Before a Hearings Panel Appointed by the Selwyn District Council and Canterbury Regional Council

Under	the Resource Management Act 1991
And	
In the Matter of	applications under section 88 of the Act by Bathurst Coal Limited in relation to the closure and rehabilitation of the Canterbury Coal Mine in the Malvern Hills, Canterbury

Statement of Evidence of **Paul Antony Weber (Mine Waste Management)** for Bathurst Coal Limited

Dated: 1 October 2021

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INTRODUCTION

1. My name is Paul Antony Weber. I am a Director and Principal Environmental Geochemist with Mine Waste Management (**MWM**) based in Christchurch, New Zealand.

2. 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, commonly referred to as **AMD**. I am a member of the Australian Institute of Mining and Metallurgy having chartered professional status for the environment discipline.

3. I have 17 years' experience as an environmental geochemist. This includes almost three years for MWM and before that ~5.5 years' for O'Kane Consultants. Both companies provide advice on AMD and closure planning for mining operations nationally and internationally. Prior to this I worked as the R&D Manager – Environment for Solid Energy for ~9 years investigating beneficial reuse of waste streams and options to manage and treat AMD at its coal operations. I have also worked in Western Australian mining industry for 5 years as a geologist / environmental geologist.

4. I have been involved in the research and operational management of AMD for 20+ years. I have worked with mining companies to deliver sustainable management approaches for AMD over this time. I developed the original concept for mussel shell bioreactors to treat AMD in 2007, using a waste stream in a beneficial manner (I understand that five mussel shell reactors are now operating in New Zealand). I have been engaged by a number of international companies and regulators, as a subject matter expert, to review mine closure plans regarding AMD and the assessment of environmental effects associated with AMD.

5. While this is not an Environment Court hearing, I have read and agree to comply with the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2014. This evidence is within my area of expertise, except where I state that I am relying on material produced by another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in my evidence.

SCOPE OF EVIDENCE

6. My evidence relates to AMD and geochemistry matters management, which is a topic I am considered a subject matter expert. I am not an expert in hydrology or hydrogeology related matters and rely on the evidence of others in relation to these aspects.

7. My team and I prepared four technical memoranda in relation to AMD management, water quality compliance and the adaptive management aspects for the closure and rehabilitation process for the Canterbury Coal Mine (**CCM**). The memoranda are attached as Appendix 5 to the Addendum AEE for Closure and Rehabilitation for the CCM.

8. I have also prepared earlier assessment work in relation to the CCM, including for the subject applications as originally lodged and in response to the requests for further information as part of the consenting process.

9. I do not repeat the contents of the technical memoranda and my earlier assessment in full in my evidence. My evidence:

   (a) explains AMD from a technical perspective;

   (b) explains Coal Combustion Residuals (**CCR**) from a technical perspective;

   (c) outlines the measures that have been implemented at the CCM to date to address AMD and the effectiveness of those measures;

   (d) outlines and comments on the proposed measures for AMD management during the closure and rehabilitation phase and post closure of the CCM;

   (e) responds to relevant submissions; and

   (f) responds to the relevant parts of the Council officers' Section 42A Reports.

10. I first visited CCM in 2004 to support student AMD research projects (University of Canterbury). I have been to the CCM on a number of occasions over the last 6 years as part of operational AMD support activities.

11. I attended a site visit to CCM with Bathurst Coal Limited (**BCL**) staff and others on the 15 September 2021 and looked at the key operational areas and site discharge points including the mussel shell bioreactor being constructed for the treatment of AMD.

EXECUTIVE SUMMARY

Overview

12. I consider that the management of AMD at CCM during the operation of the mine by BCL has been undertaken to a high standard utilising international industry standard best practicable guidance. This is explained in my evidence and is demonstrated by:

    (a) a change from a site impacted by acid rock drainage with low pH and elevated acidity and metals to a site influenced by neutral metalliferous drainage having only elevated contaminants (notably boron, zinc, iron, and manganese); and

    (b) a significant reduction in seepage rates from the CC02 underdrain over the last few years coincidental with a decrease in contaminant loads.

13. Key sites for AMD management and ongoing performance monitoring include CC02 Underdrain in Tara Stream, N02 Pit Pond, and the North Engineered Landform (**ELF**).

Coal Combustion Residue

14. CCR (i.e., coal ash) has been placed within ELFs at site that contain waste rock and the CCR has been encapsulated by 10-15 m of non-acid forming (**NAF)** materials. I consider the placement of these materials have had less than minor effect on drainage from the various ELFs at site as shown by water quality monitoring data. As noted in evidence of Adele Dawson (Paragraph 368 and Paragraph 372) there is agreement that the effect of CCR placement in the North ELF is no more than minor.

AMD Management

15. During the operation phase of the mine BCL has utilised best practicable AMD management processes using the six key steps of management, which is based on the guidance by the International Network for Acid Prevention

(INAP, 2014). I consider this a robust practicable approach for the management of AMD.

16. Of the three key sites that may be impacted by AMD (Paragraph 13), only the CC02 Underdrain and the No 2 Pit Ponds require additional management activities to meet resource consent water monitoring requirements. There remains some uncertainty in regards to the exact water quality and flow rates from these areas. This uncertainty is not unusual for mine closure projects. In my experience, this is best managed by adaptive management processes based on performance monitoring data

17. The evidence of Dr Meredith and Mr Jenkins requests further clarity on how this adaptive management process will be implemented. I have provided recommendation in my evidence on how this could be addressed to ensure closure objectives can be achieved. This is addressed in my Response to Section 42A Reports below.

Mine Closure

18. Globally many mining operations moving into closure have uncertainty associated with AMD. This uncertainty is best managed by conservative estimates to understand and identify areas of risk. These risks are then investigated to identify management options, which can be implemented as required based on performance monitoring data during the active- and post-closure phases. At CCM ongoing performance monitoring is needed to confirm the management approaches, developed for specific risks, are appropriate. With time this leads to a reduction of monitoring requirements and eventually cessation of monitoring once key closure objectives have been achieved.

ACID AND METALLIFEROUS DRAINAGE

19. AMD is a general term used to describe waters impacted chemically by mining activities and can contain significant quantities of toxic metals, salts, and acidity. AMD can be divided into three water types:

(a) acid rock drainage having low pH, elevated metals, and acidity;

(b) neutral metalliferous drainage having circum-neutral pH, low acidity, and elevated metals; and

(c) saline drainage, which is circum-neutral to alkaline in pH with elevated sulfate.

20. AMD can be generated by the oxidation of sulfide minerals. These minerals are contained within the coal measures associated with the overburden at the CCM. Exposure of these materials to water and oxygen can lead to the formation of AMD. At CCM potentially mine impacted waters are routinely analysed as part of the AMD performance monitoring program for pH, EC, Al, B, Fe, Mn, Ni, Zn, which can be elevated. Other water quality parameters are also collected.

21. I understand that when BCL acquired the CCM there were issues associated with historic AMD and acidic low pH drainage from the Shearer's Dump (pH 2.5; acidity in the order of 2,500 mg/L $CaCO_3$), which impacted site discharge water quality to the Tara Stream via the CC02 underdrain system. As part of its proactive approach to AMD management, BCL removed these materials and backfilled them in the pit void, following overburden placement techniques as explained in the EMP (BRL, 2018) to prevent further oxidation and minimise water flow through these materials, thus reducing AMD risks.

22. Due to proactive AMD management at CCM the current water quality for the CC02 underdrain, a small underdrain outflowing into Tara Gully, is now considered neutral metalliferous drainage, having circum-neutral pH > 6; acidity < 40 mg/L $CaCO_3$; with moderately elevated metals including zinc (**Zn**), manganese (**Mn**); metalloids including boron (**B**); and sulfate. Current flow rates for CC02 underdrain are ~0.076 L/s or 4.5 L/min based on 10^{th} percentile flow rates (2019/2020). This site will be the key site for treatment after closure.

23. I consider that the AMD associated with the CC02 underdrain seep can be managed by treatment through a passive treatment system that being a mussel shell bioreactor (**MSR**) for Zn, Fe, and a portion of the Mn.

24. The treatment of boron from the MSR requires diluting water to be supplied from the final N02 Pit Pond. Simple modelling indicates this should be

achieved 98.7% of the time. For the other 1.3% of the time when the model indicates there is zero flow, BCL indicated they have other options available to provide this a suitable diluting flow. This forms part of their adaptive management approach. This is discussed further in my evidence.

COAL COMBUSTION RESIDUALS

Introduction to CCR

25. **CCR** is the ash associated with the combustion of coal that includes fly ash (lighter) and bottom ash (heavier).

26. CCR is often returned back to mine sites within New Zealand and internationally (e.g., New Vale coal mine, Southland; and previously at Rotowaro coal mine, Waikato). The CCR have beneficial properties including the ability to limit oxygen ingress and the ability to provide alkalinity to neutralise some acidity generated by sulfide mineral oxidation (i.e., AMD). BCL indicate the acid neutralisation capacity of coal ash can be 50 kg $CaCO_3$/t equivalent (MWM, 2021c)

27. I have been advised by BCL that the last CCR deliveries to CCM were in June (2021) and volumes are comparable to those mentioned by MWM (2021c) in Table 7 where data is provided up to December 2019.

CCR contaminants

28. At CCM it was identified that some of the CCR has been elevated in contaminants such as boron, aluminium, nickel, and zinc (see MWM, 2021c), and appropriate management methodologies were required. Such contaminants are also associated with AMD, which is due to the CCR being from the same geological environment and is essentially combusted material from site. This also explains why the current criteria for contaminants as explained in consent CRC 170541 remain appropriate for from both AMD and CCR drainage. I have recommended some additional monitoring requirements later in my evidence at paragraphs 138-143.

29. At CCM, the CCR was intended to be blended with NAF waste rock at a minimum volumetric ratio of 1:4 for disposal within ELFs including the Green ELF and the North ELF. The actual blending ratios were much higher (see paragraph 34 below)

30. These blended materials (CCR and waste rock) were tested by the Toxicity Characteristic Leaching Procedure (TCLP, US-EPA Method 1311) test. Results demonstrated that leachate characteristics complied with Class B landfill criteria (MWM, 2021c – Appendix I).

31. Synthetic Precipitation Leaching Procedure (SPLP, US-EPA Method 1312) tests were also conducted using rainwater and AMD as extractants as another estimate of boron mobility. Results indicated that in December 2019 the potential soluble B reserve in total waste rock was four times greater than the total soluble reserve in the CCR. (MWM, 2021c).

CCR management during operational phase

32. As per the EMP (BRL, 2018), during the operational phase of the mine, CCR were placed at the back of the ELF furthest away from the ELF surface. Water was diverted away from CCR placement areas and CCR was only deployed during dry periods to prevent any interaction with surface waters. Mr Sinclair, in his evidence notes that that all CCR were generally encapsulated operationally by a layer 10-15 m thick of NAF materials.

Potential erosion effects on CCR

33. During the site visit (15 September 2021) I observed that the North ELF and other ELFs were stable with limited surface erosion. A significant surface failure would be required to expose the mixed CCR materials placed at the back of the ELF behind the 10-15 m thick NAF encapsulating layer. However, I refer to the evidence of Dr Begbie with respect to the stability of the final landforms.

CCR monitoring

34. Due to the blending process, i.e., a minimum of 1 part CCR to 4 parts waste rock there is no way to assess in isolation the discrete discharge of contaminants (e.g., boron) from the CCR at site, noting that based on material volumes (Table 7, MWM, 2021c) that the quantity of waste rock is at least 100 times greater than the quantity of CCR. Furthermore, within such a large facility there is no ability to separate effects of CCR placement on seepage quality from effects of the waste rock placement on ELF seepage quality when the reservoir of boron within the waste rock is estimated at being five times larger than the CCR reservoir. Instead, the

effects of CCR disposal were assessed by investigation of the North ELF discharge as an engineered structure containing blended CCR and waste rock which I consider to be an appropriate approach.

35. Boron was used as a conservative tracer to evaluate any effects from the CCR placement. Data for combined surface and seepage waters discharging from the North ELF that contains CCR, as monitored at CC20, shows that boron has remained stable at about 0.5 mg/L since 2018.

36. Water quality data for CC08, a historic underground mine, unrelated to this consenting application discharging into Bush Gully Stream, has boron concentrations of up to 3.77 mg/L (average 2.73 mg/L), which demonstrates that local rocks can also generate elevated boron concentrations where no CCR has been placed.

37. I consider that any potential effects of CCR placement are best understood from North ELF monitoring sites for the following reasons:

    (a) having a lower CCR to waste rock ratio of ~1 part CCR : 160 parts waste rock, compared to Tara catchment which has ~ 1 part CCR : 200 parts waste rock, which provides a conservative approach;

    (b) provides an analogue site that is a large mine domain containing blended CCR and waste rock materials;

    (c) the site has no underground workings present beneath the ELF; and

    (d) no active mining is occurring in the catchment, providing stable flow rates and water quality to understand any effects.

38. Monitoring results show an increase in boron concentration discharging from the North ELF, which has stabilised at about 0.5 mg/L at the CC20 monitoring point (MWM, 2021d – Figure 5), however this cannot be separated from any boron derived from the waste rock. Results demonstrate effects any potential effects are low and boron concentrations at CC20 are less than resource consent limits of 1.5 mg/L and stable.

39. Based on current trends it appears contaminant concentrations from the North ELF have stabilised and additional management options for CCR are not required at mine closure. I consider this will be representative for the

wider CCM site once equivalent CCR management and rehabilitation activities are complete.

Closure monitoring

40. Despite my views set out above, I recommend and endorse an observational period after mine closure, as has been proposed by BCL in the Mine Closure Addendum AEE and supporting documentation, to confirm trends in aluminium, boron, nickel, and zinc concentrations remain stable at current concentrations from the key mine domains. This monitoring should include drainage from CCO2 Underdrain, No 2 Pit Pond, and North ELF drainage at CC20 and compliance monitoring locations below the North ELF (CC24) and in Tara Steam (CC02-tele). This will provide the data to confirm any effects on the receiving environment from CCR and waste rock and whether additional management procedures are required.

41. The approach presented by CCM in the Environmental Management Plan (**EMP**) that was used to manage the potential effects of CCR placement is fit for purpose (e.g., placement under dry conditions, CCR placement further than 10-15 m from the ELF edge, compaction and final rehabilitation of the ELF to shed water). The effects of CCR appear no worse than the effects of drainage from other sites where CCR has not been placed (e.g., CC08).

Overall conclusions on CCR

42. I consider the placement of the CCR have had less than minor effect on drainage from the various ELFs at site as shown by water quality monitoring data. As noted in evidence of Adele Dawson (Paragraph 368) there is support for this where she states: "*Broadly, I consider that provided the potential leachate/run-off from the CCR is treated or below water quality limits for the receiving water bodies, the adverse effects of CCR will be acceptable*." And in paragraph 372 the evidence of Adele Dawson states: "*Therefore, based on the above, I consider the discharge of CCR on the North ELF is no more than minor*."

CURRENT MANAGEMENT MEASURES

43. During the operation phase of the mine BCL has utilised best practicable AMD management processes for the CCM using the six key steps of

management, which is based on the guidance by the International Network for Acid Prevention (INAP, 2014). This includes:

(a) identification of closure goals;

(b) prediction of potential environmental issues;

(c) prevention of sulfide mineral oxidation;

(d) minimisation of effects by minimising water flow through mine domains (which mobilises contaminants);

(e) control and treat; and

(f) performance monitoring.

44. These AMD management approaches are imbedded in the CCM EMP (BRL, 2018) and are explained further in the following paragraphs.

Closure Goals

45. Closure goals for AMD are defined by key water quality monitoring criteria as defined in resource consents CRC173823 (North ELF) and CRC170541 (Tara Stream). These criteria establish what the agreed water quality should be at closure and therefore facilitate appropriate mine planning to achieve these criteria.

Prediction

46. BCL have developed a robust understanding of the potential for overburden materials to generate AMD, which is supported by the geological model. Over 600 individual samples have been tested by the method of acid base accounting (**ABA**).

47. ABA data indicated that materials above the Main seam and Engine seam needed to be treated as potentially acid forming (**PAF**). The EMP (BRL, 2018) indicates that 12% of the waste rock block model was PAF. This is comparable to recent estimates completed in 2021 by BRL. BCL used ABA data applied to the block model to determine the overall acid potential of the site based on all materials mined since 2012. The data showed that the acid neutralisation capacity for the site is 13.7 kg H_2SO_4/t and the maximum potential acidity is 8.8 kg H_2SO_4/t, which indicates that overall the rock at the

mine is non-acid forming with a negative net acid production value (**NAPP**) of -4.9 kg H_2SO_4/t. This explains why the observed water quality at site is classified as neutral metalliferous drainage.

48. The low quantities of PAF can be confirmed visually as shown in Figure 6 of the MWM (2021c) memorandum.

Prevention

49. These ABA data facilitate the design of ELFs such as the North ELF where the materials identified as PAF can be scheduled for placement within the core of the ELF furthest away from oxygen and water. At CCM a layer of non-acid forming materials are placed on the outside of the ELF to limit oxygen ingress. BCL, in the evidence of Mr Sinclair, indicates that operationally this layer is 10-15 m wide.

50. PAF materials are co-disposed with CCR, which provides alkalinity within the ELF, raises the pH thereby slowing down pyrite oxidation rates, and generates a time lag to acid onset (or the time to put the next lift of materials down). Limestone is also applied where necessary as a conservative approach where significant compaction of final slopes cannot be completed (e.g., Backfill #3).

51. The materials at CCM are fine grained leading to matrix supported mine rock rather than clast supported. This means there are less air voids for oxygen ingress than in a matrix supported material. Together with a primary approach of paddock dumping of materials to reduce any grainsize segregation effects (see Figure 15 - EMP, BRL 2018) this significantly reduces the potential oxygen ingress and subsequent sulfide mineral oxidation rates that can lead to the formation of AMD. This also reduces the risk of AMD if there was to be a slip or damage to the cover system due to trees toppling over as oxygen ingress would be by diffusion rather than (high flow) advection processes.

52. Low permeability layers (~1×10^{-8} m/s; BRL, 2018) are also created by traffic compaction that also reduce oxygen ingress and the advection of oxygen into the ELF.

53. Such prevention methodologies are proven to minimise sulfide mineral oxidation and the formation of stored acidic oxidation products. This reduces long term risks for AMD after mine closure.

54. Adaptive management was used during waste rock placement to achieve best practicable outcomes. For instance, BRL indicate that the Backfill #3 area could not be compacted to the specifications explained in the EMP (BRL, 2018) due to the pit shell geometry. Instead, the following options were developed:

(a) no PAF or Low Risk material was placed in this area, and in addition, 1 kg of limestone was applied per tonne of waste rock into Backfill #3; and

(b) the surface of Backfill #3 will be compaction rolled to reduce infiltration prior to placing soils.

Minimisation

55. Stored acidic oxidation products can be mobilised by water flow through materials containing these acidic minerals.

56. The EMP (BRL, 2108) explains that cut-off drains and diversion fences are used to minimise the amount of water that will flow over the surface of the ELFs. Cut-off drains were used on the North ELF to divert water run-on and minimise the quantity of contaminated water.

57. BCL proactively avoid ponding water on active and completed ELF surfaces to reduce net percolation of water into waste rock and CCR, which then provides a mobilisation pathway. For instance, BCL indicate that final ELF designs avoid flat areas to increase runoff of surface water rather than allowing ponding and infiltration of rainfall.

58. BCL have focused on minimising water ingress into overburden by designing water shedding final ELF surfaces, by the construction of low permeability layers within the ELFs at site, and proactive progressive rehabilitation with final compaction of topsoil as explained in the EMP (BRL, 2018).

59. Flow rates at the toe of the North ELF are low during dry conditions and were measured by BCL at the Canterbury North ELF Pond 2 at an average of 0.24 L/s after 2 dry days or more and 0.184 L/s after 3 dry days or more.

60. Low flow rates demonstrate proactive management to minimise the interaction of PAF materials and CCR materials with water, which is the contaminant mobilisation pathway.

61. In my experience the management of water at CCM, particularly the interaction of PAF materials with water, has been effective with significant decreases in AMD load being observed at CC02. Such low flow rates and contaminant loads supports closure management processes such as passive treatment options.

Control and Treat

62. An essential part of any AMD management plan is to ensure potential AMD impacted waters are directed to discrete discharge locations to facilitate treatment options rather than discharge via diffuse flow pathways from many sites. For instance,

    (a) BCL advise that seepage from the backfill areas drains to the N02 Pit Pond, which avoids the potential for diffuse discharge; and

    (b) water tank and oyster pits are drained to the Green ELF underdrain reporting as CC02 Underdrain.

63. Based on AMD control procedures all significant potential AMD impacted water will discharge as:

    (a) seepage from the North ELF;

    (b) seepage from the Green ELF via CC02 underdrain; and

    (c) discharge from the No. 2 Pit Pond, and subsequently the Tara Pond.

64. This means there are three key areas for future AMD management at the site.

65. The potential requirement for treatment of AMD seepage from the North ELF was considered during mine planning. An adaptive management approach was undertaken and the option of installing a mussel shell bioreactor for AMD was included in resource consent applications. Performance monitoring indicates treatment is not required but remains an option for adaptive management if required in the future.

66. Contaminant loads from the Green ELF reporting to Tara Stream via CC02 Underdrain have decreased significantly due to source control activities (e.g., removing the legacy Shearers Dump (and placing the materials in the pit void) and some historic underground workings).

67. During the operational phase and active closure phase, AMD impacted waters are treated by dosing with $Ca(OH)_2$ to raise the pH and remove acidity and metals such as Al, Fe, and Zn where required, where the priority metal for removal is Zn.

68. A MSR has been partially constructed to treat AMD associated with CC02 Underdrain during the active closure phase and post closure phase. Given the low flow rates, and a need to treat CC02 underdrain waters for Zn and Fe (and some Mn) this is a logical approach using a proven technology.

69. Treatment of surface waters associated with the N02 Pit Pond is not expected based on analogue models using the water quality at CC20 (representing water from waste rock seepage from the North ELF and surface flows from the North ELF). However, options are available if waters become acidic and are included in the proposed adaptive management Trigger Action Response Plans (**TARPS**) (e.g., NaOH dosing to raise pH). Further discussion on TARPS is provided in my Response to Section 42 Reports.

70. BRL propose to manage elevated boron from CC02 Underdrain by dilution. This is discussed later in my evidence.

Performance Monitoring

71. Performance monitoring is an essential step in validating that the AMD management processes are working as expected.

72. Water quality data demonstrates that sulfate concentrations are stable at ~ 300 mg/L at CC20 for the North ELF and are not increasing, demonstrating sulfide oxidation rates are being controlled. Sulfate in drainage from CC02 Underdrain has shown some variability as would be expected in an active mine site, but appear to be stabilising (see **Appendix 1 – Figure 1**).

73. Performance monitoring of toe seepage flow rates for the North ELF and the Green ELF (i.e., CC02 Underdrain) demonstrate that the ingress of water into these mine domains has been minimised.

74. BCL have a comprehensive water quality monitoring database available, which will continue to be updated and will be an important tool for performance monitoring and implementing subsequent TARPs.

75. I believe the effectiveness of the AMD Management Plan at CCM has been good and in alignment with best practicable AMD management approaches, as explained in the EMP (BRL, 2018) and as demonstrated generally by:

    (a) an overall significant decrease in the contaminant load from the Green ELF (as shown at CC02 Underdrain) with time, transitioning from an acid rock drainage geochemical signature to a neutral metalliferous drainage signature;

    (b) minor effects in seepage water quality from the North ELF, which has stable concentrations;

    (c) control and where necessary treatment of AMD; and

    (d) excellent rehabilitation of the southern area of the site and the North ELF demonstrating progressive rehabilitation.

PROPOSED MANAGEMENT AND MONITORING

76. Contaminants requiring treatment for CCR and AMD are similar, which makes sense given that they are both derived from similar materials of the same geological environment and therefore have a similar geochemical signature. I consider the water quality monitoring parameters of pH, EC, Al, B, Fe, Mn, Ni, and Zn as per current consent conditions are therefore appropriate to monitor for potential risks from both CCR and AMD. I acknowledge that there may be benefit in monitoring several other parameters as requested by Dr Meredith and Stephen Gardner in their Evidence. This is discussed further in Paragraphs 138 to 143 of my evidence in response to Section 42A Reports.

77. CCM are proposing a number of management strategies for closure based on its expectations for long term water quality and quantity. While the previous activities explained above in paragraphs 43 to 75 give a helpful and

relevant guide as to likely effectiveness, these predictions require confirmation once closure is underway. For this reason, it is proposed in the mine closure management plan (**MCMP)** (BRL, 2021) that performance water quality monitoring will continue until 2024. This will provide water quality data for mine domains in a closure or near-closure state, including:

(a) The North ELF since 2019 when constructed neared completion (~ 5 years).

(b) CC02 underdrain since the start of 2021 (when dewatering of the area occurred) (~ 3 years).

(c) N02 Pit Pond from about late 2022 (1.5 years data).

(d) As noted previously these sites are the key discharge sites where the effects of AMD and CCR would be observed.

78. I recommend that the water quality trends and flow rate trends be reviewed in 2024 and a decision made as to the continuation of monitoring, which will be predicated on water quality trends and evidence of stable and/or decreasing concentrations and loads. I provide further discussion on this in the following sections for these specific discharge points.

Management of the CC02 Underdrain Discharge.

79. In the following paragraphs I discuss the management of the CC02 Underdrain discharge.

80. The CC02 Underdrain discharge has been present for many years with a pipe installed beneath the Green ELF by the previous mine owners, which has facilitated the drainage from this mine domain, including some surface waters, and associated historic underground workings. In 2018 flow rates were up to ~ 1 L/s (MWM, 2021a), however these have now decreased significantly to ~0.076 L/s (~ 4.5 L/min).

81. Water quality trends for CC02 Underdrain have been presented in MWM (2021a). Data for the last year shows:

(a) Lower Fe concentrations compared to previous years.

(b) Lower acidity concentrations than previous years.

(c) Higher Mn concentrations than previous years.

(d) Slightly lower Zn concentrations compared to previous years.

(e) Higher boron concentrations (by a factor of ~2) compared to previous years.

(f) Stable sulfate concentrations compared to previous years.

(g) Overall, the contaminant load has decreased compared to previous years (e.g., 2018/2019 due to a reduction in flow rate).

82. This information is provided in **Appendix 1** as **Figure 1** containing subsequent additional data since the MWM (2021a) memorandum was produced.

83. A mussel shell bioreactor (**MSR**) is proposed to treat AMD discharge from CC02 underdrain into the Tara Stream Catchment. MSR are effective long-term treatment systems for small AMD impacted flows. Numerous research papers support this proven technology. I was personally involved in the research and development of MSRs and consider the technology suitable and proven to remove the contaminants described above.

84. Based on my experience with MSRs I expect the system to work well from a geochemistry perspective due to its simplistic nature and can be relied on to achieve its proposed treatment efficiencies, which based on site specific trials are:

(a) removal of > 80% of Fe, Al, Ni, Zn and acidity;

(b) removal of approximately 30% of the Mn;

(c) negligible removal of sulfate and boron; and

(d) a contribution to additional Ca increasing water hardness.

85. Previously BCL have successfully undertaken MSR trials using 1000 L containers and site waters impacted by AMD, which provides confidence

that the full-scale system will remove Fe, Ni, and Zn with minor amounts of Mn removal.

86. Due to the MSR treatment process the MSR effluent can be low in dissolved oxygen. Once combined with Tara Pond discharge there will be a decrease in the oxygen concentrations in the combined discharge as compared to Tara Pond discharge, which could be compounded by a chemical oxygen demand as any reduced components oxidise. This could include reduced Fe, Mn, sulfur, and nitrogen[1] compounds. The evidence of Dr Hickey (Paragraph 56) suggests that aeration may also be needed. BCL explained to me that a stilling basin will be constructed at the toe of the Tara Pond discharge (a fall of ~3.5 m) where the combined flows from Tara Pond and the MSR effluent join together. An aeration system may be required in this stilling basin to ensure the waters are well oxygenated before discharge into the Tara Stream. Further explanation on methods for oxidation are provided in Paragraph 168. BCL indicate that during the active closure phase this water will be pumped back to the N02 Pit Pond. Monitoring will be undertaken prior to pumping to validate water quality expectations. Such data will also be used to confirm if aeration is required.

87. An operational trial period is needed to confirm that the constructed Tara MSR performs to these expectations. I believe this trial period sits comfortably in the proposed adaptive management period of the closure project and a good understanding of its performance will be determined by 2024.

88. Resilience of the MSR from an operational perspective is important and should be designed to consider storm events / damage. For instance, this should include the removal of nearby trees and keying in the MSR liner into the ground to prevent the wind from lifting the HDPE liner.

89. Performance monitoring of the MSR is proposed including influent and effluent flow rates and quality. More regular monitoring is recommended at the start (weekly), with monitoring decreasing with time (after 3 months) and with confidence in its performance to monthly samples that align with other water quality monitoring rounds.

[1] Crombie et al (2011) noted that with fresh shells ammoniacal nitrogen could be high (up to 46 mg/L for the first 2-3 months decreasing to 3.4 mg/L. During the commissioning phase the MSR effluent will be pumped back to the site.

90. Performance monitoring should include manual water quality sampling for contaminants as explained in Resource Consent CRC170541 for B, Mn, Ni, Zn, Fe, Al together with continuous pH and EC for both the influent and effluent of the MSR. Flow rates should also be measured. Confirmation of nitrogen concentrations are needed after the commissioning phase and that dissolved oxygen is appropriate. With time, once the performance of the MSR is understood and relationships are established between pH, EC and contaminants the manual sampling frequency could decrease to simply provide validation of real time EC measurements and expected relationships. I acknowledge that there may be benefit in monitoring several other parameters as requested by Dr Meredith and Stephen Gardner in their Evidence. This is discussed further in Paragraph 138 to 143 of my evidence in response to Section 42A Reports.

91. Maintenance of the MSR will be required including sludge removal every 10 -20 years (MWM, 2020a). For sludge removal, BRL indicate that the inflow will be turned off temporarily or directed in the Tara Pond during the desludging process. This will provide sufficient time to desludge the reactor, or replace the materials if required. This desludging will require a small excavator and truck. The sludge will require disposal off site as it is likely to be elevated in metals such as Fe, Al, Mn, Zn etc. Over the long term (years to decades) I would expect the rate of sludge generation to decrease coincident with decreasing influent concentrations (e.g., Fe) and flow rates as shown in MWM (2021a) – see **Appendix 1 – Figure 1** at the back of this evidence. Monitoring of sulfate would be an important parameter to confirm such trends.

92. Data for Green ELF underdrain monitored at CC02 (See **Appendix 1 – Figure 1)** has shown a recent increase in boron concentrations (up to 4.31 mg/L) associated with a decrease in flow, which BCL indicate is related to dewatering that area of the mine site associated with the excavation of the N02 Pit Pond, which has resulted in a concentration increase but overall, a decrease in load. Understanding long term trends in water quality is difficult during active mining phases. Boron concentrations have since decreased to 3.53 mg/L (see **Appendix 1 – Figure 1** of my evidence). Further monitoring is recommended after closure activities and mining has ceased to understand trends.

93. Based on my previous experience I expect the MSR will work well, which is supported by previous site-specific 1000 L trials, to remove Fe and Zn, and some Mn. I do not expect it to remove boron, which requires dilution flows that will be supplied by the N02 Pit Pond.

94. Management and treatment of CC02 Underdrain waters is likely to be for years to decades. This will be understood more following the active closure phase when water flows and water quality stabilises.

N02 Pit Pond

95. In the following paragraphs I discuss the management of the N02 Pit Pond.

96. To forecast water quality a number of analogue models were used from other operating ponds at the CCM to identify reasonable water quality trends for the N02 Pit Pond.

97. After closure I assume that the N02 Pit Pond will have similar water quality to the CC20 North ELF Pond 2 based on the evidence for such water quality being observed at CC20, which includes seepage from the North ELF and surface flows and hence is a comparable analogue model for the N02 Pit Pond where empirical site-specific data are used.

98. Theis data are provided in Appendix 5 to the Addendum AEE for Closure and Rehabilitation for the CCM (i.e., MWM, 2021b), which shows that forecast closure water quality of the N02 Pit Pond is circum-neutral (pH 7.1 – 7.7); with boron concentrations of 0.40 to 0.60 mg/L compared to the consent criteria of 1.5 mg/L Other contaminants including Al, Fe, Mn, Ni, and Zn are also modelled as being compliant against resource consent conditions.

99. There is potential for the N02 Pond to be affected by AMD, however as discussed at paragraphs 43 of my evidence and subsequent paragraphs of that section, BRL have been very proactive in the management of PAF materials, and I believe the risks are low if previous procedures are followed, which I expect to be the case given the high standard of previous work.

100. Mr Jenkins in his letter raises some concerns around PAF areas in the footwall area as shown in MWM (2021b) – Figure 6 by the red bands that represent PAF materials. This is provided again as **Figure 2 in Appendix**

2 for ease of reference. The majority of the highwalls do not contain PAF, however as indicated by Mr Jenkins the footwall area does and could be a risk for AMD. To address this BCL have indicated they will excavate this slope backwards rather than dozer pushing materials downslope. This means that the area remains competent rock and will be covered by 0.5 m of topsoil. With the stratigraphic units dipping away from the N02 Pit Pond (as shown in MWM 2021a – Figure 7; and reproduced as **Figure 3 in Appendix 2** of this evidence) the effects are likely to be low. N02 Pit Pond monitoring will confirm if this is the case.

101. BRL have proposed that any potential risks associated with AMD can be addressed by NaOH dosing as proposed in the TARP (see Paragraph 147 to 171 of my evidence).

102. For other mine domains such as the North ELF there is confidence that the water quality will meet water quality criteria as per Resource Consent CRC170541 as observational data are available.

103. Ammonium-nitrate based fertilisers and explosives have not been used at site, which means the potential source of nitrate is low for the mine. Measured nitrogen concentrations at site CC02 (15-12-2016) show that concentrations were <0.01 mg/L nitrite nitrogen; 0.02 nitrate nitrogen, and total nitrogen was 0.94 mg/L. Other data I reviewed were of comparable magnitude for CC02.

Use of No.2 Pit Pond to manage CC02 underdrain

104. Continuous discharge from the N02 Pit Pond is needed to dilute boron in the treated CC02 MSR effluent to comply with current resource consent limits of 1.5 mg/L (3 month rolling median) for boron.

No 2 Pit Pond Model

105. A simplistic water flow model was developed to test whether the live storage capacity (upper 0.5 m of the water column) of the N02 Pit Pond was sufficient to provide a suitable diluting flow for Tara MSR discharge and understand if there was the potential risk for zero discharge. The rational method was used with data based on rainfall records (32-year model period). Key assumptions included runoff only occurring after 5 mm of rainfall and a

conservative runoff coefficient of 0.2, which is acknowledged as being conservative by Mr Jenkins in his letter.

106. A number of models were conducted to determine if there were periods of zero flow from N02 Pit Pond and what this would mean for water quality in Tara Stream. This model information is presented again in **Appendix 3** of my evidence for flow rates and **Appendix 4** of my evidence for water quality. Some of these models can be excluded as likely scenarios, which are also set out in **Appendix 4** of my evidence.

107. Three models are important to understand potential effects and management procedures (models 4, 6, 7).

108. Model 4 demonstrates with treatment of CC02 underdrain using a MSR and no diluting flow from N02 Pit Pond that boron will be above resource consent conditions in Tara Stream (**Appendix 4** of my evidence).

109. Model 6 using 10^{th} low flow rates (0.076 L/s), which is currently being observed from the MSR, and a diluting flow of 0.18 L/s shows that water quality was compliant with resource consent conditions in Tara Stream (**Appendix 4** of my evidence) and no zero flow conditions occurred. This is shown in **Appendix 5** (Scenario 6). Based on current observed data this scenario is possible.

110. Model 7 uses the MSR design flow rate of 0.2 L/s (which is higher than currently observed), which requires a diluting flow of 0.48 L/s to achieve compliance in regards to boron. The model determined that 94.4% of the time the discharge rates are likely to be equivalent to the decant rates (0.48 L/s); with higher flows occurring 4.3% of the time; and zero flow for 1.3% of the time. Model 7 (**Appendix 5** of my evidence) shows these zero flow events over the period 1999 – 2021 were associated with seasonal cycles of lower rainfall occurring on a 2- to 7- year period) with zero flow events clustering together. Duration of these events has been tabulated (**Appendix 6** of my evidence) and range from 1 to 18 days in length with an average of 7 days with dry periods occurring every 2 to 7 years.

No 2 Pit Pond Management

111. The simplistic water flow model is indicative but suggests that during lower rainfall periods some model scenarios (Model 7) predict that zero discharge

could occur. This risk has been considered by BCL and management options are provided as set out below to supply this water for dilution if required.

112. The proposed period of performance monitoring to 2024 will provide time to understand the actual water flow rates and quality from all components in this system and determine if other management options are needed. However, this period may not coincide with an infrequent dry period of 2- to 7- years and I recommend that an empirical model be constructed to validate the potential risks.

113. Performance monitoring for the N02 Pit Pond should include monthly manual water quality sampling for contaminants as explained in Resource Consent CRC170541 for B, Mn, Ni, Zn, Fe, Al together with continuous pH and EC. Stage height of the pond and flow rates discharging the pond should also be recorded continuously.

114. With time, once the performance of the N02 Pit Pond is understood and relationships are established between pH, EC, flow and contaminants the manual sampling frequency could decrease to simply provide validation of real time EC measurements and expected relationships. Sampling frequency should be reviewed in 2024 once a suitable dataset is available.

115. Continuous monitoring of the water level in in N02 Pit Pond will support TARPs as proposed in the MCMP. If the level of the N02 Pit Pond decreases in height such that insufficient water can be discharged to provide dilution of boron from the MSR then BRL have developed a number of responses to provide sufficient flow rates for continued dilution of the MSR discharge, which include:

(a) implement improvements to increase N02 Pit Pond decant flows. BCL have indicated this could involve a siphon to draw additional diluting flows from the N02 Pit Pond;

(b) increase N02 Pit Pond live storage capacity through modifications to existing infrastructure; and

(c) investigate alternative dilution sources.

116. The simplistic water flow model does not address losses via seepage or evaporation. It equally does not address gains from groundwater seepage. Furthermore, the run-off coefficients used are likely to be conservative. The Evidence of Mr Ian Jenkins for Selwyn District Council (**SDC**) suggests further assessment should be undertaken. This makes sense and I recommend that once the N02 Pit Pond is constructed that a water balance model is developed using empirical data to confirm all assumptions and develop a robust model to support long term water quantity (and quality) predictions. With a robust model, low rainfall periods could be used as a trigger inspect the management system.

117. It is noted that Dr Meredith and Mr Jenkins raised a number of concerns about the robustness of the TAPS and required further clarifications. This is discussed in my response to Section 42A Reports.

Combined Tara Stream site discharge

118. The following paragraphs discuss the combined Tara Stream site discharge.

119. If on the occasion there is zero flow from the N02 Pit Pond, which may occur during a prolonged dry period, occurring on a 2- to 7- year basis, then the only Tara catchment discharge will be a very low flow from the Tara MSR. This would, according to the model, result in elevated boron concentrations in the seepage of ~3.7 mg/L[2] being greater than the consent limit of 1.5 mg/L, (Fe, Zn, and Mn will be treated and are expected to meet current consent criteria). However, the flow rate is expected to be very low (0.076 L/s) and hence a low contaminant load.

120. Potential management options for low flow are discussed above in Paragraph 115.

121. Management of CC02 Underdrain waters for boron is likely for years to decades and may require dilution for infrequent dry periods occurring every 2- to 7- years. This will be understood more following the active closure phase when water flows and water quality stabilises.

122. Data presented in MWM (2021c) shows a significant decrease in boron concentrations between CC02-tele and CC03, which may be attributed to

[2] A concentration of 3.7 mg/L is presented in the model outputs (e.g., MWM, 2021c), which is due to rounding up from 3.653 mg/L, which is the estimated discharge from the MSR using 90th percentile data for 2019/2020).

either dilution and/or attenuation processes as noted by Dr Hickey in his evidence.

Management of the seepage from the North ELF

123. In the following paragraphs I discuss the management of the seepage from the North ELF.

124. The North ELF was designed to be a stable long-term landform to minimise oxygen and water ingress and minimise the potential effects of AMD and CCR placement. Further explanation is provided in the Environmental Management Plan (BRL, 2018).

125. At this point in time, monitoring data for CC24, being the compliance point for the mine domain, indicate that no treatment system is needed for the North ELF seepage. Al is occasionally elevated, but BCL indicate this is likely to be a function of the coagulant dosing system used (PAC – poly aluminium chloride). Performance monitoring data indicates that concentrations of contaminants are low and water quality meets resource consent criteria at CC24. These data are provided in Appendix 5 to the Addendum AEE for Closure and Rehabilitation for the CCM.

126. As proposed in the Environmental Management Plan (2018): Section 6.7.1, if a MSR is required there is a TARP in place if one needs to be installed in the future. Based on the available data this is not currently required.

127. I believe the North ELF has been well constructed to manage the effects of CCR and AMD with minor effects on discharge waters, which is currently demonstrated by compliance with resource consent criteria for water quality. On-going performance monitoring to collate stable water quality trends and loads should confirm this is the case. If there is variance from the current trends then adaptive management options, such as a MSR are available, if required in the future. BCL note a consent is available to build this MSR if required.

128. Monthly performance monitoring for CC20 at the toe of the North ELF and at CC24 in Bush Gully Stream should include manual water quality sampling for contaminants as explained in Resource Consent CRC173823 for B, Mn, Ni, Zn, Fe, and Al.

RESPONSE TO SUBMISSIONS

129. As outlined in Craig Pilcher's and Claire Hunter's evidence for BCL, the closure proposal for the CCM is now substantially reduced from the expansion proposal that submitters originally commented on.

130. Some submitters raised concerns about the impacts of AMD on water quality. For example, one submission suggested that although BCL proposes to bury the acid-forming overburden material within the engineered landform, some acidic seepages will still occur and these may require permanent treatment and maintenance to mitigate their impacts on stream health. Other submissions, including the submissions by the Malvern Hills Protection Society and the Royal Forest and Bird Protection Society Incorporated, generally raised water quality effects from AMD.

131. AMD can generate significant deleterious effects if not managed in an appropriate manner. At CCM this was evident by the historical acidic drainage from the Shearer's Dump. Proactive AMD management activities at site have since removed this legacy landform with a resulting overall improvement in water quality such that drainage from site is no longer acidic. This is discussed in earlier evidence.

132. A key aspect of AMD management is to predict, prevent, and minimise the potential for AMD whenever possible within the associated materials, followed by control of potential poor water quality to discrete discharge locations for treatment when required. This has been done as part of the BCL AMD management approach as explained in earlier evidence. Three AMD discharge locations have been identified being CC02 (Green ELF), CC20 (North ELF) and discharge from the N02 Pit Pond. Treatment is proposed for the CC02 Underdrain and options are available to treat CC20 and N02 Pit Pond if required. I agree that treatment of AMD seepage associated with CC02 underdrain may be required for a period of years to decades, which will be determined from long term performance monitoring and geochemical trends after rehabilitation and earthworks have been completed on site.

133. Forest and Bird raised a query in their submission regarding the probability of the Alpine Fault rupturing within the next 50 years and in the event of such a significant earthquake after mine closure could this expose the PPAF

material buried in the ELF resulting in effects on downstream waterways. As Dr Begbie notes in his evidence, the mine has previously experienced a M7.1 seismic event and the site reported minimal damage. Furthermore, Dr Begbie notes that a displacement of up to 0.1 m could be expected for a 250-year earthquake event. Mr Macfarlene was engaged by Selwyn District Council (**SDC**) and also notes there is a very low risk of future instability of the ELFs. Given the PAF materials are encapsulated by 10-15 m of NAF overburden the risk of exposing PAF materials would be low.

RESPONSE TO SECTION 42A REPORTS

General Commentary on CCR disposal

134. As noted in Paragraph 13, Adele Dawson and I agree that the effects of CCR placement will be acceptable and for the North ELF the effects will be no more than minor.

135. However, a number of issues were raised in the Section 42A reports (ECAN and SDC) regarding the placement of CCR:

136. The key issue raised related to CCR management in the Section 42A reports of SDC and ECAN is the future use of the land for forestry. I agree that it is possible that erosional failure of the ELF or a tree toppling over could potentially lead to the exposure of materials within the top layers of the ELF. However, given Mr Sinclair's evidence of the 10-15 m NAF depth that has generally been distributed across the CCM, I consider this is unlikely. Even if there are areas of the NAF that are lesser in depth, I would generally not expect a few trees toppling over to be a problem given the dump construction methodology for CCR (and AMD). For instance:

(a) the ELF is constructed in short lifts that reduce oxygen ingress by avoiding high flow advective transport of oxygen. This means the risk for ongoing pyrite oxidation and hence AMD is low; and

(b) As advised by BCL, all CCR and PAF is set back from the edge of the ELF by 10-15 m, which means the risk of CCR and PAF being exposed is to oxygen and water is low.

137. Other technical issues were raised which I deal with below:

(a) The comments by Adele Dawson (Paragraph 367b) and Stephen Gardner (Paragraph 20) of their evidence explains that boron can be up to 52 times the Class B landfill guidelines is correct, but other elements such as aluminium are also elevated, which would be expected from mineral matter.

(b) These total digest data do not demonstrate whether the contaminants are mobile. Mobility of contaminants as determined by the TCLP test (Appendix 1 – MWM 2021c) shows compliance with Class B Landfill Criteria.

(c) I also note again that contaminants from CCR are likely to be comparable to contaminants in AMD being of the same geological location. I consider the monitoring suite associated with CRC 170541 reasonable for monitoring the effects of CCR leachate from ELFs. This is discussed in Paragraph 76.

(d) Due to boron mobility as evidenced in test work (i.e, TCLP – MWM, 2021c – Appendix 1) I recommend this is a key longer-term contaminant for monitoring of any effects.

(e) It was noted in Adele Dawson's evidence (Paragraph 367(g)) and in the evidence of Stephen Gardner (Paragraph 25) that limited monitoring of the Class B landfill criteria was undertaken, with only 1 sample provided in 2018. Furthermore, Adele Dawson notes (Paragraph 367(d)) that minimal assessment of other contaminants was provided. To both these points, I believe that this is covered by TCLP tests of mixed overburden and CCR undertaken on an annual basis and is reported as Appendix I of MWM (2021c) where all contaminants complied with Class B landfill criteria. Total digest data does not provide an indication of contaminant mobility, whereas TCLP assesses the soluble fraction.

(f) Ian Jenkins in his letter dated 7 July 2021 notes that CCR should not be placed with PAF materials due to higher mobilisation rates from acidic drainage. Given that the site is not generating acidic drainage and the materials are encapsulated by low permeability materials I consider the risk is low as the ANC will buffer any acidity generation generating a lag to acid onset if it was to occur.

General Monitoring Requirements

138. As noted in my evidence (Paragraph 63) the key locations impacted by AMD (and by association CCR) are the pond at the base of the North ELF, the CC02 Underdrain, and future discharge from the N02 Pit Pond. These areas should be the focus of mine closure water monitoring programs.

139. Dr Meredith recommends (Paragraph 197 of his evidence) a comprehensive monitoring program in streams that also include Oyster Gully Stream and Surveyor's Gully. BCL indicate that no seeps discharge into these locations. I recommend that a visual inspection be taken on a 3-monthly basis during the active closure period to confirm that no seepage is occurring and focus efforts on the areas mentioned in paragraph 138. If seepage was observed into these streams, then this would justify further monitoring.

140. Dr Meredith in his evidence (Paragraph 198) recommends a more comprehensive water quality monitoring program due to the placement of CCR, which is supported by Adele Dawson in Paragraph 379 of her evidence.

141. For the reasons set out in the below table, I consider the current monitoring water quality parameters are suitable for identifying the current effects of CCR placement particularly given that boron has the highest concentrations when compared to the Class B landfill criteria and is likely to be the most mobile. I do not see the need for a consent condition to monitor affected waterways for all the contaminants from CCR mentioned by Dr Meredith and Stephen Gardner and I have provided additional clarification to explain this position:

Comments on containment	**Comments on whether contaminate should be monitored.**
(a) Arsenic. Arsenic was below detection in all TCLP tests (MWM, 2021c Appendix I). Furthermore, As data for CC02 was typically 0.001 mg/L for the period ~2015 – 2017 when monitoring was stopped due to the metalloid being significantly and consistently less that the 95% trigger limit of 0.013. If As was elevated at this site it would be seen	No further monitoring required

and would also be elevated in the CCR TCLP tests	
(b) Sulfur (sulfide and sulfate). Sulfate is routinely monitored as part of the performance monitoring program. This information is provided in the MWM reports e.g., MWM (2021a) – Figure 6. It provides a good indication of long term geochemical trends.	Sulfate monitoring to be included as a performance indicator of AMD, eventually being superseded by EC relationships. Not needed for compliance.
(c) PAH (poly aromatic hydrocarbons). Data from the TCLP tests (MWM, 2021c Appendix I) showed that potential organic contaminants were below detection or very low.	No further monitoring required
(d) Hardness, Alkalinity and DOC (dissolved organic carbon) are also suggested. Water samples are already tested for Ca and Mg to determine hardness to enable hardness modifications to Zn and Ni, which is a consent condition. I consider alkalinity and DOC to be unnecessary	Ca and Mg need to be monitored for hardness calculations. Not needed for compliance.
(e) Aluminium and Iron. These metals are already monitored on a regular basis. Often metals can be elevated when there is no discharge from site due to background concentrations	No changes recommended to consent conditions (further discussion is provided in Paragraph 142).
(f) In the evidence of Stephen Gardner (Paragraph 22) he notes that arsenic and polycyclic aromatic hydrocarbons (PAH) could be elevated. I consider this unnecessary as explained above	No further monitoring required
(g) In the evidence of Stephen Gardner (Paragraph 44) he notes that As, Cd, Cr, Cu, Pb should also be included. TCLP data (MWM, 2021c – Appendix I) shows these contaminants are at least an order of magnitude lower than Class B landfill criteria and in some instances below the limit of reporting (Cu, Cr, As).	No further monitoring required
(h) I do not believe that monitoring for As, Cd, Cu, Cr, Pb, sulfide, PAH, alkalinity and DOC to be necessary and data suggests they are low in the CCR. A number of these issues are also raised in the evidence of Dr Hickey.	No further monitoring required

142. I recommend that the pH monitoring regime for the assessment of Fe at < pH 4.5; and Al at pH < 5.5 or pH > 7.5 be maintained to avoid the issues of colloidal materials affecting the analysis procedure as well as background Fe concentrations being elevated above consent conditions even when the site is not discharging. An example of this is provided in **Appendix 7 – Figure 1** as part of my evidence for Fe concentrations where elevated iron is observed in the catchment, yet the site is not discharging; and in

Appendix 7 – Figure 2, when the pH is greater than 4.5 and the site is discharging, yet at the pH conditions proposed in oxidised water the dissolved Fe is expected to be low.

143. I suggest the monitoring requirements can be resolved by caucusing prior to the hearing and ensured through requirements of the adaptive management regime.

Mussel Shell Reactor Technology

144. The evidence of Dr Meredith in paragraphs 115 – 117 suggests that the MSR technology has limited demonstration and there are some uncertainties with its performance. I consider that the technology is simple and robust and suitable to treat the CC02 Underdrain to remove Zn, being its primary purpose. Currently I understand there are five MSRs working in New Zealand. A good example is the MSR at Escarpment mine, constructed by Bathurst, demonstrating the company has internal experience in construction and maintenance of MSR (Robertson et al., 2017).

145. I accept previous information was missing an explanation on how MSR sludge would be managed as noted by Dr Meredith. I have provided further clarification on how the sludge management will be addressed as discussed in Paragraph 91.

146. A commissioning phase where treated MSR effluent is retuned to the site is proposed, to validate performance until diluting flows are available to address elevated boron. Nitrogen forms and oxygen concentrations could be monitored during this commissioning period.

Trigger Action Response Plans

147. There were comments by both Dr Meredith and Mr Jenkins that further work is needed to refine the TARPs. Dr Meredith notes in his evidence (Paragraph 216) that the current TARPs do not represent adequate adaptive management strategies. For instance, Dr Meredith (Paragraph 160) states that some red responses are not true responses but rather a series of assessments or investigations, which is not appropriate. Both Dr Meredith (Paragraph 163) and Mr Jenkins suggest that the use of “consistently” needs to be more specific.

148. Dr Hickey also supports the use of TARPs in his evidence (Paragraph 60): "*I recommend that the Trigger Action Response Plan(s) (TARP) be included in conditions of consent, key monitoring components and time points for reassessment of monitoring parameters and frequency. The objective of this updating of the document would be to better define the monitoring objectives and the adaptive management process.*".

149. I consider some of these issues associated with the TARPS can be resolved and worked through prior to the hearing by caucusing between the parties.

150. I have reviewed the draft TARPs as presented in the MCMP (BRL, 2021) and note that improvements could be made to address the comments provided by Dr Meredith and Mr Jenkins in their evidence: I provide recommendations on these TARPs in my evidence below.

151. The TARPS are divided into active and post closure phases, which can be confusing if the proposed trigger values are not considered against the phase or the water management processes available.

Active Closure Phase

Acidity / pH: N02 Pit Pond (Active Closure and Post Closure)

152. The purpose of these TARPs are to identify through performance monitoring whether AMD is influencing the water quality of the N02 Pit Pond and then provide response plans. Management options are similar for both phases and address the risks of elevated metals such as Zn with decreasing pH and increasing EC. I recommend the following changes or similar:

153. Performance Monitoring: AMD is easily identified by decreasing pH and increasing EC. Ongoing monitoring is proposed, which will be supported by monthly water quality samples for contaminants of concern (Paragraph 113) to confirm other metal concentrations (e.g., Zn). I consider this suitable as pH is a master variable influencing the fate of many contaminants. Subject to performance monitoring data, I would suggest a TARP for Zn is not needed and could be tied to a TARP for acidity (i.e., pH) once relationships are understood (As previous work has shown the pH criteria for treatment at CCM is set to treat Zn).

154. Trigger: I consider pH to be suitable, particularly when supported in the early stages of performance monitoring by other metals of concern as discussed.

The term "*consistently*" needs more definition and I suggest the following thresholds for action, where monitoring is undertaken in the N02 Pit Pond:

(a) low: pH > 6.5 and stable EC;

(b) medium: pH 6 – 6.5 and increasing EC; and

(c) high: pH < 6 and increasing EC.

155. Adaptive management options could include:

(a) Increase monitoring frequency to confirm the trigger event was significant – e.g., weekly samples for 2 weeks following.

(b) NaOH dosing.

(c) Ca(OH)2 dosing.

(d) Alkaline drains.

(e) Mussel shell bioreactors for influent seepage, where this is identified by prior mapping of acidic seeps before filling the pond (e.g. from the underdrains from the boxcut area);

156. I consider the technologies proposed are readily applied and common. No investigations are required. I recommend these options are considered and incorporated into a final TARP during the active closure phase when pumping of water at site is still occurring. The responses need to be assigned to trigger levels.

Boron: N02 Pit Pond (Active Closure Phase).

157. The purpose of this TARP is to identify through performance monitoring whether boron is elevated in the N02 Pit Pond and then provide response plans. I recommend the following changes or similar:

(a) Performance Monitoring: Boron will be monitored by monthly water and should be supported by continuous EC measurements (Paragraph 113), which will provide a dataset for any future EC – boron trends. If EC is increasing contaminants are increasing.

(b) Trigger: Boron concentration. The term "*consistently*" needs more definition and I suggest the following thresholds for action, where monitoring is undertaken in the N02 Pit Pond:

i. Low: Boron: <1 mg/L; ;

ii. Medium: Boron >1 mg/L but <1.5mg/L and EC increasing; and

iii. High: Boron > 1.5 mg/L and then B remains > 1.5 mg/L in two additional consecutive weekly samples.

158. Adaptive management options for elevated boron could include:

(a) Increase monitoring frequency to confirm the trigger event – e.g., weekly samples for 2 weeks following.

(b) Dilution / water management – i.e., raising the level float switch in the pond.

(c) Supply of clean water from off site.

(d) Irrigation of elevated boron waters to land.

(e) Wetland technologies.

(f) Adsorption technologies as mentioned by BRL (e.g., zeolites).

159. Currently CCM manage this water on site, which means the dilution water management option is suitable and working. Mr Jenkins in his evidence indicates irrigation to land might be a mitigation procedure; Dr Meredith (Paragraph) 165 suggest this is an abstraction of water from the catchment. Further work is needed on this management option as part of adaptive management planning.

160. Wetland technologies may have potential (e.g., Türker et al., 2014, 2016) and adsorption technologies may be applicable, but further work is required and in advance to facilitate effective adaptive management. I would recommend that the active closure phase provides time to investigate these

adaptive management options (wetlands, adsorption) and confirm they have potential.

161. The responses need to be assigned to trigger levels.

Water Quality at combined discharge point (Active Closure Phase).

162. The purpose of this TARP is to identify through performance monitoring whether contaminants (B, Mn, Zn) are elevated in site discharge. I recommend the following changes or similar:

(a) Performance Monitoring: Monthly monitoring is proposed and should be by continuous EC measurements (Paragraph 113). If EC is increasing contaminants are increasing.

(a) Trigger: B, Mn, Zn concentrations. The term “consistently” needs more definition and I suggest the following thresholds for action at CC02-tele:

i. Low: All metals (B, Mn, Zn) < 80% of CRC170541 trigger limits and EC stable.

ii. Medium: Any metals (B, Mn, Zn) < CRC170541 trigger limits but > 80% CRC170541 trigger limits and EC increasing.

iii. High: Any metals (B, Mn, Zn) > CRC170541 trigger limits.

163. Adaptive management options could include:

(a) Increase monitoring frequency to confirm the trigger event – e.g., weekly samples for 2 weeks following.

(b) Dilution / water management – increased flow by installing a siphon into the N02 Pit Pond;

(c) Irrigation of elevated boron waters to land;

(d) Wetland technologies;

(e) Adsorption technologies as mentioned by BRL (e.g., zeolites); and

(f) Additional passive treatment processes for Mn and Zn.

164. Currently CCM manage this water on site, which means the dilution water management option is suitable and working. Irrigation to land needs further work as noted earlier. Other technologies such as wetlands and adsorption require further analysis to facilitate effective adaptive management. Passive treatment systems for Mn (and Zn) could use steel slag to increase pH (e.g., Trumm et al., 2018) and further work is required and in advance to facilitate effective adaptive management.

Post Closure Phase

165. Many of the adaptive management options proposed during the active phase could also be options for the closure phase. Some of these options could be developed further during the active phase to enable them to be part of the post closure adaptive management plan. Some additional options that may be useful include:

166. The development of a low rainfall trigger may be useful to determine what responses are needed as discussed in Paragraph 116 of my evidence as these periods are higher risk for zero flow. BRL indicate they have already have an automatic text system when Mean Annual Low Flow Conditions (MALF) occur in the Selwyn River.

167. As noted in Paragraph115, a number of options are available for the infrequent zero flow periods, as proposed by BCL for the N02 Pit Pond including:

(a) Implement improvements to increase N02 Pit Pond decant flows. BCL have indicated this could involve a siphon to draw additional diluting flows from the N02 Pit Pond;

(b) Increase N02 Pit Pond live storage capacity through modifications to existing infrastructure;

(c) Reduce the decant flow from N02 Pit Pond to match the dilution rate required to maintain compliance with resource consents when CC02 flow rates are low;

(d) Investigate other alternative dilution sources.

168. The management of low dissolved oxygen water and possibly elevated Mn and Fe could be managed by simple technologies such as:

(a) An oxidation cascade.

(b) A Trompe (e.g., Trumm, 2013) to aerate the water.

169. Dr Hickey recommends a low-powered aeration system may be appropriate (in his response to Section 42A Reports). I recommend this be assessed during the commissioning phase when MSR effluent is pumped back to site to ascertain any oxidation technologies.

170. Dr Meredith also proposes two other TARPs may be needed for stratification of the N02 Pit Pond (Paragraph 166a) and delivery of water from the N02 Pit Pond to Tara Pond.

171. Given the active closure phase is 12-18 months this provides time to undertake some of the investigations required so that they can be considered fair options for adaptive management.

Paul Antony Weber
1 October 2021

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APPENDIX 1

CC02 UNDERDRAIN WATER QUALITY DATA

APPENDIX 1: CC02 UNDERDRAIN WATER QUALITY DATA

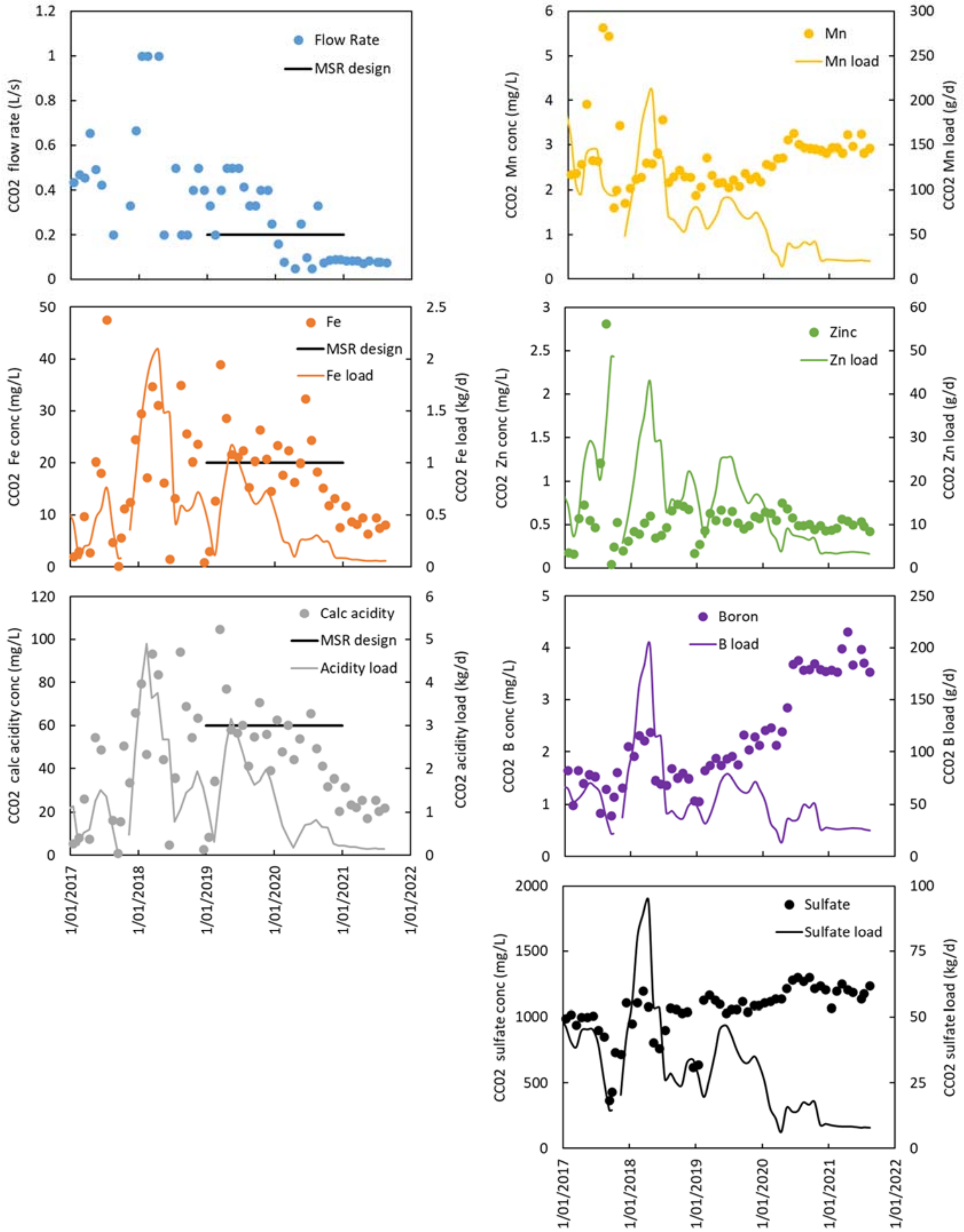


Figure 1. CC02 Underdrain key contaminant concentrations, flow rates, loads, and the nominal MSR design specification (lines).

APPENDIX 2

N02 PIT POND HIGHWALL PAF EXPOSURES

APPENDIX 2: N02 PIT POND HIGHWALL PAF EXPOSURES

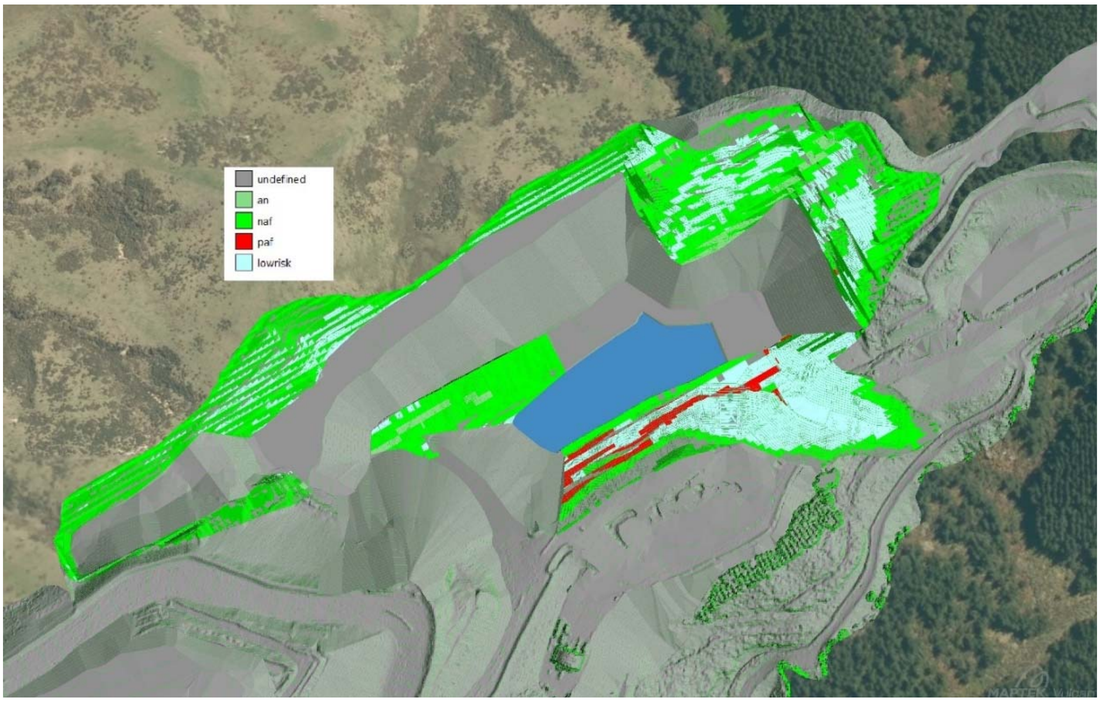


Figure 2. Geochemical block model pit wall / floor geochemical classification (from MWM, 2021b) – Figure 6. PAF units shown in red

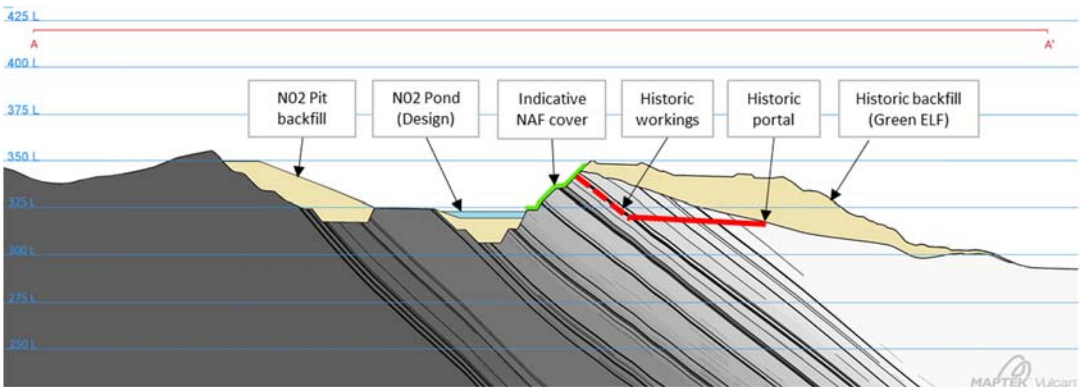


Figure 3. Cross section showing N02 Pit final landform (Source MWM 2021a Figure 7).

APPENDIX 3

MODEL FLOW RATES FOR TARA CATCHMENT

APPENDIX 3: MODEL FLOW RATES FOR TARA CATCHMENT

Table 1: Tara catchment discharge flow rates

Model No.	Scenario	CC02 underdrain (untreated)	Tara MSR (treated)	Clean water dilution	N02 Pit Pond	Combined Tara discharge
		(L/s)	(L/s)	(L/s)	(L/s)	(L/s)
1	Low flow (CC02 untreated, undiluted)	0.076	-	-	-	0.076
2	Low flow (CC02 untreated, C/W diluted @ 0.11 L/s)	0.076	-	0.11	-	0.18
3	Low flow (CC02 untreated, N02 Pit Pond diluted @ 0.78 L/s)	0.076	-	-	0.78	0.86
4	Low flow (CC02 treated, undiluted)	-	0.076	-	-	0.076
5	Low flow (CC02 treated, C/W diluted @ 0.11 L/s)	-	0.076	0.11	-	0.18
6	Low flow (CC02 treated, N02 Pit Pond diluted @ 0.18 L/s)	-	0.076	-	0.18	0.26
7	MSR design flow (CC02 treated, N02 Pit Pond diluted @ 0.48 L/s)	-	0.2	-	0.48	0.68
8	High flow (CC02 treated, N02 Pit Pond diluted @ 10 L/s)	-	0.2	-	10	10.2

Modelled flow rates for Tara Catchment Discharges from CCM (Source MWM, 2021c).

APPENDIX 4

MODEL DISCHARGE CONTAMINANT CONCENTRATIONS

APPENDIX 4: MODEL DISCHARGE CONTAMINANT CONCENTRATIONS

Table 4: Combined Tara catchment discharge contaminant load and concentration

Parameter	Tara catchment discharge combined discharge load (kg/d)								Tara catchment discharge combined discharge water quality (mg/L)							
Scenario No.	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
pH									6.1	6.5	7.1	6.9	7.3	7.1	7.5	7.1
Calc acidity	0.49	0.007	0.49	0.007	0.51	0.011	0.028	0.08	75	31	1.1	1.1	0.45	0.48	0.48	0.10
Sulfate	8.4	7.4	8.4	7.4	31	13	33	188	1277	526	19	1130	466	564	564	213
Al	0.0001	0.00003	0.0001	0.00003	0.0018	0.0004	0.0011	0.0046	0.0080	0.0033	0.0001	0.0050	0.0021	0.019	0.019	0.0052
B	0.024	0.024	0.024	0.024	0.065	0.033	0.088	0.41	3.7	1.5	0.053	3.7	1.5	1.5	1.5	0.46
Ca	1.7	1.9	1.7	1.9	7.5	3.3	8.7	46	252	104	3.7	296	122	148	148	52
Fe	0.18	0.003	0.18	0.003	0.19	0.0038	0.010	0.015	28	12	0.41	0.40	0.17	0.17	0.17	0.02
Mg	0.81	0.76	0.81	0.76	3.3	1.3	3.5	20	124	51	1.8	116	48	60	60	22
Mn	0.020	0.011	0.020	0.011	0.049	0.018	0.048	0.054	3.0	1.2	0.044	1.7	0.71	0.81	0.81	0.062
Ni	0.0007	0.0001	0.0007	0.0001	0.0014	0.0003	0.0007	0.0035	0.101	0.042	0.0015	0.015	0.0063	0.012	0.012	0.0040
Zn	0.0044	0.0004	0.0044	0.0004	0.0057	0.0007	0.0019	0.0054	0.67	0.28	0.010	0.065	0.027	0.033	0.033	0.0062
Hardness	7.5	8.0	7.5	8.0	32	14	36	196	1142	471	38	1214	500	613	613	222

NB: Values shown in red are above the CRC170541 water quality trigger limits, including after hardness modification of trigger values for Zn.

Source MWM (2021c) – Table 4.

1. Some of these models can be excluded as likely scenarios, for instance:

(a) Model 1,2,3 includes no MRS treatment of the CC02 underdrain, which shows elevated Zn on all occasions, and elevated Mn and B for Scenario 1 in the combined catchment discharge. This clearly demonstrates that Zn treatment of the CC02 Underdrain is required, which is part of the proposed closure plan. I consider that the risk of elevated Zn concentrations will be low following this treatment and these models can be excluded as being likely.

(b) Models were run using clean water supplied from off site as the diluting water (models 2 and 5). Long term supply of water during dry periods is not sustainable and these models are excluded.

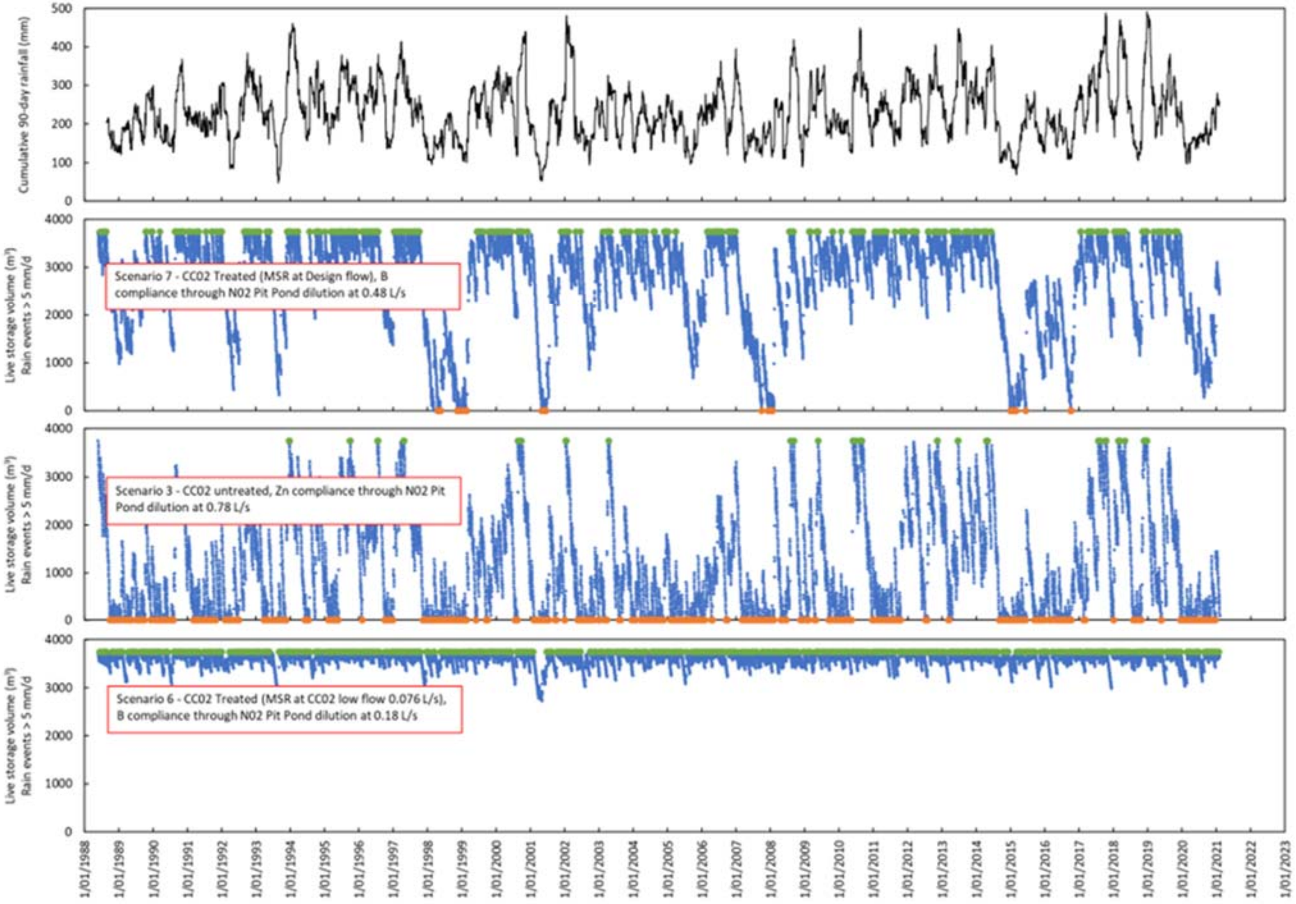
(c) Models 4, 5, and 6 use 90th percentile low flow rates (2019/2020) of 0.076 L/s for the CC02 Underdrain. This is a fair assessment of the current flow rate. Model 4 shows the effects on the Tara Stream when there is no diluting flow, i.e., only CC02 treated discharge at 0.076 L/s.

(d) Models 7 and 8 use the design flow rate for the MSR of 0.2 L/s. This is currently much higher than the current observed flow of 0.076 L/s. Scenario 8 represents a high flow event.

APPENDIX 5

MODELLED 90 DAY CUMULATIVE RAINFALL AND DAILY LIVE STORAGE VOLUMES – N02 PIT POND

APPENDIX 5: MODELLED 90 DAY CUMULATIVE RAINFALL AND DAILY LIVE STORAGE VOLUMES – N02 PIT POND



Source MWM (2021c) – Figure 6

APPENDIX 6

MODEL 7 ZERO FLOW DURATION

APPENDIX 6: MODEL 7 ZERO FLOW DURATION

Model Scenario 7 – 0.48 L/s N02 Pit Pond Flow; 0.2 L/s CC02 underdrain flow showing zero discharge days (source: MWM, 2021c).

Start date	Duration (days)
24/04/1998	4
6/05/1998	7
18/05/1998	7
16/11/1998	9
6/12/1998	2
14/12/1998	4
21/12/1998	18
17/02/1999	9
4/05/2001	1
22/05/2001	2
28/05/2001	13
16/06/2001	3
4/10/2007	1
9/12/2007	4
4/01/2008	18
31/01/2008	1
2/01/2015	18
2/02/2015	7
17/02/2015	17
13/06/2015	2
6/10/2016	6
Average	**7**

APPENDIX 7

APPENDIX 7

Figure 1: Fe concentrations measured at CC02-tele (blue dots) where samples that are marked with a red horizontal dash were during periods when the site was not discharging.

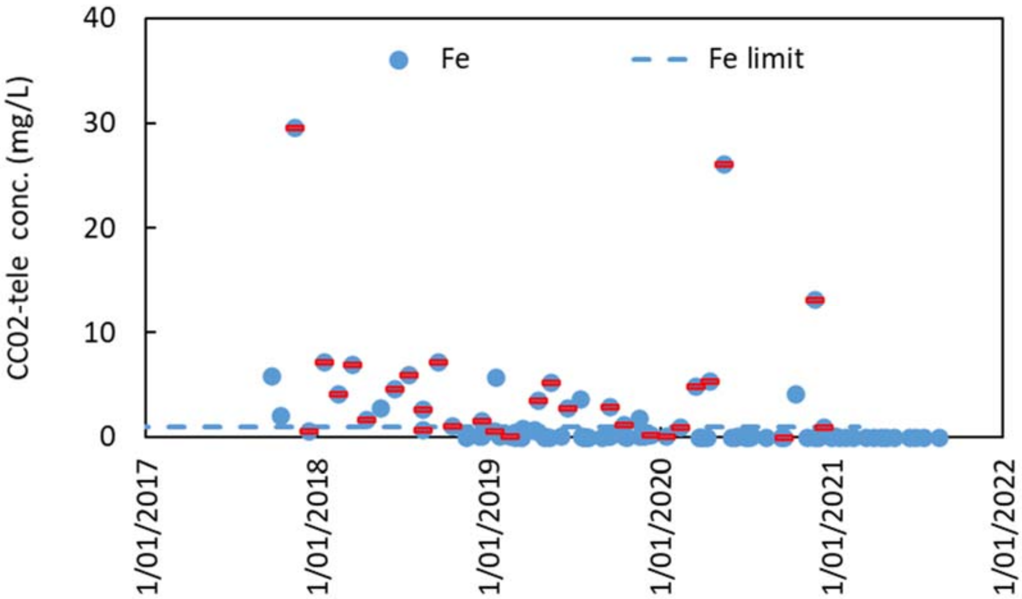


Figure 2: Fe concentrations measured at CC02-tele (blue dots) where samples that are marked with a red vertical dash had pH values > pH 4.5.