



# McArthur River Mine Independent Monitor

**Aquatic Ecosystems Audit 2022**

**Advisian**  
Worley Group

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## **Company details**

Advisian Pty Ltd  
ABN 50 098 008 818

Level 23, 123 Albert Street  
Brisbane QLD 4000  
PO Box 15081, City East QLD 4002  
Australia

T: +61 7 3239 7400

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## Executive Summary

Advisian was commissioned by the Northern Territory Government Department of Industry Tourism and Trade (DITT) to provide Independent Monitor services for the McArthur River Mine (the Mine) as required by the Independent Monitoring Assessment Conditions of Authorisation 0059. An Annual Environmental Performance Audit Report (AEPAR) is prepared by the Independent Monitor to provide an overall assessment on whether the Mine Operator and the Regulator are fulfilling and managing compliance related environmental obligations. The AEPAR is complimented by the review of specific monitoring programs conducted through targeted audits. This report presents the findings of an Aquatic Ecosystems Program audit conducted between 2 and 4 May 2022.

The objectives of this audit were to:

- Assess the adequacy of the Aquatic Ecosystems Program and monitoring practices considering industry standards
- Assess the field monitoring program and execution of fieldwork
- Confirm the Aquatic Ecosystems Program, including monitoring, supports the overarching environmental objective – protection of the McArthur River from mine related impacts.

The desktop audit component was conducted by reviewing management plans and monitoring programs relevant to aquatic ecosystems during the audit period (2019 to 2022). The audit included a site visit that coincided with annual aquatic ecology post-wet season in-stream monitoring fieldwork to gain insight regarding the execution of field activities.

The audit objectives have been addressed by considering five areas, namely:

- Aquatic Ecosystem Management
- Freshwater Ecology Monitoring Programs
- Management Actions by Operator
- Compliance with Mining Management Plan (MMP) Environmental Objectives
- Health of River System Review.

The Operator's freshwater ecology monitoring programs are comprehensive and appropriate for the Mine's receiving environment. These monitoring programs in combination with the implementation of Operator management activities, controls and management plans constitute the Aquatic Ecosystems Program.

As part of the Aquatic Ecosystems Program field data is gathered and compared with performance criteria to verify regulatory compliance and confirm MMP environmental objectives are managed appropriately. Based upon observations of aquatic ecology monitoring activities that occurred during the audit site visit, the data gathering practices in the field, (e.g. netting and acoustic tagging monitoring activities observed), were conducted appropriately and in accordance with relevant standards and accepted industry procedures.

The audit site visit found the field operators were very familiar with the aquatic ecosystems present across all sites and also understood and implemented site specific appropriate sampling methodologies.

The Aquatic Ecosystems Programs' monitoring activities have been regularly reviewed and refined since inception. The overarching MMP objectives for freshwater aquatic ecology ecosystem health have guided the Mine's monitoring activities, and the changes implemented have broadened and strengthened the management and monitoring programs as they have evolved.

In addition to monitoring, the Operator has ongoing management controls that are effective in minimising or eliminating potential impacts to aquatic ecosystems e.g., seepage capture systems, dams, sumps, inspections programs and mine water discharge management procedures.

The introduction of instream woody debris in the McArthur River Diversion Channel is providing short to medium term aquatic ecosystem benefits including bank stabilisation and enhanced habitat. This management action by the Operator is contributing to increased macroinvertebrate assemblage development and resilience.

The Mine's aquatic monitoring data achieved a high level of compliance with the conditions of Authorisation 0059 relevant to freshwater aquatic ecosystems protection. This was comparable with the 2019-2020 and 2020-2021 reviews suggesting no detectable deterioration of freshwater aquatic ecosystems over the 2021 to 2022 review period. Overall, the McArthur River and its tributaries were considered to be in good health, with exceptions noted for Barney Creek and Surprise Creek immediately adjacent to Mine operations.

The audit identified a number of opportunities for improvement including:

- Increasing the number of monitoring reference sites along the McArthur River rather than in adjacent catchments to focus effort on reference sites directly relevant to the mine
- Comparing annual aquatic fauna program data to better understand long term trends and the influence of variable annual river flows on aquatic fauna resilience
- Conducting a larger scale assessment to quantify the extent of rehabilitation and fish habitat improvement along the entire McArthur River Diversion Channel to build upon the current site-specific level assessments.

In response to the audit objectives, it was found the current aquatic ecology monitoring programs are considered suitable and sufficiently well-designed to assess potential impacts of the Mine on the McArthur River freshwater aquatic ecosystems and associated beneficial uses. The audit site visit observed that the freshwater aquatic ecology monitoring activities, including data gathering and field practices, were executed in accordance with relevant standards and accepted industry procedures. Overall, the extensive monitoring program data and analysis indicate that the aquatic ecosystems of the McArthur River and its tributaries are in good health. This audit's findings confirm that the Aquatic Ecosystems Program supports the overarching environmental objective to ensure the health of the McArthur River is protected from mine-related impacts.

# 1 Introduction

Advisian was commissioned by the Northern Territory Government Department of Industry Tourism and Trade (DITT) to provide Independent Monitor services for the McArthur River Mine (the Mine) as required by the Independent Monitoring Assessment Conditions of Authorisation 0059.

The Annual Environmental Performance Audit Report (AEPAR), prepared by the Independent Monitor, assesses the Mine's overall environmental regulatory compliance which is complimented by the review of specific monitoring programs conducted through targeted audits. The subject of this report is the findings of an Aquatic Ecosystems Program audit.

The Independent Monitor's audit assessment of the freshwater Aquatic Ecosystems Program is intended to provide transparency to the community regarding:

- Actions by the McArthur River Mine Operator (the Operator) to maintain continuous improvement in the environmental performance of the Mine with respect to freshwater aquatic ecosystems
- The Operator's performance in achieving the overarching environmental outcome i.e., protecting the health of McArthur River at all times.

This audit assesses the freshwater aquatic ecology monitoring activities and management actions related to protection of the health of the McArthur River from mine related impacts. The audit also provides an assessment of the aquatic ecosystems monitoring programs and general river system health.

## 1.1 Objectives

The objectives of this audit were to:

- Assess the adequacy of the Aquatic Ecosystems Program and monitoring practices against industry standards
- Assess the field monitoring program and execution of fieldwork
- Confirm the delivery of the Aquatic Ecosystems Program supports attainment of the overarching environmental objective.

The Mine's key environmental management objectives stated in the approved Mining Management Plan (MMP)<sup>1</sup> and Adaptive Management Plan (AMP)<sup>2</sup> related to aquatic ecosystems are listed below:

1. Protect the McArthur River beneficial uses and community values from mining impacts
2. Facilitate development of the ecosystem and their functions along the McArthur River Diversion Channel for terrestrial and aquatic flora and fauna.

The Mine's Authorisation conditions include an overarching environmental objective that requires the health of the McArthur River to be protected along its entire length at all times from Mine-related

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<sup>1</sup> Mining Management Plan, McArthur River Mine, January 2020.

<sup>2</sup> Adaptive Management Plan, McArthur River Mine, May 2022.

impacts.<sup>3</sup> This overarching environmental objective is the objective for the Aquatic Ecosystems Program and is relevant to the scope of this audit.

## 1.2 Scope

The scope of this audit was to assess the relevant freshwater aquatic ecology monitoring activities and management actions developed by the Operator to meet the Northern Territory regulatory requirements.

There is no single Aquatic Ecosystems Program document; however, the Water Management Plan (WMP) outlines all of the Mine's water-related (i.e., artificial surface water, groundwater, surface water and freshwater) monitoring programs and performance criteria to fulfil the requirements of the Authorisation conditions. In relation to freshwater aquatic ecology monitoring, the WMP sets out the objective and detailed requirements for the four freshwater aquatic ecology monitoring programs undertaken that are directly relevant to the scope of this audit, namely:

1. Macroinvertebrate Monitoring
2. Diversity and Abundance of Aquatic Fauna
3. Freshwater Sawfish and Barramundi Acoustic Monitoring
4. Metals in Aquatic Fauna.

This audit assessed the Mine's Aquatic Ecosystems Program performance at a point in time during a site visit conducted between 2 to 4 May 2022 and has regard to monitoring activities and reporting over the previous three years. The three-year periodic review for the Aquatic Ecosystems Program is in accordance with the Authorisation requirement to periodically review the AMP. The WMP is a key component of the AMP.

The audit provides an assessment of the monitoring program and general river system health, based on documentation provided by the Operator and supported by a site visit and fieldwork observations.

The audit scope included a site visit to:

- Coincide with annual aquatic ecology monitoring fieldwork conducted by the Operator
- Observe the main aquatic ecology monitoring sites to gain an overview of the program
- Review the monitoring data gathering process in the field to check it is being conducted appropriately, in accordance with the relevant standards and accepted industry procedures
- Conduct a face-to-face audit and on-site audit engagement to enable the gathering of more information to supplement previous desktop aquatic ecology reviews
- Conduct audit interviews with key Operator personnel.

The audit focused on freshwater aquatic fauna as a key component of the aquatic ecosystems monitoring program and general river system health. Related aspects of aquatic ecosystems, e.g., water quality, sediment, marine ecology, instream aquatic vegetation, are not examined in detail by

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<sup>3</sup> Variation of Authorisation 0059, Overburden Management Project, page 6 18 June 2021.



this audit but are addressed in other concurrent specific monitoring programs. This audit's scope excludes marine waters, the Bing Bong Loading Facility area and seagrass. A review of the marine ecosystem monitoring programs in the vicinity of the Bing Bong Loading Facility is a potential subject for the Independent Monitor to review by conducting a targeted audit in the future.

The river health assessment is based on data provided by the Operator and was undertaken at a high level. An assessment was undertaken of the McArthur River monitoring program areas that covers a large, but defined area, in the vicinity and downstream of the Mine. The aquatic monitoring program and this review does not provide information on the larger catchment scale area.

## 2 Approach

The independent audit of the Aquatic Ecosystems Program involved a desktop review and site visit that consisted of the following steps:

- Reviewing freshwater aquatic ecology monitoring programs and management actions developed with the aim to meet the operational requirements and MMP environmental objectives
- Assessing the Operator’s implementation of the freshwater aquatic ecology monitoring and the conclusions drawn, as well as management plans and actions.

The audit was conducted by a team with extensive relevant experience. The team’s qualifications and years of experience are provided in Table 2-1.

Table 2-1: Audit team members

Role	Qualifications	Number of Years' Experience
Lead Environmental Auditor	B. Eng., M.Env.Mgmt Internationally Certified Lead Environmental Auditor	30
Principal Aquatic Ecologist	PhD. (Hons), B.Sc. (Aquatic Science)	20
Technical Reviewer	B. Eng., M.Env.Eng (Hons)	27

The desktop audit component was conducted by reviewing the following documents relevant to aquatic ecosystems:

- McArthur River Mine (MRM) Mining Management Plan (MMP), January 2020
- McArthur River Mine (MRM) Environmental Monitoring Report (EMR) 2021
- MRM EMR Appendix C – 2021 Environmental Monitoring Schedule
- MRM EMR Appendix F – Revegetation Monitoring Report 2021 (relevant to McArthur River diversion rehabilitation related to aquatic ecosystems)
- MRM EMR Appendix J – Freshwater Aquatic Macroinvertebrate Assessment 2021
- MRM EMR Appendix K – Monitoring of Select Analytes & Lead in Fluvial Sediment & Aquatic Fauna 2021
- MRM EMR Appendix L – Aquatic Fauna Monitoring Early Dry Season 2021
- MRM EMR Appendix M – Aquatic Fauna Monitoring Late Dry Season 2021
- MRM EMR Appendix N – Acoustic Monitoring in the McArthur River 2021
- Freshwater Sawfish Management and Monitoring Plan, March 2009
- Adaptive Management Plan – Mining Management Plan, MRM, January 2020
- Adaptive Management Plan, MRM, October 2019
- Adaptive Management Plan, MRM, Appendix A, Water Management Plan, Version 1, January 2020
- Water Management Plan. Appendix E, Macroinvertebrate Monitoring Program (2020)

- Water Management Plan. Appendix F, Aquatic Fauna Abundance and Diversity Monitoring Program (2020)
- Water Management Plan. Appendix G, Freshwater Sawfish Monitoring Program (2020)
- Water Management Plan. Appendix H, Monitoring of Metal Concentrations within Freshwater Fish, Crustaceans and Molluscs of the McArthur River (2020)
- McArthur River Freshwater Aquatic Macroinvertebrate Monitoring 2018 Program Review (2018)
- AUSRIVAS, Australian River Assessment Scheme, Sampling and Processing Manual, Bioassessment Macroinvertebrates, Northern Territory Edition, 1996.

The approach used to conduct the audit site visit component included preparing and undertaking the following:

- Audit framework
- Audit schedule
- Audit plan
- Pre-audit scoping meetings
- Request for Information (RFI)
- Document review
- Site visit opening meeting
- Interviews
- Site inspection
- Discussions on matters identified during interviews and document review.
- Audit Report (Draft and Final).

The audit has been conducted by reviewing the Aquatic Ecosystems Program and presenting the findings set out under five areas in Section 3, namely:

- Aquatic Ecosystem Management (Section 3.1)
- Freshwater Ecology Monitoring Programs (Section 3.2)
- Management Actions by Operator (Section 3.3)
- Compliance with MMP Environmental Objectives (Section 3.4)
- Health of River System Review (Section 3.5).

These sections each relate to relevant audit objectives established in Section 1.1. The first audit objective to assess the adequacy of the Aquatic Ecosystems Program and monitoring practices against industry standards (AUSRIVAS Sampling and Processing Manual) is considered in Sections 3.1 and 3.2. The audit's second objective to assess the field monitoring program and fieldwork execution is examined in Section 3.2. The third audit objective to confirm the Aquatic Ecosystems Program supports the overarching environmental objective to ensure the health of the McArthur River is protected is assessed in Sections 3.4 and 3.5.

The MMP's first environmental objective to protect the McArthur River beneficial uses and community values from mining impacts is reviewed in Section 3.4 and 3.5. The second MMP objective to facilitate

development of the ecosystem and their functions along the McArthur River Diversion Channel for terrestrial and aquatic flora and fauna is considered in Section 3.3.

## **2.1 Review Limitations**

This audit considers the freshwater aquatic ecology-related environmental activities and monitoring programs undertaken by the Operator, and subcontractors engaged by the Operator.

The audit findings are based upon samples of information available at the time of the audit. Beyond the available information it is not possible to review all potential information and there is an inherent minor level of uncertainty with the audit findings.

Excluding the Freshwater Sawfish Management and Monitoring Plan, documents dated prior to 2018 were not reviewed.

## 3 Findings

Findings of the audit are presented under their relevant sections below:

- Section 3.1 – Aquatic Ecosystems Management
- Section 3.2 – Freshwater Ecology Monitoring Programs
- Section 3.3 – Management Action by Operator
- Section 3.4 – Compliance with MMP Environmental Objectives
- Section 3.5 – Health of River System Review.

Opportunities for Improvement (OFIs) and notable successes are documented in these sections. The OFIs identified are collated in Section 4.

### **3.1 Aquatic Ecosystems Management**

The Operator's management of the Aquatic Ecosystems Program activities is conducted consistent with the MMP's Environmental Management Framework (EMF), which is a group of integrated management plans, monitoring programs, guidelines, specifications and procedures designed to facilitate the management of environmental impacts and achieve its environmental objectives.

A central component of the EMF is the AMP, a document that facilitates management and decision making over time. The AMP is the overarching document that provides the strategic framework for environmental management, monitoring, mitigation and reporting of environmental performance against the conditions of the Mine's approvals.

To meet the MMP environmental objectives, the Operator has developed AMP performance indicators which are assessed through the implementation of multiple monitoring programs, Trigger Action Response Plans (TARPs) and management actions. The freshwater aquatic ecosystem specific monitoring programs, including performance criteria and TARPs, have been developed and refined over fourteen years, or more, to maximise their efficacy.

Aquatic ecosystem TARPs utilise performance triggers that have been developed to manage potential adverse environmental conditions, mitigate environmental impacts, inform mitigation options where required and to assess performance against overarching MMP environmental objectives. The TARP structure consists of three trigger levels, where exceeding increasing threshold trigger level values initiates proportionate response measures. The trigger level achieved provides an indication of environment performance:

- Level 1 trigger - achieving its environmental objective
- Level 2 trigger - above the level 1 trigger value, but the environmental objective is still being met
- Level 3 trigger - suggests adverse environmental harm may be occurring.

Level 1 performance is the best of three performance levels, whereby no trigger level criteria have been exceeded and environmental objectives are most likely to be met. At Level 1 trigger values, the TARPs monitoring and management continues as per the monitoring programs, whereas for Level 2 and 3 trigger values additional monitoring and mitigation controls are applied through the TARPs.

The management actions most relevant for freshwater aquatic ecology to meet the MMP Objective 2 are related to rehabilitation along the McArthur River Diversion Channel. This includes revegetation of waterway banks and introduction of instream woody debris. The effectiveness of these actions is assessed through the freshwater aquatic ecology monitoring programs and the Rehabilitation Management Plan (RMP) and reported in the annual EMR.

In addition to monitoring, the Operator has ongoing management controls to minimise/eliminate potential impacts to aquatic ecosystems as a result of mining related activities. The management controls which are related to mining activities include:

- A water management system to prevent contaminated water from entering the river system
- Dust emission controls to prevent contamination of waterways via dust
- The waste discharge licence which outlines the conditions under which mine affected water may be released into the surrounding waterways to minimise contamination
- An engineered design for the North Overburden Emplacement Facility (NOEF) to minimise seepage, which includes design and construction quality control checks including the requirement for an Independent Certifying Engineer (ICE)
- An engineered detailed design for the Tailings Storage Facility (TSF) to minimise seepage, which includes design and construction quality control checks including the requirement for oversight by an ICE and the Independent Tailings Review Board
- Seepage-capture ponds and sumps to prevent contaminated seepage from entering waterways
- Routine inspections and monitoring of infrastructure e.g., dams, NOEF, TSF
- Requirement to support the establishment of an Independent Panel of Experts to review the performance of the NOEF and TSF (to occur in the near future).

The Operator's management framework, under which the Aquatic Ecosystems Program has been developed and implemented, provides a system that is comprehensive and appropriate for the scale and complexity of the Mine. The MMP, AMP and WMP set out the Authorisation conditions requirements to be fulfilled and the numerous programs implemented to achieve them. The Aquatic Ecosystems Program obtains and analyses field data to verify compliance against performance criteria. Verified performance criteria compliance, or non-compliance, provides the supporting information on whether MMP environmental objectives are being met and managed appropriately with the findings reported in the annual EMR.

## 3.2 Freshwater Aquatic Ecology Monitoring Programs

The Mine has undertaken freshwater aquatic ecology monitoring with the assistance of a specialist aquatic ecology sub-contractor for many years. There are four aquatic ecosystem specific monitoring programs that have been undertaken continuously since each program's inception, with the results and findings reported to the regulator annually, namely:

- Metals in Aquatic Fauna (commenced 2005)
- Diversity and Abundance of Aquatic Fauna (commenced 2006)
- Macroinvertebrate Monitoring (commenced 2008)
- Freshwater Sawfish Acoustic Tagging Monitoring (commenced 2016)
- Barramundi External Tagging Monitoring (commenced 2017).

The specific objectives across the four freshwater aquatic ecology monitoring programs are:

- Monitor fish populations in permanent and semi-permanent pools
- Monitor populations of *Pristis pristis* (Freshwater Sawfish)
- Monitor fish diversity in temporary or semi-permanent pools and riffles
- Monitor fish passage success through the McArthur River Diversion Channel by:
  - Tag key fish species
  - Assess temporal migration patterns of the fishes within the river and determining habitat associations and the utilisation of the McArthur River Diversion Channel.
  - Sample key sites within, upstream and downstream of the McArthur River Diversion Channel
  - Collate data on sightings and the capture/re-capture of Freshwater Sawfish including information on the growth rates and movements of re-captured individuals
- Compare the abundance of *Macrobrachium spp.* (and where positive identification allows, Cherabin specifically) present within the McArthur River Diversion Channel to those occurring upstream/downstream of the McArthur River Diversion Channel as a potential indicator of habitat complexity
- Assess the effectiveness of adding woody debris to the McArthur River Diversion Channel as a key rehabilitation strategy
- Collect size and distribution data on aquatic reptiles known to occur in the McArthur River including the *Acrochordus arafurae* (Arafura File Snake) and *Emydura worrelli* (Worrell's Turtle)
- Compare the diversity and abundance of fish species within the original section of the McArthur River and the McArthur River Diversion Channel over time
- Monitor the diversity and distribution of species within Surprise and Barney Creeks.

During the audit period the monitoring programs were undertaken in full for the first time since restrictions on access were imposed due to COVID-19 in early 2020. The only exception was for the Robinson River upstream site for which access was still restricted with water over the river crossing. This site is only used as a reference for the fluvial sediment and aquatic fauna tissue metals monitoring and previously used an alternative site on the Wearyan River.

Examples of aquatic ecology fauna sampled and identified during site audit of aquatic ecosystem monitoring fieldwork are illustrated in photos 1 to 6.



*Photo 1: Craterocephalus stercusmuscarum (Fly-specked hardyhead)*



*Photo 2: Brachirus selheimi (Selheim's Sole) - topside*



*Photo 3: Brachirus selheimi (Selheim's Sole) - underneath*



*Photo 4: Ambassis spp. (North-west glassfish)*





*Photo 5: Emydura worrelli (Worrell's Turtle)*



*Photo 6: Macrobrachium rosenbergii (Cherabin)*

At the time of the audit site visit, post-wet season in-stream monitoring was being conducted. Photo 7 illustrates directional fyke netting set to capture both upstream and downstream movements for identification and release of aquatic fauna species in the diversity and abundance survey.



*Photo 7: Directional fyke net sampling at monitoring site SW11 on the McArthur River downstream of the diversion*



Photo 8: Fish size and abundance recording at monitoring site SW12 on the McArthur River downstream of the diversion

The Operator's freshwater aquatic ecology monitoring programs are comprehensive and appropriate for the targeted environmental values of the relevant freshwater aquatic ecosystems. Based upon the observations of freshwater aquatic ecology monitoring activities occurring at the time of the audit site visit the process for gathering monitoring data in the field (e.g. netting, acoustic tagging) is conducted appropriately and in accordance with industry standards (e.g. AUSRIVAS Sampling and Processing Manual, for Bioassessment of Macroinvertebrates) and generally accepted industry procedures.

There is an industry standard for monitoring aquatic macroinvertebrates (Ausrivas) and the site practices observed were consistent with Ausrivas methodology. There are commonly accepted fish sampling procedures but not industry standards, as such, due to inherent variability between sites. It was apparent that the field operators were not only very familiar with the aquatic ecosystems present across all the sites but also understood and implemented site specific appropriate sampling methodologies.

Implementation of the freshwater aquatic ecology monitoring programs is directly relevant to the Mine's performance criteria, as developed in response to the Northern Territory and Commonwealth Government's regulatory requirements. The audit found that the monitoring and management actions were well implemented and where impacts were noted, they were adequately described, and the recommended mitigation actions were consistent with the approved TARPs.

The Aquatic Ecosystems Program activities have been regularly reviewed and refined since inception. The overarching objectives for freshwater aquatic ecology ecosystem health have guided the Mine's monitoring activities, and the changes implemented have broadened and strengthened the management and monitoring programs as they have evolved. Some examples of continuous improvement in the Aquatic Ecosystems Program include:

- Adoption of non-lethal fish monitoring including acoustic tagging techniques
- Inclusion of depth recording acoustic transmitters tags allow the depths utilised by *Pristis pristis* within the McArthur River to be determined for the first time in 2020-21

- Agreement with the regulator on parameters for a reduced number of fish sampled to still provide statistically valid results providing greater efficiency in the sampling program and an annual reduction in species take
- Improvements to the metals in freshwater aquatic fauna monitoring program were made in 2009 to allow species-specific comparisons between sites and (in 2014) to incorporate larger species that are more likely to be consumed by people.

An ecotoxicological research and investigation program was conducted between 2020-2022 as an initiative of the Operator to establish the concentration of contaminants at which chronic and acute impacts to biota of relevance occur. The development of evidence based site-specific water quality trigger values were derived from the ecotoxicological testing. The resultant trigger values were highly specific to the local McArthur River catchment as the testing was completed using local reference waters from the McArthur River and ecologically relevant species. The ecotoxicological program's findings were submitted to Department of Environment, Parks and Water Security (DEPWS) and approval of changes to several site-specific trigger values (SSTVs) was given in March 2022.

The annual reporting and analysis of the aquatic monitoring results to regulators demonstrates a high level of compliance and the ongoing effectiveness of the Mine's aquatic ecosystem management actions to protect the health of the McArthur River from Mine-related impacts.

## 3.3 Management Actions by Operator

The Operator has implemented management actions to protect the health of the McArthur River from Mine related impacts. The key management actions related to aquatic ecosystems are outlined below.

### 3.3.1 Rehabilitation

A RMP has been prepared by the Operator to establish a rehabilitation monitoring and management system that enables the Operator to progress rehabilitation towards closure objectives, including MMP Objective 2. The RMP supports management of rehabilitation activities and determination of their overall effectiveness. Together with the RMP the freshwater aquatic ecology monitoring programs (such as monitoring of macroinvertebrates and diversity and abundance of aquatic fauna) provide an assessment of the effectiveness of the rehabilitation activities.

The key rehabilitation activities relevant for aquatic ecology are:

- Revegetation along the McArthur River and Barney Creek diversion channels
- Introduction of instream woody debris along the McArthur River Diversion Channel.

Revegetation of the diversion channels has continued since commencement in 2007. The key objectives of the revegetation include:

- Increase bank stability
- Provide shading within the river channel
- Provide a source of carbon for aquatic ecosystems
- Provide a long-term source of instream woody debris

To date the focus has been on replanting the upstream sections of the diversion channels.

### 3.3.2 Large Woody Debris

The installation of LWD in the McArthur River Diversion Channel has been undertaken since 2010, refer to Photos 9 and 10. The key objectives of the LWD introduction include:

- Increase meso and microhabitat diversity within the channel
- Alleviate bank erosion
- Provide a source of carbon for aquatic ecosystems
- Provide refuge holes for migrating fish.

To supplement the LWD program, small and medium sized woody debris has also been added to the McArthur River Diversion Channel, with the aim of adding additional organic matter to the channel in an attempt to improve macroinvertebrate assemblages.



*Photo 9: Large woody debris placed along the McArthur River Diversion Channel edge that encourages an intermittent area of pooled water that persists into the dryer months.*



*Photo 10: Example of medium woody debris placed to improve macroinvertebrate assemblages along the McArthur River Diversion Channel.*

### **3.3.3 Sediment Removal**

Historically elevated lead levels have been recorded in the Barney Creek Diversion Channel which have been attributed to Mine activities. In 2014, the Mine implemented targeted physical removal of contaminated sediment and the construction of silt traps to capture runoff from the haul road to address high concentrations of lead in fluvial sediments, particularly immediately downstream of the haul road. This has resulted in reduced lead concentrations in aquatic fauna sampled in years following sediment removal, refer to further discussion in Section 3.4.

## **3.4 Compliance with MMP Environmental Objectives**

An assessment of Operator's achievement of the MMP Objectives 1 and 2 are outlined below. Summary discussion is provided in Table 3-1 and Table 3-2 with respect to the implementation of each relevant monitoring program and management actions to support the MMP Objectives through the:

- Applicability of the aquatic ecosystem monitoring programs to support the MMP Objectives

- Key conclusions based upon each monitoring programs' findings.

### **3.4.1 MMP Objective 1: Protect the McArthur River beneficial uses and community values from mining impacts**

The current monitoring programs are considered suitable and sufficiently well-designed to assess potential impacts on the McArthur River freshwater aquatic ecosystems and their beneficial uses. Table 3-1 provides a summary of the applicability of each monitoring program relevant to Objective 1 along with key conclusions identified during the audit period.

For each of the monitoring programs, the 2022 EMR assesses compliance against the relevant performance triggers. The performance indicators and SSTVs provide clear direction and actions to mitigate potential impacts if they occur. Monitoring results within predicted/expected boundaries for Level 1 performance were achieved in 2021-2022 for all freshwater aquatic ecology monitoring categories relevant to the MMP Objective 1.

It is notable that with respect to fluvial sediment, samples from several sites were identified at trigger level 2a<sup>4</sup> namely, McArthur River Diversion Channel and within Barney Creek and Surprise Creek. Two fluvial sediment monitoring sites within Barney Creek were considered to be at trigger level 2b. There is a relationship between fluvial sediment metal concentrations and tissue metal concentrations in fauna, albeit that the ephemeral nature of Barney Creek and Surprise Creek is likely to reduce the exposure of aquatic fauna to periods in which water persists.

Analysis of metals in aquatic fauna during the audit period showed that exceedances of Maximum Permitted Concentrations (Australia New Zealand Food Standards Code, Standard 1.4.1, Schedule 19) in lead tissue concentrations were limited to environmental indicator species at one site on Barney Creek for one specimen of *Melanotaenia splendida* (eastern rainbowfish). The location is within the Mine and mineral lease boundary. The public do not have access to this location and waterway signage states that public access to these areas is prohibited. Reductions in tissue metal concentrations since 2018 appear to be attributable to the management actions (described at Section 3.3) to remove potentially contaminated sediments from the Barney Creek.

The Independent Monitor agrees with the conclusions of the Operator's external expert assessment that the adaptive management action undertaken to remove potentially contaminated sediments from a tributary to McArthur River (i.e., Barney Creek) and the construction of silt traps to capture runoff have contributed to the protection of downstream beneficial uses and environmental values. Results of sediment analysis show reductions in cadmium, arsenic, lead, and zinc concentrations, compared with those recorded in 2018, with cadmium and arsenic no longer in exceedance of the relevant sediment quality guideline value. This appears to have resulted in reducing lead concentrations in aquatic fauna sampled in 2021-2022 following the removal of potentially contaminated sediment.

In 2021-2022 small numbers of the *Velesunio angasi* (freshwater mussel), were collected due to their limited abundance in the environment. Tissue metal concentrations were highly variable across the study area but consistent with results of previous sampling. Very high concentrations of naturally

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<sup>4</sup> The TARP for fluvial sediment has two stages at level 2; 2a which requires an investigation to determine if additional controls or management actions can be taken to reduce analyte concentrations, and 2b requires the 2a investigation as well as sampling frequency to be increased from annually to quarterly.

occurring analytes, including aluminium, manganese and iron, have been consistently recorded in this species throughout the region, including for catchments outside of the Mine’s area of operations.

Data collected over the 2021-2022 monitoring program demonstrated that all other fish caught throughout the McArthur River catchment were considered safe to consume. This includes commonly consumed species such as *Lates calcarifer* (barramundi) and *Hephaestus fuliginosus* (sooty grunter).

Table 3-1: Monitoring Program Outcomes for Objective 1 - Protection of the McArthur River Beneficial Uses and Community Values from Mining Impacts

Monitoring Program	2021 - 2022	Key Conclusions
Freshwater Macroinvertebrate Monitoring	This monitoring program has been developed and refined since 2008 to allow for a quantifiable and site-specific assessment to detect statistically significant differences in freshwater aquatic macroinvertebrate communities attributable to Mine activities.	The Independent Monitor agrees with the conclusions of the Operator’s external expert’s assessment that it indicated no statistically significant differences in macroinvertebrate assemblages in sites upstream and downstream of the Mine’s operations for the monitoring period encompassing 2021 - 2022.
Diversity and Abundance of Freshwater Aquatic Fauna	This monitoring program has been developed and refined since 2006 to allow for a quantifiable and site-specific assessment to detect statistically significant differences in freshwater aquatic fauna attributable to Mine activities.	The monitoring program appears to have been implemented in accordance with the approved MMP.  The Independent Monitor agrees with the conclusions of the Operator’s external expert’s assessment that there has been no observable change in species diversity and abundance outside the range of natural variance (largely driven by inter-year seasonal flow variation).
Metals in Freshwater Aquatic Fauna	This monitoring program has been developed and refined since 2005. Significant improvements to the monitoring program were made in 2009 to allow species specific comparisons between sites. In 2014, larger species (more likely to be consumed by people) were included in the monitoring program. These improvements have increased the appropriateness and robustness of the program.	The Independent Monitor agrees with the conclusions of the Operator’s external expert’s assessment that the data suggests little measurable effect on tissue metal concentrations in fish found in the McArthur River and downstream environments. The program is suitably designed to detect any potential metal tissue concentration elevations in the future.  Past detection of elevated metal tissue concentrations within the Mineral Lease has informed management actions.

### 3.4.2 MMP Objective 2: Facilitate development of the ecosystems and their functions along the McArthur River Diversion Channel for terrestrial and aquatic flora and fauna

The current monitoring programs are considered by the Independent Monitor to be suitable and sufficiently well-designed to monitor the development of ecosystems and their functions along the

McArthur River Diversion Channel. The management actions to revegetate the stream banks and to introduce instream LWD are appropriate for facilitating the development of the ecosystems and their functions along the McArthur River Diversion Channel. While the McArthur River Diversion Channel appears to offer a lower level of quality aquatic habitat in edge habitats than the natural river channel, there appears to be trajectory of increasing ecosystem diversity and resilience.

Table 3-2 provides a summary of the applicability of each monitoring program, relevant to Objective 2, along with key conclusions identified during the audit period.

For each of the monitoring programs, the 2022 EMR assesses compliance against the relevant performance triggers. The performance indicators and trigger values provide clear direction and actions to mitigate potential impacts when and if they occur. Monitoring results within predicted/expected boundaries for Level 1 performance were achieved in 2021-2022 for all freshwater aquatic ecology monitoring categories relevant to MMP Objective 2.

The management action which introduces instream LWD provides short to medium term benefit including bank stabilisation, enhanced habitat, increasing mesohabitat and habitat diversity, and organic input for aquatic ecosystems. The Independent Monitor agrees with the results of the Operator's external expert assessment that the introduction of instream woody debris is most likely contributing to increased macroinvertebrate assemblage development and resilience.

While the objectives of the monitoring programs have been met (i.e., assessing responses of *Macrobrachium* (freshwater prawns) species and fish assemblages, and the effectiveness of adding LWD), it would be useful to assess and quantify the extent of rehabilitation along the entire McArthur River Diversion Channel. Such an assessment would provide a measure of habitat improvement success at a larger 'river reach' scale, as a result of the rehabilitation actions conducted to date. This would build upon the current site-specific level assessment. A reach-scale assessment may be undertaken at a coarse level and provide a measure of the success of the riparian revegetation combined with introduced woody debris over time.

The *Pristis pristis* (largetooth sawfish, previously known as *Pristis microdon*) is a species listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* and is the focus of an acoustic monitoring program in the McArthur River Diversion Channel. The recording of two sawfish at the upstream extent of the McArthur River Diversion Channel during the audit period brings the total to five individuals recorded as passing through the Diversion Channel since 2017. This supports the assertion that fish passage for this species is not impaired and exceeds the minimum requirement of demonstrating passage of sawfish through the diversion channel once every five years.



Table 3-2: Monitoring Program Outcomes for Facilitation of Development of the Ecosystems and their Functions Along the McArthur River Diversion Channel for Terrestrial and Aquatic Flora and Fauna

Monitoring Program	2021 – 2022	Key Conclusions
Freshwater Macroinvertebrate Monitoring	This monitoring program has been developed and refined since 2008 to monitor the development of instream habitats in the McArthur River and Barney Creek diversion channels. The level of sampling and monitoring sites selected were appropriate for meeting the monitoring objective to assess development of macroinvertebrate assemblages within the diversion channels.	The monitoring program appears to have been implemented in accordance with the approved MMP.  The Independent Monitor agrees with the conclusions of the Operator’s external expert assessment, that the results suggest that macroinvertebrate assemblages riffle sites along the McArthur River Diversion Channel appeared to have resembled those in reference sites within two years of channel operation, and that edge habitats were becoming more similar over time.
Diversity and Abundance of Freshwater Aquatic Fauna	Components of this monitoring program have been developed and refined since 2008 to monitor changes in aquatic fauna assemblages in the diversion channels, monitor fish passage success through the McArthur River Diversion Channel, and assess the effectiveness of adding woody debris to the McArthur River Diversion Channel as a key rehabilitation strategy.	The monitoring program appears to have been implemented in accordance with the approved MMP.  The Independent Monitor agrees with the conclusions of the Operator’s external expert’s assessment that there has been no observable change in species assemblages attributable to Mine activities. Fish assemblages in complex habitat (i.e., where woody debris has been introduced) were comparable with naturally complex habitats upstream and downstream of the diversion channel.
Freshwater Sawfish and Barramundi Acoustic Monitoring	Since 2011, tagging has focused on migratory species, notably barramundi and sawfish. This included dart tags, and for specimens captured likely to inform the objectives of the acoustic monitoring program, the specimens were fitted with acoustic tags.	The recording of two young sawfish at the upstream extent of the McArthur River Diversion Channel brings the total to five individuals recorded as passing through the diversion channel since 2017. This supports the assertion that fish passage for this species is not impaired and exceeds the minimum requirement of demonstrating passage of sawfish through the diversion channel once every five years.

Monitoring Program	2021 – 2022	Key Conclusions
Metals in Freshwater Aquatic Fauna	This monitoring program has been developed and refined since 2005. Significant improvements to the monitoring program were made in 2009 to allow species specific comparison between sites. In 2014, larger species (more likely to be consumed by people) were included in the monitoring program. These and other improvements have increased the appropriateness and robustness of the program.	The monitoring program appears to have been implemented in accordance with the approved MMP.  The Independent Monitor agrees with the conclusions of the Operator’s external expert’s assessment that Mine operations continue to have little measurable effect on the levels of metals in aquatic fauna in the McArthur River Diversion Channel. The one exceedance in the Barney Creek Diversion Channel requires ongoing monitoring/management to reduce the risk of future exceedances.

### 3.5 River System Ecosystem Health Review

The McArthur River, Barney Creek and Surprise Creek ecosystem health review has been made based on the information provided by the Operator and its consultants. It represents data collected from sites selected for the monitoring programs to meet the environmental objectives of the MMP and AMP. In most years, the McArthur River flows from December to April, with low to zero flow in the months of May to November. During the dry months, the river forms intermittent pools.

The Operator has classified the condition of the McArthur River in the vicinity of the Mine as a Level 2: slightly to moderately disturbed ecosystem, in accordance with Australian and New Zealand guidelines for fresh and marine water quality (2018). Slightly to moderately disturbed systems (95% biodiversity protection) are ecosystems in which aquatic biological diversity may have been slightly adversely affected by human activity, however, biological communities remain in a healthy condition and ecosystem integrity is largely retained.

Overall, McArthur River and its tributaries are considered to be in good health. However, Barney and Surprise creeks, adjacent to the NOEF and TSF, are highly ephemeral and retain little water for much of the year. As described above, analysis of metals in aquatic fauna during the audit period showed that exceedances of maximum permitted concentrations (Australia New Zealand Food Standards Code, Standard 1.4.1, Schedule 19) in lead tissue concentrations was limited to one specimen at one site on Barney Creek. The location is within the Mine site and mineral lease boundary. The public do not have access to this location and waterway signage states that public access to these areas is prohibited.

Data collected over the 2021-2022 monitoring program demonstrated that all other fish caught throughout the McArthur River catchment, including commonly consumed species such as barramundi and sooty grunter, were safe to consume. The review of monitoring data to date indicates there is an extremely low risk to human health from consuming the monitored fish species caught in the McArthur River catchment in the vicinity or immediately downstream of the mineral lease.

Consistent with previous sampling results, concentrations of metal in freshwater mussel tissue were highly variable and commonly included very high concentrations of naturally occurring analytes, including aluminium, manganese, iron and total arsenic, across the area monitored which includes catchments not affected by the Mine. It is considered unlikely that enough mussels could be collected and consumed by an individual to exceed an intake of metals that would have a detrimental health

effect; however, due to the high levels of metals found naturally in the mussels in the region, it is suggested that their consumption be limited.

The McArthur River Diversion Channel was constructed over the 2008-2009 wet season to enable the Mine's transition from an underground to an open pit operation. While it does not provide the same habitat as naturally formed river channels, there have been significant and ongoing efforts to reinstate habitat conditions typical of natural river channels, primarily development of the riparian vegetation and the introduction of instream woody debris. The monitoring data collected to date suggests that these actions have improved and are likely to continue to improve the aquatic habitat along the McArthur River Diversion Channel.

## 4 Opportunities for Improvement

Potential opportunities to support continuous improvement identified for aquatic ecosystems and river health through the audit process are detailed in Table 4-1, noting these are not mandatory requirements.

Table 4-1: River Health System Opportunities for Improvement

Ref.	Monitoring Program / Management Action	Opportunities for Improvement
1	Freshwater Macroinvertebrate Monitoring	Adopt the conclusions of the Operator's external experts to increase the number of reference sites along the McArthur River rather than in adjacent catchments to focus effort on reference sites directly relevant to the Mine.
2	Freshwater Macroinvertebrate Monitoring	Increase the number of downstream reference sites with riffle microhabitat to provide more reference information on this specific habitat type
3	Diversity and Abundance of Freshwater Aquatic Fauna	Maintain longer term data collection for comparison of annual aquatic fauna program to better understand longer-term trends and influences of inter-year variability in-flow on aquatic fauna community development and resilience in the McArthur River Diversion Channel.
4	Freshwater Sawfish and Barramundi Acoustic Monitoring	Increase the number of tagged fish to add to the fish where the batteries in the tag are reaching their expiry dates to maintain a reasonable sample size.
5	Diversity and Abundance of Freshwater Aquatic Fauna	Undertake a larger area 'river reach-scale' assessment to measure the extent of rehabilitation along the entire McArthur River Diversion Channel by building upon the current site specific assessments to provide an indication of the river reach's trend of rehabilitation for fish habitat. This may be undertaken at a coarse level and provide a measure of riparian revegetation success combined with introduced woody debris over time.

## 5 Conclusion

This audit provides an assessment of the freshwater Aquatic Ecosystems Program, based on documentation provided by the Operator supported by site visit and fieldwork observations. The Operator's performance against the relevant MMP environmental objectives is reported in the annual Environmental Monitoring Report (EMR) (2021-2022).

The audit site visit observed that the freshwater ecology monitoring programs were being conducted thoroughly and as planned with the full support of Mine environmental staff.

As part of the Aquatic Ecosystems Program field data is gathered and compared with performance criteria to verify regulatory compliance and confirm MMP environmental objectives are managed appropriately. The audit site visit found the field operators were very familiar with the aquatic ecosystems present across all the sites and also understood and implemented site specific appropriate sampling methodologies.

Implementation of the freshwater aquatic ecology monitoring programs is directly relevant to the Mine's performance criteria, as developed in response to the Northern Territory and Commonwealth Government's regulatory requirements. The audit found that the monitoring and management actions were well implemented and where impacts were noted, they were adequately described, and the recommended mitigation actions were consistent with the approved TARPs.

The Aquatic Ecosystems Programs' monitoring activities have been regularly reviewed and refined since inception. The overarching environmental objective to protect the McArthur River's health have guided the Mine's monitoring activities, and the changes implemented have broadened and strengthened monitoring programs as they have evolved.

In addition to monitoring, the Operator has management controls in place that are effective in minimising or eliminating potential impacts to aquatic ecosystems e.g., seepage capture systems, dams, sumps, inspections programs and mine water discharge licence procedures.

The introduction of instream woody debris in the McArthur River Diversion Channel is providing short to medium term aquatic ecosystem benefit including bank stabilisation and enhanced habitat. This management action by the Operator is contributing to increased macroinvertebrate assemblage development and resilience.

The McArthur River Mine's aquatic monitoring data achieved a high level of compliance with the conditions of Authorisation relevant to freshwater aquatic ecosystems protection. This was comparable with the 2019-2020 and 2020-2021 AEPAR reviews suggesting no detectable deterioration of freshwater aquatic ecosystems over the current review period.

This review provides a general assessment of overall health of the river system as it relates to key user definitions – fish health and general aquatic ecology based on the monitoring information provided by the Operator. Overall, the McArthur River and its tributaries were considered to be in good health, with exceptions noted for Barney Creek and Surprise Creek immediately adjacent to mine operations.

This review has assessed the adequacy of the Aquatic Ecosystems Program and monitoring practices in accordance with the stated audit objective. The audit found the current aquatic ecology monitoring programs are considered suitable and sufficiently well-designed to assess potential impacts on the

McArthur River freshwater aquatic ecosystems and its beneficial uses. The audit site visit observed that freshwater aquatic ecology monitoring activities including data gathering and field practices were executed appropriately and in accordance with the relevant standards and accepted industry procedures.

Overall, the extensive monitoring program data and analysis indicate that the aquatic ecosystems of the McArthur River and its tributaries are in good health. The aquatic specific monitoring programs in combination with the implementation of Operator management activities, controls and management plans constitute the Aquatic Ecosystems Program. This audit's findings confirm that the Aquatic Ecosystems Program supports the overarching environmental objective to ensure the health of the McArthur River is protected.