart/IMG_3522.JPG
02 Incident Reports and Complaints/Incidents/160614 Hydraulic Hose failure Water Cart/IMG_3523.JPG
02 Incident Reports and Complaints/Incidents/160614 Hydraulic Hose failure Water Cart/IMG_3524.JPG
02 Incident Reports and Complaints/Incidents/160614 Hydraulic Hose failure Water Cart/IMG_3525.JPG
02 Incident Reports and Complaints/Incidents/160614 Hydraulic Hose failure Water Cart/IMG_3526.JPG
02 Incident Reports and Complaints/Incidents/160614 Hydraulic Hose failure Water Cart/IMG_3527.JPG
02 Incident Reports and Complaints/Incidents/160614 Hydraulic Hose failure Water Cart/IMG_3528.JPG
02 Incident Reports and Complaints/Incidents/160614 Hydraulic Hose failure Water Cart/IMG_3529.JPG
02 Incident Reports and Complaints/Incidents/160807 TSF Pipeline Leak/IMG_9569.JPG
02 Incident Reports and Complaints/Incidents/160807 TSF Pipeline Leak/IMG_9570.JPG
02 Incident Reports and Complaints/Incidents/160807 TSF Pipeline Leak/IMG_9571.JPG
02 Incident Reports and Complaints/Incidents/160807 TSF Pipeline Leak/IMG_9572.JPG
02 Incident Reports and Complaints/Incidents/160807 TSF Pipeline Leak/IMG_9573.JPG
02 Incident Reports and Complaints/Incidents/160807 TSF Pipeline Leak/IMG_9574.JPG
02 Incident Reports and Complaints/Incidents/160807 TSF Pipeline Leak/IMG_9575.JPG
02 Incident Reports and Complaints/Incidents/160807 TSF Pipeline Leak/IMG_9576.JPG
02 Incident Reports and Complaints/Incidents/160826 Tails Spill/An incident has occured 32903.oft
02 Incident Reports and Complaints/Incidents/160826 Tails Spill/P8261412.JPG
02 Incident Reports and Complaints/Incidents/160826 Tails Spill/P8261413.JPG
02 Incident Reports and Complaints/Incidents/160829 BBDDP Exceedances/BB Data.xlsx
02 Incident Reports and Complaints/Incidents/160829 BBDDP Exceedances/BB Map.jpg
02 Incident Reports and Complaints/Incidents/160829 BBDDP Exceedances/BBDDP 160314.JPG
02 Incident Reports and Complaints/Incidents/160829 BBDDP Exceedances/DSD1 160314.JPG
02 Incident Reports and Complaints/Incidents/160829 BBDDP Exceedances/DSD1.JPG
02 Incident Reports and Complaints/Incidents/160829 BBDDP Exceedances/DSD2 160314.JPG
02 Incident Reports and Complaints/Incidents/160829 BBDDP Exceedances/DSD2.JPG
02 Incident Reports and Complaints/Incidents/160829 BBDDP Exceedances/DSD3 160314.JPG
02 Incident Reports and Complaints/Incidents/160829 BBDDP Exceedances/DSD3.JPG
02 Incident Reports and Complaints/Incidents/160829 BBDDP Exceedances/DSD4 160314.JPG
02 Incident Reports and Complaints/Incidents/160829 BBDDP Exceedances/DSD4.JPG
02 Incident Reports and Complaints/Incidents/MRM_Monthly HSEC Report 2016-2017.xlsx
02 Incident Reports and Complaints/SiteSafe 2015-2016.xlsx
03 Compliance/MRM - Compliance Register (Environment).xlsx
04 Audits/ChemAlert Audit Report MRM 2017.pdf
04 Audits/DME - 20160716 Inspection Report Final.pdf
04 Audits/DME - 20161005 Inspection Report.pdf
04 Audits/NIRB - MRM Site Visit Memo.pdf
05 Mining Management Plan/160118 DME OPR Instruction.pdf
05 Mining Management Plan/160329 DME OPR Instruction - MRM Request # 1.pdf

MRM-Supplied Files as Provided to ERIAS Group
05 Mining Management Plan/160606 DME OPR Instruction - MRM Request # 2.pdf
05 Mining Management Plan/160624 DME Response (Incorrect date listed on the letter).msg
05 Mining Management Plan/160624 DME Response (Incorrect date listed on the letter).pdf
05 Mining Management Plan/160830 OPR Extension Request.pdf
05 Mining Management Plan/160923 OPR Attachments.zip
05 Mining Management Plan/160923 OPR Final.pdf
05 Mining Management Plan/160923 OPR Submission Letter.pdf
06 Flora/15008_Terrestrial Veg Report_ Rev 0_310516.pdf
06 Flora/16003_MRM Vegetation_Rev B_270217.pdf
06 Flora/16018_Cattle feed_Rev 0_270317.pdf
06 Flora/Bing Bong Veg Monitoring/EZ16071-C0301-EST-R-0003 Vegetation Monitoring Bing Bong dredge spoil 2016_0.pdf
06 Flora/MRM Veg Monitoring/MRM rechannel monitoring 2016.pdf
06 Flora/MRM Veg Monitoring/Vegetation monitoring of potential saline impacts 2016.pdf
06 Flora/Planting Register/mcarthur mine del DPW.PDF
06 Flora/Planting Register/mcarthur mine DPW.PDF
06 Flora/Planting Register/Planting Register 2016.xlsx
06 Flora/Reports.msg
06 Flora/Weed Control/201705190746.pdf
06 Flora/Weed Control/201705190752.pdf
06 Flora/Weed Control/201705190754.pdf
06 Flora/Weed Control/Weed Management Plan 2013 -2014_v4.doc
06 Flora/Weed Control/Weeds Spraying Register.xlsx
07 Fauna/Birds/MR Gouldian Finch 2016 FINAL 14052017-2.pdf
07 Fauna/Birds/PM MIG BIRDS NSTAGE 6 July 2016 FINAL.pdf
07 Fauna/Birds/PM MIG BIRDS SUM 2016 FINAL 6 July 2016.pdf
07 Fauna/Birds/RIP BIRDS JUL FINAL 10 OCT 2016.pdf
07 Fauna/Birds/RIP BIRDS OCT - NOV 2016 FINAL 20 Jan 2017.pdf
07 Fauna/Cattle Management/Cattle register 2016.xlsx
07 Fauna/Cattle Management/Fencing Register 2016.xlsx
07 Fauna/Fish/16001 MRM Aquatic 2016_Rev 0_240816.pdf
07 Fauna/Fish/16001 MRM Aquatic LD_Rev 0_150517.pdf
07 Fauna/Fish/16006 Memorandum_Sawfish tagging_010217.pdf
07 Fauna/Fish/2016 Borroloola Fish Consumption Survey Rev 0.pdf
07 Fauna/Fish/2016 Early Dry Season Metals in Aquatic Fauna Report Rev 0.pdf
07 Fauna/Macroinvertebrate/2016 MACRO MRM FINAL 10 OCTOBER 2016.pdf
08 Marine/2015 - Annual Marine Study Rev 0.pdf
08 Marine/2015-16 BB DGT Monitoring Rev 4.pdf
08 Marine/2016 - Annual Seagrass Survey Rev 0.pdf
08 Marine/2016 - Nearshore Sediment Survey Rev 0.pdf
08 Marine/2016 - Transshipment Study Rev 0.pdf

MRM-Supplied Files as Provided to ERIAS Group
08 Marine/2017 - Review of Transshipment Area.pdf
09 Surface Water/160215 NT EPA Exceedance Letter - Signed.pdf
09 Surface Water/160317 NT EPA Exceedance Letter - Signed.pdf
09 Surface Water/160530 NT EPA Exceedance Letter 1 - Signed.pdf
09 Surface Water/160530 NT EPA Exceedance Letter 2 - Signed.pdf
09 Surface Water/160530 NT EPA Water Quality Probe Failure.pdf
09 Surface Water/160829 NT EPA Exceedance Letter - Signed.pdf
09 Surface Water/161125 DENR Exceedance Letter - Signed.pdf
09 Surface Water/170119 DENR Exceedance Letter - Signed.pdf
09 Surface Water/2014-16 Artificial Surface Water Monitoring Report.pdf
09 Surface Water/2014-16 Surface Water Monitoring Report.pdf
09 Surface Water/2015-16 Discharge Records.xlsx
09 Surface Water/2015-16 Water Balance Report.pdf
09 Surface Water/2016-17 Discharge Records.xlsx
09 Surface Water/2016-17 Water Monitoring Schedule - Final I001 Rev3.xlsx
09 Surface Water/Gauging station/Barney_Creek_Public.dat
09 Surface Water/Gauging station/Barney_Creek_Public.dat.2.backup
09 Surface Water/Gauging station/DownStream2_Public.dat
09 Surface Water/Gauging station/Early warning flood_Public.dat
09 Surface Water/Gauging station/Early warning flood_Public.dat.backup
09 Surface Water/Gauging station/Suprise Creek_Water 170401.dat
09 Surface Water/Gauging station/Suprise_Creek_Public.dat.3.backup
09 Surface Water/Gauging station/UpStream2_Public.dat
09 Surface Water/SW and ASW Data Historic.csv
09 Surface Water/SW and ASW Data Operational Period.csv
09 Surface Water/WDL 174-07.pdf
09 Surface Water/WDL 174-08.pdf
09 Surface Water/WDL 174-09.pdf
09 Surface Water/WDL Monitoring Report 2016 I001 Rev0.pdf
10 Groundwater/2014-16 2011 Diesel Spill Remediation Update.pdf
10 Groundwater/2014-16 Groundwater Monitoring Report.pdf
10 Groundwater/2015-16 Groundwater Raw Data.csv
10 Groundwater/GW107 Decommsioning.pdf
10 Groundwater/MRM_DRP_Quarterly_Report- OCTOBER-DECEMBER-2016.docx
10 Groundwater/SPROD Construction GHD Review Letter Rev 1.pdf
11 Sediment Dust and Soil/2014-16 Ambient Dust Monitoring Report.pdf
11 Sediment Dust and Soil/2014-16 Fluvial Sediment Monitoring Report.pdf
11 Sediment Dust and Soil/2014-16 Soil Monitoring Report.pdf
11 Sediment Dust and Soil/2016 Fluvial Sediment Fieldsheets.PDF
11 Sediment Dust and Soil/2016 Fluvial Sediment PbIR.xlsx
11 Sediment Dust and Soil/2016 Fluvial Sediment PSD.CSV

MRM-Supplied Files as Provided to ERIAS Group
11 Sediment Dust and Soil/2016 Fluvial Sediment Raw Data.csv
11 Sediment Dust and Soil/2016 Low Volume and High Volume Sampler Raw Data.csv
11 Sediment Dust and Soil/2016 Soil Fieldsheets_1.pdf
11 Sediment Dust and Soil/2016 Soil Fieldsheets_2.pdf
11 Sediment Dust and Soil/2016 Soil Fieldsheets_3.pdf
11 Sediment Dust and Soil/2016 Soil PSD Data_1.CSV
11 Sediment Dust and Soil/2016 Soil PSD Data_2.CSV
11 Sediment Dust and Soil/2016 Soil PSD Data_3.CSV
11 Sediment Dust and Soil/2016 Soil Raw Data.csv
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 06/June 2015.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 07/July 2015.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 07/MRM Borroloola Validated Data Report July 2015.zip
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 07/MRM Devils Spring Validated Data Report July 2015.zip
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 08/August 2015.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 08/MRM Borroloola Validated Data Report August 2015.xls
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 08/MRM Devils Spring Validated Data Report August 2015.xls
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 09/MRM Borroloola Validated Data Report September 2015.xls
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 09/September 2015.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 10/October 2015.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 11/MRM Borroloola Validated Data Report November 2015.xls
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 11/November 2015.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 12/December 2015.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2015/2015 12/MRM Borroloola Validated Data Report December 2015.xls
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/1601 MRM Borroloola and Devils Spring Monthly Report.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/1602 MRM Borroloola and Devils Spring Monthly Report.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/1603 MRM Monthly Report March.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/1604 MRM Monthly Report April.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/1605 MRM Borroloola Caravan and Devils Spring Monthly.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/1606 MRM Borroloola Caravan and Devils Spring Monthly.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/1608 MRM Borroloola Caravan and Devils Spring Monthly.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/1609 September MRM 3 locations.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/1610 October MRM Caravan NOEF Monthly Report.pdf

MRM-Supplied Files as Provided to ERIAS Group
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/1611 November MRM Caravan NOEF Monthly Report.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/1612 December MRM Caravan NOEF Monthly Report.pdf
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/MRM Borroloola Validated Data Report September 2016.xlsx
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/MRM Caravan NOEF Validated Data Report October 2016.xlsx
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/MRM Caravan NOEF Validated Data Report September 2016.xlsx
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/MRM Devils Spring Validated Data Report September 2016.xlsx
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/MRMNOEFValidated Data Dec2016.xlsx
11 Sediment Dust and Soil/SO2 monitoring/Ecotech Reports/2016/MRMNOEFValidated Data Nov2016.xlsx
11 Sediment Dust and Soil/SO2 monitoring/Todoroski-TAS/1609 Sept-Oct_MRM_SO2_TAS.pdf
11 Sediment Dust and Soil/SO2 monitoring/Todoroski-TAS/1611 Nov _MRM_SO2_TAS.pdf
11 Sediment Dust and Soil/SO2 monitoring/Todoroski-TAS/1612 Dec_ MRM_SO2_TAS.pdf
11 Sediment Dust and Soil/TEOMS/170208 BBDTM01.csv
11 Sediment Dust and Soil/TEOMS/20170208 MRMDTM.csv
12 TSF/Cell 2 Raise 3 - As Constructed report and review/25024-27 TSF Cell 2 Lift 4 Final Ascon.pdf
12 TSF/Cell 2 Raise 3 - As Constructed report and review/ITRB-TSF Cell 2 Raise Construction Report Review-03-04-17-Final.pdf
12 TSF/Cell 2 Raise 3 - As Constructed report and review/MRM TSF Cell 2 Stage 3 Construction Report.pdf
12 TSF/Cell 2 Raise 3 - As Constructed report and review/TSF Cell 2 RL 10055 Raise As Constructed Drawing Set.pdf
12 TSF/Geochemical Data/Tailings monitoring results - IM 20170515.csv
12 TSF/Geochemistry Reports/140305 - KCB - Tailings Classification.pdf
12 TSF/Geochemistry Reports/MRM171601_KCB Review_Rev0.pdf
12 TSF/Geochemistry Reports/MRM172401_Rev0.pdf
12 TSF/Geochemistry Reports/MRM1768_OPT_TestworkReport_Rev1.pdf
12 TSF/ITRB Reports/2526 - Review of LOM Options.pdf
12 TSF/ITRB Reports/2800-M-20160509 - ITRB Review of Life of Mine Tailings Management for TSF MRM.pdf
12 TSF/ITRB Reports/TSF Cell 2 Raise 4 review-Final3.pdf
12 TSF/Monthly TSF Operational Reports/20160113/20160113_R1 - TSF Report.docx
12 TSF/Monthly TSF Operational Reports/20160113/20160113_R1 - TSF Report.pdf
12 TSF/Monthly TSF Operational Reports/20160113/20160113_R2 - TSF Report.docx
12 TSF/Monthly TSF Operational Reports/20160113/20160113_R2 - TSF Report.pdf
12 TSF/Monthly TSF Operational Reports/20160113/Attachment A - Standpipe Piezometer Interpretation December 2016.pdf
12 TSF/Monthly TSF Operational Reports/20160113/Attachment B - Cell 1&2 Perimeter Survey Report.pdf
12 TSF/Monthly TSF Operational Reports/20160113/TSF Operational Report - December.zip
12 TSF/Monthly TSF Operational Reports/20160210/20160113_R2 - TSF Report.docx
12 TSF/Monthly TSF Operational Reports/20160210/20160210_R1 - TSF Report.pdf

MRM-Supplied Files as Provided to ERIAS Group
12 TSF/Monthly TSF Operational Reports/20160210/20160210_R2 - TSF Report.pdf
12 TSF/Monthly TSF Operational Reports/20160210/Attachment A - Standpipe Piezometer Interpretation - January 2016.pdf
12 TSF/Monthly TSF Operational Reports/20160304/20160304_R1 - TSF Report.docx
12 TSF/Monthly TSF Operational Reports/20160304/20160304_R1 - TSF Report.pdf
12 TSF/Monthly TSF Operational Reports/20160304/20160304_R2 - TSF Report.pdf
12 TSF/Monthly TSF Operational Reports/20160304/Standpipe Piezometer Interpretation February 2016.pdf
12 TSF/Monthly TSF Operational Reports/20160506/20160506_R1 - TSF Report.docx
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17 General Reports/PRO/HSEC-ENV-PRO-6040-0017 Fauna Management Procedure Issue 2.1.doc
17 General Reports/PRO/HSEC-ENV-PRO-6040-0021 Natural Surface Water Monitoring Procedure I002 Rev0.docx
17 General Reports/PRO/HSEC-ENV-PRO-6040-0021 Natural Surface Water Monitoring Procedure Issue 2.1.docx
17 General Reports/PRO/HSEC-ENV-PRO-6040-0021 Natural Surface Water Monitoring Procedure.docx
17 General Reports/PRO/HSEC-ENV-PRO-6040-0022 Groundwater Monitoring Procedure Issue 1.1.docx
17 General Reports/PRO/HSEC-ENV-PRO-6040-0023 Artificial Surface Water Monitoring Procedure Issue 1.1.docx
17 General Reports/PRO/HSEC-ENV-PRO-6040-0025 DGT Monitoring Procedure Issue 1.1.docx
17 General Reports/PRO/HSEC-ENV-PRO-6040-0026 Potable Water Monitoring Procedure Issue 1.1.docx
17 General Reports/PRO/HSEC-ENV-PRO-6040-0028 Calibration and Use of a Hydrolab Quanta Issue 1.1.docx
17 General Reports/PRO/HSEC-ENV-PRO-6040-0029 Fluvial Sediment Sampling Procedure Issue 1.1.docx

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17 General Reports/PRO/HSEC-ENV-PRO-6040-0031 Dust Monitoring Procedure Issue 1.1.docx
17 General Reports/PRO/HSEC-ENV-PRO-6040-0032 Groundwater Data Logger Download Procedure Issue 1.0.docx
17 General Reports/PRO/HSEC-ENV-PRO-6040-0032 Groundwater Data Logger Download Procedure.docx
17 General Reports/PRO/HSEC-OHS-PRO-6050-0019 Alcohol Testing Procedure Issue 4.1.docx
17 General Reports/PRO/HSEC-TRN-PRO-6080-0004 Dulevo Sweeper Procedure Issue 1.1.doc
17 General Reports/PRO/MET-ENG-PRO-2000-0001 Supply of Engineering Drawings I002 Rev3.doc
17 General Reports/PRO/MET-GEN-PRO-2000-0003 Temporary Repairs to Plant and Equipment I001 Rev 0.docx
17 General Reports/PRO/MET-GEN-PRO-2100-0001 Sodium Nitrite procedure.docx
17 General Reports/PRO/MET-GEN-PRO-2900-0001 Plant and Instrument Air Receivers - Preparation for Maintenance.dot
17 General Reports/PRO/MET-GEN-PRO-2900-0002 Control System Change Request (CSCR) Procedure.docx
17 General Reports/PRO/MET-GEN-PRO-6040-0001 Plant Change Modification Procedure I002 Rev 0.dot
17 General Reports/PRO/MET-GEN-PRO-6040-0002 Metallurgy Equipment Prestart Procedure.docx
17 General Reports/PRO/MET-GEN-SOP-2000-0031 Lead Bagging SOP.doc
17 General Reports/PRO/MET-TEC-PRO-2900-0010 Safety Auditing Procedure I001 Rev 0.doc
17 General Reports/PRO/MET-TEC-PRO-2900-0013 Metallurgy EOM Reconciliation Procedure I001 Rev 0.doc
17 General Reports/PRO/MIN-BGB-PRO-3200-0001 Determination of Moisture in MRM Concentrate Issue 2.2.docx
17 General Reports/PRO/MIN-BGB-PRO-3200-0014 Concentrate Transport Procedure Issue 1.1.docx
17 General Reports/PRO/MIN-GEN-PRO-1000-0001 Light Vehicle Procedure Issue 3.3.doc
17 General Reports/PRO/MIN-GEN-PRO-1000-0002 Simulator Operations Procedure Issue 2.2.doc
17 General Reports/PRO/MIN-GEN-PRO-1000-0003 Towing Trailers and Light Towers Procedure Issue 2.3.doc
17 General Reports/PRO/MIN-GEN-PRO-1000-0004 General Drill and Blast Procedure Issue 3.0.docx
17 General Reports/PRO/MIN-GEN-PRO-1000-0005 Blast Controlling Procedure Issue 3.2.doc
17 General Reports/PRO/MIN-GEN-PRO-1000-0006 Blast Guard Procedure Issue 2.2.doc
17 General Reports/PRO/MIN-GEN-PRO-1000-0007 Misfire Procedure Issue 1.3.doc
17 General Reports/PRO/MIN-GEN-PRO-1000-0008 Front End Loader Procedure Issue 3.0.docx
17 General Reports/PRO/MIN-GEN-PRO-1000-0011 Use of a Crane Hook as an Anchor Point Procedure Issue 1.1.doc
17 General Reports/PRO/MIN-GEN-PRO-1000-0013 Tiphead Toe Access Procedure Issue 1.1.doc
17 General Reports/PRO/MIN-GEN-PRO-1000-0015 Prism Monitoring Procedure Issue 1.2.doc
17 General Reports/PRO/MIN-GEN-PRO-1000-0016 Dozer Procedure Issue 4.0.docx
17 General Reports/PRO/MIN-GEN-PRO-1000-0017 Grader Procedure Issue 3.0.docx
17 General Reports/PRO/MIN-GEN-PRO-1000-0018 Loading Area Procedure Issue 3.0.docx
17 General Reports/PRO/MIN-GEN-PRO-1000-0019 Excavator Procedure Issue 2.5.docx
17 General Reports/PRO/MIN-GEN-PRO-1000-0020 Water Truck Procedure Issue 3.0.docx
17 General Reports/PRO/MIN-GEN-PRO-1000-0021 Haul truck Procedure Issue 4.0.docx
17 General Reports/PRO/MIN-GEN-PRO-1000-0027 Concrete Batching Plant Procedure Issue 4.1.doc
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17 General Reports/PRO/MIN-INF-PRO-1010-0007 Lathe Operation Procedure Issue 1.1.doc
17 General Reports/PRO/MIN-INF-PRO-1010-0008 Emergency Lighting Test Procedure Issue 1.1.doc
17 General Reports/PRO/MIN-INF-PRO-1010-0009 Mining Infrastructure Power Reset Procedure Issue 1.1.pdf
17 General Reports/PRO/MIN-MTC-PRO-1020-0001 Tyre and Rim Management Procedure Issue 2.1.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0002 Mobile Equipment Jacking and Blocking Procedure Issue 2.1.docx
17 General Reports/PRO/MIN-MTC-PRO-1020-0003 Towing Heavy Machinery Issue 2.0.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0004 Accumulator Charging Procedure Issue 1.1.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0005 Open Pit Servicing and Refuelling Procedure Issue 1.1.doc
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17 General Reports/PRO/MIN-MTC-PRO-1020-0012 Vehicle Hoist Procedure Issue 1.1.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0013 Power and Pneumatic Tools Issue 1.1.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0014 Welding Fuel and Hydraulic Tanks Issue 1.1.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0015 Battery Charging and Testing Issue 1.1.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0016 Cold Metal Drop Saw Issue 1.1.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0017 Automatic Parts Degreasing Machine (Hotwash) Issue 1.1.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0018 Plasma Cutter Issue 1.1.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0019 Horizontal Band Saw Issue 1.1.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0021 Mobile Maintenance Workflow Process Issue 1.2.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0022 Removal and Replacement of GET Issue 2.0.docx
17 General Reports/PRO/MIN-MTC-PRO-1020-0023 Mobile Maintenance Pressure Washer Procedure Issue 1.1.doc
17 General Reports/PRO/MIN-MTC-PRO-1020-0024 Workshop Demaraction Procedure Issue 1.0.docx
17 General Reports/PRO/MIN-MTC-PRO-1020-0025 MIA Heavy Workshop Wash Pad Issue 1.1.doc
17 General Reports/PRO/MIN-TEC-PRO-1000-0002 Pit Wall and Face Markup Issue 1.3.doc
17 General Reports/PRO/MIN-TEC-PRO-1000-0003 Pit Wall and Face Sampling Issue 1.3.doc
17 General Reports/PRO/MIN-TEC-PRO-1000-0007 Release of Mine Designs Issue 1.3.doc
17 General Reports/PRO/MIN-TEC-PRO-1000-0011 Release of Void Boundaries Issue 1.4.doc
17 General Reports/PRO/MIN-TEC-PRO-1000-0014-Reactive Ground Sampling Procedure Issue 1.2.doc
17 General Reports/PRO/MIN-TEC-PRO-1000-0015-EOM NOEF Sampling procedure Issue 1.5.doc
17 General Reports/PRO/MIN-TEC-PRO-1000-0017 Transportation of I-Site Scanner Issue 1.2.doc
17 General Reports/PRO/MIN-TEC-PRO-1000-0018 Bing Bong Concentrate Storage Facility Volume Survey Issue 1.2.doc
17 General Reports/PRO/MIN-TEC-PRO-1000-0021 Void Management Procedure Issue 3.2.docx
17 General Reports/PRO/MIN-TEC-PRO-1000-0022 Create, file, print dig plans Issue 2.3.doc
17 General Reports/PRO/MIN-TEC-PRO-1000-0023 Core Logging Procedure Issue 1.1.doc
17 General Reports/PRO/MIN-TEC-PRO-1000-0024 Importing Channel and Drillhole Data into Vulcan Procedure Issue 1.1.doc
17 General Reports/PRO/MIN-TEC-PRO-1000-0025 NOEF Asbuilt Review and Sign Off Procedure Issue 1.1.doc

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17 General Reports/PRO/MIN-TEC-PRO-1000-0032 Storage and Handling of Explosives Procedure Issue 1.1.docx
17 General Reports/PRO/MIN-TEC-PRO-1000-0033 Inspection and Reporting of Explosives Equipment Procedure Issue 1.1.docx
17 General Reports/PRO/MIN-TEC-PRO-1000-0034 Transport of Explosives Procedure Issue 1.1.docx
17 General Reports/PRO/MIN-TEC-PRO-1000-0035 Loading and Initiation of Explosives Procedure Issue 1.0.docx
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17 General Reports/PRO/MIN-TEC-PRO-1000-0039 Blast Controller and Blast Guard Procedure Issue 1.0.docx
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17 General Reports/PRO/MIN-TEC-PRO-1000-0047 Geotechnical Inspection Procedure Issue 1.0.docx
17 General Reports/PRO/MIN-TRN-PRO-1050-0001 Mining Induction and Awareness Procedure Issue 1.2.docx
17 General Reports/PRO/MIN-TRN-PRO-1050-0002 Training Records Management Procedure Issue 1.0.doc
17 General Reports/PRO/MRM-EL-QP01 Management Review.docx
17 General Reports/PRO/MRM-EL-QP02 Documentation Control.docx
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17 General Reports/PRO/MRM-EL-QP09 Laboratory Structure and Accreditation.docx
17 General Reports/PRO/MRM-EL-QP10 Laboratory Methods.docx
17 General Reports/PRO/MRM-EL-QP11 Calibration and Maintenance.docx
17 General Reports/PRO/MRM-EL-QP12 Sampling.docx
17 General Reports/PRO/MRM-EL-QP13 Receipt, Testing and Storage of Samples.docx
17 General Reports/PRO/MRM-EL-QP14 Proficiency Testing.docx
17 General Reports/PRO/MRM-EL-QP15 Reporting and Certificates.docx
17 General Reports/PRO/MRM-EL-QP16 Reporting Officer Approval.docx
17 General Reports/PRO/MRM-EL-QP17 Measurement Uncertainty.docx
17 General Reports/PRO/PRO-2300010 Line trimmer procedure Issue 1.0.docx
17 General Reports/PRO/PRO-2300011 Push Mower Procedure Issue 1.0.docx
17 General Reports/PRO/PRO-2300012 Ride on Lawn Mower Issue 1.0.docx

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17 General Reports/PRO/PRO-2600028 Adverse Weather and Lightning Procedure Issue 1.0.docx
17 General Reports/PRO/PRO-2600043 Admin, Mining and Metallurgy Evacuation Procedure Issue 1.0.docx
17 General Reports/PRO/PRO-2600045 Workflow approval part 1.pdf
17 General Reports/PRO/PRO-2600057 Mobile Phone and Multimedia Procedure Issue 1.0.docx
17 General Reports/PRO/PRO-2600060 Workflow review 1.0.pdf
17 General Reports/PRO/PRO-2600060 Workflow review 1.1.pdf
17 General Reports/PRO/PRO-2700001 Cultural Recognition Procedure Issue 1.0.docx
17 General Reports/PRO/PRO-2700005 Communication, Consultation and Shared Learning Procedure Issue 1.0.docx
17 General Reports/PRO/PRO-3100001 General Drill and Blast Procedure Issue 1.0.docx
17 General Reports/PRO/PRO-3100005 Magazine Management Procedure Issue 1.0.docx
17 General Reports/PRO/PRO-3100011 Blast Controller and Blast Guard Procedure Issue 1.0.docx
17 General Reports/PRO/PRO-3300010 Excavator Procedure Issue 1.0.docx
17 General Reports/PRO/PRO-3300017 Loading and Blasting in Reactive Ground Issue 1.0.docx
17 General Reports/PRO/PRO-3300019 Operating Equipment in Mining Areas of Spontaneous Combustion Issue 1.0.docx
17 General Reports/PRO/PRO-3500018 Quality Control and Quality Assurance of Blast Patterns Issue 1.0.docx
17 General Reports/PRO/PRO-4100003 Concentrate Transport Procedure Issue 1.0.docx
17 General Reports/PRO/PRO-4200003 Use Inspection and Testing of Electrical Equipment Issue 1.0.docx
17 General Reports/PRO/PRO-4500001 Workflow approval part 1.pdf
17 General Reports/PRO/PRO-4500001 Workflow approval.pdf
17 General Reports/PRO/PRO-4500002 Workflow approval part 1.pdf
17 General Reports/PRO/PRO-4500003 Workflow approval 1.0.pdf
20 GIS Maps and Figures/2016-17 Flora and Fauna Surveys - Final I001 Rev0.xlsx
20 GIS Maps and Figures/2016-17 Sediment, Dust, Biota Monitoring Schedule - Final I001 Rev1.xlsx
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Additional/ATTACHMENTS/Attachment A/SPROD seepage tests 2015-06.pdf
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Additional/ATTACHMENTS/Attachment AB/2015 - BB Transhipment Monitoring.pdf
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Additional/ATTACHMENTS/Attachment C/63728 CW NOEF EM and Magnetics Reprocessing Report Appendix B.pdf
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Additional/ATTACHMENTS/Attachment E/2016-17 Sediment, Soil, Dust and Biota Monitoring Schedule - Final I001 Rev1.xlsx
Additional/ATTACHMENTS/Attachment E/2016-17 Water Monitoring Schedule - Final I001 Rev1.xlsx
Additional/ATTACHMENTS/Attachment F/McArthur River Mine Waste Plan Final 2.pdf

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Additional/ATTACHMENTS/Attachment M/2014 - MRM Vegetation Monitoring at Barney and Surprise Creeks.pdf
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Additional/ATTACHMENTS/Attachment P/2015 - MRM Aquatic Fauna Late Dry Season.pdf
Air Quality Management Plan Presentation/MRM IM Presentation - 14June 2017.pdf
last year's (2015) closure costs/MRM 2015 Proposed Security Calculation .xlsx
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imagery & LiDAR from USB/2015_LiDAR/MRM_LiDAR_e621n8185_MGA53_AHD.xyz
imagery & LiDAR from USB/2015_LiDAR/MRM_LiDAR_e621n8186_MGA53_AHD.xyz
imagery & LiDAR from USB/2015_LiDAR/MRM_LiDAR_e621n8187_MGA53_AHD.xyz
imagery & LiDAR from USB/2015_LiDAR/MRM_LiDAR_e622n8183_MGA53_AHD.xyz
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imagery & LiDAR from USB/2015_LiDAR/MRM_LiDAR_e623n8187_MGA53_AHD.xyz
imagery & LiDAR from USB/2016_McArthurMine_MGA53.zip
imagery & LiDAR from USB/2016_McArthurMine_MGA53/McArthur-River-Mine_09Jul2016_10cm_MGA53.ecw
imagery & LiDAR from USB/2016_McArthurMine_MGA53/McArthur-River-Mine_09Jul2016_10cm_MGA53.ecw.aux.xml
imagery & LiDAR from USB/2016_McArthurMine_MGA53/McArthur-River-Mine_09Jul2016_10cm_MGA53.ers
imagery & LiDAR from USB/2016_McArthurMine_MGA53/McArthur-River-Mine_09Jul2016_10cm_MGA53.ers.aux.xml
imagery & LiDAR from USB/2016_McArthurMine_MGA53/McArthur-River-Mine_09Jul2016_10cm_MGA53.eww
imagery & LiDAR from USB/2016_McArthurMine_MGA53/McArthur-River-Mine_09Jul2016_10cm_MGA53.prj
imagery & LiDAR from USB/2016_McArthurMine_MGA53/McArthur-River-Mine_09Jul2016_10cm_MGA53.tab
imagery & LiDAR from USB/2016_Port-BingBong_10cm_MGA53.zip
imagery & LiDAR from USB/2016_Port-BingBong_10cm_MGA53/Port-BingBong_09Jul2016_10cm_MGA53.ecw
imagery & LiDAR from USB/2016_Port-BingBong_10cm_MGA53/Port-BingBong_09Jul2016_10cm_MGA53.ers
imagery & LiDAR from USB/2016_Port-BingBong_10cm_MGA53/Port-BingBong_09Jul2016_10cm_MGA53.eww

MRM-Supplied Files as Provided to ERIAS Group
imagery & LiDAR from USB/2016_Port-BingBong_10cm_MGA53/Port-BingBong_09Jul2016_10cm_MGA53.tab
20170628_IM_from Craig re Rob qu on gw bore/2016-17 Water Monitoring Schedule - Final I001 Rev3.xlsx
20170628_IM_from Craig re Rob qu on gw bore/20170628_E_frCraigD re RobG gw bore question.pdf
20170628_20170628_MRM Round 2 RFI Response_v2.pdf
Bing Bong Dredge Ponds Annual Inspection_2016_Rev0.pdf
CW Test Register_V4.xlsx
DGT Data/1510 MRM DGTs October 2015 Report.xlsx
DGT Data/1511 MRM DGTs November 2015 Report.xlsx
DGT Data/1512 MRM DGTs December 2015 Report.xlsx
DGT Data/1601 MRM DGTs January 2016 Report.xlsx
DGT Data/1602 MRM DGTs February 2016 Report.xlsx
DGT Data/1603 MRM DGTs March 2016 Report.xlsx
DGT Data/1604 MRM DGTs April 2016 Report.xlsx
DGT Data/1605 MRM DGTs May 2016 Report_revised 260716.xlsx
DGT Data/1606 MRM DGTs June 2016 Report_revised 260716.xlsx
DGT Data/1607 MRM DGTs July 2016 Report_revised 251116.xlsx
DGT Data/1608 MRM DGTs August 2016 Report_revised 251116.xlsx
DGT Data/1609 MRM DGTs September 2016 Report.xlsx
DRP Quarterly Report Oct-Dec 2016 - Letter.pdf
DRP Quarterly Report Oct-Dec 2016.pdf
Evaporative dispersion modelling 5864 Report v1.pdf
Event Based Data.csv
February 2016 COC/NT45093 COC.pdf
February 2016 COC/NT45093 Report.pdf
February 2016 COC/NT45093 SRA.pdf
February 2016 COC/NT45094 COC.pdf
February 2016 COC/NT45094 Report.PDF
February 2016 COC/NT45094 SRA.pdf
February 2016 COC/NT45131 COC.pdf
February 2016 COC/NT45131 Report.pdf
February 2016 COC/NT45131 SRA.pdf
February 2016 COC/NT45132 COC.pdf
February 2016 COC/NT45132 Report.pdf
February 2016 COC/NT45132 SRA.pdf
Flow vs SO4.xlsx
NIRB Documents/NIRB Requirement - Approval of Amendment to MMP.pdf
NIRB Documents/NIRB Final Report.pdf
NIRB Documents/NIRB HHERA Final.pdf
NIRB Documents/NIRB Interim Remediation Options Report.pdf
NIRB Documents/NIRB MMP Monitoring Program Review.pdf
TARP Report 0790-31-B1.pdf

MRM-Supplied Files as Provided to ERIAS Group
TSF Embankment Piezometers.xlsx
20170711_SEPROD seepage tests file found by Mick for Richard/SEPROD seepage tests 2015-11.pdf
Info for Warwick/20170703_aps_smp_entry.csv
Info for Warwick/MRM_PPP_APS_Daily_Tracking_CHY_20170706.pptx
Info for Warwick/MRM_REP_pXRF_Correction_Proposal_ECM_20170430.pdf
Info for Warwick/MRM_SPS_Correction_Factor_Analysis_ECM_20170427.xlsx
Info for Warwick/Waste_characterisation_2016.xlsm
re WQ for MJJ/150821 DME Instruction to Provide Env Monitoring Data.pdf
re WQ for MJJ/151220 Dilution Calc.pdf
re WQ for MJJ/151230 Dilution Calc.pdf
re WQ for MJJ/160202 Dilution Calc.pdf
re WQ for MJJ/20170725_E_frAdamH_re MJJ WQ qus.pdf
re incorrect piezometer readings/20170731_E_frMRM_re piezometers.pdf
re incorrect piezometer readings/Attachment A - MRM Monthly Piezometer Interpretation - June 2017.pdf
re incorrect piezometer readings/TSF Embankment Piezometers_corrected.xlsx
Gouldian finch survey shapefiles/FINAL 2015 - 2016 Gouldian Survey Sites.id
Gouldian finch survey shapefiles/FINAL 2015 - 2016 Gouldian Survey Sites.map
Gouldian finch survey shapefiles/FINAL 2015 - 2016 Gouldian Survey Sites.tab
Gouldian finch survey shapefiles/FINAL 2015 - 2016 Gouldian Survey Sites.xlsx

Table 2 – DPIR-Supplied Files Used in the Assessment

DPIR-Supplied Files as Provided to ERIAS Group
1. Mining Management Plan/20151203 - Technical Report - 201516 Site Water.PDF
1. Mining Management Plan/20151203 TSFCell 1 eastern sump spillway.msg
1. Mining Management Plan/20151211 Cell 1 Wet Season Water Mgtt.msg
1. Mining Management Plan/20151216 Request to transfer water.msg
1. Mining Management Plan/20151222 MMP Approvals.msg
1. Mining Management Plan/20151223 2013 - 2015 MMP Approval.msg
1. Mining Management Plan/20151223 2013-2015 MMPApproval Letter.PDF
1. Mining Management Plan/20160108 Approval and Request for additional Info.PDF
1. Mining Management Plan/20160108 RE Response to recent approvals requests.msg
1. Mining Management Plan/20160108 Response to recent approvals requests.msg
1. Mining Management Plan/20160118 - Instruction future MMPs and OPRs.PDF
1. Mining Management Plan/20160118 Dates of future MMPOPR submissions.msg
1. Mining Management Plan/20160118 RE Dates of future MMPOPR submissions.msg
1. Mining Management Plan/20160118Instruction re MMP Submissions.PDF
1. Mining Management Plan/20160216 Add Info - Design Details SW Sed Trap.ZIP
1. Mining Management Plan/20160226 Add Info - Design Report.PDF
1. Mining Management Plan/20160226 Response to Request for Add Info..msg
1. Mining Management Plan/20160321 Approval of Amendment.PDF
1. Mining Management Plan/20160330 -MMPOPR Submission Delay Request.EML
1. Mining Management Plan/20160331 RequestAddInfoTSF Cell 1.pdf
1. Mining Management Plan/20160607 OPR Submission Date change.EML
1. Mining Management Plan/20160609 OPR Sub Date.EML
1. Mining Management Plan/20160616 Monitoring Reports for WDL and Common.ZIP
1. Mining Management Plan/20160624Response to change in OPR sub date.MSG
1. Mining Management Plan/20161216 ITRB Reports on TSF LOM.msg
1. Mining Management Plan/Amendment SPROD/20160909 SPROD Request for further information.pdf
1. Mining Management Plan/Amendment SPROD/20161003 SPROD Request for additional information.msg
1. Mining Management Plan/Amendment SPROD/20161104 SPROD MMP Amendment Acceptance .pdf
1. Mining Management Plan/Amendment SPROD/20161107 SPROD Lining Project Acceptance.msg
1. Mining Management Plan/Amendment SPROD/MMP Amendment - SPROD Lining.zip
1. Mining Management Plan/Amendment TSF Raise 3/20151001 Conditional approval to transfer water.msg
1. Mining Management Plan/Amendment TSF Raise 3/20151001 Conditional Approval Transfer water.pdf
1. Mining Management Plan/Amendment TSF Raise 3/20151001 ReponseConditional ApprovalTranfers.msg
1. Mining Management Plan/Amendment TSF Raise 3/20151001 Request transfer of P2 water to WMD.msg
1. Mining Management Plan/Amendment TSF Raise 3/20151001 Water Transfer Conditional Approval.msg
1. Mining Management Plan/Amendment TSF Raise 3/20151019 Completion Transfer of Water.pdf
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160202 PresentationInterim PlanPhase 3 EIS.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160203 NT EPA to withdraw CWNOEF NOI.EML

DPIR-Supplied Files as Provided to ERIAS Group
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160205 Request for information CWNOEF.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160205 Email In - MMPPhase 3 EIS.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160209 Request for Add InfoPhase 3 EIS.PDF
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160209 RequestinformationNOEF CW.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160210 Addi infoLS-characterisationCWNOEF.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160210 Email in Strohmayr to HauslerCWNOEF.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160210 Request Additional InfoPhase 3 EIS.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160217 Additional Information - CWNOEF.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160219 Fogg to Strohmayr -Further Kinetic Testing Data.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160222 - RE Request for Add InfoTesting Data.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160224 ConfirmationAmendment for CW NOEF.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160224 Request for Further Info.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160229 AddInfo Amendment for CW NOEF.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160229 AddInfoBravo CWNOEF.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160229 Characterisation AmendCWNOEF.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160301 AddInfoNOEF West D Design.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160301 NOEF CWNOEF amendment.ZIP
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160302 PPTCWNOEF and NOEF Amend2 Feb2016.PDF
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160303 RequestAddInfostages and West.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160304 Hausler to Strohmayr Fish Report.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160311 AddInfoKinetic.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160311 Conditional ApprovalCWNOEF.PDF
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160311 Strohmayr to Hausler Update designs.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160314 E-mail in - AddInfoNOEF.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160318 Email out - Approval of NOEF Amend.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160321 ApprovalConditions and Instruction.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160406 Grant of ExtensionHydrobiology Report.EML

DPIR-Supplied Files as Provided to ERIAS Group
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160406 Request Hydrobiology Report.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160415 Email out Marine monitoring program.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160415 Email OutHydrobiology Report.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160415 Letter in ResponseHydrobiology Report.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160505 E-mail in SOW CWNOEF.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160512 DPIF Commentsmonitoring program.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160512 HealthCommentsMarine monitoring.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160516 Acceptance monitoring programme.PDF
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160516 Email out Acceptance Monitoring.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160530 Email in Risks from irrigation.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160621 Letter In Query regarding NOEF SOW.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160621 Letter Out Response NOEF Invest SOW.PDF
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160622 EcoMetrix Review of Monitoring.ZIP
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160622 Email In Ecometrix Review.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160622 Email In Review of Monitoring.EML
1. Mining Management Plan/CWNOEF (Amendment 05 CWNOEF)/20160629 Email chain Request CWNOEF Wording.EML
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/151130 LTTR MRM Commonwealth Environmental Report Submission.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2014 Transhipment Sediment.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2014- Annual Marine Monitoring.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2014- Aquatic Monitoring late Dry Season.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2014- Near Shore Sediment at Bing Bong Sediment.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2014- Riparian Birds Late Dry Season.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2014- Seagrass survey at Bing Bong.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2014-15 Ambient Dust Monitoring Report.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2014-15 DGT Monitoring at Bing Bong.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2014-15 Fluvial Sediment Monitoring Report.pdf

DPIR-Supplied Files as Provided to ERIAS Group
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2014-15 Groundwater Monitoring Report.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2014-15 Surface Water Monitoring Report.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2014-15 WDL Monitoring Report.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Aquatic fauna - Early Dry Season.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Aquatic Fauna - Late Dry Season.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Dry Season SO2 Monitoring Report.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Gouldian Finch Report.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Macroinvertebrate Report.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Migratory Brids Northern Staging.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Migratory Brids Summer.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Near Shore Sediment at Bing Bong.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Riparian Birds Early Dry Season.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Riparian Birds Late Dry Season.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Seagrass Survey at Bing Bong.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Vegetation Monitoring at Barney and Suprise Creeks.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Vegetation Monitoring Bing Bong Dredge Spoil.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2015 - Vegetation Monitoring Rechannel.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2016 - SO2 Air Quality Audit Program.pdf
1. Mining Management Plan/Monitoring Reports - DME Submission 160524/Reports/2016 - Wet Season SO2 Monitoring Report.pdf
10. Commonwealth Government/DMEDidNotProvideAdvicetoDoEOnEPBCMatters.txt
11. EPA/20151005 Devils Spring and BorroloolaAugust 2015.msg
11. EPA/20151102 Clause 14A Assessment of CWNOEF.msg
11. EPA/20151123 Cover letter accompanyingCWNOEF.PDF
11. EPA/20151123 ResponseMRM clause 14ACWNOEF.msg
11. EPA/20151202 NT EPA - EIS CWNOEF.PDF
11. EPA/20151215 Request for comment - draft WDL.msg
11. EPA/20151218 RE MRM presentations.msg

DPIR-Supplied Files as Provided to ERIAS Group
11. EPA/20151222 FW MRM External Advice CWNOEF.msg
11. EPA/20151222 RE MRM External AdviceCWNOEF.msg
11. EPA/20160914 Draft WDL174-09 for comment MRM.EML
11. EPA/20161102 ResponseNTEPAClause 14A Assessment.PDF
12. Procedures - Audit/CP4-001 AuditsSite Inspection Procedure.doc
13. Procedures - Sampling/aa7-024-methodology-for-the-sampling-of-groundwater.pdf
13. Procedures - Sampling/aa7-025-methodology-for-the-sampling-of-surface-water.pdf
14. Procedures - Accepting Plans/AP1-003 New Authorisation Administrative.doc
14. Procedures - Accepting Plans/AP1-004 New Authorisations Check sheet.doc
14. Procedures - Accepting Plans/AP2-003 Document Review Procedure.docx
14. Procedures - Accepting Plans/CP1-001 Existing Authorisation Administrative.doc
14. Procedures - Accepting Plans/CP1-002 Existing Authorisations Checklist.doc
15. Correspondence/20151013 Monthly water quality data.msg
15. Correspondence/20151016 Monthly water quality data.msg
15. Correspondence/20151020 Diesel Quarterly report.msg
15. Correspondence/20151204 Sept and Oct MRM Data.msg
15. Correspondence/20151222 Presentation on drilling program.msg
15. Correspondence/20151230 Nov MRM Data.msg
15. Correspondence/20160127 MRM DRP Quarterly Report.msg
15. Correspondence/20160216 Monthly Monitoring DataDec2015.EML
15. Correspondence/20160316 Monthly Monitoring DataJan2016.EML
15. Correspondence/20160405 MMA S16(2) Reminder.PDF
15. Correspondence/20160410 Monthly Monitoring DataFeb2016.EML
15. Correspondence/20160607 Monthly Monitoring DataApril 2016.EML
15. Correspondence/20160706 Monthly Monitoring DataMay 2016.EML
15. Correspondence/20160804 Monthly Monitoring DataJune 2016.EML
15. Correspondence/20160829 Decommissioning of GW107.PDF
15. Correspondence/20160917 Monthly Monitoring DataJuly 2016.EML
2. Compliance Audits and Inspections/20151027 Site Inspection Report.pdf
2. Compliance Audits and Inspections/20151117 Site Inspection Report.pdf
2. Compliance Audits and Inspections/20151209 Site Inspection Report.pdf
2. Compliance Audits and Inspections/20151224 - Receipt -Inspection Reports.msg
2. Compliance Audits and Inspections/20151224 Site Inspection Reports OctNovDec 2015.msg
2. Compliance Audits and Inspections/20160119 Site Inspection Report.pdf
2. Compliance Audits and Inspections/20160202 Site Inspection Report - 19 January 2016.EML
2. Compliance Audits and Inspections/20160415 Site Inspection Report.pdf
2. Compliance Audits and Inspections/20160524 Site Inspection Report.pdf
2. Compliance Audits and Inspections/20160603 Field Inspection Reports - April and May 2016.EML
2. Compliance Audits and Inspections/20160623 Site Inspection Report - 23 June 2015.PDF
2. Compliance Audits and Inspections/20160716 Site Inspection Report.pdf
2. Compliance Audits and Inspections/20160720 File Note ID SO2 at SOEF.docx

DPIR-Supplied Files as Provided to ERIAS Group
2. Compliance Audits and Inspections/20160920 Slite Inspection Report - 16 July 2016.EML
4. Waste Rock/20160321 InstructionNOEF Environ Harm Invest.PDF
4. Waste Rock/20160720 Instruction to cease work at NOEF.pdf
4. Waste Rock/20160817 Update on NOEF Dust Mit Plan.pdf
5. Tailings Storage Facility/20151012 MRM TSF Communication - September.msg
5. Tailings Storage Facility/20151016 RE Acknowledgment MRM TSF Communication.msg
5. Tailings Storage Facility/20151109 MRM TSF Communication - October.msg
5. Tailings Storage Facility/20151210 RE MRM TSF Communication - November.msg
5. Tailings Storage Facility/20160113MRM TSF Communication - December.msg
5. Tailings Storage Facility/20160210 MRM TSF Communication - January 2016.msg
5. Tailings Storage Facility/20160304 MRM TSF Communication - February 2016.msg
5. Tailings Storage Facility/20160413 Request for Additional information - TSF LOM Plan.PDF
5. Tailings Storage Facility/20160414 Email out - Request for Add Info - TSF LOM Plan.EML
5. Tailings Storage Facility/20160506 RE MRM TSF Communication - March and April 2016.msg
5. Tailings Storage Facility/20160513 Additional Info sent to RGC - TSF LOM Plan.EML
5. Tailings Storage Facility/20160513 Letter in - Additional info - ITRB Review.EML
5. Tailings Storage Facility/20160514 Email in - Response to Add Info for Tech Review.EML
5. Tailings Storage Facility/20160523 Instruction to resubmit TSF Monthly Report.EML
5. Tailings Storage Facility/20160523 Letter Out - Request TSF Stability Analyses - Phreatic Line.PDF
5. Tailings Storage Facility/20160523 Request Add Info - TSF Monthly Reports - MarchApril.PDF
5. Tailings Storage Facility/20160602 MRM TSF Cell 2 Monthly Report - May 2016.EML
5. Tailings Storage Facility/20160711 MRM TSF Monthly Report - June 2016.EML
5. Tailings Storage Facility/20160721 Additional Information - TSF Stability Analysis - TSF LOM.ZIP
5. Tailings Storage Facility/20160808 MRM TSF Monthly Report - July 2016.EML
5. Tailings Storage Facility/20160808 Request forAdd Info - TSF Stability Analysis - TSF LOM Plan.PDF
5. Tailings Storage Facility/20160906 MRM TSF Monthly Report - August 2016.EML
5. Tailings Storage Facility/20160909 Additional Information - TSF LOM Plan Stability Analyses.EML
5. Tailings Storage Facility/20160912 Request for Tech Review - TSF LOM.EML
5. Tailings Storage Facility/20160914 Comments from RGC on TSF LOM Concept.EML
5. Tailings Storage Facility/20160914 RGC concerns with MRM Seepage Modelling - TSF LOM.EML
5. Tailings Storage Facility/20160914 RGC Report on TSF LOM Concept.EML
5. Tailings Storage Facility/20161006 MRM TSF Monthly Report - September 2016.EML
6. Mine Closure/2016021 Draft Closure Plan 11 Feb 2016.PPTX
7. Health/20160304 Issue of Hydrobiology.PDF
8. Check Monitoring/20151224 TRIM NT44723 15.0142-15.0157.pdf
8. Check Monitoring/20170525 QA QC report.msg
8. Check Monitoring/Check Monitoring Data - MRM.xlsm
9. Incidents/20151117 APP Suction Line Leak/20151130 S29 Notification - Spillage at APP Dam.msg
9. Incidents/20160209 Hydraulic Hose Failure/20160212 S29 NotificationHydraulicspill.EML
9. Incidents/20160209 Hydraulic Hose Failure/20160225 Investigation Hydraulicspill.EML
9. Incidents/201607 PAF dumped at SOEF/20160720 s29 SOEF notification.pdf

DPIR-Supplied Files as Provided to ERIAS Group
9. Incidents/201607 PAF dumped at SOEF/20160721 Instruction to investigate incident.pdf
9. Incidents/201607 PAF dumped at SOEF/20160727 - Duty of Care to Mining Officers.pdf
9. Incidents/201607 PAF dumped at SOEF/20160805 Request for Add Info - SOEF Investigation.pdf
9. Incidents/201607 PAF dumped at SOEF/DME Response re SOEF Investigationv2 160819.pdf
9. Incidents/201607 PAF dumped at SOEF/Letter to DME re SOEF Instruction 160729.pdf
9. Incidents/20160714 SO2 Detection SOEF/20160721S29 Notification-SO2 Detection at SOEF.EML
9. Incidents/20160714 SO2 Detection SOEF/20160726Request for a copy of SO2 InductionSOEF Incident.EML
9. Incidents/20160714 SO2 Detection SOEF/20160729S29 Investigation ReportSOEF Incident.EML
9. Incidents/20160714 SO2 Detection SOEF/20160805Request for Additional Information.PDF
9. Incidents/20160714 SO2 Detection SOEF/20160819Revised SOEF Invest Report V2SOEF.EML
9. Incidents/20160714 SO2 Detection SOEF/20160901Request for Add InfoRemediation PlanSOEF.PDF
9. Incidents/20160714 SO2 Detection SOEF/20160901Request for further infoSOEF Incident RemedPlan.EML
9. Incidents/20160714 SO2 Detection SOEF/20160920 File Note following IDSO2 at SOEF.DOCX
9. Incidents/20160714 SO2 Detection SOEF/20161024 Remed Plan Revised October 2016.EML
9. Incidents/20160714 SO2 Detection SOEF/20161104 Remed Plan Acceptance.PDF
9. Incidents/20160714 SO2 Detection SOEF/20161107 SOEF Remed Plan Acceptance.EML
9. Incidents/20160723 NOEF Dust/160723 - Instruction to cease work at NOEF.PDF
9. Incidents/20160723 NOEF Dust/201607 Dust from NOEF/20160723 Instruction to cease operations..pdf
9. Incidents/20160723 NOEF Dust/201607 Dust from NOEF/20160726_Instruction to investigate.pdf
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Appendix 2.
Risk Register

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	Bing Bong Loading Facility	Water Management	Overflow of Bing Bong surface runoff pond (BBSRP)	High rainfall, or failure to clean out sediment from pond, or mismanagement of water volumes leads to overflow of one or more of the Bing Bong surface runoff ponds (BBSRP)	Poor quality water (metals, acid) affect terrestrial and aquatic ecosystems	M	L	Three adjacent surface runoff containment ponds. Annual water balance modelling undertaken. Evaporation of pond water through use of pond water as dust suppression across site. Annual marine heavy metal monitoring. Trucks transporting water to TSF (as previously required)	4	4	8	L	All three runoff ponds should be cleaned out prior to the wet season. Confirmation that water balance modelling will be undertaken annually
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	M	RI	Existing controls outlined in WRM report Site Water Balances for the McArthur River Mine and Bing Bong Loading Facility	1	3	4	H	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	M	RI	Annual revision of the water balance model. Continual improvement in the monitoring of water balance components	1	3	4	H	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	Water Balance Modelling	Use of the Underground Void/Open Pit (UG&OP) for Water Storage conflicts with mine 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	M	RI	Annual revision of the water balance model. Continual improvement in the monitoring of water balance components	1	3	4	H	Medium to long term plans to reduce the risk of water ponding in the open pit.
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	M	RI	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	1	3	4	H	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	M	RI	Annual revision of the water balance model. Continual improvement in the monitoring of water balance components	1	3	4	H	The water balance modelling needs to be fully utilised in mine site risk management and options analysis.
4.3	McArthur River	Water management	Poor management of excess dirty/ contaminated water during operations	Release of dirty/contaminated water during operations	Discharge of excess dirty/contaminated water to the McArthur River, impacting aquatic ecosystems and other beneficial uses	E	OM	Groundwater monitoring, surface water monitoring, MRM discharge calculation tool	4	2	6	M	Background and mine-derived load calculations required, including site load balance; the IM understands that loads will be reported in MRM's 2017 Operational Performance Report
4.4	Mine levee wall	Long-term structural integrity	Erosion at several points along the Mine Levee Wall	Failure of the mine levee wall during flood	Failure of the mine levee wall in extreme events and runoff from the mine site to the river	M	WM	Minor erosion sites have been inspected and are to be repaired in dry season. General erosion of the mine levee wall is to be investigated as part of the Geomorphic Assessment currently being undertaken. Plan for the long term stability of the mine levee wall to be detailed in the upcoming EIS	1	3	4	H	Recommended that the armouring is carried out in accordance with the Independent Geotechnical report.
4.4	River diversions	River diversion design performance	Stability of the McArthur River Diversion Chanel offtake	Active avulsion upstream will direct flow directly at the old course of the McArthur River and at the Mine Levee wall.	Erosion of the mine levee wall resulting in sediment laden water discharging to the McArthur River diversion channel, possible breach of the mine levee wall, erosion of the SOEF and discharge of water and sediment into the pit	E	WM	No control in place. Geomorphic Assessment recommends that that option to mitigate the avulsion are assessed and actions implemented.	2	3	5	H	Recommended that that option to mitigate the avulsion are assessed and actions implemented.
4.4	River diversions	River diversion design performance	Major erosion/failure of river diversions channel during flood	Flood event	Altered flood behavior. Increased sediment load downstream in the McArthur River. Impact on aquatic and terrestrial ecosystems	S	L	No controls in place. To be investigated as part of the Geomorphic Assessment currently being undertaken	3	4	7	M	No photograph monitoring this operation year or the 2014 operation year. No ALS topography appears to have been assessed. Despite the current geomorphic assessment, it is recommended that a formal, documented assessment of the ALS, aerial photographs and site photographs, combined with a visual inspection of key risk areas is conducted annually
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	The control does not mitigate the risk of failure of the mine levee wall. It is recommended that the long term plan for the stability of the mine levee wall is reported on in detail, given the potential consequence of failure

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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
4.4	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	3	4	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	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	It is recommended that the area be inspected after high flow events and changes reported on if any.
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.	1	3	4	H	It is recommended that the areas of instability are investigated and an options assessment conducted on mitigating the ongoing gullying.
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	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	Assessment of the drawdown impacts with results provided as part of future groundwater monitoring reports
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
4.5	Water storages	Water storage design	Poor water storage design/construction	Release of dirty/contaminated water	Seepage of dirty/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	3	1	4	H	Lining of all storages. Estimation of seepage rates using the mine-site water balance model to identify areas where unacceptable groundwater impacts may be occurring, with results presented as part of future groundwater monitoring reports
4.5	Mine Pit	Closure criteria	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
4.6	Bing Bong dredge spoil	Drainage	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	Mine site	Geochemical	Potentially acid, saline and metal leaching materials are used for construction purposes across site	Materials used in construction previously classified NAF may now be a geochemical hazard under the new criteria Material types used in construction not adequately tracked	Local impacts on re-vegetation, water quality. Potential influence on SW11 EC Compliance	L	P	Initial geochemical sampling and test program carried out on infrastructure around site	4	2	6	M	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	NOEF	Geochemical	Failure of NOEF cover	Cover breached through erosion, slumping, differential movement, cracking/heaving due to convective oxidation, and/or undermining of dump due to extreme flooding event, leading to exposure of highly pyritic waste rock to oxidation and infiltration	Acid, saline and metalliferous drainage impacts in perpetuity on groundwater, terrestrial and aquatic ecosystems	G	OM-RI	Initial cover system modelling and design has been carried out, which indicates the use of multi-layered cover system with relatively thin layers	1	2	3	E	Placement of a multi-layered cover system of the types modelled on the NOEF is expected to be challenging, with long term maintenance of these layers and their performance even more so Key uncertainties include: - Performance of cover system - requires trials - Ability to install low infiltration CCL over entire surface of dump - alternate infiltration controls should be further evaluated - Long term integrity of cover system - requires further investigation of erosion, differential settlement, and resources/equipment required for maintenance
4.6	NOEF	Geochemical	NOEF Seepage	NOEF seepage reports to groundwater during operations and ultimately to surface drainage down-gradient	Acid, saline and metalliferous drainage impacts on groundwater, terrestrial and aquatic ecosystems	M	WM	Monitoring of groundwater Leaking interception ponds NOEF SPROD/SPDS have been lined with compacted clay, which will reduce a major source of seepage.	3	1	4	H	Further investigation and analysis of monitoring data should be carried out to better understand the extent and impact of groundwater contamination from the NOEF

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4.6	NOEF	Geochemical	Development of convection cells in end tip dump areas.	End dumping of PAF materials resulting in segregation of coarse and fine materials and creation of chimney structures that encourage rapid convective oxidation, including spontaneous combustion	Greater rates of oxidation and generation of acid, salinity and dissolved metals, consequent impacts on groundwater, terrestrial and aquatic ecosystems Spontaneous combustion impacts from PAF(RE) affects the stability of the NOEF and results in breaches the of the final cover	L	WM	PAF(RE) and PAF(HC) are currently paddock-dumped and traffic-compacted. Spontaneously combusting materials are managed through excavation and compaction. Construction of a MS-NAF halo zone is almost complete around the W, E and S faces of the older West Stage of the NOEF as part of the broader cover system to help control convection/advection into PAF materials. Advection control layers are being placed on non active portions of the dump	2	2	4	H	The effectiveness of the advection covers being placed on the NOEF needs to be demonstrated, particularly for the existing end-tipped actively convecting PAF portions of the NOEF. 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	NOEF	Geochemical	Misclassification of geochemical rock types	Classification criteria not sufficiently discriminating, or the geochemical properties of geochemical rock types are different from what was expected based on results to date	Acid, saline and metalliferous drainage from unexpected parts of the dump and consequent impacts on groundwater, terrestrial and aquatic ecosystems Mis-placement of PAF(RE) leads to spontaneous combustion and consequent impacts on dump stability and increased acid, saline and metalliferous drainage	G	OM-RI	External ICP testing is now carried out in preference to pXRF, but pXRF used from time to time when ALS at full capacity. Geochemical testing and investigations carried out to date have resulted in a comprehensive dataset with an appropriate suite of static and kinetic tests, so that the geochemical properties of overburden and tailings materials at the mine are well understood	3	4	7	M	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 Resolve discrepancies between mined waste rock classes and those modelled. Better demonstrate the validity of the PAF(RE) 10%S sulfur cut off
4.6	NOEF	Geochemical	Mis-placement of waste rock materials.	Materials placed in the wrong locations Use of the older classification system in older dump areas	Acid, saline and metalliferous drainage from unexpected part of the dump and consequent impacts on groundwater, terrestrial and aquatic ecosystems	G	L	Significant improvements have been made with block modelling, materials tracking and checks.	3	4	7	M	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. Better document review and decision making process for APS tracking system. Include more detailed instructions on sampling methodology in the OEF sampling procedure
4.6	Open pit	Geochemical	Pit water quality after closure	The open pit lake becomes strongly acid and/or saline and metalliferous after closure due to oxidation of exposed pyritic PAF and NAF materials in pit walls, 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	Pit water quality modelling carried out as part of the EIS, which indicates that the recovery water level in the pit would inundate most of the pyritic materials in the pit shell so that sulfide oxidation would largely cease, with only small amounts of MS-NAF exposed to contribute ongoing AMD loadings	2	3	5	H	Additional controls will depend on the outcome of the EIS
4.6	SOEF	Geochemical	Saline and metalliferous drainage	SOEF composed of mainly MS-NAF but there is no cover system in place to control water and oxygen flux	Saline and metalliferous drainage and consequent impacts on groundwater, terrestrial and aquatic ecosystems Impacts on rehabilitation success	G	L	Kinetic testing continuing and groundwater monitoring confirms impacts, but modelling suggests seepage towards open pit Closure plan in EIS proposes re-handling to pit	3	3	6	M	Additional controls will depend on the outcome of the EIS
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
4.6	TSF	Geochemical	Tailings leachate from Cell 1	Poor design of TSF and incomplete rehabilitation of Cell 1 leads to TSF leachate into Surprise Creek	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. Aquatic fauna surveying in Surprise Creek Overflow ponds completed Piezometers installed	3	2	5	H	Install a more robust cover on Cell 1 before the next wet season that will withstand erosion and control infiltration, and progress the Cell 1 dewatering bores. The previous interim clay covers installed did not appear adequate to control seepage and impacts on Surprise Creek
4.6	TSF	Geochemical	Tailings leachate from Cell 2	Tailings leachate reports to groundwater during operations and ultimately to surface drainage down-gradient, or an uncontrolled release occurs due to high flow event	Water quality impacts on impacts on groundwater and surface drainage down-gradient Mainly elevated SO_4 salts and electrical conductivity, and possibly Zn and Mn. Could include acid and elevated metals if tailings acidify	M	WM	Monitoring of groundwater 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	3	2	5	H	Monitor 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. Carry out geochemical characterisation of tailings collected as part of TSF drilling to obtain information on historic variation through the tailings profile. 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	WOEF	Geochemical	Failure of WOEF cover	Cover breached through erosion, slumping, differential movement, and/or undermining of dump due to extreme flooding event, leading to exposure of MS-NAF and PAF materials	Acid, saline and metalliferous drainage from unexpected part of the dump and consequent impacts on groundwater, terrestrial and aquatic ecosystems Impacts on rehabilitation success	G	L	The PAF core of the dump has been encapsulated by clay, and covered with undifferentiated NAF materials. A nominal multi layered cover system has been outlined	3	3	6	M	Review/compile existing data and/or carry out a test program to confirm the distribution of geochemical rock types at the WOEF and finalise an appropriate approach to closure
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	4	5	H	Review of piezometric monitoring and interpretation, investigate and assess the reasons why seepage and piezometric levels appear to be higher than anticipated, develop measures for limiting further seepage and reducing water levels within the embankment. Use VWPs to reduce the risk of incorrect interpretation of monitoring data

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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	2	4	6	M	Ensure the Cell 1 drainage and detention system can accommodate a 1 in 200 year storm event through assessment and modification as required
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	1	5	H	Review pipeline inspection schedule and reporting responsibilities. Check pipeline connections and liner wear.
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	6	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
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	
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	2	6	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	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 atability 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. 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
4.7.1	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	
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	4	6	M	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 Measure embankment piezometers (BBEMB series) at least every 3 months and more frequently after periods of heavy rainfall
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.
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

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4.8	Mine site	Security bonds	NOEF	The current mine closure costs for the NOEF and TSF are based on a design which is not feasible	Significant financial impact if the mine was to close before revised security bonds were in place.	G	WM	A revised mine closure plan has been prepared as part of the Overburden Management Project EIS however this is currently being assessed by the NT Government	2	2	4	H	MRM have established erosion trials and plan to establish a cover trial which will provide information re the performance of the cover system to compare to modelling results
4.8	Mine site	Security bonds	Long term post closure monitoring and maintenance costs	Current closure costs allow for a period of 25 years post closure water monitoring with limited costs associated with management and maintenance of the site. Costs insufficient to manage and maintain the site post closure.	MRM have stated in the Overburdent Management Project EIS that monitoring and maintenance costs are likely to continue for several hundred years	G	OM	Some costs provided for post closure management and maintenance but these are inadequate.	1	2	3	E	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: • 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 the pit lake. • Monitoring and maintenance of the mine levee wall. • Monitoring and maintenance of McArthur River diversion channel. The IM understands that these issues will be addressed in the Overburden Management Project EIS.
4.8	Mine site	Closure criteria	Measurement of success	Some closure criteria are not specific or measureable and consequently there is uncertainty regarding whether MRM has met agreed closure criteria	MRM and DME fail to agree that aspects of the site have achieved closure criteria	NA	WM	Closure criteria have been developed, but they are not specific (measureable) to determine if an aspect has been competed					Revised closure criteria prepared as part of the review of the mine closure plan for the Overburden Management Project EIS however further work required to ensure that criteria are specific and capable of objective measurement / verification
4.8	Mine site	Security bonds	Mine closure liability - no approved closure strategy for OEF's, TSF or pit lake	MRM closes unexpectedly, leaving NOEF, TSF, river diversions, and mine site rehabilitation unfinished.	Sudden closure results in shortfall in materials to complete rehabilitation resulting in increased costs and bond unable to cover cost.	S	WM	Revegetation has started on river diversions but is not complete, monetary bond in place.	1	3	4	H	Updated mine closure cost to be prepared as soon as outcome of EIS is known and bond adjusted accordingly
4.8	Bing Bong Loading Facility	Security bonds	Dredge spoil ponds at Bing Bong Loading Facility are not included in the mine closure costs.	Closure of mine reveals shortfall in funds	Insufficient funds to rehabilitate Bing Bong Loading Facility following closure.	M	OM	Nil	2	2	4	H	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	Bing Bong dredge spoil	Terrestrial Flora	Drain surrounding dredge spoil not protecting habitat surrounding dredge spoil 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 of vegetation in undisturbed habitat surrounding the dredge spoil and alteration and/or extended periods of inudation by seawater	M	L	Annual maintenance of drain which drains saline water out to sea. Annual vegetation monitoring of vegetation surrounding spoil area. South west corner of dredge spoil removed	2	3	5	H	Continue vegetation monitoring program. Inspect outside wall of drain for pooling of seawater and log in monthly inspections. Conduct remedial works if pooling or damage to drain is identified
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 veg 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 as a result of the operations development	Cleared or areas slow to revegetate leave patches of open land 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, bi-annual riparian bird surveys, annual vegetation surveys along diversions, exclusion of cattle, weed control	5	3	8	L	Leave vegetation corridors where possible
4.9	Mine Site and Bing Bong load-out facility	Weed management	Infestation of weeds	Weeds present on mine leases from historical mining and pastoral activities 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 Parkinsonia biological control trials at Bing Bong dredge spoils ponds. Employment of local residents from Borroloola in weed management, including 3/7 local people in the monitoring section and 3/5 local people in the rehabilitation section. All seasonal workers (tree planters) are employed locally	2	3	5	H	Follow Weed Management Plan. Continue to investigate possibility of cooperative weed control with pastoral properties upstream on McArthur River
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, mortality of aquatic fauna	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 traps at Barney Creek diversion bridge. Cell 1 of TSF capped and seeded with shrubs and grass	3	3	6	M	Testing of heavy metals in vegetation in addition to current aquatic fauna heavy metal monitoring program
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 dieback	Loss of vegetation, reduction of habitat for fauna and flora, contamination of rivers and creeks, mortality of aquatic fauna	M	WM	Saline impact monitoring program, water management dams.	3	2	6	M	Review current saline impact monitoring sites. Consider adding sites in areas of known S04 deposition.
4.9	River diversions	River diversion revegetation	Slow revegetation of McArthur River diversion	Flooding in wet season causes erosion and soil redistribution on unvegetated areas. Removal of planted vegetation by flooding and trampling/grazing by feral herbivores	Channel banks are unstable with erosion occurring, reduced riparian habitat, lack of shade for aquatic species, facilitating the spread of weeds	M	L	Annual revegetation monitoring. Use of coir logs and large woody debris to create soil pockets and tubestock planting, including targeted planting in soil pockets. MRM have mustered cattle and undertaken extensive repairs and upgrading of existing fencing surrounding diversions to exclude feral herbivores	3	2	5	H	Redesign revegetation monitoring program in line with IM recommendations
4.9	River diversions	Terrestrial fauna and flora	Creation of unsuitable habitat along Barney Creek and McArthur River diversion channels	Planting 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 and primary species for riparian habitats identified. Review of the suitability of key and primary species conducted. Table provided in riparian bird monitoring report detailing suitable riparian plant species. Progation of riparian flora in MRM nursery	4	3	7	M	Investigate the suitability of current control sites. Include flora species highlighted as important for riparian bird species in the riparian bird monitoring reports in key and primary species. Increase survey sites on the Barney Creek diversion channel downstream of the Barney Creek haul road bridge

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4.9	TSF	Terrestrial fauna and flora	Clearing of Gouldian finch habitat	Removal of feeding 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. 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	Survey mine lease for potential breeding habitat and important foraging habitat, create habitat map showing locations of important habitat. Avoid clearing these areas
4.10	Mine site	Aquatic Fauna	Fugitive dust emissions and seepage as a result of operations.	Dust emissions from the TSF, haul roads, ROM pad, concentrate stores other aspects of operations and seepage from the TSF, SPROD, ROM sump and NOEF affects water and fluvial sediment quality in McArthur River and Barney, Little Barney and Surprise creeks	Reduction in water quality reduces diversity and abundance of aquatic fauna. Metals bioaccumulate in aquatic fauna causing unknown lethal and/or sub-lethal/ chronic effects. Contaminants then migrate downstream from MRM. Contaminated biota move from exposed sites around McArthur River Mine to regional reference sites.	M	RI	Dust emission controls, such as watering roads and a clay cap on TSF cell 1. Drains constructed around TSF and NOEF to capture seepage and lining the SPROD to stop seepage. Diverting drainage from the Barney Creek haul road bridge to silt traps and increased spraying of roads. Monitoring dust, contaminants in fluvial sediments, water quality, aquatic fauna diversity and abundance and assessing bioaccumulation of metals in fish around MRM. Routine inspections of infrastructure	3	2	5	H	Expand dust mitigation measures, such as regular removal of built up sediments along the haul road. Explore ways to minimise dust emissions from the ROM pad and processing plant and seepage from the ROM sump. An upgrade of the crushing plant to reduce dust emissions is planned in Q2 2017. A desktop survey should be conducted to investigate the potential for migration in contaminated fauna and its ecological effects.
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 water quality reduces diversity and abundance of freshwater fauna. Metals bioaccumulate in freshwater fauna causing unknown lethal and/or sub-lethal/ chronic effects. This then migrates downstream from MRM	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
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. No "edge" macroinvertebrate community. Fish, including marine migrants such as freshwater sawfish, are unable 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 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 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.
4.11	Bing Bong Loading Facility	Heavy metals	Unloading concentrate from road trains, storage of concentrate and transfer of concentrate to MV Aburri barge leads to dust emissions and spillages at Bing Bong Loading Facility	Spillage and dust emissions of concentrate from on site storage shed and during barge load out 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	3	2	5	H	Replace doors on the concentrate shed which remain closed unless vehicles are entering or exiting the shed. Continual spraying down of road surfaces at Bing Bong. Investigate dust and spillage minimisation measures being utilised at best practice facilities to minimise dust and spillage, and implement them at 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	Biota in the area bioaccumulate metals with unknown lethal and/or sub-lethal/chronic effects 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
4.11	Sir Edward Pellew Islands and McArthur River estuary	Heavy metals	Mining operations adjacent to McArthur River and its tributaries. Operations at Bing Bong Port.	Contaminants entering McArthur River travel downstream and settle in sediments around the McArthur River estuary and Sir Edward Pellew Islands. Dust travels across from Bing Bong Loading Facility.	Bioaccumulation of metals in sediments and biota in vicinity of McArthur River estuary and Sir Edward Pellew Islands. Unknown sub-lethal/ chronic effects, effects on higher trophic species (including humans that eat fish caught in the area)	L	RI	Numerous controls at Bing Bong loading facility and McArthur River Mine to minimise dust emissions, seepage and spills, including fully contained loading systems, watering of roads and seepage capture drains. Monitoring of contamination of soils, dust, fluvial sediments, surface water and groundwater around McArthur River Mine and Bing Bong Loading Facility Monitoring of contaminants in seawater, marine sediments and biota at Bing Bong Loading Facility and surrounds, McArthur River estuary and Sir Edward Pellew Islands	2	4	6	M	Continue current monitoring and controls. Eliminate sources of contamination along Barney Creek, including the 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 causes dust emissions and spillage of concentrate, which contaminate the marine environment with lead and zinc	Contamination of seawater and sediments with metals in the transhipment area and surrounds. Biota in the area bioaccumulate metals with unknown lethal and/or sub-lethal/ chronic effects	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	3	6	M	Monitor seawater quality in the transhipment area, particularly in the vicinity of active transfer between the MV Aburri and larger transport vessels.
4.12	Bing Bong Loading Facility	Marine sediment monitoring	Lack of appropriate QA/QC for marine sediment monitoring/analysis	Lack of 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	M	OM	Marine sediment sampling program at Bing Bong Loading Facility, the trans-shipment area, and nearby marine and nearshore areas	4	3	7	M	Present QA/QC information for marine sediment analysis as part of the MMP reporting of laboratory results
4.12	Bing Bong Loading Facility	Marine sediment management	Lack of appropriate marine sediment management	Contamination of marine sediments in the nearshore and/or offshore environment due to poor quality surface runoff, concentrate spillage or dust deposition	Consequent impacts on marine environments and ecology, and potentially health of people consuming fish and shellfish	M	OM	Measures to manage marine sediment quality include dust management and surface water management	3	3	6	M	See dust recommendations

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
4.12	Mine site and Bing Bong Loading Facility	Soil monitoring	Lack of appropriate soil 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	L	WM	Soil sampling program at mine site and Bing Bong Loading Facility	4	3	7	M	• Soil site S05 should be replaced with an appropriate reference site away from the quarry in a more 'natural' location • Monitoring of surface soil control sites S04 and S10 should be recommenced in the 2017 period 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 • Review long-term trends in Mn results across the mine site to assess the likely cause of widespread Mn EIL exceedances • Present QA/QC information for soil analysis as part of reporting of results
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	• Present QA/QC information for fluvial sediment analysis as part of the MMP reporting of laboratory results. While some discussion of QA/QC is provided in the fluvial sediment monitoring report, this could be improved. The discussion provided for the surface water quality monitoring program within the current MMP provides a possible model
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	Loc	Dust monitoring program and dust mitigation measures including maintenance of a negative pressure differential and dust extractor system in the concentrate shed to reduce dust fugitive emissions A TEOM dust sampler has been installed at the Loading Facility near the accommodation area	4	2	6	M	• The main doors of the Bing Bong Loading Facility concentrate shed should be repaired 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 • Data from the new TEOM dust sampler should be reported in 2017 • Field blank sampling should be undertaken and reported for the loading facility, as for the mine site • The IM recommends that MRM review and present all available long-term dust data (in particular, PM10 and Pb results) for the loading facility, to inform understanding and management of dust issues • MRM should develop a formal dust mitigation plan for Bing Bong Loading Facility, targeting the most impacted areas as identified by dust monitoring (i.e., BBDMV02 and BBDMV07)
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	L	OM	Dust monitoring program and dust mitigation measures including covered conveyor belt, and washdown of the concrete apron after each ship loading event	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	Loc	Extensive dust monitoring program including: • HVAS and TEOM units at the mine site • duplicate and blank sampling as part of QA/QC Dust mitigation measures at crushing plant and ROM pad include: • Covered dust generation points, including transfer points between conveyors and at the base and top of the secondary crusher • Water addition point to the head drum of the stockpile feed conveyor. A booster pump and spray bar for the head drum to improve suppression of dust as the crushed material falls to the stockpile surface • Watering around the general area by water trucks. • Use of water sprays in the primary crushing plant and conveyors. • 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	4	2	6	M	• Data from the new high-volume air sampler and TEOM dust sampler should be reported in 2017 • The IM recommends that the frequency of monitoring for PM10 and Pb be temporarily increased at two high impact sites at the mine site, and one reference site, to be sampled once every 6 days for a 1-year period, in order to determine whether the current monthly monitoring approach is statistically valid • The IM recommends that MRM review and present all available long-term dust data (in particular, PM10 and Pb results) for the mine site, to inform understanding and management of dust issues

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	Loc	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	2	6	M	MRM should develop a formal plan for dust minimisation in the vicinity of DMV43. This may be part of a formal dust mitigation plan for the mine site as a whole, targeting the most impacted areas as identified by dust monitoring An area immediately east of the decant wall on the TSF Cell 2 north wall is not being kept damp by tailings deposition; it is understood 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
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	Fugitive dust emissions during loading 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	OM	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	3	2	5	H	The bitumen surface surrounding the Bing Bong Loading Facility should be repaired to avoid future soils, water and/or dust management issues

Appendix 3.
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	Goals and objectives for mine water management		x		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 list of the current limitations (information or knowledge gaps) in the mine site water balance, ranked by impact on the water balance – An outline of the proposed mine changes during the MMP period and the site water management changes that may be required (e.g., additional levees, ponds and/or pumps)
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	Water balance model documentation and reporting		x		– This report needs to demonstrate ongoing model refinement, increased process understanding and a reduction in model parameter/calibration uncertainty – Increased detail is required in the reporting of both the rainfall-runoff model calibration and the water balance model calibration, in particular regarding how calibration was undertaken and how parameters were adjusted for each – The presentation of tabulated results could be improved for clarity
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. However, the rainfall-runoff model result are not as expected and the accuracy of the 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

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
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	Underground void/open cut	The underground void/open pit is used for water storage		x		MRM needs to provide a medium to long-term plan which resolves the conflict between mine operations and using the underground void/open pit as a water storage
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	Bing Bong Loading Facility	Surface water monitoring has been ceased at Bing Bong Loading Facility	x			Surface water monitoring at Bing Bong Loading Facility needs to be resumed
4.2	Mine Site	Water Balance	Mine site	The automated site water balance inventory database is no longer being used		x		This database needs to be reinstated
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	Model predictive uncertainty is not quantified	x			Model predictive uncertainty needs to be quantified and used in mine site risk management
4.2	Mine Site	Water Balance	Mine Site and Bing Bong Loading Facility	The information contained in the water balance model results is not fully utilised in the on-ground mine site water management			x	The water balance model results need to be better utilised in the on-ground mine site water management. The two areas where the model results could be better utilised are risk management and options analysis
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

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
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
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 2014-2015 operational period
4.4	Diversion	Hydraulics	Diversions	Cross-section topography of diversions (below water level)	x			No topographic data is available in the pools of the diversions. Cross-sectional survey's should be conducted at several locations to obtain bathymetric information currently unavailable form LiDAR data
4.4	Mine Site	Hydraulics	Diversions	Wider LiDAR Coverage to allow comparison of waterways to 2011 imagery		x		Expand annual LiDAR coverage to include the area covered by the 2011 LiDAR for effective comparison
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
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

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
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 Quality	Assessment of seepage processes and impacts on the groundwater environment			x	There is insufficient interpretation of groundwater monitoring results to identify processes controlling seepage and contaminant migration from the TSF, NOEF and water storages. This interpretation should be carried out as part of the MMP and annual groundwater review
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 identified
4.5	Mine Site	Groundwater	Background Groundwater Conditions	The background groundwater quality and levels should be assessed prior to future development	x			The background groundwater quality and levels should be assessed in areas scheduled for future development (e.g. extension of the NOEF). This should include installation of new monitoring bores and geophysical surveys ahead of development
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 contamination
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	There were large differences between mined waste rock classes versus modelled. In particular, LS-NAF materials mined were approximately 25% less than that planned, PAF(HC) were 145% more, and PAF(RE) were 85% more			x	Resolve discrepancies between mined waste rock classes and those modelled
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	The extent and impact of groundwater contamination from the NOEF not well understood			x	Carry out further investigations to determine the direct seepage contribution from the NOEF to the groundwater system

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	Uncertain proportions of geochemical rock types in NOEF		x		Carry out more drill testing of dumped materials in the NOEF to more confidently define the distribution of historically dumped materials and check the reconstruction of dump material types based on the new block model
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	The effectiveness of the advection covers being placed on the NOEF has not been demonstrated, particularly for the existing end-tipped actively-convecting PAF portions of the NOEF	x			Carry out field trials and monitoring of the end-tipped dump portions of the NOEF to confirm effectiveness of advection covers
4.6	Mine Site	Geochemistry	Waste rock Geochemistry	The DumpSim model approach used to predict seepage quality from the NOEF appears appropriate, but the model is complex and it is difficult to judge the validity of the predictions			x	Commission an independent review of DumpSim model results using other industry standard models such as ToughAMD or SULFIDOX, and including consideration of the effects of compromised final cover performance and higher seepage rates on the receiving environment
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	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 in 2017 as planned
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	Results of recent investigations suggest that the tailings are unlikely to develop acid conditions during operations, but this requires confirmation with surface sampling	x			Routine surface sampling of dry tailings and 1:2 water extraction testing (or equivalent) should be carried out to check for any acid generation from oxidising tailings and confirm the assumed lack of operational impacts
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
4.7	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 no strategy in place to manage this seepage

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Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
4.7	Mine Site	Geotechnical	TSF Cell 1	Safe operating limits			x	Beach angles should be 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 particularlty 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
4.8	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	Revegetation	Insufficient surveying of control sites planned in revegetation monitoring program		x		The current survey program outlines that the revegetation sites will be monitored annually while control site will be monitored every three years. It is recommended that analogue sites are monitored annually to provide more timely and comparable data
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 method of assessing the rehabilitation of the diversions is investigated such as Ephemeral Drainage-line Assessment. 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 likelihood of McArthur river diversion being repopulated with weeds from sources outside of the mine boundary. Will save costs in weed control and promote community relations
4.9	Mine Site	Terrestrial ecology	Flora	Lack of monitoring of flora in Surprise Creek to evaluate effect of TSF seepage	x			Currently there is monitoring in the vicinity of the processing plant and PAF run-off dams, a site at Surprise Creek in the vicinity of the TSF should be added to the program
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	Comparison to data collected in previous surveys would help to discern if fluctuations in species numbers are natural or due to anthropogenic causes. A review of the migratory bird monitoring program should be conducted to determine if it is suitable for assessing whether MRM is having an impact on migratory birds
4.9	BBLF	Terrestrial ecology	Flora	Trials for dredge spoil rehabilitation	x			Proposal sighted, but has not been undertaken as yet. CDU student failed to commence study
4.9	Mine Site	Terrestrial ecology	Rehabilitation	Lack of long-term planning and accountability for the rehabilitation of the diversion channels		x		There is no specified completion date for the rehabilitation of the diversion channels and no milestones with which to compare performance

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
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, 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
4.9	Mine site	Terrestrial ecology	Rehabilitation	The list of key and primary flora species used in the rechannel vegetation monitoring program completion criteria is inappropriate		x		Reassess the list of key and primary species to which revegetation on the diversion channels is compared with, as many of those listed are not recorded at control sites. Investigate separate key and primary species lists for McArthur River and Barney Creek as vegetation assemblages as the control sites show different assemblages
4.9	Mine Site	Terrestrial ecology	Saline Impact Monitoring	Insufficient monitoring of sites that have previously experienced SO4 deposition		X		Install sites at known locations of saline deposition at the Barney/Surprise confluence and Surprise Creek next to the TSF
4.9	Mine Site	Terrestrial ecology	Metals in common cattle pasture grasses	No investigation of metal analyses in pasture species surrounding the TSF		X		Conduct testing for metal analyte concentrations in common forage species at sites surround the TSF
4.10	Mine Site	Freshwater ecology	River Diversion	There is no monitoring of large woody debris persistence and movement in the McArthur River diversion channel	x			MRM should monitor whether large woody debris installed in the McArthur River diversion channel stays in place over the wet season. This can be used to inform woody debris installation programs in the future, and help ensure woody debris placed in the diversion does not move during high flow events
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			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 lead and zinc
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
4.10 and 4.11	Mine Site	Freshwater & marine ecology	Fauna	Lead isotope ratios are often well above present day crustal average (i.e. background) levels at control and reference sites, hence background levels are inappropriate			x	Using data from control sites and regional reference sites, establish a more relevant background lead isotope ratio

Report Section	Location	Aspect	Monitoring area	Monitoring Gap	Gap Category			Recommendations/ Comments
					1	2	3	
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
4.11	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
4.12	Mine Site	Soil & sediment quality	Soil	Inappropriate control site to be replaced		x		Soil site S05 should be replaced with an appropriate reference site away from the quarry in a more 'natural' location
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	Quality assurance/quality control data for sample analyses, and subsequent discussion, should be presented in the MMP for surface soils, fluvial sediments and nearshore/marine sediments
4.12 and 4.13	Mine Site	Soil & sediment quality	Dust, Soil and Sediments	Background heavy metal concentrations have not been determined			x	Determine background heavy metal levels as recommended in the Independent Monitor Technical Review in order to assess potential mining impacts and current conditions, and improve development of site-specific criteria. It is noted that control sites have been established by the macroinvertebrate assessment and data has been collected that can potentially be used as background heavy metal concentrations
4.13	Mine Site	Dust	Dust monitoring	More intensive monitoring required in areas of highest dust impacts		x		The frequency of monitoring for PM_{10} and Pb should be temporarily increased at two high impact sites and one reference site (e.g., once every 6 days for a 1-year period) to determine whether the current monthly monitoring approach is statistically valid
4.13	Mine Site /BBLF	Dust	Dust monitoring	Review of long-term data required			x	MRM should review and present all available long-term dust data for the mine site and Bing Bong Loading Facility, to better inform understanding and management of dust issues

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