Before the Expert Panel appointed under the Fast-track Approvals Act 2024

Under	the Fast-track Approvals Act 2024 (**Act**)
And	
In the Matter of	an application for approvals by Matakanui Gold Limited to establish, operate, rehabilitate and ultimately close an open pit and underground gold mining operation known as the Bendigo-Ophir Gold Project

Statement of Evidence of **Dr Paul Weber** on behalf of **Matakanui Gold Limited** in response to Section 53 Feedback

Environmental Geochemistry and Mine Impacted Water

Dated: 17 April 2026

Lane Neave
Level 1, 2 Memorial Street
PO Box 7348
Queenstown
Solicitors Acting: Joshua Leckie/Sarah Anderton/Mia Turner
Email: joshua.leckie@laneneave.co.nz/
sarah.anderton@laneneave.co.nz/mia.turner@laneneave.co.nz
Phone: 03 409 0321

lane neave.

INTRODUCTION

1. My full name is Paul Antony Weber.

2. I have over 25 years' experience in the field of environmental geochemistry. I hold a B.Sc. in geology and a M.Sc. (Hons) in environmental science from the University of Canterbury. I have a Ph.D. in applied science from the University of South Australia on prediction of acid and metalliferous drainage (**AMD**) and I am a Fellow of the Australian Institute of Mining and Metallurgy having chartered professional status for the environment discipline.

3. I am the Principal Environmental Geochemist and the Managing Director for Mine Waste Management Limited (**MWM**). MWM is part of the Green Road group of companies (~45 employees) that provides practical, innovative, and sustainable solutions to the international resources industry. I am a co-founder of the Green Road group of companies. Prior to this role I worked at O'Kane Consultants Limited for 5.5 years as a Director for New Zealand and as a Principal Environmental Geochemist. Both companies provide advice on AMD and closure planning for mining operations. I have also worked as the R&D Manager – Environment for Solid Energy (NZ) Limited for ~9 years investigating beneficial reuse of waste streams and options to manage and treat AMD at its coal mining operations. In this regard I am conversant with AMD from coal measures. Additionally, I worked in the Western Australian mining industry for 5 years as a geologist / environmental geologist and understand the process of mining.

4. My previous work experience includes research and operational management of AMD. I have worked with mining companies to deliver sustainable management approaches for AMD over this time. I have been engaged by several international companies and regulators (West Coast Regional Council, Waikato Regional Council), as a subject matter expert, to review mine closure plans regarding AMD and the assessment of environmental effects (**AEE**) associated with AMD

5. This statement is given as part of Matakanui Gold Limited's (**MGL**) response to comments on the Bendigo-Ophir Gold Project (**BOGP**) made under Section 53 of the Fast-track Approvals Act 2024 (FTAA). This statement responds to specific comments raised by:

   (a) Otago Regional Council;

   (b) Sustainable Tarras;

   (c) Environmental Defence Society Incorporated;

   (d) New Zealand Fish and Game Council;

(e) Ross Hanan;

(f) Minerals Council of New Zealand; and

(g) Santana Mine Supporters Group.

6. My original findings are provided in full in the Mine Impacted Water (MIW) Overview Report – Bendigo-Ophir Gold Mine. MWM Report Number: J-NZ0488-001-R-Rev0. This report was provided to the Panel as:

(a) B.06 Mine Waste Management Limited - Mine Impacted Water Overview Report (MWM 2025);

(b) B.06A Mine Waste Management Limited - Mine Impacted Water Overview Report – Appendix B to G;

(c) B.06B Mine Waste Management Limited - Mine Impacted Water Overview Report – Appendix H; and

(d) B.06C Mine Waste Management Limited - Mine Impacted Water Overview Report – Appendix I to O;

and included the following appendices:

(i) B.06A - Appendix B: Site Visit and Preliminary CSM. MWM Report Number: J-NZ0233-001-M-Rev0.

(ii) B.06A - Appendix C: Preliminary Site Investigation – Bendigo-Ophir Gold Project. Geocontam Risk Management Report Number: J-AU0005-001-R-Rev3.

(iii) B.06A - Appendix D: Baseline Water Quality Report – Bendigo-Ophir Gold Project. MWM Report Number: J-NZ0233-006-R-Rev6.

(iv) B.06A - Appendix E: Sampling and Analysis Plan for Geochemical Characterisation. MWM Report Number: J-NZ0233-002-M-Rev0.

(v) B.06A - Appendix F: Geoenvironmental Hazards Factual Report. MWM Report Number: J-NZ0233-008-R-Rev3.

(vi) B.06A - Appendix G: SPLP and SEM EDS Analysis, MWM Report Number: J-NZ0233-014-M-Rev1.

(vii) B.06B - Appendix H: Factual Report: Column Leach Test. MWM Report Number: J-NZ0233-015-R-Rev4.

(viii) B.06C - Appendix I: Source Term Definition Report Bendigo-Ophir Gold Project. MWM Report Number: J-NZ045-001-R-Rev2.

(ix) B.06C - Appendix J: Engineered Landform Design Philosophy. MWM Report Number: J-NZ0233-009-M-Rev3.

(x) B.06C - Appendix K: Net Percolation Assessment. MWM Report Number: J-NZ0455-001-M-Rev3.

(xi) B.06C - Appendix L: Engineered Landform Water Quality Forecast Model Report. MWM Report Number: J-NZ0457-002-R-Rev1.

(xii) B.06C - Appendix M: Water Treatment Study - Bendigo-Ophir Gold Project. MWM Report Number: J-NZ0464-002-R-Rev2.

(xiii) B.06C - Appendix N: Water and Load Balance Model Report – Bendigo-Ophir Gold Project. MWM Report Number: J-NZ0233-016-R-Rev1.

(xiv) B.06C - Appendix O: Water Quality Database QA/QC. MWM Report Number J-NZ0233-011-M-Rev1.

7. My evidence is also reliant on other relevant reports and management plans that have been prepared including:

(a) G.01 - Bendigo-Ophir Gold Project Water Management Plan (MGL, 2025a);

(b) G.15 - Bendigo-Ophir Engineered Landform Management Plan (MGL, 2025b);

(c) G.16 - Tailings Storage Facility Management Plan; and

(d) B.07 - Recommended water quality compliance limits for the Bendigo-Ophir Gold Project (Ryder, 2025).

8. I have prepared this statement in the limited time available for MGL to respond to comments under the Act. If the Panel requires elaboration on any of the matters raised in this statement, I am available to provide further information on request.

9. Although this is not an Environment Court proceeding my confirmation of compliance with the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2023 is included in Substantive Application Document A0.2B.

SPECIFIC RESPONSE TO COMMENTS

10. I have been asked by MGL to respond to a number of comments from invited parties. My responses are set out in turn below.

COMMENTS FROM ADMINISTERING AUTHORITIES AND RELEVANT LOCAL AUTHORITIES

Otago Regional Council (ORC)

Comments 23, 24, and 25. Comment 189 - "A series of construction controls are proposed to minimise oxygen advection, including limiting tip heights in the bulk fill zones, truck compaction of the outer fill zone, layer thickness near the surface of the ELF, and design of underdrainage pipe outlets to prevent oxygen advection. These methods are partially adopted in the Applicant's proposed consent conditions. ORC recommends some modifications to these conditions to more comprehensively require these controls to be implemented and has included these as tracked changes in Document D.04".

11. The ORC has suggested new (identified as NEW by ORC) consent conditions that should be considered for the Shepherds ELF (NEW 21) and the Western ELF (NEW 22). In principal, the consent condition details make sense, but I have provided the following clarification as explained in Paragraph 13 to Paragraph 19 and suggest edits to the proposed consent condition that has been updated and is provided in Paragraph 20.

12. Details of the design guidance is provided in the G.15 ELF Management Plan (Section 8.3.3), which is summarised below.

13. The key design objective of ELF construction is to prevent high advective airflow rates into the core of the ELF where higher-risk high arsenic materials (e.g., TZ4[1]) are placed. This ensures the key pathway for oxygen into the ELF is by diffusion.

14. Work completed by Brown et al. (2014) at Bingham Canyon Mine (USA) has demonstrated that in a poorly constructed waste rock dump, advection accounts for ~90% of oxygen ingress, and that diffusion of oxygen accounts for 10%. Hence eliminating advective airflow will significantly reduce oxygen ingress.

15. The proposed measure of success to confirm the design objectives have been achieved is:

[1] Textural Zone 4 of the Otago schist

(a) < 5% oxygen within ~20 horizontal metres of the ELF batter slope (the key zone for advective airflow) with a clear oxygen diffusion profile (specifically - no significant spikes in oxygen concentration at depth due to advective airflow).

16. Examples of oxygen diffusion profiles are provided in **Figure 1** (McCabes Dump – Stockton Mine; Barren Valley ELF – Escarpment Mine). These profiles show a strong decrease in oxygen content with horizontal distance from the batter slope of the landform. This oxygen diffusion profile is the design objective of the BOGP ELFs.

17. Monitoring data presented for the Barren Valley ELF (**Figure 1**) also shows a significant spike in oxygen concentration (> 10% oxygen) at 20 horizontal metres into the ELF that is reflective of advective airflow (oxygen ingress). This will be avoided as part of the BOGP ELF design objectives. Quality control and quality assurance (QA/QC) procedures need to be undertaken to avoid advective airflow and the QA/QC processes are explained in the G.15 ELF Management Plan.

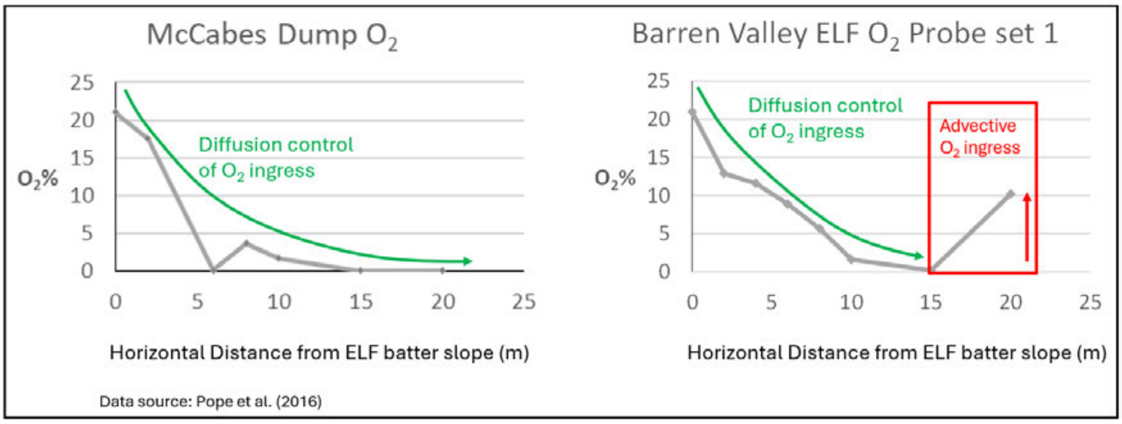


Figure 1: Oxygen ingress into ELFs (adapted from Pope et al., 2016)

18. The exact depth of the horizontal diffusive oxygen ingress is a function of the tiphead height and segregation of materials due to dumping practices,[2] materials properties, sulfide content, tiphead height, toes bunds, and compaction efforts. For the BOGP, an oxygen content of ~5% and a depth of ~20 horizontal metres is estimated (based on previous New Zealand case studies) and needs to be confirmed by site specific studies. The key objective is to prevent advective airflow. The amount of rock in the oxidising zone of the ELF influences long term solute loads.

19. ELF design flexibility is required to ensure advective oxygen ingress, that can account for up to ~90% of oxygen ingress is minimised.

[2] Fala et al. (2003) notes that ~40% of coarse material reaches the foot of the tiphead for push dumping of rock (i.e., dumping short and a dozer pushes rock over the edge of the tiphead) versus ~75% for end dumping directly over the tiphead. Such processes will influence segregation effects and tiphead height requirements.

20. It is recommended that the proposed new consent conditions (NEW 21; NEW 23; NEW 23a) be adjusted slightly, clarifying the design objectives as follows:

> *"The Consent Holder must construct and rehabilitate the ELF to ensure that oxygen ingress into the ELF is < 5 % at ~20 horizontal metres into the ELF with a clear diffusion profile and no advective oxygen ingress, where:*
>
> *(i) The diffusion profile is measured by oxygen probes installed up to depths of 50 horizontal metres into the ELF;*
>
> *(ii) Advective oxygen ingress is prevented (i.e., no significant oxygen concentration spikes);*
>
> *(iii) Oxygen profiles are reviewed by a suitably experienced and qualified person (SQEP) to confirm that the design objective has been achieved (i.e., no advective oxygen ingress);*
>
> *(iv) If oxygen depth is greater that ~20 horizontal metres, then adaptive management processes need to be implemented to understand the effects and any risks for water quality objectives."*

21. No design criteria are proposed in these new conditions. Instead, it is proposed that design criteria to manage advective oxygen ingress needs to be developed within the first 12 months of Operational Phase of the BOGP to support the design objectives once ELF construction processes are understood (taking into consideration site specific variables). An appropriate consent condition would be:

> *to develop a standard operating procedure within 12 months of earthworks commencing to achieve the ELF design objectives and that this should include performance monitoring and trigger action response plans.*

ELF Net Percolation Rate

Comments 26 and 27. Comment 200 - "ORC recommends that these cover system trials be explicitly required by conditions (if and to the extent that they cannot be conducted sooner than that) and that commencement of these trials be time-bound i.e. not left to the discretion of the consent holder through use of terms such as 'as soon as possible / practicable'."

22. The trials are recommended as a mitigation measure in the G.15 ELF Management Plan (Table 6 – Risk ELF06) to confirm net percolation (**NP**) rate.

23. ORC propose a new consent condition (NEW 20 (D.04 - Schedule Two - General Conditions for ORC Consents (17 April 2026)) to ensure these trials are undertaken. I agree that a condition is appropriate to ensure these trials are undertaken. The following comments are provided:

(a) **Appendix E** provides an explanation of what the field trials would involve.

(b) Field trials cannot start until a suitable area is available during the project Development and Construction phases. Parts of the Western ELF (WELF) could be used for this field trial as the WELF is constructed early in the project mine life. It is recommended these trials commence within 12-18 months of mining commencing.

(c) A field trial methodology is required. It is proposed this field trial methodology can be completed within 3-6 months of the project being approved. It should assess a number of cover system options to reduce net percolation rates. This methodology will be provided to the ORC.

(d) It is anticipated that trials may run for three to five years to confirm results. There may be benefit in continuing trials to understand any effects of longer-term climatic cycles.

(e) An annual monitoring report on these field trials will be provided to ORC, prepared by a SQEP.

(f) At the completion of the trials the Consent Holder must report on results. Any difference in NP compared to the model results of 20% must be managed by adaptive management processes.

24. It is recommended that the proposed new consent conditions (NEW 20 (D.04 - Schedule Two - General Conditions for ORC Consents (17 April 2026)) be adjusted slightly, clarifying timeframes, duration, and review process as follows:

> *"Within 12-18 months of commencing bulk earthworks on the BOGP the Consent Holder must initiate ELF cover system field trials for the purpose of validating the net percolation rate of 20% that was assumed in the application. The trial must include / must be undertaken in the following way:*
>
> *i.) A field trial methodology will be provided within 3-6 months of the project being approved.*
>
> *ii.) An annual monitoring report, prepared by a SQEP will be provided.*
>
> *iii.) Following completion of trials the Consent Holder must:*
>
> *a. Report on trial results and confirm net percolation rates.*
>
> *b. Ensure sufficient materials are available to construct the proposed cover system."*

Water Treatment

Comments 31 and 32. Comment 223 – "The importance of the proposed active water treatment should not be underestimated; the Applicant's modelling confirms that appropriate water quality outcomes cannot be achieved without treatment. ORC considers that the order-of-magnitude study in B.41 provides little certainty that water quality objectives can be achieved in practice."

Comments 31 and 32. Comment 225 - "ORC has identified the Applicant's proposed consent conditions omit any requirements for testing or trials, and there are no conditions applying to the detailed design, construction, operation, performance monitoring, or ongoing maintenance of the active Water Treatment Plant. ORC considers this a significant omission and has suggested a framework of conditions in Appendix 2, including requirements for bench trials, pilot trials, and operational trials."

25. Active treatment of mine impacted water (MIW) is a proven industry accepted technology but requires detailed studies to confirm the treatment approach. I support the requirement to undertake water treatment trials and that this should include the new conditions proposed by the ORC (Appendix 2: NEW 6, 7, 8, 9). New conditions (NEW 10, 11) are addressed in the evidence of Gary Smith. I have provided some addition comments below in my evidence (Paragraph 27).

26. Examples of active and passive water treatment in New Zealand are provided in **Appendix A**. This summary demonstrates local experience in the treatment of MIW.

27. Gary Smith in his evidence has provided the lead times for the water treatment plant (**WTP**) to be operational (Figure 2).

28. Noting - preliminary studies (i.e., water treatability trials) are reliant on suitable water being available from the BOGP (e.g., TSF seepage water):

    (a) Total lead time is 21 months before the WTP is operational.

    (b) It is estimated that suitable TSF seepage is expected within 1 year of tailings being deposited. ELF seepage may also be available, but concentrations are likely to be lower than concentrations at closure. A fabricated water sample may be required.

    (c) Consent Condition NEW 6 could state that water quality and dewatering testwork (Figure 2) will commence one year after tailings deposition commences.

(d) The WTP design will be informed by trials to validate the net percolation rate (as explained in Paragraph 22 to Paragraph 23), and ongoing water and load balance modelling to confirm flow rates and WTP treatment capacity requirements.

(e) Passive treatment trials to confirm the passive treatment system design and performance will commence during the Operational Phase of the BOGP.

29. Consent Condition Appendix 2: New 6 – Accepted with proposed edits on timing on studies.

30. Consent Condition Appendix 2: New 7 – Accepted. Noting consideration of triggers for commissioning the WTP are required and will be included in G.01 Water Management Plan as part of the adaptive management processes.

31. Consent Condition Appendix 2: New 8 – Accepted.

32. Consent Condition Appendix 2: New 9 – Accepted.

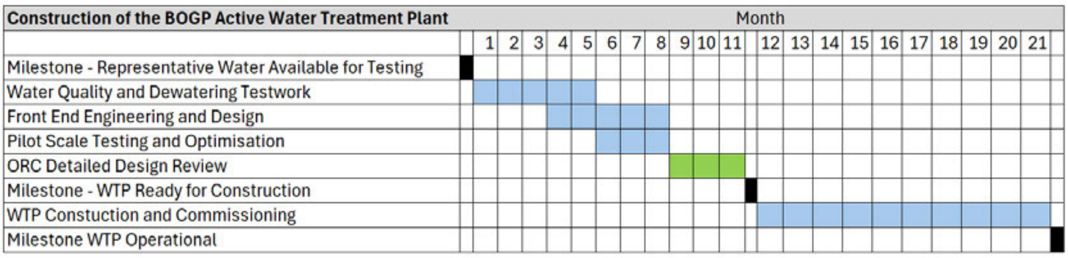


Figure 2: Gantt Chart for the Construction of the BOGP WTP (Source: Process Flow Limited – Evidence of Gary Smith).

COMMENTS FROM ENVIRONMENTAL GROUPS

Sustainable Tarras

Comment 8 - "Gypsum formation blocking TSF drains over time is a recognised issue. The application however does not address the likelihood, potential consequences or mitigation measures for long term PCOC seepage should blockages occur."

33. The risk for gypsum precipitation is sourced from data available for Macraes Gold Mine (Craw and Pope, 2017). These data are provided in Figure 3.

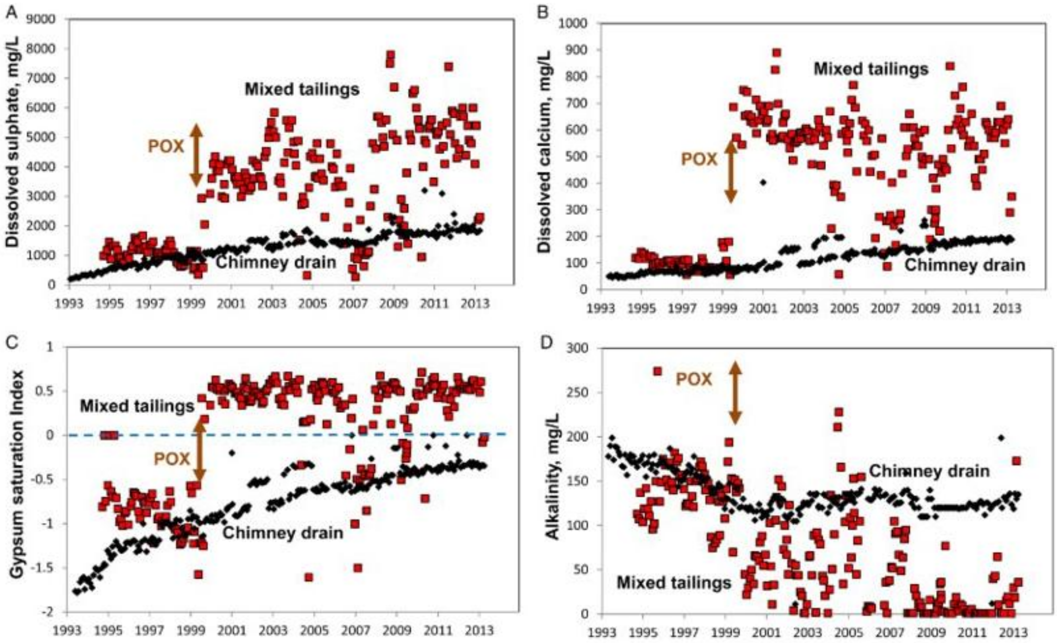


Figure 3: Geochemical time series plots comparing the water in the mixed tailings decant pond (discharged from the processing plant) and downstream chimney drain waters that are collected within the tailings dam structure.

34. The data presented in Figure 3 for Macraes shows the risk for gypsum precipitation is higher post pressure oxidation (**POX**) when significant CaO is used to neutralise acidity generated from sulfide mineral oxidation (that increases sulfate) within the tailings stream where gypsum saturation is > 1 (Figure 3).

35. The source term used for TSF seepage is derived in the Source Term Report – Table 23 (B.06C MWM MIW Overview Report – Appendix I) and is 954 mg/L sulfate, which is comparable to Macraes prior to the installation of POX. Hence, analogue data from Macraes, as reviewed by Craw and Pope (2017) suggests the potential for gypsum precipitation is low at BOGP as POX is not being undertaken.

36. For these reasons, I consider risks of gypsum precipitation are understood. However, I recommend that monitoring is undertaken of TSF drains to confirm that scaling is not an issue from gypsum and/or other precipitates.

Comment 110 - "The application does not cover the likely quantities and concentrations of arsenic to be released in tailings, waste rock dumps and dust. The effects of natural hazards and climate change impacts on the safety of arsenic to remain contained are not outlined."

37. Professor Lottermoser notes in Section 2.4 of his report that MGL "does not present any information on the density, mineralogy, geochemistry, texture, hardness and grain size of future tailings that are to be placed into the Shepherds TSF".[3]

38. It is often difficult to get data on tailings geochemistry when the tailings are not being produced (i.e., typical of a greenfield project). Instead, metallurgical samples and ore samples are used as surrogate samples to understand the geochemical nature of the materials. In this regard:

    (a) B.06A - MIW Overview Report – Appendix F (Geoenvironmental Hazards Factual Report) – clearly identifies that ore samples are non-acid forming (Figure 17 and Figure 19). Hence tailings are expected to be similar.

    (b) B.06B - MIW Overview Report – Appendix H (Column Leach Test Report) provides 13 months of column leach test data. potential constituents of concern (**PCOC**) include As, B, Co, Cu, Zn.

    (c) Furthermore, analogue data from Macraes TSF seepage, combined with metallurgical test work on BOGP ore samples were used to gain a stronger understanding of AMD risks for water quality (B.06C MIW Overview Report – Appendix I).

39. These studies provide a suitable assessment of the risks for AMD from the BOGP tailings for the assessment of environmental effects.

40. However, it is recommended that weekly samples of the tailings solid fraction are collected and tested by traditional acid-base accounting (**ABA**) techniques to validate the geochemical nature as being non-acid forming once the TSF is operational. The TSF management plan will be updated to reflect this sampling program through expert conferencing and in due course, be provided to the panel for certification.

41. The change in PCOC load for Shepherds Creek and Rise and Shine Creek due to the BOGP have been provided (**Appendix F**).

42. Climate change effects are addressed in the water balance model as described in Section 5.2.1 of MWM Source Term Report: B.06C Mine Impacted Water Overview Report – Appendix I to O.

[3] Tailings Storage Facility

Comment 12 - "The long-term stability of arsenic and likely eventual mobilisation appears heavily dependent on modelling, carbonate buffering and passive long term management assumptions, each of which provide a major challenge to successful implementation. To make interpretation even more difficult, there appears to be no single application document that explicitly covers the long-term fate of arsenic, with vague comments throughout multiple reports."

43. There is no single document that focuses on arsenic as it is assessed across multiple disciplines. However, I note that the area is naturally elevated in arsenic, and it is a significant PCOC for the BOGP along with other PCOC derived from geoenvironmental hazards.

44. Instead, the management of AMD (i.e., the oxidation of sulfide minerals such as arsenopyrite) is more appropriately assessed throughout multiple reports to address the six steps of AMD management.

45. ABA data clearly demonstrates the project materials are non-acid forming and hence carbonate buffering of any acidity generated from sulfide mineral oxidation is a reasonable assumption. This is supported by analogue data from Macraes Gold Mine (same orogenic mineralisation style and lithologies) where water quality is circum-neutral.

46. Modelling has been undertaken to understand the engineering controls that are required to prevent deleterious effects on the receiving environment (i.e., achieve water quality objectives that will be set for the project). Engineering controls include:

    (a) Materials characterisation and management within the ELF.

    (b) Construction of an ELF to prevent advection oxygen ingress and sulfide mineral oxidation in the ELF core where higher arsenic materials will be placed.

    (c) Water management.

    (d) Water treatment (active and passive treatment).

47. Water treatment sludge from the WTP and/or the passive treatment system will be disposed offsite to an appropriate landfill unless other viable options are determined through future studies.

48. The testing that has been undertaken as part of the AEE studies (described in Paragraph 38) and the proposed monitoring (described in Paragraph 40), together with other current and ongoing studies, will contribute to the geochemistry

requirements of GISTM[4] Requirement 2.2: “Prepare, document and update a detailed site characterisation of the tailings facility site(s) that includes data on climate, geomorphology, geology, geochemistry, hydrology and hydrogeology (surface and groundwater flow and quality), geotechnical, and seismicity. The physical and chemical properties of the tailings shall be characterised and updated regularly to account for variability in ore properties and processing.”

Environmental Defence Society (EDS)

Comment 9 - “Potential release of a significant quantity of hydrogen sulfide, a toxic unpleasant smelling gas, as a result of almost certain thermal stratification and expected pit lake turnover”

49. I accept that thermal stratification of the pit lakes at the BOGP will occur and this could result in lower oxygen conditions at the base of the pit lake.

50. MWM has been involved in the performance monitoring of two mature pit lakes in New Zealand including the Globe-Progress Pit Lake near Reefton and the Golden Bar Pit Lake at Macraes Gold Mine. Information is publicly available on these studies and is provided in Appendix C.

51. These pit lakes stratify on a seasonal basis in summer due to warmer surface waters. Data from the Globe-Progress Pit Lake shows that the thermocline gradually decreases in autumn and no thermocline exists in winter. The risk of ongoing solute buildup with time, at depth, is low as the lakes fully mix on a seasonal basis.

52. The long-term generation of significant quantities of hydrogen sulfide at depth is low, unless persistent reducing conditions develop. This risk of elevated hydrogen sulfide has not been ruled out, and additional studies could be undertaken to confirm the risk is low. These studies are discussed in Paragraph 56. If modelling identifies a risk, then adaptive management processes may be needed when the pits fill after mine closure. Adaptive management response options are discussed in Paragraph 55.

53. Sub-oxic conditions could also lead to an increase in iron (Fe) and arsenic (As) at the base of the pit lake during stratification events. However, data provided for Globe-Progress (Appendix C) suggest that this does not contribute to any ongoing increase in solutes over annual cycles.

[4] Global Industry Standard on Tailings Management (2020)

54. A chemocline could also lead to pit lake stratification. Noting that mineral leaching from pit walls can create a dense, heavy layer at the bottom of the pit (the monimolimnion) that is physically too heavy to be mixed by wind or surface cooling. The risks for a site such as BOGP that will generate neutral metalliferous drainage are lower than an acid pit lake, and a chemocline has not been observed at either Globe Progress Pit or the Golen Bar Pit (which are of similar geological/geochemical conditions).

55. If such conditions do occur after closure of the mine once the pit lakes fill (e.g., hydrogen sulfide, elevated iron and arsenic), then there are management options available. Examples of management options are discussed in Appendix C (e.g., oxygenation (passive and mechanical), ferric chloride dosing).

56. I recommend that a comprehensive pit lake model will be developed for the RAS Pit Lake as part of the detailed studies to provide confidence in water quality predictions. This model will include biogeochemical processes, nutrient assessment, and scenario modelling. This should be completed as part of closure readiness planning during the Operational Phase of the BOGP. A consent condition to ensure this study is completed is appropriate and is included the proposed consent conditions as Condition 6C (D.04 - Schedule Two - General Conditions for ORC Consents (17 April 2026)).

EDS: Expert advice – Professor Jenny Webster-Brown

57. EDS engaged Professor Jenny Webster-Brown to provide advice on the BOGP application.

58. Professor Jenny Webster-Brown's "main concerns" relate to "how mine geochemistry, and the type of mining operation proposed, will impact on water quality" are itemised in Paragraph 20 of her evidence. This section of my evidence addresses those concerns, where I have appropriate knowledge.

59. Professor Jenny Webster-Brown raises concerns in her evidence (Paragraph 20a) that water quality in pit lakes can deteriorate with time "forming a reservoir of contaminated water and posing a risk to ecology and human health".

    (a) The pit lakes will be considered a non-use mining area (**NUMA**) at closure due to significant health and safety risks for anyone entering into the area. Exclusion barriers will be established to keep people out.

    (b) I cannot comment on the ecology risks of the pit lake. This is addressed in Dr Simcock's evidence.

60. Professor Jenny Webster-Brown raises concerns (Paragraph 20c) about the underprediction of arsenic in mine impacted waters.

(a) MWM has used empirical data when available (e.g., metallurgical testwork supernatant water quality) and analogue data from similar geological environments to develop these source terms. Data from column leach tests were used to adjust some parameters based on sulfate relationships. These source terms are summarised in Appendix G.

Tailings

(b) Mine impacted waters associated with tailings from orogenic gold deposits (such as Macraes Gold Mine, Globe-Progress Mine, and the proposed BOGP) are elevated in arsenic.

(c) Figure 4 demonstrates that arsenic concentrations can be > 100 mg/L in the Concentrate Tailings Impoundment (CIT) decant (surface) waters at Macraes prior to POX[5]. Arsenic data for the Flotation Tailings Impoundment (FTI) is lower.

(d) Similar concentrations in the decant can be expected at the BOGP (e.g., FTI)). However, decant waters are not included in the water and load balance model as there is not a credible surface discharge pathway to the receiving environment (i.e., the TSF surface water does not discharge).

(e) If TSF decant waters need to be treated in the event that mine circuit water requires discharge, then the source term should be assessed from available monitoring data to provide a reliable source term.

[5] Noting: The water quality in the CTI was also influenced by the storage of the sulfide concentrate prior to the implementation of the autoclave for POX of tailings, which explains the higher arsenic data compared to the Flotation Tails Impoundment (FTI) – (Golder, 2011). A concentrate stream is not being produced at the BOGP.

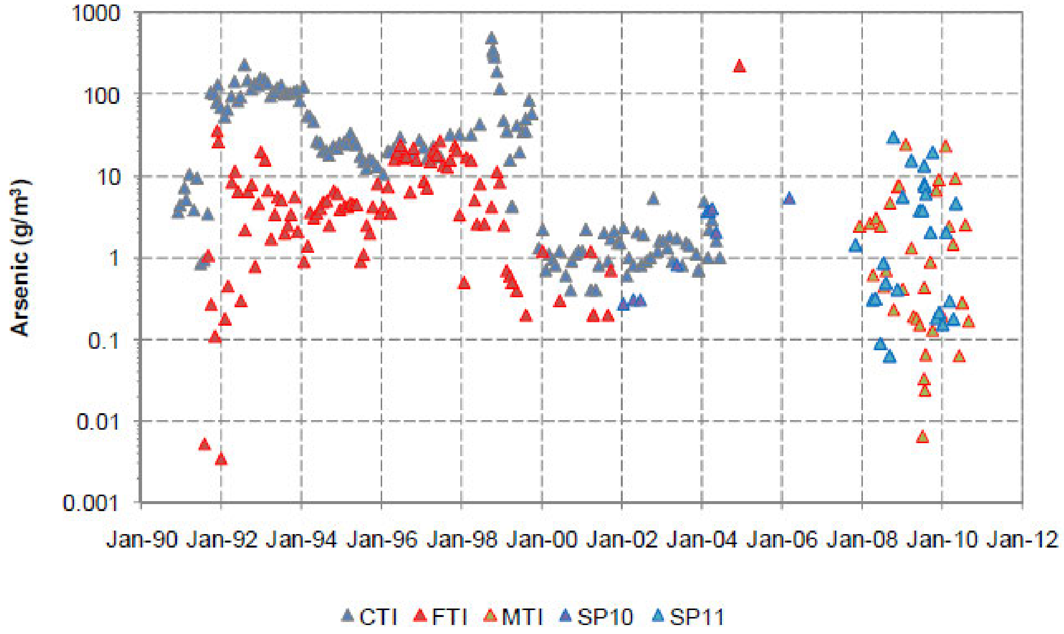


Figure 4: Arsenic concentrations within the decant ponds at Macraes (Source: Golder 2011).

(f) There is a maturation process for seepage through the tailings impoundment that reduces the TSF decant arsenic concentrations. Seepage water quality evolves from that shown in Figure 4 (10 – 100 mg As/L) to ~ 2 mg As/L in the Sump B chimney drain prior to POX (Figure 5).

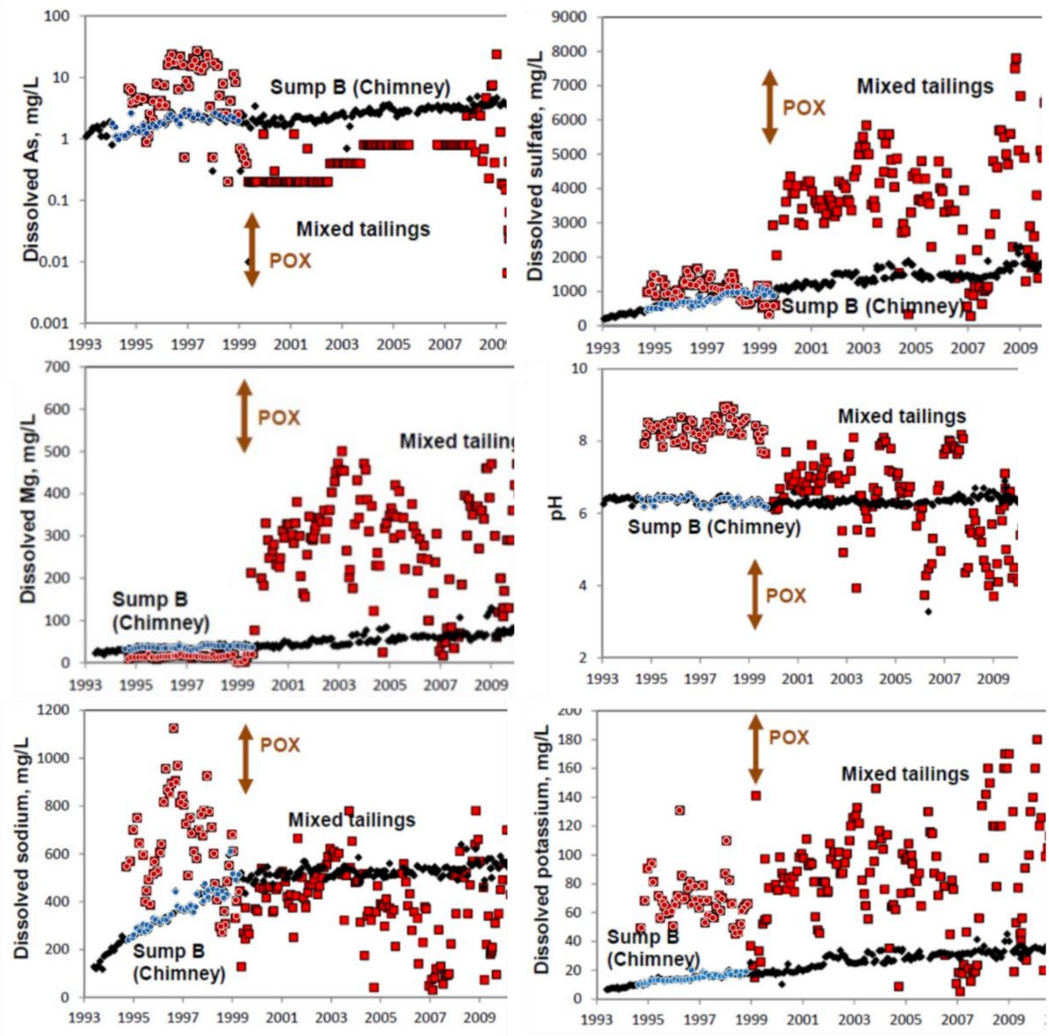


Figure 5: Macraes Tailings seepage water quality (Source: Craw and Pope, 2017).

(g) As shown in Figure 5, the sulfate concentrations in seepage (Sump B Chimney) are considerably lower prior to POX (954 mg/L)[6].

(h) The source term for tailings seepage was obtained from historical data at Macraes prior to POX (Figure 5) and process water quality obtained from metallurgical testing. These data are provided in the MWM Source Term Report (B.06C - Mine Impacted Water Overview Report – Appendix I to O).

(i) The source term is based on empirical measured data for an operating TSF with similar geoenvironmental hazards and processing to that proposed at the BOGP. It is considered a reasonable source term for the assessment of effects.

[6] This sulfate concentration was used in the development of the source term for TSF seepage at BOGP as a scaling factor for other solutes in the metallurgical test supernatant.

(j) To be conservative this source term remains constant in the model and does not consider any decrease with time or the cessation of process water discharge.

Pit Voids

(k) Modelling of pit lakes used median data obtained from the Frasers Pit as pit wall runoff water quality.

(l) Recent data, available after the MWM Source Term Report (G.06C Mine Waste Management Overview Report – Appendix **I**) was finalised is available from Macraes. This provides higher solute concentrations in pit wall runoff (**Appendix D**). This was introduced into the model as a sensitivity. The higher sulfate concentrations in pit wall runoff (~720 mg SO_4/L) extends the duration that active treatment is required in the model to ~85 years.

(m) The Macraes source term from Golden Bar Pit is considered conservative as the load is based on the initial load associated with pit lake filling. Load to the pit lake will decrease with time. Pope et al. (2018) determined that the acidity load from pit walls decreases with time (over 62 years) for rocks associated with the Brunner Coal Measures (Figure 6). These rocks generate acid rock drainage, so the decrease may not be as rapid at the BOGP, but the mechanism will still occur.

(n) Further analysis is required to understand the decrease in pit wall loads with time as this will influence (improve) water quality over the model period.

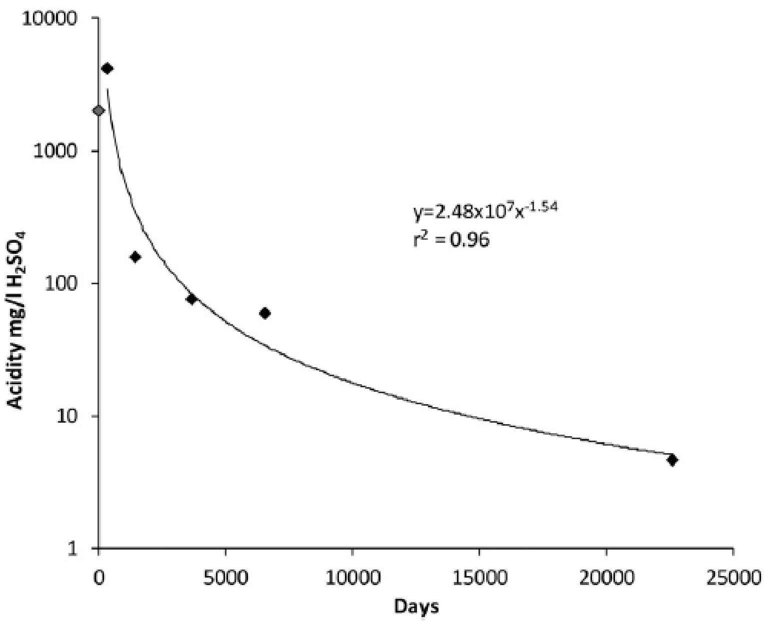


Figure 6: Average acidity data for highwall surfaces versus time (Pope et al., 2018).

Engineered Landforms

61. Waste rock will be placed in ELFs to minimise long term risks associated with sulfide mineral oxidation and the release of PCOC. If rock is not managed well and uncontrolled advective oxygen ingress occurs, then sulfate concentrations could be > 6,000 mg/L (i.e., a traditional waste rock stack). This model was provided in the MWM Engineered Landform Water Quality Forecast Report (B.06C Mine Waste Management Overview report – Appendix I) based on the average height of the Shepherds ELF and is provide as Figure 7. This provide a sensitivity for what water quality could be without the proposed engineering controls described in the G.15 Engineered Landform Management Plan.

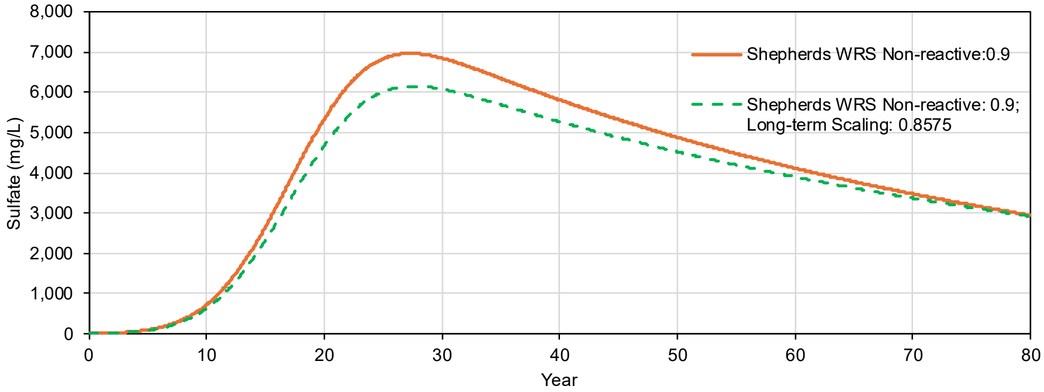


Figure 7: Traditional waste rock stack sulfate concentrations without source control to prevent advective airflow

62. Modelling indicates that if advection is controlled and only the outer shell of the ELF is oxidising, then sulfate concentrations could be ~1,200 mg/L. Robust design criteria is required to ensure advection is controlled. This is proposed in consent condition NEW 20 (D.04 - Schedule Two - General Conditions for ORC Consents (17 April 2026)).

63. Scenario modelling was undertaken for each ELF to assess the effects of a 10 m wide horizontal oxidising zone versus a 20 m wide horizontal oxidising zone. This modelling was provided in the B.06C MWM MIW Overview Report – Appendix L. These results are provided for Shepherds ELF in Figure 8 as an example.

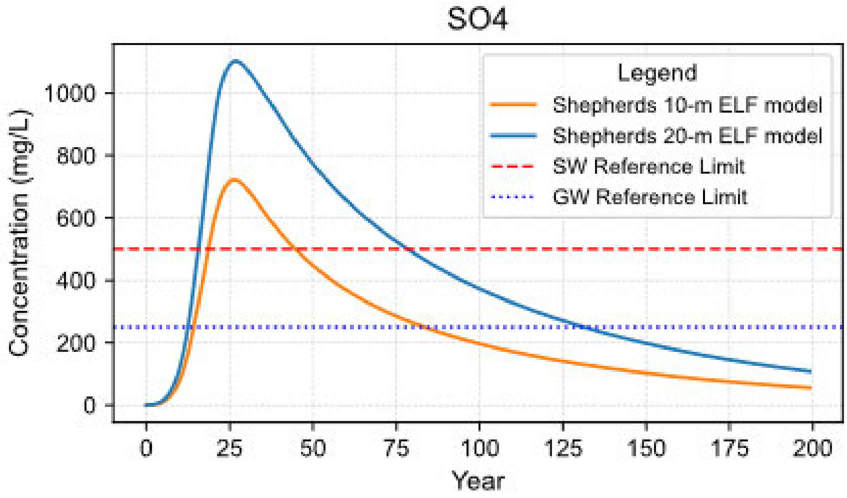


Figure 8: Model Results for Shepherds ELF: Sulfate (10 m and 20 m horizontal oxidation zones).

64. Source terms for peak solute concentrations for the engineered landforms are provided in **Appendix D** based on a 20 m horizontal oxidising zone.

65. Source terms dynamic and change with time as detailed in the MWM Engineered Landform Water Quality Forecast Report (B.06C Mine Waste Management Overview report – Appendix I).

66. To acknowledge that the ELFs are constructed to be sub-oxic in the core and iron and arsenic are likely to be higher and soluble, a source term was obtained from the Devils Waste Rock Stack at Globe Progress Mine that was sub-oxic (0.2 mg As/L and 7.6 mg Fe/L) as presented by Hayton et al. (2022). Further work is required to validate these concentrations of redox sensitive species as part of detailed design studies. Adaptive management processes need to be considered for higher concentrations of Fe and As.

Net Percolation

67. Net percolation is modelled at 20% of rainfall for the BOGP based on data available from Macraes (MWM, 2024).

68. An increase in net percolation will increase the PCOC load from ELFs, which will lead to a longer active treatment phase being modelled. Trials are proposed to validate this key model input. This will be conditioned as per the proposed consent condition NEW 20 (D.04 - Schedule Two - General Conditions for ORC Consents (17 April 2026)).

69. A detailed transient water balance model is being developed for the BOGP Operational Phase to support detailed design. This model will be used to develop a water and load balance model to support operational readiness for water management (e.g., treatment). The model should include sensitivity modelling and

would form the basis for future modelling of effects into the closure phases. This is included in the proposed consent conditions as Condition 6A (D.04 - Schedule Two - General Conditions for ORC Consents (17 April 2026)).

70. Professor Jenny Webster-Brown raises concerns (Paragraph 20d) over "The efficacy of passive treatment as a future (in perpetuity) treatment". In this regard, I would note that:

(a) Numerous studies have been undertaken in New Zealand on passive treatment of mine impacted waters. This is provided in **Appendix A**.

(b) Passive treatment of arsenic and iron mine impacted waters to meet water quality objectives has been successfully achieved at the Globe Progress Mine for the treatment of tailings seepage and waste rock stack seepage (https://oceanagold.com/sustainability/closure-and-relinquishment)

(c) The transition to passive treatment will follow confirmation that passive treatment system technologies can successfully achieve agreed water quality objectives

(d) If passive treatment cannot achieve these water quality objectives, then active treatment will continue until loads (flow and/or quality) decrease sufficiently that passive treatment is viable.

(e) Passive treatment is not a walk away solution and requires monitoring and ongoing maintenance.

71. Professor Jenny Webster-Brown has concerns that "mine impact waters do not include the undissolved component of each contaminant (e.g., the portion bound to suspended sediment or other solids in the fluid). For trace metals in particular, this can be a significant (sometimes dominant) means of transport in mine impacted waters and thereafter in receiving freshwaters.

(a) Mine circuit water, that will be elevated in suspended solids and trace metals (e.g., arsenic) that may be adsorbed to these solids will not be discharged from the BOGP without treatment. The treatment process is designed to remove solids as a sludge. Monitoring will be undertaken for total and dissolved metals in the WTP discharge to confirm these risks are managed. This monitoring is covered by the proposed consent condition NEW 10 (D.02 - ORC Consents and Conditions (17 April 2026)) that indicates weekly water quality analysis for total and dissolved metals.

(b) During operations arsenic-rich soils and rock will be excavated. Sediment loss will be managed by the G.20 Soil Management Plan rand the G.14

Erosion and Sediment Control Plan, which will minimise the loss of trace metals.

(c) If sediment from these mineralised areas is not contained on site by sediment management processes, then the entrained solids will be carried downstream, eventually precipitating out on the creek floor (noting its ephemeral nature). This could lead to a buildup of metal such as arsenic in the stream sediment. To manage this risk the following is proposed:

(i) A baseline study will be undertaken of soil/sediment within stream beds to quantify the amounts of trace metals within the existing drainage path. This needs to also identify any contamination due to historic mining in the catchment of Rise and Shine Creek.

(ii) Regular monitoring will be undertaken to assess whether there is any mobilisation of trace metals from the BOGP. The water management plan will be updated through expert conferencing and provided in due course to the panel for certification.

(iii) This monitoring program needs to address the accumulation of metals due to the adsorption of dissolved trace metals such arsenic to sediment.

(iv) The proposed consent condition NEW 8 (D.04 - Schedule Two - General Conditions for ORC Consents (17 April 2026)) addresses these monitoring requirements.

(v) An adaptive management process needs to be developed if trace metals are elevated above the baseline conditions.

72. Professor Jenny Webster-Brown has concerns about that "even if compliance with the water quality limits suggested is demonstrated, is unlikely to prevent the contamination of downstream water and sediment environments by mine-generated trace metals."

(a) It is proposed that the monitoring program set out in Paragraph 71(c) will address this issue.

Owners and Occupiers

Ross Hanan: Comments from Owners and Occupiers of the Adjacent Land

Comment 13 - "The application relies heavily on adaptive management and future mitigation measures that are not yet developed or tested, rather than presenting proven, upfront controls."

73. Adaptive management is an industry accepted process. The appropriateness of adaptive management processes to manage uncertainty through evolving project knowledge is explained in the legal submission. The adaptive management proposed is also supported by detailed conditions giving certainty as to required actions and outcomes.

74. Papers that discuss the suitability of adaptive management are available and are provided as **Appendix B**.

75. Further discussion on adaptive management is provided in the G.15 Engineered Landform Management Plan and G.01 Water Management Plan with a number of issues identified.

Other Invited Parties

New Zealand Minerals Council

Comment 16 – "The New Zealand Minerals Council provides two examples of water treatment of mine impacted waters in New Zealand. This being:

*i). OceanaGold's Reefton passive water treatment system (**PWTS**).*

ii). The use of waste mussel shells to construct PWTS."

76. MWM was involved in OceanaGold's Reefton project including the design of the PWTS and has experience in the treatment of Fe- and As- rich waters.

77. I was an early pioneer of PWTS using mussel shells in 2007 and have been involved in the operational implementation of these systems at Stockton, Canterbury, and Escarpment mines.

78. Active and passive treatment of mine impacted waters is well understood in New Zealand with many examples of such work. Further examples are provided in **Appendix A**.

79. I do not see any technical challenges with being able to treat mine-impacted waters at the BOGP using active treatment technologies and later a transition to PWTS. Further details are provided in the B.06C MWM MIW Overview Report – Appendix M.

80. However further studies are required once suitable site-specific waters are available to confirm capacity and the treatment stages/processes. As stated in the G.01 Water Management Plan:

> *"Order of magnitude studies indicate that active and passive water treatment can achieve closure water quality objectives, although further feasibility studies are*

required to confirm treatment performance and the ability to transfer from active to passive treatment."

81. A consent condition would be appropriate to ensure these active water treatment studies are undertaken in a timely manner such that the technologies can transition to operational readiness when required. The proposed consent condition NEW 6 (D.02 - ORC Consents and Conditions (17 April 2026)) explains the work that must be done.

Santana Mine Supporters Group

Comment 6 – "Supporters recognise the project involves identifiable adverse effects in relation to groundwater, waste rock, tailings management, rehabilitation and closure obligations and long-term environmental stewardship. These should be addressed through clear conditions, ongoing monitoring and enforceable obligations including financial assurance mechanisms."

82. MWM prepared a MIW Overview Report (B.06) that clearly identifies the geoenvironmental hazards (determined from laboratory trials and analysis; site-based studies; and analogue sites), potential effects, and explains the management methods and engineering controls that are required to achieve closure objectives.

83. MGL has prepared the G.15 ELF Management Plan and the G.01 Water Management Plan that explains how these geoenvironmental hazards will be managed.

84. These requirements are reflected as appropriate in consent conditions presented as part of this response package.

Comment 32 – "Comprehensive groundwater and surface water monitoring programmes should be implemented, with clearly defined trigger thresholds and response actions. Monitoring data should be independently audited and reported publicly at regular intervals"

85. Groundwater and surface water monitoring is explained in the G.01 Water Management Plan (MGL, 2025a).

86. Triggers for groundwater and surface water monitoring response actions could include:

    (a) Increasing trends in PCOC at performance and compliance monitoring locations that suggest water quality limits at the proposed compliance monitoring locations may be exceeded with time. These limits / trend rates need to be defined as part of the adaptive management process once the project is operational and data are available. This trend analysis is included as proposed consent condition NEW 5 – Document D.04 – Schedule Two – General Conditions for ORC (17 April 2026).

(b) One option for a trigger value for adaptive management is if any PCOCs are within 50% of the proposed compliance limit at compliance monitoring locations with increasing trends. This approach is similar to using 50% of maximum acceptable value (**MAV**) for New Zealand drinking water where it is used as a screening level for follow up action (Taumata Arowai, 2022). Such trigger limits should be defined in the G.01 Water Management Plan as part of an adaptive management process.

(c) The Water Management Plan (Section 11.2) requires a Suitably Qualified and Experienced Person (**SQEP**) to prepare the annual monitoring report for water management. This adaptive management process is included in the proposed consent condition NEW 5 (Document D.04 – Schedule Two – General Conditions to ORC Consents (17 April 2026).

Dr Paul Weber
17 April 2026

REFERENCES

Brown, P. L., Logsdon, M. J., Vinton, B., Schofield, I., & Payne, K., 2014. Detailed characterisation of the waste rock dumps at the Kennecott Utah Copper Bingham Canyon Mine–Optionality for Closure. In Proceedings of the Eighth Australian Workshop on Acid and Metalliferous Drainage. Adelaide (pp. 1-12).

Craw, D., Pope, J., 2017. Time-series monitoring of water–rock interactions in mine wastes, Macraes gold mine, New Zealand. New Zealand Journal of Geology and Geophysics: Vol. 60 Issue 3: https://www.tandfonline.com/doi/full/10.1080/00288306.2017.1307231#abstract

Drayton, C., 2022. Proposed Approach to Adaptive Management in relation to Effects on Surface Geothermal Features. A report for Contact Energy Limited, dated 6 September 2022.

Fala, O., Aubertin, M., Molson, J., Bussière, B., Wilson, G., Chapuis, R., Martin, V., 2003. Numerical Modelling of Unsaturated Flow in Uniform and Heterogeneous Waste Rock Piles. Proceedings, Sixth International Conference on Acid Rock Drainage.

Golder, 2011d. Macraes Phase III Project Environmental Water Quality Data Summary Report. Report 0978110-562-R012vC, 124 pp. Appendix 15. https://www.orc.govt.nz/consents-and-compliance/current-notified-applications/archived-applications/oceana-gold-new-zealand-limited-application-rm10351

Leckie, J.M.G., 2017. Environmental effects management and assessment- Adaptive management in the mining context. AusIMM New Zealand Branch Annual Conference proceedings, Christchurch, New Zealand, p. 96–104.

Leckie, J.M.G., and Weber, P.A., 2024. Planning for Closure and the Management of Uncertainty – In a Mining Context. New Zealand Annual AusIMM Branch Conference, Wellington, 19 - 21 August, 9 pp.

MGL, 2025a. Water Management Plan. Rev0 dated 23-10-2025.

MGL, 2025b. Engineered Landform Management Plan. Rev2 dated 8-10-2025.

MWM, 2024. BWWRS Geochem Model. Mine Waste Management Report J-NZ0229-M-009-Rev0. Oceana Gold (New Zealand) Limited – Macraes Mine Application No. RM24.184 - Appendix 31 – Annexure 03. https://www.orc.govt.nz/consents-and-compliance/current-notified-applications/oceana-gold-new-zealand-limited-rm24184/

MWM, 2025. Mine Impacted Water Overview Report – Bendigo-Ophir Gold Mine. Mine Waste Management Report: J-NZ0488-001-R-Rev0.

Pope, J., Christenson, H., Gordon, K., Newman, N., Trumm, D., 2018a. Decrease in acid mine drainage release rate from mine pit walls in Brunner Coal Measures. New Zealand Journal of Geology and Geophysics, Vol. 61, No. 2, 195–206.

Pope, J., Weber, P.A., Olds, W.E., 2016. Control of acid mine drainage by managing oxygen ingress into waste rock dumps at bituminous coal mines in New Zealand. Proceedings of IMWA 2016, Mining Meets Water Conflicts and Solutions. Carsten Drebenstedt, Michael Paul (Eds.) Leipzig, Germany, July 11-15, 2016, p 363-371.

Weber, P. 2020. Maintaining a social license to operate through adaptive AMD management. New Zealand Minerals Forum 17-18 November 2020 (online); p 92 -98. https://mineralsforum.vfairs.com/.

Taumata Arowai, 2022. Water Services (Drinking Water Standards for New Zealand) Regulations 2022. Available: https://www.legislation.govt.nz/regulation/public/2022/0168/latest/versions.aspx

Appendix A

Mine Waste Management Report Number: J-NZ0488-0010-M-Rev0

RFI: This appendix provides relevant water treatment experience in New Zealand for mine-impacted waters.

5 Sir William Pickering Drive, Burnside,
Christchurch 8053, New Zealand

T. +64 3 242 0221
E. admin@minewaste.com.au

MEMORANDUM

Recipient:	Matakanui Gold Limited
From:	Paul Weber– Mine Waste Management Limited
Date:	16 April 2026
Cc:	Carlos Hillman – Mine Closure Management Limited
Document Number:	J-NZ0488-010-M-Rev0
Document Title:	Appendix A – FTAA Section 53 Water Treatment Experience

Mine Waste Management Limited (MWM) has prepared this memorandum as part of the response by Matakanui Gold Limited (MGL) to a Request for Information (RFI) made under Section 53 of the Fast-track Approvals Act 2024 (FTAA).

OBJECTIVE

Minerals Council of New Zealand: RFI Comment Number #16

The Minerals Council of New Zealand provides two examples of water treatment options from mining used in NZ:

- OceanaGold's passive water treatment system at its Globe Progress Mine in use following mine closure.
- Discarded mussel shells used for passive treatment of acid and metalliferous drainage at multiple sites.

MGL has requested that further information is provided to support this statement, which is provided in this memorandum.

INTRODUCTION

Water treatment has been widely applied for the management of acid and metalliferous drainage (AMD) across many New Zealand mining operations. Over the past ~20 years, significant work has been undertaken to develop, test, and implement both active and passive treatment systems for the control of metals and metalloids in mine-impacted waters. These systems range from active chemical dosing of AMD impacted waters to passive treatment technologies and treatment trains that combine multiple processes to achieve target water quality outcomes. The following sections summarise key studies and operational examples that demonstrate the breadth of water treatment experience in New Zealand.

Active Treatment

The following section summarises key active water treatment systems of AMD impacted waters in New Zealand. Active systems, including lime (CaO) neutralisation and targeted reagent dosing (e.g. $FeCl_3$ for arsenic removal) have been implemented across New Zealand mining operations (Table 1).

Table 1: Selected active treatment systems in New Zealand

YEAR	LOCATION	SUMMARY	REFERENCES
2009	Golden Cross Mine	Active treatment of Fe and Mn-bearing AMD using lime neutralisation and precipitation processes. Demonstrates application of chemical treatment for metalloid control under NZ conditions.	MacGillivray et al. (2000).
2010	Stockton Mine	Large-scale lime dosing (CaO) systems for neutralisation and metal removal. Proven long-term operation with established sludge management practices.	Elder et al. (2011).
2021	Waihi Gold Mine	Long-term active water treatment systems using lime neutralisation and reagent dosing to manage Fe, Al, Cu, Ni, Zn, and Mn under variable flow and geochemical conditions.	OceanaGold (2021).
2021	Globe Progress Mine	Active treatment incorporating $FeCl_3$ dosing for arsenic removal via co-precipitation, demonstrating targeted metalloid control.	Escueta et al. (2013).

Passive Treatment

The following section summarises key studies and full-scale application of passive treatment systems of AMD impacted waters in New Zealand. Passive systems utilise natural physical, geochemical, and biological processes to treat metals and metalloids in mine-impacted waters. These systems can be applied as treatment trains, combining sequential processes to achieve target water quality outcomes. Examples in New Zealand include systems incorporating vertical flow reactors (VFRs), reactive media beds (such as limestone, mussel shells, or waste steel slag), as well as staged systems combining oxidation, settling, and downstream treatment processes (Trumm et al., 2018). A summary of passive treatment research, and application of these technologies in full-scale systems is provided in Table 2. A summary of some of these trials is also presented in Trumm (2025).

Table 2: Passive treatment research and implementation summary

YEAR	LOCATION	SUMMARY	REFERENCES
2003	Sullivan Mine (Denniston Plateau)	Pilot-scale systems were constructed to treat AMD. These systems consisted of a reducing and alkalinity producing system and an open limestone channel. Both systems were effective in raising pH and removing metals	Trumm et al., 2005
2007	Stockton Coal Mine	Pilot-scale down-flow cells were constructed in 2007 with 300 mm layers of crushed mussel shells under waste rock to treat acidic drainage within a waste rock dump. Results showed that the shell layer effectively increased pH and enhanced metal removal.	Weber et al. (2008)
2007	Stockton Coal Mine	Pilot-scale systems were constructed to treat AMD at Herbert Stream. These systems consisted of a limestone leaching bed, a reducing and alkalinity producing system, and an open limestone channel. All three systems were effective in raising pH and removing metals	Trumm et al. (2007)

YEAR	LOCATION	SUMMARY	REFERENCES
2008	Stockton Coal Mine	Monthly monitoring of AMD sites presented elevated trace metal concentrations and low pH, prompting lab tests of sulfate-reducing bioreactors (SRBs) using alkaline wastes like mussel shells, stack dust, and limestone. SRBs with 20-30% mussel shells showed the best metal removal (over 96% for Fe and >99% for most metals) and generated near-neutral effluent, outperforming limestone-only systems.	McCauley et al. (2008a)
2008	Stockton Coal Mine	AMD from Manchester Street Seep was treated in lab-scale bioreactors using organic and alkaline waste materials, with MSRs[1] outperforming limestone by removing over 98% of metals and neutralising acidity efficiently.	McCauley et al. (2008b)
2009	Stockton Coal Mine	AMD sites showed high concentrations of metals like Fe and Al exceeding environmental guidelines. Mesocosm tests demonstrated that biogeochemical reactors (BGCRs) using mussel shells and organic materials effectively raised pH above 6.7 and removed over 98% of metals, suggesting BGCRs as a cost-effective passive treatment alternative to existing limestone dosing systems.	McCauley et al. (2009a)
2009	Stockton Coal Mine	Six anaerobic bioreactors using organic and alkaline waste materials were tested for AMD treatment, with mussel shells outperforming limestone in removing metals and sulfate. Removal efficiencies depended on bioreactor design and loading rates, achieving up to 99% metal removal and over 94% sulfate removal under optimal conditions.	McCauley et al. (2009b)
2010	Stockton Coal Mine	BGCRs using mussel shells and organic materials were tested as passive treatment for AMD with high metal concentrations and low pH. Lab-scale trials showed these reactors could raise pH above 6.7 and remove over 98% of metal loads, highlighting their potential as a cost-effective alternative to conventional lime-based treatments.	McCauley et al. (2010)
2011	Stockton Coal Mine	To explore more cost-effective alternatives, researchers tested BGCR using mussel shells and organic materials (e.g. pine bark, wood fragments, compost). Mesocosm trials showed BGCRs increased pH to ≥6.7 and removed ≥98.2% of metal loads from AMD. Design criteria for effective treatment were developed, including optimal loading rates and hydraulic residence times. Tracer studies revealed that cylindrical reactor designs performed better than trapezoidal ones, which suffered from short-circuiting. A staged passive system, sedimentation, BGCR, then aerobic wetland is recommended.	McCauley (2011)
2011	Stockton Coal Mine, Manchester Street.	A passive mussel shell reactor (MSR) using waste mussel shells was trailed as a low-cost alternative to traditional limestone dosing AMD treatment. The reactor successfully raised pH from below 3 to above 7 and removed 96-99% of metals, achieving payback in just 480 days and demonstrating long-term operational performance.	Crombie et al. (2011)
2013	Coal Mines New Zealand	Mussel shells have been effectively used in New Zealand as a sustainable and low-cost alternative to limestone in passive bioreactors for treating AMD. Trials show that bioreactors with mussel shells, especially in upward-flow configurations, enhance alkalinity generation, metal removal, and long-term system performance by maintaining reducing conditions and preventing clogging.	Uster et al. (2013)

[1] Mussel shell reactor

YEAR	LOCATION	SUMMARY	REFERENCES
2014	Stockton Coal Mine	A MSR operated at the Stockton Coal Mine for three years successfully treated AMD generated from the highly acidic Brunner Coal Measures (BCMs). The system developed distinct geochemical layers with a redox gradient from oxidizing at the top to strongly reducing at the base. Chemical analysis showed significant removal of metals like Al, Fe, Zn, and trace metals such as Thallium (Tl), primarily through pH-driven co-precipitation and sorption onto carbonate and oxyhydroxide phases, confirming the reactor's long-term AMD neutralisation capability.	DiLoreto (2013)
2014	Stockton Coal Mine	Researchers in New Zealand have successfully used waste green-lipped mussel shells as an alternative to limestone in passive bioreactors for treating AMD, demonstrating superior performance in alkalinity generation and metal removal. Both lab and field trials, including full-scale systems, have shown mussel shells to be an effective, sustainable, and low-cost solution, especially when used alone or in upward-flow reactor designs that promote long-term reducing conditions and minimize permeability loss.	Uster et al. (2014)
2014	Active Coal Mine in New Zealand	This study tested a small-scale up-flow mussel shell reactor, which raised pH to near 8 and achieved high removal rates for Fe, Al, Zn, and Ni (95 - >99%). The up-flow design successfully established reducing conditions, enhancing sulfide formation and metal removal while preventing iron hydroxide buildup, suggesting it is a promising configuration for mussel shell-based AMD treatment.	Trumm et al. (2015)
2015	Stockton Coal Mine	This paper reviews seven years of research on using waste mussel shells in vertical flow successive alkalinity producing systems for passive treatment of AMD in New Zealand, highlighting the shells high ANC and ability to support sulfate-reducing bacteria. Field trials presented metal removal efficiencies of 96–99% for Fe, Al, Ni, and Zn, with system longevity linked to permeability changes caused by sludge layers forming during treatment.	Weber et al. (2015)
2015	Lab-based	This study evaluated four up-flow sulfate reducing bioreactors (SRBR) using waste mussel shells or limestone and organic materials to treat mine-influenced water over 10 months, testing two hydraulic retention times (3 and 10 days). Metal analysis showed effective removal and stable retention of contaminants like Fe, Cu, Zn, and Ni in sulfide or organic-bound forms, with mussel shells supporting long-term passive treatment and influencing metal mobility and distribution within the bioreactor substrates.	Uster et al. (2015a)
2015	Active Coal Mine on the South Island of New Zealand	This study tested an up-flow MSR system designed to treat AMD by promoting reducing conditions throughout the reactor and preventing Fe hydroxide buildup that can clog traditional down-flow systems. Three reactors in series showed distinct microbial communities and metal precipitation patterns, with results linking microbial diversity, especially sulphate-reducing bacteria, to effective removal of iron and trace metals. The up-flow design effectively raised pH from 2.9 to 8, removed 95 - 99% of metals like Fe, Zn, and Ni, and supported strong sulfate-reducing bacterial activity, suggesting it is a promising method for treating AMD, particularly with high iron concentrations.	Trumm et al. (2015)

YEAR	LOCATION	SUMMARY	REFERENCES
2015	Active Coal Mine on the South Island of New Zealand	This study tested SRBRs mussel shells and limestone to treat AMD from a coal mine in New Zealand, finding that all systems improved water quality by raising pH and removing most dissolved metals. Mussel shell-based SRBRs outperformed limestone in alkalinity generation and metal removal, especially with longer hydraulic retention times, demonstrating their effectiveness as a low-cost, sustainable AMD treatment option.	Uster et al. (2015b)
2015	Lab-based	Lab-scale bioreactor trials in New Zealand using waste mussel shells as an alternative to limestone demonstrated superior treatment of mining-influenced water (MIW), with higher alkalinity generation and greater metal removal, especially under longer hydraulic retention times. MSRs consistently raised pH above 6 and removed over 97% of Al and up to 95% of Fe, highlighting their effectiveness and potential as a sustainable passive treatment solution.	Uster (2015c)
2015	Stockton Coal Mine	A full-scale MSR at the Stockton Coal Mine has effectively treated AMD consistently removing ~99% of metals and neutralising acidity since 2012. Detailed autopsies and biogeochemical studies reveal that the system maintains effective vertical flow and uniform treatment through complex redox and microbial processes, supporting its potential for broader global application.	Weisner et al. (2015)
2016	Stockton Coal Mine	A full-scale MSR at the Stockton Coal Mine effectively treated AMD, raising pH from 3.4 to 8.3 and removing ~99% of Al and Fe and >90% of Ni, Tl, and Zn. Located in the Whirlwind catchment, the MSRs performance was investigated through a comprehensive analysis of its chemical, microbial, and physical processes. Results highlighted the system's strong AMD neutralisation and metal removal capabilities, supporting its potential as a globally transferable passive treatment technology.	Diloreto (2016)
2016	Stockton Coal Mine	This study evaluated a full-scale MSR for passive AMD treatment, which effectively increased pH from 3.4 to 8.3 and removed up to 99% of dissolved metals like Al, Fe, Ni, Tl, and Zn. Geochemical and microbial analyses revealed a redox gradient that supported specialised microbial communities driving metal and sulfur cycling, highlighting MSR as a low-cost, effective solution suitable for large-scale use, especially in developing regions.	DiLoreto et al. (2016)
2017	Escarpment Mine	A full-scale MSR was constructed at the Escarpment Mine to passively treat acidity and dissolved metals from mining-affected areas, including waste rock, pit lakes, and highwalls. The bioreactor significantly improved water quality, increasing pH from ~3.5 to ~7.9 and reducing metal concentrations by two orders of magnitude, demonstrating its effectiveness as a low-cost, low-maintenance treatment solution.	Roberston et al. (2017)
2017	Lab-based	Adding nutrients to SRBR significantly enhanced the activity of sulfate-reducing bacteria, resulting in over a 15-fold increase in sulfate removal from MIW. This finding demonstrates that nutrient supplementation can greatly improve the effectiveness and reliability of passive SRB-based treatment systems.	Christenson et al. (2017)

YEAR	LOCATION	SUMMARY	REFERENCES
2017	Stockton Coal Mine	This study examined microbial activity and sulfate-reducing conditions within a mussel shell-based passive bioreactor at Stockton Coal Mine. Findings showed favourable physicochemical and biological conditions for metal sulfide precipitation, with mussel shells supporting key microbial communities like Desulfotomaculum and Pseudomonas that enhance Zn immobilisation and ARD treatment effectiveness.	Falk et al. (2017)
2018	Bellvue Mine	This research tested the effectiveness of a mussel shell-based diversion well for treating AMD at the Bellvue Mine, comparing it to a traditional limestone-based system. Results showed that while mussel shells provided some treatment, limestone was more effective at increasing pH and reducing dissolved metal concentrations.	Forbes et al. (2018b)
2018	Waihi Gold Mine	Passive treatment trials combining VFRs with slag and limestone leaching beds demonstrated effective staged treatment. VFRs removed up to 98% of Fe prior to downstream treatment, while slag leaching beds achieved >97% Mn removal and significantly increased pH, confirming the effectiveness of treatment trains.	Trumm et al. (2017, 2018)
2019	Stockton Coal Mine	A MSR used for AMD remediation at a Stockton Coal Mine produced sludge whose storage and reuse risks were studied under oxic and anoxic conditions. Results showed that anoxic burial reduces metal mobility and risks by promoting sulfide mineral formation, while oxic conditions increase metal mobility but may allow sludge reuse as an oxygen barrier or soil amendment, with microbial activity influencing these outcomes.	Butler et al. (2019)
2021	Bellvue Coal Mine	This study presents the first full-scale up-flow mussel shell reactor for acid mine drainage treatment, which increased pH from 2.74 to 6.94 and removed over 97% of Fe, Al, Zn, and Ni. The upflow design maintained reducing conditions that promoted sulfide formation over hydroxides, enhancing treatment efficiency and avoiding permeability issues common in downflow systems.	Trumm et al. (2021)
2022	Echo Coal Mine	This study reports on the first full-scale up-flow MSR used at an active mine to treat AMD, which successfully increased pH from 3.3 to 7.2 and removed over 83% of key metals. The up-flow design maintained reducing conditions throughout the reactor, promoting sulfate reduction and sulfide formation while avoiding permeability issues common in downflow systems.	Trumm et al. (2022)
2024	Echo Coal Mine	This study discusses the ongoing performance of the Echo Mine upflow MSR and the effects of hydraulic residence time on treatment performance.	Trumm et al. (2024)
2025	Globe Progress Gold Mine	This paper presents the design and performance of the world-first full-scale installation of a vertical flow reactor (VFR). This system effectively oxidises water containing Fe and As and precipitates and captures Fe hydroxides with adsorbed As. This demonstrates that the VFR technology is an effective treatment system.	Trumm et al. (2025)

SUMMARY

Active and passive treatment of mine impacted waters is well understood in New Zealand with many examples of such work.

There are no foreseeable technical challenges to treating mine impacted waters at the Bendigo-Ophir Gold Project (BOGP) using active treatment technologies and later a transition to passive water treatment. However, further studies are required once suitable site-specific waters are available to confirm capacity and the treatment stages/processes.

CLOSING REMARKS

Please do not hesitate to contact Paul Weber at + 64 3 242 0221 or paul.weber@minewaste.com.au should you wish to discuss in greater detail.

REFERENCES

Butler, S. C., Pope, J., Chaganti, S. R., Heath, D. D., & Weisener, C. G., 2019. Biogeochemical characterization of metal behaviour from novel mussel shell bioreactor sludge Residues. Geosciences, 9(1), 50.

Christenson, H., Weber, P., Pope, J., Newman, N., Olds, W., Trumm, D., 2017. Enhancing Mine Drainage Treatment by Sulfate Reducing Bacteria Using Nutrient Additives. IMWA 2017.

Crombie, F., Weber, P., Lindsay, P., Thomas, D., Rutter, G., Shi, P., Rossiter, P., Pizey, M., 2011. Passive Treatment of Acid Mine Drainage Using Waste Mussel Shell, Stockton Coal Mine, New Zealand.

DiLoreto, Z., 2013. Characterisation of a Mussel Shell Bio-Reactor for Treatment of Mine Waste: Stockton Coal Mine New Zealand. Bachelor of Science Honours Thesis, University of Windsor.

DiLoreto, Z., 2016. Biogeochemical Investigations of a Full-Scale Mussel Shell Bioreactor for the Treatment of Acid Mine Drainage (AMD), the Stockton Mine, New Zealand. Master’s Thesis. University of Canterbury

DiLoreto, Z., Weber, P., Olds, W., Pope, J., Trumm, D., Chaganti, S., Heath, D. & Weisener, C., 2016. Novel Cost Effective Full Scale Mussel Shell Bioreactors for Metal Removal and Acid Neutralization. Journal of Environmental Management, 183, 3, 601- 612.

Elder, D.M., Pizey, M.H., Weber, P.A., Lindsay, P., Rossiter, P.J., Rutter, G.A., Thomas, D.G., Crombie, F.M., Cooper, T., Wildy, J.J., 2011. Addressing the environmental effects of mining on the Ngakawau River. New Zealand Water Conference, Rotorua 9-10th November 2011.

Escueta, J.G., McIntosh, C.L., Johns, J.J., Systermans, B.J., 2013. Geological source and behaviour of antimony under alkaline process condition at OceanaGold Reefton sulphide concentrating plant. AusIMM New Zealand Branch Annual Conference 2013, pp 131 – 141.

Falk, N., Weisener, C., Chaganti, S., 2017. Evaluating The Microbial Community and Gene Regulation Involved in Crystallisation Kinetics of Zn Formation in Reduced Environments.

Forbes, E., Trumm, D., Bell, D. & Pope, J., 2018. Comparison of Diversion Well Substrates for the Treatment of Acid Mine Drainage, Bellvue Mine, West Coast, New Zealand. AusIMM New Zealand Branch Annual Conference: Christchurch.

MacGillivray, Randy & Maton, T & Goldstone, A., 2000. Key mechanisms for successful reclamation-Golden Cross Mine, Coromandel, New Zealand-September 2000.

McCauley, C.A., O’Sullivan, A.D., Weber, P.A. & Trumm, D.A., 2008a. Performance of mesocosm-scale sulfate reducing bioreactors for treating acid mine drainage in New Zealand. Proceedings, Meeting of the American Society of Mining and Reclamation, 14-19 June 2008, Richmond, VA, USA. Pp. 662-698

McCauley, C., O'Sullivan, A.D., Weber, P. & Trumm, D., 2008b. Development of Passive Treatment Systems for Treating Acid Mine Drainage at Stockton Mine. Auckland, New Zealand: New

Zealand Minerals Conference, Australian Institute of Mining and Metallurgy, 29 Aug-4th Sept 2008. 329-338.

McCauley, C., O'Sullivan, A.D., Weber, P. & Trumm, D., 2009a. Stockton Mine Acid Mine Drainage and Its Treatment using Waste Substrates in Biogeochemical Reactors Biogeochemical Reactors. New Zealand Journal of Geology and Geophysics.

McCauley, C.A., O'Sullivan, A.D., Milke, M.W., Weber, P.A. & Trumm, D.A., 2009b. Sulfate and metal removal in bioreactors treating acid mine drainage dominated with iron and aluminium.

McCauley, C., O'Sullivan, A., Weber, P., & Trumm, D., 2010. Variability of Stockton Coal Mine drainage chemistry and its treatment potential with biogeochemical reactors. New Zealand Journal of Geology and Geophysics, 53(2–3), 211–226.

McCauley, C., 2011. Assessment Of Passive Treatment and Biochemical Reactors for Ameliorating Acid Mine Drainage at Stockton Coal Mine. PhD Thesis. University of Canterbury.

OceanaGold, 2021. Waihi Operation – Environmental Management and Water Management. Document available: https://www.waihigold.co.nz/environment/environmental-management/water/.

Roberston, C., Weber, P. & Olds, W., 2017. AMD Passive Treatment System: A Case Study – Escarpment Mine, Denniston Plateau. AusIMM New Zealand Branch Annual Conference: Christchurch, pp. 143-152.

Trumm, D., Black A., Gordon, K, Cavanagh, J., O'Lalloran K., deJoux, A. 2005. Acid mine drainage assessment and remediation at an abandoned West Coast coal mine. IN: Moore, T., Black A., Centeno J., Hjarding J., Trumm D. Metal Contaminants in New Zealand. Resolutionz Press, New Zealand.

Trumm, D., Watts, M., Pope, J., Lindsay, P 2007. Using pilot trials to test geochemical treatment of acid mine drainage on Stockton Plateau. New Zealand Journal of Geology & Geophysics, 51:3 Pp 175-186.

Trumm, D., Ball, J., Pope, J. & Weisener, C., 2015. Passive treatment of ARD using mussel shells - Part III: Technology improvement and future direction. In: Proceedings, 10th International Conference on Acid Rock Drainage & IMWA Annual Conference. 10 pp.

Trumm, D., Christenson, H., Pope, J., Watson, K., Mason, K., Squire, R., & Mazzetti, A., 2017. Passive treatment of Fe and Mn using vertical flow reactors, limestone leaching beds, and slag leaching beds, Waihi Gold Mine. In AusIMM New Zealand Branch Annual Conference: Christchurch (pp. 334-343).

Trumm, D., Christenson, H., Pope, J., Watson, K., Mason, K., Squire, R., McDonald, G., Mazzetti, A., 2018. Treatment of High Mn Concentrations at Waihi Gold Mine, New Zealand by Two Methods: A Limestone Leaching Bed and a Slag Leaching Bed. ICARD/IMWA Conference.

Trumm, D., Pope, J., Christenson, H., 2021: Passive Treatment of AMD Using a Full-Scale Up-Flow Mussel Shell Reactor, Bellvue Coal Mine, New Zealand. – In: Stanley, P.; Wolkersdorfer, Ch.; Wolkersdorfer, K.: Mine Water Management for Future Generations. – p. 577 – 583; Cardiff, Wales, United Kingdom (Natural Resources Wales, The Coal Authority, Welsh Government, Cardiff University).

Trumm, D., Moynihan, E., Young, J., Pope, J., 2022: Passive Treatment of AMD Using a Full-Scale Upflow Mussel Shell Reactor, Echo Coal Mine, New Zealand. – In: Pope, J.; Wolkersdorfer, C.; Rait, R.; Trumm, D.; Christenson, H.; Wolkersdorfer, K.: IMWA 2022 – Reconnect. – p. 511 – 516; Christchurch, New Zealand (International Mine Water Association).

Trumm, D., Williams, M., Cables, R., and Nyenhuis, J., 2025. Early results of a full-scale passive treatment vertical flow reactor for As and Fe treatment, Globe Progress Mine, New Zealand. AusIMM New Zealand Branch Conference.

Uster, B., O’Sullivan, A.D., Pope, J. and Trumm, D., 2013, August. Treating acid mine drainage using waste mussel shells in sulfate-reducing bioreactors operating at different hydraulic retention times. In Proceedings of Australasian Institute of Mining and Metallurgy New Zealand Branch Annual Conference, Nelson, New Zealand (pp. 24-30).

Uster, B., Trumm, D., Pope, J., Weber, P., O’Sullivan, A, D., Weisener, C., Ciloreto Z, A., 2014. Waste Mussel Shells to Treat Acid Mine Drainage: A New Zealand Initiative.

Uster, B., Milke, M., O'Sullivan, A., Pope, J., Trumm, D. & Webster-Brown, J., 2015a. Heavy metal removal and partitioning in sulfate-reducing bioreactors treating mine influenced water. In: Proceedings, 10th International Conference on Acid Rock Drainage & IMWA Annual Conference. 1 Pg Abstract.

Uster, B., O’Sullivan, A., Young Ko, S., Evans, A., Pope, J., Trumm, D. & Caruso, B., 2015b. The Use of Mussel Shells in Upward-Flow Sulfate-Reducing Bioreactors Treating Acid Mine Drainage, Mine Water Research in New Zealand, Vol 34, Issue 4, Page 442-454. ISSN: 1025-9112 (Print) 1616-1068 (Online).

Uster, B., 2015c. The Use of Waste Mussel Shell in Sulfate Reducing Bioreactors Treating Mine Influenced Waters. PhD Thesis. University of Canterbury

Weber, P.A., Lindsay, P., Hughes, J.B., Thomas, D.G., Rutter, G.A., Weisener, C.G., Pizey, M.H., 2008. ARD minimisation and treatment strategies at Stockton Coal Mine, New Zealand. In "Proceedings of the Sixth Australian Workshop on Acid and Metalliferous Drainage", Burnie, Tasmania. 15-18 April 2008. (Eds LC Bell, BMD Barrie, B Baddock, and RW MacLean) pp. 113 - 138 (ACMER: Brisbane).

Weber, P., Weisener, C., DiLoreto, Z. & Pizey, M., 2015. Passive treatment of ARD using mussel shells – Part I: System development and geochemical processes. In: Proceedings, 10th International Conference on Acid Rock Drainage & IMWA Annual Conference. 8 pp.

Weisener, C., Diloreto, Z., Trumm, D., Pope, J. and Weber, P., 2015. ARD passive treatment using waste mussel shells-Part II: System autopsy and biogeochemical investigations. In 10th International Conference on Acid Rock Drainage.

Appendix B

This appendix provides relevant papers on adaptive management including:

1. Leckie, 2017.
2. Weber, 2020.
3. Drayton, 2022.
4. Leckie and Weber, 2024.

Environmental Effects Management and Assessment – Adaptive Management in the Mining Context

J.M.G. Leckie [1]

[1] Partner, Lane Neave, PO Box 701, Queenstown 9348, joshua.leckie@laneneave.co.nz

Abstract

The use of an adaptive management approach to avoid, remedy and mitigate environmental effects in large scale mining projects is becoming increasingly common.

This is generally achieved through the use of multiple management plans conditioned at the time of resource consenting. Commonly relied on management plans for mining operations relate to construction and earthworks, rehabilitation, noise, and biodiversity. Done well, the approach provides an effective way to manage complex environmental effects that require thorough and considered environmental management.

However, the use of management plans does not mean that resource consent applicants and local authorities can defer all assessment and decision making until following the grant of consents. Although by its very nature adaptive management as an approach involves leaving some environmental management assessment and control for a subsequent process, the Courts have developed relatively rigorous criteria at the time of consenting to ensure the management plan approach works effectively.

The paper will examine these key requirements for management plans and expand on how they have been applied by decision-makers under environmental legislation and in particular in the mining context. This paper will also assess situations where adaptive management has not been considered an appropriate way to avoid, remedy or mitigate environmental effects and how these situations can be avoided (where they can be avoided).

Keywords:

***Resource Management Act 1991; Mining; Effects Management; Adaptive Management; Management Plans; King Salmon*.**

Environment Effects Management Overview

The Resource Management Act 1991

The Resource Management Act 1991 (**RMA**) is the principal legislation that governs how mining activities and their effects are managed within New Zealand. Unlike most legislation, the RMA is forward looking and ensures the country plans for future generations by protecting the physical environment now.

The key focus of the RMA is to appropriately manage the effects of activities whilst providing for the 'sustainable management' of New Zealand's natural resources.

Under the RMA 'sustainable management' means *(Resource Management Act 1991, s2):*

> *"the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economical and cultural well-being and for their health and safety while:*

a. *sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and*
b. *safeguarding the life-supporting capacity of air, water, soil and ecosystems; and*
c. *avoiding, remedying and mitigating any adverse effects of activities on the environment."*

Local authorities are tasked with ensuring 'sustainable management' under the RMA. In New Zealand there are 11 regional councils, 66 district and city councils, and 6 unitary authorities that perform this role *(http://www.localcouncils.govt.nz).*

The RMA requires councils to prepare regional and district plans which provide, where it is appropriate, for activities to be established on the basis of the effects they generate.

Regional plans manage effects on water, air, soil and the coast. District and city plans manage the use of land of an activity itself, such as mining or residential housing.

As such the RMA does not explicitly provide or prevent mining; this is dealt with by individual councils in their plans following consideration of the resources available and the adverse effects associated with the mining activity.

As an example, the Waikato District Plan provides for mining in certain zones as a permitted activity *(Waikato District Plan, Waikato Section – Rural Zone).* This means a resource consent does not need to be sought so long as the mining activity complies with all the relevant permitted activity standards. However, other resource consents such as water permits and air discharges are still required from the Waikato Regional Council to enable the mining activity to operate.

The RMA does not prescribe how activities should avoid, remedy or mitigate adverse effects which provides scope for new and innovative environmental practices to be developed to achieve the RMA's overall purpose of 'sustainable management'.

Assessments of Environmental Effects

When making any application for a resource consent there is a requirement to provide an assessment of environmental effects (**AEE**) as part of the resource consent application. Schedule 4 of the RMA details the information required to be provided in an AEE. This includes among other matters *(Resource management Act, Schedule 4, clause 6):*

(a) an assessment of the actual or potential effect on the environment of the activity;
(b) if it is likely that the activity will result in any significant adverse effect on the environment, a description of any possible alternative locations or methods for undertaking the activity;
(c) a description of the mitigation measures to be undertaken to help prevent or reduce the actual or potential effect; and
(d) identification of the persons affected by the activity, any consultation undertaken, and any response to the views of any person consulted.

An assessment of the activity's effects must address the following matters in line with the RMA's wide definition of the term effect *(Resource Management Act, Schedule 4, clause 7):*

(a) any effect on those in the neighbourhood and, where relevant, the wider community, including any social, economic, or cultural effects;
(b) any physical effect on the locality, including any landscape and visual effects;
(c) any effect on ecosystems;
(d) any effect on natural and physical resources having aesthetic, recreational, scientific, historical, spiritual, or cultural value, or other special value, for present or future generations;
(e) any discharge of contaminants into the environment; and
(f) any risk to the neighbourhood, the wider community, or the environment through natural hazards or hazardous installations.

The detail and comprehensiveness of an AEE depends on the scale of the effects of the proposed activity. As mining applications often have wide ranging effects, a high quality and comprehensive AEE is crucial and is a contributing factor as to whether a resource consent is granted or not.

Controls of Environmental Effects

The environmental effects of an activity can be controlled by conditions which are imposed as part of a decision to grant a resource consents. Generally, all resource consents contain conditions and for large scale mining projects these conditions can be extensive.

It is the consent holder's obligation to comply with the conditions of a resource consent and failure to comply would result in a breach of the consent and may result in enforcement action by the consent authority.

Therefore it is important that the conditions imposed are drafted in such a way they are clear as to what the requirements are and are workable for the consent holder.

Section 108 of the RMA authorises the imposition of conditions by consent authorities. Currently, the discretion of the consent authority to impose conditions is quite widely expressed as "any condition that the consent authority considers appropriate". However, the power to impose conditions is not unlimited and to be valid at law a condition must (*Newbury DC v Secretary of State for the Environment*; *Newbury DC v International Synthetic Rubber Co Ltd* [1981] AC 578; [1980] 1 All ER 731 (HL)):

(a) Be for a resource management purpose, not for an ulterior one;
(b) Fairly and reasonably relate to the development authorised by the consent to which the condition is attached; and
(c) Not be so unreasonable that a reasonable consenting authority, duly appreciating its statutory duties, could not have approved it.

Recently the power to impose conditions has been further constrained and clarified. As part of the recent amendments to the RMA, section 108AA has been included (coming into force on 18 October 2017). Under this new provision a consent condition cannot be included unless:

(a) the applicant for the resource consent agrees to the condition; or

(b) the condition is directly connected to an adverse effect of the activity on the environment and/or an applicable district or regional rule, or a national environmental standard; or
(c) the condition relates to administrative matters that are essential for the efficient implementation of the relevant resource consent.

This amendment provides further certainty as to the types of conditions that can be imposed.

For mining resource consents, conditions often relate to matters such as the provision of monetary bonds to cover the costs of monitoring and rehabilitation, complaints and non-compliance, noise limits, lighting restrictions, community liaison, and environmental monitoring and reporting requirements.

A common condition in mining resource consents are those that relate to the development and implementation of an adaptive management approach using various management plans. Common management plans relate to construction and earthworks, dust, hazardous substances, erosion, biodiversity and rehabilitation. The remainder of this paper assesses this approach.

Adaptive Management

Adaptive management through the use of management plans is the use of a mechanism from the RMA toolbox which strikes a balance between a decision-maker being satisfied that effects of a development can be appropriately avoided, remedied or mitigated while at the same time giving consent holders flexibility to determine at a later date how they do that. The key advantage of adaptive management is that a resource consent can be granted which gives a mining company investor certainty without all the environmental effects of what they are proposing being precisely known or mitigated in detail at the time of the consent being granted.

Adaptive management as a concept has evolved over the past two decades and has become increasingly accepted as an effects management mechanism in large developments in New Zealand. The Environment Court has described management plans as now having a "central place" in large developments (*Golden Bay Marine Farmers v Tasman District Council* EnvC Wellington W19/2003, 27 March 2003 at [411]). Adaptive management provides for ongoing assessment, design and adjustment to ensure that the environmental effects of a development are best managed. Where it differs from more traditional prescriptive conditions of consent is that it is a live evolving approach that can adapt over time. This can have benefits and pitfalls.

To strike the balance required for adaptive management to be an effective mechanism for both consent holders and local authorities, the New Zealand Courts and Boards of Inquiry have developed judicial authority specifying criteria that needs to be contained within conditions of consent that utilise an adaptive management approach. These criteria are set out below and their use in the mining context is examined.

Commonly relied on management plans for mining operations relate to construction and earthworks, rehabilitation, waste management, noise, and biodiversity. In a relatively recently granted suite of resource consents for a coal mine, the Environment Court included seven management plans within the conditions of consent.

Adaptive management over time

The Court's approach to adaptive management has changed over time. In 1994 the Planning Tribunal considered that it was not appropriate for the Council to reserve power to approve a noise management plan to a later date (*Bird v South Canterbury Car Club* PT Christchurch C027/94, 11 March 1994).

In the same year in *Affco New Zealand Ltd v Far North District Council* [1994] NZRMA 221 (PT), the Planning Tribunal considered that it was vital that they saw the content of management plans to be able to make a decision on the resource consent application.

However that thinking evolved, and in an interim decision in *Ravensdown Growing Media Ltd v Southland Regional Council* EnvC Christchurch C194/2000, 5 December 2000 the Court held that the specifics of a management plan do not need to be included in conditions as it is appropriate to give flexibility to explore ongoing improvements and alternative methods if any became available.

Case law has now established that, in allowing this flexibility, the key overarching requirement is that management plans must operate in a way that will serve the purpose of the RMA (*Crest Energy Kaipara Ltd v Northland Regional Council* EnvC Auckland A132/09, 22 December 2009 at [229] (*Crest Energy Kaipara Ltd*).

To assist in deciding whether a management plan will meet this purpose, the Environment Court and Boards of Inquiry have sought to establish parameters within which the management plan approach must operate. In particular, the decision-makers have stated that the conditions which provide for the use of management plans must include clear, reasonably certain and enforceable objectives (*Crest Energy Kaipara Ltd* at [227]; *Groome v West Coast Regional Council* [2010] NZEnvC 399 at [14]) and that conditions should contain quantifiable standards and performance criteria against which management plans can be assessed (*Final Report and Decision of the Board of Inquiry into the Transmission Gully Proposal* Board of Inquiry, EPA 0175, June 2012 at [187] (the *Transmission Gully* decision)).

Legal criteria – not "suck it and see"

The use of an adaptive management approach is therefore not unfettered, and consideration by decision-makers is needed in order to clearly establish that an adaptive management approach will operate in a way that serves the purpose of the RMA. An adaptive management approach must provide for a minimum criteria of information and specific requirements for it to be considered appropriate by a decision-maker. It is not a "suck it and see" approach (the writer borrows the phrase from the Supreme Court)is decision in (*Sustain our Sounds Inc v New Zealand King Salmon Ltd* [2014] NZSC 40 (*King Salmon*)).

The RMA does not prescribe what an adaptive management approach must contain. This has been set out by various Courts and decision-makers over the past few decades. Relatively recently New Zealand's highest Court, the Supreme Court has also considered the legal criteria for adaptive management through the use of management plans.

The Supreme Court considered that as a first question there must be an adequate evidential foundation to have reasonable assurance that the adaptive management approach will achieve its goals of reducing uncertainty and adequately managing any remaining risk (*King Salmon* at [125]).

Secondly, whether adaptive management is appropriate will depend on an assessment of factors including (*King Salmon* at [129]):

(a) the extent of the environmental risk (including the gravity of the consequences if the risk is realised;
(b) the importance of the activity (which could in some circumstances be an activity it is hoped will protect the environment);
(c) the degree of uncertainty; and
(d) the extent to which an adaptive management approach will sufficiently diminish the risk and the uncertainty.

Overall, the Supreme Court considered that the ultimate question in that case (a marine environment) was whether any adaptive management regime could be considered consistent with a precautionary approach (*King Salmon* at [124]). They considered that the vital part of the adaptive management test was the ability for a adaptive management regime to deal with risk and uncertainty (*King Salmon* at [133]). In applying that test the Supreme Court considered the following factors:

(a) there would be good baseline information about the receiving environment;
(b) the conditions provide for effective monitoring of adverse effects using appropriate indicators;
(c) thresholds are set to trigger remedial action before the effects become overly damaging; and
(d) effects that might arise can be remedied before they become irreversible.

In relation to bullet point one above, a management plan should provide for the collection of baseline knowledge to establish the existing state of the environment upon which management plans can build in an ongoing and cyclical process (*Crest Energy Kaipara Ltd* 2009 at [228]; *Transmission Gully* decision at [186]).

The management plan can then set out a design for management, monitoring, evaluation of monitoring results and reviewing and refining of hypotheses (*Crest Energy Kaipara Ltd* at [226]).

In relation to bullet point two above, the proposed conditions need to clearly set out the mechanisms for review and update of management plans, usually as monitoring feedback becomes available (*Transmission Gully* decision at [184]-[185]). The updating of these plans is relatively straight forward, the real challenges arise around the review and approval processes. Review is important as by allowing management plans to control environmental effects, decision-makers risk delegating their decision-making powers. This is acceptable for the certification of details, however decision-makers should not delegate the making of substantive decisions (*Royal Forest and Bird Protection Society v Gisborne District Council* [2010] NZEnvC 128).

Land based mining - adaptive management working well

The use of management plans is driven by mining companies not always being in a position of knowing all mitigation and effects management methods for their mining proposal prior to making an application. The Environment Court has stated that it would be unfair and unreasonable to expect an applicant to anticipate and research all hypotheses that may occur during the course of the application process (*Crest Energy Kaipara Ltd* at [228]). Adaptive management through management plans recognise this and provide an appropriate regime within which applicants can manage the effects of their applications.

What the case law identifies is that adaptive management, often through the use of management plans, is an effective way to manage environmental effects from mining activities where those activities are in stable environments with well established environmental characteristics such as rainfall and soil typography.

Management plans also have the advantage of enabling greater flexibility for an evolving mining operation in complying with consent conditions. This allows for a miner to make adjustments when, for example, improved technologies become available or further information is obtained which assists in reducing effects (*Wood v West Coast Regional Council* [2000] NZRMA 193 (EnvC)). The ability to make these changes within the management plan regime relieves the applicant of the need to follow the formal process to vary consent conditions.

This is particularly beneficial in land based mining contexts where the environmental effects of an activity (for example progressive rehabilitation of a mine site) can progress in an adaptive manner without irreversible negative impacts occurring. In relation to progressive rehabilitation, an example is a management plan providing for translocation rehabilitation to occur in a particular manner, ongoing monitoring then establishing that the strike rates of that rehabilitation is low, and the management plan process providing for a different rehabilitation approach on the same land.

Adaptive management not considered appropriate by decision-makers

The use of management plans is not however without criticism.

One concern is that those affected by a proposal do not have the opportunity to submit on management plan provisions in the way that they would have input into conditions through the hearing and appeal process. This can have the perceived effect of locking out of the process those who are potentially affected. Another concern is that delegating the management of effects to management plans is to delegate the function of RMA decision-makers.

These negative outcomes can be managed through the Court imposed criteria that require clear established parameters for the use of management plans. This approach is tested through the resource consenting process which means the general public and those potentially affected by a mining proposal can be part of the effects management process.

Another situation where adaptive management has not been considered an effective way to management the effects of mining relates to some offshore mining proposals. Offshore mining between 12 and 200 nautical miles is controlled by the Exclusive Economic Zone and

Continental Shelf (Environmental Effects) Act 2012 (**EEZ Act**). Unlike the RMA, the EEZ Act expressly provides for adaptive management. The EEZ Act directs that if favouring caution and environmental protection means that consent is likely to be refused, then the option of adaptive management must first be contemplated *(Section 61(3))*. The EEZ Act defines adaptive management and although it includes a management plan type approach which has been the focus of this paper, it also includes allowing an activity to commence on a small scale or for a short period so that effects can be monitored *(Section 64)*.

The Decision-making Committee in the *Decision on Marine Consent Application by Chatham Rock Phosphate Limited*, EPA EEZ000006, February 2015 at [835] (the *Chatham Rock* decision) which proposed to mine phosphorite modules half way between Banks Peninsular and the Chatham Islands, concluded that although the situation before the Supreme Court in the *King Salmon* decision referred to earlier was arguably dissimilar, the factors the Supreme Court identified are appropriate and helpful to an EEZ Act Inquiry.

However, in that decision the Committee was mindful of the fact that the mining activity proposed was in the open ocean, at depth and an environment which there existed uncertainty of knowledge and consequence (Chatham Rock at [843]). They ultimately concluded that an adaptive management approach would not resolve the primary question of the adverse effect on the benthic environment without considerable pre-mining research and model validation in situ.

In a different EEZ decision (*Trans-Tasman Resources Limited Marine Consent Decision*, EPA, June 2014 (*the Trans-Tasman Resources decisions*)) the decision-makers also considered the uncertainty of effects as a concern of an offshore iron ore extraction proposal in the South Taranaki Bright. Several parties, including the applicant Trans-Tasman Resources agreed that there was uncertainty associated with the information provided in relation to the project however Trans-Tasman Resources did not consider that this was material to the extent it called into question whether or not consent should be granted (*Trans-Tasman Resources* at [676]).

In making their overall findings on adaptive management in that case the decision-maker was required to consider the use of adaptive management given uncertainties in relation to that information uncertainty. The applicant proposed environmental performance objectives as the "cornerstone pillars" of the adaptive management approach (*Trans-Tasman Resources* at [816]). The decision making committee did not support this approach and considered that the objectives lack sufficient certainty, clarity and robustness.

In both these offshore mining decisions the use of adaptive management was not successful due in part to uncertainty over the existing environment and management of the effects of the mining in the offshore mining environment.

Conclusion

Overall, adaptive management provides an important and effective mechanism for enabling and appropriately managing the effects of large scale land based mining developments in New Zealand.

Various decision-makers, up to the Supreme Court have established a set of requirements for conditions of resource consent allowing for this adaptive management, generally through the use of management plans. These include having good baseline information, setting clear, reasonable and certain objectives, quantifiable standards, performance criteria, and review mechanisms.

Given their inherent operational flexibility, mining companies and their legal and consultant teams are likely to continue to seek the use of management plans in resource consent applications. As that happens, further consideration by decision-makers would be expected in upcoming years to ensure that the environmental effects of mining are appropriately considered and controlled at the time of resource consenting. Even if the precise methods of doing that are not known at the time a resource consent is granted it is likely that decision-makers will continue to require high levels of certainty in relation to those baseline and future effects.

Acknowledgements

Joshua Leckie wishes to acknowledge the assistance of colleagues Samantha Buckley and Sophie Reese (both Senior Solicitors at Lane Neave) for their assistance in the preparation of this paper.

References

Affco New Zealand Ltd v Far North District Council [1994] NZRMA 221 (PT)
Bird v South Canterbury Car Club PT Christchurch C027/94, 11 March 1994
Crest Energy Kaipara Ltd v Northland Regional Council EnvC Auckland A132/09, 22 December 2009
Decision on Marine Consent Application by Chatham Rock Phosphate Limited, EPA EEZ000006, February 2015
Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012, s61(3) and s64
Final Report and Decision of the Board of Inquiry into the Transmission Gully Proposal Board of Inquiry, EPA 0175, June 2012
Golden Bay Marine Farmers v Tasman District Council EnvC Wellington W19/2003, 27 March 2003
Groome v West Coast Regional Council [2010] NZEnvC 399
http://www.localcouncils.govt.nz
Newbury DC v Secretary of State for the Environment; *Newbury DC v International Synthetic*
Ravensdown Growing Media Ltd v Southland Regional Council EnvC Christchurch C194/2000, 5 December 2000
Resource Management Act 1991, s2, s108, Schedule 4 cl6, cl6 and cl7
Rubber Co Ltd [1981] AC 578; [1980] 1 All ER 731 (HL)
Sustain our Sounds Inc v New Zealand King Salmon Ltd [2014] NZSC 40
Trans-Tasman Resources Limited Marine Consent Decision, EPA, June 2014
Waikato District Plan, Waikato Section – Rural Zone

Maintaining a social licence to operate through adaptive AMD management

Paul A. Weber[1]

[1]*Mine Waste Management, Unit 7/41 Pickering Drive, Burnside, Christchurch, New Zealand. paul.weber@minewaste.com.au*

Keywords
AMD,
SLTO,
adaptive
management

ABSTRACT

Acid and metalliferous drainage (AMD) is a common issue across the global mining industry. The worldwide cost for the remediation of current and future AMD has been estimated at one hundred billion dollars (Lottermoser, 2015). This liability does not present an image of sustainability and negatively affects the mining industry's social licence to operate (SLTO).

Sustainability of mining is further brought into question by the fact that many mine owners have adopted treatment in perpetuity as the solution to manage AMD without addressing source control. This approach introduces many additional issues, including current and future risks.

Many mining operations in New Zealand employ recognised world class approaches for the management of AMD. These operations achieve this success through adaptive management processes to manage uncertainty associated with AMD, which is both a current and future risk.

One important risk is future stakeholders (inter-generational risk) and their acceptance of AMD treatment and the standards (water quality and contaminant load) driving any treatment process. It is likely that future generations will expect an ever-increasing, sustainable approach to mining, the management of AMD, and more stringent water quality standards. Again, although this can be anticipated, in some instances the future costs have not been captured during optioneering studies. This can result in increased mine closure liabilities with time.

One approach to minimise these future risks is to focus on source control of AMD rather than the treatment of AMD. From a SLTO perspective, in the future it is likely that owners of mines that could generate AMD will need to demonstrate that they have taken all practicable efforts to reduce the quantity of AMD (i.e. source control) and that they also have contingency plans in place for event risks and uncertainty. Uncertainty can be addressed through adaptive management processes, which provides internal and external stakeholders confidence that the future risks associated with AMD can be managed. Furthermore, adaptive management is a recognised approach from the resource management act toolbox, however it requires clear environmental objectives against which management options can be measured.

The process of adaptive management is often incorporated into management plans and supporting procedures to manage uncertainty. Contemporary mine operators now utilise trigger action response plans (TARPS) to manage this uncertainty. TARPS should be developed from risk assessment workshops that are based on data and scientific analysis. This paper discusses these concepts and provides examples of the operational implementation of adaptive management.

INTRODUCTION

Acid and metalliferous drainage (AMD) is a common issue across the global mining industry. Internationally, there are many examples of legacy sites where AMD risks have not been understood or managed correctly, resulting in on-going and significantly adverse impacts to the environment. The current worldwide cost for the remediation of current and future AMD has been estimated at one hundred billion dollars (Lottermoser, 2015). This liability does not present an image of sustainability and negatively affects the mining industry's social licence to operate (SLTO).

Sustainability of mining is further brought into question by the fact that many mine owners have adopted treatment in perpetuity as the solution to manage AMD without addressing source control. For instance, nearly half the mining companies surveyed by the Mine Environmental Neutral Drainage (MEND) programme (Zinck & Griffith, 2013), plan to treat AMD impacted waters in perpetuity. Treatment in perpetuity introduces additional risks, which can lead to future legacy issues, where funds may or may not be available to address these issues should they arise.

This paper looks at two key aspects of AMD management:

- AMD risk management; and
- adaptive management of AMD risks

Identification of AMD risks (for the operational and closure phases of a mine) and developing adaptive management processes to more adequately address these risks can support SLTO. Such an approach provides internal and external stakeholders with more confidence that the future risks (and costs) associated with AMD can be managed. Adaptive management is a recognised approach from the resource management act toolbox (Leckie, 2017), however it requires clear environmental objectives against which management options can be measured.

Many mining operations in New Zealand have recognised world class approaches to the management of AMD (e.g. International Network for Acid Prevention (INAP, 2020). Such operations need to be acknowledged. These operations achieve success through adaptive management processes to manage uncertainty, which can also be considered a source of risk for the mine in regard to AMD.

AMD RISK MANAGEMENT

SLTO has been identified as the number one business risk for the mining industry two years in a row, (e.g. Ernst & Young, 2019, 2020). The way AMD is managed, and importantly community acceptance of the management process, is both a current and future risk for the mining industry and its ongoing access to minerals.

There are many risks associated with the management and treatment of AMD. For instance, the long-term treatment of AMD often has financial appeal as costs occur a long way into the future, yet often the costs of some key longer-term risks have not been considered. Examples include:

- event risk as long-term treatment of AMD will have greater exposure to infrequent high-risk events;
- current datasets may not be appropriate for the effects of climate change; and
- changing community expectations with time leading to more stringent water quality standards.

Such risks can add to unforeseen costs later in the mine life and erode final project value if they were not considered during project planning and financial analysis using net present value (NPV) calculations. Inclusion of costs for such risks in any NPV calculation of options provides a fairer assessment of source control costs versus long term treatment costs. For instance, the upfront cost of source control (i.e., AMD prevention and minimisation) is often less favoured when compared to long term treatment options that occur a long way into the future. The mining industry needs to focus on minimising AMD as the best practicable approach to the management of AMD and have AMD treatment as a lesser, although necessary minor management option. In this regard, there are many excellent examples of source control in New Zealand supported by low-cost treatment, as necessary.

Generally, the risks associated with AMD can be assessed by a Source-Pathway-Receptor (SPR) model platform, which shows that a risk is only present when there is:

- a source of AMD;
- a pathway from the AMD source to the receptor; and
- a receptor that could be affected by the AMD.

The SPR platform should be based on the site conceptual model that identifies all key mine domains (potential AMD source hazards), physical pathways, and receptors of concern. Such models, supported by detailed scientific and engineering studies, can facilitate risk assessments and determine potential options and costs for AMD management.

Research (e.g. INAP, 2020) demonstrates that in general, the AMD source hazard represents close to 80% of the potential risk for any site affected by AMD with pathway and receptors contributing to the remainder (Richards *et al*., 2006). Hence, definition of the AMD source hazards helps with clarifying understanding of the potential AMD risks for any mine domain that contains hazardous materials.

Risk assessments are an essential planning step for the management of AMD at sites that have potential issues and/or have potential uncertainty about the effects of AMD. Many mining companies use an AMD risk assessment process as a key management step following source hazard characterisation (e.g. Pearce *et al*., 2019).

It is recommended that the AMD risk assessment is based on data obtained from prediction activities (e.g. source hazard characterisation testing). The risk assessment is a fundamental step in prediction of potential AMD effects and will be revisited many times over the mine life.

The determination of potential effects (risks) provides the opportunity to consider additional management options that may, or may not, be required. This could include AMD management techniques such as prevention and minimisation, and if necessary, the treatment of AMD.

The six steps of AMD management (Figure 1) and the risk assessment (represented by a star) are the backbone of any AMD Management Plan. Furthermore, management plans are acknowledged as a suitable mechanism to present adaptive management (e.g. Leckie, 2017).

For operational functionality, management plans are supported by standard operating procedures (SOP).

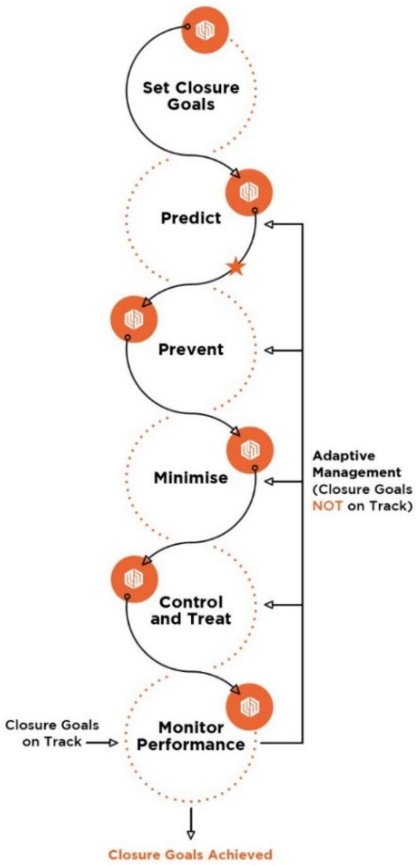


Figure 1 AMD Management Steps

ADAPTIVE MANAGEMENT

Introduction

All mining projects have some degree of uncertainty in regards to outcome and effects. This uncertainty can be managed by a process of adaptive management. Adaptive management is a learning-orientated approach to environmental management where uncertainty exists, which may change over time to reflect new information as it becomes available. Adaptive management is a recognised management option under the Resource Management Act (RMA) (e.g. Leckie, 2017), however it requires clear environmental objectives against which management options can be measured.

Effective adaptive management is supported by understanding the nature and duration of possible events that could occur, monitoring these events, and then having options in place should there be variance from the expected condition. This requires:

- understanding the risks (source hazards);
- monitoring (as early warning, i.e., performance monitoring);
- variance planning; and
- Trigger Action Response Plans.

Understanding risk

Identification of the key AMD risks that could affect closure of the site are identified in the AMD risk assessment. This AMD risk assessment therefore helps refine what effects could occur, what monitoring is required, and hence what key adaptive management strategies should be developed. Minor risks do not generally need adaptive management processes to be developed.

For instance, projects risks relating to AMD management could include:

- the amount of rock that will be ore or low-grade ore, and the amounts of rock that will be potentially acid forming (PAF) and/or non-acid forming (NAF).
- the materials schedule for PAF and NAF and its availability for key construction activities such as NAF covers or infrastructure areas.
- waste rock placement (correct domain and correct placement style).
- the quality and quantity of water flow from mine domains that have the potential for AMD, e.g. toe seepage from a tailings storage facility.
- contaminant load predictions such as the amount of acidity or other contaminants produced over time.
- climate change and higher flow rates/contaminant loads.

Each potential risk should have a range of potential controls and actions developed in case there is variance from the expected case and appropriate monitoring in place, together with assigned responsibilities. Responsibilities are often managed by a RACI matrix (Responsibility, Accountability, Consulted, Informed).

Monitoring of Key Risks

Monitoring of performance is critical to help identify early departure from the expected case. Performance monitoring is an early warning system to enable a timely response to develop and implement other management options to manage the change. Monitoring should be specific to the risk and the duration of the risk. For instance, construction of a waste rock dump (WRD) to reduce impacts, such as acidity loads, on the receiving environment may include monitoring of the WRD to ensure oxygen concentrations are in accordance with design specifications.

Variance Planning

Variance from the expected case is inevitable, although it can be minor, and there needs to be supporting management options to show how such variance will be managed. Therefore, for key AMD risks, it is necessary that the following processes relating to AMD uncertainty are considered:

- a range is determined such that there is confidence in the conservative and optimistic model bounds;
- the expected case, the most reasonable estimate, sits within these model bounds; and
- management options are available for the proposed range to achieve agreed operational and closure criteria.

This range of management options can be referred to as the “adaptive management regime” and needs to be acceptable to both internal and external stakeholders. Figure 2 provides an illustrative example of the adaptive management regime for AMD impacted waters at a mine site. It provides a clear graphic for explaining to stakeholders how variance will be managed as part of a learning-orientated approach (with time) to environmental management where uncertainty exists.

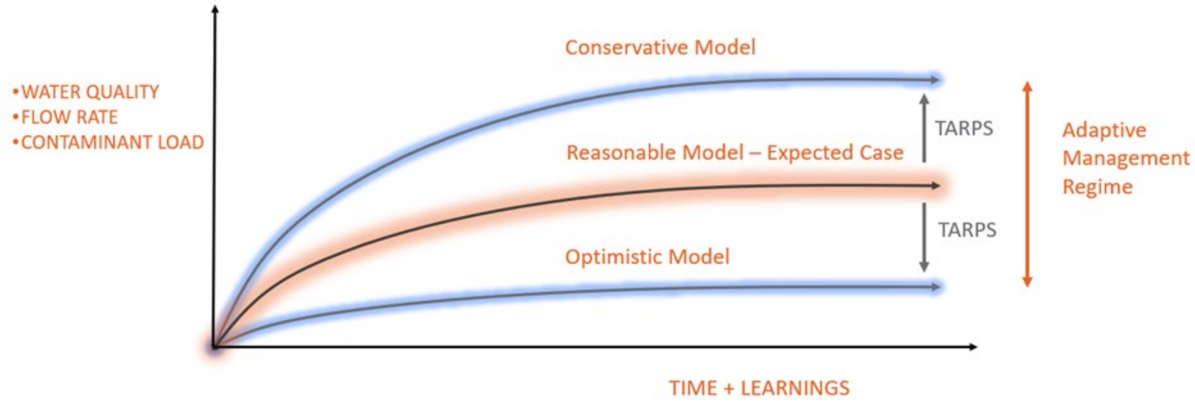


Figure 2 Adaptive Management Regime (after Weber *et al*., 2018).

Trigger Action Response Plans (TARPS)

Almost any variance from the expected case can be managed by Trigger Action Response Plans (TARPs) where appropriate. The number of TARPs is based on the desktop risk assessment process to ensure potential higher risk effects have management options in place. Generally, a TARP has set trigger limits to define what a significant change is, and then describes the actions to respond to the variance. TARPs need to be developed to cover the adaptive management regime. Examples of this include:

- reconciliation of waste rock block model material volumes versus mined material quantities.
- waste rock placement verification to ensure design methodologies are achieved (e.g. Figure 3).
- performance monitoring of waste rock dumps for oxygen content and net percolation rates.
- monitoring of AMD discharge (rates and quality).
- performance monitoring of treatment system effluent against design expectations.

The use of TARPS provides the framework to manage uncertainty in a manner that makes (most) stakeholders more comfortable that solutions are available and are ready to be implemented if there is variance from the expected case. Done effectively, consistently, and by adapting to new learnings about the impact of uncertainties, this approach will fundamentally support SLTO. The benefits of this approach should be demonstrated through rigorous environmental performance monitoring that demonstrates the agreed closure goals will be achieved.

Figure 3 provides an example TARP for the placement of waste rock on a NAF WRD and explains monitoring requirements, event trigger levels, and responsibilities as per the RACI matrix.

CONCLUSION

The mining industry plays a key role in enabling a sustainable future for society by providing the minerals needed for society to function. However, the process of mining also needs to be sustainable and undertaken in a best practicable manner. Many operations in New Zealand have recognised world class approaches to the management of AMD, which has been recognised in industry leading publications for the source control of AMD (e.g. INAP, 2020).

Social Licence to Operate is now a fundamental risk to the business of mining and must be earned by the actions of mining companies. For AMD management, the mining industry needs to demonstrate that uncertainty can be managed with a greater focus on source control. The current approach of treatment in perpetuity is no longer an acceptable sole-choice option for AMD management in the future. From here on, the following needs to be undertaken:

- characterisation of the AMD source hazards and understanding of the potential risks;
- prevention of sulfide mineral oxidation;
- minimisation of contaminant loads from these mine domains; and
- where necessary control and treatment options may be required.

State	**Normal State**	**Event Trigger 1**	**Event Trigger 2**
Monitoring Programme	Mine Environment to complete: • Visual Inspections • Acid Base Accounting QA/QC • Vehicle Fleet management • Consult and Inform as per SOP	Mine Environment to complete: • Visual Inspections • Acid Base Accounting QA/QC • Vehicle Fleet management • Consult and Inform as per SOP	Mine Environment to complete: • Visual Inspections • Acid Base Accounting QA/QC • Vehicle Fleet management • Consult and Inform and per SOP
Trigger	No PAF or materials with visible sulfides are placed on the NAF WRD each month.	PAF materials and materials with visible sulfides are being placed on the NAF WRD on a weekly basis.	PAF materials and materials with visible sulfides are being placed on the NAF WRD on a daily basis.
RACI	**Action/Response**	**Action/Response**	**Action/Response**
Mine Environment	Continue operations as per the procedure.	Undertake weekly inspections of the WRD to ensure that the issue is resolved. Ensure the quantity of materials rehandled from the NAF WRD to the PAF WRD are tracked for audit purposes	ICAM investigation to be completed. Undertake daily inspections of the NAF WRD to ensure that the issue is resolved. Ensure the quantity of materials rehandled from the NAF WRD to the PAF WRD are tracked for audit purposes
Mine Geology	Continue operations as per the procedure.	Review waste rock block model and Vehicle Fleet Management Log to understand discrepancy. Review the materials mark-up process Identify and resolve any issues.	Immediately review waste rock block model and Vehicle Fleet Management Log to understand discrepancy. Immediately review the materials Mark-up process Identify and resolve any issues.
Mine Planning	Continue operations as per the procedure.	Remove any PAF materials or materials with sulfides from the NAF WRD and place on the PAF WRD. Record incident and materials quantities.	Remove any PAF materials or materials with sulfides from the NAF WRD and place on the PAF WRD. Record incident and materials quantities.
Mine Manager	Continue operations as per the procedure.	Continue operations as per the procedure.	Review/endorse as necessary ICAM outcomes. Continue operations as per the procedure.

Figure 3 Example TARP: Materials Placement – NAF WRD.

The use of adaptive management processes can help with knowledge transfer, community engagement, and stakeholder acceptance of most AMD risks. Adaptive management enables a project to proceed where uncertainty exists, provided the variance can be managed, and enables time orientated learning processes as further data becomes available to ensure operational and closure criteria are achieved.

Risk assessments and robust adaptive management combined with proof of outcomes and clear informed stakeholder communication earns the social licence to operate.

REFERENCES

Ernst & Young, 2019. Top 10 business risks and opportunities – 2020. Available from: https://www.ey.com/en_gl/mining-metals/10-business-risks-facing-mining-and-metals.

Leckie, J.M.G., 2017. Environmental effects management and assessment- Adaptive management in the mining context. AusIMM New Zealand Branch Annual Conference proceedings, Christchurch, New Zealand, p. 96–104.

Lottermoser, B.G., 2012. Environmental indicators for acid mine drainage: advances in knowledge and challenges ahead. Seventh International Conference on Mine Closure proceedings, Brisbane, Australia.

INAP, 2020. Rock Placement Strategies to Enhance Operational and Closure Performance of Mine Rock Stockpiles. *Phase 1 Work Program – Review, Assessment & Summary of Improved Construction Methods*, Earth Systems and Okane Consultants report, INAP, p. 105. https://www.inap.com.au.

Pearce, J., Cooper, T., & Heyes, J., 2019. Global Acid and Metalliferous Drainage Management Standard – BHP's Approach to Reducing Global AMD Closure Risk. Thirteenth International Conference on Mine Closure proceedings, Perth, Australia.

Richards, D.G., Borden, R.K., Bennett, J.W., Blowes, D.W., Logsdon, M.J., Miller, S.D., Slater, S., Smith, L., & Wilson, G.W., 2006. Design and implementation of a strategic review of ARD risk in Rio Tinto. Seventh International Conference on Acid Rock Drainage (ICARD) proceedings, St. Louis MO, U.S.A, p. 1657–1672.

Weber, P., Malloch, K., Olds, W., & Christenson, H., 2018. Managing the effects of modern day mining. ALGA Contaminated Land 2018. Available from: https://landandgroundwater.softlinkhosting.com.au:443/liberty3/OpacLogin?mode=BASIC&openDetail=true&corporation=alga&action=search&queryTerm=uuid%3D%225e4ea1430a0200fd7dbfbd22001e84e6%22&operator=OR&url=%2Fopac%2Fsearch.do.

Zinck, J., & Griffith, W., 2013. Review of mine drainage treatment and sludge management operations. MEND Report 3.43.1. p. 101.

GeoFuture

Proposed Approach to Adaptive Management in relation to Effects on Surface Geothermal Features

Prepared by Chris Drayton

on behalf of Contact Energy Limited

6 SEPTEMBER 2022

Contents

Appendices

1. INTRODUCTION

Geothermal systems are dynamic, meaning they are constantly changing in response to both natural phenomena (such as geological and meteorological factors) and human activities, the latter particularly being the case in relation to a geothermal system developed and used for large scale renewable electricity generation purposes.

Despite the Wairākei-Tauhara Geothermal System being widely acknowledged as the most studied geothermal system in the world and Contact's GeoFuture applications being the subject of a comprehensive Assessment of Environmental Effects (**AEE**), there are aspects of its ongoing use, management and future effects which are not completely certain.

"Adaptive management" is an approach to the management of natural and physical resources, including geothermal systems which is appropriate to apply where there is uncertainty about environmental effects over the longer term arising from any particular management regime, including:

- whether an effect will actually occur;
- how fast an effect might occur; and/or
- how significant the magnitude of the effect might be.

An adaptive management regime requires flexibility to determine and implement the most appropriate response to any given situation at the time. However, adaptive management is not just a 'make it up as you go along' approach. It requires forethought, planning and a reasonable level of certainty about the type of responses that can be realistically implemented in relation to any particular type of environmental effect (should it occur).

The regional policy regime relating to the management of Development Geothermal Systems (including the Wairākei-Tauhara Geothermal System) recognises and requires adaptive management as follows:

- Objective 3.3 in the Waikato Regional Policy Statement (**RPS**) is that *"Resource management decision making … adopts [inter alia] a precautionary approach, including the use of adaptive management, where appropriate, towards any proposed activity whose effects may be significant or irreversible but are as yet uncertain, unknown or little understood"*.
- In the Waikato Regional Plan (**WRP**), Policy 9.3 relating to the management of Development Geothermal Systems requires the preparation of a System Management Plan which *"provides for, as appropriate, … operational flexibility and adaptive management"*. The System Management Plan must include a Discharge Strategy which considers, inter alia, *"the need for adaptive management and flexibility over time"*.

Contact has a well-established and widely accepted adaptive management regime in place in relation to ongoing management of the geothermal system and to deal with any adverse effects on buildings and structures as a result of subsidence within the Wairākei-Tauhara Geothermal System.

2. PURPOSE OF THIS DOCUMENT

The purpose of this document is to set out Contact's proposed approach to adaptive management in relation to the effects of GeoFuture on surface geothermal features, particularly thermotolerant vegetation, within the Wairākei-Tauhara Geothermal System.

While GeoFuture (without any mitigation) will result in better outcomes for thermotolerant vegetation compared with the 'no consent' scenario over the term of any new consent, Contact is proposing a comprehensive range of mitigation measures (which will be implemented in any event)[1] coupled with an additional adaptive management regime to address any unanticipated effects on surface geothermal features, particularly thermotolerant vegetation.

The adaptive management approach proposed in this report includes "triggers" for adaptive management to occur and a "menu" of adaptive management measures that could be adopted in the event of a trigger being exceeded. It needs to be recognised that the exceedance of some of the triggers will be a matter of professional judgement by suitably qualified and experienced technical experts, including independent experts acting on behalf of the consent authority.

A draft of this document has been provided to the following key stakeholders to obtain their views and input regarding the nature and content of the adaptive management approach proposed:

- Iwi / hapū (via the Wairākei Hapū Collective); and
- Geothermal experts at Waikato Regional Council.

It is intended that this document will form part of and/or be integrated into the updated version of the Draft System Management Plan (SMP) (Part C of the Application) that is to be submitted within six months of the GeoFuture consents being granted.

3. BACKGROUND / POSITION STATEMENT

During the earlier stages of development on the Wairākei-Tauhara Geothermal System (1950's-1980's), the extent of vegetation typical of geothermally heated habitats, particularly areas dominated by geothermal kānuka (*Kunzea tenuicaulis*), increased quite markedly compared to the pre-development state due to the expansion of thermally-heated ground. This occurred as a result of pressure drawdown in the geothermal reservoir, leading to an increase in boiling and the extent of shallow steam zones and associated heat flows to surface.

However, due to the commencement of large-scale reinjection in the late 1990's and the subsequent increase in reservoir pressure, the extent of heated ground has been slowly declining, leading to a more recent reduction in the extent and/or quality of thermotolerant vegetation that had occurred on thermally heated ground habitats. The extent and/or quality of thermotolerant vegetation has also been affected by the invasion of pest plant and animal species, farm animals and third-party human land use activities, all of which are matters unrelated to Contact's electricity generation activities.

It's important to note that ongoing development of the geothermal resource will continue to require choices to be made between different effects on the reservoir and the overlying surface environment. This means that in most circumstances, due to the policy framework set out below which encourages large scale

[1] Contact's Proposed Mitigation Package is presented in Appendix 18 of the GeoFuture AEE, dated 17 December 2021.

infield reinjection as the primary means of discharge of geothermal fluid, Contact will be unable to take direct action to cease or reverse the cooling of the surface of the system. When practical, Contact may use reinjected fluid at an appropriate temperature for targeted aquifer reinjection to assist in minimising any long-term adverse cooling or heating effects to springs. Displacement of in-situ fluids by reinjection or production has the potential to cause transients in temperature as the fluids move. This could influence the temperature of any rejuvenated springs and may or may not have the intended outcomes (Bromley and Reeves, 2021).

The policy framework, Contact's consents and the draft SMP set out the prioritisation of various effects, including:

(a) Te Ture Whaimana o Te Awa o Waikato, The Vision and Strategy for the Waikato River, which is the priority planning document. To ensure consistency with the Vision and Strategy, the priority of WGPS production/operations is to reinject/inject nearly all geothermal water rather than discharge to the Waikato River and its tributaries (Wairākei Stream). This will reduce the extent of hot stream margins along the lower reaches of the Wairākei Stream (above the confluence with the Te Kiri-o-Hinekai Stream) which, currently (due to Contact's discharges of geothermal water), provide habitat for thermotolerant vegetation. One of the effects of increasing reinjection is to increase reservoir pressure which suppresses boiling which reduces surface heat flow.

(b) Mitigating the effects of subsidence is the secondary priority in the current System Management Plan. This requires reinjection/injection of geothermal water which, as a result of pressure retention or increases, will reduce the extent of shallow steam zones. This reduces the extent of heated ground and some habitat for some thermotolerant vegetation types; and

(c) The Discharge Strategy, as described in the Draft SMP, gives effect to the two priorities above, but also seeks (as a lower priority) to manage effects on Significant Geothermal Features (**SGFs**), including thermotolerant vegetation, which are listed and mapped in the Waikato Regional Plan.

Importantly, the relevant and applicable planning framework (Waikato Regional Policy Statement (**RPS**) and Waikato Regional Plan) recognises that geothermal development and renewable energy generation activities may have adverse effects on SGFs within Development Geothermal Systems. While effects should be avoided where practicable, avoidance is not required in relation to all effects and the focus is on mitigating or remedying significant adverse effects.

Specifically, Implementation Method 9.3.1(a)(vi) in the RPS (large scale takes and use) requires (in the context of a System Management Plan for a Development Geothermal System):

> *"identification of anticipated significant adverse effects on Significant Geothermal Features and the remediation or mitigation to be undertaken, which may include 'like for like' remediation or mitigation in any geothermal system, including in the Bay of Plenty".*

Implementation Method 9.3.1(d)(vii) in the RPS requires (in the context of a Discharge Strategy to be prepared as part of a System Management Plan for a Development Geothermal System) consideration of:

> *"remedying or mitigating significant adverse effects on Significant Geothermal Features".*

The explanation in the RPS states:

> *"The policy recognises that it is not possible to avoid all adverse effects on Significant Geothermal Features when large-scale takes, uses and discharges of geothermal energy and water are allowed in Development Geothermal Systems. Accordingly, it is appropriate that where extractive uses cause significant adverse effects on Significant Geothermal Features these effects should be addressed by remediation or mitigation within the Regional Geothermal Resource. This may include remediation or mitigation of existing adverse effects and/or protection from potential adverse effects in similar types of surface features (as listed in section 9B) in the same or other geothermal system to an extent commensurate with the adverse effect being caused ('like for like' mitigation)."*

The technical reports in the AEE relating to surface geothermal features including thermotolerant vegetation, conclude that any adverse effects of GeoFuture are likely to be less than minor compared to the baseline / existing environment / "no consents" scenario, (whereby all of Contact's activities on the Wairākei Geothermal Field cease on 30 June 2026) with the implementation of mitigation and monitoring as recommended, over the term of the consents sought.[2] For the purposes of this report, the "baseline" is the 2020-21 assessment report presented as Appendix A.

While the effects of GeoFuture on surface geothermal features, including thermotolerant vegetation, are predicted to be generally less than the baseline existing environment scenario (over the term of the consents sought), there remains some uncertainty about the magnitude and significance of some of the potential effects of GeoFuture at specific locations.

Contact is therefore proactively proposing a number of mitigation measures (including those which have been recommended by Contact's technical experts) to address, in particular, the continuing cooling of surface geothermal features in the Wairākei-Tauhara Geothermal System and consequential decline of thermotolerant vegetation.

4. PRIMARY MITIGATION MEASURES IN RELATION TO EFFECTS ON SURFACE FEATURES

The proposed mitigation measures are detailed in the "Proposed Mitigation Package" (Appendix 18 of the AEE). This package was further updated and refined following the receipt of the Wairākei Hapū Collective Cultural Impact Assessment in June 2022 and through ongoing engagement with iwi, hapū and other parties.

The proposed mitigation measures relating to effects on the Wairākei geothermal reservoir and consequential effects on surface geothermal features (including thermotolerant vegetation) includes as follows (in summary):

(a) Maintaining and where necessary improving and upscaling existing environmental enhancement and restoration projects either required under the existing resource consents held by Contact or undertaken voluntarily by Contact including:

(i) predator pest control, weed control, fencing to exclude stock, riparian planting, and other protection and mitigation measures right across the Wairākei Geothermal Field

[2] Bromley, C.J. and Reeves, R.R., 2021: Shallow hydrothermal effects of proposed ongoing operation of Wairakei Geothermal Field. GNS Science Consultancy Report 2021/13, December 2021.

(committing a proposed $150,000 per year (inflation adjusted) to fund these 'manaaki whenua' projects for the life of the consents); and

(ii) providing additional and more sustainable funding to the Wairākei Environmental Mitigation Charitable Trust (**WEMCT**) to further its objectives, including to protect and enhance geothermal biodiversity across the Waikato Region (committing a proposed up to $150,000 per year (inflation adjusted) to WEMCT for the life of the consents to achieve these joint objectives).

(b) Undertaking new enhancement and restoration projects including:

(i) continuing and expanding the extensive Ecological Restoration Plan for Te Rau-o-Te Huia Stream gully, including for example committing a further $100,000 to help fund this project alongside hapū;

(ii) continuing flows of separated geothermal water (**SGW**) into the Te Kiri-o-Hinekai Stream, of up to 600 tonnes per day discharged by Contact, along with up to 15,000 tonnes per day discharged by Netcor (being SGW supplied to Netcor by Contact). This will maintain and provide the conditions to enhance the habitat for rare geothermal plants living in, or capable of living in, the margins of the stream. Funding of up to $100,000 will be provided to undertake thermotolerant vegetation enhancement work along Te Kiri-o-Hinekai Stream in accordance with a management plan proposed to be prepared by Wildlands, in consultation with hapū; and

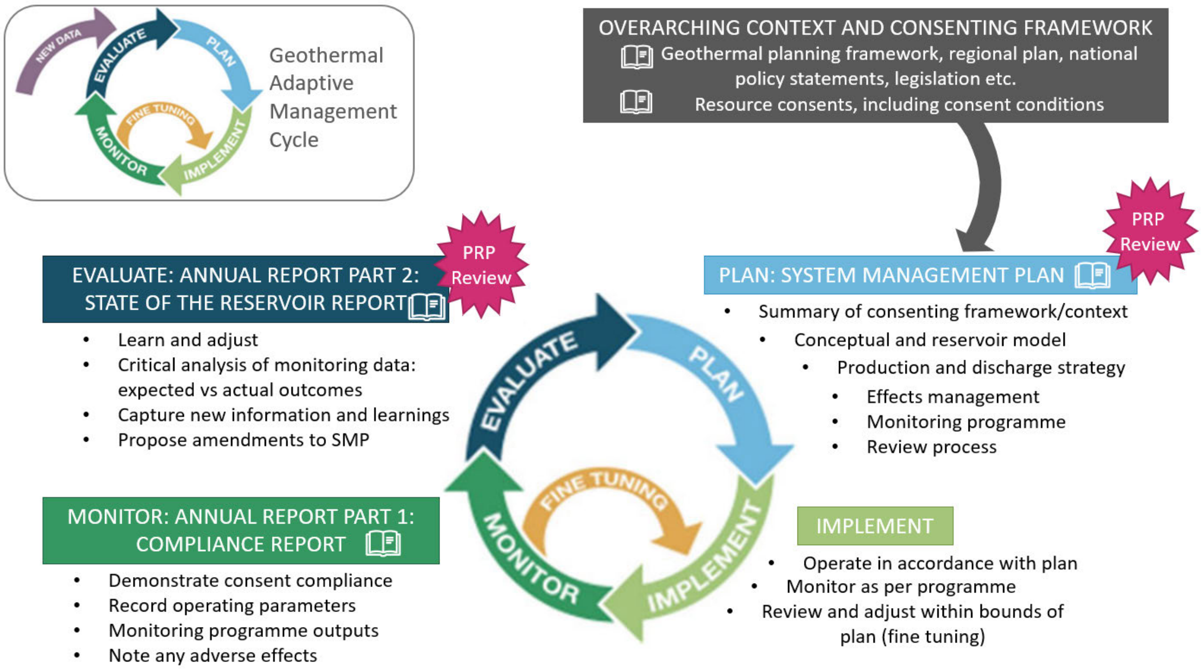
(iii) following consultation with hapū both prior to and following the CIA, committing a further $200,000 into the restoration and enhancement of geothermal features and ecology in the Wairākei Geothermal Valley, working with hapū and landowners to plan and execute projects in that area.

(c) Subject to landowner approval, restoration of some of the habitat and values of the Otumuheke Stream valley through the addition of a mix of SGW and heated Waikato River water and preparing and implementing a management plan to enhance the streamside thermotolerant habitat and geothermal biodiversity of this area.

5. ADAPTIVE MANAGEMENT APPROACH

Contact manages the Wairākei-Tauhara Geothermal System using a System Management Plan which embodies the principles of adaptive management (as shown in the diagram below). With specific regard to thermotolerant vegetation associated with surface geothermal features, Contact proposes, in addition to the mitigation measures described above, to use the adaptive management approach which requires further mitigation actions to be taken when any significant unanticipated effects on surface geothermal features are identified on the Wairākei-Tauhara Geothermal System. This approach is consistent with the way Contact has managed the Wairākei-Tauhara Geothermal System in the past, but the following provides some more specificity to the approach.

The proposed adaptive management approach is illustrated in the following diagram.



The key elements of the adaptive management approach proposed for thermotolerant vegetation associated with geothermal surface features include the following:

Baseline Database – this has already been completed. Following detailed site investigations, Wildlands has prepared and recently finalised a report which summarises the vegetation and habitats of all identified geothermal sites in the Wairākei-Tauhara Geothermal System with terrestrial geothermal vegetation and/or wetlands (attached as **Appendix A**). This report identifies key values of each of the sites, including the values for flora and fauna, detailed vegetation descriptions and site photographs, and also key threats to each site. The report builds on knowledge obtained from regular site surveys by the authors of the report since the early 2000s and detailed scientific studies dating back to the 1950s. While there are always some limitations to baseline surveys, it should be recognised that the existing knowledge of the geothermal vegetation and habitats are greater in the Wairākei-Tauhara Geothermal System than for any other large geothermal systems in New Zealand and possibly internationally. The baseline has built on extensive knowledge of the geothermal system over the last 20 years when monitoring has been undertaken on a more regular basis, as well as a comprehensive series of photo-points, plots, and rare plant monitoring.

Monitoring and Reporting – Wildlands has recommended, and Contact accepts, that the vegetation plots are to continue to be re-measured at four yearly intervals (as presently occurs) and the results recorded. The vegetation plots to be re-measured include both existing plots/transects and also additional plots/transects as required (the latter being determined by the expert undertaking the monitoring).[3]

The four-yearly monitoring will utilise the same methodology associated with the preparation of, and reporting in (including maps of the vegetation), the Baseline Database (attached as **Appendix A**) so that the results of each four-yearly monitoring can be compared with the Baseline Database. This survey should be preceded with either aerial or drone photography of as many sites as possible.

[3] Crown Road / Broadlands surveys are currently two yearly in accordance with existing consent conditions.

The four-yearly survey of the thermotolerant vegetation will be undertaken in conjunction with thermal feature photographic survey and the aerial thermal infrared survey which also occur every four years. Recording soil temperatures will also be undertaken as part of the four-yearly monitoring.

In addition to the four-yearly monitoring, it is proposed that monitoring of areas of thermotolerant vegetation will be undertaken between each four-yearly monitoring (i.e. two years after each four-yearly monitoring) and a comparison with the baseline database undertaken. This means that a site visit to all sites will be undertaken on a two-yearly basis, as close as possible to the same time of year on each occasion. The monitoring between each four-yearly monitoring will involve visiting key plant populations, and photo point sites, and undertaking a general assessment to determine if there are any significant changes (in terms of both rate and scale of change) compared to the Baseline Database (attached as **Appendix A**) that were not anticipated as part of operations in accordance with the GeoFuture and/or Tauhara consents at the time of consenting. This assessment may be assisted by the use of drone photography. The outcomes of the monitoring will be recorded, evaluated and an expert report produced.

Contact will report to the Waikato Regional Council the results of these surveys, including a comparison with the Baseline Database (attached as **Appendix A**) as part of the Annual Monitoring Report. The results of these surveys will inform Contact's ongoing adaptive management of the system and the results of the surveys will be reviewed and assessed in consultation with WRC and the PRP to determine if Contact's response to any changes is appropriate. If in the opinion of the vegetation expert, any of the above monitoring identifies any of the proposed triggers (discussed below) which, signal the potential future occurrence of significant changes (in terms of either rate or scale of change) that were not anticipated as part of GeoFuture, Contact will undertake a review of the SMP and associated Surface Geothermal Features Management Strategy (proposed in a new condition below) to ensure the strategy still appropriately addresses the requirement to mitigate the loss of thermotolerant vegetation.

Triggers for Adaptive Management – To respond to any significant and unanticipated changes and provide rigour and certainty to Contact's proposed adaptive management approach, Contact proposes a set of "triggers" for when a revision to its adaptive management response is required. This will require it to initiate a response from a "menu" of reactive mitigation measures to manage unforeseen effects or effects that are associated with GeoFuture operations and that are more significant than anticipated.

Neither the set of 'triggers' nor 'menu' of mitigation measures are exhaustive but provide a robust indication of the types of significant unanticipated effects where, upon identification through the above monitoring programme, Contact will take action to address the effects.

Baseline monitoring establishes reference conditions. Over time, changes to the condition and extent of geothermal habitat can be compared to the baseline. While a baseline might be expected to be what existed pre-development, the evidence shows that we cannot accurately determine what this was, nor can we expect any return to a pre-development state in any reasonable timeframe, if ever. Within the Wairākei-Tauhara Geothermal System, and in the context of GeoFuture, the baseline can only be the extent and condition of the geothermal habitat in 2020-2021. This approach is consistent with decisions of the Environment Court that confirm that effects need to be assessed relative to the environment as it currently exists, and is projected to change in future as a result, among other things, of past actions that have set in train processes that are irreversible in practice. It does not look back to a past environment that has irreversibly changed.

EPOCH assessments (evaluation of population change) could potentially be used to establish a baseline (Rodrigues et al 2019[4]), however a considerable amount of additional work would be required to do so (examples to date using this model are all marine focused and thus the ability to apply such a model to terrestrial vegetation remains to be determined). In addition, such models will not account for the historic heat pulse which saw geothermal vegetation expand in the 1980's and thus may still not provide an adequate measure of baseline. Further, historical baselines will not account for the loss of geothermal vegetation from the system due to activities not due to the use of the geothermal system for electricity generation (e.g. land clearance for roading, farming, and industrial/residential development).

The surveys to date thus represent our best knowledge of what the baseline within the Wairākei-Tauhara system is. The baseline report builds on 20 years of monitoring data which is now starting to show trends. The Wildlands team is confident that these data are adequate to show that the percentage changes discussed later will be detectable with the current information held. Losses to date such as the declines in geothermal springs have already triggered Contact to prepare a restoration plan for the Otumuheke Valley, and to explore options to release geothermal water into the lower part of Otumuheke Stream in part to maintain habitats for ferns that require steamy environments. It has also triggered Contact to propose a plan to enhance steamy environments alongside the lower sections of Te Kiri-o-Hinekai Stream, and to propose restoration management alongside this waterway. While these changes do not address the losses so much in terms geophysical diversity losses, it does address many of the geothermal biodiversity losses.

The triggers, and the nature of potential adaptive management measures to address each of the triggers, are set out below:

- **Loss of heated geothermal ground habitats (in particular, geothermal kanuka scrub and shrubland) beyond predicted levels due to a response to impacts related to the consented activities and cannot be accounted for by other means (e.g. fire, land clearance by another party):** Limits of Anticipated Loss: 5% over 4 years, 10% over 8 years, or 20% over 35 years compared with the Baseline Database (attached as **Appendix A** based on the 2020-2021 site surveys). This is based on the reality that this habitat will be lost under both the baseline and application scenarios. The following additional adaptive management measures would be taken to address such effects:
    - Because loss will be against the background of Contact's mitigation actions already occurring in the Wairākei-Tauhara Geothermal System, then there are unlikely to be further opportunities for additional actions with this system in terms of creating new thermally heated ground and geothermal kānuka habitat. As a first step, any opportunities to improve the condition of geothermal kānuka scrub and shrubland and other thermal ground habitats, through for example, additional weed control or planting, within the

[4] Rodrigues ASL, Monsarrat S, Charpentier A, Brooks TM, Hoffmann M, Reeves R, Palomares MLD, Turvey ST. 2019 Unshifting the baseline: a framework for documenting historical population changes and assessing long-term anthropogenic impacts. *Phil. Trans. R. Soc. B 374*: 20190220. http://dx.doi.org/10.1098/rstb.2019.0220

Wairākei-Tauhara Geothermal System will be explored by an appropriately experienced geothermal ecologist.

  - In areas where geothermal ground habitats have declined due to the energy extraction from the Wairākei-Tauhara Geothermal System, action will be taken to reduce the spread of invasive pest plants except where species are useful successional species where indigenous species will eventually replace them. Actions may involve both pest plant control and planting indigenous species. What is required will be specific at each site due to the varied nature of geothermal sites. The goal in these areas is that these areas do not become dominated by pest plant species, and in most cases become good quality indigenous habitat, provided it is left undisturbed (e.g. from farming). An ecologist experienced with restoration ecology in geothermal systems will advise the most appropriate response at each site where geothermal activity has declined. Restoration of Pirorirori and Waiora Hill are high priorities in this regard.
  - Where geothermal habitat has declined and cannot be replicated elsewhere in the Wairākei-Tauhara Geothermal Systems, options to improve the indigenous character of geothermal kānuka scrub and shrubland will then be explored at other geothermal sites in the Waikato Region in the first instance. Actions for the management of threats to geothermal kānuka scrub and shrubland could include fencing of sites from stock and other grazing animals, pest plant control, and planting of geothermal kānuka on cleared heated ground.
  - If no options exist within the Waikato Region, then sites within the Bay of Plenty Region will be explored.

- **Decline of steamy habitats associated with geothermal springs and geothermal streams:** Limits of Anticipated Loss: 5% over 10 years, 10% over 35 years. This is a higher threshold as these plants and habitats are rarer. It should be noted that the current extent of geothermal streamside habitat is currently very small in the Wairākei-Tauhara Geothermal system, with *c.*3.4 kilometres of steamy stream margin habitat. This figure is based on the geothermal habitat prior to the decline of Otumuheke Stream, in addition to other examples in the lower Te Kiri-o-Hinekai Stream and Wairākei Stream, and at Waipahihi Valley). The following adaptive management measures would be taken to address such effects:
  - Create or recreate new steamy habitats such as has been done at Te Kiri-o-Hinekai Stream and is proposed at Otumuheke Stream, and provide for the sustainable planting, replanting, translocation or other means for establishing or re-establishing viable populations of suitable indigenous geothermal vegetation.
- **For the following At Risk and Threatened species: *Cyclosorus interruptus*, *Dicranopteris linearis*, *Christella* sp. 'thermal', and *Nephrolepis flexuosa***: The underlying principle is that sustainable populations of these species shall remain within the Wairākei-Tauhara Geothermal System, for at least the life of the consents, and ideally in perpetuity. While the principal loss scenario would depend on the viability of populations of these species within the geothermal system (to a maximum allowed decline of 5% loss over 10 years, 10% loss over 35 years), Contact may need to take into account natural fluctuations in some species, particularly *Hypolepis*

dicksonioides, where a higher threshold will be appropriate, e.g. 20% loss in a 10 year period. If the risk is considered high that any viable populations[5] of these species will be lost at any site then the following adaptive management measures would be taken to address such effects:

- Attempt to create new steamy habitat that is suitable for *Cyclosorus interruptus, Nephrolepis flexuosa* and *Hypolepis dicksonioides*.
- Maintain back-up populations (e.g. by way of a glass house at botanic garden or plant nursery, or around key artificial geothermal features and habitats) of species listed above which are the same genetic population as those found in the Wairākei-Tauhara Geothermal System. Genetic diversity should be considered in source plants for each species (i.e. preference for multiple plants not of the same clone).
- If there is suitable habitat within the Wairākei-Tauhara Geothermal System where At Risk and Threatened species have not naturally colonised where they have occurred in the past, then it may be appropriate to transplant some plants from the back-up populations to these sites if it is feasible to do so (note: if ecological conditions have changed and no suitable habitat remains, other sites or actions should be chosen).
- If none of the above activities remains a viable option and the plant species has declined markedly or has become extinct in the Wairākei-Tauhara Geothermal System, undertake actions aimed at improving the viability of Threatened and At Risk plant populations at geothermal sites within the Waikato or, if not, the Bay of Plenty. Such actions could include, but not be limited to fencing, and pest animal and plant control.

"Loss" in relation to these triggers must be directly related to the impacts of Contact's activities and energy extraction, including subsidence. The wording of any adaptive management conditions in relation to effects on surface geothermal features needs to ensure that this does not include factors outside of the control of Contact, such as loss of vegetation due to fire, land clearance by other parties, or other actions that are not a result of actions by Contact. If there is no obvious explanation for any loss as a result of third-party actions, the presumption will be that Contact is responsible for the loss (like the situation in relation to subsidence effects).

Nonetheless, the overall approach to mitigation, offsetting, and compensation outlined in the GeoFuture application is aimed at retaining and where possible enhancing viable plant populations and habitats, irrespective of the causes of loss.

It should also be noted that any "new" actions may require the permission of relevant landowners and/or additional resource consents to enable work and/or discharges to occur. These permissions will be sought at the time they are needed.

[5] Viable population means a population that is large enough to not be threatened with extinction due to changes to natural succession, and onsite disturbance (e.g. local fluctuations to geothermal activity, flooding, one off local-scale hydrothermal eruption, and impacts of other human-use of sites. The population size required to meet this criterion will vary for each species at each site due to the specific ecological requirements and threats for each individual species), The assessment will be a matter of expert opinion.

6. PROPOSED CONSENT CONDITIONS

A set of proposed consent conditions advanced by Contact is presented in Appendix 21 of the GeoFuture AEE dated 17 December 2021. A key aspect of the conditions (forming part of the General Conditions) is the requirement to prepare and update (every four years) a System Management Plan for the Wairākei-Tauhara Geothermal System (**SMP**).

The SMP is the appropriate document in which to incorporate any adaptive management regime relating to actual or potential effects on surface geothermal features, including thermotolerant vegetation. The four yearly review of the SMP dovetails with the frequency of additional monitoring proposed above (i.e. a comprehensive monitoring programme every four years interspersed with a general assessment two years following the comprehensive four-yearly monitoring).

General Condition 1.6 already sets out the functions of the Peer Review Panel including clause (c) as follows:

> *"Reviewing the Wairākei-Tauhara Geothermal System Management Plan, annual reports and other plans and reports as appropriate, and making recommendations to Waikato Regional Council with respect to the same where appropriate."*

General Condition 5.3(e) already requires Contact to include as part of the SMP:

> *"Operational procedures for monitoring and responding to any adverse effects that may be caused by the exercise of these consents."*

General Condition 5.10(i) already requires, as part of the Annual Report, a:

> *"Summary of any other surveys or interpretative reports conducted."*

General Condition 6.9 already requires monitoring of thermotolerant vegetation.

In order to provide legal certainty associated with the proposed approach to adaptive management set out above, Contact is proposing the following amendments and additional conditions of consent.

Amend General Condition 5.3(e) of the General Conditions as follows:

> *"Operational procedures for monitoring and responding to any adverse effects that may be caused by the exercise of the consents, <u>including a Surface Geothermal Features Management Strategy covering effects on surface geothermal features, including thermotolerant vegetation (see Condition X below)</u>."*

Insert a new condition (being Condition X referred to above) following General Condition 5.5 as follows:

> *"The System Management Plan shall incorporate a Surface Geothermal Features Management Strategy in relation to actual or potential effects of the Consent Holder's activities on surface geothermal features, including thermotolerant vegetation, which at a minimum shall include the following:*
>
> *a) A summary of the Baseline Database which summarises the vegetation and habitats of all geothermal sites identified as SGFs in the Wairākei-Tauhara Geothermal System with terrestrial geothermal vegetation and/or wetlands as documented in the Wildlands, [insert reference].*

b) The objectives of the Surface Geothermal Features Management Strategy and a description of the monitoring to be undertaken in accordance with General Condition 6.9 and Schedules A and B to achieve the objectives of the Surface Geothermal Features Management Strategy, which, at a minimum, shall include:

i. Vegetation plots are to be re-measured at four-yearly intervals, as far as practicable, at the same time of year. The vegetation plots to be re-measured include both existing plots/transects and also additional plots/transects as required (the latter being determined by the expert undertaking the monitoring).

ii. A site visit to all sites undertaken every two years following each four-yearly monitoring, as far as practicable, at the same time of year, to supplement the above four-yearly monitoring. This site visit will involve visiting key plant populations, and photo point sites, and undertaking a general assessment to determine if there are any significant changes (in terms of both rate and scale of change) that were not anticipated as part of GeoFuture. This assessment may be assisted by the use of drone photography.

c) The results of the four-yearly monitoring required in clause (b)(i) above shall be reported in the same manner as the Baseline Database required by clause (a) above to enable a comparison, and the results of the monitoring required in clause (b) above shall be recorded and a summary of the findings shall be documented in the Annual Report required by General Condition 5.10.

d) A set of "triggers" and a "menu" of potential adaptive management mitigation measures to manage unforeseen effects or effects that are associated with GeoFuture operations and that are more significant than anticipated (the latter being as documented in the GeoFuture AEE dated 17 December 2021 and relevant appendices).

e) Any adaptive management mitigation measures undertaken by the Consent Holder within a Consent Year shall be documented in the Annual Report required by General Condition 5.10.

<u>Advice Note:</u>

The requirements of this condition do not include obligations in relation to factors beyond the control of the Consent Holder such as loss of vegetation due to fire, land clearance by other parties, or other actions that are not a result of the activities of the Consent Holder.

The Surface Geothermal Features Management Strategy referred to in the condition above would be an appropriately amended and updated version of Sections 1 – 5 of this report.

Planning for Closure and the Management of Uncertainty – In a Mining Context

J.M.G Leckie[1] *and* *P.A. Weber*[2]

1. Partner, Lane Neave, Queenstown, 9300 joshua.leckie@laneneave.co.nz
2. Director, Principal Environmental Geochemist, Mine Waste Management, Christchurch, 8041 paul.weber@minewaste.com.au

Keywords: Resource Management Act 1991, Adaptive Management, Trigger Action Response Plans, TARPS, Projects, Minerals, Mining, Energy

ABSTRACT

The process of adaptive management is often incorporated into resource consent conditions, management plans and supporting procedures to manage uncertainty. Contemporary mine operators now utilise trigger action response plans (TARPS) to manage this uncertainty. TARPS should be developed from risk assessment workshops that are based on data and scientific analysis.

Were significant uncertainty exists in methods to manage predicted adverse effects for the receiving environment, it is reasonable to have consent conditions that require TARPS. However, TARPS need to be organic and should be recognised as a management tool that will change (e.g., trigger values may need to be adjusted based on new information) and may even expire during the consent term. Hence the inclusion of trigger values as resource consent conditions is unfavourable if this inhibits flexible adaptive management.

THE MANAGEMENT OF ENVIRONMENTAL EFFECTS

The Resource Management Act 1991 (RMA) is the principal legislation in New Zealand that governs the environmental effects of mining activities. The overarching purpose of the RMA is to provide for the sustainable management of New Zealand's natural resources. This requires the enablement of people and communities while avoiding, remedying or mitigating adverse effects on the environment of activities.

The RMA does not prescribe how activities should avoid, remedy or mitigate adverse effects, which provides a degree of flexibility for the development of new and innovative environmental practices to achieve sustainable management. These practices must be carried out within the framework of relevant National and Regional Direction and judicial interpretation.

ADAPTIVE MANAGEMENT AS AN EFFECTS MANAGEMENT TOOL – THE LAW

Adaptive management is a resource management tool that enables large scale projects including large mineral extraction activities to be undertaken where there is a degree of uncertainty present around the best management tools/processes to be implemented to achieve prescribed environmental outcomes.

Adaptive management through the use of management plans and robust conditions of consent differs from the more traditional prescriptive conditions of consent in that it is a live evolving approach that can adapt over time. The adaptive management approach strikes a balance between a decision-maker expressly prescribing how effects of a development are to be appropriately avoided, remedied or mitigated (or offset or compensated) and provides consent holders the flexibility that is necessary to determine how those outcomes will be achieved.

A key advantage of adaptive management is that it provides for a "adapt as you go method" which allows for mineral extraction activities to proceed cautiously while effects management knowledge is gained about the activity. Knowledge is gained through ongoing assessment, design and adjustment, reducing uncertainty and ensuring the effects of the activity are best managed to achieve both operational and project closure environmental objectives.

Adaptive management has become increasingly accepted as an effects management mechanism in large scale projects in New Zealand. The Environment Court has described management plans as now having a "central place" in large developments[1] and has increasingly found reliance on adaptive management to be appropriate and beneficial in the New Zealand mining context.[2]

Without the option to adopt an adaptive management approach, if a decision maker applies a precautionary approach, many mineral extraction activities may be unable to proceed until further information on the optimal way to manage effects is available. The Environment Court has previously stated that it would be unfair and unreasonable to expect applicants to anticipate and research all hypotheses that may occur during the course of the application process.[3]

The Supreme Court has considered whether an adaptive management approach can be considered consistent with a precautionary approach.[4] The conclusion of the Court indicated that whether an adaptive management regime will be considered consistent with a precautionary approach is case specific and in this instance, given the uncertainty would be largely eliminated, and the risk managed appropriately, the regime was consistent with a precautionary approach.[5] In scenarios where there is a large degree of risk and uncertainty remaining and the gravity of the consequences if the risk is realised is high, there is unlikely to be room for an adaptive management approach.

The RMA does not prescribe what an adaptive management approach must contain and this has instead been extensively discussed by various Courts and decision makers over the past few decades and is now well settled law. By comparison, the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 expressly provides for an adaptive management approach (except for in relation to marine discharge and dumping consents) and defines this as:[6]

(a) allowing an activity to commence on a small scale or for a short period so that its effects on the environment and existing interests can be monitored; and

(b) any other approach that allows an activity to be undertaken so that its effects can be assessed and the activity discontinued, or continued with or without amendment, on the basis of those effects.

Back in the RMA context, the Supreme Court has determined that an adaptive management approach must provide for a minimum criteria of information and specific requirements for it to be considered appropriate by a decision maker.[7] As the Supreme Court determined it is not a "suck it and see" approach.[8]

The Supreme Court considered that as a first question there must be an adequate evidential foundation to have reasonable assurance that the adaptive management approach will achieve its goals of reducing uncertainty and adequately managing any remaining risk.[9]

Secondly whether adaptive management is appropriate is dependent on an assessment of factors including:[10]

(a) the extent of the environmental risk (including the gravity of the consequences if the risk is realised);

---

[1] *Golden Bay Marine Farmers v Tasman District Council* NZEnvC Wellington W19/2003, 27 March 2003 at [411].
[2] *West Coast Environmental Network Incorporated v West Coast Regional Council* [2013] NZEnvC 253; *Biodiversity Defence Society Incorporated v Solid Energy New Zealand Limited* [2013] NZEnvC 195;
[3] *Crest Energy Limited v Northland Regional Council* NZEnvC Auckland A132/09, 22 December 2009 at [228].
[4] *Sustain our Sounds Incorporated v New Zealand King Salmon Limited* [2014] NZSC 40.
[5] *Sustain our Sounds Incorporated v New Zealand King Salmon Limited* [2014] NZSC 40 at [139] – [140].
[6] Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 Section 64(2).
[7] *Sustain our Sounds Incorporated v New Zealand King Salmon Limited* [2014] NZSC 40.
[8] *Sustain our Sounds Incorporated v New Zealand King Salmon Limited* [2014] NZSC 40 at [125].
[9] *Sustain our Sounds Incorporated v New Zealand King Salmon Limited* [2014] NZSC 40 at [125].
[10] *Sustain our Sounds Incorporated v New Zealand King Salmon Limited* [2014] NZSC 40 at [129].

(b) the importance of the activity (which could in some circumstances be an activity it is hoped will protect the environment);

(c) the degree of uncertainty; and

(d) the extent to which an adaptive management approach will sufficiently diminish the risk and the uncertainty.

Ultimately the Supreme Court considered that the vital part of the of the adaptive management test was the ability for an adaptive management regime to deal with risk and uncertainty.[11] In applying that test the Supreme Court considered the following factors:

(a) there would be good baseline information about the receiving environment;

(b) the conditions provide for effective monitoring of adverse effects using appropriate indicators;

(c) thresholds are set to trigger remedial action before the effects become overly damaging; and

(d) effects that might arise can be remedied before they become irreversible.

In relation to the baseline information limb, an application should provide for the collection of baseline knowledge to establish the existing state of the environment upon which management plans can build in an ongoing and cyclical process.[12] The management plan can then set out a design for management, monitoring, evaluation of monitoring results and reviewing and refining of hypotheses.[13]

In relation to monitoring ensured through conditions, the proposed conditions need to clearly set out the mechanisms for review and update of management plans, usually as monitoring feedback becomes available.[14] Review is important as by allowing management plans to control environmental effects, decision-makers risk delegating their decision-making powers. This is acceptable for the certification of details. However, decision-makers should not delegate the making of substantive decisions.[15]

ADAPTIVE MANAGEMENT CONDITIONS OF CONSENT

The environmental effects of an activity are controlled by conditions imposed as part of a decision to grant a resource consent. Generally, all resource consents contain conditions and for large scale comprehensive mining projects the conditions are often extensive and complex.

The RMA authorises the imposition of conditions by consent authorities. The discretion of the consent authority to impose conditions is relatively widely expressed as “any condition that the consent authority considers appropriate”. However, this discretion is not unlimited and to be valid at law a condition must:[16]

---

[11] *Sustain our Sounds Incorporated v New Zealand King Salmon Limited* [2014] NZSC 40 at [133].
[12] *Crest Energy Limited v Northland Regional Council* NZEnvC Auckland A132/09, 22 December 2009 at [228]; *Final Report and Decision of the Board of Inquiry into the Transmission Gully Proposal* Board of Inquiry, EPA 0175, June 2012 at [186].
[13] *Crest Energy Limited v Northland Regional Council* NZEnvC Auckland A132/09, 22 December 2009 at [226].
[14] *Final Report and Decision of the Board of Inquiry into the Transmission Gully Proposal* Board of Inquiry, EPA 0175, June 2012 at [184]-[185].
[15] *Royal Forest and Bird Protection Society v Gisborne District Council* [2010] NZEnvc 128
[16] *Newbury DC v Secretary of State for the Environment; Newbury DC v International Synthetic Rubber Co Ltd* [1981] AC 578; [1980] 1 All ER 731 (HL).

(a) be imposed for a planning purpose and not for an ulterior one;

(b) fairly and reasonably relate to the development permitted by the consent; and

(c) not be so unreasonable that no reasonable planning authority could have imposed it.

Section 108AA further clarifies the requirements for valid conditions of consent and provides certainty to applicants as to the types of conditions that can be imposed. Pursuant to Section 108AA a condition cannot be imposed unless:

(a) the applicant for the resource consent agrees to the condition; or

(b) the condition is directly connected to an adverse effect of the activity on the environment and/or an applicable district or regional rule, or a national environmental standard; or

(c) the condition relates to administrative matters that are essential for the efficient implementation of the relevant resource consent.

As described earlier in this paper, an adaptive management approach requires specific conditions to be set by the relevant decision maker. For these conditions to be appropriate they must contain certain and enforceable objectives that are essential to trigger the need for remedial work if required.

The Environment Court has provided useful practical drafting direction as to the technical drafting of adaptive management conditions following concerns that proposed conditions failed to meet basic requirements of enforceability and certainty.[17] That drafting direction draws on established case law regarding the content and structure of management plan conditions.[18]

The Courts have also held that management plan conditions that impose an open-ended certification is a de facto delegation of approval and is not appropriate.[19] If a management plan condition requires certification the condition must be clear as to what certification would be with reference to such as a performance or standard being met. Certification should generally be undertaken by a specifically qualified person. If there is no benchmark for certification the condition should not require certification.

Importantly, adaptive management conditions need to not unlawfully delegate decision making to a later council officer. It has been argued before the Court that a combination of broad objectives for a list of areas rather than specific targets to be met resulted in the role of the certifier going beyond the acceptable parameters of the role and make findings of fact on matters that were essential to the grant of the consent. This was argued to be an unlawful delegation of decision making.[20] In this scenario the Court held that as the knowledge of the relevant ecosystems was incomplete the conditions managing the ecosystems needed to be flexible enough to allow the best possible environmental outcome to be achieved in the light of advancing knowledge and experience.[21] The Court found that the management plan certifier was being required to confirm that the management plan concerned was the most appropriate means available at any given time to achieve the objectives stated in the conditions and that this did not unlawfully delegate the Court's decision making function.[22] In relation to adaptive management conditions it is therefore important that council officers are certifying actions, drawing on skills and experience rather than acting as a delegated decision maker as to how a matter is to be provided for.[23]

---

[17] *Skyline Enterprises Limited v Queenstown Lakes District Council* [2018] NZEnvC 242 at [121] (Interim Decision). See also final decision *Skyline Enterprises Limited v Queenstown Lakes District Council* [2019] NZEnvC 26.

[18] *Skyline Enterprises Limited v Queenstown Lakes District Council* (ENV-2018-CHC-14).

[19] *Skyline Enterprises Limited v Queenstown Lakes District Council* (ENV-2018-CHC-14).

[20] *West Coast Environmental Network v West Coast Regional Council* [2013] NZEnvC 178 at [40].

[21] *West Coast Environmental Network v West Coast Regional Council* [2013] NZEnvC 178 at [43].

[22] *West Coast Environmental Network v West Coast Regional Council* [2013] NZEnvC 178 at [46].

[23] Te Korowai o Ngāruahine Trust v Hiringa Energy Limited and Balance Agri-Nutrients Limited [2022] NZHC 2810 at [268].

IMPLEMENTATION OF ADAPTIVE MANAGEMENT IN THE MINING CONTEXT

All mining projects have some degree of uncertainty in regards to outcome and effects, hence there is a need for adaptive management. Adaptive management is a learning-orientated approach to environmental management where uncertainty exists, which may change over time to reflect new information as it becomes available. It is also considered an observation approach.

Adaptive management is identified as an appropriate tool for the mining industry to manage uncertainty with many international industry guidance documents supporting its approach. For instance, the Global Industry Standard on Tailings Management (GISTM) developed by the International Council on Mining and Metals (ICMM, 2020) supports the use of adaptive management and TARPS. The International Network for Acid Prevention (INAP) supports the use of Adaptive Management (INAP, 2009)

As noted above, the Supreme Court considered that the vital part of the of the adaptive management test was the ability for an adaptive management regime to deal with risk and uncertainty. Every mining project should complete a risk assessment to identify operational and closure risks. The risk assessment should consider uncertainty.

THE APPLICATION OF ADAPTIVE MANAGEMENT TO MINING PROJECTS

There are many risks associated with the management of mine-influenced water such as acid and metalliferous drainage (AMD). One common risk is uncertainty. Examples of uncertainty (risk) include:

- The quality and quantity of water flow from mine domains that have the potential for AMD, e.g., toe seepage from a tailings storage facility.
- Contaminant load predictions such as the amount of acidity or other contaminants produced over time from various mine domains.

Generally, the risks associated with AMD can be assessed by an informed risk assessment process. The AMD risk assessment should be based on data obtained from prediction activities (e.g., source hazard characterisation testing) to understand potential effects. The determination of these potential effects (risks) provides the opportunity to consider additional management options that may, or may not, be required. This could include AMD management techniques (engineering controls) such as prevention and minimisation, and if necessary, the control and treatment of AMD.

AMD management plans are acknowledged as a suitable mechanism to explain the necessary engineering controls to mitigate the effects of AMD. They are used widely by industry. Often these plans incorporate adaptive management processes.

Effective adaptive management is supported by understanding the nature and duration of possible events that could occur, monitoring for these events, and then having management options in place should there be variance from the expected condition. This requires:

- Understand the baseline environmental conditions.
- Understand the geoenvironmental hazards (e.g., potential for AMD).
- Understanding the uncertainty associated with the potential project effects.
- Monitoring (i.e., performance monitoring).
- Variance planning.
- Trigger Action Response Plans (TARPs)

Understanding The Uncertainty

Identification of potential AMD risks that could affect the closure of the site, or operational performance are identified in the AMD risk assessment. Minor risks do not generally need adaptive management processes.

Each potential risk should have a range of controls and actions identified in case there is variance from the expected case. Monitoring is required, together with assigned responsibilities. Responsibilities associated with any variance are often managed by a RACI matrix (Responsibility, Accountability, Consulted, Informed).

Monitoring Of Key Risks

Monitoring of performance is critical to help identify early departure from the expected case. Performance monitoring is an early warning system to enable a timely response to develop and implement other management options to manage the change. Monitoring should be specific to the risk and the duration of the risk. Performance monitoring is divided into leading and lagging indicators. For instance:

- Leading performance monitoring could include monitoring of oxygen content in a waste rock dump to ensure paddock dumped lifts are excluding oxygen as per the design.
- Lagging performance indicators could include monitoring of waste rock dump toe seepage water quality to confirm water quality meets expectations (i.e., the expected case).

Variance Planning

Variance from the expected case is common. There needs to be supporting management options to show how such variance will be managed. For key AMD risks, it is necessary that the following processes relating to AMD uncertainty are considered.

- A range is determined such that there is confidence in the conservative and optimistic model bounds;
- The expected case, the most reasonable estimate, sits within these model bounds; and
- Management options are available for the proposed range to achieve agreed operational and closure criteria.

This range of management options can be referred to as the “adaptive management regime” and needs to be acceptable to both internal and external stakeholders.

Figure 1 provides an illustrative example of the adaptive management regime for AMD impacted waters at a mine site. It provides a clear graphic for explaining to stakeholders how variance will be managed as part of a learning-orientated approach (with time) to environmental management where uncertainty exists.

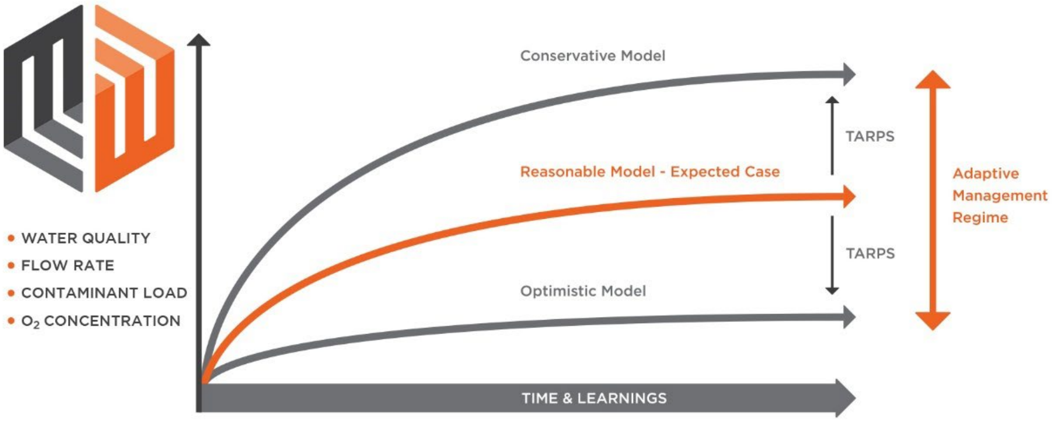


Figure 1: Adaptive Management Regime

Trigger Action Response Plans

Almost any variance from the expected case can be managed by TARPS. The number of TARPs is based on the risk assessment process to ensure potential higher risk effects have management options in place. Generally, a TARP has set trigger limits for performance monitoring data to define what a significant change is, and then describes the actions to respond to the variance. TARPs need to be developed to cover the adaptive management regime. Examples of this include:

- Reconciliation of waste rock block model material volumes versus mined material quantities.
- Waste rock placement verification to ensure design methodologies are achieved.
- Performance monitoring of waste rock dumps for oxygen content and net percolation rates.
- Monitoring of AMD discharge (rates and quality).
- Performance monitoring of treatment system effluent quality against design expectations.

The use of TARPS provides the framework to manage uncertainty in a manner that makes stakeholders (internal and external) more comfortable that solutions are available and are ready to be implemented if there is variance from the expected case. Done effectively, consistently, and by adapting to new learnings the approach will fundamentally support successful AMD management.

TARPS are secured by robust conditions of consent. TARPS provide for ongoing monitoring with triggers that alert the applicant to any variances or potential non-compliances with a set environmental bottom line. TARPS often contain “performance limits” which are distinct from “compliance limits” which are more appropriately located in conditions of consent.

Performance limits should be considered organic and will require review and updating as further knowledge is obtained about the project and its potential effects. Furthermore, its likely as the project matures the need for some TARPS will naturally expire once risks are resolved.

Concluding Thoughts - Benefits of Adaptive Management

Adaptive management provides an important and effective mechanism for enabling and appropriately managing the effects of large-scale mining development in New Zealand. Without the benefit of operational flexibility and adaptability provided by an adaptive management approach it is likely that many activities would not be able to commence operations.

Given the nationally and regionally significant nature of the projects that necessitate adaptive management, and the timeframes proposed, adaptive management is anticipated to form an important part of the fast track consenting regime proposed by the Fast-track Approvals Bill (**Bill**).

The Bill provides access to a fast track consenting regime for projects of regional or national significance. If accepted for referral into the fast track regime the projects will be considered by an expert panel. The expert panel's role will be to consider how effects will be managed, seek comments from certain groups, draft conditions and provide a recommendation to the Ministers who are the ultimate decision makers on a project.

As the focus of the expert panels in this process will be on recommending appropriate conditions it will be critical for applicants to ensure conditions around adaptive management are well framed and informed due to this. It will also be critical for applicants to ensure applications are robust and demonstrate there is sufficient baseline knowledge about the receiving environment to support the use of an adaptive management regime. Advisors to the applicants will need to robustly apply the adaptive management test set out by the Supreme Court and consider the minimum criteria required to support adaptive management early in the application process.

It is considered that the use of adaptive management in process provided for in the Bill can be achieved in a way that does not diminish the quality or robustness of decision making.

7. REFERENCES

Bromley CJ, Reeves RR. 2021. Shallow hydrothermal effects of proposed ongoing operation of Wairākei Geothermal Field. Wairākei (NZ): GNS Science. 79 p. Consultancy Report 2021/13.

Rodrigues ASL, Monsarrat S, Charpentier A, Brooks TM, Hoffmann M, Reeves R, Palomares MLD, Turvey ST. 2019 Unshifting the baseline: a framework for documenting historical population changes and assessing long-term anthropogenic impacts. *Phil. Trans. R. Soc. B 374*: 20190220. http://dx.doi.org/10.1098/rstb.2019.0220

APPENDIX C

Mine Waste Management Report Number: J-NZ0488-0011-M-Rev0

RFI: This appendix provides further discuss on pit lake stratification

5 Sir William Pickering Drive, Burnside,
Christchurch 8053, New Zealand

T. +64 3 242 0221
E. admin@minewaste.com.au

MEMORANDUM

Recipient:	Matakanui Gold Limited
From:	Paul Weber– Mine Waste Management Limited
Date:	14 April 2026
Cc:	Simone Hoodhills – Mine Waste Management Limited; Leonardo Navarro – Mine Waste Management
Document Number:	J-NZ0488-011-M-Rev0
Document Title:	Appendix C – FTAA Section 53 Pit Lake Stratification

Mine Waste Management Limited (MWM) has prepared this memorandum as part of the response by Matakanui Gold Limited (MGL) to the Panel's Request for Information (RFI) made under Section 53 of the Fast-track Approvals Act 2024 (FTAA).

This appendix presents the following:

- Mechanisms for pit lake stratification.
- Case studies of pit lake stratification documented at orogenic gold mines in New Zealand.
- Management options should pit lake stratification arise and poor water quality occurs.
- Bendigo-Ophir Gold Project (BOGP) pit lake modelling.

MECHANISMS FOR PIT LAKE STRATIFICATION

Pit lake stratification (e.g., thermal stratification) can have significant impacts on the distribution of potential constituents of concern (PCOC) and other elements in the pit lake water column.

When layers of different densities exist within a pit lake, the water column becomes "stratified," forming distinct horizontal layers that do not easily mix. This physical separation is a critical driver of water quality, as it restricts the exchange of oxygen and dissolved constituents between the surface and the deeper pit water. As illustrated in Figure 7, density gradients are typically established through two primary mechanisms: thermal stratification and chemical stratification.

Thermal stratification is driven by temperature differences. Solar radiation heats the surface layer, making it lighter and more buoyant than the cooler, denser water beneath. This is the dominant process observed at the Globe-Progress Pit Lake and Golden Bar Pit Lake (discussed in the following sections). Lakes that mix fully at least once a year are termed holomictic (Figure 1).

Lower oxygen in the denser lower layer could increase the solubility of some metals/metalloids such as iron (Fe) and arsenic (As). Other processes such as denitrification-nitrification could also be affected. As a result, the deeper waters of a pit lake can have higher concentrations of arsenic or other solutes.

Chemical stratification (Meromixis) is driven by differences in total dissolved solids (TDS). High-salinity groundwater inflows or mineral leaching from pit walls can create a dense, heavy layer at the bottom of the pit (the monimolimnion) that is physically too heavy to be mixed by wind or surface cooling (Figure 1).

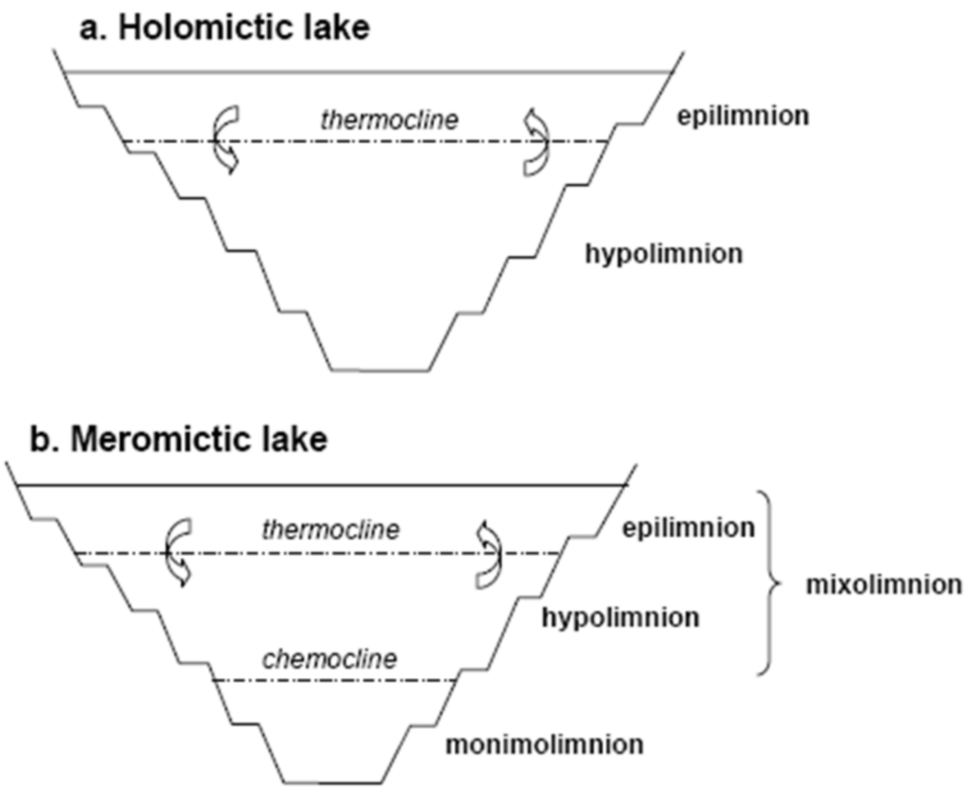


Figure 1: Limnological classifications of stratification and mixing regimes in an (a) holomictic mine pit lake, and (d) a meromictic mine pit lake

Source: Soni et al. (2014).

<u>CASE STUDIES</u>

Seasonal stratification occurrence at orogenic goldmines in New Zealand is documented for the Macraes Gold Mine (Golden Bar Pit Lake) and Globe Progress Mine (Globe Pit Lake). Data are accessed from publicly available information.

Macraes Gold Mine

The Golden Bar pit lake at the Macraes Mine is reported to be 45 m deep and is currently spilling into an un-named tributary of the Golden Bar Creek. Spill started in ~2018, hence the pit lake has undergone numerous seasonal changes. Field campaigns were conducted to assess potential stratification effects for the Golden Bar Pit Lake (MWM, 2024). Key findings include:

- Thermal stratification in the pit lake (Figure 2):
    - In the winter (25/10/2022: red line) there was a slight temperature decrease with depth from 11.2°C (at surface) down to 6.6°C (35 m deep); and

    - in the summer (31/03/2023: (green line) the decrease occurred between 10 - 20 m deep from 12.9°C at the surface down to ~7°C at 20 m depth.

- pH follows a similar trend, decreasing at depth correlating with lower temperatures.
- Arsenic concentration is uniform through winter at different depths (~0.12 mg/L), however in the summer, an increase in concentration is observed with depth up to 0.17 mg/L.
- Sulfate concentration remained constant independent of depth.

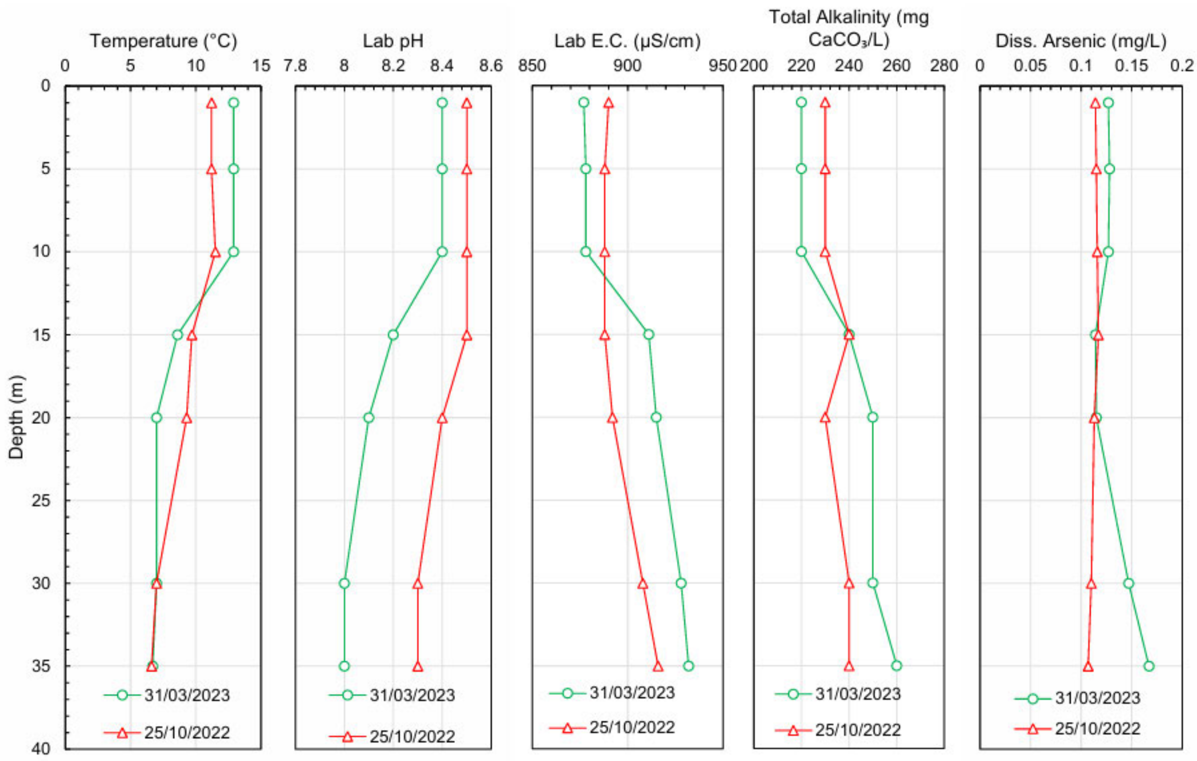


Figure 2: Golden Bar Pit Lake multi-depth analysis results.

Source: MWM (2024).

These data (2 datapoints) suggest seasonal stratification risks, but during winter the thermocline dissolves and the pit lake equilibrates.

Globe Progress Mine

Previous work has demonstrated thermal stratification within the Globe Pit Lake during warmer months and full mixing of the water during the winter as thermal stratification ceases and the thermocline layer thickness gradually decays. A temperature profile is provided in Figure 3 (Hayton et al., 2020).

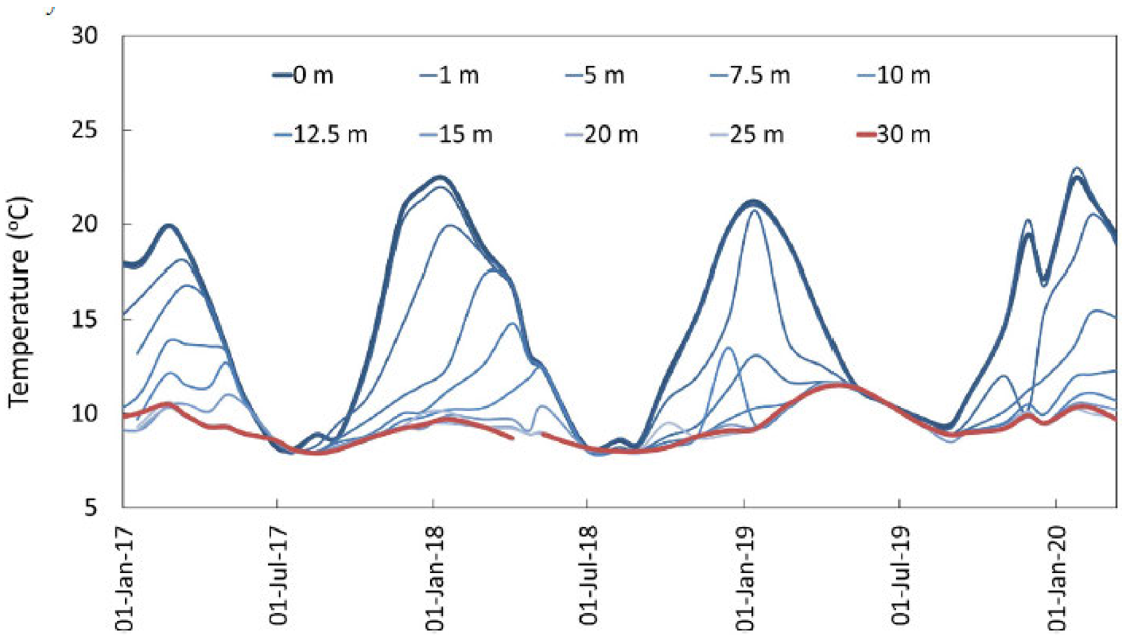


Figure 3: Globe Lake temperature stratification monitoring data.

Source: Hayton et al. (2020).

MANAGEMENT OPTIONS

Documented management options if pit lake stratification persists include:

- Aeration / mixing options for the pit lake prior to dewatering.
- Dosing with $FeCl_3$ to remove As.

Aeration / Mixing

Oxidation is a common approach for the treatment of waters discharging from suboxic / reduced environments (e.g., seepage from the ELF, underground workings, etc.) impacted by Fe and As. The oxidation treatment process involves aerating water (to increase the dissolved oxygen content), which allows Fe^{2+} to oxidise to Fe^{3+} and form $Fe(OH)_3$ precipitates. Aeration is a common technology used to remove sulfide (HS^-) from water. The following physical aeration systems are available to increase aeration:

- A trompe utilises falling water to compress air, drawing air into a vertical downpipe as water flows through an airhead (Leavitt et al., 2015).
- Mechanical aeration systems or pumping of deep water to surface to reduce stratification (e.g., Sánchez-España et al., 2020).
- Bubble diffusers (or similar) generate high surface area air particles to allow sufficient chemical oxidation of sulfide and ammoniacal nitrogen. Fine bubble diffusers create fine bubbles by pushing air through tiny holes in the diffuser plate, resulting in a large water-air interface and high oxygen transfer rate (Dorman, 2019).

Ferric Chloride Addition

Additon of ferric chloride ($FeCl_3$) to pit lakes can be used to treat arsenic impacted waters. Arsenic removal through $FeCl_3$ addition is documented by in-pit dosing at Globe-Progress Lake resulting in decreased As load through co-precipitation / adsorption onto hydrous ferric oxides (HFO). Monitoring at the Globe Pit Lake indicates decrease in As load after ferric dosing (Figure 4).

Navarro et al., (2022), estimate a decrease in 2,156 kg of arsenic over the three events indicated in Figure 4: two $FeCl_3$ dosing events and a "spillway rock mixing" event where a significant amount of rock and sediment were pushed in to the pit lake.

Monitoring data for arsenic concentration to assess stratification are provided in Figure 5. Data indicate stratification trends for arsenic (as observed for temperature in Figure 3) were minimised during the summer months after $FeCl_3$ dosing.

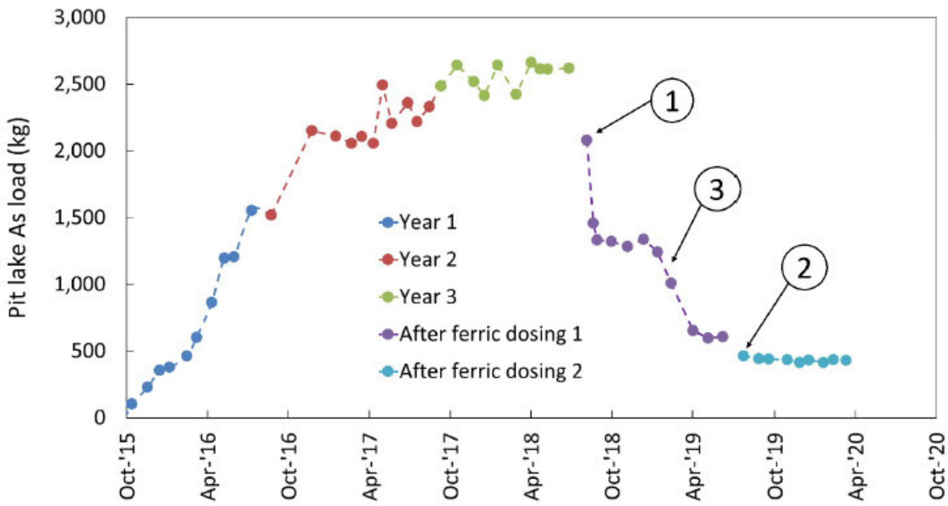


Figure 4: Globe-Progress Pit Lake arsenic load tracking.

Source: Hayton et al. (2020). Ferric dosing indicated by (1) and (2). Event (3) indicates a period of "spillway rock mixing" due to earthworks.

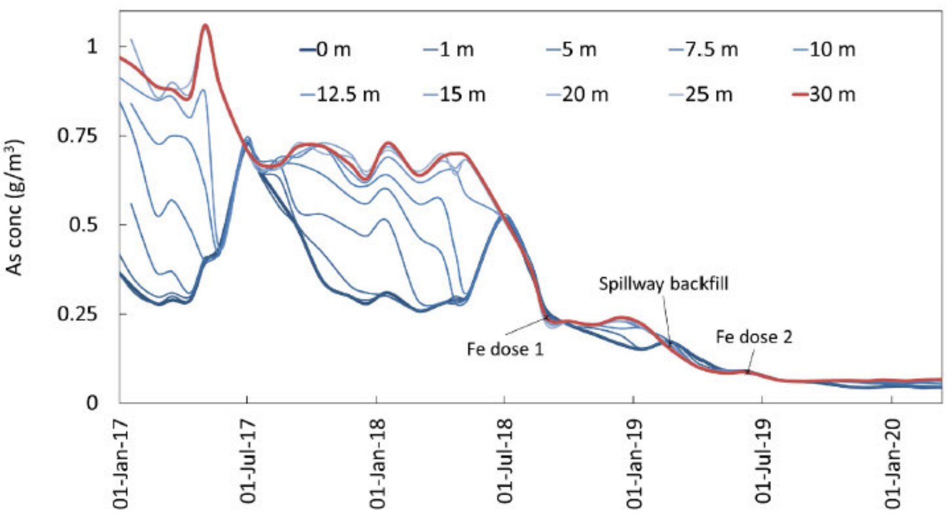


Figure 5: Globe-Progress Pit Lake arsenic concentration stratification modelling.

Source: Hayton et al. (2020).

MODELLING APPROACH AND DISCUSSION

It is assumed that some stratification may occur for the RAS Pit Lake during summer months, however, on an annual basis this stratification will break down in winter as documented at other orogenic gold mines in New Zealand. It is a reasonable comparison to use Macraes as an analogue site for stratification effects due to similar lithologies and mineralisation style; structurally controlled gold mineralisation within Otago Schist greenschist facies host rock.

Source terms are largely derived from modelling of empirical data from Macraes using a data set that span over two decades (MWM, 2025a). Site specific BOGP data is included in the modelling process including leachate data from column leachate testing (MWM, 2025b). It is reasonable to expect that pit lake water quality for RAS Pit at BOGP will be comparable to the larger pits at Macraes (e.g., Frasers Pit) once developed to maximum footprint and depth.

RAS Pit Lake receives input from three inflows: groundwater, pit wall runoff, and rainfall. Of these, only groundwater and pit wall runoff contribute significant solute loads. The water quality results for selected parameters are show in Figure 6 and Figure 7.

The pit wall runoff source term is held constant throughout the model duration to ensure a conservative estimation of mass loading. In reality, sulfide minerals that release potential constituents of concern such as As and SO_4, typically decay over time. This depletion of reactive mass is often represented by the decay term $(m/m0)^n$ where *m* is the remaining sulfide mass, *m0* is the initial mass, and *n* is an exponent typically being 0.67 for sulfides (assuming spherical particles). While integrating kinetic decay or geochemical maturation (via software such as PHREEQC) might provide more 'realistic' results, assuming no exhaustion represents the worst-case scenario. By maintaining constant concentrations, the model intentionally disregards the natural decline in mineral reactivity, providing a conservative estimate of long-term water quality.

Furthermore, the current source term does not account for secondary attenuation processes, such as mineral precipitation or sorption, which would naturally reduce the dissolved contaminant load.

The risk of the water body developing anaerobic (anoxic) conditions within the lower layers (the hypolimnion) is explicitly acknowledged. Further studies may be necessary once site-specific data are available.

However, rather than attempting to model these complex dynamics with no site-specific data, the project focuses on identifying management and mitigation options to address any effects.

The adaptive management approach ensures that potential environmental effects are addressed through performance monitoring and proven engineering controls (see Management Option section) rather than relying on uncalibrated theoretical simulations. As the project transitions from feasibility studies to the operational phase, the increased resolution of monitoring data will provide the necessary evidence to refine these management strategies and, where appropriate, implement more sophisticated predictive tools for the pit lake model.

More detailed modelling has been undertaken for the Waihi Pit Lake (Hydronumerics, 2018). Such studies could be undertaken during the Operational Phase of the BOGP to confirm the expected pit lake water quality to support closure planning.

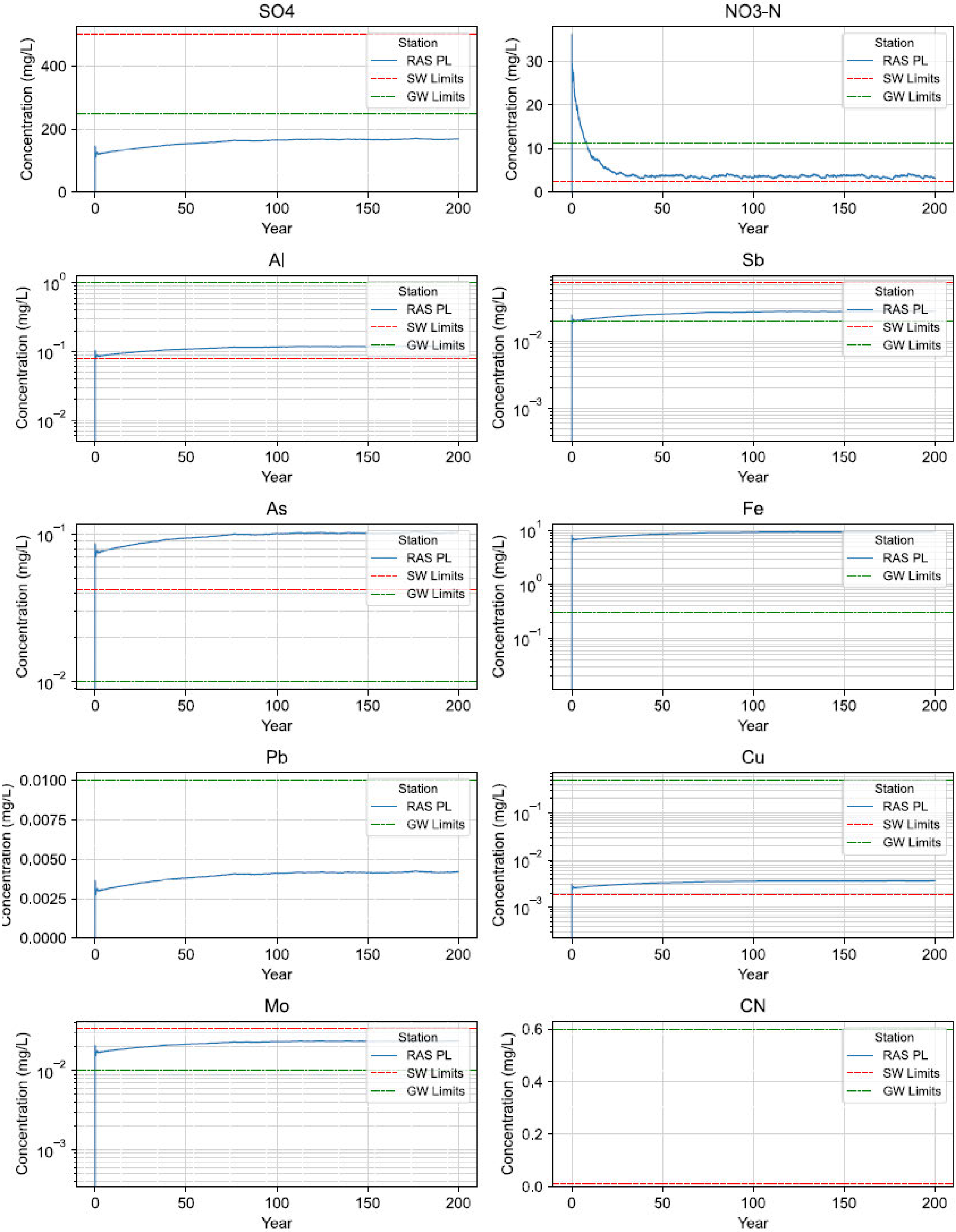


Figure 6: RAS pit lake water quality results. Part 1 or 2.

Source: MWM (2025a).

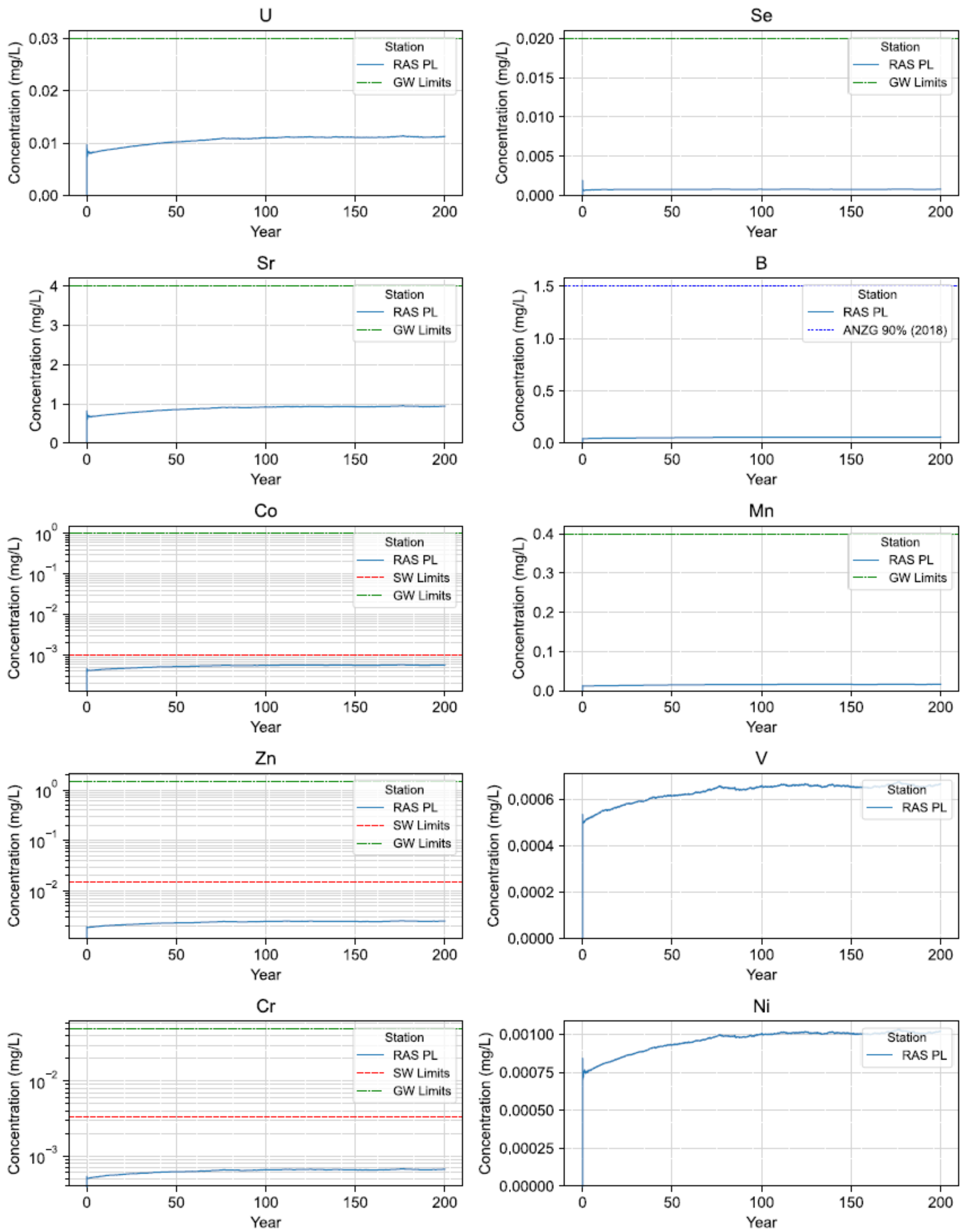


Figure 7: RAS pit lake water quality results. Part 2 or 2.

Source: MWM (2025a).

SUMMARY

The following summary is provided:

- Annual pit lake stratification is expected in the proposed pit lakes at the BOGP. Multi-year stratification is not anticipated. However detailed pit lake modelling could be undertaken to validate this assumption and confirm the risk is not present.
- Management options are available if pit waters become elevated in solutes. This includes oxidation of bottom waters to precipitate reduced compounds and ferric dosing to remove As (and potentially other metals) if concentrations are elevated.
- Modelling uses the average water quality data. With discharge from the RAS pit lake through the pit floor, during the winter months when stratification is higher the dissolved solute load could be higher as there is no rainfall dilution. In addition, in a lower oxygen environment at the bottom of the RAS pit lake, dissolution of redox sensitive metals could also occur (e.g., As and Fe) that could increase concentrations.
- A detailed pit lake model could be undertaken once further information is available that considers stratification effects, nutrient cycling, redox sensitive metals, and revised source terms.

REFERENCES

Dorman, D., 2019. The Role of Solar-Powered Float-Mix Aerators on Iron Retention in Passive Treatment Oxidation Ponds. MSc Thesis. University of Oklahoma. 149 pp.

Hayton, S., Olds, W., Matheson, L., Wu, C., Ross, D., Nyenhuis, J., Williams, M., & Weber, P., 2020. Globe Progress Pit Closure Planning. Planning for Closure 2020. 3rd Internation Congress on Planning for Closure of Mining Operations.

HydroNumerics, (2018). Scoping Study of Water Quality – Nutrients and Primary Production. Prepared for Oceana Gold (NZ) Limited. Project Martha Phase 4 Pit Extension Appendix V: Pit Lake Limnology Assessment (Hydronumerics). Available: https://www.waihigold.co.nz/uploads/documents/project-martha/Appendix-V-Pit-Lake-Limnology-Assessment_Hydronumerics.pdf?_cchid=7e50e741da614bed5f2ac2fbf9e83857

Leavitt, B., Page B. J., Mahony R. M., Danehy. T. P., Neely C. A. and Dunn M. H., 2015. TROMPE: From The Past Will Come the Future. Summary Final Report. Cooperative Agreement S11AC2033. Applied Science Program, U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement, 46 pp.

MWM, 2024. Macraes Mine Phase 4.3: Environmental Geochemistry Assessment – OceanaGold Macraes Mine Site. Mine Waste Management Report J-NZ0229-004-R-Rev0. Sourced from: https://www.orc.govt.nz/media/rniji3w2/appendix-8-mwm-2024-macraes-mine-phase-43-environmental-geochemistry-assessment.pdf

MWM, 2025a. Water Load Balance Model Report – Bendigo-Ophir Gold Project. Mine Waste Management Report: J-NZ0233-016-Rev1. (B.06C Mine Waste Management Limited - Mine Impacted Water Overview Report – Appendix I to O).

MWM, 2025b. Factual Report: Column Leach Test – Bendigo-Ophir Gold Project. Mine Waste Management Report: J-NZ0233-015-Rev3. (B.06B Mine Waste Management Limited - Mine Impacted Water Overview Report – Appendix H).

Navarro, L., Hayton, S., Williams, M. and Weber, P., 2022. Globe Progress Lake–Closure Performance Monitoring and Adaptive Management. IMWA 2022 Proceedings.

Sánchez-España, J., Yusta, I. and Boehrer, B., 2020. Degassing pit lakes: Technical issues and lessons learnt from the HERCO2 project in the Guadiana Open Pit (Herrerías Mine, SW Spain). Mine Water and the Environment, 39(3), pp.517-534.

Soni, A., Mishra, B., & Singh, S., 2014. Pit lakes as an end use of mining: A review. Journal of Mining and Environment, 5(2), 99-111.

APPENDIX D

Mine Waste Management Report Number: J-NZ0488-0012-M-Rev0

RFI: This appendix provides additional sensitivity modelling for the pit lakes.

Response: Please see the attached Memorandum for pit lake scenario modelling.

5 Sir William Pickering Drive, Burnside,
Christchurch 8053, New Zealand

T. +64 3 242 0221
E. admin@minewaste.com.au

MEMORANDUM

Recipient:	Matakanui Gold Limited
From:	Paul Weber– Mine Waste Management Limited
Date:	16 April 2026
Cc:	Leonardo Navarro – Mine Waste Management
Document Number:	J-NZ0488-012-M-Rev0
Document Title:	ELF Seepage Peak Concentrations and Pit Lake Scenarios

Mine Waste Management Limited (MWM) has prepared this memorandum as part of the response by Matakanui Gold Limited (MGL) to a Request for Information (RFI) for the Fast-track Approvals Act 2024 (FTAA) application.

This appendix presents the following:

- Peak ELF seepage predicted concentrations.
- Pit Lake Scenarios Results for a modified pit wall source run-off.

PEAK ELF CONCENTRATIONS

Peak ELF seepage concentrations are summarised in Table 1, with the detailed derivation of these source terms presented in MWM (2025a). These generated source terms are used in the Water and Load Balance Model (MWM, 2025b).

Table 1: Peak ELF Source Term Concentrations (with oxygen exclusion)

PARAMETER	SW REF LIMIT	GW REF LIMIT	SHEPHERDS	SRX	WELF	CIT BACKFILL	SCK FILL
			ELF - 20 M MODEL	ELF - 20 M MODEL	ELF - 20 M MODEL	ELF - 20 M MODEL	WRS
			YEAR 27	YEAR 5	YEAR 10	YEAR 5	YEAR 5
Al	0.08	1	0.0035	0.0033	0.0036	0.0032	0.0031
B	-	-	1.378	0.418	0.401	0.462	0.072
Co	0.001[a]	1	**0.1718**	**0.0449**	**0.0871**	**0.029**	**0.0156**
Mn	-	0.4	**0.9529**	**0.5755**	**1.0979**	**0.4259**	0.2757
Mo	0.034	0.01	**1.2953**	**0.6579**	**0.9763**	**0.6041**	**0.2425**
NO3-N	2.4[b]	11.3	**78.36**	**21.11**	**36.45**	**15.73**	**6.52**
Sb	0.074[a]	0.02	**3.3105**	**2.173**	**4.536**	**1.444**	**1.143**
Se	-	0.02	**0.1712**	**0.1111**	**0.2342**	**0.0727**	**0.0588**
SO4	500	250	**1102**	**646**	**1275**	**430**	**327**
Sr	-	4	**15.73**	**14.44**	**14.26**	**13.03**	**11.95**
U	-	0.03	**0.341**	**0.179**	**0.339**	**0.132**	**0.082**
Zn	0.015	1.5	**0.0155**	0.004	0.0079	0.0026	0.0014
V			0.1398	0.082	0.1708	0.0542	0.0421
Cr	0.0033[c]	0.05	0.00019	0.00019	0.00019	0.00018	0.00018

Units in mg/L

a: Chronic value is used for reference.

b: Annual median used for NO3-N

c: Cr(III) recommended compliance limit is used.

*Bold **red text** indicates values greater than the GW and SW reference limit.*

*Bold **orange text** indicates values greater than the SW reference limit.*

*Bold **purple text** indicates values greater than the GW reference limit.*

PIT LAKE SCENARIOS RESULTS

To account for the variability of pit wall source terms and their subsequent release into the pit lake, three simulation scenarios were developed using different reference sulfate (SO_4) concentrations (measured in mg/L):

- Scenario 1 (PitWall SO4 = 160): Utilises the mean concentration of the Frasers Pit. The detailed construction of this source term is presented in MWM (2025b) and was the primary term applied in the MWM (2025c) assessment model.
- Scenario 2 (PitWall SO4 = 320): Applies the 95th percentile of the same Frasers Pit dataset, constructed using an identical methodology and dataset as the first scenario.
- Scenario 3 (PitWall SO4 = 720): Incorporates the Golden Bar Pit Wall Runoff source term, which was recently made publicly (MP4.3 Macraes Application). This term was based on an approximately 25-year data record from the Golden Bar Pit Lake (MWM, 2024).

Table 2: Source terms utilised as an input in the RAS and SRX Pit Lake Models.

	BOGP PIT WALL RUNOFF SOURCE TERM (MWM, 2025)		GOLDEN BAR (MWM, 2024) PIT WALL RUNOFF
SCENARIO	PitWall SO4 = 160	PitWall SO4 = 320	PitWall SO4 = 720
PARAMETER	MEAN	95TH PERCENTILE	CALIBRATED RUNOFF
Alkalinity	61.3	140.5	572.5
(mg $CaCO_3$/L)			
pH (pH units)	8.2	8.4	8.37
EC (µS/cm)	566	1037	-
Ca	55	93	190.3
Cl	13	20	15.6
F	0.21	0.83	-
Mg	37	78	186.4
Na	33	59	32.4
K	3.9	7.1	11.2
TOC	-	-	-
Al	0.114	0.24	-
As	0.093	0.36	0.409
B	0.046	0.104	-
Cd	0.0001	0.0001	-
Co	0.0005	0.001	-
Cr	0.0005	0.0005	-
Cu	0.0034	0.0082	0.001
Fe	9.1[1]	21	0.065
Mn	0.014	0.039	-
Mo[1]	0.023	0.045	0.223
Ni	0.0009	0.003	-
Pb	0.004	0.01	0.0003
Sb	0.027	0.14	0.008
Se	0.00025	0.00025	-
Sr	0.91	1.84	-
Tl	0.00025	0.00025	-
U	0.0106	0.0162	-
V	0.0005	0.0005	-
Zn	0.002	0.007	0.005
Sulfate	160	320	718.9
Ammoniacal-N	10	10	0.038
Nitrate-N	30	30	0.019

Source: Blue cells from Golder (2011d) – Appendix E

1.- Molybdenum has been introduced into the PitWall SO4 = 720, based on the sulfate relationship (latest column leach test (CLT) data; MWM 2025c) given the identified potential risks for water quality. Future sensitivity modelling will use updated CLT data for all parameters.

It should be noted that the source term concentrations are modelled as fixed values, assuming no solute decay over time (i.e., a decline in weathering rates). In reality, the concentrations of certain elements, particularly those associated with sulfides, such as arsenic (As) and sulfate (SO_4), are expected to decay over the model timeframe. Although the precise rate of this decay is undefined, applying constant concentrations represents a conservative assumption for long-term modelling (e.g., 200 years).

The simulated concentrations for SO_4, As, Mo, and Sb, are presented in Figure 3 for the RAS Pit Lake, and Figure 4 for the SRX Pit Lake. The following key observations can be drawn:

RAS Pit Lake (Figure 3):

- **Source Term Convergence:** Long-term concentrations for all parameters converge toward their respective fixed source term values. This pattern is likely driven by the large surface area of exposed pit walls relative to the lake volume, even when the pit lake reaches its stable level.
- **Molybdenum (Mo) Input:** The Mo data for the PitWall SO4 model has been updated using the Mo:SO_4 relationship defined in the MWM Column Leach Test report as Mo is identified as key constituent of concern.

SRX Pit Lake (Figure 4):

- **Dilution Effects:** Overall solute concentrations are lower in SRX Pit Lake than those observed in the RAS Pit Lake. This is primarily attributed to a lower ratio of exposed pit wall area relative to the lake surface, which reduces solute ingress while maximising dilution from direct rainfall. Additionally, a higher rate of groundwater inflow provides further dilution.
- **Sulfate Compliance:** Across all simulated scenarios, SO_4 concentrations remain consistently below approximately 150 mg/L.
- **Decaying trend**: A distinct decaying concentration pattern is observed for Mo, Sb, and to a lesser extent, SO_4. This trend is driven by the inflow and gradually decreasing source concentrations of the SRX ELF seepage entering the SRX Pit Lake.

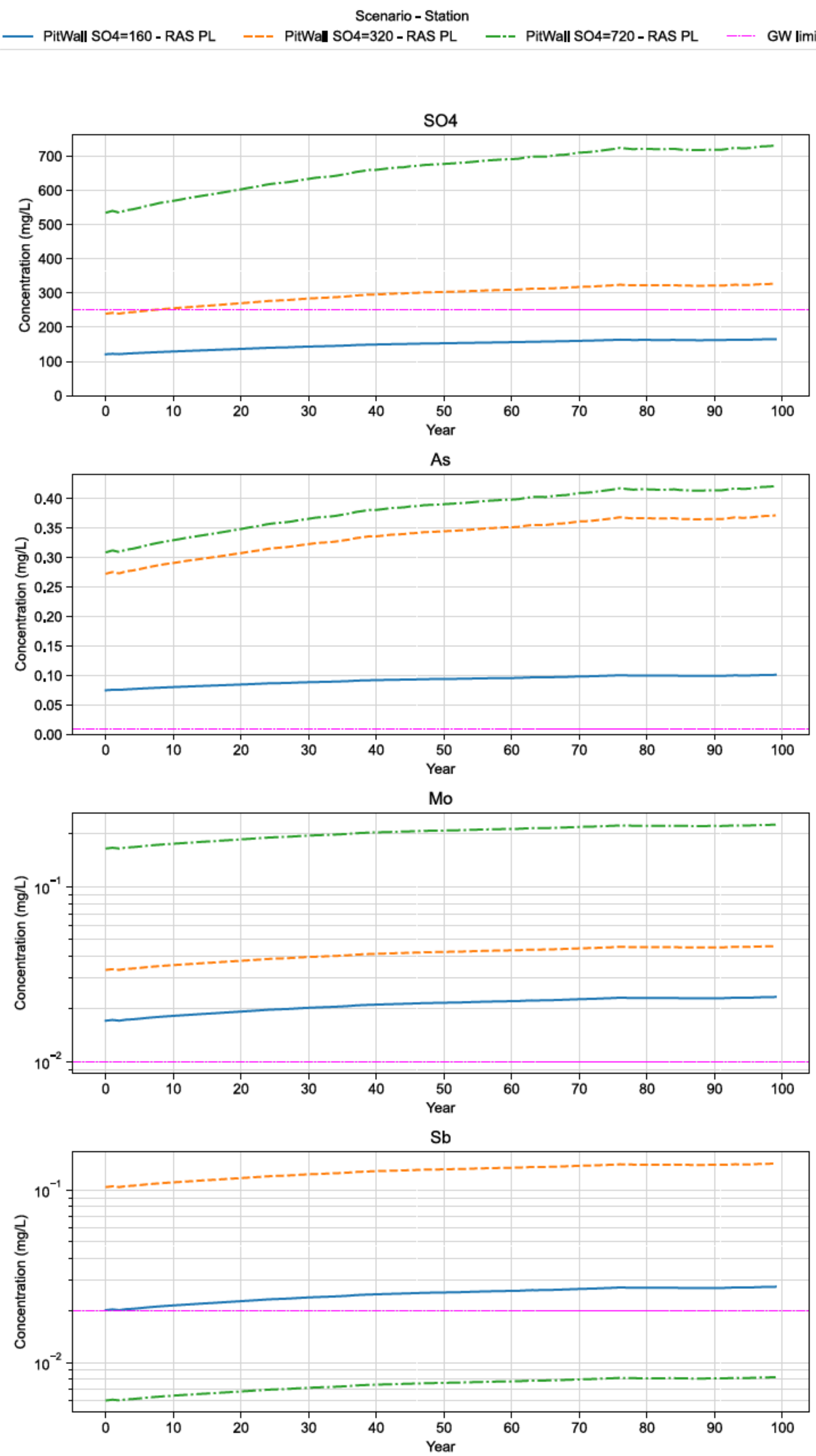


Figure 1: Comparison of scenario model results of the RAS Pit Lake.

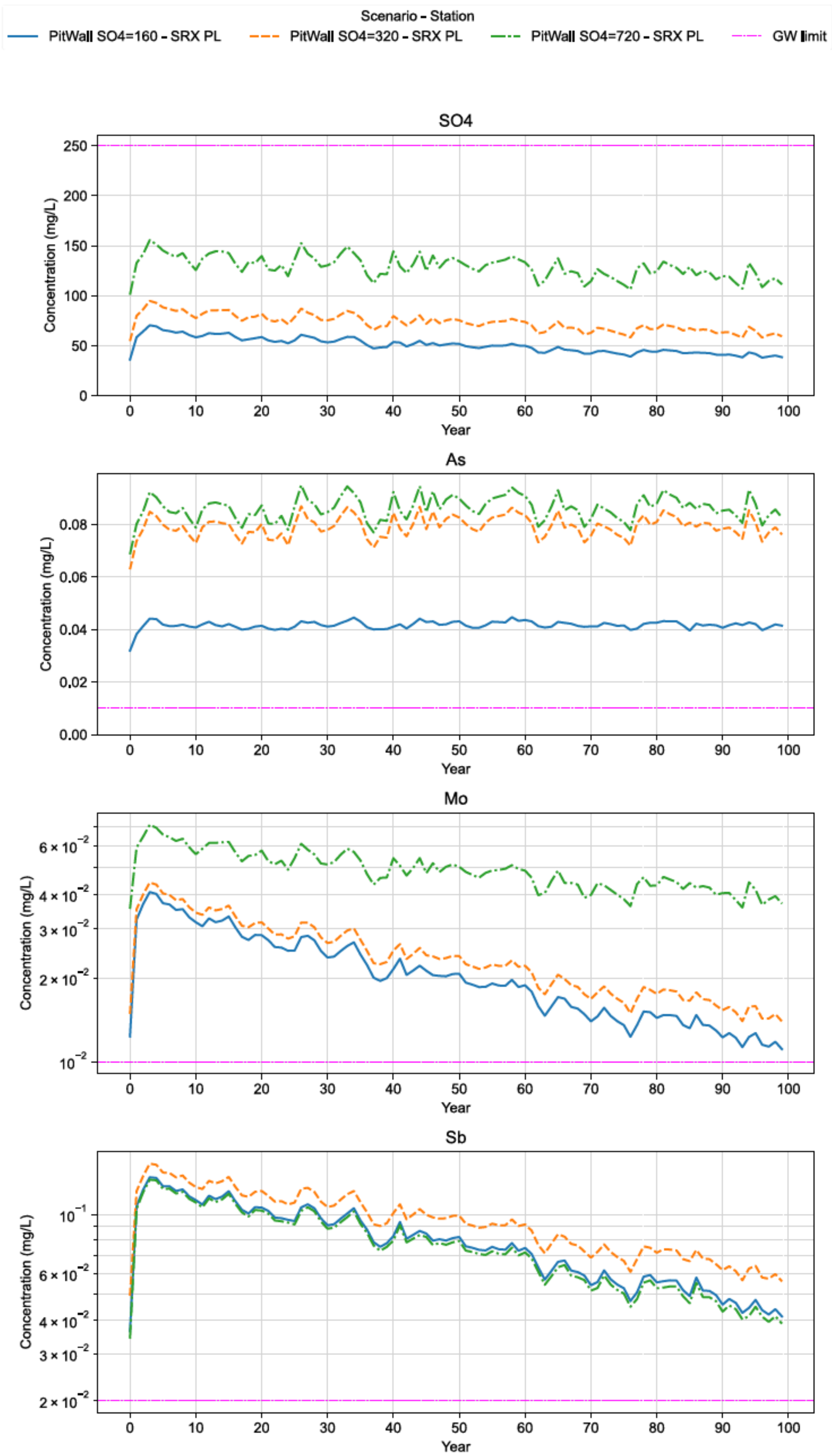


Figure 2: Comparison of scenario model results of the SRX Pit Lake.

CONCENTRATIONS AT SC01 AND RS03

The simulated concentrations at monitoring locations SC01 and RS03 for the passive water treatment scenarios are presented in Figure 5 and Figure 6, respectively. The following observations can be made:

Monitoring Point SC01:

- Differences between the modelled scenarios becomes noticeable around year 25, which coincides with the pit lake beginning to flow to SC01 through the RAS underground portal.
- While arsenic concentrations are slightly higher under the higher sulfate scenarios, the overall material impact is minor. Similarly, variations Sb are negligible.
- Molybdenum is noticeably higher in the PitWall SO4 = 720 Scenario with the model forecasting an single exceedance of proposed water quality limits at year 85.
- SO_4 concentrations exhibit the most significant response to the varying source terms. From an operational perspective, the PitWall SO4 = 720 scenario indicates that active water treatment will need to be maintained for an extended duration, until SO4 concentrations decrease below the 250 mg/L compliance threshold (projected at year 86).

Monitoring point RS03:

- The varying source terms produce no significant impact at this location. Although minor concentration increases are observed over time, they remain below proposed water quality limits.

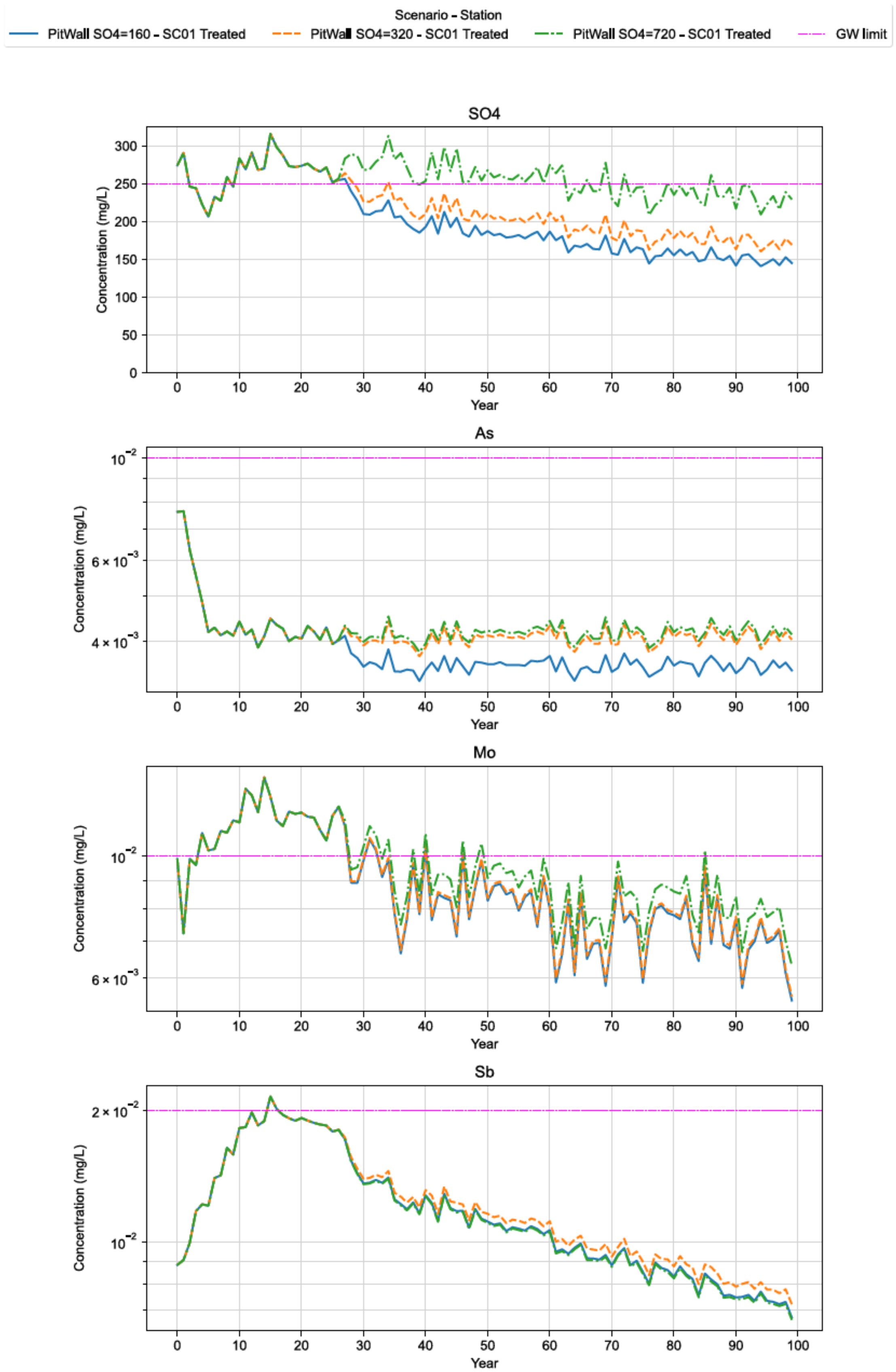


Figure 3: Comparison of scenario model results at SC01.

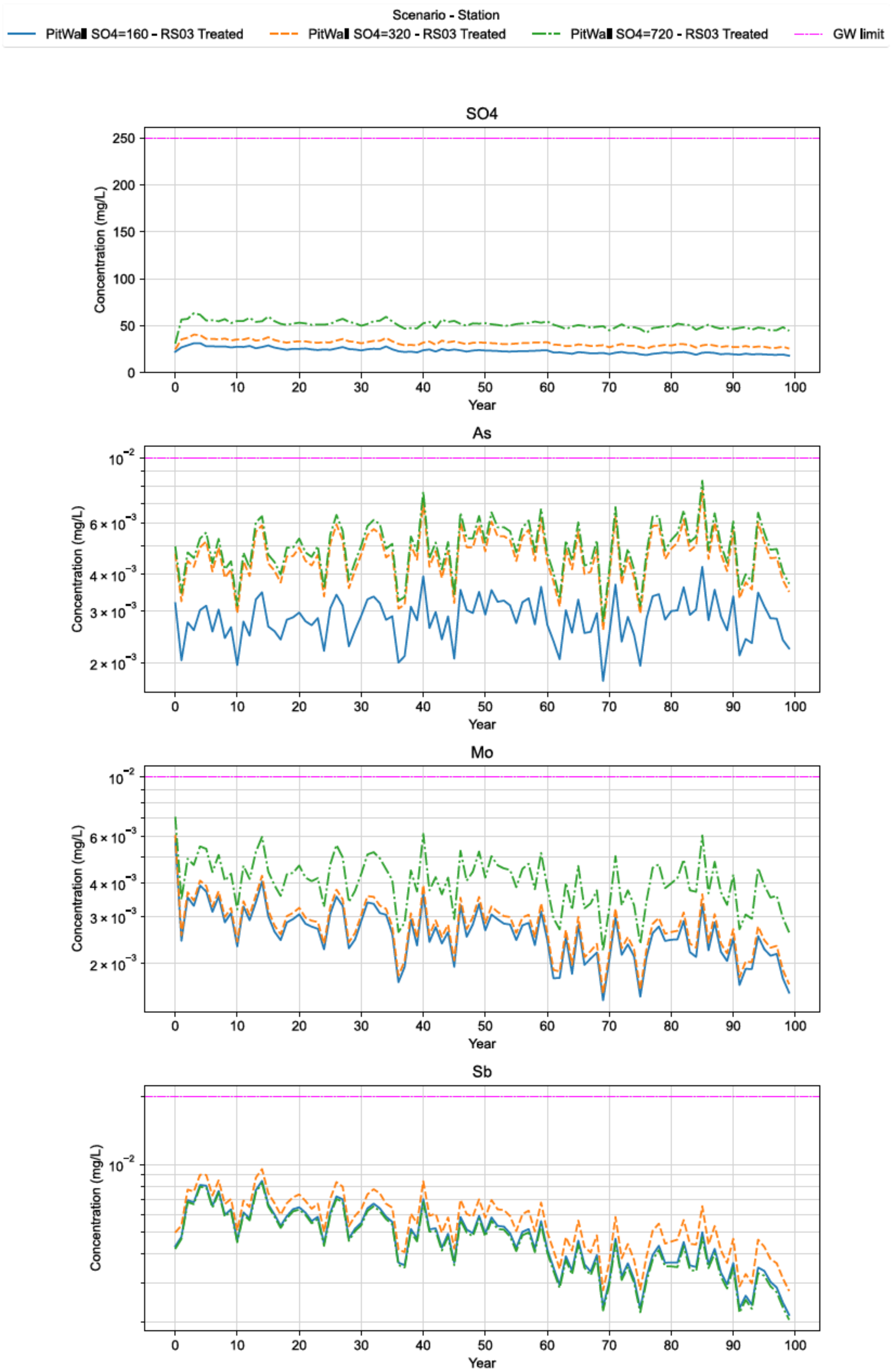


Figure 4: Comparison of scenario model results at RS03.

PIT LAKE MODEL SUMMARY

This memorandum assesses scenario models for BOGP pit lake water quality under three variable pit wall runoff scenarios (SO_4 = 160, 320, and 720 mg/L). Scenarios 1 and 2 utilise baseline and 95th-percentile data from the analogous site (Macraes, Frasers Pit Lake, Golder, 2011, Appendix-E), while Scenario 3 applies a more recent publicly available source term from the Golden Bar Pit Lake at Macraes (MWM, 2024). The model assumes fixed source concentrations with no decay over time.

Key Findings:

- Pit Lakes (RAS & SRX): RAS long-term concentrations converge towards their source limits due to high relative pit wall exposure. Conversely, SRX benefits from greater dilution and depleting ELF seepage inputs, resulting in lower overall concentrations and consistent SO_4 recommended compliance limits (<150 mg/L).
- SC01: Scenario divergence occurs around Year 25. While variations in As, Mo, and Sb remain negligible across all scenarios, the PitWall SO4 = 720 case would necessitate active water treatment until approximately Year 90 to naturally stabilise below the 250 mg/L compliance limit.
- RS03: Varying source terms have a negligible impact at this location, with all concentrations remaining well within acceptable thresholds and posing no risk of exceedance.

REFERENCES

MWM, 2024. Macraes Mine Phase 4.3: Environmental Geochemistry Assessment – OceanaGold Macraes Mine Site. Mine Waste Management Report J-NZ0229-004-R-Rev0. Sourced from: https://www.orc.govt.nz/media/rniji3w2/appendix-8-mwm-2024-macraes-mine-phase-43-environmental-geochemistry-assessment.pdf

MWM, 2025a. Engineered Landform Water Quality Forecast Model Report – Bendigo-Ophir Gold Project. Mine Waste Management Report: J-NZ0457-002-Rev1. (B.06C Mine Waste Management Limited - Mine Impacted Water Overview Report – Appendix H).

MWM, 2025b. Water Load Balance Model Report – Bendigo-Ophir Gold Project. Mine Waste Management Report: J-NZ0233-016-Rev1 (B.06C Mine Waste Management Limited - Mine Impacted Water Overview Report – Appendix N).

MWM, 2025c. Source Term Definition Report – Bendigo-Ophir Gold Project. Mine Waste Management Report: J-NZ0475-001-Rev2 (B.06C Mine Waste Management Limited - Mine Impacted Water Overview Report – Appendix I).

MWM, 2025d. Factual Report: Column Leach Test – Bendigo-Ophir Gold Project. Mine Waste Management Report: J-NZ0233-015-R-Rev3 (B.06B Mine Waste Management Limited - Mine Impacted Water Overview Report – Appendix H)

APPENDIX E

Mine Closure Management Report Number: J-M-NZ0005-001-L-Rev0

RFI: This appendix provides an explanation of what the field trials would involve.

MINE CLOSURE MANAGEMENT
GREENROAD GROUP

5 Sir William Pickering Drive, Burnside
Christchurch 8053, New Zealand

T. +64 3 242 0221
E. admin@grmcm.com

15 April 2026 J-M-NZ0005-001-L-Rev0

Cheryl Low
Environment Manager
Matakanui Gold Limited
15a Chardonnay Street
Cromwell, 9310

Bendigo-Ophir Gold Project – Field-Based Cover System Net Percolation Rates to Support the Water and Load Balance Model

Dear Cheryl,

Matakanui Gold Limited (MGL) requires field-based net percolation (or water ingress) rates to forecast solute loading from mined materials at the Bendigo-Ophir Gold Project (BOGP). This document provides guidance for MGL to establish field-based test cover system to estimate net percolation rates to support closure strategies and water quality forecasts.

TEST COVER OBJECTIVES

The current base case cover system design for the BOGP Mine Waste Storage Facilities (MWSFs) consists of a nominally thick 0.2 m layer of topsoil / subsoil placed over a 0.3 m layer of moderately weathered mine rock (brown rock). A field-based test cover system(s) for the BOGP would support the following key objectives:

- Develop a database of field performance monitoring data to calibrate a numerical simulation model (field response model) and optimise cover system design. Groundwater flow occurs due to hydraulic gradients imposed by phreatic surface elevations across the landscape. Similarly, water flow within the unsaturated (vadose) zone occurs in response to hydraulic gradients, albeit the hydraulic gradients are primarily driven by negative pore-water conditions. Measured test cover performance will provide negative pore-water pressure conditions which allows for the calibration of numerical simulation models used to forecast net percolation rates, like phreatic surface elevations are used to simulate groundwater flow.
- Develop an understanding for key physical, biological, and chemical processes that influence performance. Cover system soil-plant-atmospheric finite element numerical models simulate water, heat, and airflow within the vadose zone using an upper and lower boundary condition.
    - Hydraulic properties – Cover system hydraulic properties are typically established based on material texture and mineralogy, laboratory and field tests, and test cover field measurements. This multiphase approach is particularly important for developing vadose zone hydraulic properties given that the saturated hydraulic conductivity is influenced by in-situ structure and density and the effective hydraulic conductivity is a function of negative porewater pressure, with this relationship defined over at least five orders of magnitude (i.e., 0 to 100,000 kPa). The hydraulic properties of the cover system surficial materials have a substantial effect on the partitioning of rainfall into runoff and infiltration and will have a direct influence on net percolation. Surficial hydraulic properties can be influenced by physical (i.e., wet-dry cycles, material texture, clay minerology, etc), biological (i.e., vegetation), and chemical (i.e., dispersity

/ salinity, cations exchange, weathering) processes. Test cover(s) for BOGP would provide for field based hydraulic properties to refine numerical models and field measured water balances to vet the simulated runoff and overall water balance.

- Vegetation cover – Cover system finite element numerical models are used to simulate transpiration, which is a biological process. Vegetation within the model is defined using root and leaf area characteristics and plant limiting function. Transpiration rates from vegetation can be gained through a monitored test cover area and / or analogue vegetation cover areas. Monitored BOGP test cover(s) would provide understanding of measured negative porewater pressure induced by the vegetation cover. This would assist in refining the trajectory of long-term cover performance under a vegetative cover.

TEST COVER LAYOUT CONSIDERATIONS

The field-based test cover(s) should be designed and constructed to capture key processes that influence performance, limit edge or boundary effects, assess construction methods (utilising proposed earthworks equipment envisioned for full-scale earthworks), and meet field resource safety requirements.

Field test covers typically have a footprint in the range of 900 m^2 to 2,500 m^2. This size allows for the installation of multiple monitoring locations, if required, and provides earthworks equipment adequate room to build and traffic/dump/grade the landform. While monitoring systems can be installed after test cover construction is complete, it is beneficial to install the monitoring system in parallel with construction activity to ensure as-contracted conditions are monitored, as opposed having measurements being potentially influenced by the properties of the backfill materials associated with an after-construction sensor installation. Also, the backfill or re-construction of cover layers in an excavation can add additional challenges. As such, the size should enable monitoring system installation to occur concurrently with test cover construction providing safe trafficking distances with field personnel.

The field test cover system will need to consider the MWSF aspects and surface water management to ensure that test cover performance can be scaled up to a landform performance. This means that there may be horizontal and a sloping section and runoff could be restricted. In addition, the waste material below the cover system will influence performance; hence, a test cover may be required, at some point, for waste rock and tailings. However, at an early stage it is proposed that a test cover(s) would be constructed at one Engineered Landform (ELF) location with the measured field performance monitoring data used to inform and optimise the design of a test cover for the other MWSFs (e.g., the tailings storage facility).

TEST COVER OPTIMISATION

The design of field test covers is typically based on some level of understanding for how the cover system will perform, relative magnitude of each water balance component, and factors that influence performance. As such, it is recommended that informative one-dimensional soil-plant-atmospheric numerical simulations would be completed to guide test cover material selection and layer thickness to optimise the current base case cover design. The design of the monitoring system, including direct and indirect measurements, would also be developed based on an understanding of the test cover water balance and ELF landform aspects. Indirect and direct methods of estimating net percolation from field test covers would align with that proposed by Meiers et al.[1] and address any material boundary conditions, in particular those associated with tailings.

As previously noted, physical, chemical, and biological processes will influence the performance of the field test cover system. It is important to document the period over which these processes will evolve and provide changes in performance. This will ensure that the trajectory of cover system performance can be developed. In general, it is recommended that field tests covers are monitored for a period of three to five years. The three-year period typically encompasses the period over which changes in hydraulic properties occur and the vegetation cover starts to develop.

The field response model, based on a foundation of measured water balance data, can then be used to simulate performance under long-term historic climatic. This will provide an understanding for the probability of meeting defined success criteria for net percolation, which is understood to be less than 20% of annual precipitation. The field response model, if required, can be used to simulate performance under various climate change scenarios.

CLOSING REMARKS

This document was prepared to provide high-level field test cover system objectives, design / layout considerations, and initial steps of optimising the field test cover design.

Please do not hesitate to contact Greg Meiers [redacted]) should you wish to discuss the document in further detail.

MINE CLOSURE MANAGEMENT LIMITED

Greg Meiers, P.Geo. M.Eng.
Principal Consultant (Closure)

[1] Meiers G, O'Kane M, and Barbour S, (2009). Measuring net percolation rates for waste storage facility cover systems. Paper presented at the 62nd Canadian Geotechnical Conference 7th, Halifax, NS, Canada, September 20-24.

APPENDIX F

Mine Waste Management Report Number: J-NZ0488-009-M-Rev0

RFI: Set out what changes in relative contaminant mass loads to receiving surface water and groundwater are anticipated post-closure and how these changes have been assessed in terms of effects.

Response: Please see the attached Memorandum.

5 Sir William Pickering Drive, Burnside,
Christchurch 8053, New Zealand

T. +64 3 242 0221
E. admin@minewaste.com.au

MEMORANDUM

Recipient:	Matakanui Gold Limited
From:	Paul Weber– Mine Waste Management Limited
Date:	16 April 2026
Cc:	Simone Hoodhills – Mine Waste Management Limited
Document Number:	J-NZ0488-009-M-Rev0
Document Title:	Panel RFI Comment Number #28

Mine Waste Management Limited (MWM) has prepared this memorandum as part of the response by Matakanui Gold Limited (MGL) to the Panel's Request for Information (RFI) made under Section 67 of the Act on 1 April 2026.

OBJECTIVE

RFI Comment Number #28

Set out what changes in relative contaminant mass loads to receiving surface water and groundwater are anticipated post-closure and how these changes have been assessed in terms of effects.

Note: This memorandum provides a summary of the loads associated with potential constituents of concern (PCOC). It does not discuss effects.

DATA SOURCE

Data are sourced from the following documents submitted as part of the Substantive FTA Application:

- Water and load balance model (WLBM) report[1]
- Baseline water quality report[2]
- Source Term Definition Report[3]

[1] MWM (2025a) Water and Load Balance Model Report: Bendigo-Ophir Gold Project. Available in BC.06C Mine Waste Management Limited - Mine Impacted Water Overview Report – Appendix I to O.

[2] MWM (2025b) Source Term Definition Report: Bendigo-Ophir Gold Project. Available in BC.06A Mine Waste Management Limited - Mine Impacted Water Overview Report – Appendix B to G.

[3] MWM (2025c) Source Term Definition Report: Bendigo-Ophir Gold Project. Available in BC.06C Mine Waste Management Limited - Mine Impacted Water Overview Report – Appendix I to O.

BASELINE LOAD CALCULATION

An annual baseline contaminant load was estimated by applying the mean flow rate to the baseline water quality concentrations.

The following flow rates were applied from estimated flows as detailed in the WLBM (MWM, 2025a) (Table 1):

- SC01 – 18 L/s
- RS03 – 12 L/s

Table 1: Forecast creek flow summary statistics.

	PEAK FLOW (L/s)	MEAN FLOW (L/s)	MEDIAN FLOW (L/s)	7D MALF (L/s)	5YR-7D LF (L/s)
SC01 Simulated Baseline	176	18	12	2	1
SC01 Simulated Post-Closure	563	29	23	13	11
Change	387 (+220%)	11 (+59%)	11 (+92%)	11 (+535%)	10 (+787%)
RS03 Simulated Baseline	117	12	8	1	1
RS03 Simulated Post-Closure	229	18	14	5	5
Change	113 (+97%)	6 (+52%)	6 (+70%)	4 (+282%)	4 (+426%)

7D MALF = seven day mean annual low flow.
5YR-7D LF is the lowest weekly average flow that has a reoccurrence interval of 1 in 5 years.
Note flow values are rounded to reflect inferred accuracy.
Source: MWM (2025a).

The following baseline solute concentrations were applied as derived from MWM (2025b) for SC01 in Shepards Creek and RS03 in Rise and Shine Creek (Table 2).

Table 2: Surface water quality source terms for SC01 and RS03.

PARAMETERS	SC01 (n=25)	RS03 (n=25)
	AVE (mg/L)	AVE (mg/L)
Alkalinity (mg $CaCO_3$/L)	216.0	39.1
pH (pH units)	8.11	7.42
EC (µS/cm)	488.9	86.4
Ca	60.8	11.1
Cl	6.08	1.33
F	0.103	0.057
Mg	21.3	1.99
Na	20.3	39.5
K	2.01	0.578
TOC	2.08	1.75
Al	0.00454	0.00756
As	0.00239	0.0085
B	0.03304	0.0188

PARAMETERS	SC01 (n=25) AVE (mg/L)	RS03 (n=25) AVE (mg/L)
Cd	0.00010	0.00010
Co	0.00026	0.00025
Cr	0.00056	0.00059
Cu	0.00055	0.00046
Fe	0.01135	0.0375
Hg	0.00026	0.00026
Mn	0.00265	0.0095
Mo	0.00051	0.00033
Ni	0.00035	0.00035
Pb	0.00025	0.00025
Sb	0.00053	0.00050
Se	0.0025	0.0025
Sr	0.947	0.136
Tl	0.00023	0.00023
U	0.0051	0.00012
V	0.0005	0.00050
Zn	0.0017	0.00229
Sulfate	40.5	1.57
Ammoniacal nitrogen	0.0103	0.0092
Nitrate-N	0.083	0.0088
TCN	0.0028	0.0028

Note: Green data are ½ limit of reporting (LOR) and are included in the source term as '0'

ESTIMATED ANNUAL LOAD

Estimated annual PCOC loads from the WLBM are provided in Attachment A:

- From Year 50 at the commencement of passive treatment.
- Data are provided up to Year 199
- Data includes baseline solute loads and PCOC loads due to the proposed BOGP project.

To put the solute load data into perspective, the maximum annual solute load from the BOGP (Attachment A) is applied to median flow rates of the Clutha River and Lindis River. Results provide an estimate of additional concentration change where:

- Median discharge of 279.384 m^3/s for the Clutha River Below Cardrona Confluence monitoring location[4].
- Median discharge of 4.303 m^3/s for the Lindis River at Ardgour Road monitoring location[5].
- Maximum annual load - corresponding to year 85 (Attachment A).

[4] Derived from the Otago Regional Council Environmental Data Portal for Discharge.Hydrotel.NIWA@EM381. Median flow data as reported at 14 April 2026

[5] Derived from the Otago Regional Council Environmental Data Portal for Discharge.Master@EM631. Median flow data as reported at 14 April 2026

Results are presented in Table 3. Data indicates the estimated SO_4 concentration increase is:

- 0.03 mg/Lin the Clutha River.
- 1.7 mg/L in the Lindis River.

Noting these data are for median flow as context and do not consider the effect during drier periods (e.g., mean annual low flow periods).

Table 3: Estimated concentration associated with maximum annual load (year 85) for median flow

PARAMETER	CLUTHA RIVER (SC01 + RS03)	LINDIS RIVER AT ARDGOUR ROAD (SC01)
Median flow m^3/s	279.4	4.3
Al (mg/L)	0.000006	0.0003
As (mg/L)	0.000002	0.00005
Cd (mg/L)	0.00000003	0.000001
Co (mg/L)	0.0000001	0.000003
Cr (mg/L)	0.0000001	0.000005
Cu (mg/L)	0.0000002	0.000006
Fe (mg/L)	0.00005	0.0007
Mn (mg/L)	0.0000032	0.0002
Mo (mg/L)	0.000004	0.0002
NO3-N (mg/L)	0.0001	0.002
Pb (mg/L)	0.00000007	0.000003
Sb (mg/L)	0.000003	0.0001
SO4 (mg/L)	0.03	1.7
Sr (mg/L)	0.0001	0.006
CN (mg/L)	0.0000003	0.00002
U (mg/L)	0.000002	0.0001
Zn (mg/L)	0.0000003	0.00001

CLOSING REMARKS

Please do not hesitate to contact Paul Weber at + 64 3 242 0221 or paul.weber@minewaste.com.au should you wish to discuss in greater detail.

Attachments: Attachment A – SC01 and RS03 Solute Load Estimates

ATTACHMENT A – SC01 AND RS03 SOLUTE LOAD ESTIMATES

Estimated annual contaminant load - SC01

Year	Flow Rate (Mm3/yr)	Al (t/year)	As (t/year)	Cd (t/year)	Co (t/year)	Cr (t/year)	Cu (t/year)	Fe (t/year)	Mn (t/year)	Mo (t/year)	NO3-N (t/year)	Pb (t/year)	Sb (t/year)	SO4 (t/year)	Sr (t/year)	CN (t/year)	U (t/year)	Zn (t/year)
Baseline Estimated/yr	0.568	0.003	0.001	0.0001	0.0001	0.0003	0.0003	0.006	0.002	0.0003	0.047	0.0001	0.0003	23.01	0.54	0.002	0.003	0.001
WLBM Average (year 50 to 199)	0.988	0.019	0.004	0.0001	0.0002	0.0003	0.0004	0.058	0.013	0.0133	0.115	0.0002	0.0078	137.3	0.42	0.002	0.009	0.001
Estimated load by year																		
50		0.017	0.004	0.0001	0.0003	0.0003	0.0004	0.056	0.020	0.0121	0.118	0.0002	0.0109	172.07	0.38	0.002	0.012	0.001
51		0.023	0.005	0.0001	0.0004	0.0005	0.0006	0.067	0.022	0.0168	0.171	0.0003	0.0129	192.74	0.59	0.002	0.015	0.001
52		0.022	0.004	0.0001	0.0003	0.0004	0.0005	0.064	0.021	0.0159	0.151	0.0002	0.0124	187.17	0.51	0.002	0.014	0.001
53		0.018	0.004	0.0001	0.0003	0.0004	0.0005	0.059	0.019	0.0127	0.137	0.0002	0.0107	168.62	0.48	0.002	0.012	0.001
54		0.022	0.004	0.0001	0.0003	0.0004	0.0005	0.063	0.020	0.0166	0.142	0.0002	0.0124	186.11	0.47	0.002	0.014	0.001
55		0.017	0.004	0.0001	0.0003	0.0003	0.0004	0.056	0.019	0.0127	0.116	0.0002	0.0108	168.32	0.39	0.002	0.012	0.001
56		0.023	0.005	0.0001	0.0003	0.0004	0.0005	0.065	0.020	0.0173	0.155	0.0002	0.0125	187.24	0.53	0.002	0.014	0.001
57		0.019	0.004	0.0001	0.0003	0.0003	0.0004	0.061	0.021	0.0146	0.126	0.0002	0.0119	183.02	0.42	0.003	0.013	0.001
58		0.020	0.004	0.0001	0.0003	0.0003	0.0004	0.060	0.020	0.0155	0.118	0.0002	0.0118	180.77	0.38	0.003	0.013	0.001
59		0.025	0.005	0.0001	0.0003	0.0004	0.0005	0.068	0.021	0.0184	0.159	0.0003	0.0130	195.48	0.55	0.003	0.015	0.001
60		0.018	0.004	0.0001	0.0002	0.0003	0.0004	0.057	0.019	0.0132	0.104	0.0002	0.0106	168.69	0.34	0.002	0.012	0.001
61		0.012	0.003	0.0001	0.0002	0.0003	0.0004	0.049	0.016	0.0078	0.095	0.0002	0.0080	138.09	0.35	0.002	0.009	0.001
62		0.011	0.003	0.0001	0.0002	0.0002	0.0003	0.040	0.013	0.0078	0.070	0.0001	0.0067	112.83	0.24	0.002	0.007	0.000
63		0.022	0.004	0.0001	0.0003	0.0004	0.0005	0.055	0.016	0.0164	0.138	0.0002	0.0104	151.01	0.49	0.002	0.012	0.001
64		0.016	0.004	0.0001	0.0003	0.0004	0.0004	0.055	0.018	0.0113	0.119	0.0002	0.0098	153.49	0.44	0.002	0.011	0.001
65		0.023	0.005	0.0001	0.0003	0.0004	0.0005	0.065	0.020	0.0171	0.136	0.0002	0.0124	186.62	0.47	0.003	0.014	0.001
66		0.014	0.003	0.0001	0.0002	0.0003	0.0004	0.049	0.015	0.0090	0.094	0.0002	0.0080	135.05	0.34	0.002	0.009	0.001
67		0.021	0.004	0.0001	0.0003	0.0003	0.0004	0.058	0.017	0.0164	0.123	0.0002	0.0108	161.87	0.42	0.002	0.012	0.001
68		0.016	0.003	0.0001	0.0003	0.0004	0.0005	0.055	0.017	0.0104	0.123	0.0002	0.0088	145.03	0.47	0.002	0.010	0.001
69		0.009	0.002	0.0001	0.0001	0.0002	0.0002	0.038	0.012	0.0061	0.056	0.0001	0.0059	105.24	0.20	0.002	0.006	0.000
70		0.020	0.004	0.0001	0.0002	0.0003	0.0004	0.052	0.014	0.0157	0.115	0.0002	0.0097	142.74	0.40	0.002	0.011	0.001
71		0.024	0.005	0.0001	0.0003	0.0005	0.0006	0.065	0.019	0.0174	0.156	0.0003	0.0117	173.64	0.57	0.002	0.013	0.001
72		0.015	0.003	0.0001	0.0002	0.0002	0.0003	0.048	0.015	0.0107	0.081	0.0001	0.0083	136.23	0.28	0.002	0.009	0.000
73		0.016	0.003	0.0001	0.0002	0.0003	0.0004	0.050	0.014	0.0111	0.106	0.0002	0.0082	132.32	0.39	0.002	0.009	0.001
74		0.014	0.003	0.0001	0.0002	0.0002	0.0003	0.045	0.013	0.0098	0.084	0.0001	0.0074	121.64	0.31	0.002	0.008	0.001
75		0.010	0.002	0.0001	0.0002	0.0002	0.0003	0.038	0.012	0.0063	0.064	0.0001	0.0058	101.68	0.25	0.002	0.006	0.000
76		0.016	0.003	0.0001	0.0002	0.0004	0.0004	0.047	0.013	0.0109	0.117	0.0002	0.0075	117.46	0.45	0.002	0.009	0.001
77		0.025	0.005	0.0001	0.0003	0.0005	0.0006	0.068	0.019	0.0188	0.154	0.0003	0.0122	180.74	0.56	0.002	0.014	0.001
78		0.025	0.005	0.0001	0.0003	0.0004	0.0005	0.070	0.020	0.0187	0.148	0.0002	0.0123	189.47	0.53	0.003	0.014	0.001
79		0.019	0.004	0.0001	0.0002	0.0003	0.0004	0.056	0.016	0.0133	0.103	0.0002	0.0091	151.38	0.37	0.002	0.010	0.001
80		0.019	0.004	0.0001	0.0002	0.0003	0.0004	0.057	0.016	0.0131	0.113	0.0002	0.0091	149.45	0.41	0.002	0.010	0.001
81		0.022	0.005	0.0001	0.0003	0.0003	0.0005	0.065	0.018	0.0163	0.123	0.0002	0.0109	173.72	0.44	0.003	0.012	0.001
82		0.026	0.005	0.0001	0.0003	0.0004	0.0006	0.070	0.018	0.0194	0.153	0.0003	0.0118	183.06	0.55	0.003	0.013	0.001
83		0.017	0.004	0.0001	0.0002	0.0003	0.0004	0.058	0.016	0.0117	0.106	0.0002	0.0088	151.35	0.40	0.002	0.010	0.001

Year	Flow Rate (Mm3/yr)	Al (t/year)	As (t/year)	Cd (t/year)	Co (t/year)	Cr (t/year)	Cu (t/year)	Fe (t/year)	Mn (t/year)	Mo (t/year)	NO3-N (t/year)	Pb (t/year)	Sb (t/year)	SO4 (t/year)	Sr (t/year)	CN (t/year)	U (t/year)	Zn (t/year)
84		0.019	0.004	0.0001	0.0003	0.0004	0.0005	0.061	0.016	0.0128	0.136	0.0002	0.0089	151.23	0.52	0.002	0.010	0.001
85		0.036	0.006	0.0002	0.0005	0.0007	0.0008	0.090	0.022	0.0261	0.226	0.0004	0.0152	226.96	0.83	0.003	0.017	0.002
86		0.017	0.004	0.0001	0.0002	0.0003	0.0004	0.059	0.016	0.0108	0.101	0.0002	0.0084	152.42	0.38	0.003	0.009	0.001
87		0.023	0.005	0.0001	0.0003	0.0004	0.0005	0.069	0.018	0.0158	0.144	0.0003	0.0103	171.93	0.54	0.003	0.012	0.001
88		0.021	0.004	0.0001	0.0003	0.0004	0.0005	0.064	0.016	0.0149	0.124	0.0002	0.0096	161.47	0.45	0.003	0.011	0.001
89		0.017	0.004	0.0001	0.0002	0.0003	0.0004	0.055	0.014	0.0116	0.105	0.0002	0.0078	136.95	0.39	0.002	0.009	0.001
90		0.021	0.004	0.0001	0.0003	0.0004	0.0005	0.062	0.016	0.0145	0.135	0.0002	0.0093	152.96	0.51	0.002	0.011	0.001
91		0.014	0.003	0.0001	0.0002	0.0002	0.0003	0.051	0.014	0.0095	0.083	0.0002	0.0072	129.98	0.31	0.002	0.008	0.001
92		0.012	0.003	0.0001	0.0002	0.0002	0.0003	0.044	0.011	0.0083	0.070	0.0001	0.0060	110.12	0.26	0.002	0.007	0.000
93		0.016	0.003	0.0001	0.0002	0.0002	0.0003	0.044	0.011	0.0114	0.082	0.0001	0.0068	111.17	0.29	0.002	0.008	0.001
94		0.029	0.005	0.0001	0.0003	0.0004	0.0005	0.071	0.017	0.0219	0.152	0.0002	0.0123	182.99	0.54	0.002	0.014	0.001
95		0.021	0.004	0.0001	0.0003	0.0005	0.0006	0.065	0.016	0.0144	0.145	0.0003	0.0092	154.70	0.56	0.002	0.011	0.001
96		0.018	0.004	0.0001	0.0002	0.0004	0.0004	0.055	0.013	0.0122	0.115	0.0002	0.0077	132.70	0.44	0.002	0.009	0.001
97		0.018	0.004	0.0001	0.0002	0.0004	0.0004	0.055	0.014	0.0128	0.115	0.0002	0.0080	134.40	0.43	0.002	0.009	0.001
98		0.012	0.003	0.0001	0.0002	0.0002	0.0003	0.047	0.012	0.0075	0.073	0.0001	0.0061	115.04	0.29	0.002	0.007	0.001
99		0.015	0.003	0.0001	0.0002	0.0003	0.0003	0.048	0.012	0.0103	0.089	0.0002	0.0067	116.47	0.34	0.002	0.008	0.001
100		0.029	0.005	0.0001	0.0004	0.0006	0.0007	0.071	0.016	0.0205	0.184	0.0003	0.0109	165.96	0.69	0.002	0.013	0.001
101		0.014	0.003	0.0001	0.0002	0.0003	0.0003	0.052	0.014	0.0086	0.083	0.0002	0.0068	127.68	0.33	0.002	0.008	0.001
102		0.018	0.004	0.0001	0.0002	0.0003	0.0004	0.054	0.013	0.0128	0.093	0.0002	0.0079	136.12	0.34	0.002	0.009	0.001
103		0.019	0.004	0.0001	0.0002	0.0003	0.0004	0.057	0.014	0.0142	0.092	0.0002	0.0087	147.01	0.32	0.002	0.010	0.001
104		0.020	0.004	0.0001	0.0002	0.0003	0.0004	0.057	0.014	0.0143	0.102	0.0002	0.0084	142.99	0.37	0.002	0.009	0.001
105		0.022	0.004	0.0001	0.0003	0.0005	0.0006	0.065	0.015	0.0145	0.148	0.0003	0.0087	149.36	0.57	0.002	0.010	0.001
106		0.017	0.004	0.0001	0.0002	0.0003	0.0004	0.055	0.013	0.0111	0.096	0.0002	0.0073	133.09	0.36	0.002	0.008	0.001
107		0.019	0.004	0.0001	0.0003	0.0004	0.0005	0.058	0.014	0.0128	0.124	0.0002	0.0078	135.73	0.48	0.002	0.009	0.001
108		0.015	0.003	0.0001	0.0002	0.0003	0.0004	0.053	0.013	0.0101	0.090	0.0002	0.0068	126.90	0.35	0.002	0.008	0.001
109		0.017	0.003	0.0001	0.0002	0.0003	0.0004	0.052	0.012	0.0112	0.104	0.0002	0.0068	121.98	0.40	0.002	0.008	0.001
110		0.012	0.003	0.0001	0.0002	0.0002	0.0003	0.042	0.010	0.0082	0.066	0.0001	0.0053	100.34	0.25	0.002	0.006	0.000
111		0.022	0.004	0.0001	0.0002	0.0003	0.0004	0.056	0.013	0.0169	0.110	0.0002	0.0089	139.64	0.39	0.002	0.010	0.001
112		0.016	0.004	0.0001	0.0002	0.0003	0.0004	0.052	0.012	0.0114	0.091	0.0002	0.0070	124.45	0.34	0.002	0.008	0.001
113		0.022	0.004	0.0001	0.0003	0.0005	0.0006	0.066	0.015	0.0146	0.147	0.0003	0.0087	149.93	0.57	0.002	0.010	0.001
114		0.029	0.005	0.0001	0.0003	0.0005	0.0006	0.073	0.016	0.0214	0.154	0.0003	0.0110	176.66	0.55	0.003	0.013	0.001
115		0.018	0.004	0.0001	0.0002	0.0003	0.0004	0.059	0.014	0.0115	0.101	0.0002	0.0073	138.64	0.38	0.003	0.008	0.001
116		0.017	0.004	0.0001	0.0002	0.0003	0.0004	0.056	0.012	0.0109	0.109	0.0002	0.0067	125.97	0.42	0.002	0.008	0.001
117		0.016	0.003	0.0001	0.0002	0.0003	0.0004	0.051	0.011	0.0104	0.102	0.0002	0.0062	115.33	0.39	0.002	0.007	0.001
118		0.022	0.004	0.0001	0.0003	0.0004	0.0005	0.061	0.013	0.0153	0.122	0.0002	0.0084	142.11	0.45	0.002	0.010	0.001
119		0.018	0.004	0.0001	0.0002	0.0004	0.0004	0.056	0.012	0.0116	0.111	0.0002	0.0069	126.78	0.43	0.002	0.008	0.001
120		0.021	0.004	0.0001	0.0003	0.0004	0.0005	0.062	0.014	0.0142	0.123	0.0002	0.0082	144.05	0.46	0.002	0.010	0.001
121		0.016	0.003	0.0001	0.0002	0.0003	0.0004	0.053	0.012	0.0104	0.107	0.0002	0.0063	119.06	0.41	0.002	0.007	0.001
122		0.018	0.004	0.0001	0.0002	0.0004	0.0004	0.054	0.012	0.0116	0.110	0.0002	0.0067	121.87	0.42	0.002	0.008	0.001
123		0.019	0.004	0.0001	0.0003	0.0004	0.0005	0.058	0.013	0.0120	0.122	0.0002	0.0071	129.36	0.47	0.002	0.008	0.001
124		0.016	0.003	0.0001	0.0002	0.0003	0.0004	0.048	0.010	0.0109	0.090	0.0002	0.0060	110.23	0.34	0.002	0.007	0.001

Year	Flow Rate (Mm3/yr)	Al (t/year)	As (t/year)	Cd (t/year)	Co (t/year)	Cr (t/year)	Cu (t/year)	Fe (t/year)	Mn (t/year)	Mo (t/year)	NO3-N (t/year)	Pb (t/year)	Sb (t/year)	SO4 (t/year)	Sr (t/year)	CN (t/year)	U (t/year)	Zn (t/year)
125		0.024	0.005	0.0001	0.0003	0.0004	0.0005	0.064	0.013	0.0173	0.134	0.0002	0.0089	148.36	0.49	0.002	0.010	0.001
126		0.029	0.006	0.0001	0.0003	0.0004	0.0006	0.077	0.016	0.0218	0.152	0.0003	0.0111	182.16	0.54	0.003	0.013	0.001
127		0.024	0.005	0.0001	0.0003	0.0004	0.0005	0.069	0.014	0.0163	0.135	0.0002	0.0087	157.29	0.49	0.003	0.010	0.001
128		0.015	0.003	0.0001	0.0002	0.0003	0.0004	0.054	0.012	0.0092	0.084	0.0002	0.0059	122.12	0.32	0.002	0.007	0.001
129		0.016	0.003	0.0001	0.0002	0.0003	0.0004	0.054	0.011	0.0099	0.102	0.0002	0.0059	117.49	0.40	0.002	0.007	0.001
130		0.020	0.004	0.0001	0.0002	0.0003	0.0004	0.058	0.012	0.0142	0.113	0.0002	0.0075	133.14	0.41	0.002	0.009	0.001
131		0.023	0.005	0.0001	0.0003	0.0004	0.0005	0.064	0.013	0.0166	0.131	0.0002	0.0084	144.81	0.48	0.002	0.010	0.001
132		0.021	0.004	0.0001	0.0003	0.0004	0.0005	0.064	0.014	0.0139	0.124	0.0002	0.0078	144.35	0.47	0.003	0.009	0.001
133		0.029	0.006	0.0001	0.0003	0.0004	0.0006	0.076	0.015	0.0217	0.147	0.0002	0.0107	179.69	0.51	0.003	0.012	0.001
134		0.019	0.004	0.0001	0.0002	0.0002	0.0004	0.059	0.012	0.0133	0.088	0.0002	0.0072	138.51	0.30	0.003	0.008	0.001
135		0.023	0.004	0.0001	0.0003	0.0004	0.0005	0.064	0.013	0.0158	0.136	0.0002	0.0080	143.30	0.50	0.002	0.010	0.001
136		0.011	0.003	0.0001	0.0002	0.0003	0.0003	0.046	0.010	0.0060	0.077	0.0002	0.0042	97.45	0.31	0.002	0.005	0.001
137		0.013	0.003	0.0001	0.0002	0.0003	0.0003	0.043	0.009	0.0079	0.080	0.0002	0.0046	92.95	0.31	0.002	0.006	0.001
138		0.021	0.004	0.0001	0.0002	0.0004	0.0004	0.056	0.011	0.0155	0.118	0.0002	0.0076	126.79	0.43	0.002	0.009	0.001
139		0.017	0.004	0.0001	0.0003	0.0004	0.0005	0.054	0.011	0.0110	0.124	0.0002	0.0060	113.87	0.49	0.002	0.007	0.001
140		0.029	0.006	0.0001	0.0003	0.0005	0.0006	0.079	0.016	0.0203	0.173	0.0003	0.0103	175.28	0.64	0.003	0.012	0.001
141		0.014	0.003	0.0001	0.0002	0.0003	0.0004	0.055	0.012	0.0077	0.093	0.0002	0.0051	116.66	0.37	0.002	0.006	0.001
142		0.022	0.004	0.0001	0.0003	0.0004	0.0005	0.062	0.012	0.0146	0.135	0.0002	0.0073	133.35	0.51	0.002	0.009	0.001
143		0.020	0.004	0.0001	0.0002	0.0003	0.0004	0.057	0.011	0.0145	0.092	0.0002	0.0073	132.53	0.31	0.002	0.008	0.001
144		0.022	0.004	0.0001	0.0002	0.0004	0.0005	0.065	0.013	0.0153	0.118	0.0002	0.0079	144.96	0.43	0.003	0.009	0.001
145		0.013	0.003	0.0001	0.0002	0.0002	0.0003	0.047	0.010	0.0083	0.072	0.0001	0.0047	103.15	0.27	0.002	0.006	0.001
146		0.026	0.005	0.0001	0.0003	0.0004	0.0005	0.069	0.013	0.0191	0.140	0.0002	0.0091	155.84	0.50	0.002	0.011	0.001
147		0.018	0.004	0.0001	0.0003	0.0004	0.0005	0.059	0.012	0.0105	0.127	0.0002	0.0059	121.87	0.50	0.002	0.007	0.001
148		0.025	0.005	0.0001	0.0003	0.0003	0.0005	0.067	0.013	0.0186	0.123	0.0002	0.0088	153.53	0.43	0.003	0.010	0.001
149		0.026	0.005	0.0001	0.0003	0.0004	0.0005	0.070	0.013	0.0188	0.137	0.0002	0.0089	156.47	0.48	0.003	0.011	0.001
150		0.017	0.004	0.0001	0.0002	0.0003	0.0004	0.058	0.012	0.0109	0.099	0.0002	0.0060	126.09	0.37	0.002	0.007	0.001
151		0.024	0.005	0.0001	0.0003	0.0005	0.0006	0.069	0.013	0.0157	0.153	0.0003	0.0078	145.25	0.58	0.002	0.010	0.001
152		0.022	0.004	0.0001	0.0003	0.0004	0.0005	0.066	0.013	0.0149	0.134	0.0002	0.0075	141.38	0.50	0.002	0.009	0.001
153		0.019	0.004	0.0001	0.0003	0.0004	0.0005	0.060	0.012	0.0116	0.122	0.0002	0.0062	126.14	0.47	0.002	0.008	0.001
154		0.022	0.004	0.0001	0.0003	0.0004	0.0005	0.064	0.012	0.0155	0.125	0.0002	0.0076	140.63	0.45	0.002	0.009	0.001
155		0.018	0.004	0.0001	0.0002	0.0003	0.0004	0.058	0.011	0.0117	0.101	0.0002	0.0062	125.27	0.37	0.002	0.007	0.001
156		0.024	0.005	0.0001	0.0003	0.0004	0.0005	0.067	0.013	0.0163	0.140	0.0002	0.0078	143.48	0.52	0.002	0.010	0.001
157		0.020	0.004	0.0001	0.0002	0.0003	0.0004	0.063	0.012	0.0134	0.110	0.0002	0.0069	136.07	0.40	0.003	0.008	0.001
158		0.021	0.004	0.0001	0.0002	0.0003	0.0004	0.062	0.012	0.0144	0.104	0.0002	0.0071	137.01	0.36	0.003	0.008	0.001
159		0.025	0.005	0.0001	0.0003	0.0004	0.0006	0.070	0.013	0.0172	0.145	0.0003	0.0082	150.09	0.53	0.003	0.010	0.001
160		0.018	0.004	0.0001	0.0002	0.0003	0.0004	0.058	0.011	0.0121	0.091	0.0002	0.0062	127.46	0.32	0.003	0.007	0.001
161		0.013	0.003	0.0001	0.0002	0.0003	0.0004	0.051	0.010	0.0071	0.085	0.0002	0.0043	103.48	0.33	0.002	0.005	0.001
162		0.011	0.003	0.0001	0.0001	0.0002	0.0003	0.041	0.008	0.0071	0.062	0.0001	0.0038	86.77	0.23	0.002	0.005	0.000
163		0.022	0.004	0.0001	0.0003	0.0004	0.0005	0.056	0.010	0.0156	0.129	0.0002	0.0070	119.38	0.47	0.002	0.009	0.001
164		0.016	0.004	0.0001	0.0002	0.0004	0.0004	0.056	0.011	0.0102	0.108	0.0002	0.0055	113.94	0.42	0.002	0.007	0.001
165		0.023	0.005	0.0001	0.0003	0.0004	0.0005	0.066	0.012	0.0160	0.124	0.0002	0.0076	142.06	0.45	0.003	0.009	0.001

Year	Flow Rate (Mm3/yr)	Al (t/year)	As (t/year)	Cd (t/year)	Co (t/year)	Cr (t/year)	Cu (t/year)	Fe (t/year)	Mn (t/year)	Mo (t/year)	NO3-N (t/year)	Pb (t/year)	Sb (t/year)	SO4 (t/year)	Sr (t/year)	CN (t/year)	U (t/year)	Zn (t/year)
166		0.014	0.003	0.0001	0.0002	0.0003	0.0004	0.050	0.010	0.0082	0.086	0.0002	0.0045	103.03	0.33	0.002	0.006	0.001
167		0.022	0.004	0.0001	0.0002	0.0003	0.0004	0.058	0.011	0.0155	0.114	0.0002	0.0070	127.28	0.40	0.002	0.008	0.001
168		0.016	0.003	0.0001	0.0002	0.0004	0.0005	0.056	0.011	0.0095	0.114	0.0002	0.0051	110.62	0.45	0.002	0.007	0.001
169		0.009	0.002	0.0001	0.0001	0.0002	0.0002	0.038	0.008	0.0054	0.050	0.0001	0.0032	80.35	0.19	0.002	0.004	0.000
170		0.021	0.004	0.0001	0.0002	0.0003	0.0004	0.053	0.009	0.0149	0.109	0.0002	0.0066	114.13	0.38	0.002	0.008	0.001
171		0.024	0.005	0.0001	0.0003	0.0005	0.0006	0.065	0.012	0.0164	0.148	0.0003	0.0076	135.58	0.55	0.002	0.009	0.001
172		0.015	0.003	0.0001	0.0002	0.0002	0.0003	0.049	0.009	0.0100	0.074	0.0001	0.0050	105.47	0.26	0.002	0.006	0.000
173		0.016	0.003	0.0001	0.0002	0.0003	0.0004	0.050	0.009	0.0103	0.100	0.0002	0.0051	103.96	0.38	0.002	0.006	0.001
174		0.014	0.003	0.0001	0.0002	0.0002	0.0003	0.045	0.009	0.0091	0.079	0.0001	0.0045	95.14	0.29	0.002	0.006	0.001
175		0.010	0.002	0.0001	0.0001	0.0002	0.0003	0.038	0.007	0.0057	0.060	0.0001	0.0032	78.25	0.23	0.002	0.004	0.000
176		0.016	0.003	0.0001	0.0002	0.0004	0.0004	0.047	0.009	0.0103	0.113	0.0002	0.0048	93.77	0.43	0.002	0.006	0.001
177		0.025	0.005	0.0001	0.0003	0.0005	0.0006	0.068	0.012	0.0179	0.148	0.0003	0.0081	142.62	0.54	0.002	0.010	0.001
178		0.025	0.005	0.0001	0.0003	0.0004	0.0005	0.071	0.013	0.0178	0.142	0.0002	0.0081	150.66	0.51	0.003	0.010	0.001
179		0.019	0.004	0.0001	0.0002	0.0003	0.0004	0.057	0.010	0.0125	0.098	0.0002	0.0059	121.67	0.35	0.002	0.007	0.001
180		0.019	0.004	0.0001	0.0002	0.0003	0.0004	0.058	0.010	0.0123	0.108	0.0002	0.0058	119.86	0.39	0.002	0.007	0.001
181		0.022	0.005	0.0001	0.0002	0.0003	0.0005	0.065	0.012	0.0154	0.118	0.0002	0.0071	138.59	0.41	0.003	0.009	0.001
182		0.027	0.005	0.0001	0.0003	0.0004	0.0006	0.071	0.012	0.0186	0.148	0.0003	0.0081	149.87	0.52	0.003	0.010	0.001
183		0.017	0.004	0.0001	0.0002	0.0003	0.0004	0.059	0.011	0.0109	0.102	0.0002	0.0054	120.77	0.37	0.002	0.007	0.001
184		0.020	0.004	0.0001	0.0003	0.0004	0.0005	0.062	0.011	0.0121	0.132	0.0002	0.0058	122.48	0.50	0.002	0.008	0.001
185		0.036	0.006	0.0002	0.0004	0.0007	0.0008	0.091	0.015	0.0251	0.220	0.0004	0.0108	186.53	0.80	0.003	0.013	0.002
186		0.017	0.004	0.0001	0.0002	0.0003	0.0004	0.060	0.011	0.0101	0.097	0.0002	0.0051	122.63	0.35	0.003	0.007	0.001
187		0.023	0.005	0.0001	0.0003	0.0004	0.0005	0.069	0.012	0.0150	0.140	0.0003	0.0069	140.58	0.51	0.003	0.009	0.001
188		0.021	0.004	0.0001	0.0003	0.0004	0.0005	0.064	0.011	0.0141	0.121	0.0002	0.0064	132.63	0.43	0.003	0.008	0.001
189		0.017	0.004	0.0001	0.0002	0.0003	0.0004	0.055	0.010	0.0110	0.102	0.0002	0.0052	113.00	0.37	0.002	0.007	0.001
190		0.021	0.004	0.0001	0.0003	0.0004	0.0005	0.063	0.011	0.0139	0.132	0.0002	0.0063	126.14	0.49	0.002	0.008	0.001
191		0.014	0.003	0.0001	0.0002	0.0002	0.0003	0.052	0.009	0.0089	0.080	0.0002	0.0045	105.29	0.29	0.002	0.006	0.001
192		0.012	0.003	0.0001	0.0002	0.0002	0.0003	0.044	0.008	0.0078	0.068	0.0001	0.0038	90.49	0.24	0.002	0.005	0.000
193		0.016	0.003	0.0001	0.0002	0.0002	0.0003	0.044	0.008	0.0110	0.080	0.0001	0.0048	93.77	0.28	0.002	0.006	0.001
194		0.029	0.005	0.0001	0.0003	0.0004	0.0005	0.071	0.012	0.0211	0.149	0.0002	0.0090	152.67	0.51	0.002	0.011	0.001
195		0.022	0.004	0.0001	0.0003	0.0005	0.0006	0.065	0.011	0.0138	0.143	0.0003	0.0064	129.16	0.54	0.002	0.008	0.001
196		0.018	0.004	0.0001	0.0002	0.0004	0.0004	0.055	0.010	0.0117	0.114	0.0002	0.0054	111.98	0.42	0.002	0.007	0.001
197		0.019	0.004	0.0001	0.0002	0.0004	0.0004	0.055	0.010	0.0123	0.113	0.0002	0.0056	112.89	0.42	0.002	0.007	0.001
198		0.012	0.003	0.0001	0.0002	0.0002	0.0003	0.047	0.009	0.0070	0.072	0.0001	0.0038	94.26	0.27	0.002	0.005	0.001
199		0.015	0.003	0.0001	0.0002	0.0003	0.0003	0.048	0.009	0.0098	0.087	0.0002	0.0046	98.13	0.32	0.002	0.006	0.001

Estimated annual contaminant load - RS03

Year	Flow Rate (Mm3/yr)	Al (t/year)	As (t/year)	Cd (t/year)	Co (t/year)	Cr (t/year)	Cu (t/year)	Fe (t/year)	Mn (t/year)	Mo (t/year)	NO3-N (t/year)	Pb (t/year)	Sb (t/year)	SO4 (t/year)	Sr (t/year)	U (t/year)	Zn (t/year)
Baseline Estimated/yr	0.379	0.003	0.003	0.00004	0.00009	0.0002	0.0002	0.014	0.004	0.0001	0.003	0.00009	0.0002	0.59	0.052	0.00005	0.0009
WLBM Average (year 50 to 199)	0.592	0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.127	0.003	0.0028	0.291	0.00010	0.0031	14.54	0.105	0.0013	0.0006
Estimated load by year																	
50		0.006	0.003	0.00004	0.00008	0.0001	0.0002	0.104	0.003	0.0027	0.234	0.00008	0.0047	15.14	0.105	0.0014	0.0005
51		0.010	0.005	0.00005	0.00013	0.0002	0.0004	0.198	0.005	0.0043	0.476	0.00015	0.0079	19.71	0.179	0.0019	0.0009
52		0.009	0.004	0.00005	0.00011	0.0002	0.0003	0.159	0.004	0.0039	0.371	0.00012	0.0067	18.26	0.152	0.0018	0.0007
53		0.008	0.003	0.00004	0.00010	0.0002	0.0003	0.136	0.004	0.0031	0.307	0.00011	0.0057	15.84	0.137	0.0015	0.0007
54		0.008	0.004	0.00004	0.00010	0.0002	0.0003	0.144	0.004	0.0038	0.338	0.00011	0.0060	18.19	0.137	0.0017	0.0007
55		0.006	0.003	0.00004	0.00007	0.0001	0.0002	0.104	0.003	0.0028	0.235	0.00008	0.0044	15.25	0.105	0.0014	0.0005
56		0.009	0.004	0.00005	0.00011	0.0002	0.0004	0.175	0.004	0.0042	0.407	0.00013	0.0071	19.39	0.162	0.0019	0.0008
57		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.141	0.003	0.0034	0.343	0.00010	0.0056	17.16	0.126	0.0016	0.0006
58		0.007	0.003	0.00004	0.00007	0.0001	0.0002	0.122	0.003	0.0034	0.280	0.00009	0.0052	17.18	0.113	0.0016	0.0005
59		0.010	0.005	0.00005	0.00011	0.0002	0.0004	0.195	0.004	0.0044	0.471	0.00014	0.0074	20.64	0.170	0.0020	0.0008
60		0.006	0.003	0.00003	0.00006	0.0001	0.0002	0.101	0.003	0.0028	0.231	0.00007	0.0043	15.30	0.097	0.0014	0.0004
61		0.005	0.002	0.00003	0.00006	0.0001	0.0002	0.081	0.002	0.0018	0.170	0.00007	0.0032	11.80	0.088	0.0010	0.0005
62		0.004	0.002	0.00003	0.00004	0.0001	0.0002	0.053	0.002	0.0016	0.107	0.00005	0.0023	10.18	0.060	0.0009	0.0003
63		0.008	0.004	0.00005	0.00010	0.0002	0.0003	0.137	0.003	0.0036	0.314	0.00011	0.0050	17.39	0.134	0.0016	0.0007
64		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.110	0.003	0.0025	0.249	0.00009	0.0040	14.11	0.113	0.0012	0.0006
65		0.008	0.004	0.00004	0.00009	0.0002	0.0003	0.149	0.003	0.0038	0.359	0.00011	0.0054	18.73	0.135	0.0017	0.0006
66		0.005	0.002	0.00003	0.00006	0.0001	0.0002	0.086	0.002	0.0020	0.180	0.00007	0.0033	12.31	0.091	0.0011	0.0005
67		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.120	0.003	0.0035	0.272	0.00009	0.0046	17.01	0.117	0.0016	0.0006
68		0.007	0.003	0.00004	0.00009	0.0002	0.0003	0.128	0.003	0.0025	0.285	0.00011	0.0044	14.07	0.128	0.0012	0.0007
69		0.003	0.001	0.00002	0.00003	0.0001	0.0001	0.038	0.001	0.0012	0.076	0.00004	0.0016	8.54	0.046	0.0007	0.0003
70		0.007	0.003	0.00004	0.00007	0.0002	0.0003	0.094	0.003	0.0031	0.203	0.00008	0.0036	15.41	0.101	0.0014	0.0005
71		0.010	0.005	0.00005	0.00011	0.0002	0.0004	0.185	0.004	0.0040	0.447	0.00014	0.0060	19.26	0.166	0.0018	0.0009
72		0.005	0.002	0.00003	0.00005	0.0001	0.0002	0.073	0.002	0.0022	0.160	0.00006	0.0028	12.44	0.075	0.0011	0.0004
73		0.006	0.003	0.00004	0.00007	0.0002	0.0003	0.098	0.003	0.0024	0.209	0.00009	0.0035	13.49	0.103	0.0012	0.0006
74		0.005	0.002	0.00003	0.00006	0.0001	0.0002	0.073	0.002	0.0020	0.155	0.00006	0.0026	11.81	0.078	0.0010	0.0004
75		0.004	0.001	0.00003	0.00004	0.0001	0.0002	0.046	0.002	0.0012	0.092	0.00005	0.0017	9.02	0.056	0.0007	0.0003
76		0.007	0.003	0.00004	0.00009	0.0002	0.0003	0.107	0.003	0.0024	0.228	0.00010	0.0034	13.23	0.115	0.0012	0.0007
77		0.010	0.005	0.00005	0.00011	0.0002	0.0004	0.190	0.004	0.0042	0.478	0.00014	0.0057	19.75	0.162	0.0018	0.0008
78		0.009	0.004	0.00005	0.00010	0.0002	0.0004	0.180	0.004	0.0042	0.435	0.00013	0.0059	19.88	0.159	0.0019	0.0008
79		0.006	0.003	0.00004	0.00007	0.0001	0.0002	0.107	0.003	0.0028	0.236	0.00008	0.0038	14.87	0.104	0.0013	0.0005
80		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.116	0.003	0.0028	0.258	0.00009	0.0039	15.06	0.114	0.0013	0.0006

Year	Flow Rate (Mm3/yr)	Al (t/year)	As (t/year)	Cd (t/year)	Co (t/year)	Cr (t/year)	Cu (t/year)	Fe (t/year)	Mn (t/year)	Mo (t/year)	NO3-N (t/year)	Pb (t/year)	Sb (t/year)	SO4 (t/year)	Sr (t/year)	U (t/year)	Zn (t/year)
81		0.008	0.004	0.00004	0.00008	0.0002	0.0003	0.146	0.003	0.0035	0.354	0.00010	0.0046	17.39	0.126	0.0016	0.0006
82		0.010	0.005	0.00005	0.00011	0.0002	0.0004	0.192	0.004	0.0044	0.447	0.00014	0.0062	20.44	0.170	0.0019	0.0008
83		0.007	0.003	0.00004	0.00007	0.0002	0.0003	0.115	0.003	0.0026	0.255	0.00009	0.0037	14.24	0.110	0.0012	0.0006
84		0.008	0.004	0.00005	0.00010	0.0002	0.0004	0.149	0.003	0.0030	0.331	0.00012	0.0045	15.44	0.145	0.0014	0.0008
85		0.015	0.007	0.00007	0.00017	0.0004	0.0006	0.336	0.006	0.0062	0.880	0.00023	0.0089	26.68	0.264	0.0026	0.0013
86		0.006	0.003	0.00004	0.00007	0.0001	0.0002	0.104	0.003	0.0024	0.220	0.00008	0.0035	13.27	0.105	0.0012	0.0005
87		0.009	0.004	0.00005	0.00010	0.0002	0.0004	0.171	0.004	0.0036	0.403	0.00013	0.0051	17.75	0.155	0.0016	0.0008
88		0.008	0.003	0.00004	0.00008	0.0002	0.0003	0.131	0.003	0.0032	0.293	0.00010	0.0041	16.17	0.126	0.0015	0.0006
89		0.006	0.003	0.00004	0.00007	0.0002	0.0003	0.102	0.003	0.0025	0.218	0.00008	0.0032	13.43	0.103	0.0012	0.0005
90		0.008	0.004	0.00005	0.00010	0.0002	0.0003	0.149	0.003	0.0032	0.343	0.00012	0.0042	16.40	0.138	0.0015	0.0007
91		0.005	0.002	0.00003	0.00005	0.0001	0.0002	0.069	0.002	0.0019	0.148	0.00006	0.0022	11.31	0.073	0.0009	0.0004
92		0.004	0.002	0.00003	0.00005	0.0001	0.0002	0.063	0.002	0.0017	0.133	0.00005	0.0020	10.45	0.065	0.0009	0.0004
93		0.005	0.002	0.00003	0.00005	0.0001	0.0002	0.073	0.002	0.0022	0.153	0.00006	0.0024	12.12	0.073	0.0011	0.0004
94		0.010	0.005	0.00005	0.00010	0.0002	0.0004	0.185	0.003	0.0044	0.465	0.00013	0.0050	21.00	0.148	0.0019	0.0008
95		0.009	0.004	0.00005	0.00011	0.0002	0.0004	0.172	0.004	0.0033	0.386	0.00013	0.0047	16.61	0.155	0.0015	0.0008
96		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.123	0.003	0.0027	0.266	0.00010	0.0035	13.69	0.118	0.0012	0.0006
97		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.116	0.003	0.0027	0.260	0.00010	0.0032	14.31	0.111	0.0013	0.0006
98		0.005	0.002	0.00003	0.00005	0.0001	0.0002	0.066	0.002	0.0015	0.144	0.00006	0.0019	10.19	0.067	0.0008	0.0004
99		0.006	0.002	0.00003	0.00006	0.0001	0.0002	0.083	0.002	0.0021	0.179	0.00007	0.0024	11.87	0.081	0.0010	0.0005
100		0.012	0.006	0.00006	0.00014	0.0003	0.0005	0.237	0.004	0.0046	0.569	0.00018	0.0058	21.17	0.195	0.0020	0.0011
101		0.005	0.002	0.00003	0.00006	0.0001	0.0002	0.077	0.002	0.0017	0.166	0.00007	0.0021	10.95	0.077	0.0009	0.0004
102		0.006	0.003	0.00003	0.00006	0.0001	0.0002	0.104	0.002	0.0026	0.237	0.00008	0.0029	14.00	0.088	0.0012	0.0005
103		0.006	0.003	0.00003	0.00006	0.0001	0.0002	0.110	0.002	0.0028	0.262	0.00008	0.0031	15.12	0.086	0.0013	0.0004
104		0.007	0.003	0.00004	0.00007	0.0001	0.0002	0.121	0.002	0.0030	0.275	0.00009	0.0034	15.47	0.099	0.0014	0.0005
105		0.009	0.004	0.00005	0.00011	0.0002	0.0004	0.182	0.004	0.0033	0.419	0.00014	0.0044	16.77	0.153	0.0015	0.0009
106		0.006	0.003	0.00004	0.00006	0.0001	0.0002	0.099	0.002	0.0023	0.219	0.00008	0.0026	12.81	0.090	0.0011	0.0005
107		0.008	0.003	0.00004	0.00009	0.0002	0.0003	0.136	0.003	0.0028	0.302	0.00011	0.0034	14.73	0.122	0.0013	0.0007
108		0.006	0.002	0.00003	0.00006	0.0001	0.0002	0.092	0.002	0.0020	0.205	0.00008	0.0023	12.11	0.083	0.0010	0.0005
109		0.006	0.003	0.00004	0.00007	0.0002	0.0003	0.100	0.002	0.0023	0.214	0.00009	0.0026	12.91	0.095	0.0011	0.0006
110		0.004	0.002	0.00003	0.00004	0.0001	0.0002	0.056	0.002	0.0016	0.115	0.00005	0.0016	9.69	0.056	0.0008	0.0003
111		0.007	0.003	0.00004	0.00007	0.0002	0.0003	0.121	0.002	0.0033	0.283	0.00009	0.0032	16.46	0.098	0.0015	0.0005
112		0.006	0.002	0.00003	0.00006	0.0001	0.0002	0.091	0.002	0.0023	0.202	0.00007	0.0023	12.90	0.080	0.0011	0.0005
113		0.009	0.004	0.00005	0.00011	0.0002	0.0004	0.185	0.003	0.0032	0.436	0.00014	0.0041	16.90	0.148	0.0015	0.0009
114		0.010	0.005	0.00005	0.00010	0.0002	0.0004	0.186	0.003	0.0043	0.437	0.00013	0.0046	20.26	0.147	0.0019	0.0008
115		0.006	0.003	0.00004	0.00007	0.0002	0.0003	0.115	0.002	0.0024	0.260	0.00009	0.0028	13.35	0.096	0.0011	0.0005
116		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.114	0.003	0.0023	0.247	0.00009	0.0027	12.74	0.102	0.0011	0.0006
117		0.006	0.003	0.00004	0.00007	0.0002	0.0003	0.098	0.002	0.0021	0.204	0.00009	0.0024	11.92	0.092	0.0010	0.0006
118		0.008	0.003	0.00004	0.00008	0.0002	0.0003	0.137	0.003	0.0031	0.323	0.00011	0.0031	15.73	0.111	0.0014	0.0006

Year	Flow Rate (Mm3/yr)	Al (t/year)	As (t/year)	Cd (t/year)	Co (t/year)	Cr (t/year)	Cu (t/year)	Fe (t/year)	Mn (t/year)	Mo (t/year)	NO3-N (t/year)	Pb (t/year)	Sb (t/year)	SO4 (t/year)	Sr (t/year)	U (t/year)	Zn (t/year)
119		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.124	0.003	0.0025	0.274	0.00010	0.0029	13.52	0.105	0.0012	0.0006
120		0.008	0.004	0.00004	0.00009	0.0002	0.0003	0.145	0.003	0.0030	0.340	0.00011	0.0032	15.50	0.115	0.0013	0.0007
121		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.113	0.002	0.0022	0.244	0.00009	0.0026	12.41	0.099	0.0010	0.0006
122		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.116	0.002	0.0024	0.256	0.00010	0.0026	12.99	0.100	0.0011	0.0006
123		0.008	0.003	0.00004	0.00009	0.0002	0.0003	0.135	0.003	0.0026	0.306	0.00011	0.0029	13.87	0.114	0.0012	0.0007
124		0.006	0.002	0.00003	0.00006	0.0001	0.0002	0.080	0.002	0.0021	0.165	0.00007	0.0020	11.67	0.076	0.0010	0.0005
125		0.009	0.004	0.00005	0.00009	0.0002	0.0003	0.153	0.003	0.0035	0.361	0.00012	0.0034	17.25	0.120	0.0015	0.0007
126		0.010	0.005	0.00005	0.00010	0.0002	0.0004	0.192	0.003	0.0043	0.475	0.00013	0.0042	20.73	0.137	0.0019	0.0008
127		0.009	0.004	0.00004	0.00009	0.0002	0.0003	0.170	0.003	0.0034	0.390	0.00012	0.0038	17.07	0.128	0.0015	0.0007
128		0.005	0.002	0.00003	0.00005	0.0001	0.0002	0.078	0.002	0.0018	0.167	0.00007	0.0018	11.20	0.070	0.0009	0.0004
129		0.006	0.003	0.00004	0.00007	0.0002	0.0003	0.114	0.002	0.0021	0.247	0.00009	0.0024	12.07	0.094	0.0010	0.0006
130		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.118	0.002	0.0028	0.267	0.00009	0.0026	14.71	0.097	0.0013	0.0006
131		0.009	0.004	0.00004	0.00009	0.0002	0.0003	0.154	0.003	0.0034	0.359	0.00012	0.0033	16.77	0.118	0.0015	0.0007
132		0.008	0.004	0.00004	0.00009	0.0002	0.0003	0.148	0.003	0.0029	0.345	0.00011	0.0030	15.46	0.113	0.0013	0.0007
133		0.010	0.004	0.00004	0.00009	0.0002	0.0003	0.185	0.003	0.0042	0.449	0.00013	0.0039	20.21	0.129	0.0018	0.0007
134		0.006	0.003	0.00003	0.00005	0.0001	0.0002	0.103	0.002	0.0026	0.234	0.00007	0.0024	13.83	0.075	0.0012	0.0004
135		0.009	0.004	0.00005	0.00010	0.0002	0.0003	0.164	0.003	0.0033	0.365	0.00012	0.0034	16.44	0.124	0.0015	0.0007
136		0.005	0.002	0.00003	0.00005	0.0001	0.0002	0.063	0.002	0.0012	0.123	0.00006	0.0013	8.58	0.064	0.0006	0.0004
137		0.005	0.002	0.00003	0.00006	0.0001	0.0002	0.066	0.002	0.0015	0.131	0.00006	0.0014	9.55	0.065	0.0008	0.0004
138		0.008	0.003	0.00004	0.00008	0.0002	0.0003	0.126	0.002	0.0030	0.290	0.00010	0.0026	15.25	0.099	0.0013	0.0006
139		0.008	0.003	0.00005	0.00009	0.0002	0.0003	0.129	0.003	0.0023	0.283	0.00011	0.0024	13.00	0.111	0.0011	0.0007
140		0.012	0.006	0.00006	0.00012	0.0003	0.0005	0.249	0.004	0.0043	0.641	0.00017	0.0043	21.01	0.163	0.0019	0.0010
141		0.006	0.002	0.00004	0.00007	0.0002	0.0002	0.096	0.002	0.0016	0.201	0.00008	0.0019	10.43	0.082	0.0008	0.0005
142		0.009	0.004	0.00005	0.00010	0.0002	0.0003	0.145	0.003	0.0030	0.319	0.00012	0.0029	15.15	0.118	0.0013	0.0008
143		0.006	0.003	0.00003	0.00006	0.0001	0.0002	0.104	0.002	0.0028	0.242	0.00007	0.0023	14.16	0.075	0.0012	0.0004
144		0.008	0.003	0.00004	0.00008	0.0002	0.0003	0.137	0.002	0.0030	0.323	0.00010	0.0027	15.98	0.099	0.0014	0.0006
145		0.005	0.002	0.00003	0.00005	0.0001	0.0002	0.065	0.002	0.0016	0.132	0.00006	0.0014	9.79	0.057	0.0008	0.0004
146		0.009	0.004	0.00005	0.00009	0.0002	0.0003	0.181	0.003	0.0038	0.437	0.00013	0.0034	18.82	0.121	0.0017	0.0007
147		0.008	0.003	0.00005	0.00009	0.0002	0.0003	0.138	0.003	0.0022	0.297	0.00012	0.0024	12.94	0.113	0.0011	0.0008
148		0.008	0.003	0.00004	0.00008	0.0002	0.0003	0.140	0.002	0.0035	0.334	0.00010	0.0028	17.10	0.099	0.0015	0.0006
149		0.009	0.004	0.00004	0.00009	0.0002	0.0003	0.166	0.003	0.0037	0.389	0.00012	0.0032	18.27	0.116	0.0016	0.0007
150		0.006	0.003	0.00004	0.00007	0.0002	0.0002	0.107	0.002	0.0022	0.238	0.00008	0.0020	12.58	0.083	0.0010	0.0005
151		0.010	0.005	0.00005	0.00011	0.0003	0.0004	0.203	0.003	0.0033	0.483	0.00015	0.0034	16.86	0.140	0.0015	0.0009
152		0.009	0.004	0.00005	0.00009	0.0002	0.0003	0.163	0.003	0.0031	0.375	0.00012	0.0029	15.64	0.118	0.0014	0.0007
153		0.008	0.003	0.00004	0.00009	0.0002	0.0003	0.139	0.003	0.0024	0.311	0.00011	0.0024	13.30	0.107	0.0011	0.0007
154		0.008	0.004	0.00004	0.00009	0.0002	0.0003	0.147	0.003	0.0031	0.342	0.00011	0.0027	15.67	0.106	0.0014	0.0007
155		0.006	0.003	0.00004	0.00007	0.0002	0.0003	0.106	0.002	0.0023	0.238	0.00008	0.0020	12.92	0.082	0.0011	0.0005
156		0.009	0.004	0.00005	0.00010	0.0002	0.0004	0.178	0.003	0.0033	0.409	0.00013	0.0031	16.75	0.123	0.0015	0.0008

Year	Flow Rate (Mm3/yr)	Al (t/year)	As (t/year)	Cd (t/year)	Co (t/year)	Cr (t/year)	Cu (t/year)	Fe (t/year)	Mn (t/year)	Mo (t/year)	NO3-N (t/year)	Pb (t/year)	Sb (t/year)	SO4 (t/year)	Sr (t/year)	U (t/year)	Zn (t/year)
157		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.144	0.002	0.0027	0.345	0.00010	0.0024	14.63	0.095	0.0012	0.0006
158		0.007	0.003	0.00004	0.00007	0.0001	0.0002	0.123	0.002	0.0028	0.281	0.00009	0.0023	14.67	0.084	0.0012	0.0005
159		0.010	0.005	0.00005	0.00010	0.0002	0.0004	0.197	0.003	0.0035	0.472	0.00014	0.0032	17.81	0.127	0.0016	0.0008
160		0.006	0.003	0.00003	0.00006	0.0001	0.0002	0.102	0.002	0.0023	0.231	0.00008	0.0019	12.94	0.072	0.0011	0.0004
161		0.005	0.002	0.00003	0.00006	0.0001	0.0002	0.082	0.002	0.0014	0.170	0.00007	0.0014	9.75	0.069	0.0007	0.0005
162		0.004	0.002	0.00003	0.00004	0.0001	0.0002	0.053	0.001	0.0013	0.106	0.00005	0.0010	8.51	0.047	0.0007	0.0003
163		0.008	0.004	0.00005	0.00009	0.0002	0.0003	0.137	0.003	0.0030	0.313	0.00011	0.0023	15.34	0.104	0.0013	0.0007
164		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.111	0.002	0.0020	0.248	0.00009	0.0018	12.06	0.089	0.0010	0.0006
165		0.008	0.004	0.00004	0.00008	0.0002	0.0003	0.149	0.002	0.0031	0.356	0.00011	0.0025	16.28	0.101	0.0014	0.0006
166		0.005	0.002	0.00003	0.00006	0.0001	0.0002	0.086	0.002	0.0016	0.178	0.00007	0.0015	10.24	0.069	0.0008	0.0005
167		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.120	0.002	0.0029	0.270	0.00009	0.0022	14.92	0.088	0.0013	0.0006
168		0.007	0.003	0.00004	0.00009	0.0002	0.0003	0.128	0.002	0.0020	0.283	0.00011	0.0019	11.95	0.098	0.0010	0.0007
169		0.003	0.001	0.00002	0.00003	0.0001	0.0001	0.038	0.001	0.0010	0.076	0.00004	0.0007	7.11	0.036	0.0005	0.0003
170		0.007	0.003	0.00004	0.00007	0.0002	0.0003	0.094	0.002	0.0027	0.202	0.00008	0.0018	13.69	0.079	0.0012	0.0005
171		0.010	0.005	0.00005	0.00011	0.0002	0.0004	0.185	0.003	0.0033	0.444	0.00014	0.0027	17.02	0.125	0.0015	0.0009
172		0.005	0.002	0.00003	0.00005	0.0001	0.0002	0.073	0.001	0.0019	0.159	0.00006	0.0013	10.68	0.056	0.0009	0.0004
173		0.006	0.003	0.00004	0.00007	0.0002	0.0003	0.098	0.002	0.0020	0.208	0.00009	0.0016	11.66	0.079	0.0009	0.0006
174		0.005	0.002	0.00003	0.00005	0.0001	0.0002	0.073	0.002	0.0017	0.154	0.00006	0.0013	10.23	0.060	0.0008	0.0004
175		0.004	0.001	0.00003	0.00004	0.0001	0.0002	0.046	0.001	0.0011	0.092	0.00005	0.0008	7.67	0.044	0.0005	0.0003
176		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.107	0.002	0.0020	0.227	0.00010	0.0016	11.66	0.091	0.0010	0.0007
177		0.010	0.005	0.00005	0.00010	0.0002	0.0004	0.190	0.003	0.0035	0.477	0.00014	0.0027	17.74	0.122	0.0015	0.0008
178		0.009	0.004	0.00005	0.00010	0.0002	0.0004	0.180	0.003	0.0035	0.433	0.00013	0.0027	17.60	0.116	0.0015	0.0008
179		0.006	0.003	0.00004	0.00006	0.0001	0.0002	0.107	0.002	0.0024	0.235	0.00008	0.0018	12.95	0.076	0.0011	0.0005
180		0.007	0.003	0.00004	0.00007	0.0002	0.0003	0.116	0.002	0.0024	0.257	0.00009	0.0018	13.20	0.085	0.0011	0.0006
181		0.008	0.004	0.00004	0.00008	0.0002	0.0003	0.146	0.002	0.0030	0.353	0.00010	0.0022	15.47	0.092	0.0013	0.0006
182		0.010	0.005	0.00005	0.00010	0.0002	0.0004	0.192	0.003	0.0037	0.445	0.00014	0.0029	18.18	0.121	0.0016	0.0008
183		0.007	0.003	0.00004	0.00007	0.0002	0.0003	0.115	0.002	0.0021	0.254	0.00009	0.0017	12.39	0.081	0.0010	0.0006
184		0.008	0.004	0.00005	0.00010	0.0002	0.0004	0.149	0.003	0.0025	0.330	0.00012	0.0021	13.59	0.109	0.0011	0.0008
185		0.015	0.007	0.00007	0.00016	0.0004	0.0006	0.336	0.004	0.0052	0.878	0.00023	0.0042	24.23	0.193	0.0022	0.0013
186		0.006	0.003	0.00004	0.00007	0.0001	0.0002	0.104	0.002	0.0020	0.220	0.00008	0.0016	11.41	0.076	0.0009	0.0005
187		0.009	0.004	0.00005	0.00010	0.0002	0.0004	0.171	0.003	0.0030	0.402	0.00013	0.0024	15.78	0.114	0.0013	0.0008
188		0.008	0.003	0.00004	0.00008	0.0002	0.0003	0.131	0.002	0.0027	0.292	0.00010	0.0020	14.38	0.093	0.0012	0.0006
189		0.006	0.003	0.00004	0.00007	0.0002	0.0003	0.102	0.002	0.0021	0.218	0.00008	0.0016	11.86	0.078	0.0010	0.0005
190		0.008	0.004	0.00005	0.00009	0.0002	0.0003	0.149	0.003	0.0027	0.342	0.00012	0.0021	14.72	0.105	0.0012	0.0007
191		0.005	0.002	0.00003	0.00005	0.0001	0.0002	0.069	0.001	0.0016	0.147	0.00006	0.0011	10.00	0.057	0.0008	0.0004
192		0.004	0.002	0.00003	0.00004	0.0001	0.0002	0.063	0.001	0.0015	0.132	0.00005	0.0010	9.20	0.050	0.0007	0.0004
193		0.005	0.002	0.00003	0.00005	0.0001	0.0002	0.073	0.002	0.0020	0.153	0.00006	0.0013	10.95	0.057	0.0009	0.0004
194		0.010	0.005	0.00005	0.00010	0.0002	0.0004	0.185	0.003	0.0040	0.464	0.00013	0.0027	19.36	0.113	0.0017	0.0008

Year	Flow Rate (Mm3/yr)	Al (t/year)	As (t/year)	Cd (t/year)	Co (t/year)	Cr (t/year)	Cu (t/year)	Fe (t/year)	Mn (t/year)	Mo (t/year)	NO3-N (t/year)	Pb (t/year)	Sb (t/year)	SO4 (t/year)	Sr (t/year)	U (t/year)	Zn (t/year)
195		0.009	0.004	0.00005	0.00010	0.0002	0.0004	0.172	0.003	0.0028	0.385	0.00013	0.0023	14.91	0.119	0.0013	0.0008
196		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.123	0.002	0.0023	0.265	0.00010	0.0018	12.32	0.091	0.0010	0.0006
197		0.007	0.003	0.00004	0.00008	0.0002	0.0003	0.116	0.002	0.0024	0.259	0.00010	0.0017	12.99	0.088	0.0011	0.0006
198		0.005	0.002	0.00003	0.00005	0.0001	0.0002	0.066	0.001	0.0013	0.143	0.00006	0.0010	9.04	0.054	0.0007	0.0004
199		0.006	0.002	0.00003	0.00006	0.0001	0.0002	0.083	0.002	0.0019	0.178	0.00007	0.0013	10.74	0.065	0.0009	0.0005

APPENDIX G

Mine Waste Management Report Number: J-NZ0488-007-M-Rev0

RFI: This appendix set out the source terms used for the water and load balance model.

MINE WASTE MANAGEMENT
GREENROAD GROUP

5 Sir William Pickering Drive, Burnside,
Christchurch 8053, New Zealand

T. +64 3 242 0221
E. admin@minewaste.com.au

MEMORANDUM

Recipient:	Matakanui Gold Limited
From:	Paul Weber– Mine Waste Management Limited
Date:	14 April 2026
Cc:	Leo Navarro – Mine Waste Management Limited
Document Number:	J-NZ0488-007-M-Rev0
Document Title:	RFI Comment Number #3

Mine Waste Management Limited (MWM) has prepared this memorandum as part of the response by Matakanui Gold Limited (MGL) to the Panel's Request for Information (RFI) made under Section 67 of the Act on 1 April 2026.

OBJECTIVE

RFI Comment Number #3

Provide a single table outlining all defined source terms used in the Water and Load Balance Model, including:

a) Source data used to derive each source term (with data/summary and references where not currently provided);

b) Justification for applicability;

c) Variations in concentrations used (e.g. mean, 95th percentile);

d) Limitations of each source term; and

e) Steps underway or proposed to refine or improve each source term.

RESULTS

A summary table for source terms was constructed based on the request for information. Noting that the Mine Waste Management reports (MWM, 2025) contain this information.

With greenfield projects that do not have operational data, the development of source terms is more difficult than an established site with years of operational data that can be used to construct suitable source terms for water quality. Hence for the BOGP, the key objective of the water and load balance model is to 1.) understand risks for water quality, and 2.) estimate likely water quality concentrations over time, such that appropriate engineering controls are developed and are available to minimise the potential effects and achieve agreed closure objectives for water quality using the principles of adaptive management.

A transient site-wide water and load balance model is being developed as part of the detailed design studies to improve water quality estimates. This will include sensitivity modelling to understand the potential range of effects that will require management.

CLOSING REMARKS

Please do not hesitate to contact Paul Weber at + 64 3 242 0221 or paul.weber@minewaste.com.au should you wish to discuss in greater detail.

Attachments: Attachment A: Summary for Source Terms Table

REFERENCES

Craw, D. and Pope, J., 2017. Time-series monitoring of water–rock interactions in mine wastes, Macraes gold mine, New Zealand. New Zealand Journal of Geology and Geophysics, 60(3), pp.159-175.

GHD, 2020. Deepdell North Stage III Project Receiving Water Quality Analysis. GHD Report 125/02848 dated November 2019. https://www.orc.govt.nz/consents-and-compliance/current-notified-applications/oceana-gold-new-zealand-limited-rm20024/

Golder, 2011. Macraes Phase III Project Environmental Water Quality Data Summary Report. Report 0978110-562-R012vC, 124 pp. Appendix 15. https://www.orc.govt.nz/consents-and-compliance/current-notified-applications/archived-applications/oceana-gold-new-zealand-limited-application-rm10351

MACA, 2025. Bendigo Ophir Gold Project Pre-feasibility Study. Provided for Matakanui Gold Limited.

MWM, 2025a. Source Term Definition Report – Bendigo-Ophir Gold Project. Mine Waste Management report: J-NZ0475-001-R-Rev2

MWM, 2025b. Baseline Water Quality Report – Bendigo-Ophir Gold Project. Mine Waste Management report: J-NZ0233-006-R-Rev5

Navarro-Valdivia, L., Weber, P.A., Tuck, J., Hillman, C., 2023. Natural Decay of ANFO-Derived Nitrate in Pit Lakes: Insights from the Golden Bar Pit Lake, Macraes Gold Mine, Otago, New Zealand. 2023 AusIMM New Zealand Branch Annual Conference. Available: https://www.ausimm.com/news-and-media/community-news/new-zealand-branch-2023-annual-conference-presentations--abstracts

Nichol, S. E., Harvey, M. J., & Boyd, I. S. (1997). Ten years of rainfall chemistry in New Zealand. Clean Air: Journal of the Clean Air Society of Australia and New Zealand, 31(1), 30-37 .

Oceana Gold (NZ) Ltd 2020. Deepdell North Stage III Project Assessment of Environmental Effects Part 1. Dated 29 January 2020, 252 pp. https://www.orc.govt.nz/consents-and-compliance/current-notified-applications/oceana-gold-new-zealand-limited-rm20024/

ATTACHMENT A ‐ SUMMARY FOR SOURCE TERMS TABLE

Model	Source Term	MWM (2025a) Report Reference	Source Data	Justification for applicability	Stats Description	Steps to improve the Source Term
Operational	Baseline SW SC01	Section 4.1.1 Table 3: Surface water quality source terms for Shepherds Creek	MWM, 2025b. Baseline Water Quality Report – Bendigo-Ophir Gold Project. Mine Waste Management report: J-NZ0233-006-R-Rev6. Appendix D Data Analyses	This source term represents the ari hmetic mean of the baseline water quality at SC01	Average (n=25)	Continue long-term baseline monitoring.
	Baseline SW RS03	Section 4.1.2 Table 4: Surface water quality source terms for Bendigo Creek	MWM, 2025b. Baseline Water Quality Report – B	This source term represents the ari hmetic mean of the baseline water quality at RS03	Average (n=25)	Continue long-term baseline monitoring.
	TZ4 / RSSZ Mine Impacted Surfaces - bore DS	Section 8.3 Table 20: Source terms: Mine impacted Surfaces and Rehabilitated Surfaces	MWM (2025a) J-NZ0475-001-R-Rev2 Table 20, constructed based on data from Golder (2011), OceanaGold (2020), Navarro-Valdivia et al. (2023)	This source term represents the mine impacted surfaces from TZ4/RSSZ geological unit (as stated on the Golder, 2011 Appendix E report) based on he 95th Percentile for the following parameters: pH, EC, Ca, Cl, Mg, K, Na, SO4, As, Cu, Fe, Pb based on the Golder (2011) Appendix E.	95th percentile (as stated in the source data report)	Integrate emerging data from rehabilitated mine impacted areas to refine the predicted runoff chemistry for aged and rehabilitated waste rock surfaces. It is recommended that in-situ trials be established to collect runoff data directly from rehabilita ion of mine impacted areas to validate long-term performance.
Post-Closure	Rehabilitated ELF Runoff Water Quality	Section 8.3 Table 20: Source terms: Mine impacted Surfaces and Rehabilitated Surfaces	J-NZ0475-001-R-Rev2 Table 20, constructed based on data from Golder (2011), OceanaGold (2020), Navarro-Valdivia et al. (2023)	This source term is sourced from the Macraes Deepdell North Stage III Project (GHD, 2020), utilising mean concentrations derived from long-term OGNZL monitoring data. The application of this dataset is justified by the geological similarities between the Macraes and BOGP lithologies. Furthermore, this approach relies on a verified technical precedent wi hin the Otago region, using values that have been previously audited and accepted for similar geochemical models. In the absence of multi-year, site-specific field data, these regional analogues provide a more reliable basis for modelling than laboratory-scale testing (such as columns or leachates). This approach intentionally avoids he inherent scaling issues and 'lab-to-field' uncertainties associated with extrapolating small-scale kinetic tests to full-scale landform drainage chemistry.	Average (as stated in the source data report)	Integrate emerging data from rehabilitated landforms to refine the predicted runoff chemistry for aged and rehabilitated waste rock surfaces. It is recommended that in-situ trials be established to collect runoff data directly from site-specific cover systems to validate long-term performance.
	Pit Walls Runoff.	Section 6.4.1 Table 16 BOGP Pit Wall Runoff Source Term	Analogue Site Data from Macraes: Frasers West Data set, Golder (2011)	This source term is based on the arithmetic mean of publicly available monitoring data from the Frasers West pit at Macraes (n=7, 1999–2003). The Macraes analogue is considered appropriate due to the high degree of geological, climatic, and scale similarity between the two sites. This analogue approach is preferred over laboratory-scale testing (e.g., l;eachate tests or humidity cells) as it accounts for the physical scaling factors inherent to large-scale pit walls. Laboratory tests don't represent the complex interactions of fracture-controlled flow, blasting-induced mineral exposure, and site-specific weathering rates found in an operational pit environment. By utilising a field-verified analogue, the model avoids the significant uncertainties associated with upscaling processes.	Average (n=7)	Implement in-situ runoff collection at the pit floor during operations to calibrate the model with site-specific wall-wash data. Addi ionally, integrate any emerging analogue data from similar geological settings where available.
	Rehabilitated TSF Runoff	Section 8.3 Table 20: Source terms: Mine impacted Surfaces and Rehabilitated Surfaces	Source data is same as Rehabilitated ELF Runoff Water Quality.	These source term assumes the same composition as the one from The ELF Runoff, associated with Rehabilitated Impacted Surfaces waters.	Average (as stated in the source data report)	Integrate emerging data from rehabilitated landforms to refine the predicted runoff chemistry for aged and rehabilitated TSF Surfaces. It is recommended that in-situ trials be established to collect runoff data directly from site-specific cover systems to validate long-term performance.
	Surface water quality for Clearwater Creek	Section 4.1.2 Table 4 Surface Water Quality Source Terms for Bendigo Creek (CC01)	MWM, 2025. Baseline Water Quality Report – Bendigo-Ophir Gold Project. Mine Waste Management report: J-NZ0233-006-R-Rev6. Appendix D Data Analyses	These source terms are based on the ari hmetic mean of the baseline water quality at monitoring points. The WLBM operates on a daily time-step where flow volumes fluctuate according to climatic inputs while concentrations remain constant (fixed concentration). This approach is inheren ly conservative; during high-flow events, natural dilution would typically lower in-situ concentrations. By applying a fixed average concentration to these elevated volumes, the model overes imates the total mass load contributed by he baseline. Furthermore, the total mass loading from background sources is negligible compared to the primary load contributions from ELF Seepage, TSF Seepage, and Pit Wall runoff. Consequently, the model outcomes are highly sensitive to the mine-derived source terms, while any minor adjustments to the baseline concentrations would not materially impact the overall predicted water quality at the compliance points.	Average (n=16)	Continue long-term baseline monitoring.
	RS03 Rise and Shine Creek Background Water Quality	Section 4.1.2 Table 4 Surface Water Quality Source Terms for Bendigo Creek (RS03)	MWM, 2025. Baseline Water Quality Report – Bendigo-Ophir Gold Project. Mine Waste Management report: J-NZ0233-006-R-Rev6. Appendix D Data Analyses		Average (n=25)	Continue long-term baseline monitoring.
	RS04 Rise and Shine Creek Background Water Quality	Section 4.1.2 Table 4 Surface Water Quality Source Terms for Bendigo Creek (RS04)	MWM, 2025. Baseline Water Quality Report – Bendigo-Ophir Gold Project. Mine Waste Management report: J-NZ0233-006-R-Rev6. Appendix D Data Analyses		Average (n=14)	Continue long-term baseline monitoring.
	SC03 Rise and Shine Creek Background Water Quality	Section 4.1.1 Table 3 Surface Water Quality Source Terms for Shepherds Creek (SC03)	MWM, 2025. Baseline Water Quality Report – Bendigo-Ophir Gold Project. Mine Waste Management report: J-NZ0233-006-R-Rev6. Appendix D Data Analyses		Average (n=21)	Continue long-term baseline monitoring.
	MDD015 Background Groundwater Quality	Section 4.2.1 Table 6 Water Quality Source Terms for Groundwater (MDD015)	MWM, 2025. Baseline Water Quality Report – Bendigo-Ophir Gold Project. Mine Waste Management report: J-NZ0233-006-R-Rev6. Appendix D Data Analyses		Average (n=18)	Continue long-term baseline monitoring.
	Rainfall	Section 3.1.1. Table 2. Rainfall Quality Source Term Data.	Nichol et al., 1997	The source term for average rainfall water quality is obtained	Average (n=45)	No further improvement required. Rainfall chemistry provides negligible mass loading; updates will not impact model outcomes.
	Tailings Storage Facility Seepage Water Quality (from Underdrains)	Section 9.3.2. Table 23 Process Water Quality and Tailings Seepage Water	MACA, 2025. Bendigo Ophir Gold Project Pre-feasibility Study. Provided for Matakanui Gold Limited. Craw and Pope (2017). Golder (2011) - Appendix B and C	The source term for the TSF was primarily derived from a process water quality dataset (MACA, 2025) complemented with analogue site data (Macraes TSF Seepage). To address the inherent uncertainty of a limited dataset, several conservative assumptions were integrated into the model. Specifically, the source term remains fixed throughout the 200-year simulation period, disregarding potential long-term improvements in water quality following closure. Furthermore, a concentration factor was applied to account for the buildup of solutes due to operational recirculation and evaporative concentration, ensuring the model provides an upper-bound estimate of potential environmental effects.	Not applicable. Because in-situ data is not yet available, this source term is based on a conservative estimation rather than a specific statistical distribution (such as an average or 95th percentile).	Refine the source term as addi ional metallurgical testwork results become available. Data from future process metallurgical testwork will be used to update the geochemical evolution assumptions. Furthermore, during the operational phase, direct monitoring of TSF underdrainage should be integrated into the model to validate and update he seepage source term with site-specific data.

Source Term	Al (mg/L)	Alkalinity (mgCaCO3/L)	As (mg/L)	B (mg/L)	Ca (mg/L)	Cd (mg/L)	Cl (mg/L)	Co (mg/L)	Cr (mg/L)	Cu (mg/L)	DOC (mg/L)	F (mg/L)	Fe (mg/L)	Hg (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)	Mo (mg/L)	NO3-N + Amm-N (mg/L)	Na (mg/L)	Ni (mg/L)	Pb (mg/L)	Sb (mg/L)	Se (mg/L)	SO_4 (mg/L)	Sr (mg/L)	Tl (mg/L)	TOC (mg/L)	CN (mg/L)	U (mg/L)	V (mg/L)	Zn (mg/L)	pH
Baseline SW SC01	0.00454	216	0 00239	0.03304	60.8	0	6.08	0 00026	0.00056	0.00055	-	0.103	0.011	0	2.01	21.3	0.00265	0.00051	0.0933	20 3	0.00035	0	0 00053	0.0025	40.5	0.947	0.00023	2.08	0	0.0051	0	0.0017	8.11
Baseline SW RS03	0.00756	39.1	0 0085	0	11.1	0.0001	1.33	0 00025	0.00059	0.00046	-	0.057	0 0375	0	0.578	1.99	0.0095	0	0.018	39 5	0.00035	0	0	0	1.57	0.136	0	1.75	0	0.00012	0	0 00229	7.42
TZ4 / RSSZ Mine Impacted Surfaces - bore DS	0.00016	140.5	0	0.104	90.4	0	20	0	0	0	-	0.83	0	-	7.1	76.42	0.039	0.045	0.106	59	0.003	0.003	0.14	0	320	1.84	0	-	0	0.016	0	0.007	8.4
Rehabilitated ELF Runoff Water Quality	0.155	140.5	0 02	0.064	15.68	0 0001	3.1	0.0005	0.0005	0.001	2.01	0 34	0.14	-	8.66	1 95	0.0115	0.147	0.4	32.88	0.0005	0.00019	0.049	0.00025	470	0.67	0.00025	2.01	0	0.053	0.0005	0 001	8.4
Pit Walls Runoff.	0.114	61.3	0.093	0.046	55	0 0001	13	0.0005	0.0005	0.0034	0	0.21	9.1	-	39	37	0.014	0.023	40	33	0.0009	0.004	0 027	0.00025	160	0.91	0.00025	0	0	0.0106	0.0005	0 002	8.2
Rehabilitated TSF Runoff	0.155	140.5	0 02	0.064	15.68	0 0001	3.1	0.0005	0.0005	0.001	2.01	0 34	0.14		8.66	1 95	0.0115	0.147	0.4	32.88	0.0005	0.00019	0 049	0.00025	470	0.67	0.00025	2.01	0	0.053	0.0005	0 001	8.4
Surface water quality for Clearwater Creek	0.01231	14.7	0.001	0.0175	3 88	0.00009	0.794	0.00021	0 00056	0.00043	1.23	0.055	0.0293	0.00024	0.335	0.844	0.0009	0.00033	0.0096	2.35	0.00056	0.00022	0.00044	0.0022	0.843	0 042	0.00019	1.23	0	0 00009	0.0005	0.00161	7.03
RS03 Rise and Shine Creek Background Water Quality	0.00756	39.1	0.009	0.0188	11.1	0 0001	1.33	0.00025	0 00059	0.00046	1.75	0.057	0.0375	0.00026	0.578	1 99	0.0095	0.00033	0.0088	39.5	0.00035	0.00025	0.0005	0.0025	1 57	0.136	0.00023	1.75	0	0 00012	0.0005	0.00229	7.42
RS04 Rise and Shine Creek Background Water Quality	0.00686	72.8	0.001	0.011	23.3	0.00003	1.96	0.00013	0 00026	0.00083	2.75	0.059	0.068	0.00011	1.18	3.74	0.006	0.00022	0.0033	5.15	0.00049	0.00008	0.00017	0.0008	2.8	0 315	0.00005	2.75	0	0.0003	0.0005	0.00142	7.51
SC03 Rise and Shine Creek Background Water Quality	0 0064	136.2	0.001	0.028	40.9	0.00011	2.74	0.00029	0 00062	0.00055	2.01	0.119	0.0215	0.0003	1.43	10.2	0.00357	0.00044	0.1507	36.2	0.00036	0.00029	0.00058	0.0029	14.4	0.675	0.00027	2.01	0	0.0022	0.0005	0.0015	7.88
MDD015 Background Groundwater Quality	0 0061	201.6	0.024	0.0331	38.9	0.00008	9.42	0.00019	0.0005	0.0003	0 3	0.162	0.0147	0.0002	1.44	16.2	0.0068	0 0004	0.0051	43.6	0.0003	0.0002	0.0004	0.0018	10.3		0.0003	0.3	0	0.001	0.0005	0.0015	8.1
Rainfall	-	0.81	-	-	0.11	-	0.31	-	-	-	-	-	-	-	0.88	0 09	-	-	0.06	0.32	-	-	-	-	0.18	-	-	-	0	-	-	-	5.2
Tailings Storage Facility Seepage Water Quality (from Underdrains)	0.01	73.21	2.050	0.825	297	0 0002	804	0 053	0.0055	1.598	0	1.93	15.3	0	50.8	99	0.59	0.14	2 005	848	0.678	0.0275	0.18	0.003	954	4.4	0	0	0.35	0.028	0.004	0.0296	6.41