AA

Appendix AA – TSF Load Assessment Forward Work Program

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Environment · Water · Sustainability

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PROPOSAL

PROPOSAL TO ESTIMATE THE ACIDITY LOAD GENERATED AND STORED WITHIN TAILINGS AT MCARTHUR RIVER MINE

Prepared for

McArthur River Mining Limited

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INTRODUCTION

Earth Systems is pleased to provide McArthur River Mining Limited (MRM) with a proposal to estimate the acidity load generated and stored within tailings deposits at McArthur River Mine (the site).

Project background

McArthur River Mine is a zinc-lead mine, located 900 km southeast of Darwin, Northern Territory, Australia. The mine has been operational since 1995. Key mine domains include an open pit, Overburden Emplacement Facilities (OEFs), the Run of Mine (ROM) pad, Perimeter Runoff Dams (PRODs), a processing area, and a Tailings Storage Facility (TSF). The TSF is subdivided into two distinct cells: Cell 1 and Cell 2. Cell 1 has been decommissioned and is covered with a clay cap, while Cell 2 is currently operational. Cell 3 will ultimately encompass Cell 1 and Cell 2, and commence operation soon. Cell 3 will continue to operate until closure.

Previous studies have identified two sources of acidity in the TSF. Historical investigations by MRM have identified the TSF as containing highly sulfidic tailings that are commonly classified as potentially acid forming (PAF). However, despite the PAF status of the tailings materials, they contain significant acid neutralising capacity (ANC), which is assumed to provide an extended lag phase (i.e. period prior to the onset of acid release) and probably the formation of neutral metalliferous drainage (NMD). Available water chemistry data has also identified the current pore water and supernatant water within the tailings (Cells 1 and 2) as being dominated by increasingly metalliferous and sulfate rich water, that is occasionally acid (see Earth Systems, 2015 and 2016). It was established by Earth Systems (2016) that the increasing acid and metal loads within the TSF supernatant water are substantially derived from the residual PbOx process water. The PbOx circuit generates significant quantities of acid and soluble zinc, lead and sulfate from the dissolution of the lead/zinc concentrate using sulfuric acid. Residual PbOx process water is routinely discharged to the tailings discharge water. This observation indicates that acidity within the tailings can be expected to be related to the oxidation of tailings and to the addition of acidity for the PbOx circuit.

Previous studies by GHD (2016a) determined the change in density of the tailings in the TSF Cell 2 over time. It was concluded that the initial settled density of the tailings at 100% saturation was 1.4 tonnes/m^3 dry density. The study also concluded that as the tailings progressively drain and dry, they can increase in density to approximately 1.9 tonnes/m^3, and if the beach is compacted, this density could rise further to 2.15 tonnes/m^3 (GHD, 2016a and 2016b).

Earth Systems conducted a preliminary investigation into the impact of the oxidation of sulfidic tailings on pore water and supernatant water and quantified the bulk acid and metalliferous drainage (AMD) generation from Cell 2, through limited oxygen penetration test work (OPT) (Earth Systems, 2017). The OPT methodology was developed by Earth Systems to measure the depth to which oxygen penetrates into tailings and to measure the flux of oxygen that enters the tailings as a function of surface area (not mass). The latter measurements can then be used directly to estimate the amount of acidity generated during the operations phase for a given TSF surface area exposed to the atmosphere. The OPT methodology was developed because conventional column leach test work, humidity cells and standard oxygen consumption tests could not be used to readily determine the risk from such fine grained and O_2 penetration limited materials. The test work method has been accepted as leading practice in the current edition of the Australian Federal Government's Leading Practice Handbook for Sustainable Development - Prevention of Acid and Metalliferous Drainage (DIIS, 2016).

Earth Systems used OPT to clarify the significance of the progressive drying of tailings for sulfide oxidation and acidity generation. The preliminary OPT program was carried out by Earth Systems (2017) on tailings at a density of 1.7 tonnes/m^3 and moisture contents ranging from 70%, 80% and 90% saturation. The results indicated that increases in acidity generation due to drying of the tailings will lead to increased ANC consumption and increased sulfate and metal loadings to the pore water, and likely the product of NMD. These results provided a snapshot of the impact of oxidation on the deposited tailings materials during operations, on a 45-day spigot cycle. To assess the impact of the oxidation of sulfidic tailings over the life of the TSF and at closure, the completion of several additional OPT scenarios are recommended. The results will then be used to develop a numerical model that can be used to estimate the acidity load generated by the tailings, as well as that stored within the tailings as a result of the PbOx circuit.

PURPOSE

The purpose of this study is to calculate (model) the total acidity loads expected to be produced within the tailings at MRM, as a function of the density, moisture content and exposed surface area of the tailings over time, from commencement of tailings deposition through to mine closure, as well as the acidity load added via the PbOx circuit. This will involve the generation of primary data on the tailings materials through a laboratory analytical program, and the use of this data to inform and develop a numerical model.

SCOPE OF WORKS

To determine the total acidity generated and store within the tailings, the different physical and chemical conditions within the tailings in Cell 1, Cell 2 and Cell 3 need to be understood or predicted over time. This includes an understanding of the variation in the density of the tailings over time (e.g. 1.7 tonnes/m^3 is indicative of the initial deposition of tailings, whereas 1.9 tonnes/m^3 is representative of the tailings following dewatering and natural short term compaction), the variation in moisture content over time (due to changes to the spigot cycle and seasonal variability), changes in the surface area over time (due to lift construction and pond variation), and whether the Cell is operational or has been decommissioned and capped.

The work program outlined below aims to identify various oxidation scenarios within the tailings deposits, and measure acidity generation rates under these various conditions. Key tasks will include the following:

- Task 1: Collate, manage and analyse current, historical and predicted geochemical, environmental, and physical data and information relating to the operation of all TSF cells;
- Task 2: Conduct an OPT program on tailings materials under carefully defined scenarios with variable density, moisture content and capping conditions;
- Task 3: Using data from Tasks 1 and 2, develop a numerical model that can generate acidity load estimates associated with all TSF cells, and can be used and refined over time;
- Task 4: Produce a report that summarises the test work program and documents the predicted acidity loads from the TSF from internal and external sources since tailings deposition commenced, through to closure;
- Task 5: Identify potential management strategies for dealing with estimated acidity; and
- Task 6: Establish a work program for identifying the optimum management strategy.

This proposal outlines proposed methods, work program, and timeframe.

PROPOSED METHOD

Task 1: Data collation, data management and analysis

Collation, management and analysis of key historic, current and proposed configurations to assist in building the acid generation model:

- Construction and operation of TSF:
    - Tailings porosity data at different densities;
    - Commencement and closure date of Cell 1;
    - Commencement dates and projected closure dates of Cell 2 and Cell 3;
    - Projected maximum and minimum surface areas of Cell 1, Cell 2, and Cell 3 over time (associated with upstream lifts);
    - Tailings tonnage production rates over time for Cell 1, Cell 2, and Cell 3;
    - Design of Cell 1, Cell 2, and Cell 3, including as built plans, if possible;
    - Any mineralogical data for the capping materials used at Cell 1;
    - Information on the spigotting cycle (e.g. change in days of cycle, etc.) for Cell 1, Cell 2, and Cell 3, if possible;
    - Information that will assist us to estimate the extent of water cover on all TSF cells over time (e.g. photos, water depth measurements, etc.);
    - Start-stop dates for PbOx discharge into TSF cells over time, or total days of operations; and
    - Recorded and/or predicted volumes of PbOx water discharged to TSF cells over time (if available).
- Geochemistry of TSF:
    - Tailings composition data over time (e.g. static geochemical data, assay data, mineralogical data); and

- Surface water quality data, groundwater quality data, groundwater level data, seepage rates from the TSF, etc., as a function of time.

Task 2: OPT program

Previous OPT studies undertaken by Earth Systems (2017) identified the AMD generation rate of the tailings (kg H_2SO_4/t/m^2/day) in Cell 2 based on the current operational scenario (density of 1.7 tonnes/m^3 and moisture contents ranging from 70% to 90%). To determine the AMD generation rates in scenarios where the tailings cells are more progressed (higher density, lower moisture contents), it is recommended that five additional OPT analyses are undertaken. The OPT program should build on the previous studies, by:

- Analysing the tailings acidity generation rates per square metre at the known operational density (1.7 tonnes/m^2) and a lower moisture content (50%) to simulate the progressive drying of Cell 2;
- Analysing the tailings acidity generation rates per square metre at density levels expected at closure (1.9 tonnes/m^2) and various moisture contents (50%, 70% and 90%) to simulate deposition and progressive drying of tailings; and
- Analysing the tailings acidity generation rates per square metre at density levels expected at closure (1.9 tonnes/m^2), a low moisture content (50%) and with a 200 mm clay cap, to simulate the conditions in Cell 1, during operation of Cell 2 (see sample requirements, below).

The proposed OPT work program is outlined in Table 1.

Table 1: Proposed OPT work program

OPT number	Rationale	Density (tonnes/m^3)	% saturation	Other
1	To simulate the progressive drying of Cell 2	1.7	50	NA
2	To simulate the conditions upon closure of the TSF, but prior to reprocessing of the tailings	1.9	50	NA
3		1.9	70	NA
4		1.9	90	NA
5	To simulate the conditions of Cell 1 during operation of Cell 2	1.9	50	200 mm clay cap

Results from the physical and geochemical characterisation, and OPT test work will be used to estimate:

- Tailings Acidity Generation Rates per square metre as a function of the density and moisture content;
- Tailings Net Acidity Generation Rates based on available ANC for the above densities;
- The oxygen penetration depth (m) from the surface of the tailings to the point at which the oxygen concentration reaches zero; and
- The oxygen flux into the tailings as a function of surface area (kg O_2/m^2/year) – directly related to the AMD generation rate (kg H_2SO_4/m^2/year-eq).

Prior to the commencement of the OPT test work, representative sub-samples of the tailings will undergo physical and geochemical characterisation including:

- Sulfur speciation;

- Carbon speciation;
- Acid-base accounting (maximum potential acidity [MPA], acid neutralising capacity [ANC] and net acid production potential [NAPP]);
- Net acid generation (NAG) suite test work (including $NAG_{9.5}$);
- Particle specific gravity (dry basis);
- Moisture content;
- Acid buffering characterisation curve (ABCC);
- X-ray diffraction (XRD) analysis (crystalline and amorphous content); and
- Particle size distribution (sieves and hydrometer).

Sub-samples will be prepared according to the desired moisture contents and each sample will be loaded into an OPT column and compacted to the desired dry density equivalent. Oxygen and carbon dioxide measurements will be conducted over time.

Sample requirements

For the physical and geochemical testing and OPT, a bulk tailings sample of ~30-50 kg (dry basis) will be required. Earth Systems already has a representative tailings sample from previous work, and can use this material for the proposed test work.

A sample of the clay capping material used at Cell 1 will be required (~10 kg).

Task 3: Development of numerical model

The numerical model will be developed to use the measured Acidity Generation Rate data in conjunction with information on the surface area of the tailings and the changing surface area and extent of flooding for the various TSF Cells over the life of the TSF (from commencement to closure). The model will include:

- The annual rate of acidity generation (AMD) from the unflooded TSF surface area as a function of density and degree of saturation (informed by the OPT program);
- The annual consumption rate of ANC and the expected lag time before the onset of acid conditions, to demonstrate that the TSF will not generate acidic conditions during operations;
- The likely minimum duration of acidity generation from the tailings under the range of scenarios tested in the laboratory;
- Acidity contributions from the PbOx circuit over time; and
- Estimated acidity losses from tailings due to seepage.

Tasks 4-6: Reporting and development of work programs

The results of this test work should demonstrate to the Northern Territory Regulators the relatively low risk posed by the tailings on site, during mining operations and at closure, over a range of operational scenarios. In addition, it should also confirm the proposed pit backfill strategy for the tailings as an appropriate Closure plan.

KEY DELIVERABLES

Key project deliverables will include the following:

- A numerical model that can be used and refined over time;
- A report that summarises the works program listed above and documents the predicted acidity loads from the TSF from internal and external sources since tailings deposition commenced;
- Potential management strategies for dealing with this mass of acidity will be identified; and
- A work program for identifying the optimum management strategy will be provided.

PROPOSED PROJECT TIMING

The proposed timing is summarised in Table 2.

Table 2: Proposed project timing

Task	Time to complete (weeks)
Project management	Ongoing
Task 1: Data management and analysis	2
Task 2: OPT program (5 OP Tests)	4-6
Task 3: Development of numerical model	2-3
Tasks 4-6: Reporting & Management	2
Total time	**10-13**

It is proposed that the project will be completed by the end of May 2018.

ASSUMPTIONS

The following assumptions have been made in preparing this proposal:

- MRM will provide all relevant existing data to Earth Systems in a timely manner;
- Timing assumes that only minor edits are required to transform the Draft Report into a Final Report (1-3 hours). If a more detailed edit is required, additional time will be required;
- One full day has been allocated to client liaison;
- This project will be conducted under Earth Systems standard terms of engagement (Attachment A), unless the client has pre-established terms prepared for this scope of work.

We trust that this proposal meets your requirements. Please do not hesitate to contact Earth Systems should you have any queries.

REFERENCES

DIIS, 2016, Preventing Acid and Metalliferous Drainage. Leading Practice in Sustainable Development Handbook, produced by the Department of Industry, Innovation and Science. https://www.industry.gov.au/resource/Programs/LPSD/Pages/LPSDhandbooks.aspx#

Earth Systems, 2015. Review of Tailings Static Geochemistry Report for the McArthur River Mine, Northern Territory. Confidential Consultant's Report prepared for McArthur River Mining. Dated September, 2015. MRMSG1668_KCB Review_Rev0.

Earth Systems, 2016. Influence of the PbOx process on TSF water chemistry and tailings geochemistry. Consultant's Report prepared for McArthur River Mining. Dated May 2016.

Earth Systems, 2017. Tailings Water Quality Management - Operations and Closure: *In situ* Oxidation of Tailings. Consultant's Report prepared for McArthur River Mining. Dated February 2017.

GHD, 2016a. Tailings Storage Facility Preliminary Design – Life of Mine Plan. Draft Report January, 2016. Confidential Consultant's Report prepared for McArthur River Mining. 32/17476.

GHD. 2016b. Tailings moisture content profiles - chart. Email correspondence received 16/2/2016.

ATTACHMENT A

TERMS OF ENGAGEMENT

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TERMS OF ENGAGEMENT

AGREEMENT:

These terms of engagement together with any accompanying document(s) and/or any related document(s) incorporating these terms of engagement comprise the agreement between the Client and Earth Systems. Accompanying or related documents comprising the agreement are referred to herein as attachments.

IT IS AGREED:

1. Performance of Services

Earth Systems shall perform the services described in the attachments (the Services) with due care, skill and diligence and in accordance with the standard of performance considered acceptable by the members of the profession in similar circumstances.

2. Client Brief

The Client shall provide to Earth Systems briefing and all information concerning the Client's requirements for the Services.

3. Payment

The Client agrees to pay Earth Systems the remuneration described in the attachments as payable to Earth Systems for performing the Services (the Payment).

4. Additional Services

The parties hereto may agree to vary, add or delete parts of the work comprising the Services. The provisions of this agreement shall apply to all such variations and additions. Work performed by Earth Systems in addition to the Services shall be charged to the Client as provided in the attachments.

5. Escalation

Earth Systems hourly rates and any lump sum fees are reviewable in accordance with the Consumer Price Index applicable where the Services are principally performed unless otherwise provided in the attachments.

6. Invoices

Earth Systems invoices for the Payment shall be payable within 14 days of receipt by the Client. Interest at Earth Systems overdraft rates plus 4% shall accrue on accounts which are overdue.

7. Unforeseen Circumstances

Earth Systems shall be entitled to an equitable variation to this agreement and an appropriate adjustment to the Payment where delays, events or circumstances beyond the reasonable control of Earth Systems, or reasonable anticipation of the parties hereto, delay, increase or adversely affect performance of the Services.

8. Outgoings

The Client shall reimburse Earth Systems outgoings incurred in performing the Services at cost plus 10%.

9. Termination

Where the Project is finally terminated, the Client may terminate this agreement by 10 days notice in writing to Earth Systems. In the case of termination, the Client shall pay all moneys owing to Earth Systems plus reasonable costs of early demobilisation.

10. Suspension

Where the Services are suspended or delayed for a period, the Client shall compensate Earth Systems for the costs of suspended personnel and expenses incurred during such period, subject to a maximum of 10 working days in each period.

11. Limitation of Liability

The liability of Earth Systems to the Client, whether in contract or in tort and whether for negligence or otherwise, is hereby limited to the total aggregate amount of $20,000 or reperformance of the Services, whichever is the lesser. Earth Systems shall in no event be liable to the Client in respect of matters not notified within 12 months from completion or termination (whichever is earlier) of the Services.

12. Consequential Loss and Estimating

Earth Systems shall in no event be liable to the Client for consequential or indirect financial loss or damage, nor in respect of any estimate of the time or cost to complete the project.

13. Insurance

Earth Systems shall have in effect during the currency of this agreement the following insurances:

a) Public Liability Insurance covering injury to persons and damage to property in an amount not less than $10,000,000.

b) Statutory Workers Compensation Insurance.

14. Contractors and Approvals

Earth Systems shall have no liability in respect of any act, omission or negligence of any sub-consultant, contractor, workman, supplier or fabricator or other third party involved in the project.

15. Copyright

Copyright in all drawings, reports, specifications, bills of quantity, calculations and other documents provided by Earth Systems in connection with the project shall remain the property of Earth Systems.

16. Licence

Subject to Clause 17, the Client alone shall have a licence to use the documents referred to in Clause 15 for the purpose of completing the project, but the Client shall not use, or make copies of, such documents in connection with any work not included in the project.

17. Breach by Client

If the Client is in breach of any obligation to make payment to Earth Systems, Earth Systems may revoke the licence referred to in Clause 16, and the Client shall then cause to be returned to Earth Systems all documents referred to in Clause 15, and all copies thereof.

18. Intellectual Property Rights

The intellectual property rights subsisting in all inventions, discoveries, improvements and innovations created by Earth Systems during the course of carrying out the project shall be owned by Earth Systems.

19. Publication of Documents

The Client has no right to publish any of the documents referred to in Clause 15 without prior consent.

20. Disputes

Any disputes between Earth Systems and the Client shall first be the subject of mediation, provided that this provision does not prevent Earth Systems from instituting legal action at any time to recover monies owing.

21. Governing Law and Jurisdiction

This agreement shall be construed and governed by the laws of the State of Australia in which the Services are principally performed, or the State of Victoria if the Services are principally performed outside Australia.

22. Subsurface Installations

The Client is requested to provide Earth Systems with information regarding subsurface installations, including drains, pipes and cables. If such information is not provided, or is in error, Earth Systems will take care but does not accept responsibility for damage to any installations.

23. Event of emergency

Where Earth Systems staff or contractors are working on the site of a client, it will be expected that the client will assist in providing health support services in the event of emergency.

24. Commencement of Agreement

This agreement shall be deemed effective on and from the date of commencement of the Services by Earth Systems.